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Aspects of the Organic Carbon Cycle on Walker Branch Watershed: A Study in Land/Water Interaction

Charles Edward Comiskey
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To the Graduate Council:

I am submitting herewith a dissertation written by Charles Edward Comiskey entitled "Aspects of the Organic Carbon Cycle on Walker Branch Watershed: A Study in Land/Water Interaction." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology and Evolutionary Biology.

Frank W. Woods, Major Professor

We have read this dissertation and recommend its acceptance:

Gary S. Henderson, Edward E. C. Clebsch, D. L. Bunting

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor
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ASPECTS OF THE ORGANIC CARBON CYCLE
ON WALKER BRANCH WATERSHED:
A STUDY OF LAND/WATER INTERACTION

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Charles Edward Comiskey

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ABSTRACT

Aspects of the organic carbon cycle in a deciduous forest watershed were studied with emphasis on meteorological inputs to the watershed system, transfers of organic material from the terrestrial to the aquatic subsystems, the hydrologic transport of organic carbon in the stream subsystem, and organic outputs from the watershed system via geological vectors.

Transfer of large (> 1 mm) particulate organic material to the heterotrophically based aquatic subsystem occurred primarily as direct leaf fall and blow-in. Annual litterfall was 222.1 g/m^2 organic carbon, of which leaves contributed 80.6%, fruits and reproductive parts 11.3%, twigs 5.6%, and frass 2.5%. Peak inputs for all components except frass occurred during autumn.

The steepest southwest-facing slopes generally contributed the highest inputs, with peak inputs for leaf and twig material occurring during the winter to early spring period when aeolian forcing factors were greatest. Fruit and frass inputs were more closely related to seasonal litterfall patterns than to aeolian factors. Total yearly organic carbon input of blow-in to the stream channel was 52.1 g/m^2, of which 82.4% was leaves, 13.6% was fruits, 3.8% was twigs, and 0.2% was frass.

Standing crops of large (> 1 mm) particulate organic material in four stream habitat types (dry gravel > stream gravel > dry bedrock > bedrock pools) showed significant date and habitat type differences, reflecting the influences of the hydrologic cycle and within-system biological processing on the allochthonous inputs. Largest standing

crops were found during November (62.76 - 283.00 g/m^2) and smallest in early February (0.55 - 13.21 g/m^2), the decrease due mainly to hydrologic transport. Largest relative contribution of leaves occurred during autumn (> 90% in November), while lowest relative contribution occurred during the June sampling, due mainly to increased twig inputs during the previous weeks.

Concentrations of dissolved organic carbon (DOC) and fine particulate organic carbon (FPOC) in throughfall were highest in July (32.32 and 20.27 mg/l, respectively) and lowest in December (1.90 and 0.49 mg/l, respectively), when canopy was absent and rainfall heavy. Both DOC and FPOC data had a negative logarithmic relationship with volume of throughfall. Similar trends were seen for DOC and FPOC in incident precipitation, but concentrations were generally lower (1.55 - 8.78 mg/l for DOC and 0.88 - 2.12 mg/l for FPOC), as were r^2 values. Trends for concentrations of DOC and FPOC attributable to canopy removal generally followed those for throughfall, ranging from 0.67 to 23.46 mg/l, and 0.19 to 18.18 mg/l, respectively). For throughfall, the presence or absence of a canopy generally influenced both the slope and intercept of the regressions. Inputs of organic carbon in throughfall and incident precipitation showed less month to month variation than concentration, with only FPOC in incident precipitation showing a significant relationship (positive logarithmic) to volume of rainfall. DOC inputs ranged from 3.32 to 10.05, 1.40 to 6.55, and 0.08 to 8.64 kg/ha/mo for throughfall, incident precipitation, and canopy contribution, respectively. For FPOC, inputs ranged from 0.85 to 3.82, 0.55 to 3.18, and -0.19 to 3.90 kg/ha/mo for

throughfall, incident precipitation and canopy contribution, respectively. Two-thirds of the total input (95.2 kg/ha/yr) of organic carbon in throughfall was in dissolved form. Net canopy removal for the year was 38.68 kg/ha, of which 61.6% was dissolved.

Soil water had low concentrations of DOC for all four forest types studied (0.62 - 2.60 mg/l). Significant date and forest type differences were apparent, with highest concentrations in late summer and fall through winter and lower concentrations in spring and early summer. Oak-hickory and chestnut oak types had higher concentrations of DOC than the pine and yellow poplar types due, in the case of pine, to a lower pool of decomposable and/or soluble organic material and, in the latter case, to lower slope position, allowing longer contact of infiltrate with the soil matrix. No significant relationship was found between concentration of DOC and volume of infiltrating rainfall. Outputs from the computer code PROSPER were utilized to calculate the flux of organic material (1.34 $g/m^2/yr$) past the 75 cm soil depth.

Springflow concentrations of DOC and FPOC were low and invariable through the year, with highest concentrations (0.59 and 0.82 mg/l, respectively, for DOC and FPOC) recorded during the week which included the most intense storm of the study period. Most weekly means were below 0.25 mg/l for both species, due primarily to the diffuse flow nature of the spring system, allowing intimate contact of the water with the bedrock system.

Analyses of storm cycles occurring throughout the water year indicated that DOC followed the hydrograph much more closely than FPOC, the

latter responding very quickly to hydrographic rises, with concentrations often decreasing before peak discharge was reached. Ratio of concentration of DOC to concentration of FPOC thus decreased early in the storm, increasing after the initial FPOC peak. For "non-rain" or delayed increases in streamflow, FPOC concentration behaved similarly to that for a rise due to direct channel input, but DOC concentration showed no increase. The different responses were due to different source areas of streamflow and organic material. Highest concentrations of FPOC (77 mg/l) were seen during major storms, while for DOC, highest concentrations (13.55 mg/l) were found in the summer to fall period due to throughfall contributions. Concentrations of DOC and especially FPOC were dependent on antecedent events on the watershed. Regression analyses for the relation of DOC and FPOC concentrations in individual samples to discharge showed poor fits, especially for DOC, with the fits improving somewhat when the data were sorted by season and month. For the same regression form, FPOC had the greater slope, and the ratio DOC/FPOC vs discharge virtually always had a negative slope, further indicating the dominance of FPOC at high discharge. Good fits were found for outputs of DOC and FPOC vs discharge, with the untransformed regression best explaining the DOC output trends and the logarithmic relationship best fitting the FPOC data. Slopes for FPOC were generally higher, with highest slopes for both DOC and FPOC in summer and fall. Generally similar results were found for regressions involving the weighted weekly concentration and weekly output and discharge, except that the semilogarithmic relationship gave the best fit in many cases.

Baseflow concentrations were very low (0.1 - 0.4 mg/l) for both DOC and FPOC, with only the autumn litterfall period showing elevated DOC baseflow levels. Lowest weekly outputs occurred during the late summer - early fall period due to low baseflow and lack of significant storm events. Low baseflow levels led to large ranges (greater than two orders of magnitude) in concentration during the year.

Highest weekly weighted concentrations (1.87 mg/l for DOC and 7.45 mg/l for FPOC) and lowest ratios of DOC to FPOC occurred during week 48 of 1973, during which the highest peak flow of the study occurred. Large storms during other parts of the year, while generally decreasing the DOC/FPOC ratios, did not decrease the ratio to the extent that the storm of week 48 did, due to less standing crop of FPOC in and adjacent to the stream channel. The forty-eighth week, with 9% of the discharge for the water year, had 49.6% of the total organic output for the year. For DOC this was 30.7% of the yearly output and for FPOC 58.18%. The weighted mean concentration for the 1973-1974 water year was 0.56 mg/l DOC and 1.16 mg/l FPOC. Total output for the 1973-1974 water year was 1016.9 kg, of which 32.5% was DOC and 67.5% was FPOC.

Litterfall dominated the inputs of organic carbon to both the forest floor and the stream system. DOC losses from the 75 cm layer were inconsequential compared to losses of CO_2. Loss of TOC in streamflow, corrected for interbasin transfer, was 24.89 kg/ha/yr, amounting to only 44% of the meteorological input of DOC and FPOC. However, the two organic types behaved quite differently with FPOC actually showing a net loss of material for the year.

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VOLUME I

INTRODUCTION

Stream investigations have centered on two somewhat distinct but necessarily related areas of emphasis. In the larger watershed framework, viewing the watershed as an ecological unit (Bormann and Likens 1966, 1967), the stream subsystem functions as the principal mode of egress of nutrients and other elements from the watershed. But it is also itself an ecosystem, whose internal dynamics are geared toward these exports from the terrestrial system (Hynes 1963, Ross 1963). Any attempt to investigate or discuss the aquatic subsystem of a small forested watershed as a separate entity is a failure to perceive that the structure and functioning of the terrestrial subsystem are embodied within the physical, chemical, and biological processes in the streams draining them. The phenological and physiological dynamics of the surrounding terrestrial community will not only determine the relative importance of autochthonous versus allochthonous sources as the aquatic food base, but will even determine, along with the atmospheric and geological subsystems, the amount, seasonal pattern (Swank and Miner 1968, Hornbeck et al. 1970, Douglass and Swank 1972) and quality (Johnson and Needham 1966, Likens et al. 1970) of the very water that delineates the stream subsystem. Of prime importance, therefore, both for the delineation of nutrient cycles and for a proper understanding of the structure and functioning of the stream subsystem, is the determination of interactions between the terrestrial and aquatic subsystems.

Ohle (1965) found positive correlation between the degree of land-water interaction (expressed as the ratio of drainage basin area/lake

surface) to primary productivity in European lakes. Similar phenomena were observed by Vollenweider (1968) and Schindler (1971). Hutchinson (1969) stressed the importance of the entire drainage basin when considering the question of water quality and eutrophication. Nelson (1969) emphasized the close correlation between stream load (organic and inorganic) and events on land and suggested that the slope of the regression of particulate organic matter on stream discharge could be used as an indicator of the relationship between autochthonous production and allochthonous organic matter in streams. Likens (1974) observed a significant direct relationship between export of inorganic nitrogen and phosphorus in stream water and the extent of agricultural and urban activity, respectively, on the watersheds. As man's activities increased, meteorological inputs became quantitatively less important.

If relationships between terrestrial and aquatic productivity are to be quantified, the cycling of organic matter between land and water subsystems must be studied. Leaf litter contains substances other than carbon which were ultimately derived from the geological and atmospheric subsystems, and contributes them to stream water upon leaching or decomposition, or carries them out of the system during periods of high discharge, still organically bound. Therefore, a knowledge of organic inputs via litterfall, blow-in, or throughfall becomes important in considerations concerning other major and trace elements. Not only are leaves and other allochthonous organic material important as sources of nutrients and energy for the stream community, they can also prove detrimental under certain conditions (especially low flow periods). Impair-

ment of water quality during periods of low flow has been demonstrated by Slack (1955, 1964), Schneller (1955), and Larimore et al. (1959). Slack and Feltz (1968) reported the effects of autumn leaf fall on water quality in pools in the north fork of Quantico Creek during low flow periods in the autumn. All parameters measured showed major changes coinciding with the rate of leaf fall. Large decreases in O_2 and similar decreases in pH were seen, while sharp increases in water color, specific conductance, soluble iron, soluble manganese and bicarbonate were observed.

While much work is presently being done regarding the structural and functional relationships of stream communities, the overall context into which these studies must be woven has not received adequate attention. There is still a clear lack of baseline, quantitative data on the input-output relations of organic matter in stream systems. Unlike the study of inorganic elements in streams, where the major emphasis has been on the input-output characteristics, present research on stream communities lacks the perspective of relating the biotic activity to the real world meteorological/hydrologic background. This is especially true when one considers the fact that in the situations (such as in headwater streams) where allochthonous organics are most important for ecosystem functioning, there exists the greatest potential for physical control of the stream system. It is thus the purpose of the work herein discussed to provide that framework which would allow stream community studies to be evaluated in the broader ecosystem context. The primary goals of this study are as follows:

1. Determination of the meteorological inputs of organic carbon to Walker Branch watershed,
2. Quantification of the fluxes of organic carbon which represent significant transfers from the terrestrial to the aquatic sub-systems, and
3. Characterization of the hydrologic transport of organic carbon in Walker Branch, with special emphasis on the influence of storm cycles on organic transfers and outputs.

CHAPTER I

BACKGROUND

An impressive volume of literature is accumulating which stresses the heterotrophic nature of woodland stream systems (Nelson and Scott 1962, Hynes 1963, Minshall 1967, Fisher and Likens 1972, Sedell et al. 1974, and Cummins 1973). This heterotrophic dominance is especially true in headwater streams, with their high ratio of land to water surface area and their dense canopy coverage.

Most small mountain streams such as Walker Branch are dominated by rhithron reaches, characterized by rock, stone, or gravel bottoms, turbulent flows, consistently high oxygen concentrations, and relatively low summer temperatures (Hynes 1963). The primary consumer component, consisting mainly of benthic invertebrates (including Plecoptera, Trichoptera, Ephemeroptera, Amphipoda, Decapoda, and Gastropoda) is usually rich in number of species and biomass. At the same time, the primary producer component, which is usually restricted to attached algae (dominated by diatoms) and mosses, in most cases appears to be incapable of supporting the consumer members of the community. In such a habitat, allochthonous organic matter plays a dominant role.

The importance of allochthonous plant detritus to benthic organisms was shown by earlier workers (Slack 1936, Hynes 1941, and Jones 1949, 1950). More recently, Hynes (1961), in his study of the invertebrate fauna of a mountain stream in Wales, found that activity of both herbivore and carnivore components was substantially greater in winter than in summer, thus demonstrating the importance of the seasonal pulse of

leaf litter into the system. Nelson and Scott (1962), working in a somewhat larger stream (Middle Oconee River) in Georgia, found that the primary consumer organisms of a rock outcrop community derived 66% of their energy from allochthonous organic matter. Minshall (1967) found that, of the thirty-seven taxa studied in Morgan's Creek (Kentucky), twenty-four were herbivores and five were omnivores, all of which derived much or most of their energy requirements from allochthonous leaf material. Egglishaw (1968), who took monthly bottom samples in riffle habitats of several Scottish streams, noted significant correlations between the distribution of some invertebrate species and the distribution of detritus. Cummins (1973) stated that the information at hand supported the contention that most aquatic insects are trophic generalists, consuming whatever type of organic material is available in the proper size classes.

Hynes (1963) reviewed a considerable amount of literature dealing with secondary production in streams and concluded ". . . at least a very large part of the productivity of all running water is based on photosysthesis which takes place elsewhere, and without this source of allochthonous organic matter the inherent instability of running water, and its consequent inability to grow much in the way of plants, except in favored places, would cause it to be almost a desert habitat." Fisher and Likens (1972), in their effort to provide a complete annual organic matter budget for a section of Bear Brook (in the Hubbard Brook Experimental Forest), found that autochthonous inputs constituted less than 1% of the total organic matter available to consumer organisms, and concluded that the stream system was highly heterotrophic in nature.

The most significant single factor contributing to this allochthonous organic input appeared to be the annual introduction of litter from the arboreal components of the forest, especially the riparian aspect, in the form of litterfall and blow-in. A number of authors (Egglishaw 1964, 1969; Darnell 1964; Minshall 1967) reported that most of the organic detritus found in the surface substrate of a fast-flowing stream comes from terrestrial vegetation surrounding the stream. Jewell (1927) noted the depauperate faunistic condition of many prairie streams which receive little allochthonous organic input, as compared to streams flowing through forests. Berner (1951) reported that 54% of the organic matter ingested by fish collected in the Missouri River was terrestrial in origin.

Work in the last ten years has done much to explain the dynamics of leaf processing in the stream system. Recently more emphasis has been placed on the role of microbes in leaf degradation.

The first, rapid weight loss from litter material after introduction into the stream system is via leaching. Petersen and Cummins (1974) reported mean leaching loss of all species of leaf studied was approximately 15% of the weight of the leaf pack. For many species of deciduous trees, shed leaf material is invaded by members of the aquatic microfloral community virtually as soon as it enters the stream. Rodina (1963) had previously stated that microbes were a major component of detritus. In streams, the fungi, especially the aquatic hyphomycetes play a large role in early leaf conditioning. Triska (1970), who followed leaf decomposition over a one year period in a small Pennsylvania

stream, found significant correlation between aquatic hyphomycete spore density and rate of disappearance of the leaf material. Boling et al. (1975) found that spores of aquatic hyphomycetes can be found on leaves one to three days after introduction to the stream system. However, Barlocher and Kendrick (1973 a and b) pointed out that senescent leaves, even before they fall from the tree, already carry many propagules of several fungi which can rapidly recolonize the leaf when conditions are favorable. They stated that the dominance of aquatic hyphomycetes in the winter is apparently related to their ability to tolerate low temperatures, but more importantly to their ability to sporulate underwater. This cannot be accomplished by the terrestrial fungi which must rain a continual supply of propagules on the stream system.

There exist some differences of opinion concerning the importance of benthic invertebrates to leaf processing. Mathews and Kowalczewski (1969), using litter bags of several mesh sizes, found the presence of an invertebrate fauna unimportant in breakdown of allochthonous leaf litter (oak, willow, and sycamore) in the river Thames, with microbes principally responsible for the disappearance. Results of Hargrave (1970) and Bjarnov (1972) indicated that benthic invertebrates which consume detritus can actually digest very little of it (cellulose and ligninlike substances), indicating much of the allochthonous organic matter is unavailable to them without a microfloral intermediary. Fenchel (1970) felt that the amphipod Parhyalella whelpleyi digested only the microorganisms on the plant detritus and not the detritus itself. However, Petersen and Cummins (1974) presented evidence indicating that for

certain genera of trees (e.g. Carya) the presence of invertebrates does contribute to the rate of leaf degradation, with about equal amounts of breakdown due to microflora and invertebrates. This may have been due to the relatively slow rate of microbial decomposition for these species. They found that leaves of trees with more slowly decomposing foliage were invaded less rapidly by particle-feeding benthic invertebrates than were the leaves of faster decomposing types. The existence of a period of time when animals were absent from leaf packs indicated that selective feeding may be a function of microbial colonization. Sedell et al. (1975) found that, during the first 100 days after deposition in the stream system, conifer leaf breakdown was due primarily to microbial colonization and decomposition, after which there was rapid consumption by the "shredder" insects.

Triska et al (1975) have shown that differences in rates of disappearance of leaf material of tree species are accompanied by differences in chemical composition, with rate of microbial colonization and conditioning the critical factor. Leaves that decomposed faster had a higher acid detergent cell wall fraction and lower lignin content. Suberkropp et al. (1976) postulated that plant phenolics interact with nitrogen-containing compounds in leaves to form decay-resistant complexes, which in turn determine the interspecific differences seen in decomposition rates. Petersen and Cummins (1974) and Sedell et al. (1975) have indicated that the presence of leaf material from several species, varying in rates of colonization and hence breakdown, allows for a continual food supply to the stream community. They reported leaf

processing rates forming a continuum from a low of 0.5% per day to a high of 2.0% per day.

Several authors (Dolling 1962, Wallace et al. 1970, Kaushik and Hynes 1971, Barlocher and Kendrick 1973) showed feeding preferences by stream invertebrates, with elm, maple, ash, and alder preferred to beech and oak. This selection generally conformed to the rate of colonization by microflora and rate of decay in the stream system. Triska (1970), Iversen (1973), Boling et al. (1975), and Anderson and Grafuis (1975) have shown that conditioned leaf material is preferred to unconditioned leaf material.

Barlocher and Kendrick (1973) demonstrated that amphipods had a preference for fungi isolated from maple leaf discs rather than for the discs themselves. They also showed a preference for fungal types, which could help explain the preference for different species of leaves.

Increases in nitrogen concentration of leaf litter have been shown for many species under terrestrial conditions (Melin 1930, Bocock et al. 1960). Mathews and Kowalczewski (1969) and Iversen (1973) reported concentrations of nitrogen increasing throughout stream decomposition of leaf material, with absolute increases in nitrogen content present at the early stages. Temperature and added nutrients (nitrogen and phosphorus) significantly influenced leaf litter decomposition in laboratory stream water, leading to an overall increase in the content of protein (Kaushik and Hynes 1968, 1971), indicating that ambient conditions can influence leaf breakdown by absorption of nutrients from the water column by the microflora. Further evidence of this was presented by Egglishaw

(1968), who found, for nine Scottish Highland streams with varying calcium concentrations, that the higher the concentration of Ca and HCO_3, the faster the rate of decomposition of dead plant tissue. Streams with faster rates of decomposition had higher standing stocks of invertebrates, indicating that the decomposition process was the factor limiting the size of standing stocks of bottom fauna.

Leaf material is repeatedly reprocessed as long as it remains in the system, becoming more finely shredded, with bacterial activity becoming more prevalent. Much of the trophic specialization in stream systems is based on particle size (Cummins 1973). The organisms themselves become part of the detrital pool when they die. Living organisms are transported out of the sytem by behavioral or catastrophic drift (Waters 1972).

Non-cultural allochthonous organic material has recently been shown to be important in certain lake situations also. Rau (1976), who studied the input of particulate allochthonous organic material (mainly conifer foliage) to Findley Lake, Washington, found the main source to be aeolian inputs. The litter traps in the center of the lake (> 200 meters from shore) received no plant debris, while a sharp gradient in deposition was seen in the traps 10 meters inland, on shore, and 10 meters offshore, with mean values of 285, 173, and 6 mg/m^2/day. He compared the calculated mean allochthonous input for the whole lake (1.5 g carbon/m^2/yr) to that portion of the autochthonous production reaching the benthic community (0.8 g carbon/m^2/yr), suggesting that the allochthonous source is quantitatively important for the functioning of the benthic ecosystem.

A similar situation has been shown for estuaries. Seki et al. (1968, 1969) reported that a large fraction of the organic material which served as a food source for benthos of the Straits of Georgia, British Columbia was derived from the land and was readily utilized by bacteria. The latter worker used 250 μg POC/liter of river water as an average value in calculating the total input of particulate organic carbon (POC) to the sea. Based on a soluble to particulate ratio of about 7:1, they estimated a total organic input to the Straits of Georgia of 1-2 x 10^6 tons/yr. They stated that this was very similar to the estimate for primary productivity, indicating that allochthonous sources were quantitatively equivalent to autochthonous sources of organic matter.

In looking for a basis on which to develop a plan for analysis of organic carbon behavior, one inevitably comes to the hydrologic cycle. Indeed, in all aspects of a watershed study, from the production of terrestrial vegetation to its exit from the basin in streamflow, it is water that unites the system. This is especially true in the more physically controlled of first and second order streams, where a majority of the annual downstream export of particulate matter may occur in a very short time during intense storm events (Leopold et al. 1964). Bormann, Likens, and Eaton (1969) reported that a single autumn storm exported 54% of the total particulate matter for a two year period in the Hubbard Brook watershed. More catastrophic flow rates with severe spating have completely disrupted some stream systems, severely depleting the community and its food base. Thus, hydrologic phenomena are

extremely important in determining the characteristics of the stream community at a particular time. In the intermittent portions of the drainage system, surface water can serve as an agent of erosion and sediment transport for only short periods during the year. Of particular interest then is the behavior of the aquatic subsystem and terrestrial-aquatic interactions during different hydrologic regimes.

Because of the relatively small size of Walker Branch, even small storms cause a rapid increase in streamflow, especially during the growing season when low baseflows predominate. During these times, when canopy is present, the dynamics of the dissolved and fine particulate organic matter in streamflow are dominated by meteorological inputs, including within-system transfers due to canopy leaching/washing. While canopy leaching/washing has been studied for a number of elements, including organic matter (Carlisle 1965; Carlisle et al. 1966, 1967) there is still a great deal of controversy over the relative contributions of dissolved organic carbon (DOC) and fine particulate organic carbon (FPOC), and of washing and leaching to canopy removal. Laboratory and field studies headed by the efforts of Tukey and his coworkers (see Tukey 1970 for a summary of much of this work) have shown that many organic materials can be leached from foliage in quantitatively significant amounts, including free sugars and sugar alcohols, amino acids, organic acids, and pectinaceous compounds. To this list can be added growth-regulating substances, alkaloids, and phenolics (Kozel and Tukey 1968). The allelopathic effect of leaf leachates is now well established (Bonner 1950, Borner 1960). What is much less well known is the importance of

incident precipitation and the role of the various forms of particulate material in the organic cycle, especially with regard to aerosol dynamics.

Aerosols can be classified as primary (emitted in particulate form) or secondary, the latter produced in the atmosphere from gas-phase chemical reactions which generate species capable of condensing as a particulate phase. Primary sources, 80% of which are natural in origin (Vandergrift and Shannon 1971), have both continental (dust and volcanic particles) and marine (sea spray) sources and occur in all sizes. Man-made sources of primary aerosols are dominated by combustion processes. Secondary aerosols result from reaction of hydrocarbons emitted from vegetation with ozone and from photochemical reactions involving SO_2, H_2S, NH_3, and unburned or partially burned hydrocarbons.

Junge (1963, 1972) first introduced the concept that the vast majority (85%) of the troposphere is filled with a rather uniform aerosol (tropospheric background aerosol). Above 5 km the distribution of aerosols is rather uniform in time and space, but below 5 km (over the continents and adjacent areas over the oceans) concentrations are higher owing to proximity to sources. Tropospheric (3-12 km above earth) background aerosols and continental aerosols (including marine from surface to 3 km) constitute 25% and 70% by mass, respectively, of the total aerosol content of the atmosphere.

The question of the ocean, and expecially the sea surface, as a primary source of atmospheric organics has been studied for some time, and the phenomenon is now generally accepted (Wallace et al. 1952,

Wilson 1959, Blanchard 1963, Barger and Garrett 1970). Air bubbles are effective in transporting surface active organic molecules to the sea surface (Garrett 1967, Wallace and Wilson 1969), a site of organic accumulation. White cap formation and bubble-bursting release organics of marine origin into the atmosphere (Blanchard 1964, 1968; Barger and Garrett 1970), generally as a compressed film of surface active material on sea salt particles.

Hoffman and Duce (1976) found that filtration of sea water had little effect on the organic carbon to sodium ratio in the atmosphere of their ocean microcosm, indicating that the dissolved and colloidal components of organic matter were primarily responsible for the organic carbon present in aerosols in their laboratory experiment.

Gambell (1962), based on observations of Ca^{++}/Cl^{-} ratios, concluded that, excluding immediate coastal areas, water-soluble continental aerosols constitute a large majority of the soluble material brought down in precipitation over land, and that the majority of these continentally derived aerosols do not travel very far from their source areas before being brought down in precipitation (320-640 km maximum displacement). However, he did not discount the possibility that some material finds its way into the upper atmosphere where it is then distributed great distances (vertically and horizontally).

Gas-phase organics, especially hydrocarbons, form a major component of the continental atmospheric organic load. National Academy of Sciences (1976) states that U. S. man-made sources account for about 40% of the world total of anthropogenic hydrocarbons emitted into the atmos-

phere. Compared to the estimated 72 x 10^6 tons/yr for natural source U. S. hydrocarbon emissions, man-made sources account for approximately 31.5 x 10^6 tons/yr, of which 17.6 x 10^6 tons/yr are from mobile sources (mainly motor vehicles) and 13.9 x 10^6 tons/yr are from stationary sources (greatest single contributor is solvent evaporation). Neligan (1962) found that hydrocarbon samples from air in Los Angeles Basin were similar in composition to auto emissions.

Methane is the chief constituent of naturally arising hydrocarbons in the atmosphere, accounting for 1.6 x 10^9 tons/yr (Robinson and Robbins 1968), with concentrations generally in the range of 1-2 mg/l (Junge 1963, Stephens and Burleson 1969, Cavanaugh et al. 1967, and Swinnerton et al. 1969). Since methane is chemically relatively inert (does not enter into photochemical oxidation), most data on air pollution separate this source from the more reactive hydrocarbons.

Another major source of gas-phase atmospheric organics only recently recognized as quantitatively important is plant vapors. Went (1960) hypothesized that pigment decomposition results in emission of volatile organics to the atmosphere. He also felt that terpenes produced in plants were volatilized into the air.

Subsequent investigations in this area have proved extremely fruitful. Rasmussen (1964, 1972) and Rasmussen and Went (1965) found terpene concentrations of 2-50 ppb in remote forested regions of the Southeast and Midwest (average 10 ppb), with ambient concentrations increasing with temperature and light intensity, the latter indicating diurnal variations. They found higher than normal readings during periods of

leaf senescence (autumn) or where fields had recently been mowed. Quantity of emissions was related to the mass of living foliage and, on a global basis, was calculated as 483 x 10^6 tons/yr. Rasmussen and Hutton (1972) observed in the laboratory that organic volatiles emitted from tropical foliage can be utilized by populations of fungi as the sole carbon source for growth. These studies also suggested that significant absorption of the volatile organics occurred in the soil, especially the litter layer and the rhizosphere. National Academy of Sciences (1976) concluded that, based on estimates of worldwide methane and terpene emissions, the natural hydrocarbon emission is about 2 x 10^9 tons/yr.

The volatile organics released from the vegetation are particularized in the atmosphere through the action of ultraviolet light in the presence of nitrogen oxides (Haagen-Smit 1952), the end product being the formation of blue haze particles (less than 0.1 m in diameter). The blue haze particles, called Aitken nuclei, then gradually grow to a size of about 1 m by macromolecular aggregation. Since these particles are resistant to chemical or photochemical breakdown, they are removed from the atmosphere by precipitation (rain or snow), serving as condensation nuclei. See Husar and Whitby (1973) for a summary of the present knowledge of the photochemical aerosol formation.

Precipitation scavenging of aerosols and gases from the troposphere can be separated into two components (Junge 1963a; Rodhe and Grandell 1972). Rainout is the process whereby the chemical species is incorporated into cloud droplets within the cloud, while washout is the removal

by falling precipitation below the cloud. Junge (1963) felt that the rainout effect is by far the more important factor (compared to the washout effect) except in areas where aerosols are concentrated in the lowest layers of the atmosphere and for particles greater than 1 μm. He gave an average residence time of aerosols in the upper troposphere at eight days, while those found at lower layers of the troposphere had a residence time of only two to four days. He found, in most cases, greater than half of the total aerosol mass was in the sub-cloud layer. Rodhe and Grandell (1972) calculated turnover times for tropospheric aerosols to be 35 - 80 hours in winter and 100 - 300 hours in summer. Seinfeld (1975) stated that the residence time of particles in the troposphere depends on the amount of precipitation in the particular area, with typical residence times in the lower troposphere of several days to a few weeks, whereas in the upper troposphere residence times can be up to a month. White and Turner (1970) stated that the major mechanisms operating close to the ground for the removal of aerosols are settling and impaction on surfaces. At altitudes above 100 meters, the main vehicles for removal of aerosols are rainout and washout.

From all this, it can be seen that organic matter, living or decomposing, is involved in the actual production of aerosol material as well as its possible capture on leaf surfaces. If the particle is water-soluble, the organic molecule will have gone through three physical states before entering the stream system.

It has become apparent in recent years that the organic constituents in throughfall, the latter including incident precipitation and

canopy washings/leachates, are not only decomposed in the soil (Waksman 1928, Nykvist 1961a), but are replaced by other biochemicals secreted or excreted by the soil decomposers (Nykvist 1961a). It has further been shown that these substances have significant pedogenic properties. In lysimeter studies of soil water passing through the A2 horizon of an immature forest podzol, Joffe (1933) noted a marked rise in pH (4.8 to 6.4) and specific conductivity (four-fold) during autumn when leaf fall was greatest. Bloomfield (1953) has shown that water extracts from litter from a number of tree species are capable of mobilizing iron and aluminum from insoluble compounds. Lutwick and Delong (1954), Schnitzer and Delong (1954), and Delong and Schnitzer (1955) showed that the ability to mobilize iron and aluminum from insoluble compounds is a property attributable to both natural soil leachates from decomposed litter and from organisms extracted from the A horizon in a podzol soil, as well as to throughfall itself. Shapiro (1957), who studied the yellow organic acids in lake water, postulated that their similarity to the yellow organic acids in soils (and lake sediments) makes the soil systems the logical source for this allochthonous organic material.

Schnitzer and Skinner (1963, 1966), Schnitzer and Kodami (1967), Schnitzer and Dejardins (1969), and Sowden and Schnitzer (1967) have investigated the role of organic acids in the transport of metals in the soil profile and in other related pedogenic processes. Working with a humic podzol in Newfoundland, they found that the fulvic acid they extracted from a Podzol Bh horizon was very efficient in bringing into solution substantial amounts of metals from practically insoluble

hydrous iron and aluminum oxides. These water-soluble complexes of fulvic acid and di- and tri-valent metals were very stable and the fulvic acid adsorbed onto the surface of Na montmorillonite or formed interlamellar complexes at pH 4.5. They found that 87% of the leachate collected from between the Ae and Bhf horizons was fulvic acid. They showed that the leachate could mobilize and transport substantial amounts of silica. The fulvic acid was formed in the LH horizon and was water-soluble and very reactive because of its content of high oxygen containing functional groups. They conclude that the organic matter in leachate has all the characteristics of an efficient metal-complexing agent, capable of playing a significant role in soil genesis, as well as in many other reactions that occur in soils. Polysaccharide plus protein contents of organic matter constituted a maximum of 15% of the total. The fact that such a large amount of the leachate was fulvic acid and was formed in-situ indicated that a large portion of the soluble organic matter passed through the microbial population.

That similar processes occur in streams has recently been shown. Bretthauer (1971) found that humic substances from autumn-shed leaves often lead to yellow to brown water color, which can be removed by ultrafiltration. Lush (1970) showed that turbulence, freezing, and pH of water can control the amount of precipitation of material leached from maple leaves, with species differences also evident. Acer saccharinum lost 15% of its initial dry weight as precipitate, while precipitation accounted for less than 5% of the initial dry weight of Acer saccharum. Hynes et al. (1974) stated that the formation of particles by complexing

of dissolved organic matter (DOM) with divalent metals, e.g., humus/metal complexes (Schnitzer 1969), are probably found in streams. Within one hour after introduction, sterile leaf/water cultures showed precipitates similar to detritus found in the field. Infrared spectroscopy showed that there was a great similarity between detritus and metal/organic complexes of known weight of fulvic acid. Greater variability was seen comparing the laboratory precipitates and fulvic acid complexes, possibly due to the lack of "aging" for the laboratory material.

The significance of dissolved organic carbon to the consumer in the stream system is still poorly understood, but some headway is now being made. In the early 1960's, oceanographers became actively interested in the fate of the large dissolved organic carbon pool (1 mg/l) in the ocean. For the whole ocean column, quantities of DOC are several orders of magnitude greater than the living fraction. Previous to this time dissolved organic carbon was thought to be available to consumers only through bacterial metabolism. However, several investigators were able to show that organic particles commonly form by abiotic aggregation. This involves adsorption on free surfaces, such as solid objects, bubbles, or the sea surface itself. The aggregates are soon invaded by bacteria. Baylor and Sutcliffe (1963) successfully grew brine shrimp on particulate matter obtained by bubbling air through filtered sea water. One source of the dissolved organic carbon was exudates from phytoplankton (Fogg 1965). This formation may have long term survival value for the community as a whole, since it provides a source of nutrients for the zooplankton during times of low phytoplankton density.

Several investigators attempted to duplicate these results in fresh water with little success. However, Lush and Hynes (1973) clearly showed that the phenomenon does occur in fresh water. The authors leached senescing leaves of various species of vegetation and followed the pattern of particulate matter formation (after filtration) in both sterile and nonsterile conditions, differing pH regimes, and differing ion concentrations. They found that the amount of aggregation was dependent on the pH of the solution (higher pH-faster formation), the species of plant, the presence of ions (specifically calcium), and the degree of turbulence. Particles formed from leaf leachates at rates ranging from 3% to 23% of initial amounts of dissolved organic matter in 24 hours.

CHAPTER II

THE STUDY SITE

Walker Branch watershed (Figure 1) is situated in the Ridge and Valley Province of the Appalachian Highlands (Fenneman 1938) and is located on the Department of Energy Reservation in Anderson County, Tennessee, latitude 35° N, longitude 84° W. It occupies 97.5 hectares (ha) and consists of two subcatchments, the west fork (38.4 ha) and the east fork (59.1 ha), drained by the west and east forks of Walker Branch, respectively, From the confluence of these two branches, 30 meters below the gaging stations, Walker Branch flows approximately 800 meters south, emptying into Melton Hill Lake, which is formed by the impoundment of the Clinch River, 53 river kilometers above the confluence of the Clinch and Tennessee Rivers.

Oak Ridge is located in the broad Tennessee Valley between the Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast. From its greatest elevation in the state (a point near Bristol 640 meters above sea level), the valley gradually slopes southwestward to an height of about 180 meters in the vicinity of Chattanooga.

The Tennessee Valley was formed by the weathering of the underlying limestone and shale that are less resistant than the rock underlying the adjoining Highlands. It varies from place to place in both relief and elevation. Severe folding and faulting have left many of the rock beds inclined at high angles or actually overturned, so that there may be several exposures of the same beds. Folding faulting, and differential

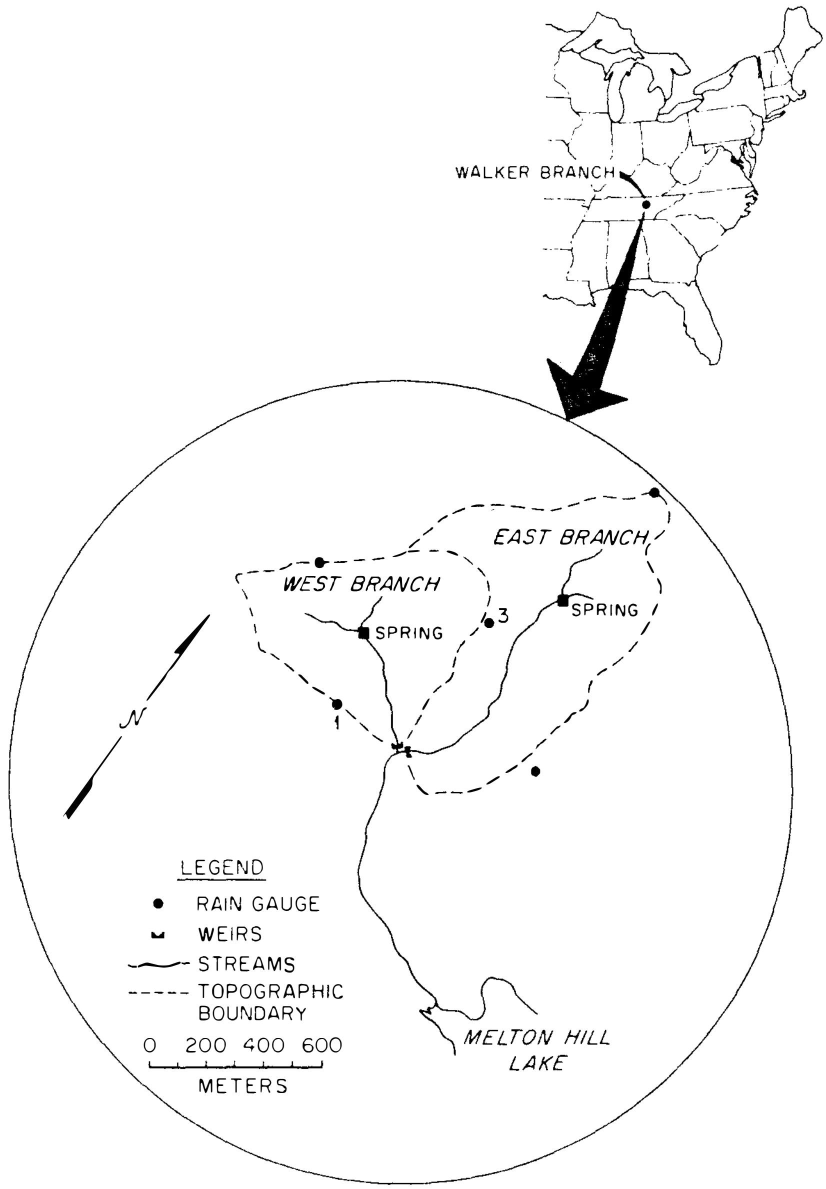

Figure 1. Location and General Characteristics of Walker Branch Watershed.

ORNL Drawing 71-14194R2

weathering have caused ridges to form on the more resistant rocks. As a consequence, the dominant ridges and valleys follow the structure of the exposed rock formations. The result is a series of parallel, relatively narrow physiographic belts (ridges and valleys), the axes of which cross the area in a northeast-southwest direction. Most of the more rugged ridges are on interbedded sandstone and shale and argillaceous limestone. Much of the landscape over cherty dolomitic limestone is almost as high as the rugged shale ridges, but the ridgetops are broader and less sharply broken, with smoother round-topped ridges, typical of karst-like topography. Many of the small surface drains lead to sinkholes, where the runoff water enters subterranean channels. Part of the runoff water, however, proceeds through a partially formed dendritic surface system to permanent surface streams in the shale valleys.

One such dolomitic ridge, Chestnut Ridge, forms the northern boundary of Walker Branch watershed, with a maximum elevation on the watershed of over 375 meters. It is drained by Walker Branch, which has an elevation of 265 meters at the confluence of the two forks, and flows in an approximately northwest to southeast direction. Topography is hilly (Figure 2) with two-thirds of the land surface having slopes greater than 20% and 45% of the land having greater than 30% slope (Curlin and Nelson 1968). The steepest slopes are generally along drainage channels, although the upper reaches of intermittent channels extend near ridgetops where slopes are generally 15-30% or less. Also present are areas of slope less than 30% around the confluence of certain drainage channels, while there are isolated benches 3-15 meters wide along the

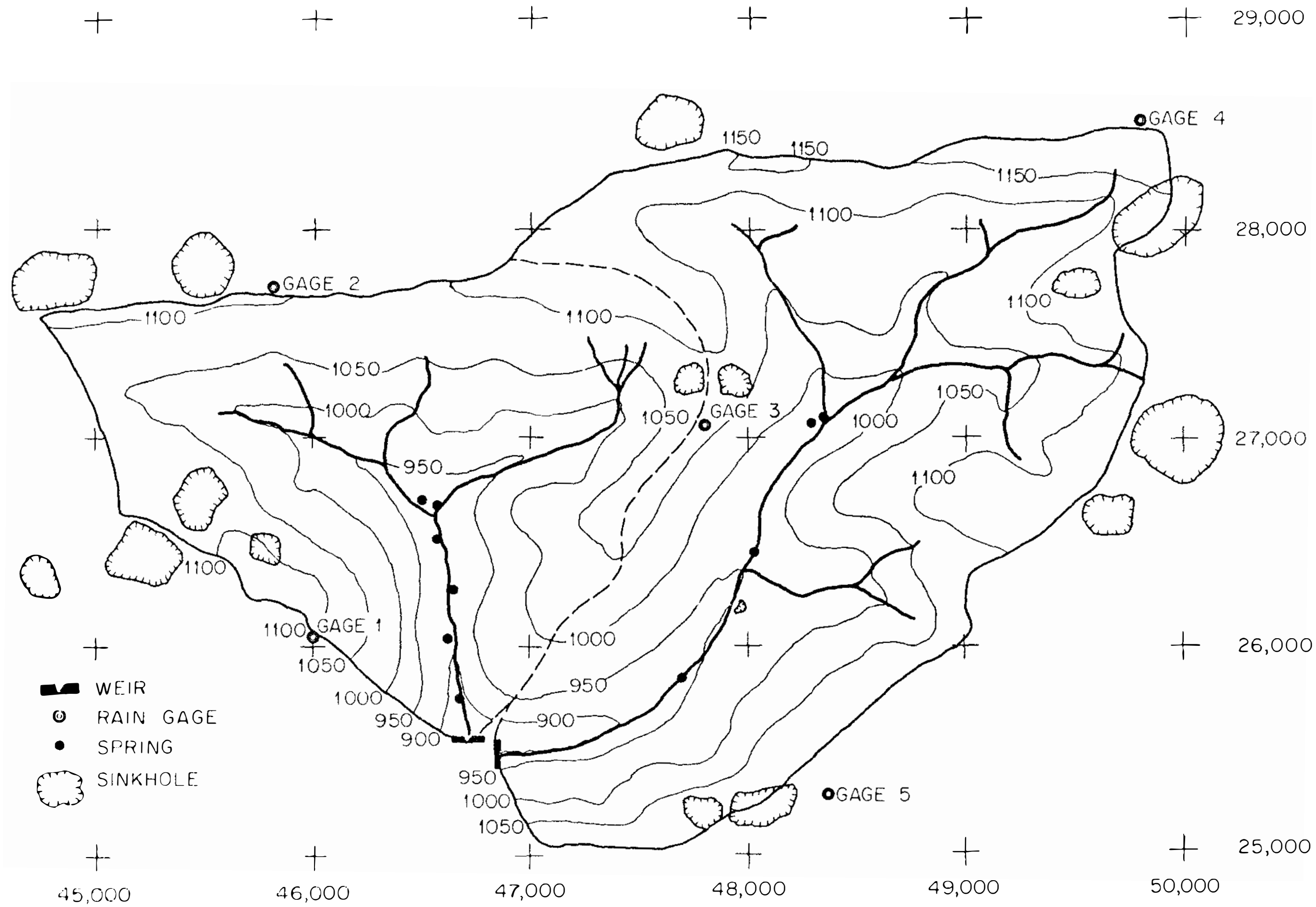

Figure 2. Topographic Map of Walker Branch Watershed on the ERDA Reservation, Oak Ridge, Tennessee, Showing the Location of Gaging Stations on the Two Subcatchments.

Source: Huff et al. (1977).

lower reaches of the drainage network. Only 11% of the watershed has slopes less than 12% (Curlin and Nelson 1968).

The watershed lies on Knox Dolomite, the major aquifer in the area. Its light to medium gray rock is siliceous, crystalline, and basic in reaction, with chert abundant in the upper part. It is easily weathered and contains large solution cavities. It is overlain by a 10-30 meter residual mantle of cherty clay which is also pocked with solution channels leading down to bedrock. The bedrock is of late Cambrian to early Ordovician age and dips to the southeast at a 35° angle, with bedding planes striking N60E (Curlin and Nelson 1968).

Soils formed over this bedrock are Typic Paleudults characterized by large amounts of chert. Low base saturation and exchangeable bases, poor nutrient status (P and N), low cation exchange capacity (CEC, expressed as meq/100g), and high infiltration capacity (and permeability) are characteristic with clays consisting of kaolinite with lesser amounts of vermiculite, hydrous mica, and quartz. These residual soils are so highly weathered that the pH is quite low (4.2-4.6) considering the nature of the parent material. Organic matter content ranges from 5.74 to 6.31 ppm in the A1 horizon of these soils, while values for the B2t horizon range from 0.54 to 0.63 ppm. (Peters et al. 1970).

Predominant soil series are Fullerton on the ridgetops and Bodine on steeper slopes, together encompassing 90-96% of the watershed area. Claiborne series occupies isolated positions along the creek and lower slopes. The major difference between Fullerton and Bodine is that the former contains twice as much clay in the B horizon. Therefore, it has

slightly higher CEC, while the Bodine has more chert in the lower horizons. Peters et al. (1970) stated that a comparison of the Bodine and Fullerton reveals an overriding similarity. The Claiborne soil, morphologically similar to the Bodine and Fullerton, has a higher CEC in upper horizons and overall higher base saturation.

Typical of the oak-chestnut forest region of the Appalachain Mountains (Braun 1950), the forest is dominated by oaks (especially Quercus prinus, Q. alba, and Q. rubra) and hickories (Carya tomentosa, C. cordiformis, and C. ovata) with mesophytes (especially Liriodendron tulipifera and Aesculus octandra) present in the coves and bottoms and some pine on the ridges. The terrestrial vegetation has been classified on the basis of an integrated ordination-classification analysis of the overstory vegetation (Grigal and Goldstein 1971), with four vegetation types recognized: (1) pine (predominantly Pinus echinata and P. virginiana), (2) yellow poplar (Liriodendron tulipifera), (3) oak-hickory (Quercus spp., Carya spp.), and (4) chestnut oak (Quercus prinus). Characteristics of these four vegetation types are presented in Table 1. The forest types have a mean basal area ranging from 22.2 m^2/ha for the oak-hickory type, to 26.0 m^2/ha for the chestnut oak type.

Small open areas, the result of southern pine beetle (Dendroctonus frontalis) infestation, are now in a state of rapid succession. In 1967, two fires occurred on the watershed. One affected four acres and the other 86 acres, the latter mainly confined to the east fork watershed. Together, the fires burned 38% of the total watershed area, 15% severely. In these latter areas, some overstory was destroyed and is now being replaced by herbaceous and woody undergrowth.

Table 1. Characteristics of the vegetation, topography and soils of the forest-types studied on the Walker Branch Watershed; each forest-type is represented by six 0.08 ha plots and, where appropriate, mean values of properties and their ranges (in parentheses) over these plots are given.

	Forest-Type[a]			
Parameter	Pinus	Liriodendron tulipfera	Quercus Prinus	Quercus-Carya
Basal area (m^2ha^{-1})	24.0(19.1-29.4)	25.4(23.5-30.7)	26.0(19.9-42.4)	22.2(19.3-29.3)
Percentage of basal area in various species				
Pinus echinata & P. virginiana	64.3(45.2-86.8)	1.7(0-10.0)	4.3(0-9.7)	1.5(0-5.0)
Quercus rubra, Q. velutina, Q. coccinea & Q. falcata	3.3(0-9.9)	4.5(0-9.0)	11.2(0-28.2)	8.7(0-25.7)
Quercus alba & Q. stellata	0.5(0-2.0)	9.3(0-28.3)	9.8(1.5-26.6)	18.5(0-44.8)
Quercus prinus	0	2.6(0-8.5)	47.5(28.3-72.0)	18.2(0-27.5)
Liriodendron tulipfera	16.6(4.9-37.5)	49.9(36.5-70.5)	0.3(0-1.7)	3.1(0-17.0)
Carya spp.	1.7(0-4.9)	7.1(0-22.0)	6.2(0-8.4)	27.4(1.3-51.6)
Acer rubrum	0.7(0-3.5)	4.7(0-13.8)	8.3(0-14.2)	6.4(0-10.8)
Nyssa sylvatica, Cornus florida & Oxydendron arboreum	9.2(1.1-19.1)	6.9(1.4-29.5)	9.1(3.3-19.7)	12.8(7.5-16.6)
Fagus grandifolia	0	3.5(0-17.5)	0	0.9(0-5.6)
Other species	3.8(0-15.5)	9.8(0.7-35.9)	3.3(0-8.5)	2.6(1.1-7.3)
Slope(°)	13(3-22)	16(5-28)	15(4-23)	14(3-21)
Topographic position	Upper ridge slopes	Stream bottoms, lower slopes, protected upper slopes	Upper ridge slopes	Mid- and upper ridge slopes
Soil characteristics				
Organic matter content %[b]	1.8-6.5	3.3-6.3	1.5-5.7	1.8-6.5
pH[b]	4.2-4.5	4.2-4.3	4.5-4.6	4.2-4.5

[a] According to the classification of Grigal & Goldstein (1971).

[b] A horizon.

Source: Henderson et al. 1977b

The land which includes Walker Branch watershed was acquired by the U.S. government in 1942 as the AEC Oak Ridge Reservation. Four homesites were located directly on the watershed, with agriculture practiced on 21% of the area with varying degrees of intensity. Poor agricultural practices (with cultivation and burn pasturing) led to substantial erosion. The area has undergone succession since 1942 (Auerbach et al. 1971).

This paper reports research on the 38.4 ha west fork catchment. The west fork of Walker Branch is a perennial flow stream fed exclusively by springs and seeps that arise in the dolomitic limestone. Stream gradient averages 55.9 m/km and mean annual discharge is 10.5 liter/sec (Elwood and Nelson 1972). The substrate consists primarily of sandy and cobbly gravel and bedrock. Average channel width, stream width, and mean depth are 2.77 m, 1.95 m, and 7 cm respectively, the latter two values defined at base flow conditions. Approximately 60 species of benthic macroinvertebrates characterize the bottom community, with nearly all orders of aquatic invertebrates represented. Primary production ($\sim$ 20 mg/m^2/ day, Elwood and Nelson 1972) is accomplished mainly by diatoms, with some filamentous algae and moss (*Fontinalis* sp.) present in isolated areas, along with small stands of watercress (*Nasturtium officinale*) near the spring mouths.

Based on one and one-half years' data from Surber samples taken in the stony riffle habitat (the most widespread type of habitat in Walker Branch), Elwood (personal communication) found that of the 16 dominant species of benthic macroinvertebrates present in Walker Branch, all but

three were detritivores to one degree or another. Further evidence of the dependence of the consumer population on allochthonous detritus was given by Elwood (in Auerbach and Nelson 1971b), where diversity of benthic macrofauna (modification of the Shannon index) was shown to be at peak levels during fall to early spring when input of allochthonous leaf litter was maximal, indicating that the life cycles of members of the benthic community were keyed to seasonal inputs of allochthonous organic matter.

This dependence on allochthonous detritus was further demonstrated by P^{32} tracer studies (Auerbach and Nelson 1971a), which showed that the populations of snails (*Goniobasis clavaeformis*) alone had a consumption greater than could be supplied by the periphytic diatoms. Auerbach et al. (1970) concluded, "It appears that almost the entire trophic structure of the stream is heterotrophically based, since most of the food source of primary consumers is dependent on production that occurs outside the stream ecosystem."

The study reach extended from the most downstream point of unconfined flow (38.1 meters above the weir) to the upper limit of perennial flow, a distance of 335.3 meters.

CHAPTER III

METEOROLOGY AND HYDROLOGY

The climate of the area is classified as humid mesothermal (Thornthwaite 1948) and typical of the southern Appalachian region, with moderately cool summers and mild winters. Because of its location in a valley surrounded by mountains, the local climate is somewhat moderated.

Annual mean temperature, based on Oak Ridge Townsite Station data for 1948-1972 (ORATDL 1972) was 14.4°C, with a range of monthly means of 3.3°C in January to 24.9°C in July. Temperatures less than -17.8°C (0°F) or greater than 37.8°C (100°F) are uncommon. The frost-free period averages 200 days (ORATDL 1972). Using the Thornthwaite and Mather (1957) monthly temperature index to estimate potential evapotranspiration, a value of 76.5 cm/yr can be calculated for the Oak Ridge area.

Mean annual precipitation for the Oak Ridge area is 140.1 cm (ORATDL 1972, and yearly supplements), but the mean for the 1970-1976 period was greater, averaging 151.1 cm (Henderson et al. 1977b). Based on the historic record for monthly mean precipitation, rainfall is relatively evenly distributed through the year (Figure 3) with the general trend being toward wet winters, comparatively dry springs, wet summers, and dry autumns. Average monthly frequency of precipitation generally follows the trend for monthly volume. Approximately one day in every three receives precipitation, with 55% of these days receiving less than 1 cm of rain and 90% receiving less than 3 cm (Henderson et al. 1977b). However, the rainfall during days with precipitation greater than 3 cm

account for 35% of the total annual rainfall, while only 20% is accounted for by the days with less than 1 cm of rain. Periods of five consecutive days with no precipitation occur four to five times per year while periods of 10 consecutive days occur one to two times per year, with dry periods of greater than 11 days occurring less than once per year. Less than 20% of the periods of no rain exceed one week for a given year. Snowfall averages 24.2 cm, with a maximum of 105.2 cm, and with some years having only a trace (ORATDL 1972). Once snow is on the ground, it usually disappears rapidly.

While monthly mean values for rainfall (from the historic record) show seasonal trends, precipitation is highly variable both on an annual basis (95.0-187.5 cm) and for any month from year to year. For example, October, the driest month, had precipitation ranging from a trace to 17.65 cm. July (mean 14.20 cm) and January (mean 13.74 cm) are the wettest months, indicating the bimodality in seasonal distribution of precipitation. Records indicate that monthly precipitation has varied from 3.94 cm to 48.95 cm for July and from 4.72 cm to 33.70 cm for January. Some of the highest monthly means have occurred during normally dry autumn months.

McMaster (1967) presented an isohyetal map of the Oak Ridge area based on TVA data (Tennessee Valley Authority 1960) for the water years 1936-1960. It showed a range of mean annual precipitation from greater than 147.32 cm to the northwest of Oak Ridge (edge of Cumberland Plateau) to 116.84 cm in the northeast, a distance of approximately 20 miles. This could further explain the variable nature of the precipitation regime.

Another factor contributing to the variability in the precipitation regime involves localized intense storms. The most intensive storms occur as violent thunderstorms in summer, one (August 10, 1960) having brought nearly 23 cm of rain in 3 hours. The limited areal extent of this storm is evidenced by the fact that only 0.08 cm was recorded at a recording gage 12 miles away (McMaster 1967). Maximum intensity of the storm was 8.71 cm/hr, which has a recurrence interval of greater than 100 years. The 100 year maximum 24 hour rainfall is 21.59 cm (McMaster 1967).

Using the annual water balance of the watershed for six-year period (1970-1976), Henderson et al. (1977b) have calculated actual evapotranspiration as 65.3 cm/yr. The difference (11.2 cm) between predicted evapotranspiration of 76.5 cm (Thornthwaite and Mather 1957) and actual evapotranspiration indicates a water deficit during the growing season of most years, and brings into focus the importance of the seasonal distribution of precipitation. Under average yearly conditions, soil moisture utilization increases during the dry spring period, leading to soil water deficits during the summer; but summer rainfall, especially during July, usually prevents serious impairment of plant growth (Curlin and Nelson 1968). Years with high but unevenly distributed rainfall, with drought periods during the growing season, will restrict transpiration losses to a greater extent than years with less, but more evenly distributed rainfall. Sheppard and Henderson (1973) concluded that the restriction of transpiration during the growing season restricts biomass production on Walker Branch watershed.

The yearly pattern of streamflow on Walker Branch is directly related to the precipitation regime and to seasonal changes in solar radiation (energy), temperature, and biotic activities on the watershed (which in turn determine evapotranspiration) being modified by the geology of the basin.

Figure 3, based on 1970-1976 watershed data, shows the yearly cycle of soil moisture as the result of the interaction of its determining factors, precipitation and evapotranspiration. Beginning in mid-fall, after base-flow has reached its yearly low, increases in precipitation and decreases in evapotranspiration lead first to a recharging of soil moisture and eventually to a soil water surplus. Most of this surplus is not immediately apparent as streamflow, but recharges the residual cherty clay material overlying the bedrock, which in turn feeds underlying solution cavities in the bedrock itself (McMaster 1967).

As saturation of the aquifer system continues, increases in groundwater discharge eventually occur, yielding higher baseflow levels during the latter part of fall (Figure 4). Base flow continues to increase through winter and early spring when water input greatly exceeds evapotranspiration, leaving a large water surplus, some of which recharges the groundwater system. This can be seen in the data of McMaster (1967) from a nearby watershed, where peak volume of groundwater occurred in mid-March. Unsaturated soil water drainage also probably contributes a significant portion of the baseflow.

Decreasing precipitation in mid-spring (Figure 3) combined with renewal of plant growth and increase of transpirational surfaces with

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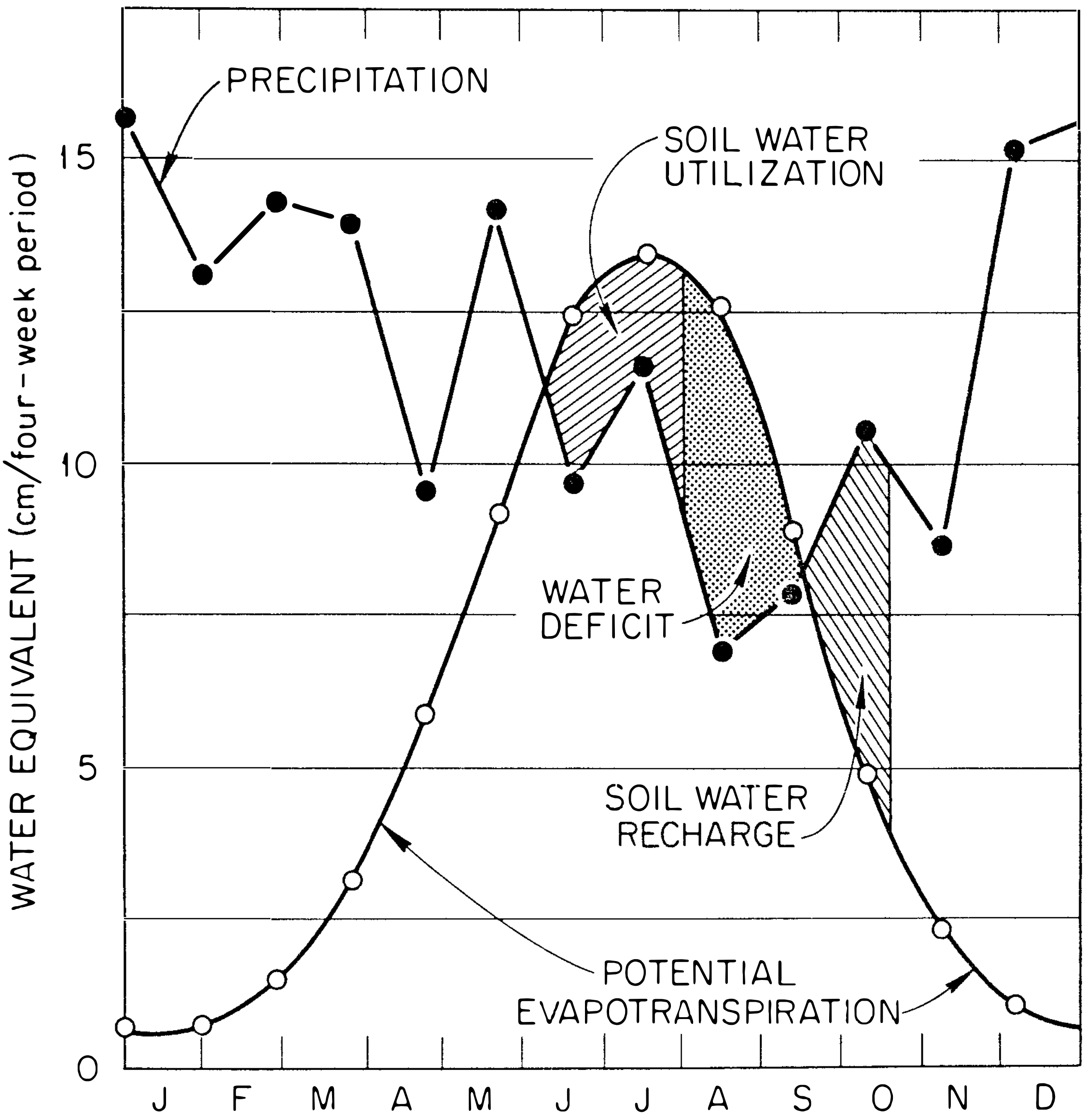

Figure 3. Seasonal Relationship Between Precipitation and Potential Evapotranspiration for Walker Branch Watershed Showing Periods of Soil Water Utilization, Water Deficit, and Soil Water Recharge.

Source: Henderson et al. (1977b).

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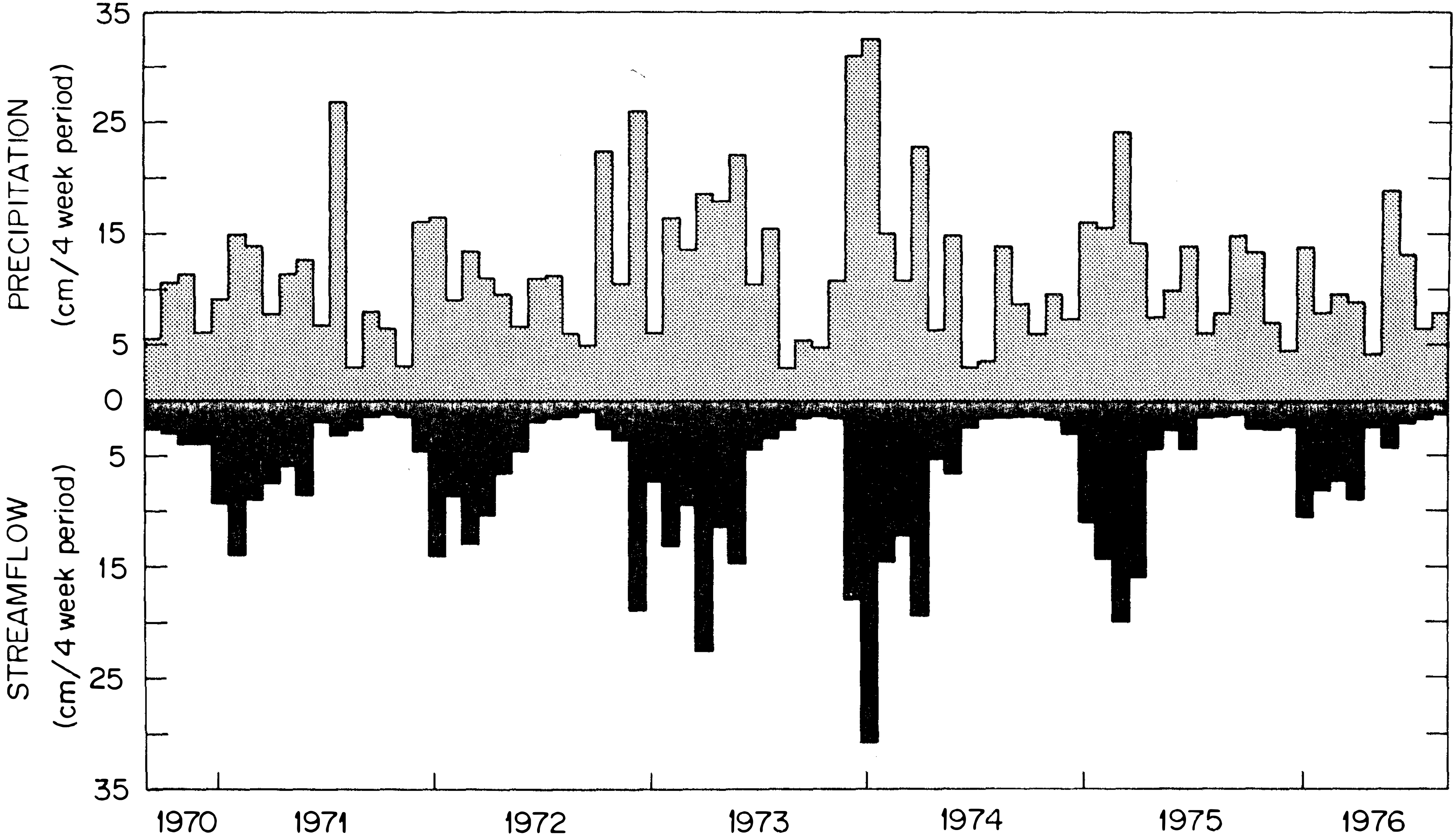

Figure 4. Seasonal Distributions by Four-Week Intervals (13/Year) of Precipitation and Streamflow for Walker Branch Watershed from September 1, 1970 through August 31, 1976.

Source: Henderson et al. (1977b).

increasing air temperatures, leads to soil moisture utilization and ultimately, by mid-summer, to soil moisture deficiency. This disallows indirect contributions of precipitation to the aquifer system, leading to decreased base flow levels (Figure 4). The increased precipitation from late June through early August is usually insufficient to recharge the entire soil-mantle-bedrock system, mainly due to the fact that potential evapotranspiration is at its maximum for the year. Thus, in most years, runoff decreases during this period (Figure 4). The deficiency in soil moisture builds through the end of summer. Base flow continues to decrease through this period and into early fall (Figure 4), while soil water/aquifer recharge is taking place (Figure 3). This seasonal relationship is demonstrated by the fact that summer months (July-September) have, on the average, the second highest rainfall of any quarter, and the lowest runoff. This is true even during years of higher than average rainfall during the growing season. Shephard and Henderson (1973) noted that, in the dormant season, streamflow followed precipitation closely, with net input near zero. In the growing season, streamflow was independent of precipitation. Of interest is the dramatic increase in May in net input as leaf development proceeds rapidly. While the fall period (October 1 to December 31) has slightly more rainfall and substantially less potential evapotranspiration than spring (April 1 to June 30), runoff is substantially greater in spring, due mainly to the fact that it begins with a maximally charged watershed, while the fall period usually begins with a dry system. The buffering capacity of the terrestrial system can be seen in Figure 4 by the smaller oscillations

in streamflow as compared to precipitation, especially during the summer months.

The degree of soil saturation on the watershed, as shown in Figure 3, has a profound effect on the severity of flooding which can be produced by a given precipitation event. Soils on Walker Branch have a high infiltration capacity (13.8 cm/hr for the Fullerton B horizon, Peters et al. 1970), and thus there is little or no overland flow even when precipitation is greatest. Most precipitation infiltrates the soil, either being utilized in evapotranspiration or in recharging the groundwater system. Average water storage capacity of soils on the watershed is only 4.6 cm for the upper 100 cm of the soil profile (Peters et al. 1970). This can lead to rather rapid changes in discharge characteristics during mid to late fall when evapotranspiration is low and frontal storm activity begins.

During periods of soil water surplus, the chance for peak flow is much greater than during periods of recharge or deficiency. Under saturation conditions, rainfall literally pushes water through the soil-mantle-bedrock system, increasing the head pressure on the aquifer system, thereby increasing springflow and source area contributions. This increased groundwater, combined with the rain falling directly into the expanded stream channel and that portion running laterally through the soil profile toward the stream channel, will yield high flows. The same amount of precipitation falling during periods of soil moisture deficiency would cause little or no water input to the aquifer system or lateral transport to source areas, with virtually all available water

being redistributed and utilized within the rooting zone (Henderson et al. 1977). This would lead to no increase in streamflow, and the storm hydrograph would represent an increase in flow due predominantly to water falling directly into the stream channel.

The nature of the bedrock aquifer system in controlling streamflow cannot be overemphasized. McMaster (1967) presented flow-duration curves for Oak Ridge area watersheds which clearly demonstrate the differing capacity of the several bedrock types of the area to moderate streamflow. Of importance here is the range between the high and low values for each catchment, with dolomite basins exhibiting the least spread. Greatest differences lie in the low flow side, because dolomite basins maintain much higher base flows due to their greater aquifer storage capacity allowing them to release water slowly as springflow. This larger storage capacity could lead to a higher peak flow when one storm is followed closely by another.

Prevailing wind directions are influenced by topography, with the majority running up the valley (from west to southwest) or down the valley (north to northeast). Mean wind speed is 2.0 m/s (ORATDL 1972). Of special interest is the predominance of strong winds in late fall through spring from the west-southwest.

CHAPTER IV

METHODS

Litterfall

Coarse organic litter (>1 mm) falling directly into the stream channel was sampled with a series of forty-two 0.16 m^2 polyethylene tubs suspended at 1 meter height over randomly selected locations along the entire drainage network. Sampling began on September 1, 1973 and terminated on September 1, 1974, with weekly collections through November, 1973 and monthly collections thereafter.

Litter material was taken to the laboratory, dried at 70°C to constant weight, separated into leaves, fruits and reproductive parts, twigs, and frass (fecal pellets), and weighed. Representative samples were ashed at 525°C and reweighed, with all weights expressed as ash-free dry weight. Representative samples were analyzed for organic carbon content by high temperature combustion (950°C) in a pure oxygen atmosphere under static conditions, followed by passage through a reduction furnace and subsequent quantitative determination of the liberated CO_2 by paired thermal conductivity cells using helium as the carrier.

Blow-In

Blow-in traps consisted of 1 m^2 wooden frames oriented vertically with the upslope side open and a 1 mm wire mesh over the downslope side, the latter expanded at the bottom to form a pocket for retaining material between collections. Traps were placed within 1 meter of the streambank

whenever possible. To minimize spurious entrapment of litterfall, a 1 m^2 awning (1 mm wire mesh) was secured at a +45° angle (with the horizontal) above the open upslope face of the trap. The awning also increased the effective height of the trap.

Traps were emptied monthly from September 1, 1973 to September 1, 1974. Blow-in material was taken to the laboratory, separated into leaf, fruit and reproductive part, twig, and frass components, dried at 70°C and weighed. Representative samples were ashed at 525°C and reweighed, with all dry weights being expressed as ash-free. Representative samples were analyzed for organic carbon content in a manner identical to that for litterfall.

The experimental design of trap placement involved consideration of two major variables, aspect and slope class. Two aspects (northeast- and southwest) and four slope classes (0-10% or benches, 15-30%, 30-45%, and 45-60%) were recognized. Except for the northeast- and southwest-facing benches (0-10%), which received four traps each, eight traps were employed for each subgroup, for a total of 56 traps.

The statistical model for blow-in consisted of a 3-way Factorial ANOVA (Kirk 1968) with main effects being aspect, slope class, and date. Analyses of variance utilized Statistical Analysis System (SAS 76.5) General Linear Model procedures (Barr et al. 1976). Subsequent analyses depended on the significance of interaction terms in the overall ANOVA. For cases of insignificant interaction terms, multiple means tests were performed, while the presence of significant interaction required simple main effects tests and interaction tests, according to Kirk (1968). In

the case of the multiple means tests, all possible pairwise comparisons of means for each significant main effect were made (over all levels of the other main effects) using Tukey's $t_{0.05}$ (0.707 x studentized range) as the criterion of significance. The simple main effects prodedures involved tests of means of a significant main effect within levels of the other main effect involved in the significant interaction, using the F statistic as the criterion of significance and the significance level (0.05/n) determined by the number (n) of levels of the other main effect involved in the significant interaction. Interaction tests were made within each level of the third main effect using the F statistic, with the level of significance (0.05/n) determined by the number of levels of the third main effect. Blow-in data were transformed for ANOVA using the natural logarithm plus 1.

Hydrologic Monitoring

Five precipitation gages were located on ridgetops surrounding the two watersheds (See Figure 2, page 28), with three of the five (gages 1-3) used to determine precipitation inputs to the west fork. Total precipitation was measured using Fisher and Porter Model 1548 automatic weighing precipitation recorders with data punched on paper tape at five minute intervals. The instrumentation detects changes of 0.03 inches (0.075 cm) of precipitation, but data are recorded in 0.1 inch (0.25 cm) increments.

The weighted average precipitation received by each subwatershed was estimated using the Thiessen polygon method (Thiessen 1911). Fur-

ther description of the precipitation monitoring facilities at Walker Branch can be found in Curlin and Nelson (1968).

Streamflow was measured on the branch draining each subwatershed using sharp-edged stainless steel weir blades with a 120° V-notch. Stage height was recorded at five-minute intervals on binary coded punched tape using analog-to-digital Fisher and Porter water level recorders with resolution of 0.001 foot (0.03 cm) stage height. Streamflow as high as 41.6 ft^3/sec (1.2 m^3/sec) can be measured by the weir blades. Higher volumes of flows which occur during intensive storms are measured by the sharp-crested rectangular section above the V-notch with slightly less accuracy (0.003 foot or 0.09 cm stage height). The weir, which is set in concrete, and the stilling basin were built to the capacity of a predicted 100 year flood. Further description of weir construction and operation are given in Curlin and Nelson (1968) and Nelson (1970).

Streamflow was calculated from the recorded stage heights and the equation of Hertzler (1938) for 120° v-notch weirs:

$$Q = 4.43\ H^{2.449} \times 0.0283$$

or $$Q = [41.779 + 66.8(H - 2.5)^{1.47}] \times 0.0283$$ for stage height >2.5 ft (0.76 m)

where Q is discharge in m^3/sec and H is stage height in feet.

Allochthonous Standing Crops in the Stream Channel

The aim of the sampling design in the stream channel was to determine the effects of substrate type and hydrologic and biologic factors

associated with the length of exposure to the streamflow regime on the standing crop of organic detritus (> 1 mm). The four stream habitat types discussed in this paper included stream gravel (including both riffle and gravel pools), dry gravel (generally located along the edges of the channel), and bedrock pools, as defined by base flow conditions. The bedrock pools and stream gravel were covered with water during all flow conditions, while the dry types were exposed to the streamflow regime only during high flow periods. All coarse organic material within a 0.05 m^2 rubber ring was hand picked from the surface of the substrate, with occasional use of a 25 cm^2 hand net (1 mm mesh) where much detritus was present.

Degree of replication was determined to a large extent by the proportional representation of each habitat type in the channel. For all but the first sampling period, 20, 10, 5, and 5 samples were collected from randomly selected locations in the stream gravel, dry gravel, dry bedrock, and bedrock pools, respectively. At the initial sampling only 10 stream gravel and 5 dry gravel samples were taken. Samples were collected monthly from September through December 1973, and thereafter approximately every 9 weeks (February 8, April 15, June 21, and September 1, 1974).

Detritus was taken to the laboratory, separated into leaves, fruits and reproductive parts, and twigs, dried at 70°C, and each component weighed. Representative samples were ashed at 525° C and reweighed, with all weights expressed as ash-free dry weight. Representative samples were then analyzed for organic carbon content using the same method as previously described for litterfall.

The experimental design for standing crops involved a 2-way Factorial ANOVA (Kirk 1968) with date and habitat type as main effects. Analyses of variance utilized Statistical Analysis System (SAS 76.5) General Linear Model procedures (Barr et al. 1976), with subsequent analyses utilizing multiple means tests (Kirk 1968) as described for blow-in data. For the ANOVA's, standing crop data were transformed using the natural logarithm plus 1 to more closely approximate normality.

Incident Precipitation and Throughfall

As discussed herein, incident precipitation represents atmospheric contributions to the watershed system, while throughfall represents the material carried to the forest floor after passage of the incident precipitation through the forest canopy. Throughfall, therefore, includes those components of incident precipitation which are not intercepted or biologically removed by the vegetation canopy. The difference between throughfall and incident precipitation is due to removal from or uptake by the canopy (Eaton et al. 1973, Henderson et al. 1977a). Net removal of organic material from the canopy would therefore include the material washed and leached from the surface of the vegetation minus that portion of the incident precipitation load retained by the canopy as interception or taken up by the foliage. Since equipment was not available for segregating rainfall inputs from those occurring during dry periods, incident precipitation and throughfall include both dryfall and wetfall contributions.

Organic carbon in incident precipitation and throughfall was monitored using either two- or four-liter polyethylene bottles, each with a polypropylene funnel (12 cm wide at the outer edge of the cone) inserted in the neck. The funnel mouth was fitted with wire mesh cones (1 mm mesh opening) to prevent the entrance of coarse particulate matter into samples.

Throughfall collectors were placed at randomly selected points in the stream channel, positions being chosen from a table of random numbers after mapping. Collectors were strapped to metal stakes driven into the stream substrate. If a random choice turned out to be a section of channel with bedrock substrate, the closest spot with adequate substrate for anchoring the stake was chosen. Funnel mouths were 0.6 meters above the substrate or water level to prevent splash inputs. Twelve throughfall collectors were deployed, but equipment damage and sample contamination resulted in fewer samples being realized during some months.

One collector was also deployed at each of the three ridge-top meteorological stations bordering the west fork watershed (see Figure 2, page 26). Since each ridge-top station is located in the center of a 50 meter (radius) clearing which is kept mowed, data from these collectors were expected to give a realistic estimate of total (dryfall plus wetfall) allochthonous meteorological inputs. Again, damage to and obvious contamination of some of the samples resulted in fewer intact collectors during some months. No collectors were deployed for incident precipitation during the winter months (December through February), since no leaf canopy was present and appreciable differences in organic content between

incident precipitation and throughfall were not expected. The lack of data for November 1973 was due to the large amount of precipitation during the storm of November 26-28, during which time the collectors overflowed. However, since the overwhelming majority of the rainfall during this month occurred after leaf fall, little difference between incident precipitation and throughfall organic carbon content would be expected.

Collectors were generally rotated monthly. However, on several occasions when individual storm events were being studied or when required by large volumes of precipitation, more frequent sample retrieval was made. Due to the length of the sample interval, HCl was used as a preservative (Lohammar 1938, Neumann et al. 1959), so that the final pH was below 2.0. According to Skinner et al. (1949), few microorganisms are active at pH below 2. Collectors were also painted black to help prevent the development of autotrophic contaminants. Prior to deployment, bottles were acid-washed (3 N HCl) and rinsed twice in distilled water (total organic carbon content of distilled rinse < 0.1 mg/l).

After being taken to the laboratory, the contents of each collector were passed through a 250 μm mesh Nitex net to remove coarse particulate organic material (250 μm - 1 mm). After recording the volume, the sample or a subsample thereof was filtered through a precombusted (525°C) 0.45 μm opening glass-fiber filter (Reeve Angel No 984-H). Filter and filtrate were then analyzed for organic carbon.

All organic carbon analyses were accomplished using an Oceanographic International Model 0524 Total Carbon System (Oceanography International

Corp. 1972). The procedure is based on the persulfate oxidation and subsequent infrared analysis method described by Menzel and Vaccaro (1964), with substantial labor-saving modifications (also see Fredericks and Hood 1965). Organic carbon is oxidized to CO_2 with persulfate at elevated temperatures (>120°C), and the carbon dioxide thus produced is swept through a nondispersive infrared analyzer, with the output being sent to a chart recorder equipped with a disc integrator. Glucose and inorganic carbon standards were used to prepare calibration curves. Strickland and Parsons (1968) felt that the persulfate oxidation renders essentially total oxidation of soluble organic carbon. Lower limit of detection was less than 0.1 mg/l.

Regression analyses were performed for concentration of dissolved organic carbon (DOC), fine particulate organic carbon (FPOC), and total organic carbon (TOC) vs volume of sample employing a number of linear models, including normal, semilogarithmic, logarithmic, and inverse forms. Statistical Analysis System (SAS 76.5) General Linear Model Procedures (Barr et al. 1976) were utilized in the regression analyses.

For statistical analysis of input of DOC, FPOC, and TOC, calculated inputs (concentration times collection volume) were regressed on the weighted average input of precipitation, as measured by the three raingages surrounding the west fork watershed. Techniques followed those of Sokal and Rohlf (1969) for situations involving multiple values of the dependent variable per observation of the independent variable.

Soil Water

Twenty-four pressure tube lysimeters, one in each of six 0.08 ha circular plots in each of the four forest types on Walker Branch watershed, were used to monitor the concentration of DOC in the soil water. They had been in place for several years before initiation of this study and were well equilibrated with the surrounding soil.

Each lysimeter consisted of a 1 meter long polyvinyl chloride tube with a porous ceramic cup at the sampling end, through which soil water was drawn by a 15 psi vacuum applied to the lysimeter at the beginning of each sampling interval. The ceramic cups were situated 75 cm below the soil surface. Wagner (1962) stated that the pores in the ceramic cup become filled with soil water due to capillary suction, the pore size being such that water is held in the pores with a force sufficient to seal the cup against air pressure of at least 15 psi, thus allowing a vacuum to be drawn. Openings within the ceramic cups are less than 1 μm and do not allow the passage of particulate matter, including many bacteria. Parizek and Lane (1970) stated that these pressure vacuum lysimeters can be used to collect soil water samples long after pan lysimeters fail to provide samples.

Lysimeters were serviced approximately once every three weeks, with occasionally more frequent attention when large rainfall events occurred. At servicing, the vacuum was released, the rubber stopper at the upper end of the tube removed, and a hand pump used to recover water from the tube. Upon evacuation of the tube, the stopper was replaced and suction drawn on the tube to 15 psi. Tests using distilled water (DOC concentra-

tion <0.1 mg/l) showed no contamination of the water as it passed through the pump.

After being taken to the laboratory, a subsample of the water recovered from each lysimeter was passed through a precombusted (525°C) 0.45 μm opening glass fiber filter (Reeve Angel No. 984-H) and the filtrate analyzed for DOC. Organic carbon analyses were accomplished using an Oceanographic International Model 0524 Total Carbon System as described for the throughfall. Although a balanced design was planned, loss of vaccum in some lysimeters, along with collection of water in only a few of the lysimeters in some months (due to lack of adequate quantities of groundwater at certain drier sites), led to a realization of less than the planned number of observations during some months.

All analyses of variance for groundwater utilized Statistical Analysis System (SAS 76.5) General Linear Model procedures (Barr et al. 1976), followed by multiple means testing (Kirk 1968). Regression analyses relating DOC concentration to infiltration, computed by the computer code PROSPER, a model of Atmospheric-Soil-Plant Water Flow (Goldstein and Mankin 1972), followed the procedures of Sokal and Rohlf (1969) for multiple values of the dependent variable per observation of independent variable. No data transformations were necessary to achieve normality.

DOC and FPOC in Streamflow and Springflow

A continuous proportional water sampler, similar to that developed at ORNL for use in the Clinch River (Struxness et al. 1967), was employed at each weir. However, certain modifications relating to storm

sampling have been added, and are discussed in detail by Johnson and Miller (1970).

Non-storm samples were composited in a refrigerated carbuoy (Figure 5). The sampling system automatically switched to a fast sampling mode when the discharge rate derivative circuit detected a rate of flow change that exceeded a preset adjustable value. A sample diverting solenoid valve was activated which diverted water samples through a collector arm which moved sequentially from one bottle to the next at preset time intervals, directed by a counter in the fraction collector control unit that was activated at the same time the sample diverting solenoid was activated. Up to 250 individual storm samples could be collected before new bottles had to be added. The fraction collector was activated manually during non-storm periods for detailed studies such as diurnal cycles, or activated in anticipation of approaching storms so the very early part of storm events could be sampled. The sampler was often manually activated for short (5-10 minute) periods so that a "grab" sample could be taken. Occasional line "freeze-up," caused by malfunctioning temperature control systems, caused either no composite sample or one encompassing only a portion of the weekly discharge. A further description of the sampler is found in Curlin and Nelson (1968), Johnson and Miller (1970), and Nelson (1970).

Proportional water samples were taken at the major spring (SW3) with a continuous flow portable water sampler. No fast mode was available. Weekly composite samples were usually available from spring SW3, but the sampler was not housed in an enclosure and was thus subject to

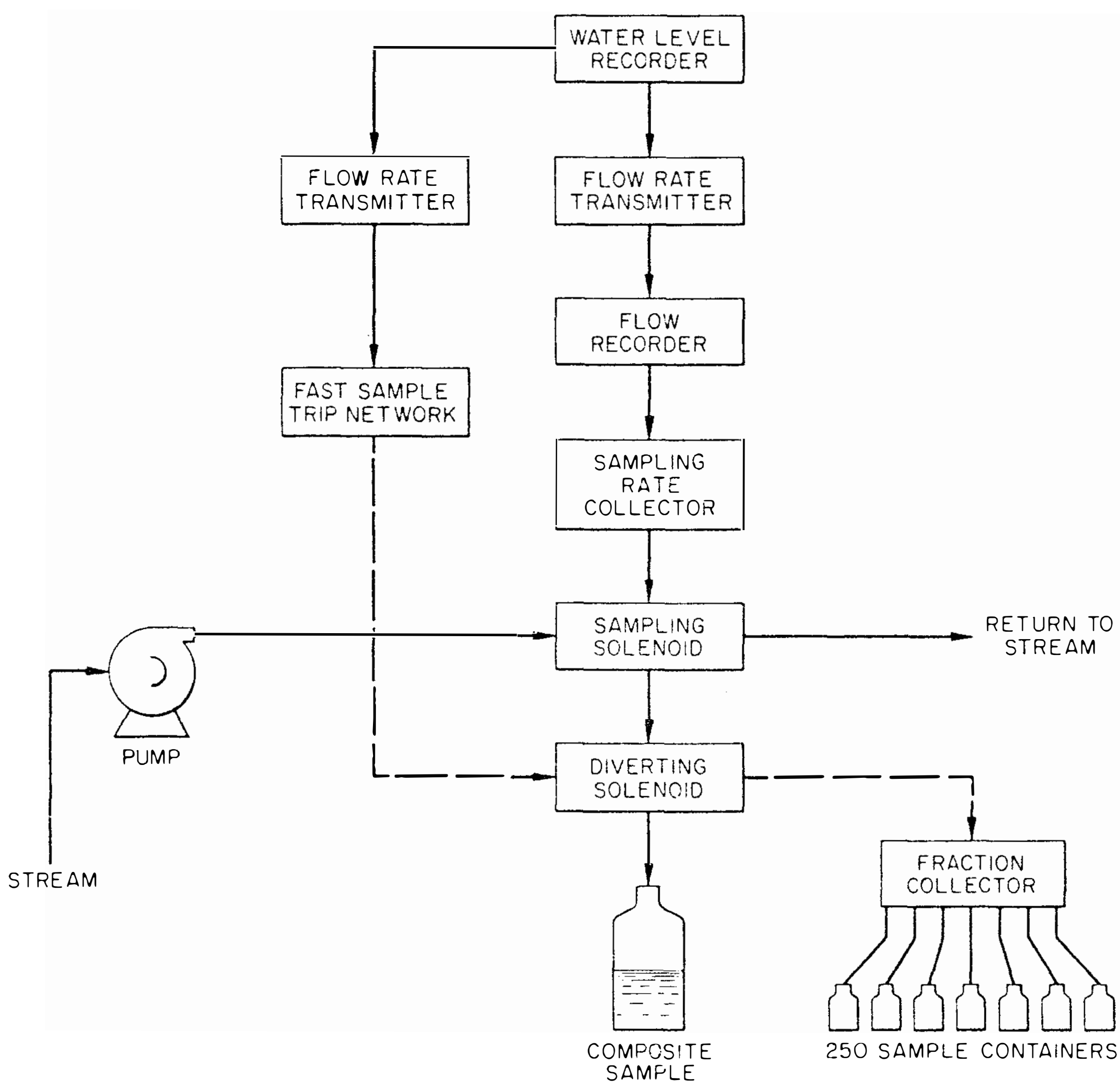

Figure 5. Schematic Diagram of the Water Sampling System.

Source: Curlin and Nelson (1968).

vagaries of the weather. This was especially true during winter months, when frozen sampler lines were common.

Nelson (1970) discussed the different ways water samples can be taken. He stated that in situations where the chemical quality of the water does not change with stream discharge, grab samples are completely acceptable. This appears to be the general rule at Hubbard Brook (Bormann and Likens 1966). However, in situations like those at Walker Branch, where water quality varies with stream discharge, a proportional sampler is required. Actually it is difficult to imagine a situation where concentration of organic carbon does not vary with streamflow, especially in summer thunderstorms in which large canopy inputs and minor groundwater inputs occur.

All samples were taken in pre-leached Nalgene bottles and were preserved with HCl. Processing was the same as for throughfall samples. The sample volume was measured and the sample was filtered through a 0.45 μm opening glass-fiber filter. The filtrate was stored in pre-leached glass bottles until analysis. Filters were air dried and stored in labeled petri dishes. Because of the 1 mm mesh wire screen covering the receiving end of the PVC tube, the particulate fraction represented the 1 mm to 0.45 μm range. Samples were subsequently analyzed for concentration of organic carbon using the Oceanography Model 0524 Total Carbon System (Oceanography International Corp. 1972), using the persulfate oxidation procedure discussed for analyses of throughfall, incident precipitation and soil water samples.

This thesis reports on streamwater samples collected during the period from January 1973 to September 1974. Approximately 1600 data observations were made during the twenty-month period. During the period from mid-March 1973 to mid-March 1974, virtually every significant event was intensively sampled.

Weekly weighted mean concentrations and weekly outputs of DOC and FPOC were calculated according to a computer code which coupled concentration and discharge data sets. This code operated in a manner analogous to the composite stream-water sampler in that calculations are based on individual storm samples, with the composite data used during non-storm periods. In the present study, grab samples were often utilized in the calculations during non-storm periods, especially during weeks involving a long receding hydrograph, or in other cases when malfunctioning of the composite sampler (especially freezing lines) led to a significant portion of the weekly flow being unsampled.

Concentration and output data from both individual samples (storm and "grab") and weekly weighted concentrations (as calculated from the computer code) were statistically analyzed for relationship to stream discharge (cms) using standard linear regression procedures available under Procedure GLM (General Linear Models) in SAS 76.5 (Barr et al. 1976). A number of models were employed, including normal, semilogarithmic, and logarithmic forms.

CHAPTER V

RESULTS AND DISCUSSION

Litterfall

Leaf Inputs

Direct leaf fall mean daily inputs to the west fork of Walker Branch during the 1973-1974 water year are shown in Figure 6. These means ± one standard error are shown in Table A1 of Appendix A. Highest mean daily inputs occurred during the first two weeks of November (7.47 $g/m^2/day$), although the maximum mean monthly input was in October (148.49 g/m^2). Mean daily rate of input for the October 16 - November 2 period (6.17 g/m^2) approached that for the subsequent two week period.

Results for the autumn period are very close to those of Grizzard et al. (1976), who studied litterfall in the four forest types (Curlin and Nelson 1968) on Walker Branch watershed. Comparing Figure 6 to Figure 17 of Grizzard et al. (1976), small differences in the pattern, timing, and magnitude of leaf fall were due to the slightly different timing of sample collection. Results of the present study suggest that leaf fall in the stream system at Walker Branch represents a composite of the deciduous forest types studied by Grizzard et al. (1976).

A minor increase in leaf fall occurred during July and August (22.64 g/m^2 for the two months), probably a response to the extremely dry conditions from mid-June to mid-August, led to the early abscission of some leaves. From December through June, monthly means were less than 1.70 g/m^2. The data of Grizzard et al. (1976) showed no indication of an early

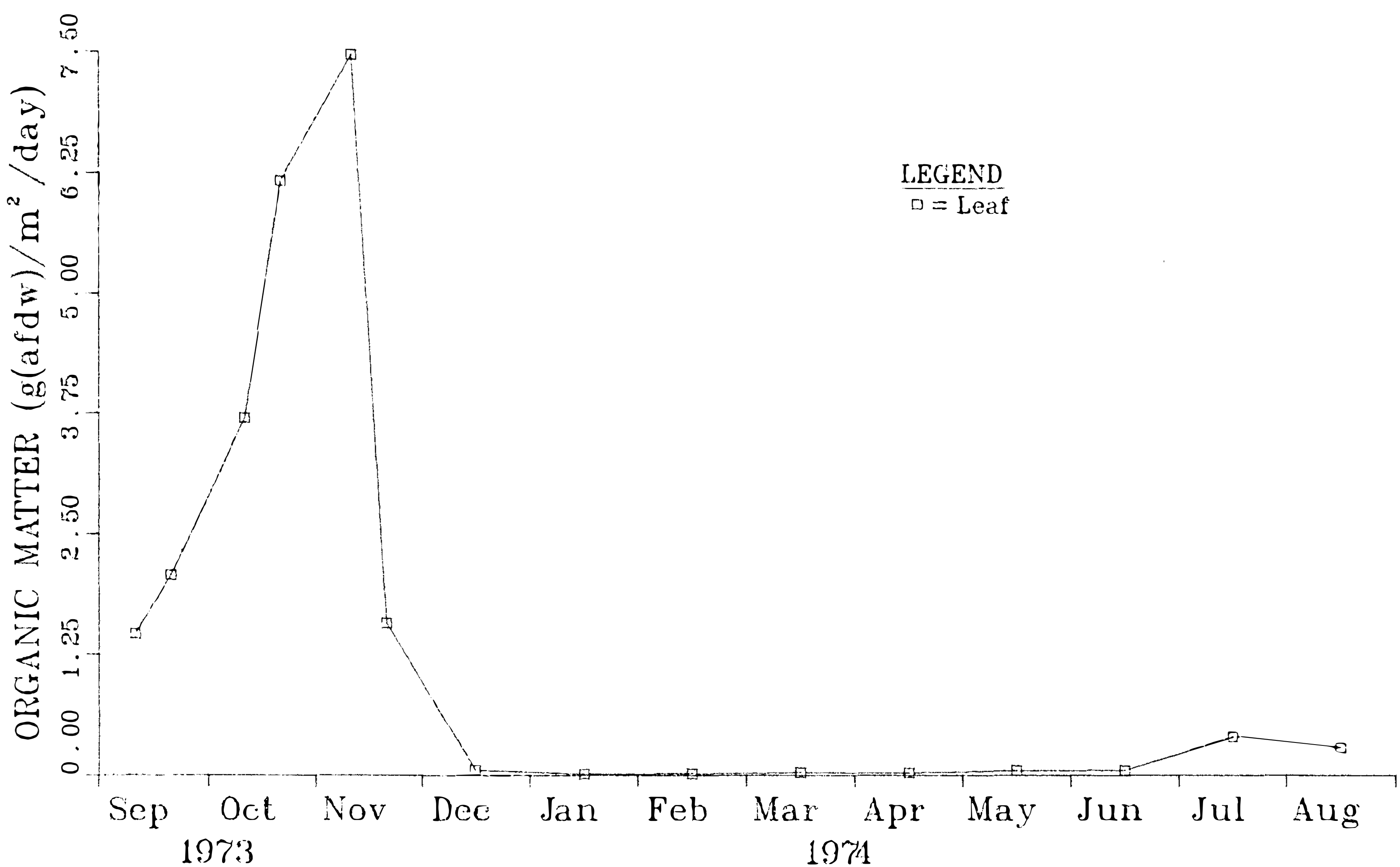

Figure 6. Mean Daily Rates of Input of Leaves via Litterfall to the Drainage Network of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

to mid-summer increase in leaf fall, with the first discernible increase in the September 2 collection for the deciduous forest types they studied.

Yearly total leaf fall to the entire stream network was 372.0 g/m^2 (344.92 kg), which is in the range of the 300-400 $g/m^2/yr$ reported by Rodin and Bazilevich (1967) for deciduous forests. Grizzard et al. (1976) and Grigal and Grizzard (1975) found, for the four cover types (Curlin and Nelson 1968) and four numerical forest types (Grigal and Goldstein 1971) on Walker Branch watershed, annual leaf fall inputs to the forest floor of 342-398 g/m^2 and 308-395 g/m^2, respectively.

Reported values for leaf fall to lotic systems include 305 g/m^2 (Fisher 1970), 476 g/m^2 (Hall 1972), 315 g/m^2 (Dawson 1976), and 274 g/m^2 for a 77 day autumn period (McDowell and Fisher 1976).

Total annual leaf fall input to the perennial flow study reach of Walker Branch was 345.4 kg.

Fruit and Reproductive Part Inputs

Figure 7 presents mean daily rates of input of fruits and reproductive parts in litterfall for the fifteen collection periods. These means ± one standard error are shown in Table A2 of Appendix A. Daily rates of input varied from a minimum of 0.01 and 0.03 $g/m^2/day$ for January and February to 0.44 $g/m^2/day$ for the period September 15 to October 2, 1973. Autumn inputs showed some bimodality, due to higher inputs for the October 16 to November 2, 1973 period than for the preceeding two week period. A second peak for fruit inputs was seen in April and May, when daily rates of input were 0.26 and 0.21 g/m^2, approximately equivalent to the rates for the periods November 2-16 and November 16 to December

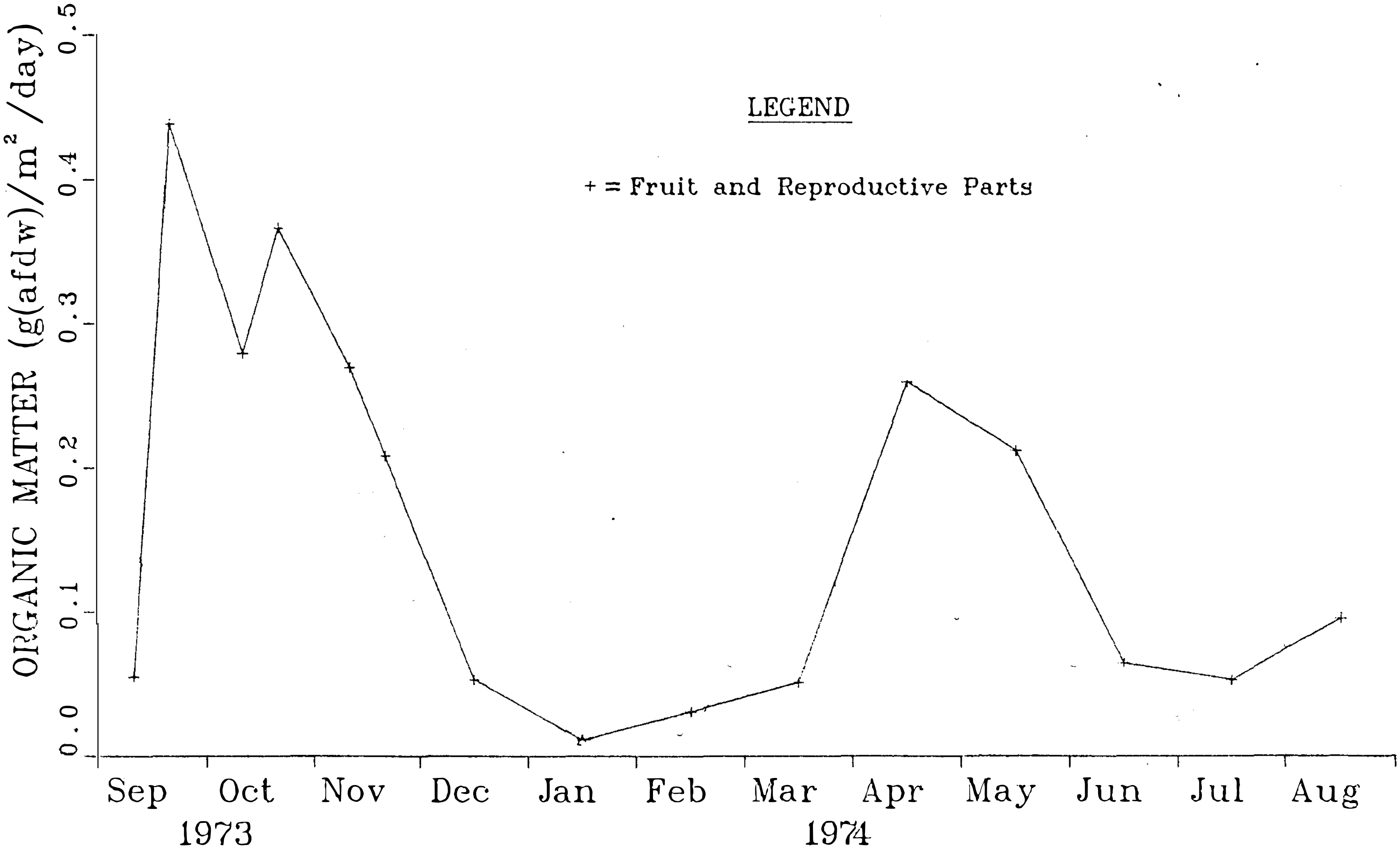

Figure 7. Mean Daily Rates of Input of Fruits and Reproductive Parts via Litterfall to the Drainage Network of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

2, 1973, respectively. The spring peak was due mainly to floral parts of a number of species of trees, while the fall peak was primarily due to fruits (especially hickory, tulip poplar, and beech). Low input rates during winter to early spring period were maintained almost exclusively by tulip poplar fruits, supplemented in late winter-early spring by maple flowers. On a monthly basis, October had the highest mean inputs of 10.1 g/m^2.

Results were somewhat different from those presented by Grizzard et al. (1976) for the oak-hickory and mesophytic hardwood forest types on Walker Branch for 1969-1970, especially with regard to magnitude and timing. For example, the peak input rates for mesophytic hardwood and oak-hickory forest types during the autumn were 0.39 and 0.14 g/m^2/ day respectively, while the corresponding value for the present study was 0.44 g/m^2/day.

In both studies, bimodal peaks were seen, but the relative magnitude of the two peaks and their temporal pattern differed. In the present study peak inputs (0.44 g/m^2/day) occurred in the latter part of September, with a secondary peak for fruit falling over the last half of October. Data from Grizzard et al. (1976) showed peaks for both deciduous forest types falling over the last half of October and the last half of November, one month later than in the present study. During the last half of November, when peak inputs were occurring in the mesophytic hardwood type in their study, fruitfall in the present study occurred at a rate (0.21 g/m^2/day) which was only fifth highest for the autumn collection periods. Comparing the two peaks for each forest type, the October peak was greater than that for November for the oak-hickory type,

while the reverse was true for the mesophytic hardwood type. However, for the two types there was not a great difference between peak inputs (0.36 and 0.39 g/m^2/day for mesophytic hardwood and 0.15 and 0.13 g/m^2/day for the oak-hickory type), but there was a great difference between forest types, with the peaks for the mesophytic hardwood type about 2.5 times those in the oak-hickory type. In the present study the two peaks were also similar (0.44 and 0.37 g/m^2/day). Large year to year variations in mast production are common in deciduous forests.

Another difference between results of the present study and those of Grizzard et al. (1976) involved winter and spring fruit fall data. They found a mean daily input for the December 2 - March 5 period of 0.11 and 0.16 g/m^2/day for the mesophytic hardwood and oak-hickory forest types, respectively, while the present study showed mean daily inputs of 0.01 - 0.13 g/m^2/day, based on monthly data for a comparable period. Since the data of Grizzard et al. involved only one collection over the winter, the high mean may have been due to a substantial input early in the period. This is expected to be the case, since the overall peak input for the mesophytic hardwood type and second highest peak (highest fall peak) for the oak-hickory type occurred in their December 2 collection. This conjecture is further substantiated because the input rate for the oak-hickory type during the winter period of 1970 was the highest of the summer through winter period, being exceeded only by the rate for the next period (March 5 - June 1). Means for this latter period were 0.27 and 0.28 g/m^2/day for the oak-hickory and mesophytic hardwood forest types respectively, while the peak input, based on monthly means, in the present study was 0.26 g/m^2/day recorded in April.

Because only one collection was taken during this early spring period, no further meaningful comparisons can be made with data from the present study, except that when data for the three monthly collections (April-June) are averaged, a value of 0.17 $g/m^2/day$ is realized, considerably smaller than the mean found by Grizzard et al. (1976). Input rates from the latter study for June (0.12 and 0.21 $g/m^2/day$ for the oak-hickory and mesophytic hardwood types, respectively) were also higher than those found in the present study (0.06 $g/m^2/day$). The July data (0.05-0.06 $g/m^2/day$) were comparable for the two studies.

Total yearly input of fruits and reproductive parts to Walker Branch stream channel as litterfall was 50.61 g/m^2 or 46.93 kg/yr to the entire channel. In the study by Grizzard et al. (1976), inputs from the oak-hickory and mesophytic hardwood forest types were 52-63 g/m^2, with no significant differences found between forest types. Thus, data from the present study, when compared on an annual basis with that of Grizzard et al. (1976), are quite similar.

Twig Inputs

Figure 8 presents mean daily input rates of woody material via litterfall to the stream channel of Walker Branch for the fifteen collection periods of the 1973-1974 water year. Those means ± one standard error are shown in Table A3 of Appendix A. Daily rates of input varied from a low of 0.01 g/m^2 for January and February to a maximum of 0.22 and 0.21 g/m^2 for the October 16 to November 2 and November 2 - 16, 1973 periods, respectively. Daily input rates for the November 16 to December 2, 1973 period of 0.15 g/m^2 were very near the daily rates for March and May (0.15 g/m^2 for each month). Daily input rates for other months

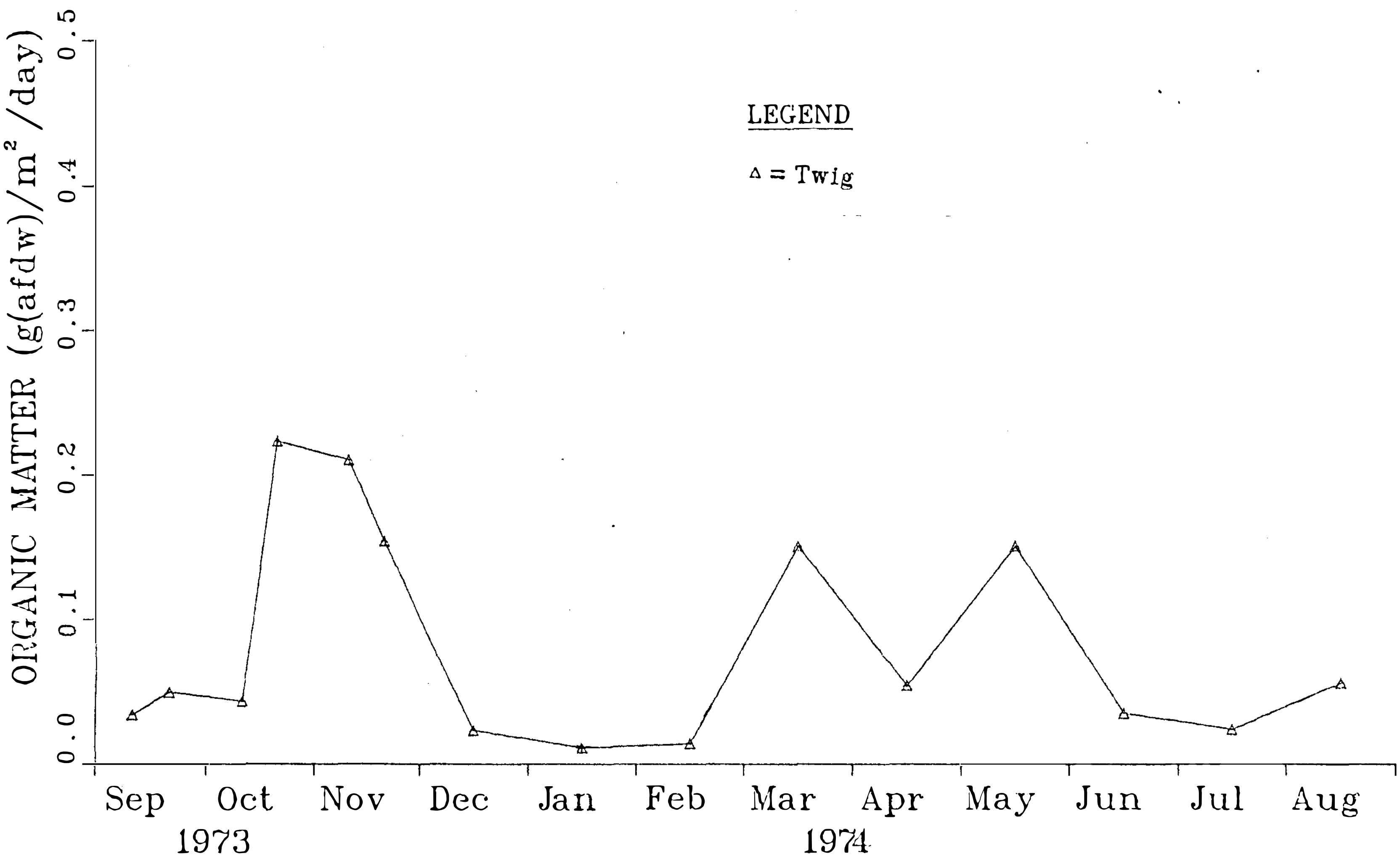

Figure 8. Mean Daily Rates of Input of Twigs via Litterfall to the Drainage Network of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

were 0.06 g/m^2 or less, with the highest monthly value in November (5.40 g/m^2).

The data reveal a peak during autumn as trees shed dead branches. Spring peaks are also evident, with the relatively lower input seen during April as compared to March or May indicating that a factor such as wind may have been operative. Gosz et al. (1972) reported that branch fall on Hubbard Brook was related to extreme environmental factors (i.e., strong winds). Strong persistent winds in March (as exhibited by the blow-in discussed below) and gusts associated with spring storms in May could have been a factor in the present study.

Grizzard et al. (1976) also showed the pattern of rate of input of branches in litterfall on Walker Branch to have several peaks, with maximum daily rates of input occurring in July (0.43 g/m^2/day) for the oak-hickory type and in the last half of October (0.27 g/m^2/day) for the mesophytic hardwood type. For the latter type, a second peak (0.22 g/m^2/day) occurred during the March to June period, while the spring peak for the oak-hickory type was in June (0.13 g/m^2/day).

Lowest overall rates of input found by Grizzard et al. (1976) were in the December 2 - March 5 period (0.01 and 0.02 g/m^2/day for the oak-hickory and mesophytic hardwood types, respectively). Except for the peak for oak-hickory in July, which may have accompanied a major meteorological event, trends for twig fall are quite similar in the two studies.

Total twig input to the stream channel on Walker Branch for the 1973-1974 water year via litterfall was 26.27 g/m^2 (24.36 kg/yr) for the entire stream channel. For the two deciduous forest types studied by Grizzard et al. (1976) the total yearly mean branch fall was 37 and 38

g/m^2 for the oak-hickory and mesophytic hardwood types, respectively. That is somewhat higher than the values found in the present study. One factor which might have contributed to this difference was the fact that Grizzard et al. (1976) used a considerably larger (1 m^2) litter trap, which should have been more efficient at collecting branch and twig fall. Thus, it is possible that branch fall may have been underestimated in the present study, but stochastic elements involved with twig fall deny a conclusive resolution of this point.

Grizzard et al. (1976) pointed out that, in addition to meteorological factors, the age of the particular forest stand studied could influence timing as well as quantity of twig fall.

Frass Inputs

The mean daily rates of input of frass to the stream channel of Walker Branch are shown for the fifteen collection periods in Figure 9. These means ± one standard error are shown in Table A4 of Appendix A.

Frass inputs were restricted to the periods September 1 to October 16, 1973 and June 1 to September 1, 1974, Daily input rates were equivalent for the September 1 to September 15, 1973 period and the July 1 to August 1, 1974 period, with 0.15 g/m^2 recorded for both. No other period of collection had input rates greater than 0.08 g/m^2/day. July had the highest mean monthly inputs with 4.59 g/m^2, followed by 3.43 g/m^2 for September 1973.

In light of the data for September 1973 and July 1974, the results for August 1974 (0.41 g/m^2) seem anomalously low. Since a killing frost did not occur during August, the most likely environmental factor accounting for this decline was the low rainfall from mid- June through

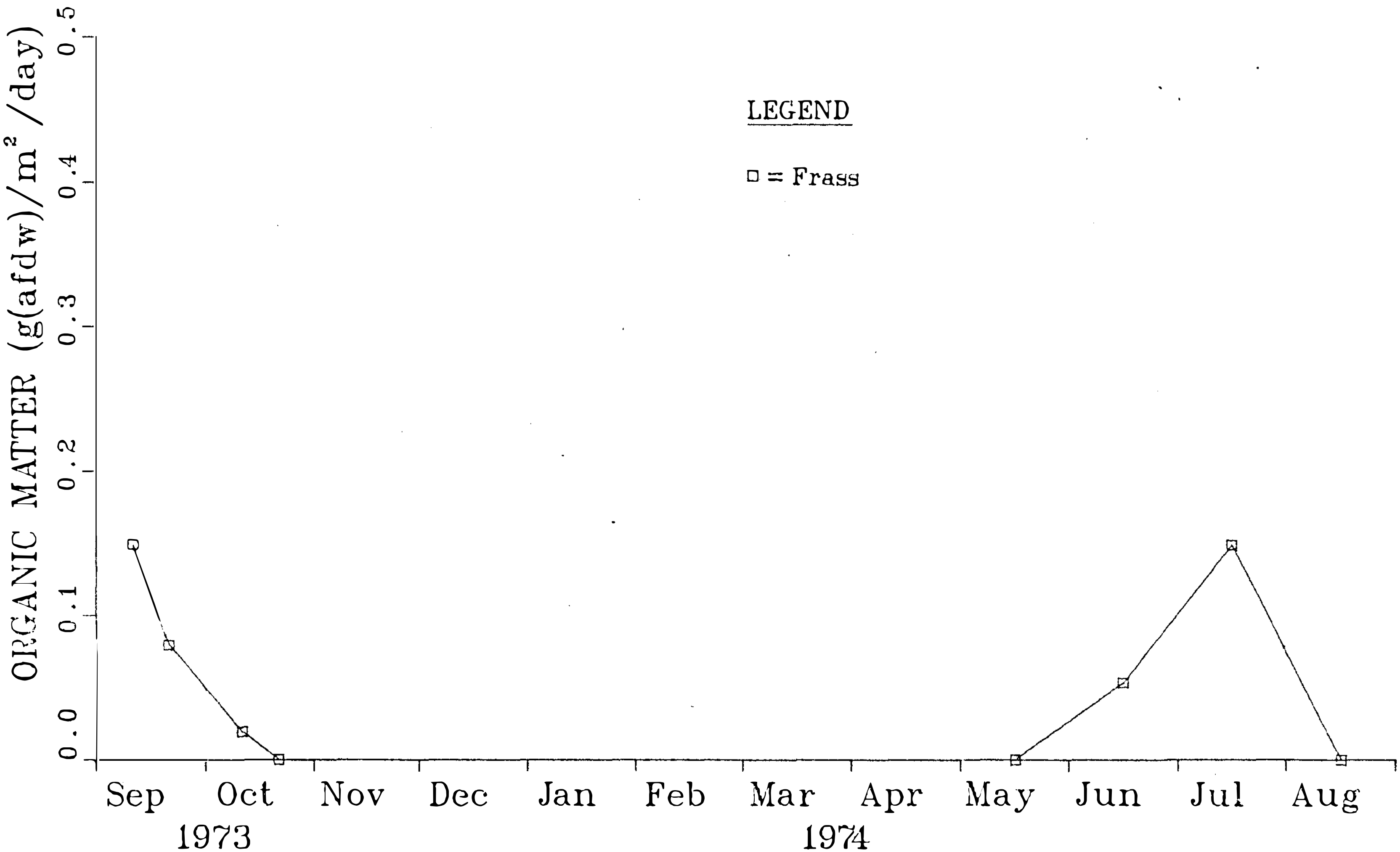

Figure 9. Mean Daily Rates of Input of Frass via Litterfall to the Drainage Network of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

July. For July, rainfall was only 12.60 cm (11.6 cm below normal), while for the June 7 to August 1 period, rainfall was only 5.66 cm (16.79 cm below normal). This lack of rainfall may have adversely affected vegetative growth, causing early senescence with possible debilitating effects on canopy insect populations. The increased leaf fall during July and August, 1974 has already been discussed.

Total yearly frass inputs to the stream channel of Walker Branch were 10.21 g/m^2 or 9.46 kg/yr for the input to the entire stream channel.

Gosz et al. (1973), working on Hubbard Brook watershed, reported an average frass fall from July 10 to September 2, 1969 of 180.2 kg/ha, indicating a consumption of 210 kg/ha. The amount of leaf material consumed ranged from 374 kg/ha below 600 m to 42 kg/ha above 750 m, indicating a range of 1.8% to 10.7% of total leaf production. In this northern hardwood forest the elevational differences in frass fall were due to the distribution of beech, the preferred food source of primary canopy consumers. Frass production peaked during the first two weeks of August.

Results from the present study indicate that fairly substantial differences can occur from year to year regarding frass inputs. Compared to the mean yearly input of 103.38 kg/ha in the present study, the mean for the study at Hubbard Brook is substantially greater, but Gosz et al. (1973) indicated that a large amount of variability existed within the watershed system they studied. Their data were collected over a shorter period of time than the work reported here, possibly because of the shorter growing season at Hubbard Brook.

Sedell et al. (1974) reported, for a conifer watershed in Oregon, that peak frass fall (0.05 $g/m^2/day$) occurred from mid- June to mid-July. Very little input was found at other times. Comparison of the results of Sedell et al. (1974) with the results of the present study and those of Gosz et al. (1973) indicate that frass fall (and hence foliage consumption) from primary consumers may be relatively less important as a pathway of elemental cycling in the conifer forest than in deciduous forests.

If we assume that leaf production (as a minimum estimate) is equal to leaf fall plus insect consumption, and that frass fall equals 86% of insect consumption of leaf material (from feeding studies, Gosz et al. 1973), then a leaf production of 371.97 $g/m^2/yr$ + (100/86 x 10.21 $g/m^2/yr$) or 383.84 $g/m^2/yr$ can be calculated. The calculated consumption of leaf material by insects (11.87 $g/m^2/yr$) would then be 3.2% of total leaf production. This could be looked upon as a minimum estimate of canopy consumption, due to a probable underestimation of frass fall. However, since leaf production estimates were based mainly on leaf fall and took no canopy leaching, translocation, or respiration into account, the estimate of percent of canopy consumed by insects could be too high. The data of Grizzard et al. (1976) for weights of individual leaves showed a definite decrease for most species before leaf fall (mean 28%), indicating either translocation or leaching of organic materials, or that both were operative. Olson (1963) and Crossley (1963) indicated that approximately 5% of net primary production in plants is used by canopy insects, with 95% entering the detritus pool. Bray (1964) reported 3.1 - 14.3% consumption of canopy by insects. Whittaker and Woodwell

(1969) estimated that 9% of total leaf production was consumed by insects at a Brookhaven oak forest. Reichle et al. (1973) found that average herbivorous insect consumption over three years averaged 2.6% of net primary production in a Liriodendron forest, but because of leaf hole expansion with leaf growth a 7.7% loss in photosynthetic surface area was found. For the three-year period, insect consumption varied by a factor of almost two (1.9 - 3.4%).

Total Inputs

Total mean daily litterfall for the fifteen collection periods of the study year, along with percent contribution from each litterfall component, are shown in Table 2. Leaf material contributed from 8.5 to 94.0% of total litterfall for the fifteen collections, with the highest percentage in early November and the lowest in April, the latter due to the increased amount of fruit inputs during this month. For the period September 1 through December 2, 1973, no less than 78.5% of total litterfall was leaf material. After April, percent of leaf contributions increased to 25.9% in June and later to 63.8% and 63.0% in July and August, respectively, due mainly to increased leaf fall rather than to decreases in other components.

Percent of litterfall occurring as fruit ranged from 75.7% in April to 3.2% in early September and 2.4% in early November. Highest percentages for fall were during the last half of September (16.6%) and late November (10.7%). After December, percent fruit contribution increased dramatically as inputs occurred at a low level throughout the winter, consisting largely of tulip poplar fruits. Fruit contributions for March (22.1%) were lower than for either February (48.4%) or May (51.3%), due

Table 2. Summary of Litterfall Data for West Fork of Walker Branch for the 1973-1974 Water Year.

Collection Interval Begin	End	Input Rate ($g/m^2/day$)	Total Input (g/m^2)	Input: Leaf (g/m^2)	Input: Fruit (g/m^2)	Input: Twig (g/m^2)	Input: Frass (g/m^2)	Relative Contribution: Leaf (g/m^2)	Relative Contribution: Fruit (g/m^2)	Relative Contribution: Twig (g/m^2)	Relative Contribution: Frass (g/m^2)
09/01/73	09/15/73	1.71	25.62	22.04	0.83	0.51	2.24	86.1	03.2	02.0	08.7
09/16/73	10/02/73	2.64	44.79	35.17	7.45	0.83	1.34	78.5	16.6	01.9	03.0
10/03/73	11/02/73	4.04	56.61	51.83	3.91	0.60	0.27	91.6	06.9	01.1	00.5
10/17/73	11/02/73	6.76	114.20	104.86	6.22	3.12	0.00	91.3	05.4	03.3	00.0
11/03/73	11/16/73	7.94	111.22	104.51	3.77	2.94	0.00	94.0	03.4	02.6	00.0
11/17/73	12/02/73	1.94	30.96	25.17	3.33	2.46	0.00	81.3	10.7	08.0	00.0
12/03/73	01/01/74	0.13	3.96	1.68	1.59	0.69	0.00	42.4	40.2	17.4	00.0
01/02/74	02/01/74	0.01	1.15	0.47	0.34	0.34	0.00	40.5	29.7	29.7	00.0
02/02/74	03/01/74	0.06	1.79	0.53	0.87	0.39	0.00	29.7	48.4	21.9	00.0
03/02/74	04/01/74	0.23	7.16	0.93	1.58	4.65	0.00	13.0	22.1	64.9	00.0
04/02/74	05/02/74	0.34	10.26	0.87	7.77	1.62	0.00	08.5	75.7	15.8	00.0
05/02/74	06/01/74	0.41	12.74	1.55	6.54	4.65	0.00	12.2	51.3	36.5	00.0
06/02/75	07/01/74	0.21	6.15	1.59	1.92	1.05	1.59	25.9	31.2	17.1	25.9
07/02/74	08/01/74	0.62	19.25	12.28	1.64	0.74	4.59	63.8	08.5	03.9	23.8
08/02/74	09/01/74	0.45	13.47	8.49	2.85	1.68	0.45	63.0	21.2	12.5	03.3
Total Input ($g/m^2/yr$)		459.06	371.97	50.61	26.27	10.21					
Total Input (kg)		425.67	344.92	46.93	24.36	9.46					
Relative Contribution (%)			81.03	11.02	5.72	2.22					

to increased twig inputs during March. From the peak percentage in April (due to floral parts), the relative contribution of fruits declined gradually through June, with a low of 8.5% in July, due to increased leaf inputs and decreasing floral inputs.

Twigs made up only 1.1 - 3.3% of total litterfall during the peak litterfall period in autumn (September 1 to November 16, 1973). Twig percentage subsequently increased rather steadily from 8% in late November to 29.7% in January. Peak percentage (64.9%) was recorded in March, due to order of magnitude increases in twig inputs. Although the magnitude of inputs was almost identical in May and in March, percentage for May was only 36.5, due to large increases in the percent of fruits. Percent contribution of twigs was low (3.9%) in July, due to relatively large increases in leaf inputs.

During the period of peak inputs (September 1-15,), frass contributed only 8.7% of the total monthly input due to relatively large inputs of leaves and fruits during this month. For the last part of September and the first half of October, frass percentages were 3.0 and 0.5%, respectively, due to greatly increased inputs of leaves and fruits and a decrease in frass inputs. For June, the first month of renewed frass input, percentage of total input was 25.9, and for July it was 23.8%, the two months yielding the greatest percent contributions of frass for the year. Due to a precipitous decline in frass inputs in August, percent contribution during this month was only 3.3%, similar to late September 1973.

Due to the overwhelming importance of leaf fall to total litterfall during autumn, trends for the latter paralleled those for the former

during this period, with maximum total daily input rate of 7.94 g/m^2 during the first two weeks of November. Maximum divergence from the trend for leaf fall was seen during the months of March through May, during which total mean daily inputs increased from 0.23 to 0.41 g/m^2/day, the latter being nine times the mean daily input for leaf material. The total daily input for June (0.21 g/m^2/day) was four times that for leaf fall. For the rest of the study year (July and August) total mean daily inputs averaged 0.54 g/m^2/day, with leaves contributing approximately 63% of the total input for both months.

For the year as a whole, leaf material contributed 81.0% (372.0 g/m^2) of the total litterfall of 459.1 g/m^2 (4600.2 kg/ha), while fruits, twigs, and frass contributed 11.0% (50.6 g/m^2), 5.7% (26.5 g/m^2), and 2.3% (10.2 g/m^2), respectively. These values are close to those of Grizzard et al. (1976), working on the same watershed during the 1969-1970 period, who found for the mesophytic hardwood and oak-hickory forest types, respectively, that yearly litterfall was composed of 342 g/m^2 (77.2%) and 398 g/m^2 (81.7%) leaves, 38 g/m^2 (8.6%), and 37 g/m^2 (7.6%) twigs, and for fruits and reproductive parts 63 g/m^2 (14.2%) and 52 g/m^2 (10.7%). For total litterfall, yearly values were 443 g/m^2 and 487 g/m^2 for mesophytic hardwood and oak-hickory forest types, respectively. Frass fall was not measured in their study. Total inputs to the study reach were 344.92, 46.93, 24.36, and 9.46 kg for leaves, fruits, twigs, and frass, respectively, for a total input of 425.67 kg.

Rodin and Bazilevich (1967) reported that mature deciduous forests have leaf fall as 40-65% of total litterfall, down from 75-85% in younger forests. Gosz et al. (1972) reported a total litterfall of 5702 kg/ha

for a mature hardwood forest in New Hampshire, of which 49.1% was leaf material, 22.2% branches, 14.1% stems, and 1.7% bark. Miscellaneous components (fruit and flower parts and frass) were 10.0% of the total. The overstory contributed 98.0% of total litterfall. They reported that approximately 9% of the year's total leaf fall fell as green leaves, with a hailstorm in August removing a large number of leaves from the tree canopy.

Total input of organic material to the stream channel (perennial flow) of the west fork subwatershed of Walker Branch was 4543 kg for the 1973-1974 water year.

For litterfall, organic carbon was, on the average, 48.15% of the organic matter (AFDW) in the leaves, for a total leaf input to the stream system of 166.08 kg organic carbon. Corresponding input values of organic carbon for fruits, twigs, and frass were 23.20, 11.58, and 5.09 kg, respectively. These corresponded to a percent organic carbon (AFDW) of 49.45%, 47.57%, and 49.83% for fruits, twigs, and frass, respectively. Total organic carbon input to the stream channel for the 1973-1974 water year for litterfall was 205.95 kg.

On a per unit area basis these yearly values are 179.1, 25.0, 12.5, and 5.5 g/m^2 for leaf, fruit, twig, and frass inputs, respectively, for a total yearly organic carbon input of 222.1 g/m^2 (2221 kg/ha). This is somewhat higher than the 161.5 g carbon/m^2/yr reported by Edwards and Harris (1975) in the *Liriodendron* forest in Oak Ridge, Tennessee.

Blow-In

Leaf Input

The amount of coarse (> 1 mm) leaf material transported by aeolian forces from adjoining slopes into channels of the west fork of Walker Branch for each slope class (g/m streambank/day) is shown in Figures 10 and 11 for northeast- and southwest-facing aspects, respectively. (See Table A5 and A6 Appendix A for the 95% confidence limits for these monthly means.) Note the difference in scale in the two figures. A bimodal trend is apparent for both aspects and for all slope classes. However, the two aspects did demonstrate differences in total input and in the relative magnitudes of seasonal input rates. With minor exceptions, southwest-facing slopes had consistently higher means for all slope classes during all seasons. For northeast-facing slopes, peak inputs for all slope classes occurred in the fall to early winter period, while peak inputs for southwest-facing slopes occurred in the mid-winter to mid-spring period. Except for the high rates of input for 15-30% slopes during some months, input rates generally increased with increasing slope, with benches generally having lowest means. High input rates for the 15-30% slope class occurred during fall for southwest-facing slopes and during the entire fall to spring period for northeast-facing slopes.

For northeast-facing slopes, highest mean monthly inputs (November) ranged from 0.17 g/m streambank/day for benches to 0.71 g/m streambank/day for the 45-60% slope class. For southwest-facing slopes, peak inputs for benches occurred during October (0.32 g/m streambank/day), and for the 15-30% slope class during November (1.50 g/m streambank/day). For 30-45% and 45-60% slope classes, peak inputs (1.70 and 4.82 g/m streambank/day, respectively) occurred during March.

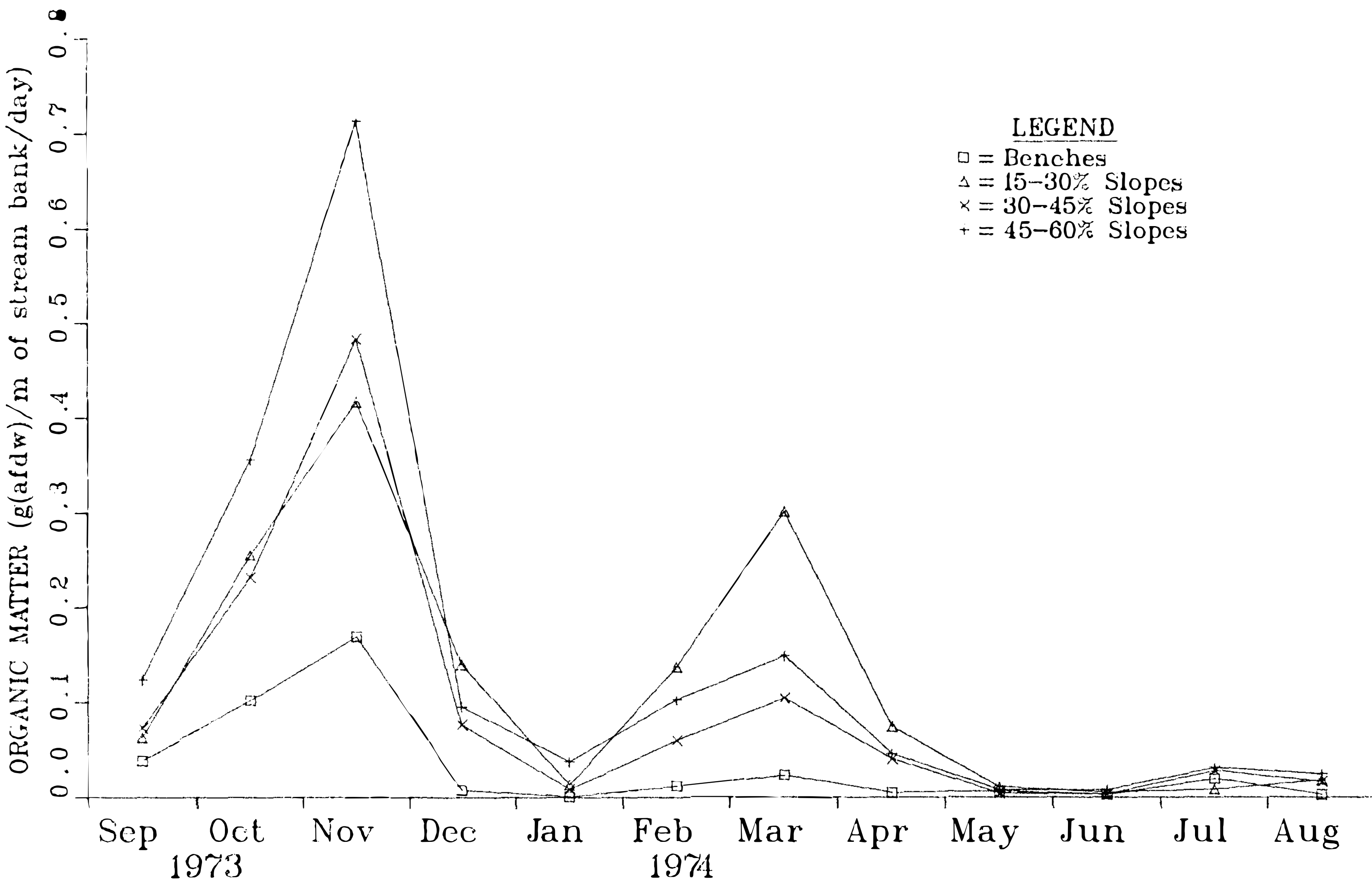

Figure 10. Mean Daily Rates of Transport of Wind-Blown Leaves from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

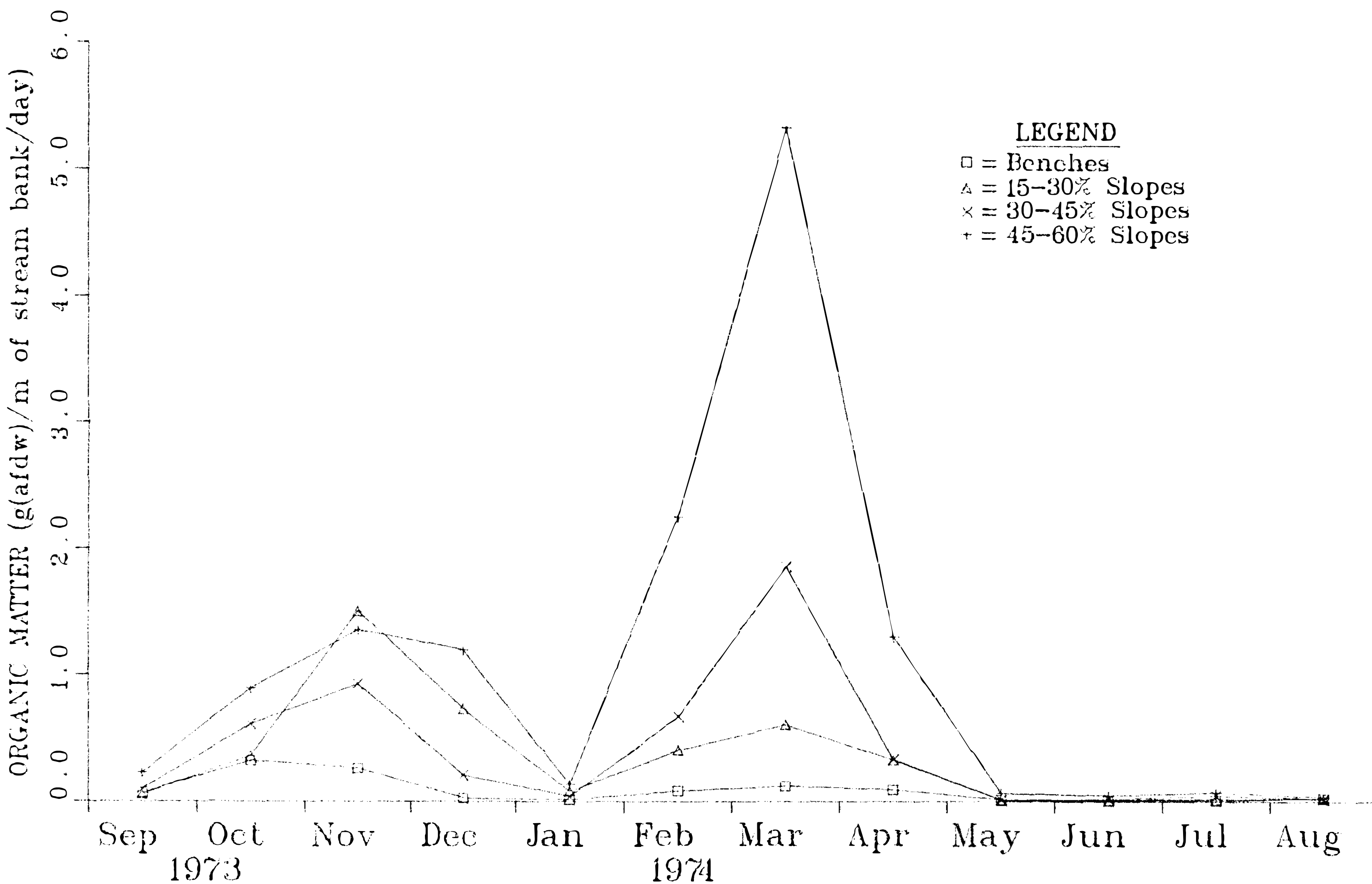

Figure 11. Mean Daily Rates of Transport of Wind-Blown Leaves from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

For a number of months, especially those from May through August but also including January, most inputs were less than 0.05 $g/m^2/day$.

Interpretation of experimental results for blow-in involves the interaction of meteorological, geomorphic, and phenological factors. Of prime importance are seasonal wind patterns (Figures 12-15) for the 1973-1974 water year for the watershed area (data from TVA, Air Quality Branch, Mussel Shoals, Alabama for Bull Run Steam Plant, Anderson County, Tennessee). Overall, the windroses exhibit general upvalley (southwest) and downvalley (northeast) trends during all seasons, with strongest winds predominantly from the west to southwest. The March through May (Figure 14) and December through February (Figure 13) periods had the greatest and second greatest percentage of winds in the strongest class (12.40 m/s or greater), respectively. Fall and summer seasons (Figures 12 and 15, respectively) had few if any winds in the strongest wind classes. Since aeolian transport of leaf material appears to be a threshold phenomenon, the strongest winds are emphasized.

A number of other factors modify aeolian influences. The degree to which incident winds and direct solar radiation reach the forest floor depends largely on presence or absence of a forest canopy. Period of canopy cover varies somewhat from year to year with climatic regime. Grizzard et al. (1976) found appreciable amounts of new leaf growth present by May 1 for both years of their study, and the present study indicated that autumn leaf fall was not completed until near the end of November. The canopy acts to decrease blow-in by lessening wind speed at the forest floor and by blocking solar radiation, preventing litter drying and thereby rendering the litter less likely to be transported by

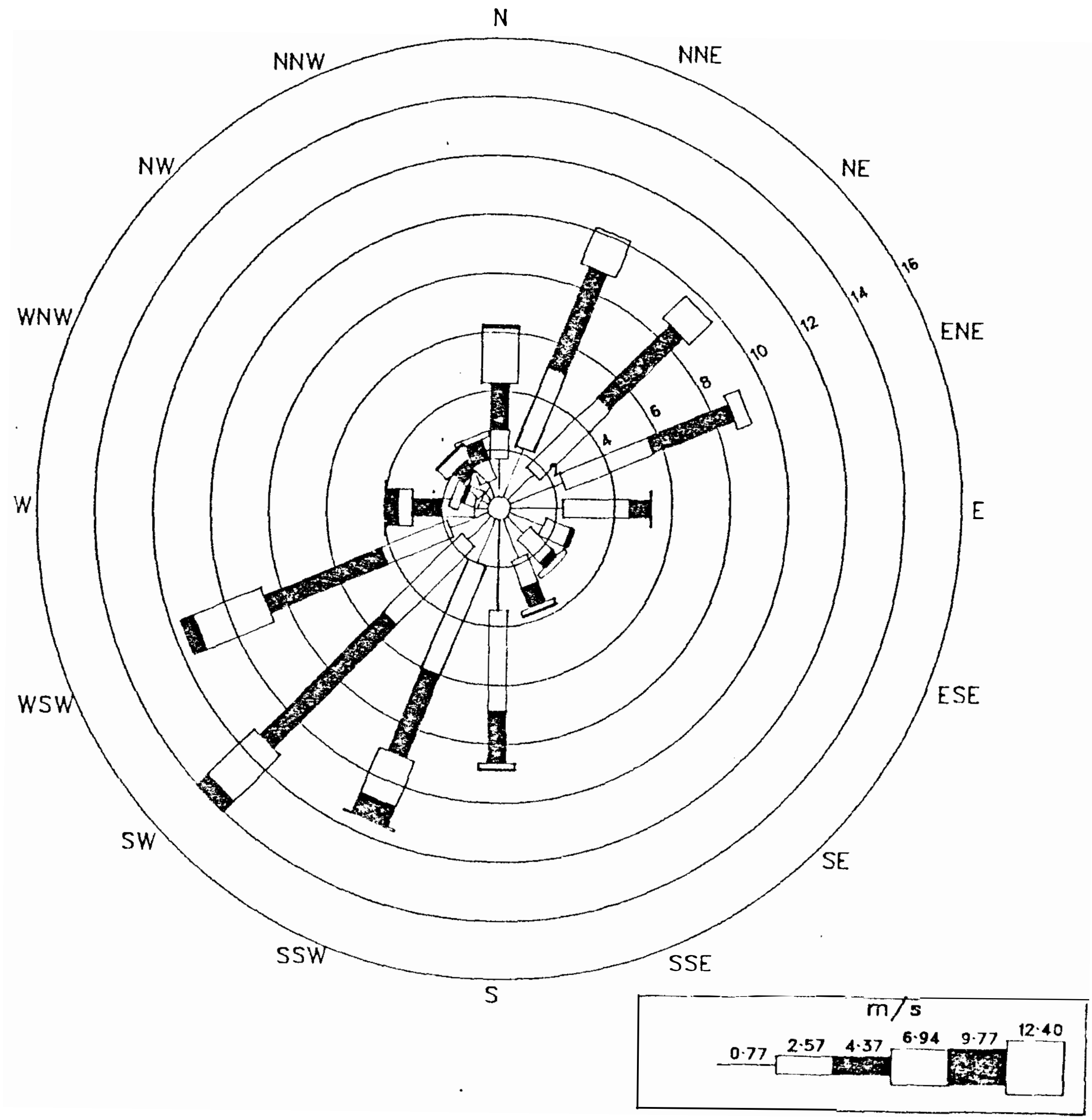

Figure 12. Wind Rose for the Period September through November 1973 for the Oak Ridge Area.

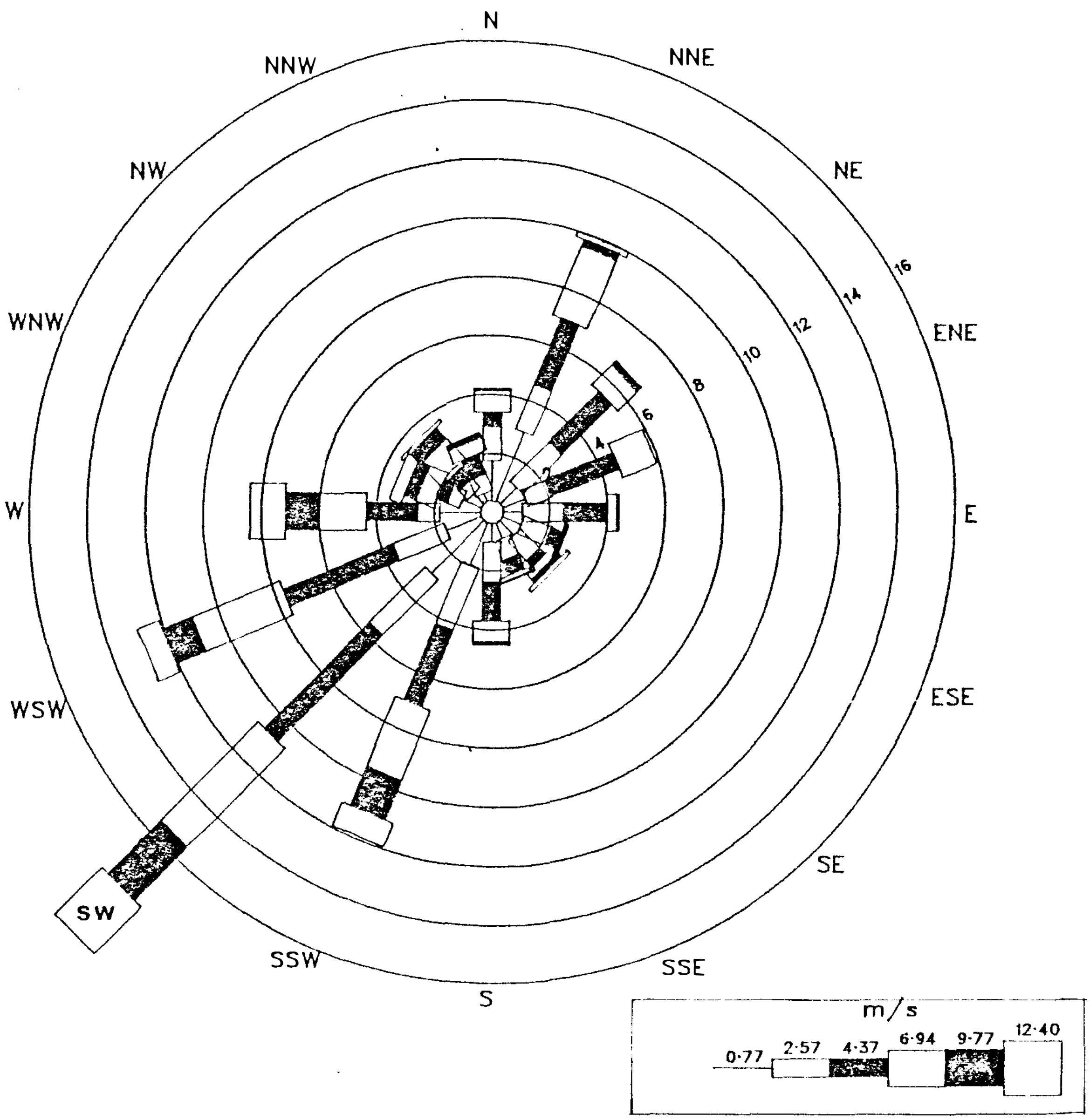

Figure 13. Wind Rose for the Period December 1973 through February 1974 for the Oak Ridge Area.

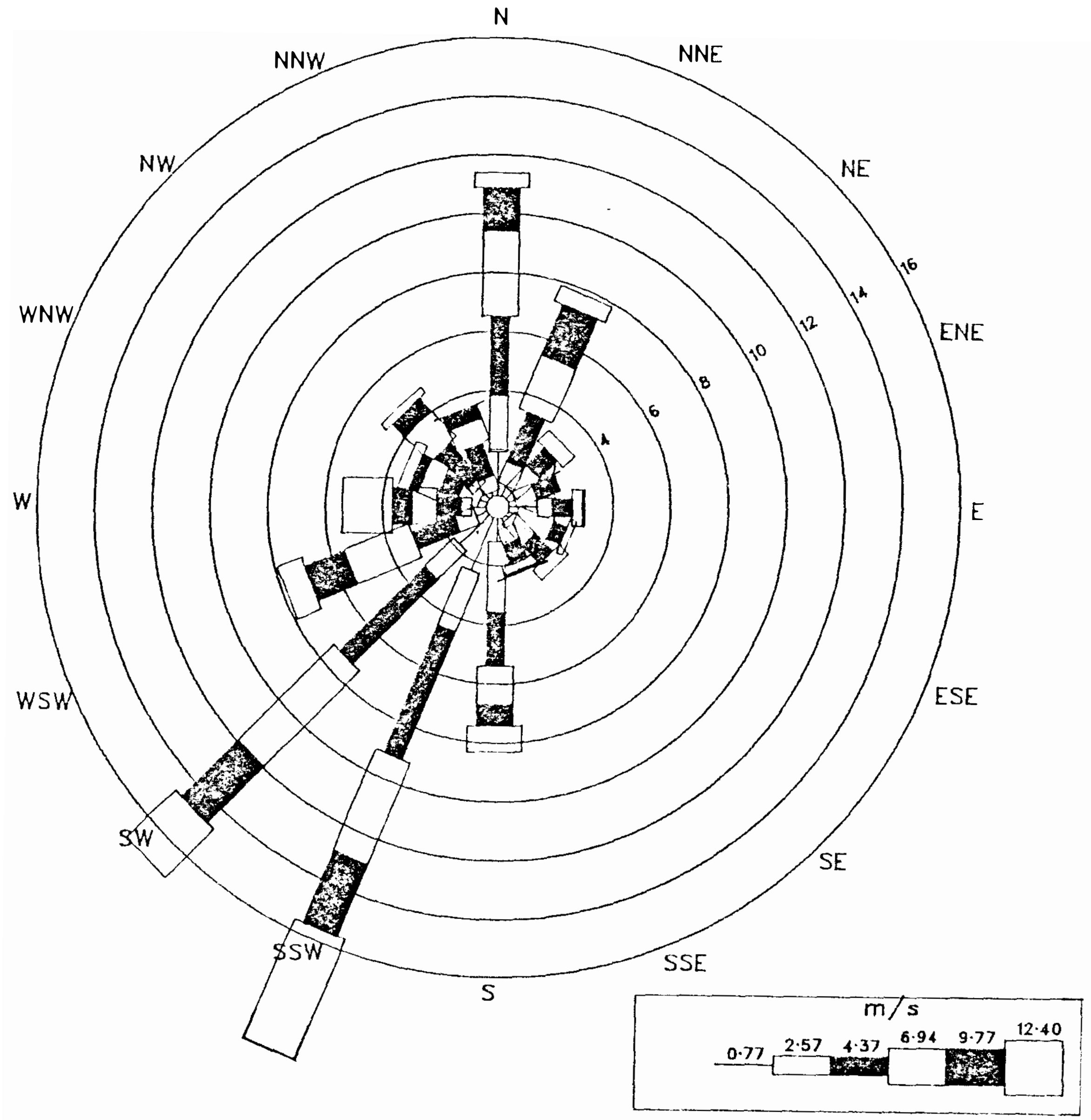

Figure 14. Wind Rose for the Period March through May 1974 for the Oak Ridge Area.

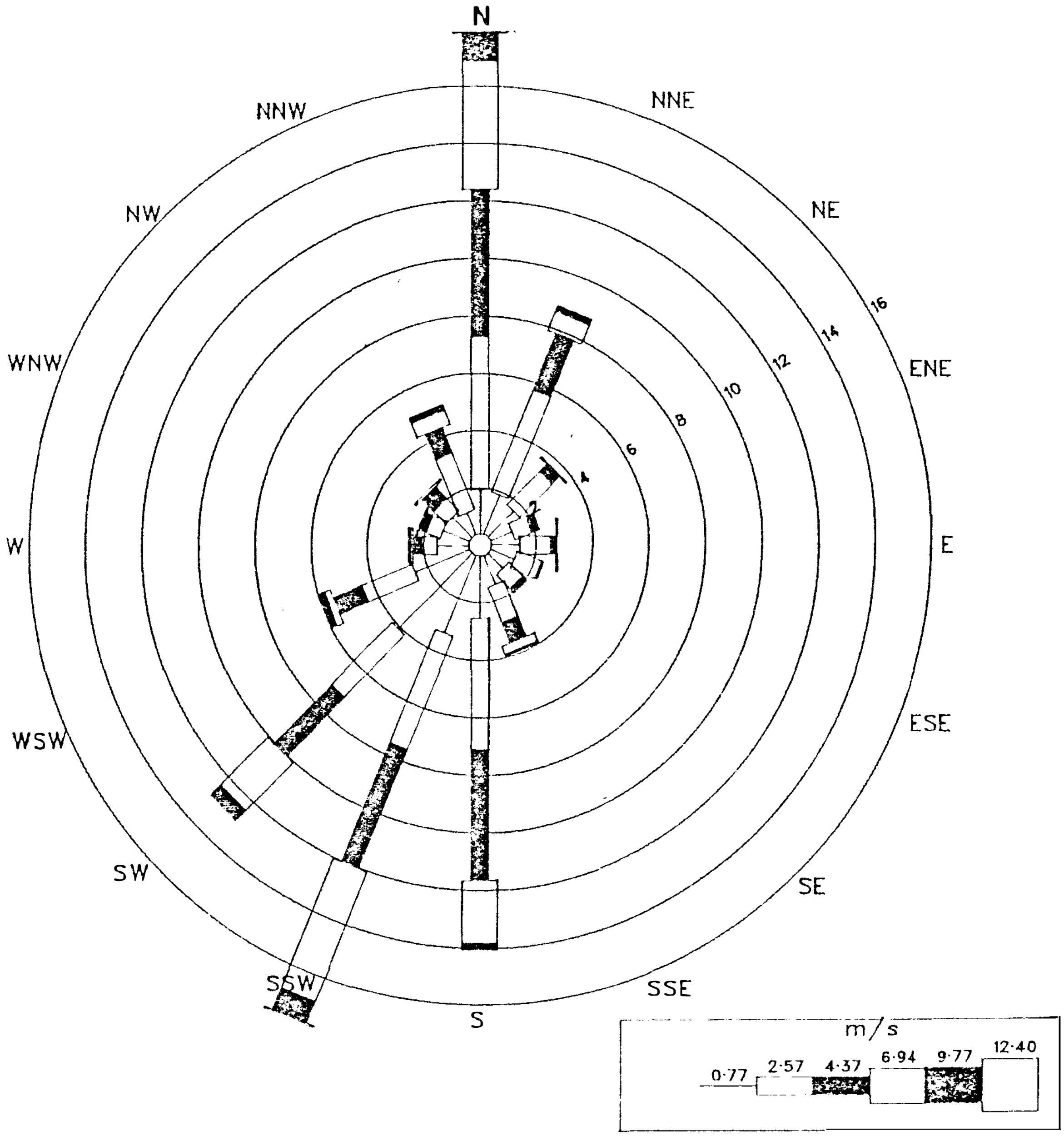

Figure 15. Wind Rose for the Period June through August 1974 for the Oak Ridge Area.

wind. In this regard, months that are very wet or have a high percentage of cloud cover should have less blow-in than dry months with comparable winds. In addition, presence of an herbaceous layer can physically block transport of leaves along the forest floor (Dawson 1976).

Cover type is another factor. Differences in potential transfer of conifer versus deciduous foliage are obvious, but differences would also be expected for leaves of different genera of deciduous trees, depending on their shape, wettability, decomposability, and susceptibility to physical weathering. Also, since leaf fall is more or less a pulse phenomenon as the months pass, more leaves are permanently incorporated into the litter layer and become unavailable for aeolian transport.

While the experimental model used in this study considered time, slope class, and aspect as main effects, other geomorphic factors are important. Slope length probably has a major effect by determining total pool of leaf litter available for transport, but it may also have an effect on wind speed at the base of the slope. Slopes with severe discontinuities would be expected to yield less blow-in than slopes of even grade because of lee-type trapping. Topographic position should also be a factor, as is discussed below.

Results of the 3-way ANOVA (Table A7, Appendix A) showed all main effects and interactions to be highly significant ($Pr > F = 0.001$). The next step in the analysis procedure involved tests of simple main effects, with each main effect being tested against each level of one of the other main effects. Within each set of tests (e.g., tests of aspect differences at each date) the significance level for individual comparisons was α/number of levels of the second effect, where α was the experi-

mentwise error level ($\alpha = 0.05$). This procedure was used to decrease the possibility of falsely rejecting the null hypothesis (Kirk 1968).

Tests involving each of 12 levels of date for aspect effects (Table 3) showed significant ($\alpha/12 \cong 0.005$) aspect differences for all months from October through April, with the exception of January. No other significant aspect differences were seen.

Significant aspect differences at individual months appear to be associated with periods of high winds (from the southwest) and absence of canopy. The only month during the period from November through April that did not show a significant difference for aspect was January, a month with low rates of blow-in (Figures 10 and 11). Examination of meteorological records for the Oak Ridge area (ORATDL 1974) reveals that January was the wettest month of the 1973-1974 water year, with measurable rain falling on 19 days. Only two days had less than 50% cloud cover, and no days had winds greater than 13.41 m/s. Thus, the overall meteorological regime favored low levels of aeolian input during the month. All other months with insignificant aspect differences were characterized by presence of a canopy and low levels of incident wind.

Figures 10 and 11 reveal most blow-in occurred from southwest-facing slopes. This took place mainly during periods when strongest winds were from the west to southwest (Figures 13 and 14), intersecting the secondary ridges, such as those bordering Walker Branch (see Figure 2, page 26), at approximately right angles. When this happens, a separation of flow occurs (Scorer 1958 and Slade 1968), with a significant component entering the valley on the lee side. During periods of stable atmospheric conditions near the ground, generally associated with low

Table 3. Results of Analyses for Monthly Aspect Effects for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
0.36^{ns}	15.50^{sd}	37.58^{sd}	44.00^{sd}	0.93^{ns}	92.21^{sd}	200.61^{sd}	42.92^{sd}	0.09^{ns}	0.08^{ns}	0.09^{ns}	0.01^{ns}

Note: All tests run at $F_{0.01(1,568)} = 7.88$; ns = not significant; sd = significant difference.

wind speeds, the component entering the valleys simply follows slope contours (Figure 16a). During unstable conditions, generally correlated with higher wind speeds, the wind vector that enters the valley does so as a turbulent eddy (Figure 16b). On Walker Branch, with winds blowing from the southwest, this eddy would blow down southwest slopes and up northeast slopes. This eddy phenomenon, which has been seen in wind tunnel experiments (Vermi and Cermak 1974) and observed on numerous occasions on Walker Branch watershed, would explain the aspect differences observed in this experiment.

Analyses of four levels of slope class for aspect effects (Table 4) showed significant differences ($\alpha/4 \cong 0.01$) for all slope classes except benches, demonstrating that directional differences in meteorological factors which are known to be important to blow-in were effective on virtually any sloping landscape, but not for level surfaces at the base of these same slopes. Since these results would not be expected on a uniformly flat surface, it appears that benches exhibit a discontinuity effect.

Since the 3-way interaction term in the original ANOVA was significant, testing for aspect differences at individual levels of slope class/date combinations was desirable, and these results are presented in Table 5. In no case were there significant aspect differences for benches. Significant aspect effects were seen most often for 45-60% slopes. The 15-30% slopes had significant aspect effects in autumn (November and December) while 30-45% slopes had significant aspect effects in March and April. This can be seen by comparing monthly means in Figures 10 and 11. In March, for example, 15-30% slopes had means of

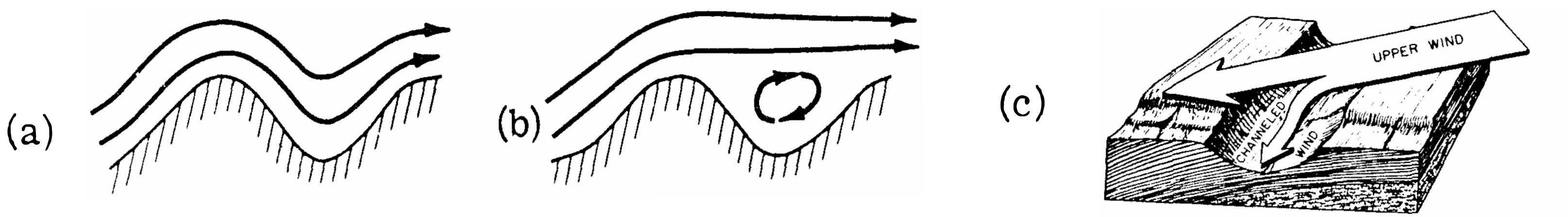

Figure 16. Interaction of Wind with Topography: a. Stable Atmospheric Conditions; b. Unstable Atmospheric Conditions; c. Funnelling Along Drainage System.

Source: Slade (1968).

Table 4. Results of Analyses for Aspect Effects for Each Slope Class for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Benches	15-30%	30-45%	45-60%
1.01^{ns}	22.08^{sd}	42.60^{sd}	210.91^{sd}

Note: All tests run at $F_{0.01(1,508)} = 6.64$; ns = not significant; sd = significant difference.

Table 5. Results of Analyses for Aspect Effects at Each Date/Slope Class Combination for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

	Slope Class			
Month	15-30%	30-45%	45-60%	Benches
Sep	0.0006^{ns}	0.048^{ns}	0.73^{ns}	0.03^{ns}
Oct	0.57^{ns}	6.48^{ns}	10.20^{ns}	1.52^{ns}
Nov	25.74^{sd}	6.24^{ns}	9.11^{ns}	0.15^{ns}
Dec	15.82^{sd}	1.12^{ns}	44.10^{sd}	0.01^{ns}
Jan	0.37^{ns}	0.08^{ns}	0.74^{ns}	0.01^{ns}
Feb	4.62^{ns}	21.14^{sd}	118.23^{sd}	0.24^{ns}
Mar	3.49^{ns}	74.45^{sd}	243.86^{sd}	0.30^{ns}
Apr	4.03^{ns}	5.51^{ns}	56.29^{sd}	0.32^{ns}
May	$<0.01^{ns}$	$<0.01^{ns}$	0.04^{ns}	$<0.01^{ns}$
Jun	$<0.01^{ns}$	0.01^{ns}	0.12^{ns}	$<0.01^{ns}$
Jul	0.02^{ns}	0.03^{ns}	0.11^{ns}	0.01^{ns}
Aug	$<0.01^{ns}$	$<0.01^{ns}$	$<0.01^{ns}$	0.02^{ns}

All tests run at $F_{0.001(1,568)} = 10.8$; ns = not significant; sd = significant difference.

0.30 and 0.60 g/m streambank/day for northeast and southwest-facing slopes, respectively, compared to 0.14 and 0.72 g/m streambank/day for northeast and southwest-facing slopes, respectively, for December. The reverse trend is present for 30-45% slopes, with greatest effects in spring.

Results of the simple main effects test for slope class effects at each date (Table 6) were identical to results of the test for aspect effects (Table 3), with the exception of October, in which mean inputs were not significantly different ($\alpha/12 \cong 0.005$) for slope class. On no other dates were there significant slope class differences over both aspects. The same general explanation can be applied here as for aspect results. Significant slope effects were seen during months when winds were strongest. The lack of a significant difference in the November means was most likely due to high input rates for 15-30% slopes and benches during this period. The excessively high blow-in rates for 15-30% slopes can be explained on the basis of local topographic effects. This slope class is not widespread along the drainage system, being primarily located near the rounded ridge tops and, lower in the drainage system, in areas of confluence in the drainage network. Examination of data for individual traps in the 15-30% slope class reveals substantially larger catches in traps in lower topographic positions, indicating local channeling of wind along the drainage system, and increased rates of blow-in where these channels reach the main valley axis. For winds passing over ridges and for those forming eddies, a component of each apparently seeks out the path of least resistance, in this case the drainage channel (Figure 16c). From the seasonal nature of higher rates of input

Table 6. Results of Analyses for Monthly Slope Class Effects for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
0.86[ns]	4.13[ns]	8.20[sd]	9.82[sd]	0.31[ns]	19.86[sd]	38.62[sd]	8.18[sd]	0.06[nd]	0.03[ns]	0.09[ns]	0.01[ns]

Note: All tests run at $F_{0.005(3,568)} = 4.28$; ns = not significant; sd = significant difference.

for 15-30% slopes for each aspect, it appears that the channeling phenomenon had its greatest effect during periods of moderate wind speed. During the late-winter to mid-spring period when winds were strongest, this funneling effect apparently assumed a secondary role for southwest-facing slopes. However, since northeast-facing slopes were not subject to strong downslope winds for long periods at any time of the year, this funneling phenomenon retained its importance throughout the leafless period for this aspect.

Analyses for slope class effects at each aspect (Table 7) again demonstrated the influence of strong winds, with the aspect receiving strongest downslope winds (southwest-facing) showing significant slope class differences ($\alpha/2 = 0.025$) over all dates, while its counterpart (northeast-facing) showed insignificant slope class effects for mean input rates.

Results of the simple means tests for slope class effects at each date/aspect combination are presented in Table 8, and confirm results obtained from the simple means tests. For every date for which significant slope class differences were seen, it was the southwest-facing slope showing these differences. Northeast-facing slopes, receiving little downslope wind, showed no significant slope class differences for any month.

Analyses of four levels of slope class for date effects (Table 9) showed significant differences ($\alpha/4 \cong 0.01$) for all slope classes except the benches, demonstrating that seasonal differences in meteorological factors which are known to be important to blow-in are effective on all uniformly sloping landscapes. This reinforces the view that benches exhibit a discontinuity effect.

Table 7. Results of Analyses for Slope Class Effects for Each Aspect for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

NE-Facing	SW-Facing
2.18^{ns}	67.56^{sd}

Note: Both tests run at $F_{0.025(3,568)} = 3.11$; ns = not significant; sd = significant difference.

Table 8. Results of Analyses for Slope Class Effects at Each Date/Aspect Combination for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Month	Aspect	
	NE-Facing	SW-Facing
Sep	0.16^{ns}	0.85^{ns}
Oct	0.90^{ns}	4.33^{ns}
Nov	2.67^{ns}	6.75^{sd}
Dec	0.32^{ns}	15.18^{sd}
Jan	0.04^{ns}	0.36^{ns}
Feb	0.39^{ns}	36.80^{sd}
Mar	1.23^{ns}	77.89^{sd}
Apr	0.09^{ns}	15.83^{sd}
May	$<0.01^{ns}$	0.12^{ns}
Jun	$<0.01^{ns}$	0.05^{ns}
Jul	0.02^{ns}	0.09^{ns}
Aug	0.01^{ns}	0.01^{ns}

Note: Both tests run at $F_{0.002(3,568)} = \sim 5.25$; ns = not significant; sd = significant difference.

Table 9. Results of Analyses for Date Effects for Each Slope Class for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Benches	15-30%	30-45%	45-60%
0.67^{ns}	12.86^{sd}	14.43^{sd}	36.79^{sd}

Note: All tests run at $F_{0.0125(11,568)} = 2.25$; ns = not significant; sd = significant difference.

Results of statistical tests for date effects for each of the two aspects (Table 10) showed significant ($\alpha/2 = 0.025$) differences for each aspect. Differences in blow-in rates among dates are explained primarily on the basis of the seasonality of strong winds and presence or absence of a canopy.

To further clarify these results, simple main effects tests were performed and results presented in Table 11. For all southwest-facing slopes except the benches, significant differences in dates occurred, while for the northeast-facing slopes, only the steepest slopes (45-60%) showed significant date differences, leading one to surmise for the northeast-facing aspect, that either the steeper slopes were most responsive to what little downslope wind did occur, or temporal differences were due to factors relatively unrelated to wind. Undoubtedly it was the November mean that yielded the significant date difference. Since this occurred at a time of relatively slack wind, but during leaf fall when dry leaves could roll downslope, the significantly higher mean for this date may have been relatively unrelated to wind.

Analyses were carried one step further, with interaction tests (Kirk 1968) being performed. Results of tests for slope class/date interactions are presented in Table 12. As can be seen, significant interaction occurred with southwest-facing slopes. A visual inspection of Figure 11 reveals that the interaction involved the behavior of the 15-30% slope class, in that it assumed greater importance (based on input rate) in fall than its degree of inclination would indicate. Reasons for this have already been discussed and essentially involve a factor not taken into account in the model (proximity to drainage channels).

Table 10. Results of Analyses for Date Effects for Each Aspect for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

NE-Facing	SW-Facing
8.14^{sd}	65.39^{sd}

Note: Both tests run at $F_{0.025(11,568)} = 1.99$; ns = not significant; sd = significant difference.

Table 11. Results of Analyses for Date Effects at Each Slope Class/ Aspect Combination for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

	Aspect	
Slope Class	NE-Facing	SW-Facing
Benches	0.18^{ns}	0.64^{ns}
15-30%	2.24^{ns}	13.59^{sd}
30-45%	2.33^{ns}	18.70^{sd}
45-60%	4.40^{sd}	57.20^{sd}

Note: Both tests run at $F_{0.005(11,568)} = 2.43$; ns = not significant; sd = significant difference.

Table 12. Results of Analyses for Interaction Between Slope Class and Date at Each Aspect for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

NE-Facing	SW-Facing
0.33^{ns}	9.06^{sd}

Note: Both tests run at $F_{0.025(33,568)} = 1.57$; ns = not significant; sd = significant difference.

Interaction tests for aspect/date at each slope class (Table 13) reveal that the two aspects were functioning divergently for all slope classes except the benches. This is clearly seen in comparing Figures 10 and 11 (pages 75-76), which represent southwest- and northeast-facing slopes, respectively. In the latter case, peak inputs were in autumn, while the former showed peak inputs in spring, due to inputs from southwest-facing slopes which were dominated by strong winds during spring, Those for northeast-facing slopes, which receive little downslope wind during any season, were dominated by factors operative during litterfall season. While this holds true for all slopes greater than 15%, Figures 10 and 11 reveal that this was not the case for benches; like the steeper northeast-facing slope classes, benches for both aspects had higher inputs during fall.

Tests for slope class/aspect interactions at each date are presented in Table 14, with significant interaction seen during February and March. Results of the simple main effects tests for aspect effects at each date/slope class combination (Table 5, page 88) revealed significant aspect effects during February and March for 30-45% and 45-60% slope classes, with the 15-30% slope class not significantly different for the two aspects, due to the fact that this slope class had highest inputs of any northeast-facing slope class for these months. Thus, just as with the slope class/date interaction, the different behavior of the 15-30% slope class introduced interaction into the interpretation. One can observe from Figures 10 and 11 that the magnitude of inputs was always in the same direction as steepness of slope. This again points up the fact that a factor was involved with the 15-30% slope class that did not act on the other slope classes.

Table 13. Results of Analyses for Interaction Between Aspect and Date at Each Slope Class for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Benches	15-30%	30-45%	45-60%
0.15[ns]	2.96[sd]	6.58[sd]	24.80[sd]

Note: All tests run at $F_{0.0125(11,568)} = 2.25$; ns = not significant; sd = significant difference.

Table 14. Results of Analyses for Interaction Between Aspect and Slope Class at Each Date for Blow-In of Leaves to the West Fork of Walker Branch for the 1973-1974 Water Year.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
0.07^{ns}	0.46^{ns}	0.52^{ns}	2.32^{ns}	0.03^{ns}	7.43^{sd}	17.35^{sd}	3.32^{ns}	0.02^{ns}	$<0.01^{ns}$	$<0.01^{ns}$	$<0.01^{ns}$

Note: All tests run at $F_{0.005(3,568)} = 4.28$; ns = not significant; sd = significant difference.

Factors determining the autumn peak blow-in are more complex than those for the mid-winter to mid-spring peak, because autumn is a period of rapid change in the physical and biological characteristics of the watershed system, particularly those associated with leaf fall. Peak blow-in rates during autumn closely followed the peak in litter fall. Similar results were observed by McDowell and Fisher (1975). Apparently, falling leaves continue moving for short distances once they reach the forest floor, especially so during periods when wind is acting to remove them from the canopy. Leaves would roll farther on steeper slopes from gravitational phenomena alone (Vannote 1969). During and soon after leaf fall, they would be most susceptible to aeolian transport, the negligible degree of their physical incorporation into the soil litter layer being fostered by dry conditions during this time. Higher rates of blow-in for November as compared with October were probably due to several factors including generally higher incident winds, less canopy cover, and higher standing crops of leaf litter on the forest floor.

The mid-winter to mid-spring peak in rate of leaf blow-in is less complicated due to the absence of litterfall. All inputs can be directly related to aeolian factors, and results of analyses clearly show significant aspect and slope class effects for this period.

Total blow-in of leaf material to the study reach was calculated on the basis on the length of stream bordered by each slope class for each aspect. Total annual inputs were 12.9 kg (38.5 g/m streambank/yr) and 67.6 kg (201.6 g/m streambank/yr) for the northeast- and southwest-facing slopes, respectively, for a total input of 80.5 kg/yr or 240.1 g/m stream/yr. On a unit basis, the figure is 86.8 $g/m^2/yr$.

Total annual leaf input to the study reach was 458.8 g/m^2, of which 18.9% was blow-in and 81.1% was direct leaf fall. Fisher (1970) found that 21.6% of leaf input to Bear Brook was by lateral transport. Of this, 77.2% was transported into the system in autumn and 22.8% in spring. Snow pack in winter disallows any lateral transport during this time in New Hampshire. Total leaf input was 431.7 g/m^2/yr. McDowell and Fisher (1975), working on a Massachusetts watershed, found for a 77-day autumnal period that total litter blow-in was 21% of the total litter input. Sedell et al. (1973) working in a steeply sloped coniferous forest watershed, reported preliminary findings of approximately 1 g/m^2/day for total allochthonous inputs to the stream subsystem, with 1.5 times as much entering the stream system from the steep slopes as from litterfall. Rau (1976) showed that conifer leaf litter introduced by aeolian factors into Findley Lake, Washington was quantitatively equivalent to that portion of the autochthonous production reaching the benthic community.

While leaf fall input on a unit area basis is relatively constant over the entire drainage system of an evenly forested small watershed, blow-in values and hence the ratio of leaf fall to blow-in will vary, depending on channel width and steepness of adjoining slopes. On Walker Branch, steepest slopes occur along the lower channel reaches where maximum channel widths occur. Depending on the overall geomorphology of the watershed system, in other situations the reverse trend in slope distribution is possible.

Fruit and Reproductive Part Inputs

Figures 17 and 18 present mean monthly values for inputs of fruit material via lateral transport into the stream channel of Walker Branch

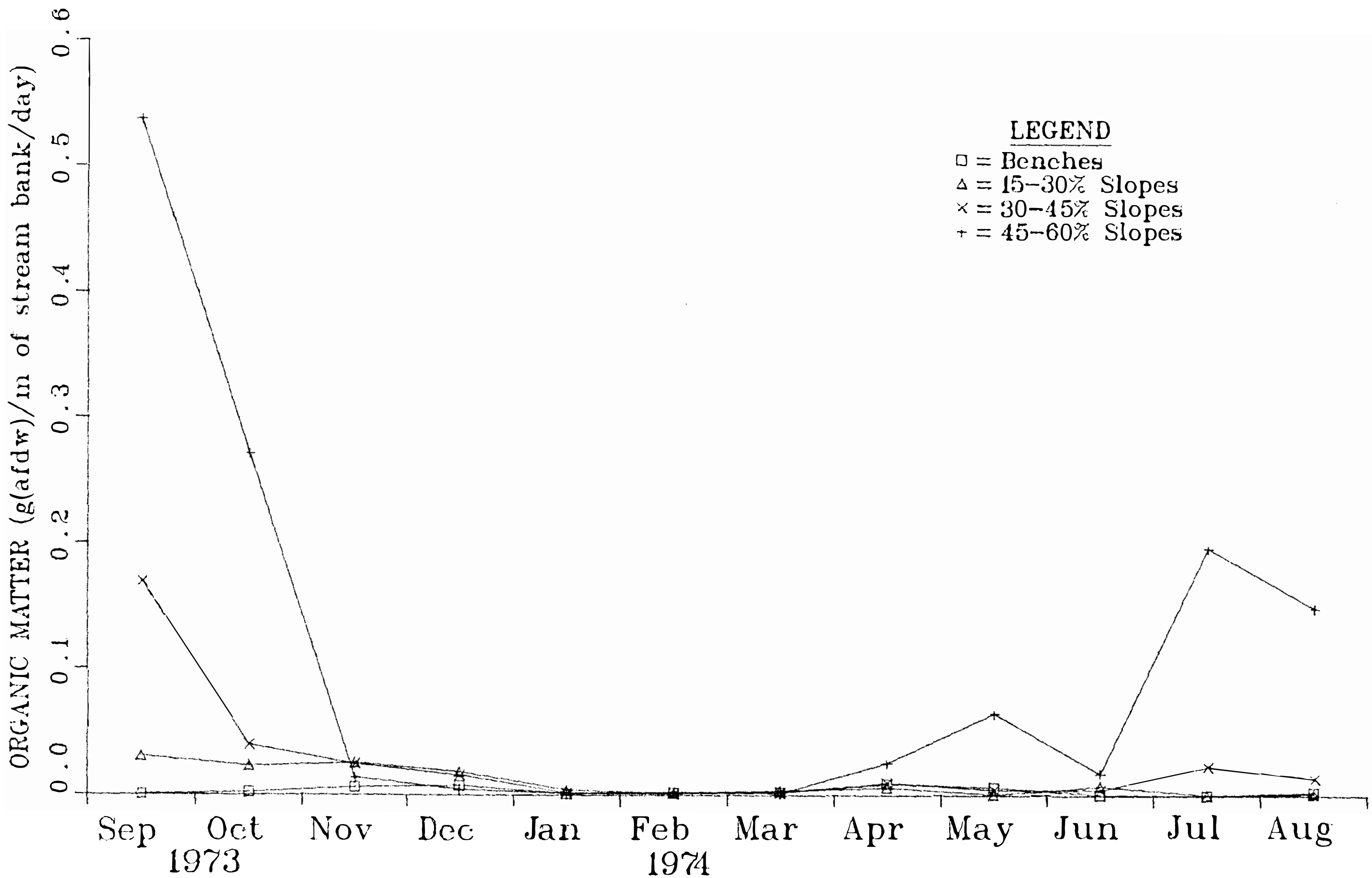

Figure 17. Mean Daily Rates of Transport of Wind-Blown Fruits and Reproductive Parts from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

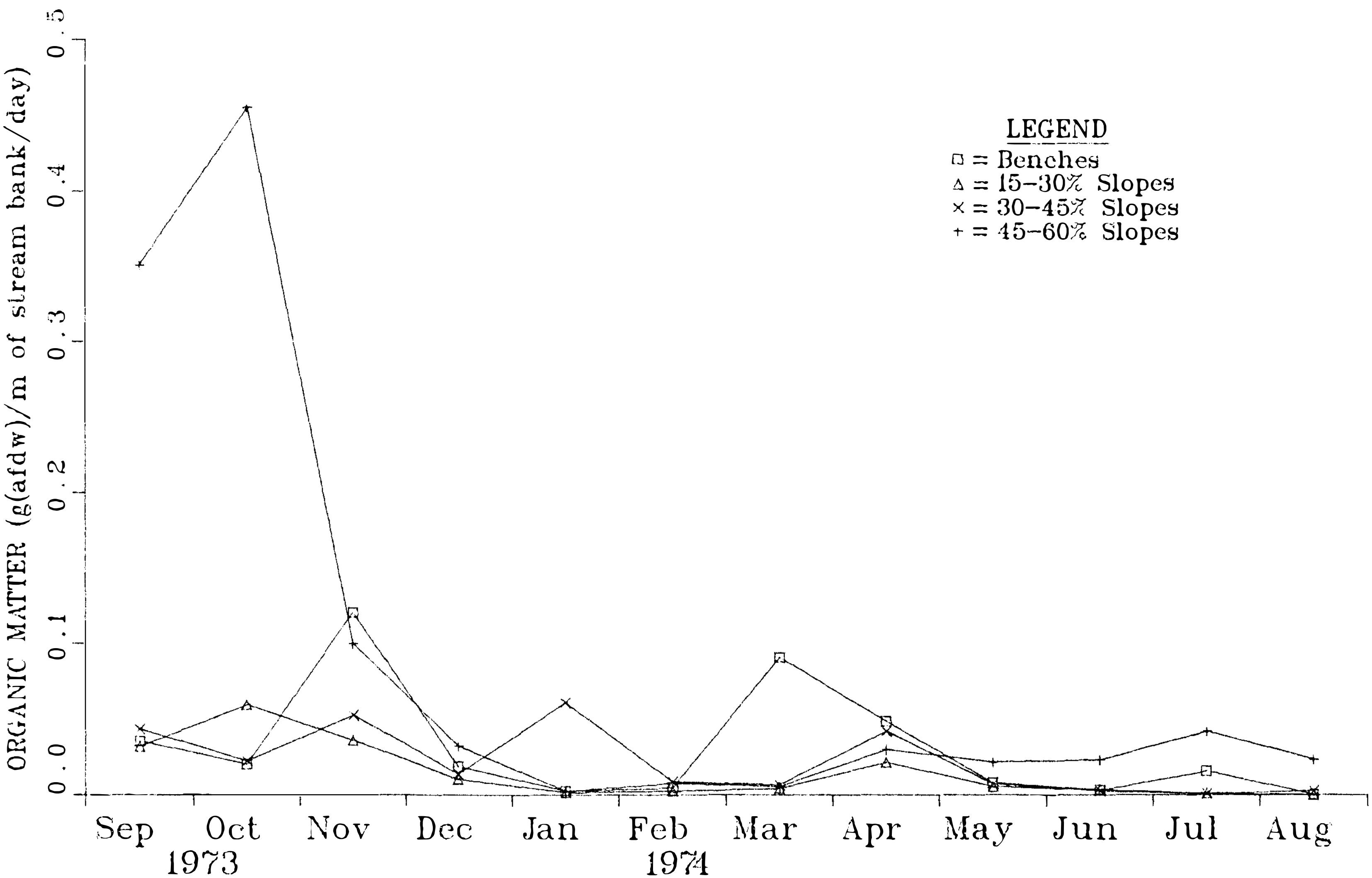

Figure 18. Mean Daily Rates of Transport of Wind-Blown Fruits and Reproductive Parts from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

by slope class for the northeast- and southwest-facing slopes, respectively. (See Tables A8 and A9, Appendix A for 95% confidence limits for these means.) Highest monthly means were found in the late summer to mid-autumn period, coinciding with maximum litterfall. The high value for benches for November was probably erroneous. Because benches are close to stream bank level, they are prone to temporary flooding during large spates. Such a catastrophic event occurred during November of the study year. Of four blow-in traps collecting material from southwest-facing benches, two were obviously contaminated with flood water and the data were discarded. The other two were not discarded since there was no discernible leaf contamination. However, contamination by fruits, especially poplar fruits, was quite probable, and the November value for benches for southwest-facing slopes should be regarded with caution. The data were left in the model, since there was no obvious date or slope class effect associated with this possible contamination, and a missing data cell would have greatly confounded the analysis.

Higher than average readings for February and April for 30-45% slopes and benches, respectively, for southwest-facing slopes were each due to one high value, but did not lead to significant differences with regard to either slope class, aspect, or date.

Unlike the situation for leaf inputs, no significant aspect differences were evident, suggesting that the phenomenon of fruit input was not directly related to aeolian factors. Peak monthly inputs for both aspects, occurring during September for northeast-facing slopes and September and October for southwest-facing slopes, were approximately 0.4-0.5 $g/m^2/day$. The higher values for the northeast-facing 45-60%

slopes during July and August (0.20 and 0.15 g/m streambank/day) were not matched by coincident increases in inputs from the steepest southwest-facing slopes, and were probably due to the location of particular trees bearing and dropping fruit material upslope from traps.

The 3-way ANOVA for inputs of fruit and reproductive material is presented in Table A7, Appendix A. Both date and slope class were significant, while none of the interaction terms was significant. Because of the lack of confounding by interaction, further analyses were directed towards comparison of all possible pairs of means using Tukey's t test (Kirk 1968).

Results of these multiple means tests are presented in Table 15 for date comparisons and Table 16 for slope class comparisons. For date comparisons (over both aspects), only those involving either September or October collections showed significant differences. September was significantly higher than all other months except October, the latter being significantly higher than all other months with lower means except July.

Results clearly show that fruit inputs via lateral transport were not directly related to aeolian factors, but rather to season of fruit fall. Litterfall data (Table 2, page 70) indicated that highest fruit inputs occurred in September, October, and November. The high values for the northeast-facing 45-60% slope class for July and August were not accompanied by increases in the litterfall for the month. These high values were due to several collectors located downslope from hickory trees, which dropped fruit at an early date. Since hickories are not generally found in the proximity of the stream channel, it is not surprising that concurrent increases in fruit weight in litterfall were absent.

Table 15. Results of Multiple Means Tests for Date Effects (Over All Slope Classes and Aspects) for Blow-In of Fruits and Reproductive Parts to the West Fork of Walker Branch for the 1973-1974 Water Year.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Sep	1.38^{ns}	3.79^{sd}	5.02^{sd}	5.26^{sd}	5.49^{sd}	5.28^{sd}	4.69^{sd}	4.98^{sd}	5.32^{sd}	4.23^{sd}	4.65^{sd}
Oct	--	2.48^{ns}	3.66^{sd}	3.89^{sd}	4.12^{sd}	3.91^{sd}	3.33^{sd}	3.61^{sd}	3.94^{sd}	2.86^{sd}	3.27^{sd}
Nov	--	--	1.02^{ns}	1.23^{ns}	1.43^{ns}	1.24^{ns}	0.72^{ns}	0.98^{ns}	1.26^{ns}	0.24^{ns}	0.63^{ns}
Dec	--	--	--	0.22^{ns}	0.42^{ns}	0.23^{ns}	0.31^{ns}	0.05^{ns}	0.25^{ns}	0.81^{ns}	0.42^{ns}
Jan	--	--	--	--	0.20^{ns}	0.02^{ns}	0.53^{ns}	0.26^{ns}	0.03^{ns}	1.03^{ns}	0.64^{ns}
Feb	--	--	--	--	--	0.19^{ns}	0.73^{ns}	0.46^{ns}	0.17^{ns}	1.24^{ns}	0.84^{ns}
Mar	--	--	--	--	--	--	0.54^{ns}	0.28^{ns}	0.02^{ns}	1.05^{ns}	0.65^{ns}
Apr	--	--	--	--	--	--	--	0.27^{ns}	0.56^{ns}	0.50^{ns}	0.10^{ns}
May	--	--	--	--	--	--	--	--	0.29^{ns}	0.77^{ns}	0.37^{ns}
Jun	--	--	--	--	--	--	--	--	--	1.07^{ns}	0.67^{ns}
Jul	--	--	--	--	--	--	--	--	--	--	0.40^{ns}

Note: Analysis run at studentized range/$\sqrt{2}$ = 3.27; Tukey's test at α = 0.05; and error D F = ∞.

Table 16. Results of Multiple Means Tests for Slope Clsss Effects (Over All Dates and Aspects) for Blow-In of Fruits and Reproductive Parts to the West Fork of Walker Branch for the 1973 - 1974 Water Year.

	Slope Class		
Slope Class	30-45%	45-60%	Benches
15-30%	0.75^{ns}	5.36^{sd}	0.09^{ns}
30-45%	--	4.64^{sd}	0.52^{ns}
45-60%	--	--	4.26^{ns}

Note: All tests run at studentized range/$\sqrt{2}$ = 2.57, Tukey's test at α = 0.05, and Error DF = $\propto$; sd = significant difference, ns = not significant.

Results of the multiple means tests for slope class differences (Table 16) show that 45-60% slopes, as expected, were significantly higher than the other slope classes, and no other significant slope class differences occurred. This conforms to the general reasoning that the steepest slopes should enhance the downslope travel of fruit material.

Total blow-in of fruits and reproductive parts to the study reach was calculated as 13.08 kg, of which 8.45 kg (61.2%) was contributed from northeast-facing slopes and 5.35 kg (38.8%) was contributed from southwest-facing slopes. Total annual input of fruits and reproductive parts to the study reach (litterfall and blow-in) was 60.73 kg. of which blow-in contributed 22.7% and litterfall contributed 77.3%. Expressed on a unit area basis, yearly input to the study reach was 65.49 g/m^2, of which litterfall contributed 50.61 g/m^2 and blow-in contributed 14.88 g/m^2.

Twig Inputs

Mean monthly inputs of twigs via lateral transport to Walker Branch are shown in Figures 19 and 20. (See Tables A10 and A11, Appendix A for 95% confidence limits for these means.) For northeast-facing slopes, values were low and variable throughout the year, with only three means (all in March) at or above 0.02 g/m streambank/day. It is interesting to note that the March inputs for northeast-facing slopes were unrelated to slope class, with the steepest slope having the lowest mean for the month, and benches having the highest mean (0.05 g/m streambank/day). When dealing with low levels of input, such spuriously high means as those for benches are always possible.

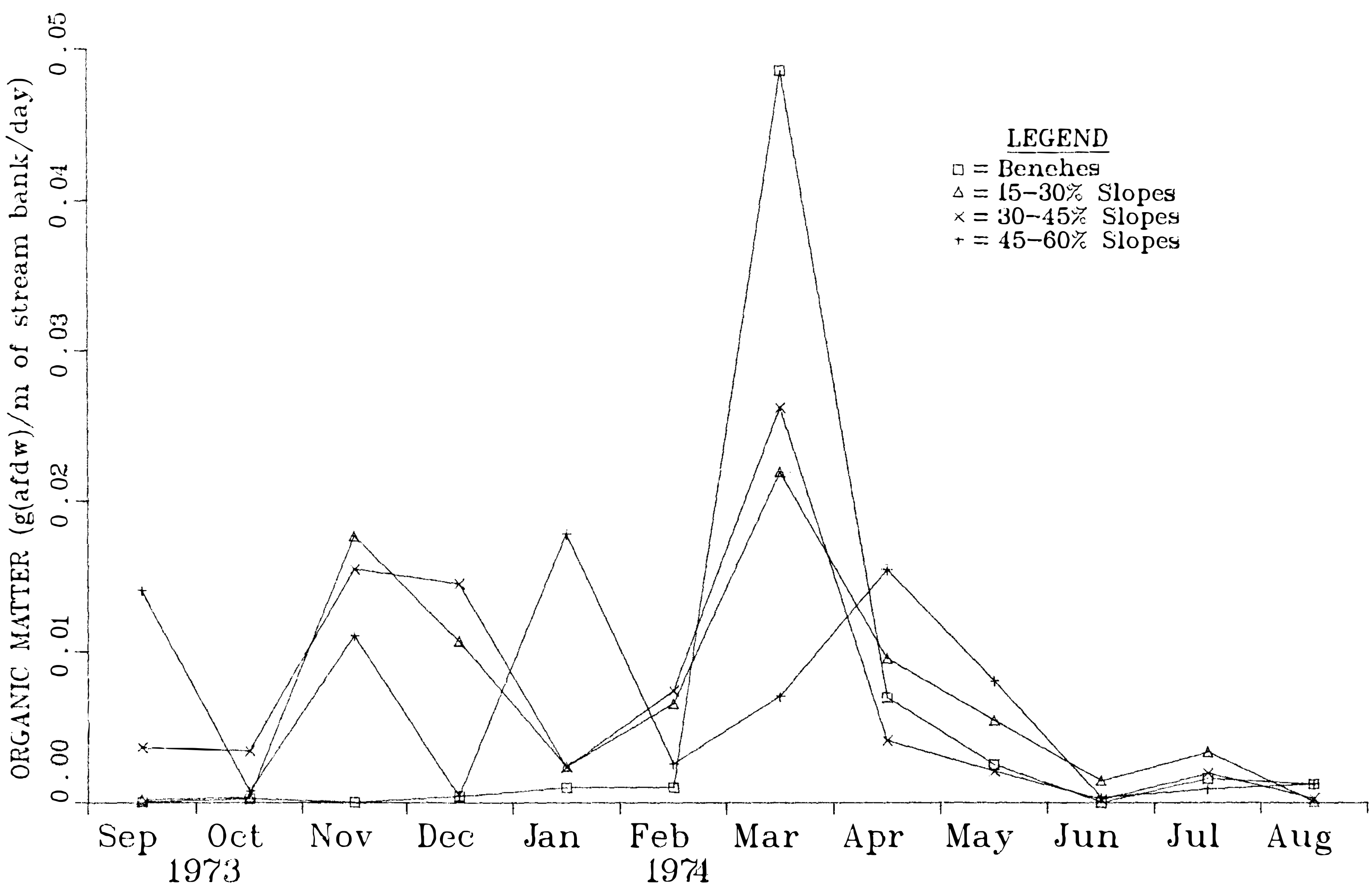

Figure 19. Mean Daily Rates of Transport of Wind-Blown Twigs from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

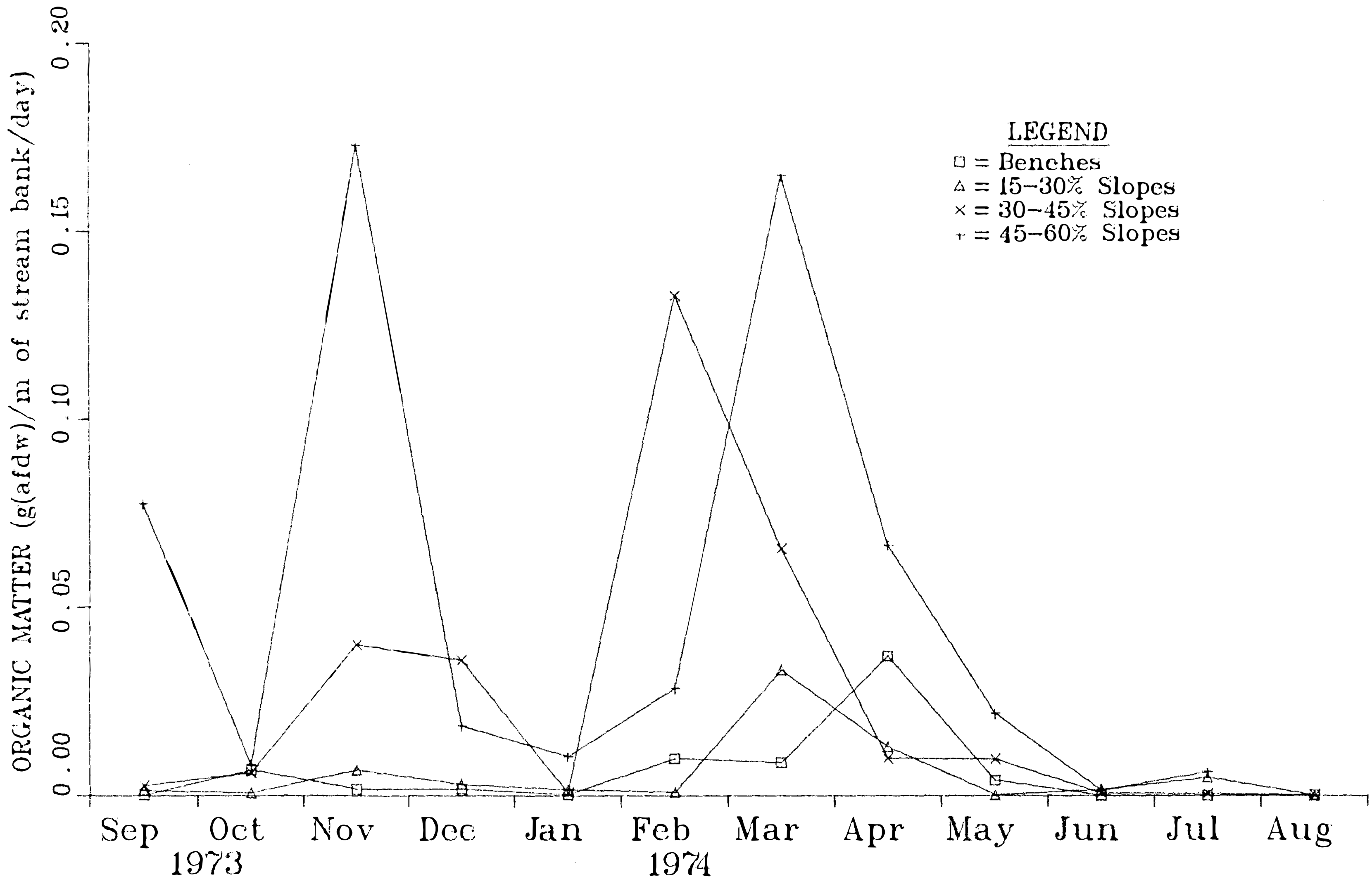

Figure 20. Mean Daily Rates of Transport of Wind-Blown Twigs from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Although values for southwest-facing slopes were also variable throughout the year, a pattern is readily discernible. For any month, either the 30-45% or the 45-60% slope classes had the highest mean input. While most monthly values were low, there were six monthly means greater than 0.05 g/m streambank/day, all higher than the highest monthly mean for northeast-facing slopes. Three monthly means, those for the 30-45% slope class for February, and the November and March means for the 45-60% slope class, were 0.14 g/m streambank/day or greater. Low monthly means for the 30-45% slope classes occurred during October, January and May through August. In general, this conforms rather well with the trend for blow-in of leaf material, especially the January minimum. Peak inputs for benches and the 15-30% slope class occurred during the months of March and April, both months of substantial leaf blow-in. Otherwise, the values are quite low, with monthly means of 0.01 g/m streambank/day or less quite common.

While there was some coincidence of peaks of twig input via litterfall (Figure 8, page 63) with those for blow-in, the obvious slope effects would tend to suggest that seasonal patterns exhibited in Figures 19 and 20 were due to a combination of phenological, topographic, meteorologic, and stochastic processes.

Results of the 3-way ANOVA for inputs of twigs to the stream system via lateral transport (Table A7, Appendix A) showed all three main effects to be significant, as was the interaction between slope class and aspect. As such, the subsequent analysis took two paths. For the analyses of date effects, multiple means tests involving all possible pairwise comparisons were made. For slope class and aspect, due to significant interaction, simple main effects were tested.

Results of the multiple means tests for date effects are presented in Table 17 and can be summarized as follows. The three months with the highest means, November, February, and March were not significantly different from each other, but all significant differences in the analyses were related to these three months. The three months with highest means were either those with high inputs of twigs in litterfall (November and March) or were periods of maximum blow-in of leaf material (November, February and March). This coincidence of peaks in twig blow-in with those for leaf material could indicate that twig material entangled in leaf material on the forest floor can be carried along by a moving mass of leaves. It could also mean that the same factor leading to blow-in of leaf material, e.g., gusting winds, could enhance removal of senescent twigs from the canopy, which could then bounce down the slope. Both factors were probably operative to a certain degree. The fact that southwest-facing slopes generally had much higher peak values (for November nine times as high) would tend to indicate that some actual transport of twig litter already on the forest floor did occur. When considering the large amounts of leaves swept off the forest floor in February and March, it is quite likely that small entrapped twig material was carried along with the leaves.

Results of simple main effects tests are shown in Tables 18 and 19. As expected, no significant aspect differences (overall dates) were found for smaller slope classes (benches and 15-30% slopes), but for 30-45% and 45-60% slopes, aspect effects were significant (Table 18), with inputs from southwest-facing slopes being higher than those from northeast-facing slopes. For slope class effects (over all dates), north-

Table 17. Results of Multiple Means Tests for Date Effects (Over All Slope Classes and Aspects) for Blow-In of Twigs to the West Fork of Walker Branch for the 1973-1974 Water Year.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Sep	1.57^{ns}	3.51^{sd}	0.37^{ns}	1.28^{ns}	2.04^{ns}	4.45^{sd}	0.89^{ns}	0.94^{ns}	0.84^{ns}	1.38^{ns}	1.79^{ns}
Oct	--	5.00^{sd}	1.19^{ns}	0.28^{ns}	3.61^{sd}	6.01^{sd}	2.43^{ns}	0.62^{ns}	0.73^{ns}	0.10^{ns}	0.32^{ns}
Nov	--	--	3.83^{sd}	4.71^{ns}	1.57^{ns}	0.73^{ns}	2.62^{ns}	4.37^{sd}	4.30^{sd}	5.07^{sd}	14.07^{sd}
Dec	--	--	--	0.09^{ns}	2.39^{ns}	11.40^{sd}	1.24^{ns}	0.56^{ns}	0.46^{ns}	1.28^{ns}	1.51^{ns}
Jan	--	--	--	--	3.30^{sd}	5.70^{sd}	2.15^{ns}	0.34^{ns}	0.45^{ns}	0.38^{ns}	0.60^{ns}
Feb	--	--	--	--	--	2.42^{ns}	1.12^{ns}	2.95^{ns}	2.88^{ns}	3.69^{sd}	3.93^{sd}
Mar	--	--	--	--	--	--	3.51^{sd}	5.34^{sd}	5.28^{sd}	6.08^{sd}	6.33^{sd}
Apr	--	--	--	--	--	--	--	1.80^{ns}	1.71^{ns}	2.52^{ns}	2.75^{ns}
May	--	--	--	--	--	--	--	--	0.10^{ns}	0.72^{ns}	0.94^{ns}
Jun	--	--	--	--	--	--	--	--	--	0.83^{ns}	1.05^{ns}
Jul	--	--	--	--	--	--	--	--	--	--	0.22^{ns}

Note: Analysis run at studentized range/$\sqrt{2}$ = 3.27; Tukey's test at $\alpha = 0.05$; and error D F = ∞; sd = significant difference, ns = not significant.

Table 18. Results of Analyses for Aspect Effects for Each Slope Class for Blow-In of Twigs to the West Fork of Walker Branch for the 1973-1974 Water Year.

Benches	15-30%	30-45%	45-60%
<0.01^ns^	0.01^ns^	6.40^sd^	27.03^sd^

Note: All tests run at $F_{0.01(1,508)} = 6.64$; ns = not significant; sd = significant difference.

Table 19. Results of Analyses for Slope Class Effects for Each Aspect for Blow-In of Twigs to the West Fork of Walker Branch for the 1973-1974 Water Year.

NE-Facing	SW-Facing
0.01^{ns}	11.44^{sd}

Note: Both test run at $F_{0.025(3,568)} = 3.11$; ns = not significant; sd = significant difference.

east-facing slopes showed no significant differences for slope class inputs, while southwest-facing slope classes did have significantly different inputs. Both these results lend confirmation to the hypothesis that transport of leaves by wind along the forest floor aids in transport of twig material. Were this just an effect of wind blowing dead or senescent twigs out of the canopy, such aspect differences as seen here would not occur, with only differential slope class responses. When results of these analyses are coupled with those from the multiple means tests for date effects (in which the temporal pattern of inputs coincided with that for leaf blow-in) the coupling of the two processes is more probable.

Total blow-in of twigs to the study reach was calculated as 3.97 kg, of which 19.1% (0.76 kg) entered from northeast-facing slopes and 80.9% (3.21 kg) came from southwest-facing slopes. Total annual input of twigs to the study reach (litterfall and blow-in) was 28.33 kg. of which blow-in contributed 14.0% and litterfall contributed 86.0% (24.36 kg). Expressed on a unit area basis, yearly input to the study reach was 34.57 g/m^2, of which litterfall contributed 26.27 g/m^2 and blow-in contributed 11.30 g/m^2.

Frass Inputs

Inputs of frass via lateral transport to Walker Branch are shown in Figures 21 and 22 for northeast and southwest-facing slopes, respectively. (See Tables A12 and A13, Appendix A for 95% confidence limits for these means.) Peak inputs occurred during summer and fall with especially high inputs for the steepest slope classes for both aspects during September 1973. During September 1973, inputs of frass (g/m streambank/

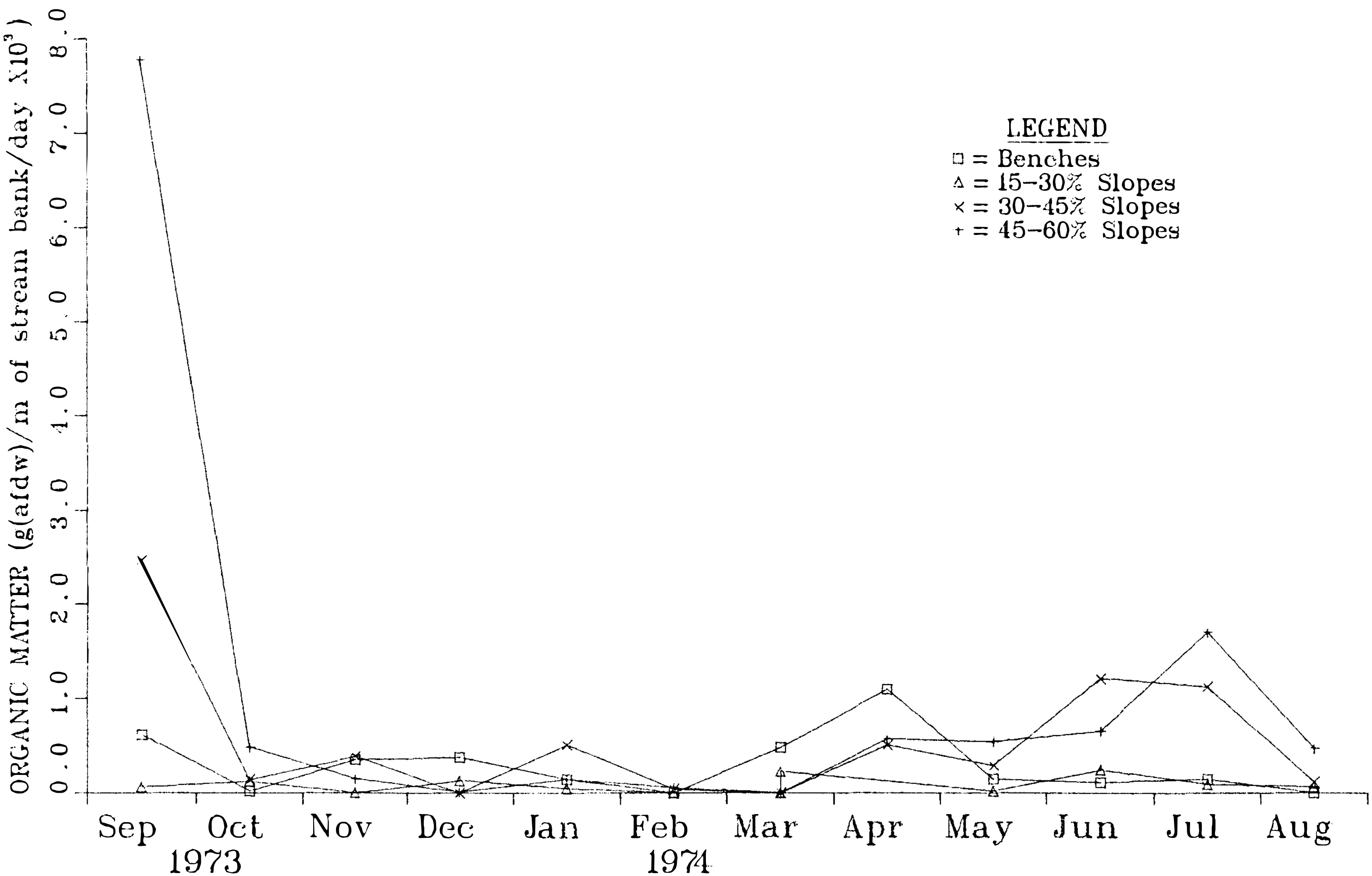

Figure 21. Mean Daily Rates of Transport of Wind-Blown Frass from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

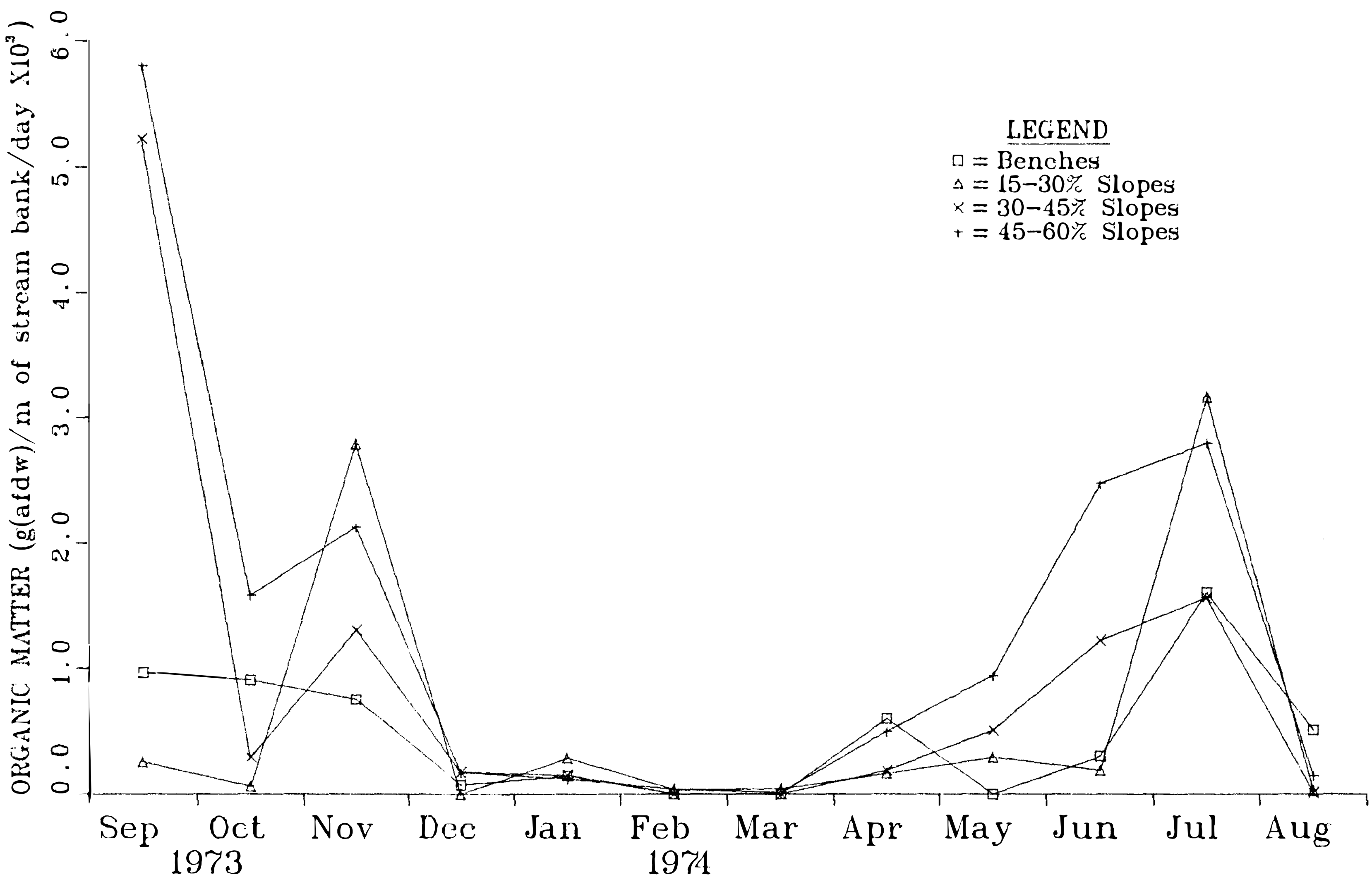

Figure 22. Mean Daily Rates of Transport of Wind-Blown Frass from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

day) ranged from 0.0078 for the 45-60% slope class for northeast-facing slopes to 0.0007 for the 15-30% slope class for northeast-facing slopes. Unlike leaf inputs, little in the way of aspect differences was seen in the rate of frass input. Several trends were similar for both aspects, especially a secondary peak in June-July. However, southwest-facing slopes also showed an increase in frass inputs during November, which northeast-facing slopes did not. It is interesting that during this month inputs from the 15-30% slope class, which were lowest for the southwest-facing aspect for September and October, were highest in November. This was consistent with the trend for leaffall for the 15-30% southwest-facing slopes (See Figure 11, page 75).

From December through March, inputs continued at a very low level and began to increase in May and June. For southwest-facing slopes, all slope classes showed an increase during July, the peak month during summer, while northeast-facing slopes did not show this increase for benches and 15-30% slopes.

A partial explanation for the pattern of lateral transport of frass can be made from the pattern of litterfall inputs of frass (see Figure 9 page 67). Highest frass inputs via litterfall occurred during September (3.43 g/m^2), while none was recorded after October 16, 1973. Thus, any inputs via blow-in after mid October probably resided on the forest floor at that time. It is proposed that these and any other frass inputs occurring during the November to April period must have been transported along with leaves via aeolian forces acting on the forest floor. Fallen leaves have often been observed with attached frass which could be transported along with the leaf itself. Southwest-facing slopes exhibited

this November peak and also did not reach the low levels of northeast-facing slopes in October, because of the larger amounts of blow-in of leaf material from the slopes during October and November. The south-west-facing 15-30% slopes, which had highest mean blow-in of leaves for all aspect/slope class combinations during November, also had highest inputs of frass for the month.

Since a canopy was present through the summer period, and since blow-in of leaves was negligible (see Figures 21 and 22, pages 119 and 120, respectively), summer peaks were due to frass fall from the canopy and subsequent bouncing or rolling down the slopes. The precipitous decline in August, while not completely understood, was consistent with the pattern for litterfall inputs (see Figure 9, page 66) where a drastic decline (0.15 $g/m^2/day$ in July vs 0.02 $g/m^2/day$ in August) in frass inputs also occurred. One possible explanation is that the severely dry mid-summer period (June 17 to August 1 total rainfall of 5.82 cm with July being 9.35 cm below normal) stressed the insect populations, either directly or indirectly, and thereby caused their decline. Litterfall data (See Figure 6, page 57) showed a relatively large amount of leaf input during July and August, indicating early senescence of the vegetation.

Results of the 3-way ANOVA for frass is presented in Table A7, Appendix A. Both date and slope class were significant, as is the slope class/date interaction. Aspect is of borderline significance, having a Pr >F slightly greater than 0.05. Thus, indications are that there was some aspect effect, probably attributable to the November differences discussed earlier. The analyses next proceeded to simple main effects

tests with date effects tested over each level of slope class and vice versa. Results of these analyses are presented in Tables 20 and 21. Only the mean for September showed significant slope class effects (Table 20), while the two steepest slope classes, 30-45% and 45-60%, showed significant date differences (Table 21). Thus, inputs from the two steepest slopes (over both aspects) showed significant differences over time, while those from benches and 15-30% slopes showed no significant differences over time. In September, inputs from the two steepest slope classes were significantly higher than from benches or 15-30% slopes. On no other date were slope class differences significantly different from 0, due to small overall inputs plus natural spatial variation based on the mosaic pattern of vegetation of the watershed. Gosz et al. (1973) have shown that canopy insects show preferences for the leaves of particular species of trees.

Total blow-in of frass to the study reach was calculated as 0.21 kg, of which 0.10 kg (48%) was contributed from northeast-facing slopes and 0.11 kg (52%) came from southwest-facing slopes. Total annual input of frass to the study reach (litterfall and blow-in) was 9.67 kg, of which blow-in contributed 1.7% and litterfall 98.1%. Expressed on a unit area basis, yearly input to the study reach was 10.44 g/m^2, of which litterfall contributed 10.21 g/m^2 and blow-in contributed 0.23 g/m^2.

Total Inputs

Table 22 presents results for the yearly inputs of organic material to Walker Branch perennial flow section (from 38.10 meters above the weir to 373.38 meters above the weir), based on the sum of mean monthly inputs for each slope class/aspect combination and the length of streambank

Table 20. Results of Analyses for Slope Class Effects for Each Month for Blow-In of Frass to the West Fork of Walker Branch for the 1973-1974 Water Year.

Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
29.16^{sd}	0.61^{ns}	0.22^{ns}	0.01^{ns}	0.03^{ns}	$<0.01^{ns}$	0.02^{ns}	0.47^{ns}	0.27^{ns}	1.44^{ns}	0.79^{ns}	0.05^{ns}

Note: All tests run at $F_{0.005(3,568)} = 4.28$; ns = not significant; sd = significant difference.

Table 21. Results of Analyses for Date Effects for Each Slope Class for Blow-In of Frass to the West Fork of Walker Branch for the 1973-1974 Water Year.

Benches	15-30%	30-45%	45-60%
0.56^{ns}	0.92^{ns}	4.03^{sd}	44.20^{sd}

Note: All tests run at $F_{0.0125(11,568)} = 2.25$; ns = not significant; sd = significant difference.

Table 22. Summary of Data for Blow-In of Organic Material (kg) to the West Fork of Walker Branch for the 1973-1974 Water Year.

Type of Organic Matter (kg)	Northeast-Facing Slopes					Southwest-Facing Slopes					
	15-30% (0)	30-45% (51.5)	45-60% (198.1)	Benches (85.7)	Total	15-30% (67.8)	30-45% (127.6)	45-60% (106.7)	Benches (36.2)	Total	Grand Total
Leaf	0	1.72	10.14	1.05	12.91 (58.1%)	7.96	18.12	40.45	1.12	67.64 (81.6%)	80.55 (81.8%)
Fruit	0	0.49	7.86	0.10	8.45 (38.0%)	0.35	1.02	3.59	0.39	5.35 (7.0%)	13.80 (14.0%)
Twig	0	0.12	0.48	0.15	0.76 (3.4%)	0.13	1.17	1.84	0.08	3.21 (4.2%)	3.97 (4.0%)
Frass	0	0.01	0.01	0.09	0.10 (0.4%)	0.01	0.04	0.05	0.01	0.11 (0.2%)	0.21 (0.2%)
Total Organic Matter					22.22 (22.5%)					76.32 (76.5%)	98.53 (100.0%)

Note: meters of streambank bordered by each slope class is given in parentheses in the heading; Percentages listed under totals indicate the relative contribution of each blow-in component.

bordered by each combination. There was no portion of the perennial flow section that was bordered by 15-30% northeast-facing slopes.

A total of 98.53 kg of organic material entered the perennial flow channel via blow-in. Of this total, 76.32 kg (77.46%) was from southwest-facing slopes and 22.21 kg (22.54%) came from northeast-facing slopes. For each meter of stream bank (total of 335.28 meters), these inputs constitute 0.07 kg and 0.23 kg for northeast-facing and southwest-facing slopes, respectively.

The relative contribution of each type of organic material for the two aspects is revealing, and relates to the greater influence of wind for inputs from southwest-facing slopes. For northeast-facing slopes, leaf inputs constituted only 58.11% of total input, while the southwest-facing slopes, leaf inputs were 88.63% of the total. Fruits, on the other hand, contributed 38.04% of the inputs for northeast-facing slopes, as compared to only 7.01% for southwest-facing slopes, with the absolute amount also being greater from northeast-facing slopes, due mainly to the greater proportion of streambank bordered by 45-60% slopes for the northeast-facing group. These results are consistent with the statistical analyses presented above. Little difference was seen for relative contribution of twig input between the two aspects (3.41% vs 4.21% for northeast-facing and southwest-facing slopes, respectively), but the absolute magnitude was approximately four times greater for southwest-facing slopes. Frass inputs were, overall, quite similar for the two aspects, with frass constituting 0.44% and 0.15% for northeast- and southwest-facing slopes, respectively.

For both aspects combined, total inputs to the stream channel were 80.55 kg (81.8%) of leaves, 13.80 kg (14.0%) of fruits and reproductive parts, 3.97 kg (4.0%) of twigs, and 0.22 kg (0.2%) of frass, for a total of 98.54 kg. This constituted 240.3 g of leaves, 41.2 g of fruits and reproductive parts, 11.9 g of twigs, and 0.7 g of frass per meter of stream channel, for a total input (per meter of stream channel) of 294.1 g/yr. On a per unit area basis, the values are 86.9, 14.9, 4.3, and 0.2 g/m^2 for leaves, fruits, twigs, and frass, respectively, for a total input of 106.3 g/m^2 or 1063 kg/ha.

Total input (litterfall and blow-in) of coarse organic material to the study reach was 565.4 g/m^2 (5654 kg/kg/ha), with leaves (458.9 g/m^2) constituting 81.2% of the total. Fruits, twigs, and frass contributed 65.5 g/m^2 (11.6%), 30.6 g/m^2 (5.4%), and 10.4 g/m^2 (1.8%), respectively. Litterfall contributed similar percentages of leaves (81.1%), fruits (77.3%), and twigs (85.9%) to the total input and greatly dominated inputs of frass (98.1%). Input via litterfall for all components was 81.2% of total inputs, while blow-in contributed 18.8%.

For blow-in components, organic carbon was, on the average, 49.4% of the organic content of the leaf component (AFDW), while corresponding values for fruits, twigs, and frass were 47.5%, 47.5%, and 49.8% organic carbon, respectively. Inputs of organic carbon to the stream channel were 39.77 kg leaves, 6.56 kg fruits, 1.89 kg twigs, and 0.11 kg frass, for a total organic carbon input of 48.33 kg for the 1973-1974 water year. On a per unit area basis, these yearly values are 42.9, 7.1, 2.0, and 0.1 g/m^2 for leaf, fruit, twig, and frass inputs, respectively, for a total yearly organic carbon input of 52.1 g/m^2 or 521 kg/ha.

Hydrologic Regime

The two water years during which this study took place were among the wettest on record for the Oak Ridge area. The water year from September 1, 1972 to August 31, 1973 had the larger amount of rainfall, with 187.5 cm of precipitation. This is 36.4 cm above the six-year (1970-1976) average of 151.1 cm (Henderson et al. 1977). Streamflow was 114.8 cm, lower than that for the 1973-1974 water year (116.6 cm), when 174.7 cm of precipitation fell, the latter being some 25 cm above the six-year watershed average (Table 23). The reason for the apparent inverse relationship between yearly precipitation and discharge for the two water years involved different seasonality of precipitation inputs for the two years (See Figure 4, page 39). The 1972-1973 water year was characterized by a wet late spring and summer, while 1973-1974 had a dry summer with most rain falling during periods of low photosynthetic activity (especially late November through March). Thus, although the 1973-1974 water year had rainfall 24% greater than the six-year mean, there was a large deficit in evapotranspiration (58.6 cm actual vs 76.5 cm potential), due to the June through September precipitation being 12 cm below normal. Actual evapotranspiration for 1972-1973 was 72.7 cm, within 4 cm of the norm, due mainly to a wetter summer (Henderson et al. 1977). The difference in net input (14.1 cm) was sufficient to cause a lower yearly discharge for the wetter 1972-1973 water year.

Figure 23 shows the relationship between monthly precipitation (cm) and discharge (m^3/ha/wk) for the two study years. Included for comparison is the mean monthly precipitation for the Oak Ridge area (McMaster 1967) for the period 1931-1960.

Table 23. Annual Water Balance on Walker Branch Watershed from September 1, 1970 to August 31, 1976.

Water Year[a]	Precipitation (cm/yr)	Streamflow (cm/yr)	Net Input (cm/yr)	Evaporation[b] (cm/yr)	Transpiration[c] (cm/yr)
1970-71	139.5	74.5	65.0	17.8	47.2
1971-72	128.2	71.0	57.2	17.0	40.2
1972-73	187.5	114.8	72.7	22.3	50.4
1973-74	174.7	116.1	58.6	19.3	29.3
1974-75	146.4	83.1	63.3	17.9	45.4
1975-76	130.0	55.3	74.7	17.6	57.1
Six-year Average	151.1	85.8	65.3	18.7	46.6

[a]A water year extends from September 1 to August 31 of the following calendar year.

[b]Estimated with equations of Helvey and Patric (1965).

[c]Calculated as net input minus evaporation.

Source: Henderson et al. 1977b.

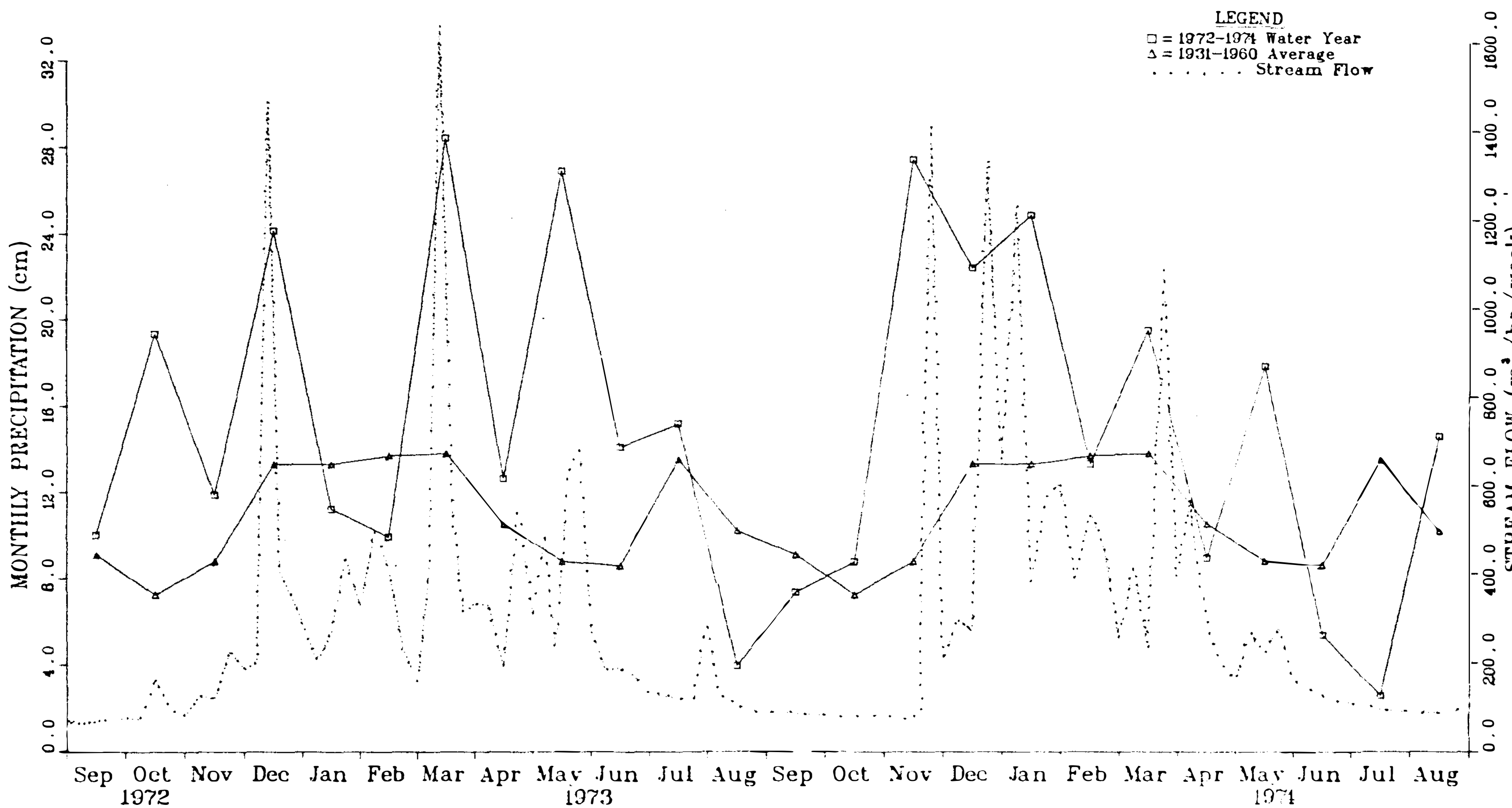

Figure 23. Monthly Precipitation (cm) and Weekly Discharge (m^3/ha) for the 1972-73 and 1973-74 Water Years on the West Fork Catchment of Walker Branch Watershed.

The 1972-1973 water year was characterized by low flows during early fall due to low precipitation extending over a five week period centering on September 1, 1972. From the middle of September through the rest of 1972, at least one cm of rainfall was recorded during every week, with greater than 3 cm/week falling during the period from mid-September through the third week in October. Until this time, the higher than average rainfall had only a minor effect on discharge. In most years, discharge decreases from week-to-week during this early fall period. In 1972, it showed a modest overall increase. A dramatic rise in discharge was seen during the third week in October, when 9.31 cm of rain fell on a relatively well-charged watershed system.

Streamflow continued at above-average levels for the rest of the calendar year with overall increasing flows as winter approached. A dramatic rise in discharge during the second week in December was due to an input of almost 16 cm of rainfall during the period (weekly discharge was 1476 m^3/ha). Peak discharge, occurring on December 10, was 1.09 m^3/sec. After this storm receded and baseflow conditions were restored, streamflow continued at seasonally low to moderate flow rates during winter, due to lower than average precipitation. No major discharge event occurred until the eleventh week of 1973, when 17.37 cm of precipitation fell, yielding a discharge of 1640 m^3/ha, the largest weekly streamflow recorded during the two-year period. Peak discharge of 1.00 m^3/sec occurred on March 16. Discharge then declined through the third week in April, but during the fourth week in April over 8 cm of rain fell, yielding higher flows. The second week in May also had substantial rainfall (7.18 cm), again yielding increased flows which abated

during the next week as less than 2 cm of rain fell during the interval. This receding trend continued until the end of the twenty-first week, when on May 27 a large storm occurred (weekly rainfall input 15.82 cm) giving rise to high streamflow which carried over into the twenty-second week, even though little additional rain (0.51 cm) fell in the week after the storm. Peak discharge during this storm was 0.66 m^3/sec.

Streamflow declined gradually from week to week during the rest of June and July, as evapotranspiration increased, with flows above 100 m^3/ha/wk sustained by frequent summer storms. One large storm occurred on July 31, due to rainfall of approximately 7 cm falling on a relatively well-charged system (rainfall the previous week being 4.25 cm). Discharge declined significantly after the thirty-first week of the calendar year, with weekly flows declining below 100 m^3/ha/wk during the thirty-fourth and thirty-fifth weeks (last two weeks in August).

The 1973-1974 water year was characterized by seasonally low flow rates (less than 100 m^3/ha/wk) from September 1 through most of November, during which time precipitation approached mean monthly values. Low flow rates were abruptly altered with a large storm on November 26 and 27. The mean value for streamflow on November 26 was 0.27 m^3/sec compared to the prestorm value of 0.005 m^3/sec. Peak discharge was 1.63 m^3/sec, the highest ever recorded on the west fork of Walker Branch. High flow rates with intermittent peak flows (during major storm events during late December and mid-March) were sustained through March due to greater than average precipitation during all these months except February, which approached the 30-year mean. Peak discharge rates on December 26 and March 21 were 0.70 m^3/sec and 0.79 m^3/sec, respectively.

Streamflow declined in April, due in part to lower than normal precipitation for the month. The trend of decreasing streamflow begun in April was interrupted by higher flows associated with greater than normal precipitation in early May. Flow rates resumed their decline in late May and continued to decrease through mid-August as a result of increases in evapotranspiration on the watershed combined with lower than normal precipitation. Weekly discharge during July and August was below 100 m^3/ha/wk. July, normally one of the wettest months, had only 2.60 cm of rain. In late August streamflow leveled off, corresponding to increases in precipitation during this time.

The overall picture that emerges for Walker Branch is one in which the potential for abnormally high discharge rates exists for virtually any part of the year, but these high rates are most likely during late fall through early spring. From the records that exist for Walker Branch, it seems that, on the average, one could expect disruptively high flow rates at least once every two to three years. These conditions appear to hold for virtually any headwater (first or second order) stream in the Appalachain Highlands, given a similar precipitation regime.

Standing Crops

Leaves

Mean standing crops of coarse (> 1 mm) leaf detritus on the four habitat types in Walker Branch during the 1973-1974 water year (Figure 24) (See Table A14, Appendix A, for the 95% confidence limits for these means) showed large seasonal and consistent habitat type differences. These results demonstrate a dependence of standing crop on the seasonal

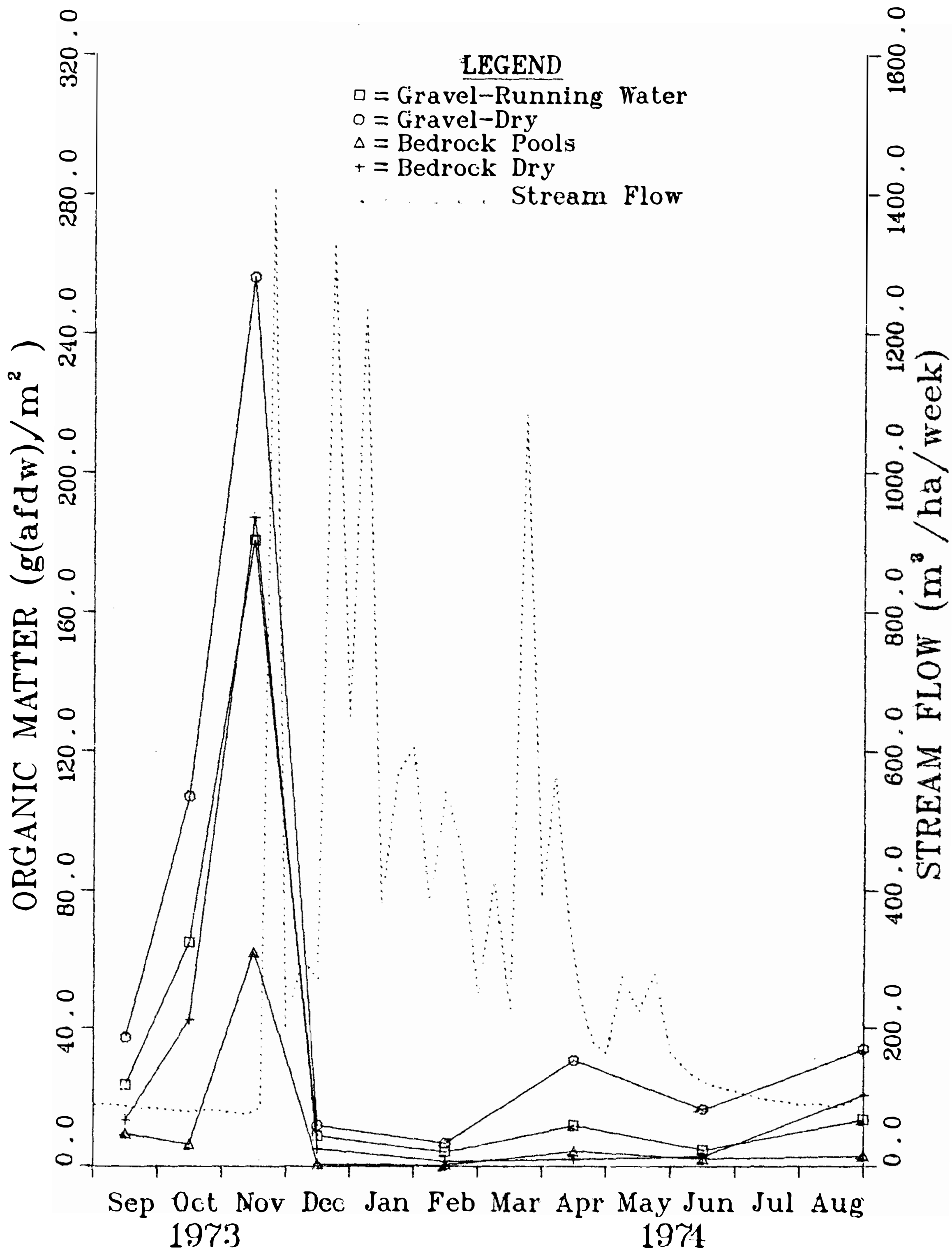

Figure 24. Standing Crop of Coarse Leaf (>1 mm) Material on Four Habitat Types in the West Fork of Walker Branch and Weekly Discharge for the West Fork of Walker Branch for the 1973-1974 Water Year.

pattern of transport of leaf material to the stream system, and the influence of the hydrologic cycle, as related to physical transport and within-system biological processing.

Standing crops of coarse (> 1 mm) leaf detritus increased during autumn for all habitat types with maximum standing crops (61.87-256.02 g/m^2) observed during early November. Decreases in standing crops occurred in all habitat types in December, with the mean for each habitat type (0.55-11.58 g/m^2) less than in September 1973 (9.31-37.18 g/m^2), before the main input of leaf fall began. Had the high discharge of late November not occurred, the December sample means would have been considerably higher than those in November, due to high rates of leaf input through November (daily average for the November 1 to December 1 period was 5.20 g/m^2). Thus, a greater peak amount of organic leaf material was present in, and subsequently exported from the system than is implied by Figure 24.

Lowest overall means were found in the early February collection (0.35 - 6.57 g/m^2), with both dry habitat types showing declines from the December values. During the large storm of November 26-27, water flowed in the entire drainage system, flushing large quantities of leaves from the perennial-flow channels and intermittent-flow portions of the drainage as well as from the forest floor adjacent to the stream-banks. During streamflow recession some leaf material was deposited on the dry substrates, and recorded in the December data. However, before the December 26 storm, few leaves were present in the drainage system. During streamflow recession following peak flow, little material was available for redeposition. Generally high flows and low input rates of

leaf material occurred through early February, keeping the mean standing crops for all habitat types low.

All habitat types retained low levels of leaf detritus through the February to September period of the study year. Except for the dry bedrock habitat type, which had a higher mean in September 1974, mean standing crops for the month (2.86 - 33.85 g/m^2) approached, but did not attain, the levels for September, 1973. All habitat types had increased mean standing crops for the April 15 collection (Figure 24) as compared to those for February. During the March 22 (after the large storm on March 21) to April 15 period, large amounts of wind-blown leaf material entered the drainage system (Figures 10 and 11, pages 75 and 76, respectively). The fact that the dry gravel habitat had a comparatively greater increase (24.0 g/m^2) in standing crop was due to its position in the cross-section of the stream channel. Much wind-blown material accumulated along the edges of the channel where dry gravel predominated. Since no high flows occurred during this time, much of the blow-in material remained in the system for some time. These moderate flows would also explain the increases in mean standing crop for the bedrock pools (3.93 g/m^2) during this time. Under moderate flow conditions, pools were areas of accumulation of organic material.

The decrease in standing crops from the mid-April to late June sampling periods was the result of cessation of significant blow-in inputs during late April accompanied by relatively high flows during much of May.

The increases in standing crop in the June 21 to September 1 period appear to be related to increased leaf fall inputs during July and

August (see Figure 6, page 57), along with low flow conditions during the period. Larger increases in standing crop for the dry habitat types were probably due to greater transport from and biological processing within the wet types.

Nelson and Scott (1962) reported a range of 2.0 to 34.0 g/m^2 for fourteen monthly measurements of standing crop of allochthonous leaf material in the Middle Oconee River in Georgia. Eleven of the readings were less than 2.0 g/m^2, averaging 1.0 g/m^2. These values for a larger river system are comparable to the lowest values from Walker Branch.

Results of the 2-way ANOVA (Table A15, Appendix A) show both main effects (habitat type and date) to be highly significant ($Pr > 0.001$) and the interaction term not significant ($Pr > F = 0.05$). This latter result is seen graphically in Figure 24, where the seasonal trends for all habitat types being quite similar. Thus, over all dates there were significant differences in the means for habitat types, and over all habitat types significant date differences existed. Because the interaction term was not significant, the ANOVA was rerun without the interaction term to determine the error mean square for subsequent multiple means tests (Table A15, Appendix A).

Results of the multiple means tests for all possible pairwise comparisons for date effects over all habitat types are shown in Table 24. November and October, with highest and second highest means, respectively, were significantly higher than all other months, as well as being significantly different from each other. September 1973, with the third highest mean, did not differ significantly from September 1974 (with the fourth highest mean), and neither was significantly higher than April

Table 24. Results of Multiple Means Tests for Date Effects (Over All Habitat Types) for Standing Crops of Leaf Material in the West Fork of Walker Branch for the 1973 - 1974 Water Year.

Month	Oct	Nov	Dec	Feb	Apr	Jun	Sep 74
Sep 73	4.31^{sd}	9.97^{sd}	4.64^{sd}	7.31^{sd}	2.38^{ns}	5.09^{sd}	1.06^{sd}
Oct	--	6.40^{sd}	10.24^{sd}	13.21^{sd}	7.74^{sd}	10.79^{sd}	1.06^{sd}
Nov	--	--	16.86^{sd}	19.78^{sd}	14.40^{sd}	17.46^{sd}	6.31^{sd}
Dec	--	--	--	3.13^{sd}	2.66^{ns}	0.50^{ns}	13.07^{sd}
Feb	--	--	--	--	5.80^{sd}	2.66^{ns}	4.28^{sd}
Apr	--	--	--	--	--	3.18^{sd}	7.44^{ns}
Jun	--	--	--	--	--	--	4.82^{sd}

Note: Analysis run at studentized range/$\sqrt{2}$ = 3.03, Tukey's test at α = 0.05, and error D F = ∞; ns = not significant, sd = significant difference.

1974 (with the fifth highest mean). They were, however, significantly higher than all other months with lower means. April was not significantly greater than December (sixth highest mean), but was significantly higher than all other months with lower means. December was significantly higher than February but not June, while the latter, with the second lowest mean, was not significantly different from February, which had the lowest mean. February was significantly lower than all months except June.

During all sampling periods the dry gravel habitat had highest mean standing crops of coarse leaf detritus, followed rather consistently by stream gravel. Mean standing crop for the stream gravel habitat was less than that for one of the bedrock types (dry bedrock) only in September 1974, with mean standing crops for stream gravel and dry bedrock being quite similar in November. Except for April, the bedrock pool habitat had lower standing crops than did the dry bedrock habitat.

Results of the multiple means tests for habitat type differences (Table 25) for mean standing crops of leaf detritus show that, over all dates, all habitat types were significantly different from all other habitat types ($Pr > F = 0.05$), with the order being dry gravel > stream gravel >dry bedrock > bedrock pools. These results demonstrate the effect of substrate type, length of exposure to the streamflow regime, aquatic biological processing, and location of the habitat type in the channel cross-section on standing crops of coarse leaf detritus. Means comparisons are particularly pertinent for stream gravel with either bedrock habitat, since none of the three was characteristic of any particular part of the channel cross-section, and would not be expected to

Table 25. Results of Multiple Means Tests for Habitat Type Effects (Over All Dates) for Standing Crops of Leaf Material in the West Fork of Walker Branch for the 1973-1974 Water Year.

	Habitat Type		
Habitat Type	Dry Gravel	Bedrock Pools	Dry Bedrock
Stream Gravel	5.01[sd]	8.50[sd]	2.93[sd]
Dry Gravel	--	11.40[sd]	6.32[sd]
Bedrock Pools	--	--	4.53[sd]

Note: All tests run at studentized range/$\sqrt{2}$ = 2.57, Tukey's test at α - 0.05, and Error DF = ∞; sd = significant difference.

receive a proportionally larger input of leaf material from blow-in. In this case, the differences in standing crop can best be explained in terms of the greater ability of gravel substrate to retard the removal of detritus. The comparison of standing crops on stream gravel and dry bedrock is particularly interesting, since the latter habitat type was exposed to discharge influences and within-system biological processing for a much shorter period of time than the stream gravel.

The significant differences seen for the two bedrock habitats indicate that during periods of low flow the dry habitat received a larger portion of material falling from above, and its standing crop underwent less biological decomposition than did that of bedrock pools. Leaf material falling into pools often floated right through, being deposited in the first obstruction downstream. This should be contrasted to the situation for moderate flows (late March to early April) where higher water levels favored more leaf material being transported through riffle areas and being deposited in pools, due to decreased currents in the pools.

The two gravel habitats showed significant differences in means over all dates, due to their relative positions in the cross-section of the channel, favoring more lateral input to and less removal (biological and hydrological) from the dry gravel type.

Fruits and Reproductive Parts

Monthly mean standing crops of fruits and reproductive parts in the different habitat types in Walker Branch during the 1973 - 1974 water year are shown in Figure 25. (See Table A16, Appendix A for the 95% confidence limits for these means.) These data showed less consistent trends

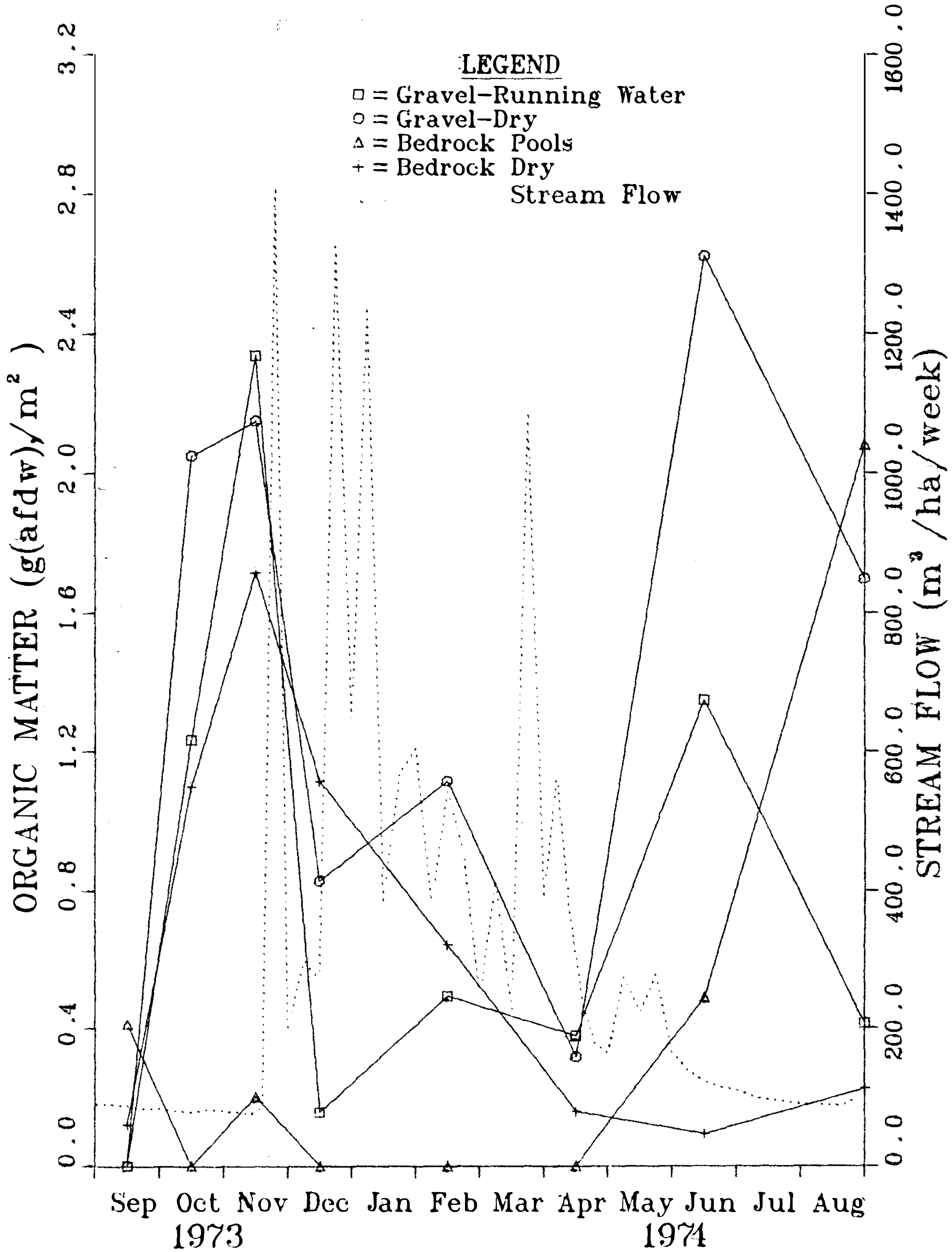

Figure 25. Standing Crop of Fruits and Reproductive Parts (>1 mm) Material on Four Habitat Types in West Fork of Walker Branch and Weekly Discharge for West Fork of Walker Branch for the 1973-1974 Water Year.

than did data for leaf material. Major reasons for this were the heterogeneous character of fruit material, the less well defined seasonality of fruit inputs, and the generally low quantities found. One large hickory nut would greatly outweigh the contribution of a multitude of floral parts of, for example, maple.

Even so, overall trends are evident, with a general buildup in standing crops during early fall and a decline during the high water period from late November through mid-April. November standing crops ranged from 0.20 g/m^2 for bedrock pools to 2.34 g/m^2 for dry gravel, while April values ranged from 0 for the bedrock pools to 0.38 g/m^2 for dry gravel. However, for stream gravel and dry gravel habitats, the April means were still higher than those for September 1973, where no fruit material was found for either habitat type. Low values would be expected for early September, at least during some years, when autumn fruit fall has not yet commenced and the residuum from floral parts deposited during spring had undergone nearly complete decomposition or had been transported out of the system. Figure 7 (page 59) demonstrates that an insignificant amount of fruit fall occurred during the first two weeks of September. Thus, most of the blow-in for fruits seen in Figures 17 and 18, pages 104 and 105, respectively, occurred after September 8, since it has been shown that lateral transport of fruits is not dependent on aeolian factors, but rather on concurrent fruit fall.

For all habitat types except dry bedrock, a spring-summer peak was seen, with gravel substrates having higher means (1.35 and 2.62 g/m^2 for stream and dry gravel, respectively) during the June collections and bedrock pools having higher means during the September 1974 collections,

this high value being due to the presence of several hickory nuts in the September collections for this habitat type. The declines for gravel habitat types during the June-September period were due to physical, chemical, and biological breakdown of readily decomposable floral parts entering the stream during spring, since no large flows occurred from mid-June till the end of the study period.

Autumn increases were due to both litterfall and blow-in (Figures 7 and 17-18, pages 59, 104, and 105, respectively, while increases between the April low and the June values were primarily due to litterfall, which had a second peak input during this period.

Results of the 2-way ANOVA for fruits (Table A15, Appendix A) show both main effects to be significant and the interaction not significant. Thus, over all dates there were significant differences in mean standing crops for habitat types and over all habitat types significant date effects occurred. The ANOVA was rerun with interaction terms omitted to obtain the error mean square for the subsequent multiple means tests (Table A15, Appendix A).

Results of multiple means tests of all possible pairwise comparisons for date effects over all habitat types for standing crops of fruit and reproductive parts are shown in Table 26. September 1973, the month with the lowest mean, was significantly different from only November, June and October, the three months with the highest means. None of these latter months were significantly different from each other or from September 1974, the month with the fourth highest mean. In addition to being significantly higher than September 1973, November was also significantly higher than the three months (April, December, and February)

Table 26. Results of Multiple Means Tests for Date Effects (Over All Habitat Types) for Standing Crops of Fruits and Reproductive Parts in the West Fork of Walker Branch for the 1973 - 1974 Water Year.

Month	Oct	Nov	Dec	Feb	Apr	Jun	Sep 74
Sep 73	3.79^{sd}	5.36^{sd}	1.32^{ns}	2.06^{ns}	0.94^{ns}	4.23^{sd}	2.89^{ns}
Oct	--	1.75^{ns}	2.86^{ns}	1.96^{ns}	3.33^{sd}	0.44^{ns}	1.16^{ns}
Nov	--	--	4.66^{sd}	3.73^{sd}	5.17^{sd}	1.34^{ns}	3.00^{ns}
Dec	--	--	--	0.87^{ns}	0.45^{ns}	3.36^{sd}	1.80^{ns}
Feb	--	--	--	--	1.32^{ns}	2.44^{ns}	0.88^{ns}
Apr	--	--	--	--	--	3.85^{sd}	2.28^{ns}
Jun	--	--	--	--	--	--	1.65^{ns}

Note: Analysis run at studentized range/$\sqrt{2}$ = 3.03, Tukey's test at $\alpha = 0.05$, and error D F = ∞; ns = not significant, sd = significant difference.

with the second, third, and fourth lowest means respectively. February was not significantly lower than any month except November, while December was significantly lower than only June and November. October, in addition to being significantly higher than September, was significantly higher than April (second lowest mean), as was June (with the second highest mean). September 1974 was the only month not significantly different from any other month.

Results show the contrasting influences of seasonality of input and occurrence of high flow conditions on the standing crops of fruits in the stream channel. While Figure 25 shows a decline in standing crops from the December through April sampling periods, results of the multiple means tests show these dates not to be significantly different from one another, an indication of the high variability in the data due to low standing crops of fruit in the stream system.

Results of the multiple means tests for all possible pairwise comparisons for habitat type effects over all dates are shown in Table 27 for fruits and reproductive parts. Dry gravel, with the highest mean, was significantly higher than all other habitat types. No other significant differences were seen among habitat types. The dry gravel habitat type had significantly higher standing crops than the other types due to its peripheral location in the cross-section of the stream channel (favoring accumulation, especially from blow-in) and lower biological decomposition. The substrate type, which retarded the removal of material by streamflow, was also a factor.

Table 27. Results of Multiple Means Tests for Habitat Type Effects (Over All Dates) for Standing Crops of Fruits and Reproductive Parts in the West Fork of Walker Branch for the 1973 - 1974 Water Year.

	Habitat Type		
Habitat Type	Dry Gravel	Bedrock Pools	Dry Bedrock
Stream Gravel	2.94^{sd}	2.29^{ns}	0.84^{ns}
Dry Gravel	--	4.20^{sd}	2.90^{sd}
Bedrock Pools	--	--	1.18^{ns}

Note: All tests run at studentized range/$\sqrt{2}$ = 2.57, Tukey's test at $\alpha = 0.05$, and Error DF = ∞; ns = not significant, sd = significant difference.

Twigs

Monthly mean standing crops of twigs in the different habitat types in Walker Branch are shown in Figure 26. The standard errors associated with these means are shown in Table A17, Appendix A. The data show rather consistent trends between habitat types, with the exception of several spuriously high means (e.g., September 1973 for dry gravel) due to very large amounts of twig material being collected in a single sample. Even so, the trend was clearly for gravel habitat types to have higher means than those for bedrock types, again showing the retentive capacity of the gravel substrate. Means were higher for dry bedrock than for bedrock pools in autumn, while means were quite similar for the rest of the year.

The general temporal trend was for increasing standing crops during the litterfall season followed by an abrupt decline in the December collection, which occurred soon after the large storm of late November. Standing crops for gravel habitat types in the November collection were 11.19 g/m^2 for stream gravel and 15.15 g/m^2 for dry gravel. These means were much higher than those for bedrock pools (0.69 g/m^2). In contrast, values for December were 0.70, 0.80, 0.00, and 0.50 g/m^2 for stream gravel, dry gravel, bedrock pools, and dry bedrock, respectively.

Throughout the remainder of the study year, standing crops generally increased from the December low. This was especially true for the gravel types, with both increasing through the September 1974 sampling period. (September means were 9.51 and 15.28 g/m^2 for stream gravel and dry gravel habitat types, respectively.) Means for the bedrock types increased to a lesser extent from the December low, with September 1974

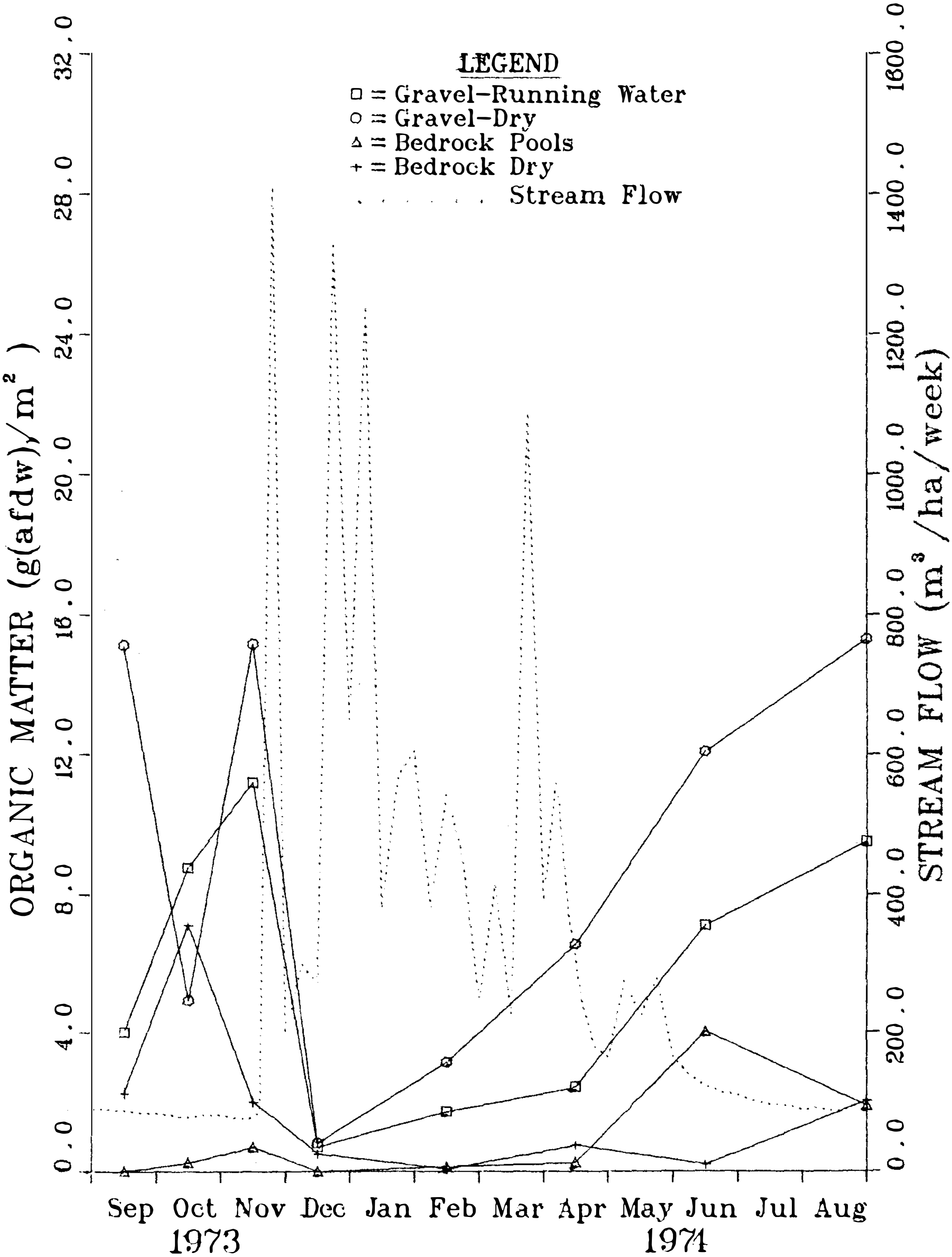

Figure 26. Standing Crop of Twigs (>1 mm) on Four Habitat Types in the West Fork of Walker Branch and Weekly Discharge for the West Fork of Walker Branch for the 1973-1974 Water Year.

values of 1.86 and 2.02 g/m^2 for bedrock pools and dry bedrock, respectively.

The November peaks in standing crops were due mainly to litterfall inputs accompanying low stream flows, with little material being transported from the watershed. Highest twig inputs for the year via litterfall occurred during the months of October and November (See Figure 8 page 64). Litterfall seemed at least partially responsible for the increases following the December low, with March and May having high inputs. This was supplemented by higher than average blow-in of twig material during February, March, April, and August (Figure 19 and 20, pages 111 and 112). The fact that the gravel habitats had increases during periods of high flow (December through May) indicated that the twig component of benthic organic pools was resistant to all but the most disruptive flow conditions. This is in opposition to the situation for leaf material, where fluvial transport was very responsive to flow conditions.

Results of the 2-way ANOVA for twigs (Table A15, Appendix A) shows both main effects (date and habitat type) to be significant and the interaction term not significantly different from zero, as can be seen from Figure 26, where all habitat types showed similar trends and similar relationships to one another over time. Thus, over all dates there were significant differences in mean standing crops for habitat type, and over all habitat types significant date effects occurred. Because the interaction term was not significantly different from zero, the ANOVA was run again, this time with the interaction term omitted. The error mean

square used in the subsequent multiple means tests was obtained from this ANOVA (Table A15, Appendix A).

Results of the multiple means tests for all possible pairwise comparisons for date effects over all habitat types are shown in Table 28. December, with the lowest mean, was significantly lower than all other months except February, which had the second lowest mean. February was significantly lower than October, November, June, and September 1974, with the four highest means. The only other date showing a significant difference was April, which was significantly lower than September and November 1974, the two months with the highest means. Thus, the results indicate that the severe disruption associated with the flood of late November caused significant decreases in the standing crops of twig material, with significant monthly differences (compared to November) persisting for several collection periods thereafter.

Results of the multiple means tests for all possible pairwise comparisons for habitat type effects over all dates for standing crops of twigs are shown in Table 29. The gravel habitat types were each significantly higher than each bedrock type, but neither of the two gravel types or the two bedrock types were significantly different. This indicates that substrate type, especially with regard to its capacity to retain twig material during high flow conditions, was by far the most important factor in determining standing crops in the stream channel. Indications are for redistribution within the stream system favoring gravel habitats at the expense of the bedrock types.

Table 28. Results of Multiple Means Tests for Date Effects (Over All Habitat Types) for Standing Crops of Twigs in the West Fork of Walker Branch for the 1973 - 1974 Water Year.

Month	Oct	Nov	Dec	Feb	Apr	Jun	Sep 74
Sep 73	1.27^{ns}	2.26^{ns}	3.55^{sd}	2.13^{ns}	0.83^{ns}	1.56^{ns}	2.35^{ns}
Oct	--	1.12^{ns}	5.51^{sd}	3.86^{sd}	2.43^{ns}	0.31^{ns}	1.19^{ns}
Nov	--	--	6.72^{sd}	5.03^{sd}	3.61^{sd}	0.83^{ns}	0.05^{ns}
Dec	--	--	--	1.60^{ns}	3.19^{sd}	5.93^{sd}	6.96^{sd}
Feb	--	--	--	--	1.53^{ns}	4.24^{sd}	5.22^{sd}
Apr	--	--	--	--	--	2.79^{ns}	3.76^{sd}
Jun	--	--	--	--	--	--	0.90^{ns}

Note: Analysis run at studentized range/$\sqrt{2}$ = 3.03, Tukey's test at α = 0.05, and error D F = ∞; ns = not significant, sd = significant difference.

Table 29. Results of Multiple Means Tests for Habitat Type Effects (Over All Dates) for Standing Crops of Twigs in the West Fork of Walker Branch for the 1973 - 1974 Water Year.

	Habitat Type		
Habitat Type	Dry Gravel	Bedrock Pools	Dry Bedrock
Stream Gravel	2.34^{ns}	6.12^{sd}	4.43^{sd}
Dry Gravel	--	7.30^{sd}	5.76^{sd}
Bedrock Pools	--	--	1.43^{ns}

Note: All tests run at studentized range/$\sqrt{2}$ = 2.57, Tukey's test at $\alpha = 0.05$, and Error DF = ∞; sd = significant difference.

Total Organic Matter

Total standing crops of organic material in the various habitat types for the eight collection periods for the 1973-74 water year are listed in Table 30, along with percentage contribution of each type to the total.

For the fall through mid-spring period, trends for total standing crops generally paralleled those for standing crops of leaf material, with leaf material composing greater than 70% of the total standing crops for all habitat types for the period of September through January. Highest overall standing crops were seen in the November 4, 1973 sampling, with 273.32 g/m^2 for the dry gravel being the highest standing crop value for any date/habitat type combination for the study year. For the other habitat types, standing crops ranged from 62.76 to 194.10 g/m^2. Lowest standing crops were found during the February 7, 1974 sampling (0.55 -13.21 g/m^2), with standing crops generally increasing through the rest of the year. Overall values for September 1973 and September 1974 were quite similar, with ranges of 9.7 - 52.2 g/m^2 for September 4, 1974.

Relative contribution of leaf material to the total increased rather consistently through the autumn leaf fall period, attaining a maximum during the November 4 sampling, when greater than 90% of the standing crop for all habitat types was leaf material. Percent leaf material declined through the February 7 sampling, due to continued low standing crops of leaves and higher standing crops of twigs and fruits in the February samples. The low standing crops of leaves were due to

Table 30. Summary of Data for Standing Crop of Organic Material (>1 mm) in the West Fork of Walker Branch for the 1973-1974 Water Year.

Date of Collection	Habitat Type	Mean Standing Crop (g/m^2)	Percent Contribution		
			Leaves	Fruits	Twigs
09/08/73	Stream Gravel	27.37	85.4	0.0	14.6
	Dry Gravel	52.24	71.1	0.0	28.9
	Bedrock Pools	9.72	95.8	4.2	0.0
	Dry Bedrock	15.45	84.9	0.8	14.0
10/15/73	Stream Gravel	74.98	86.7	1.6	11.7
	Dry Gravel	113.87	93.9	1.8	4.3
	Bedrock Pools	6.44	96.3	0.0	3.7
	Dry Bedrock	50.67	83.8	2.2	14.1
11/04/73	Stream Gravel	194.10	93.0	1.2	5.8
	Dry Gravel	273.32	93.7	0.8	5.5
	Bedrock Pools	62.76	98.6	0.3	0.1
	Dry Bedrock	190.74	98.1	0.9	1.0
12/03/73	Stream Gravel	9.39	90.9	1.6	7.4
	Dry Gravel	13.21	87.6	6.2	6.1
	Bedrock Pools	0.55	100.0	0.0	0.0
	Dry Bedrock	6.56	75.4	17.0	7.6
02/07/73	Stream Gravel	6.21	64.5	7.9	27.5
	Dry Gravel	10.81	60.8	10.3	28.9
	Bedrock Pools	0.49	71.9	0.0	28.1
	Dry Bedrock	2.10	66.3	30.7	3.0
04/15/74	Stream Gravel	14.48	80.8	2.6	16.6
	Dry Gravel	37.42	81.7	0.8	17.5
	Bedrock Pools	4.53	94.6	0.0	5.4
	Dry Bedrock	2.90	68.8	5.4	25.8
06/21/74	Stream Gravel	13.18	35.7	10.2	54.0
	Dry Gravel	31.07	52.7	8.4	38.9
	Bedrock Pools	6.67	32.6	7.3	60.1
	Dry Bedrock	3.10	91.0	3.0	6.0
09/04/74	Stream Gravel	23.26	57.3	1.8	40.9
	Dry Gravel	50.83	66.6	3.3	30.1
	Bedrock Pools	6.81	42.0	30.5	27.4
	Dry Bedrock	22.77	90.1	1.0	8.9

low inputs via blow-in during the month of January while increased lateral transport of fruits and twigs occurred during January and February. Blow-in of leaf material following the large storm of March 19 to March 20 caused the percent contribution of leaves to increase in the period before the sampling of April 15, 1974. The relative contribution of leaves was greater than 80% for all habitat types except the dry bedrock type, due to continued high relative contribution (25.8%) by twigs in this habitat type. Lowest relative contribution of leaves occurred during the June 21 sampling due, not to increased fruit standing crops, but instead to greater contributions by twigs for all habitats except dry bedrock. These twig inputs came mainly from litterfall (See Figure 8, page 64). While relatively large increases in standing crops of fruit material were seen in the June 21 sampling, the absolute values were low compared to those for leaves or twigs, so that changes in fruit standing crops had little effect on percent contributions during most months. The generally low standing crops for dry bedrock led to relatively large variations in percent contribution of the various litter types through time, as was seen in the June 21 data.

Relative contribution of leaf material to total standing crops increased somewhat during the June 21 to September 3, 1974 period, even though twig weights generally increased, due to the increase in standing crops of leaf material as premature leaf fall occurred during the very dry summer. This was not the case however for bedrock pools, where there was no overall increase in quantity of leaf material, a decrease in standing crop of twigs, and an increase in standing crop of fruits.

During this time, the pools had by far the lowest overall standing crops of organic matter (6.81 g/m^2), so a substantial percent contribution from fruits was possible, even though the relative magnitude of fruit inputs was low, compared to those for other litter components.

Fruits composed from 0% to almost 30% of the total litter standing crops, the latter value occurring for dry bedrock for the February sampling. Only two other date/habitat type combinations showed contributions of fruits greater than 10% with 21 of the 32 date/habitat combinations showing less than 5% fruits. Highest overall relative contribution occurred for the June collection (3.0 to 10.2%) due to large inputs of fruit material during the previous weeks.

Twig contributions varied from 0 to 60%, the latter occurring for bedrock pools for the June 21, 1974 sampling, the month of greatest overall percent contribution by twigs. Generally, lowest relative contributions were found during the November and December sampling, with no habitat type having greater than 8% twigs. The low November values were due to relatively larger inputs of leaves and fruits, while the low December values were due to effective removal of twig material from the system along with little replenishment during this period.

Minshall (1967) reported mean standing crops of POM in Morgan's Creek, Kentucky of 0 to 14.2 g/m^2, with a range of means for all collection periods of 0.16 to 7.37 g/m^2. He noticed a decline in standing crops at some downstream stations due to the lack of riparian vegetation along these sections. However, he noted that the decline was not dramatic, due to introduction from upstream and wind-blown inputs from the

surrounding landscape. He reported good seasonal coincidence between peak standing crops and leaf litter production, with high standing crops in autumn to early winter and a low in mid-summer. He observed that the quantity of dead leaf material varied with discharge and degree of wind action and related standing crops to the algebraic sum of inflow and outflow for any time of the year. Results are not dissimilar to those found in the present study.

Fisher (1970), from two midsummer samplings (approximately one year apart), found no statistically significant differences in standing crops of detritus with the detrital reserve (leaves plus twigs and branches) of approximately 1 kg/m^2, with the branch fraction comprising 40% of the total standing crop in both 1968 and 1969. He considered these to be minimum values since they directly preceded the start of autumn litter-fall. He further stated that the uneven distribution of detritus in the stream was reflected in the rather large variance in the samples. From this and ancillary data, he assumed that the system was in a steady state.

Based on results of the present study and the known dependence of particulate output on large discharge events, a conclusion of this sort in the context of a headwater stream is not acceptable unless the discharge regime is very similar from year to year and does not include randomly occurring large storm events. However, Fisher's data (1970), demonstrating very high standing crops of organic detritus, indicate that disruptive flows may be less important in New England than in east Tennessee. During his study year no major storm events occurred.

ASPECTS OF THE ORGANIC CARBON CYCLE

ON WALKER BRANCH WATERSHED:

A STUDY OF LAND/WATER INTERACTION

VOLUME II

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Charles Edward Comiskey

August 1978

Throughfall and Incident Precipitation

Concentration of Dissolved Organic Carbon (DOC)

Mean monthly concentrations of dissolved organic carbon (mg/l) in incident precipitation and throughfall are shown in Figure 27. See Table B1, Appendix B, for the (± one) standard errors associated with these means. Also shown are the differences between throughfall and incident precipitation concentrations for each month, representing net removal or that portion contributed by canopy leaching, canopy washing, and dryfall.

Values for concentration of dissolved organic carbon in throughfall ranged from a low of 1.90 mg/l during December to a high of 32.32 mg/l in July. The latter value, accompanied by the lowest monthly precipitation of the study period (2.60 cm), represented an extremely high monthly mean, being three times greater than the next highest monthly mean (11.33 mg/l) recorded in September 1973. Generally low concentrations (1.90 to 3.22 mg/l) were found during the leafless season (November through March), with the highest concentration found for February, a month of comparatively lower rainfall. Concentrations during the early leaf period of April and May were 4.44 to 5.02 mg/l, respectively. Except for the extremely high mean concentration in July, summer concentrations (June through August) were not particularly great (4.03 to 8.94 mg/l), with the August value actually being lower than corresponding values for both April and May. The concentration in October 1973 was quite similar to that for June.

For those months (September and October 1973 and March through August 1974) when incident precipitation was monitored, trends for dissolved organic carbon concentrations generally paralleled those for

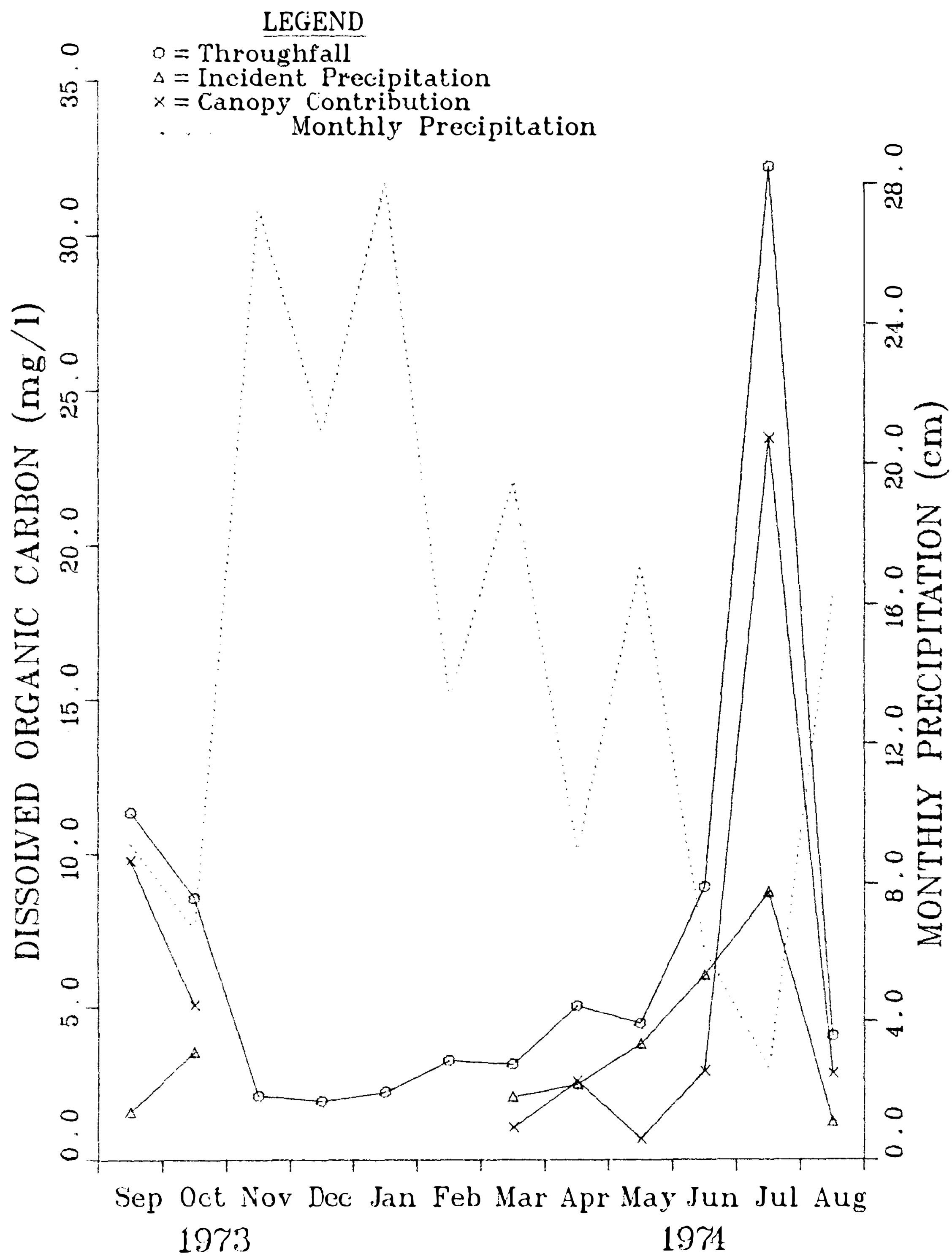

Figure 27. Mean Monthly Concentration of Dissolved Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

throughfall, but concentrations and fluctuations were of lesser magnitude (Figure 27). The highest mean concentration (8.78 mg/l) was found during July. The seasonal trend for DOC in incident precipitation differed from that of throughfall only in September 1973, when relatively high (11.33 mg/l) throughfall concentrations were accompanied by low (1.55 mg/l) concentrations of DOC in incident precipitation, indicating considerable removal from the canopy, possibly accompanying senescence of the vegetation.

Based on the data for incident precipitation for the September - October and March - April periods, along with the low throughfall values for the November through February period, it can be assumed that incident precipitation concentrations of DOC during this latter period, when no direct measurements of incident precipitation were made, ranged between 1.5 and 2.5 mg/l.

Trends for DOC concentration due to canopy leaching/washing for September and October 1973 and March through August 1974 generally followed those for throughfall with highest mean concentrations in July 1974 (23.46 mg/l), followed by the means for September and October 1973 (9.78 and 5.07 mg/l respectively) (Figure 27). Departures from the trend for throughfall occurred in May and June 1974, when comparatively high DOC concentrations in incident precipitation led to comparatively low values for canopy contribution 0.67 and 2.89 mg/l, respectively. The former value represented the smallest increase in concentration due to canopy leaching/washing for the eight month period. For the remaining months (March, April, and August), mean DOC concentrations attributable to canopy/washing fell in the range of the May and June means.

Several processes can possibly explain the low DOC concentrations due to canopy washing in the early and mid-spring samples. Tukey (1970) states young, actively growing tissue is relatively immune to loss of carbohydrates, whereas more mature tissue approaching senescence is very susceptible to leaching. In rapidly growing young leaves very few carbohydrates would be present, with all photosynthate being utilized for the production of new tissue. An alternate explanation is the low population of primary consumers in the canopy yielding less frass (a portion of which is assumed to be dissolvable in rainwater) and producing less honeydew. Litterfall data for frass showed no inputs through May of 1974.

The data for September and October 1973 give indications of leaf leaching, especially so in September, a month of average rainfall and high concentrations of DOC from canopy removal.

Combes and Kohler (1922) estimated that approximately 55% of the soluble carbohydrates are lost from deciduous leaves before leaf fall, with less than one-half being translocated back to the plant, the remainder are utilized in respiration and leaching.

Sampson and Samesch (1935) found a 14% weight loss for oak leaves prior to abscission, and Viro (1955) reported 21% average weight loss for four deciduous species prior to abscission. Grizzard et al. (1976) reported that the leaves of deciduous species on Walker Branch watershed lost an average of 28% of their maximum weight from two to six weeks prior to abscission. However, loss of weight does not necessarily equate with leaching loss. Hurter (1910), Leclerc du Sablon (1904) showed little loss of carbohydrates prior to abscission.

Denny (1933) found no important changes in amounts of total carbohydrates in the leaves of Viburnum dentatum and Syringa vulgaris during the period September 24 to November 4. Dry weight of the leaves was nearly constant throughout the period of sampling, indicating little translocation or leaching after this date.

Gosz et al (1973), discussing results of their work on nutrients in litterfall on Hubbard Brook, noted that organic content, like the mobile elements (N, P, K), should be translocated out of a senescing leaf before abscission. Thus, leaves falling prematurely due to storm conditions should have higher concentrations of dissolved organics.

Concentrations of Fine Particulate Organic Carbon (FPOC)

Mean monthly concentrations of fine particulate organic carbon (FPOC) in incident precipitation and throughfall are shown in Figure 28, along with the difference between the two, representing net canopy contribution. See Table B2, Appendix B for the (± 1) standard errors associated with these means. In general, the trends closely parallel those for concentration of DOC, with an extremely high mean value in July (20.27 mg/l). During the rest of the year concentrations ranged from a very low mean of 0.49 mg/l in December to 6.98 mg/l in June. Values during the leafless period (November through March) ranged from the December low to 1.47 mg/l in March, with three months (November through January) with concentrations 0.72 mg/l or less. Those for the early leaf period (April and May) were somewhat higher (2.02 to 2.12 mg/l), while concentrations for the late summer-early fall period (September and October 1973, August 1974) were similar to each other, ranging from 3.03 to 4.27 mg/l, with the latter in September.

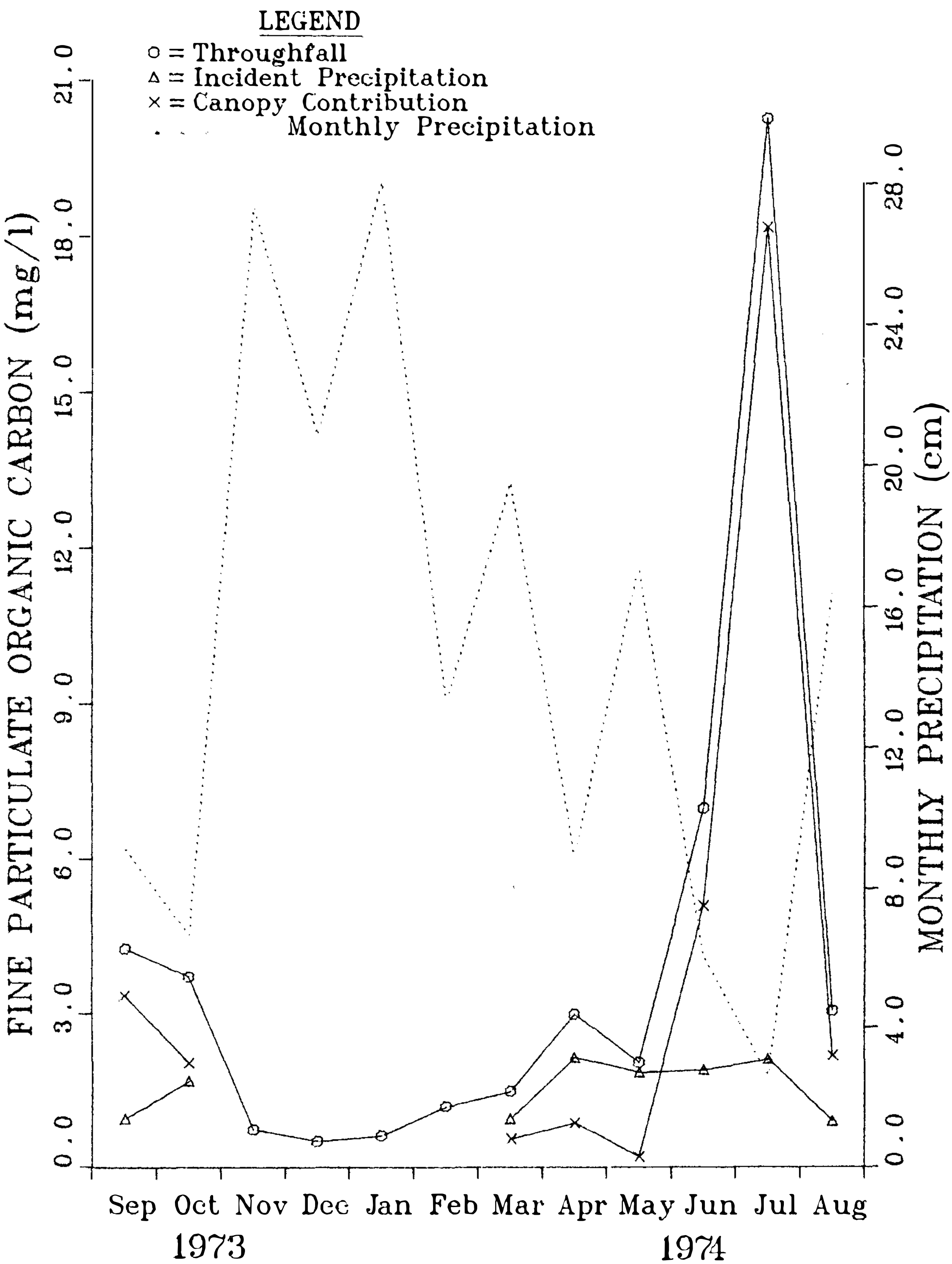

Figure 28. Mean Monthly Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

For March through October, when incident precipitation was monitored, seasonal trends in concentrations of FPOC were noted. Values increased during the early spring to mid-summer period from a March low of 0.93 mg/l to a rather steady level (1.83 to 2.12 mg/l) for the April through July period. The August 1974 and September 1973 concentrations were lower (0.88 - 0.93 mg/l), but the October 1973 value was 1.68 mg/l. This value may be erroneously high since it is based on only one sample and is, therefore, not a mean.

Unlike the situation for DOC, trends for concentrations of FPOC in incident precipitation differed somewhat from those for throughfall, especially regarding the amplitude of monthly changes. In July, the throughfall concentrations increased by threefold over those of June (6.98 vs 20.27 mg/l), while values for incident precipitation increased only slightly (1.89 to 2.09 mg/l). In fact, the month with highest concentrations of FPOC in incident precipitation (April) had only sixth highest throughfall levels.

Although incident precipitation was not monitored during the November through Febraury period, the low concentrations of FPOC in throughfall during this time, along with consistently higher concentrations of FPOC in throughfall as compared to those in incident precipitation, allow an estimation of 0.5 to 1.0 mg/l for FPOC concentrations in incident precipitation during the mid-fall through mid-winter months.

Canopy contributions to FPOC concentrations in throughfall closely paralleled FPOC levels in throughfall due to the rather unchanging nature (range of 0.88 to 2.12 mg/l) of the FPOC concentrations in incident precipitation. July (18.18 mg/l) and June (5.10 mg/l) contributions were

greatest. For the remainer of the eight month period, increases in FPOC concentration due to canopy contributions fell into two groups. For September and October 1973 and August 1974, canopy contributions ranged from 2.03 to 3.34 mg/l, while the March through May period showed the smallest increases (0.19 - 0.85 mg/l), with April having the lowest value. These trends are quite consistent with results for canopy insect activity, as expressed through the appearance and relative magnitude of frass in monthly litterfall and blow-in. Litterfall data (See Figure 9) show no frass input through May, with frass fall beginning in June (0.05 g/m^2/day) and peaking in July (0.15 g/m^2). The data from September and October 1973 also show substantial frass inputs during these months. Thus, at least a portion of the higher canopy contributions seen in the summer and early fall was due to frass fall.

Another potential source of FPOC during the leaf period (growing season) is aerosol impaction. The role of canopy in providing surface area for impaction of aerosols has been recognized by several authors. Sugawara (1951) suggested that the chloride content of streams may vary under different types of vegetation cover due to variations in the effectiveness of the particular plant cover in filtering salt from air. White and Turner (1970) stated that impaction on vegetation surfaces can contribute significantly to removal of aerosols from the atmosphere. Eriksson (1960) has suggested that vegetation is an important collector of dry salt particles from the air in Sweden, in order to explain the fact that concentrations of chloride in rivers exceed that supplied by precipitation and rock-weathering. Nihlgard (1970) found that, during experiments with plastic nets situated above rainfall collectors, in-

creased concentrations of certain elements (e.g., Mg, Na, Ca, and Cl) under the plastic , as compared to collectors in the open, could be due to aerosols sticking to the net. If the sticking properties of the plastic are at all similar to those for leaf surfaces, aerosol washout could be an important source of canopy "leachate".

Chamberlain (1966), studying the transport of club moss spores and other particles in the air and their subsequent deposition, found for low wind speeds that velocity of deposition was equal to terminal velocity. For higher wind speeds deposition by impaction on roughness elements became progressively more important. Stickiness of surface was important in determining the effectiveness of deposition for particles of 10 microns in diameter and upwards, but not for smaller particles. The amount of deposition was particularly high when vegetation surfaces were wet. The relative importance of direct deposition to the ground and washout of the air by rain was shown to depend on the effective height of the cloud of particles, with approximately 25% of total deposition of pollen grains by rain. He found that natural vegetation surfaces such as leaves do not retain all of the 20 - 30 particles striking them, with most bouncing off. However, if they do settle they are not easily removed. For particles in the size range 1 - 5 μm, deposition is dependent on the micro-roughness on the collection surfaces with degree of stickiness of surfaces no longer important.

The fact that aerosol particles bounce off the vegetation is an indication that, aside from insect canopy activity or other autochthonous sources, there should be a greater concentration of FPOC as dryfall strictly because the canopy can intercept aerosols.

White and Turner (1970) felt that an overestimate of aerosol input may have been realized in their study due to a downdraft effect of wind into the forest clearing where they were making aerosol determinations. By the criteria they set, a similar situation may well have existed at the raingage stations on Walker Branch watershed, since the opening in the forest canopy was much wider than one they suggested.

While the data for April and May showed an increase in FPOC concentrations for throughfall over that for March, the larger concentration of FPOC in incident precipitation could be explained by pollen associated with the spring flowering of many species of trees on the watershed. Smirnov (1961) noted a number of published cases where large volumes of pollen and spores (especially from coniferous trees and ferns) have been observed being released into the atmosphere. For the Rybinsk Reservoir, two peaks of pollen deposition were seen, the first (58×10^5 pollen grains/m^2/day) in May due to _Betula_ and 117×10^5 spores/m^2/day in October due to fungal release. For weight, only one peak (May) was seen due to the much larger size of pollen grains as compared to spores. Highest weight of pollen settling in spring was 23 mg/m^2/day or 230 g/ha/day. During the year, the reservoir received about 59.6 mg pollen/m^2, or 6 kg/ha/year.

Van Campo (1949) noted that during the peak months of pollen release (April for arboreal pollen and June for grasses) up to 60×10^5 pollen grains/m^2/day were deposited on the water surface of the Seine River. Maximum weight for a twenty-four period was 840 g/ha (84 mg/m^2).

Chamberlain (1966), found the medium range of travel of _Lycopodium_ spores to be approximately 1 km for particles liberated at 50 cm from

ground (herbaceous layer) but 10 km for release 10 m (canopy) from ground.

Thus, the relatively high concentration of FPOC in incident precipitation during spring, along with low canopy contributions, could have been affected by the ubiquitous presence of pollen in the ambient atmosphere during that period. Since the period was characterized by relatively high winds (see Figure 14, page 80), dispersal of pollen to non-forested areas is probable.

Concentration of Total Organic Carbon (TOC)

Mean monthly concentrations of TOC in incident precipitation and throughfall are shown in Figure 29 for the September 1973 to August 1974 year. See Table B3 , Appendix B for the (±1) standard errors associated with these means. TOC concentrations in incident precipitation showed values of 2.09 to 2.99 mg/l for the August to September period and also for the March sampling. October 1973 had higher TOC concentrations (5.2 mg/l) due to increases in both DOC and FPOC. From April through July, TOC inputs increased from 4.58 mg/l to a yearly peak of 10.87 mg/l. The increase during this period was due primarily to greater DOC concentrations in June and July (6.05 and 8.78 mg/l, respectively) with FPOC concentrations remaining around 2.0 mg/l. The importance of the DOC component in TOC concentrations in incident precipitation during the April to July period is reflected in higher DOC/FPOC ratios (discussed below).

A few other values are available for atmospheric content of TOC or TOM. Viro (1953) presented results of the analysis of ten samples of of Finnish snow for concentration of organic matter. Loss on ignition ranged from 1.58 to 8.17 mg/l. Gorham (1961) reported on data for Nova

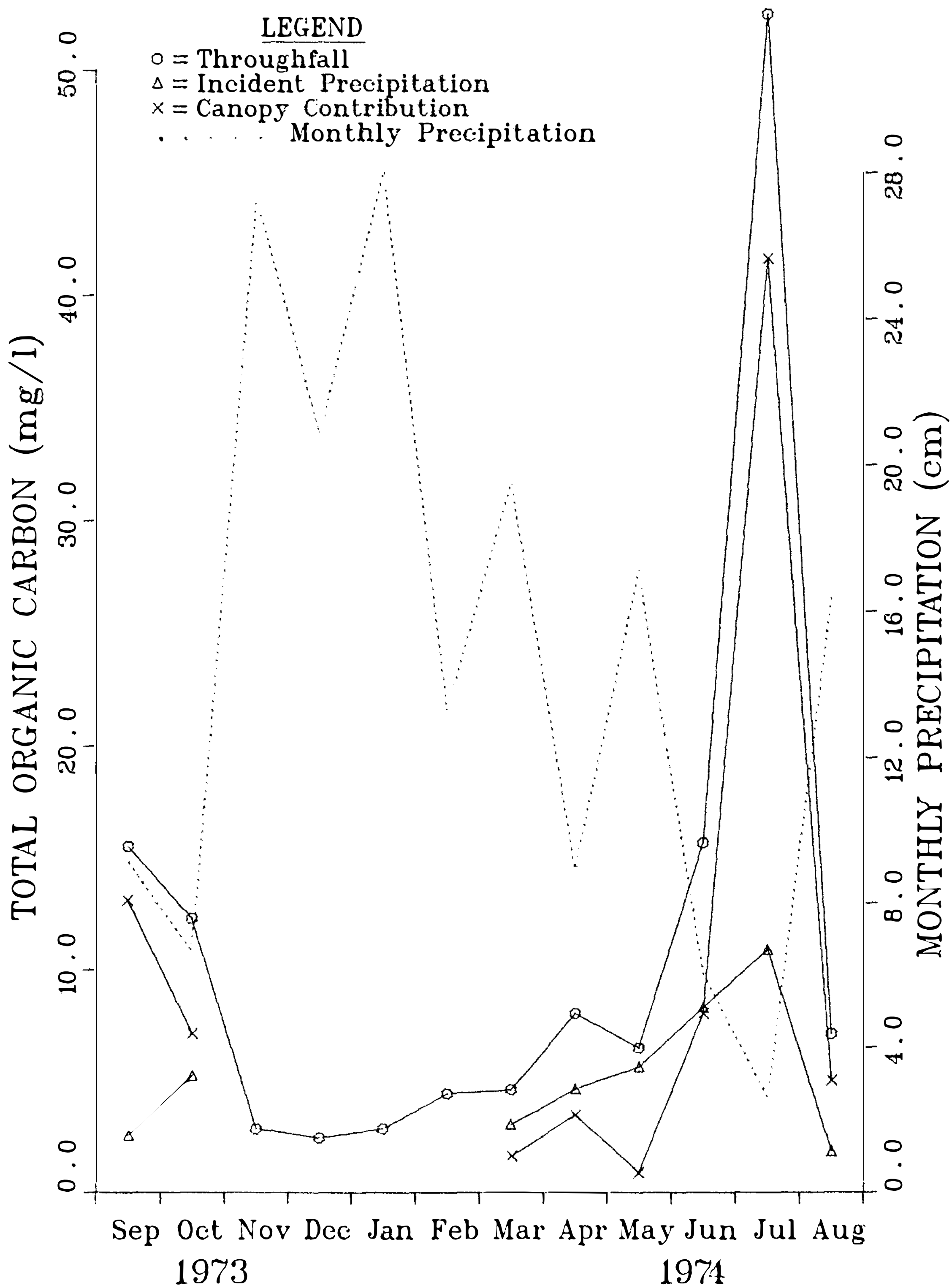

Figure 29. Mean Monthly Concentration of Total (≤1 mm) Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

Scotia precipitation samples, which showed an average loss on (approximately equal to organic matter) of 13 mg/l. Seventeen snow samples had 4.3 mg/l loss on ignition. Data from CAMP or Continuous Air Monitoring Program, (U. S. National Pollution Control Administration 1969) collected since 1962, showed yearly average carbon concentrations ranging from 1.43 mg/l in Washington, D. C. to 3.3 mg/l in Chicago , with a yearly maximum one hour average from 8 to 17 mg/l. Neumann et al. (1959) found, for nine stations in the Scandinavian network for chemical examination of air and precipitation, average content of organic carbon for the period May - August 1958 of 1.7 - 3.4 mg/l, with a mean of 2.52 mg/l. They also reported that the ratio of organic to inorganic matter increased from 0.6 at the coast to 2.0 inland, indicating depletion of the inorganic component near the coast. They also presented results for snow samples, showing organic carbon content of 0.8 to 1.9 mg/l, or an average of 1.3 mg/l. Due to uniform content of samples at the various stations, they concluded that organic matter in precipitation must have a very extended source area. They discussed the importance of transport of organic matter from the sea surface (where it collects as a film) to the atmosphere by the bursting of bubbles, and they attributed the uniform distribution of organic matter in precipitation partly to its being less hygroscopic than the larger salt nuclei. They also felt that this could explain the decreases in inorganic to organic ratios in precipitation as one proceeds inland.

Data from Walker Branch show an increase in DOC and FPOC concentrations in incident precipitation during the period of April through July. Since this was the growing season, it is possible that released volatiles

from plants undergo some photochemical transformation, with both water-soluble dissolved and particulate forms (with some assumed to have water-soluble components) washed out of the atmosphere with rainfall. However, low concentrations of DOC and FPOC in incident rainfall in September and October would tend to indicate that large scale release of volatile organics, with gas to solid transformation and subsequent washout, was not occurring at this time. Carlisle (1965) and Carlisle, Brown, and White (1966, 1967) studied aspects of the cycling of organic matter in a sessile oak woodland in Great Britain over a two year period and provided data comparable to that of the present study. For the 1963-1964 year, concentrations of organic matter in incident precipitation ranged from a low of 4.7 mg/l in October (third highest rainfall month) to 13.09 mg/l in February (lowest rainfall month). Little seasonal trend is seen, possibly due to high precipitation levels coinciding with the growing season. The mean for the year was 6.45 mg/l. For the 1964-1965 year, incident precipitation levels of organic matter ranged from 2.58 to 7.48 mg/l (no seasonal data given) with a mean concentration of 4.46 mg/l (as calculated from Table 3, Carlisle et al. 1967).

These values for incident precipitation organic matter can be compared to the range of 1.80 mg/l (August 1974) to 10.87 mg/l for the organic carbon in incident precipitation at Walker Branch. Assuming organic matter equals approximately two times organic carbon, the range for the 1963-1964 year in the sessile oak forest is quite comparable to that at Walker Branch, while ranges for the 1964-65 year are considerably lower. However, the February peak in incident precipitation concentration of organic carbon in Great Britain was not seen for data from

Walker Branch, possibly due to the different precipitation regime. Differences in seasonality of rainfall between the two sites, with little winter rainfall in Great Britain in comparison to Oak Ridge, complicate comparison of trends for carbon concentration, leading to different relationships between DOC concentration and rainfall.

Lowest concentrations of throughfall TOC in the present study were found during the November through January period (2.39 to 2.80 mg/l), due to low concentrations of both DOC and FPOC (Figure 29). February and March TOC levels in throughfall were similar to each other (4.38 mg/l and 4.56 mg/l, respectively), the increases over those of the late fall to early winter period due to increases in both DOC and FPOC concentrations. TOC increased during April and May (7.99 and 6.46 mg/l respectively), with the increase continuing into June (15.90 mg/l) and reaching a peak in July of 52.50 mg/l. The August mean concentration was 7.07 mg/l, a substantial decline from the July levels.

Canopy contributions of TOC to throughfall ranged from 0.86 mg/l in May to 41.64 mg/l in July, the former low value being due to the high concentrations of TOC in incident precipitation as compared to that for throughfall. When the throughfall and incident precipitation concentrations for May are compared to those for April and June, throughfall concentration appears lower than expected, probably due to the fact that vegetation was recently emergent and also that insect populations had not had time to build up to substantial numbers. Relative to both months, there was probably a dilution effect due to the much larger volume of incident precipitation during May. Lausberg (1935) found that organic material was leached in much smaller quantities from young vegetation

than from older leaves. Tukey (1970) found smaller amounts of leachate from the young leaves of the species he studied in the tropical rain forest at El Verde.

Except for the low May value, canopy contributions increased from 1.58 mg/l in March to the July high. As in May, high amounts of rainfall in August led to low TOC concentrations in throughfall and relatively low concentration increases (4.98 mg/l) due to canopy. September and October 1973 had higher contributions (13.13 and 7.10 mg/l) from canopy due to higher TOC concentrations in throughfall compared to concentrations in incident precipitation, due most probably to leaching.

Comparable values of total organic matter concentration in throughfall are available in the literature for a number of forest situations. Tamm (1951) studied the removal of total organic matter from spruce (Picea abies) and (Pinus sylvestris) during three periods (October 19 to November 1, November 1 to November 15, and November 15 to November 30). Concentration of organic matter was inversely related to volume of precipitation. For spruce, concentrations ranged from 15-60 mg/l, while for pine, the range was 22 to 114 mg/l. Except for somewhat erratic results from the first storm, incident precipitation levels were 2 to 5 mg/l. While the latter values fall into the same range found for a comparable period (November) at Walker Branch (assume organic carbon equals approximately one-half organic matter), the upper range for throughfall concentrations were considerably higher than those found for the late summer - early fall pre-leaf fall period at Walker Branch, with lowest readings given by Tamm comparable to the means at Walker Branch for this early fall period. Since Tamm was working in a conifer forest, the seasonal effects could be considerably different.

Carlisle (1965), and Carlisle, Brown, and White (1966, 1967), working in a Quercus petraea woodland in Great Britain, where annual rainfall averages 171 cm/yr, presented two years' data (June 1963 to May 1965) for total organic matter (dissolved plus fine particulate <200 μm), including some data for soluble carbohydrates. Rainfall for the 1964-1965 year was near the historic annual mean, while that for 1963-1964 was about 10 cm less. Figures for the sessile oak forest for throughfall during the 1963-1964 year show a range from 8.60 mg/l in January to 99.12 mg/l in June (calculated from Table 1, Carlisle et al. 1966), and 9.2 to 34.0 mg/l for the 1964-1965 year. Yearly means were 32.25 mg/l and 16.02 mg/l for 1963-1964 and 1964-1965, respectively. For 1963-1964, where monthly means were presented, high concentrations of throughfall were found during the June through August period (80.5 and 99.12 mg/l) while, for the rest of the year, concentration ranged from the low in January to 25.20 mg/l in May, with little else in the way of a seasonal trend discernible.

Results from Walker Branch are again quite comparable to those for the 1963-1964 year in Great Britain, although the low values for Walker Branch (2.39 - 2.80 for November through February) are about three-fifths the low values for the sessile oak forest. Highest mean concentrations of total organic carbon at Walker Branch occurred during August (52.51 mg/l organic carbon or approximately 105 mg/l organic matter) and are very close to the 99.12 mg/l organic matter for June for the sessile oak forest. However, for the latter forest, very high total organic matter was found from June through August, while these greatly elevated levels occurred only during August at Walker Branch. The elevated levels in the

sessile oak forest for June through August accompanied relatively high precipitation volumes, while the high concentrations at Walker Branch in July were accompanied by the lowest monthly rainfall of the year.

Both the Walker Branch data and that for the 1963-1964 year in England show considerably higher mean concentrations than the 1964-1965 year for the sessile oak forest, where the mean yearly concentration for the 1964-1965 year was one-half that for the 1963-1964 period.

For 1963-1964, Carlisle et al. (1966) found that canopy contributions to throughfall showed very high concentrations (72.83 -87.06 mg/l) during the early through mid-summer period (June through August), with greatly declining concentrations during September and October (17.24 and 13.29 mg/l respectively) and a further decline during the November through February period (5.32 to 2.32 mg/l). Concentrations rose again during March, April, and May (6.20, 8.23, and 19.40 mg/l, respectively). For the 1965-1965 year, yearly mean canopy contribution was 11.56 mg/l.

While incident precipitation was not measured during the November through February period at Walker Branch, the low concentrations in throughfall preclude canopy contributions of this magnitude at Walker Branch. Different phenological patterns, as well as low rainfall and heavy epiphytic growth in the British forest, probably contributed to the substantially larger canopy contributions in the winter months. For the rest of the year, only one month (July) at Walker Branch had canopy contributions to the concentration of total organic carbon in throughfall equivalent to those for the June to August 1963 period in the sessile oak forest. Canopy contributions were similar for the September and October period at both sites, while those for the spring in England

were somewhat higher than those at Walker Branch for a comparable period.

At least part of the explanation for the high levels of organic matter in throughfall during the June through August period in Great Britain was the carbohydrate content, which was found to consist, to a large degree, of melizitose. For August, the only month of the three (in 1963) for which carbohydrates were analyzed, 70.7% of the total organic concentration was due to carbohydrates. No carbohydrates were found in incident precipitation at any time. During the leafless period, no carbohydrates were found in the throughfall, while for the remaining months, the contribution of carbohydrates was 25% or less of the total concentration. Carlisle et al. (1966, 1967) attributed the melizitose production to aphid populations, through honeydew production. Reichle et al. (1973), who studied aphid populations in the Liriodendron forest at Oak Ridge, found peak populations during late spring. Based on their calculations for honeydew production (0.5 $g/m^2/yr$), contributions on the order reported by Carlisle et al. (1966) are not likely to occur at the present study site.

While this "washing effect" may partially explain the high values for July on Walker Branch, Mitchell (1968) (in accordance with the results of Stenlid, 1958, for inorganic ions) found leaching of carbohydrate from leaves greatest at highest ambient temperatures. In this regard, Tukey et al. (1958) found a direct relationship between light intensity and carbohydrate loss on leaching, with only small losses through leaching in the dark part of the cycle. This would coincide with the period of maximum available free carbohydrates.

Thus, the diurnal factor brings another variable into the picture. Storms occurring during the day might be expected to have higher concentrations due to the presence of soluble sugars in leaves. Maximum effects would be expected on those hot sunny summer days when afternoon thunderstorms occur. This might help to explain why storms on successive days might not show a depletion phenomenon. This aspect of organic carbon cycling will be further evaluated when behavior of DOC in storm cycles is discussed. Tukey (1970) stated that organic substances, principally carbohydrates, account for the major quantity of leached materials. Thus, summer increases in canopy contribution are undoubtedly due to both leaching and washing effects.

Eaton et al. (1973) found average weighted concentrations of organic matter (dissolved and very fine particulate) in throughfall, for the June through October period at the Hubbard Brook forest, ranging from 18.2 mg/l for yellow birch to 28.3 mg/l for sugar maple, with beech intermediate with 22.9 mg/l. There was apparently no significant difference between species. Values for these dominant species were used to calculate weighted average concentrations for the watershed. Calculations show that the associated concentrations (in mg/l) were 19.02, 22.13, 22.76, 27.29, and 31.39 for the months June through October respectively, with an overall mean concentration for the five months of 23.06. Their explanation for the seasonal trend in concentration is not clear. They observed that levels (concentrations) of organic matter in throughfall remained at relatively low levels during early summer and increased in fall to a maximum during senescence. While higher concentrations were seen during September and October, the concentrations for

the entire growing season had a relatively narrow range (from 19.02 to 31.39 mg/l), with increases during September and October possibly due as much to the lower levels of incident precipitation during September and October (3.43 to 4.86 cm, respectively) compared to July and August (17.22 to 12.19 cm, respectively), as to any inherent changes in leachability of the foliage. Because of the lack of data for organic loads in incident precipitation, all conclusions relative to leaching/washing based on this work are speculative.

Fisher and Likens (1973), reporting on calculations made from the same data used by Eaton et al. (1973) for the June through October growing season at Hubbard Brook, found mean throughfall concentrations to Bear Brook of 17.8 mg/l. Comparing these values from Hubbard Brook to those for organic carbon from Walker Branch for the same months (June, 15.65 mg/l; July, 52.51 mg/l; August, 7.07 mg/l; September, 15.53 mg/l; and October, 12.31 mg/l), the range of concentrations is comparable except for the very high July values for Walker Branch. Also, the trend for the five months on Walker Branch was somewhat more erratic, being more closely related (inversely) to volume of precipitation.

Analysis of Concentration of DOC and FPOC in Throughfall vs Collector Volume

Scattergrams showing the relationship between concentration of DOC, FPOC, and TOC in throughfall and volume of throughfall are presented in Figures 30, 31, and 32, respectively. The great similarity in the behavior of DOC, FPOC, and TOC as the volume of throughfall increases is clearly seen, with highest concentrations of each species at lowest volumes of throughfall. The lowest monthly volumes of throughfall

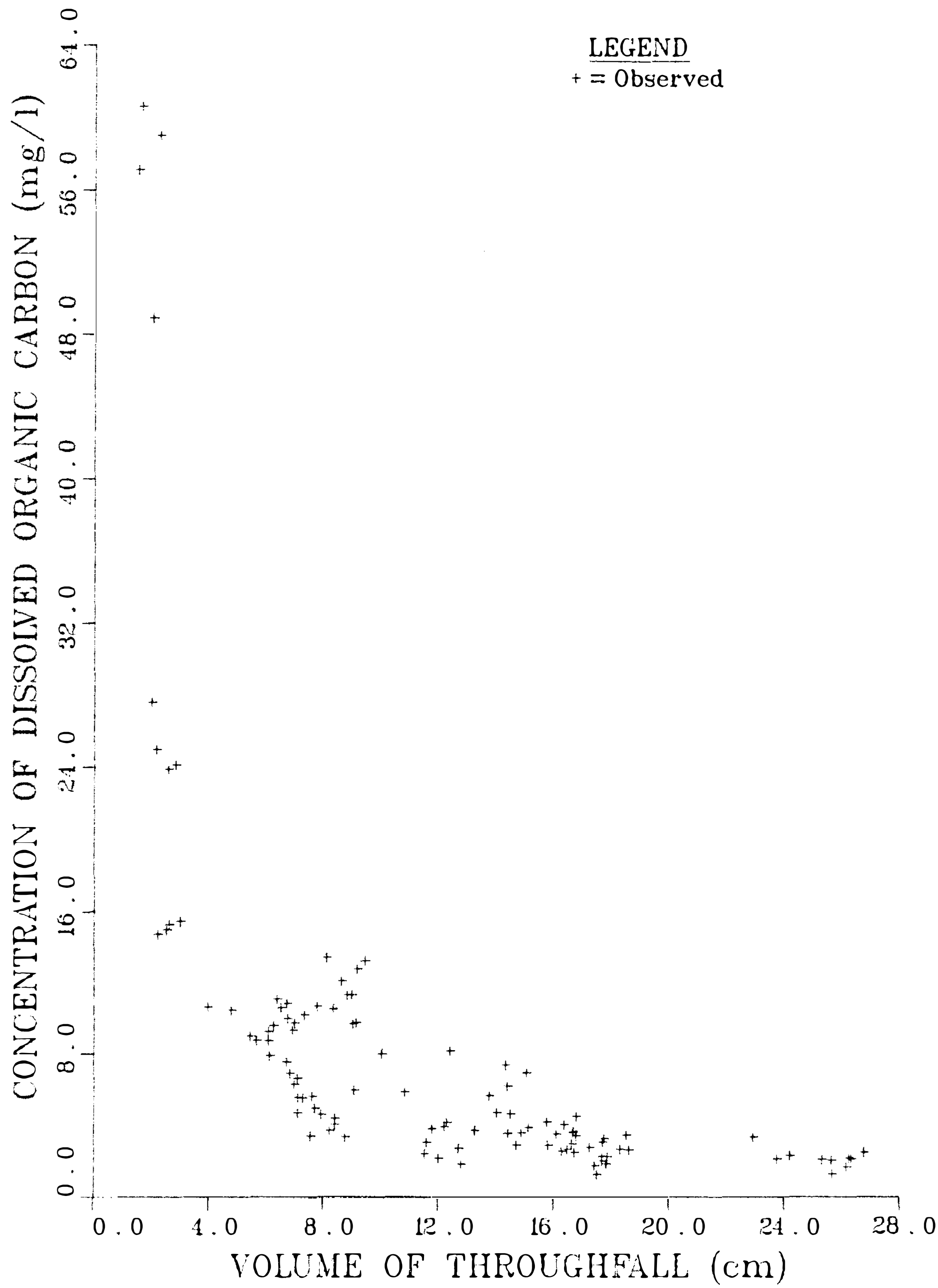

Figure 30. Scattergram Showing the Relationship of Concentration of Dissolved Organic Carbon in Throughfall and Volume of Throughfall for the 1973-1974 Water Year on the West Fork of Walker Branch.

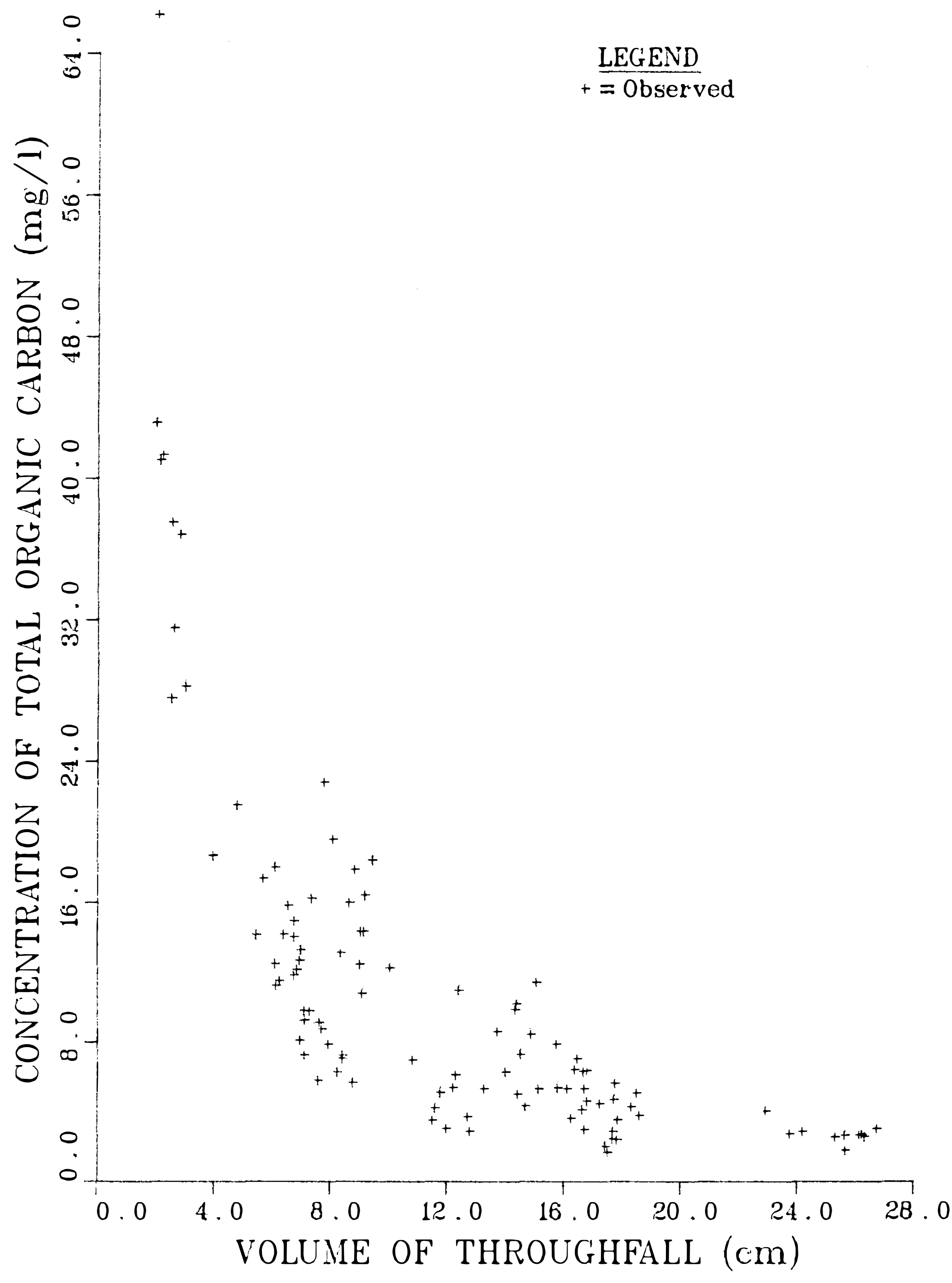

Figure 31. Scattergram Showing the Relationship of Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the 1973-1974 Water Year on the West Fork of Walker Branch.

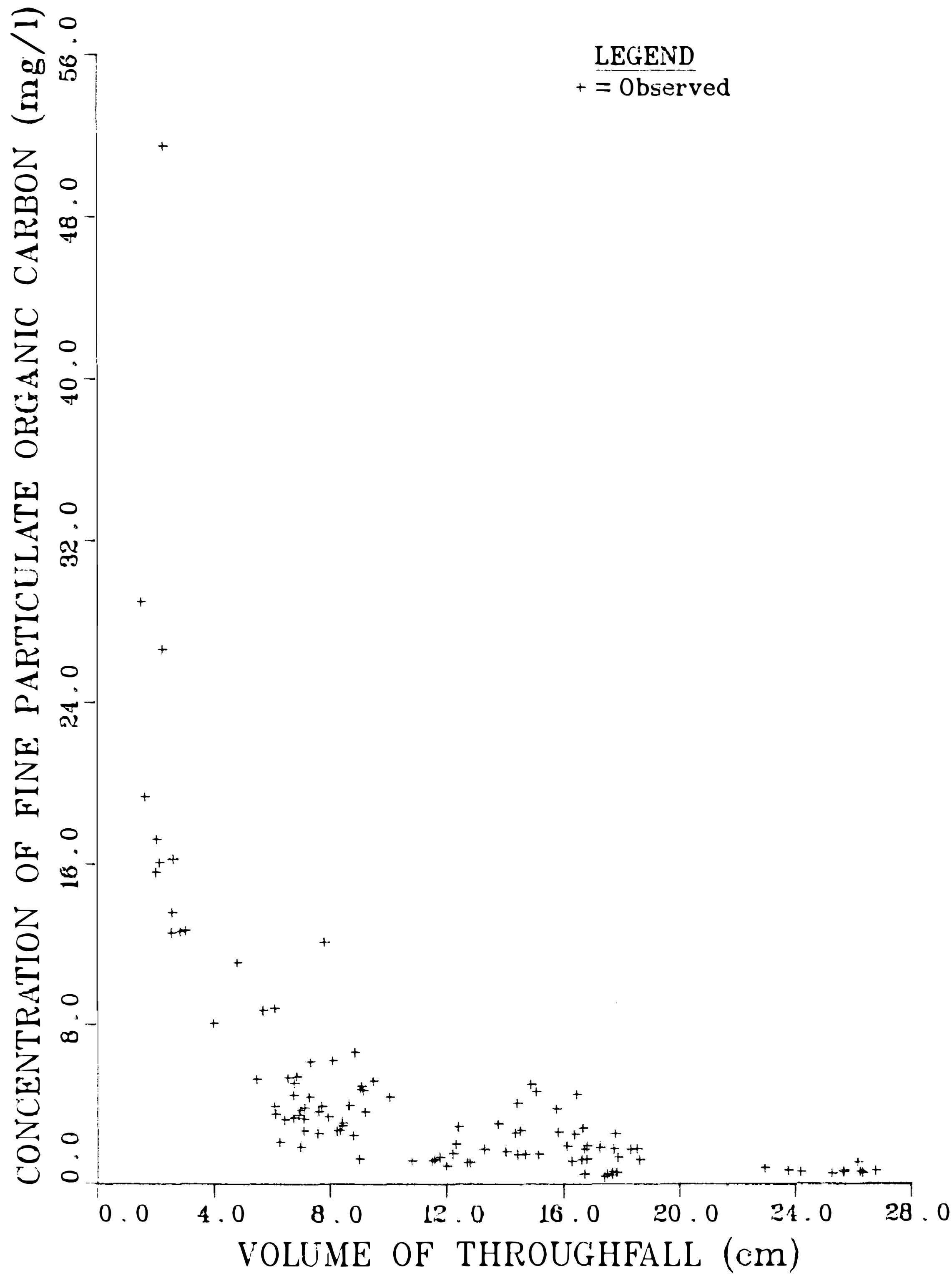

Figure 32. Scattergram Showing the Relationship of Concentration of Total (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the 1973-1974 Water Year on the West Fork of Walker Branch.

occurred during July, the period of maximum biological activity on the watershed, while most larger volumes of throughfall occurred during the leafless period. As discussed earlier, such a precipitation regime, especially with respect to the mid-summer period, is not typical.

These data were tested against several linear models, with two, logarithmic and inverse, yielding the best fits. Two steps were used in the analyses. The dependent variable (either log concentration or 1/concentration) was first fitted to the model

$$Y = a + bX$$

where X is the independent variable (either log throughfall or throughfall). If a slope significantly different from zero ($\alpha = 0.05$) was realized, the data were then tested against the model

$$Y = a + bX + cZ_1 + dZ_2$$

where Z_1 and Z_2 are qualitative intercept and slope variables respectively, and are related to the presence or absence of canopy (dormant or growing season). Therefore:

$Z_1 = 0$ if canopy is absent

$Z_1 = 1$ if canopy is present

and $Z_2 = 0$ if canopy is absent

$Z_2 = X$ if canopy is present

where X is the particular independent variable (either volume of throughfall or log of volume of throughfall).

The model therefore tests for the significance of intercept or slope changes related to presence or absence of a forest canopy. Canopy was considered present from May through October, while the November through April period was considered the dormant season.

Results of the initial regressions are shown in Table 31. Values for r^2 were 0.55 for FPOC and 0.66 and 0.67 for DOC and TOC, respectively for the inverse regression. For the logarithmic regressions, r^2 values were 0.79, 0.75, and 0.82 for DOC, FPOC, and TOC, respectively. In both cases (inverse and logarithmic forms), all slopes are significantly different from zero. All slopes were positive in the inverse model, with that for FPOC being the largest. In accordance with these results, the logarithmic regressions showed all slopes negative, with that for FPOC again having the largest absolute value and therefore being the steepest. Figures 33 to 35 and 36 to 38 show the plots for the data in the inverse, and logarithmic regressions, respectively. Plots of predicted values are also shown in the Figures. Since all regressions showed slopes significantly different from zero, the analyses were continued.

Results of analyses using qualitative variables for the inverse regressions are shown in Table 32, with r^2 values of 0.76, 0.71, and 0.79 being realized for DOC, FPOC, and TOC, respectively. For 1/concentration DOC, both the intercept and coefficient for Z_1 were significantly different from zero. The fact that this coefficient, which is an intercept, was significantly different from zero, indicates that the entire regression line was shifted higher when canopy was present. This conforms to expected ecological processes, with enrichment of incident precipitation as it passes through a forest canopy in leaf.

The slope of the regression was significantly different from 0, while the coefficient for Z_2, the qualitative slope variable, was not significant, indicating that slope did not differ significantly between leafless and leaf periods. This is depicted in the plots for predicted

Table 31. Results of Initial Regression Analyses for Relationship Between Concentration of Organic Carbon in Throughfall (mg/l) and Volume of Throughfall (cm).

Dependent Variable	Independent Variable	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Log DOC	Log Throughfall	0.79	4.19	0.0001	-1.09	0.0001
Log FPOC	Log Throughfall	0.75	3.97	0.0001	-1.31	0.0001
Log TOC	Log Throughfall	0.82	4.78	0.0001	-1.16	0.0001
1/DOC	Throughfall	0.66	-0.065	0.7357	0.002	0.0001
1/FPOC	Throughfall	0.55	-0.200	0.0120	0.007	0.0001
1/TOC	Throughfall	0.67	-0.021	0.1483	0.002	0.0001

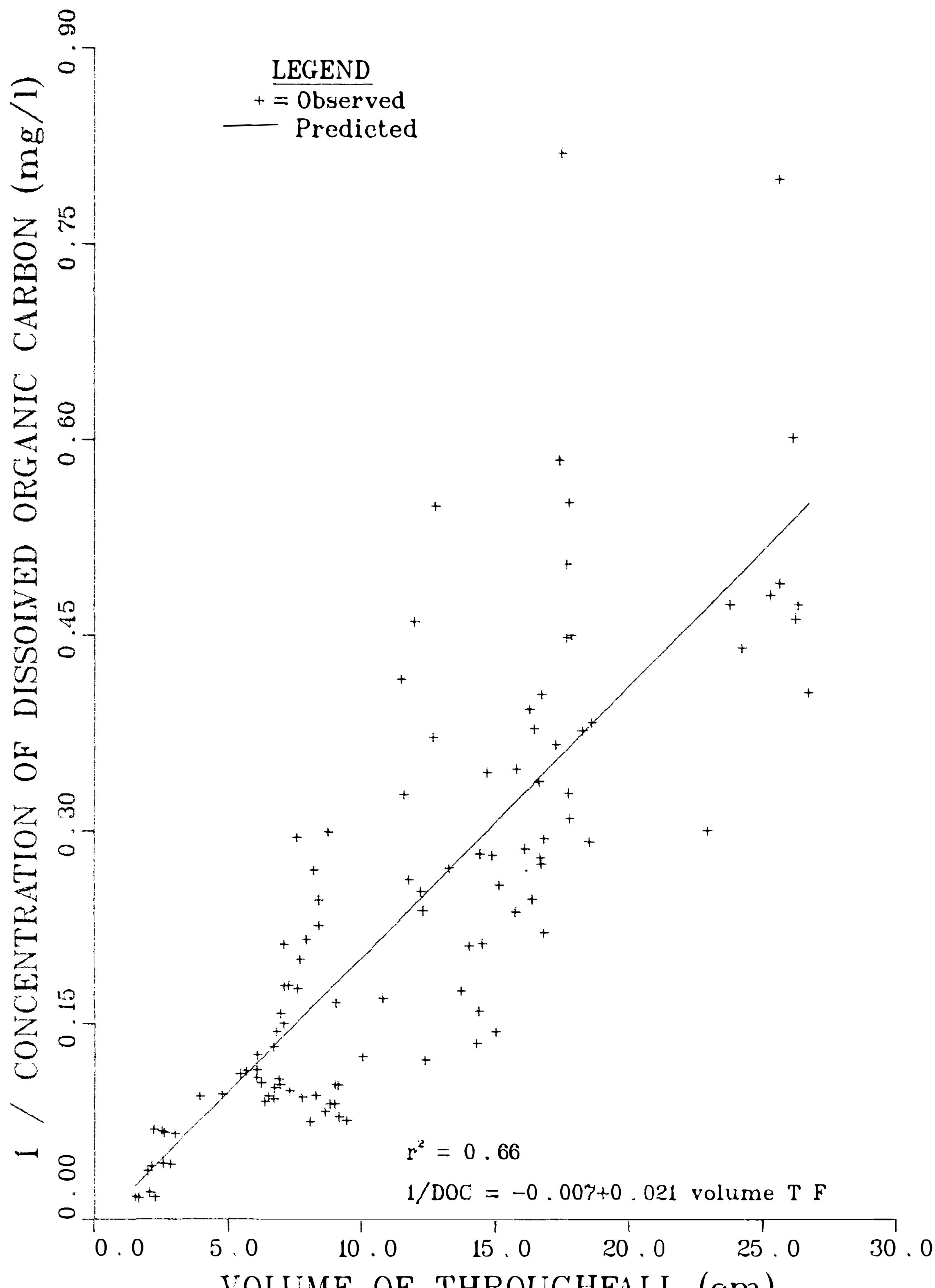

Figure 33. Scattergram Showing the Relationship of Reciprocal of Concentration of Dissolved Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

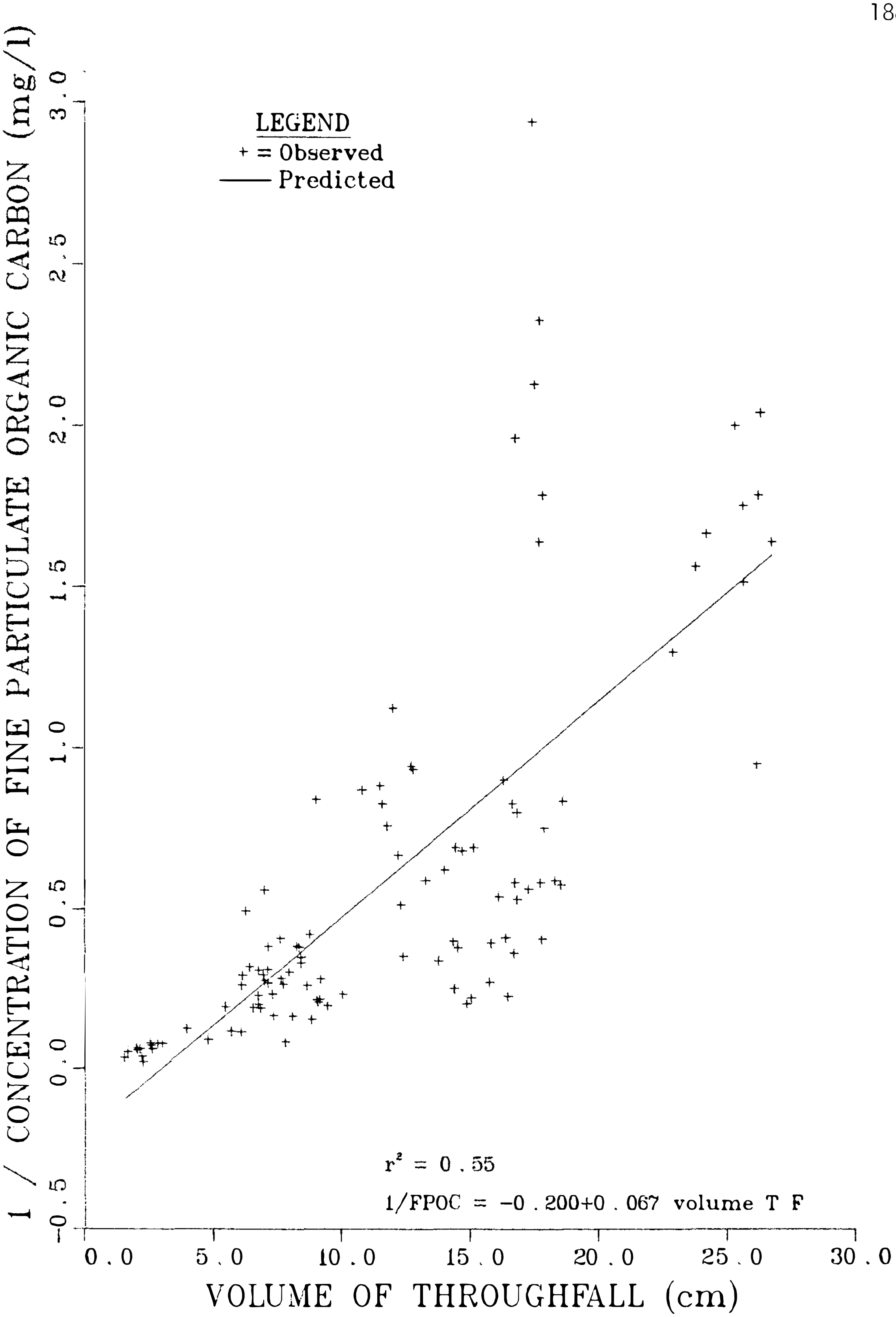

Figure 34. Scattergram Showing the Relationship of Reciprocal of Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

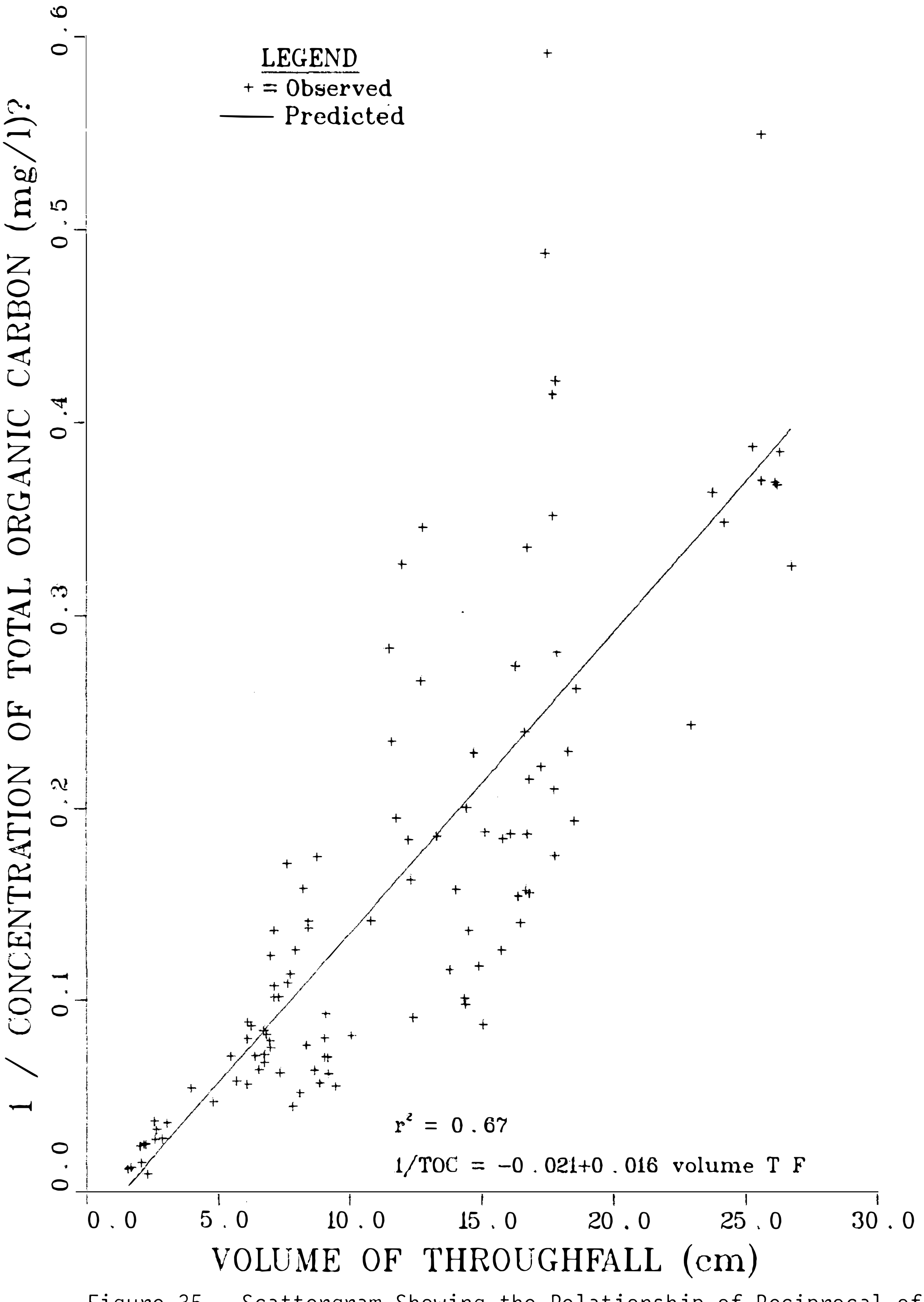

Figure 35. Scattergram Showing the Relationship of Reciprocal of Concentration of Total (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

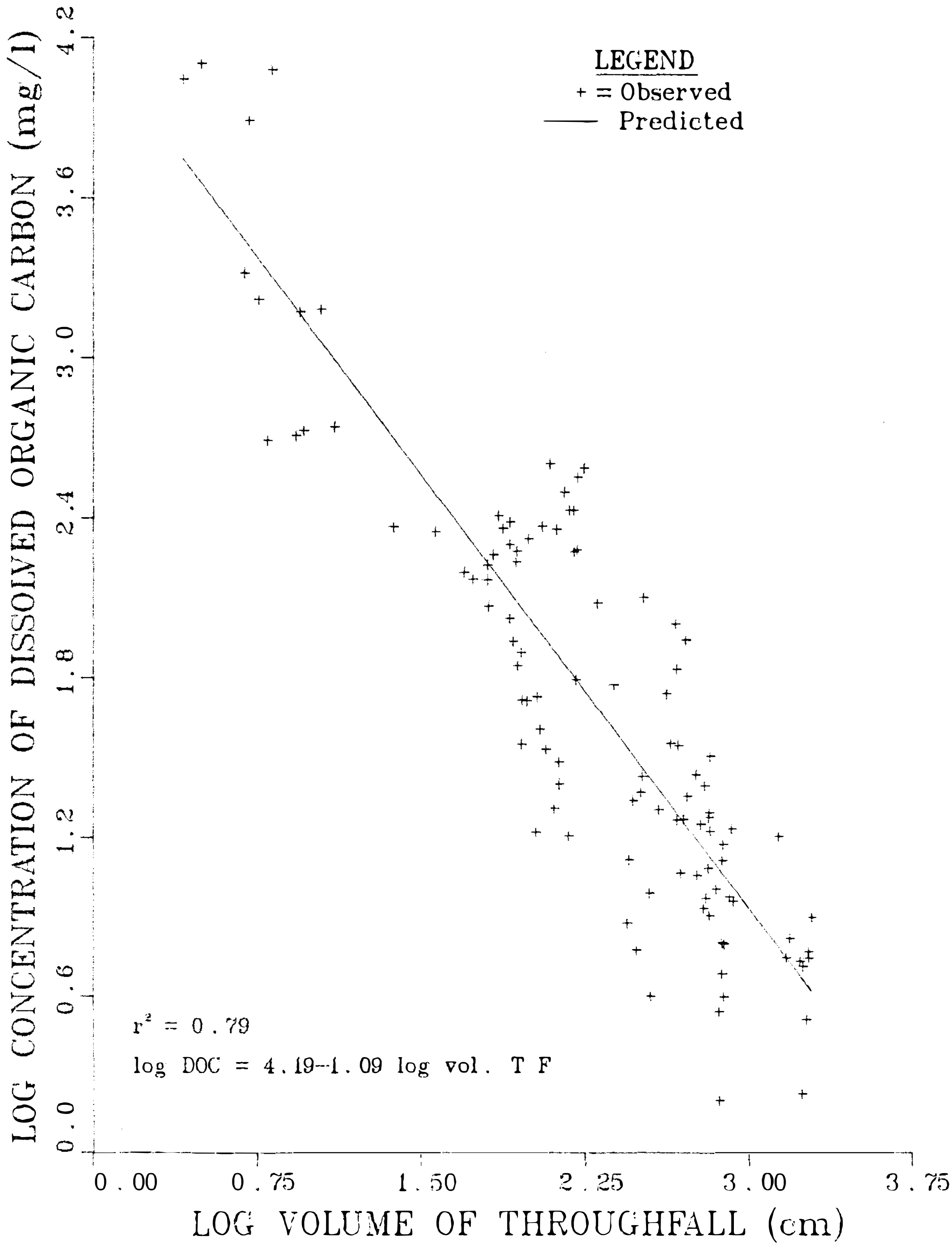

Figure 36. Scattergram Showing the Relationship Between the Logarithm of Concentration of Dissolved Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

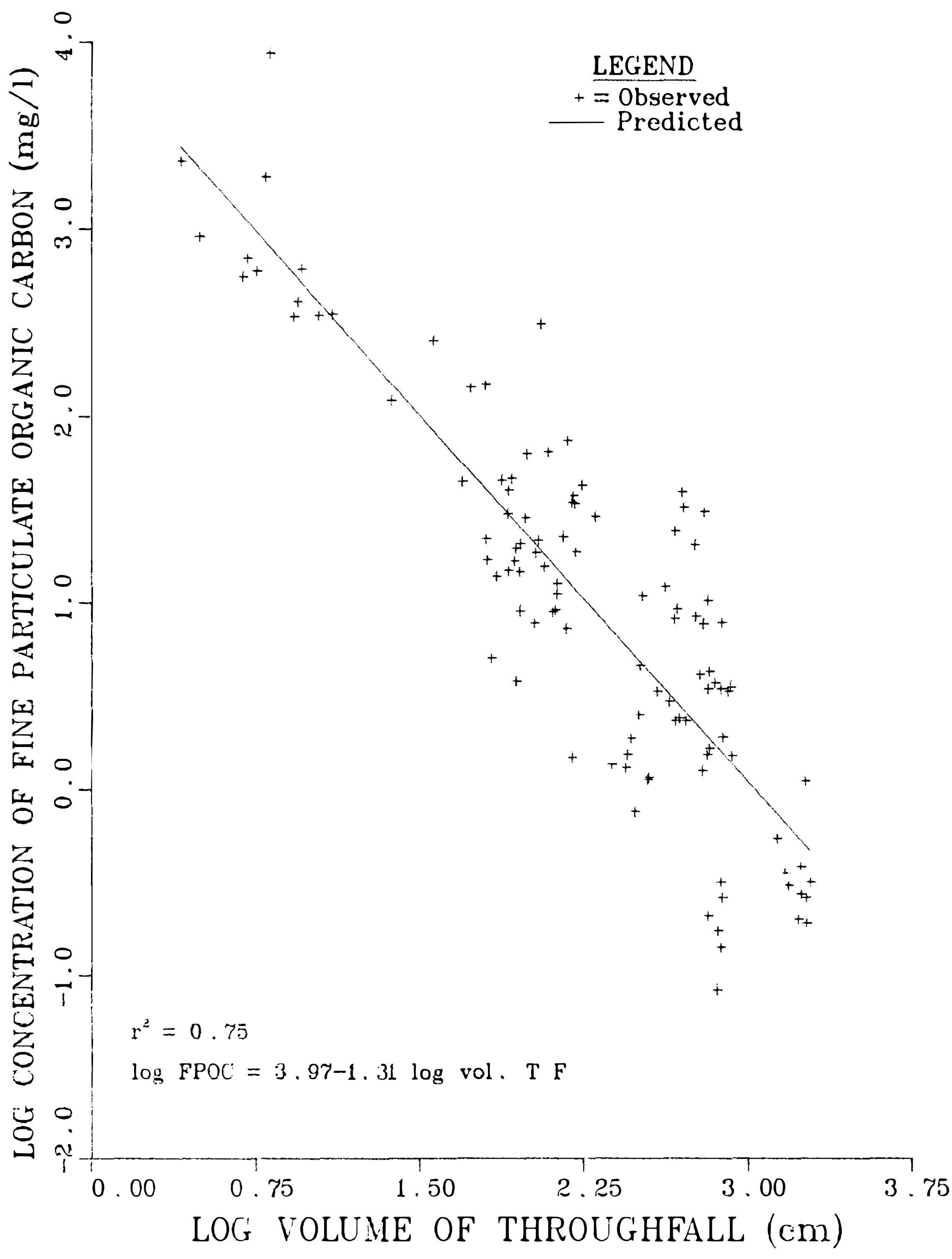

Figure 37. Scattergram Showing the Relationship Between the Logarithm of Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

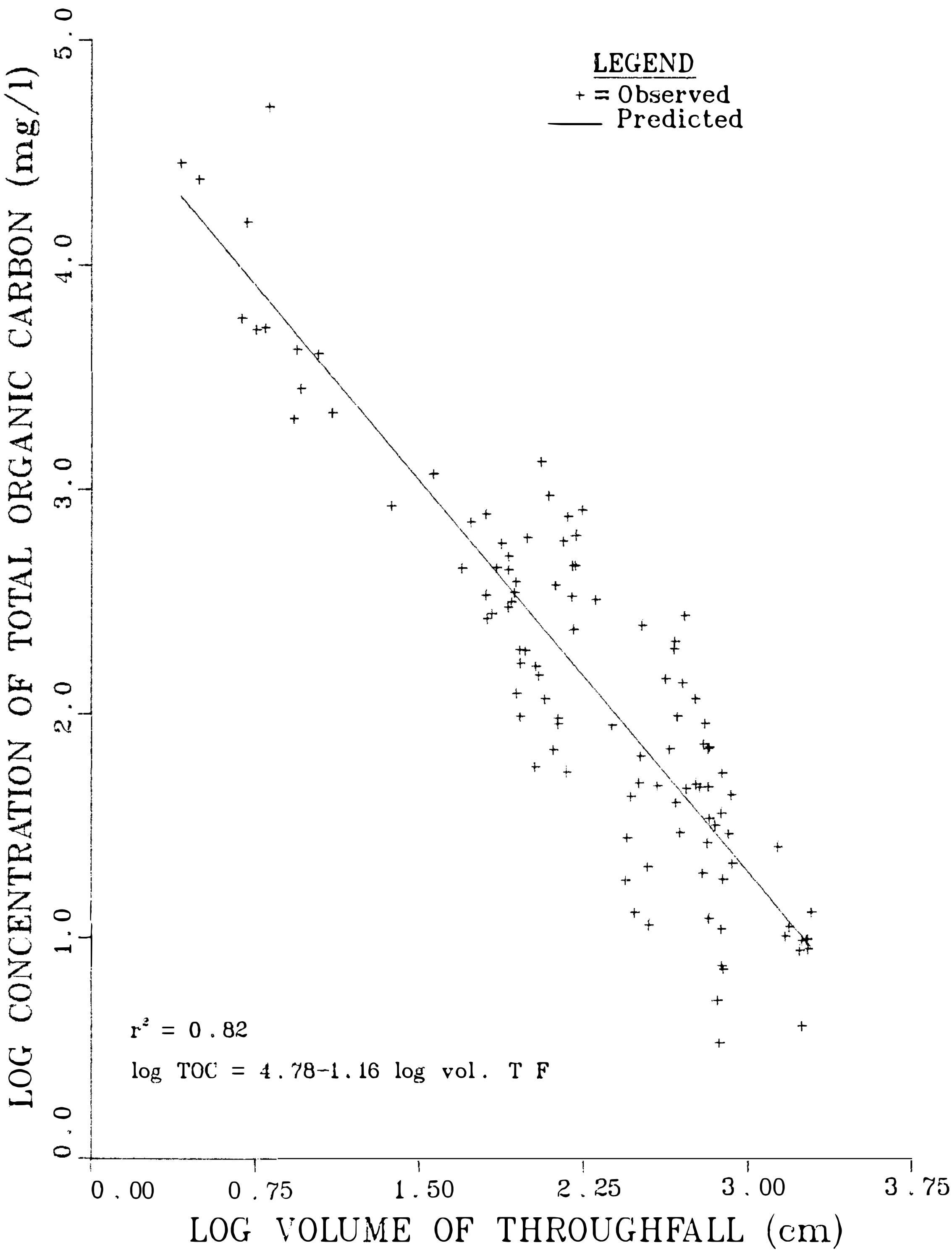

Figure 38. Scattergram Showing the Relationship Between the Logarithm of Concentration of Total (<1 mm) Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

Table 32. Results of Regression Analyses for Relationship Between Concentration of Organic Carbon (mg/l) in Throughfall and Volume of Throughfall (cm) Using the Reciprocal of the Independent Variable and Incorporating the Effects of Growing vs. Dormant Season by Utilizing Qualitative Slope and Intercept Variables.

Dependent Variable	Independent Variable	r^2	Intercept		Slope		Coefficient of Z1		Coefficient of Log Z2	
			Estimate	Pr>T	Estimate	Pr>T	Estimate	Pr>T	Estimate	Pr>T
1/DOC	Throughfall	0.76	0.128	0.0003	0.016	0.0001	-0.133	0.0013	0.01	0.7725
1/FPOC	Throughfall	0.71	-0.075	0.5666	0.073	0.0001	0.105	0.4968	-0.05	0.0001
1/TOC	Throughfall	0.79	0.057	0.0173	0.014	0.0001	-0.058	0.0402	0.01	0.0861

values of 1/concentration DOC shown in Figure 39, where only a slightly greater slope appears for growing season dates.

For 1/concentration FPOC, neither the intercept nor the coefficient for Z_1 was significantly different from zero, but both b and the coefficient for Z_2 were significant. These results are shown in Figure 40, which also depicts predicted values of 1/concentration FPOC vs throughfall. The plot clearly shows that the slope of the regression was steeper when leaf canopy was absent. This rather surprising result, the opposite of what might initially have been expected, is discussed below after the log/log relationships are shown.

Results of the regression for 1/conc TOC vs volume of throughfall (collector volume), which combine the effects of DOC and FPOC, showed the coefficient for Z_2 to be significant at only the 90% level (a two-tailed test was required here). Again, the overall relationship was for a positive slope, indicating a negative relationship between carbon concentration and volume of throughfall; but, as with FPOC, the presence of canopy actually led to a significantly smaller slope value than that without canopy. The intercept is significant, ($Pr>T = 0.05$) as is Z ($Pr>T = 0.05$), the latter indicating an overall enrichment of organic carbon in the presence of canopy. The plot of predicted values of 1/TOC vs throughfall volume is shown in Figure 41. The tendency for the overall negative relationship to be less intense during the growing season is seen in the smaller positive slope for this period. This result is due to the behavior of FPOC.

For the logarithmic regressions incorporating Z_1 and Z_2, r^2 values for concentrations of DOC, FPOC, and TOC were 0.85, 0.84, and 0.89,

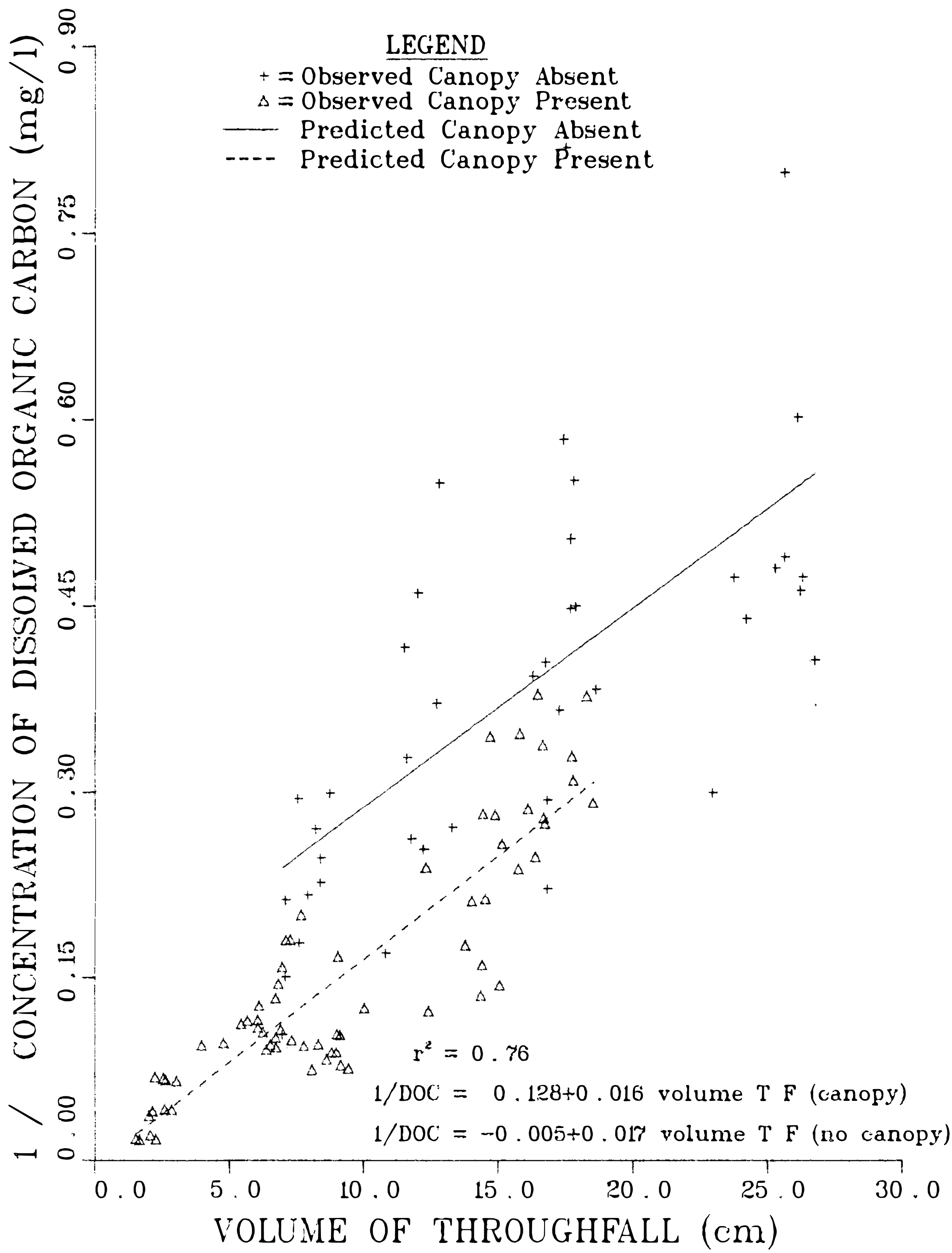

Figure 39. Scattergram Showing the Relationship Between the Reciprocal of Concentration of Dissolved Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

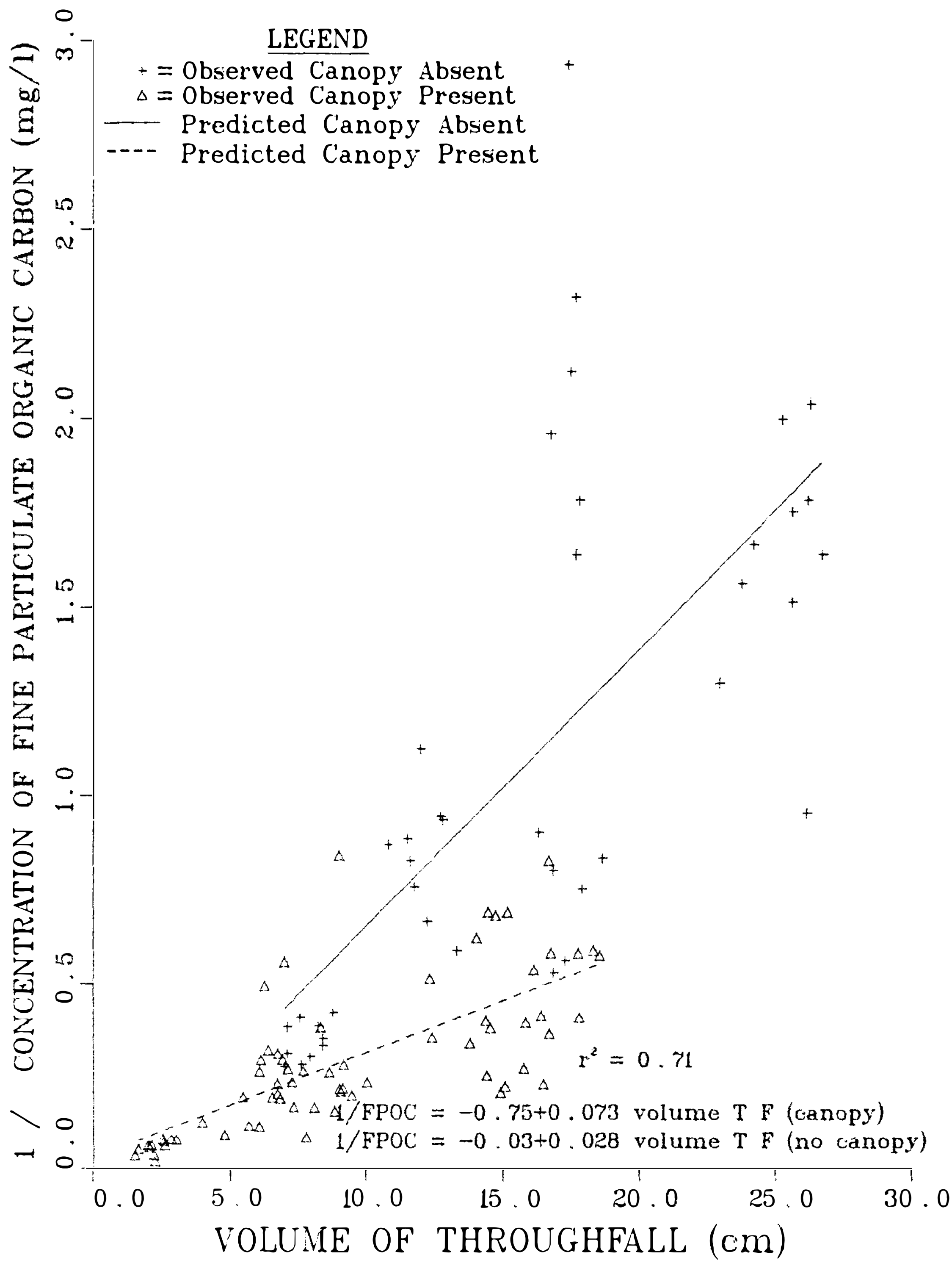

Figure 40. Scattergram Showing the Relationship Between the Reciprocal of Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

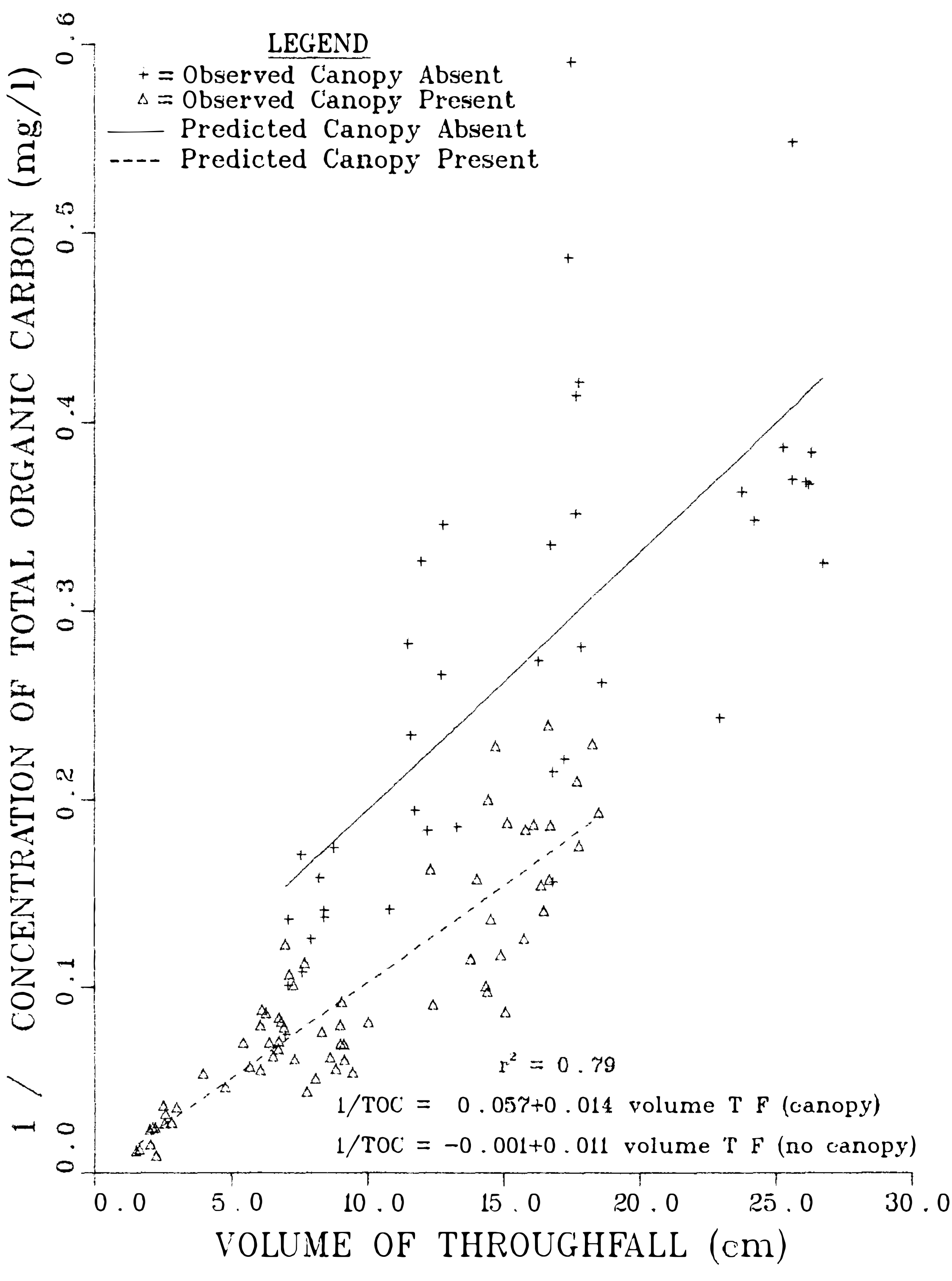

Figure 41. Scattergram Showing the Relationship Between the Reciprocal of Concentration of Total (<1 mm) Organic Carbon in Throughfall and Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

respectively (Table 33), indicating that the variation in collector volume accounted for a large proportion of the variation in the dependent variable when the seasonal factor was included.

For DOC concentration, the intercept (positive) and slope (negative) for the dormant season data were both significantly different from zero, as was the coefficient of Z_1 (positive), intercept change associated with presence of canopy. This indicated that there was an overall enrichment at all levels of the independent variable. This is shown in Figure 42, which is a plot of predicted values for log DOC vs log collector volume. The qualitative slope variable log Z_2 had a significant coefficient at the 90% level (two-tailed test), this being of the same sign as the value for b, indicating that when canopy was present, the negative relationship between DOC concentration and volume of throughfall was intensified. Overall, the results are quite comparable for those for 1/DOC concentration vs volume of throughfall.

The regression for log concentration of FPOC vs log volume of throughfall showed a negative slope, steeper than that for DOC during the leafless period. Z_1 and Z_2 were not significantly different from from zero in this case (at the 10% level), but the trend for slope changes was opposite to that for the leafless period (different signs). That is, just as for 1/FPOC concentration, the presence of canopy tended to decrease the negative relationship between concentration of FPOC and volume of throughfall. This is shown in Figure 43, which is a plot of predicted values of log FPOC vs log collector volume. The same trend was seen in the inverse relationship, in which the presence of canopy caused the positive relationship to be less intense.

Table 33. Results of Regression Analyses for Relationship Between Concentration of Organic Carbon (mg/l) in Throughfall and Volume of Throughfall (cm) Using the Logarithm of Both the Independent and Dependent Variables and Incorporating the Effects of Growing vs. Dormant Season by Utilizing Qualitative Slope and Intercept Variables.

Dependent Variable	Independent Variable	r^2	Intercept		Slope		Coefficient of Z1		Coefficient of Log Z2	
			Estimate	Pr>T	Estimate	Pr>T	Estimate	Pr>T	Estimate	Pr>T
Log DOC	Log Throughfall	0.85	3.06	0.0001	-0.75	0.0001	1.05	0.0024	-0.23	0.0811
Log FPOC	Log Throughfall	0.86	3.58	0.0001	-1.29	0.0001	0.04	0.9243	0.26	0.1267
Log TOC	Log Throughfall	0.89	3.83	0.0001	-0.91	0.0001	0.79	0.0110	-0.09	0.4246

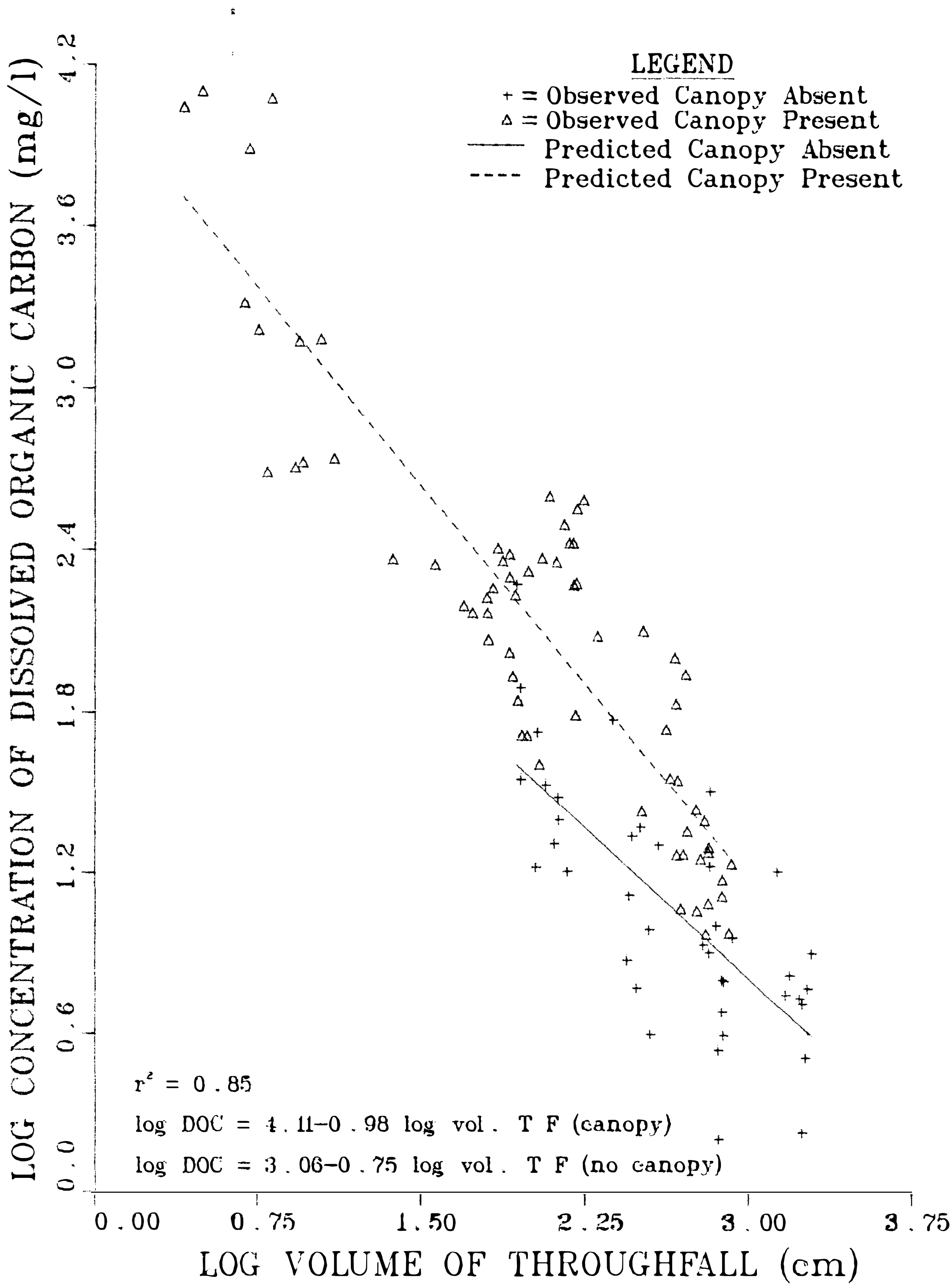

Figure 42. Scattergram Showing the Relationship Between the Logarithm of Concentration of Dissolved Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

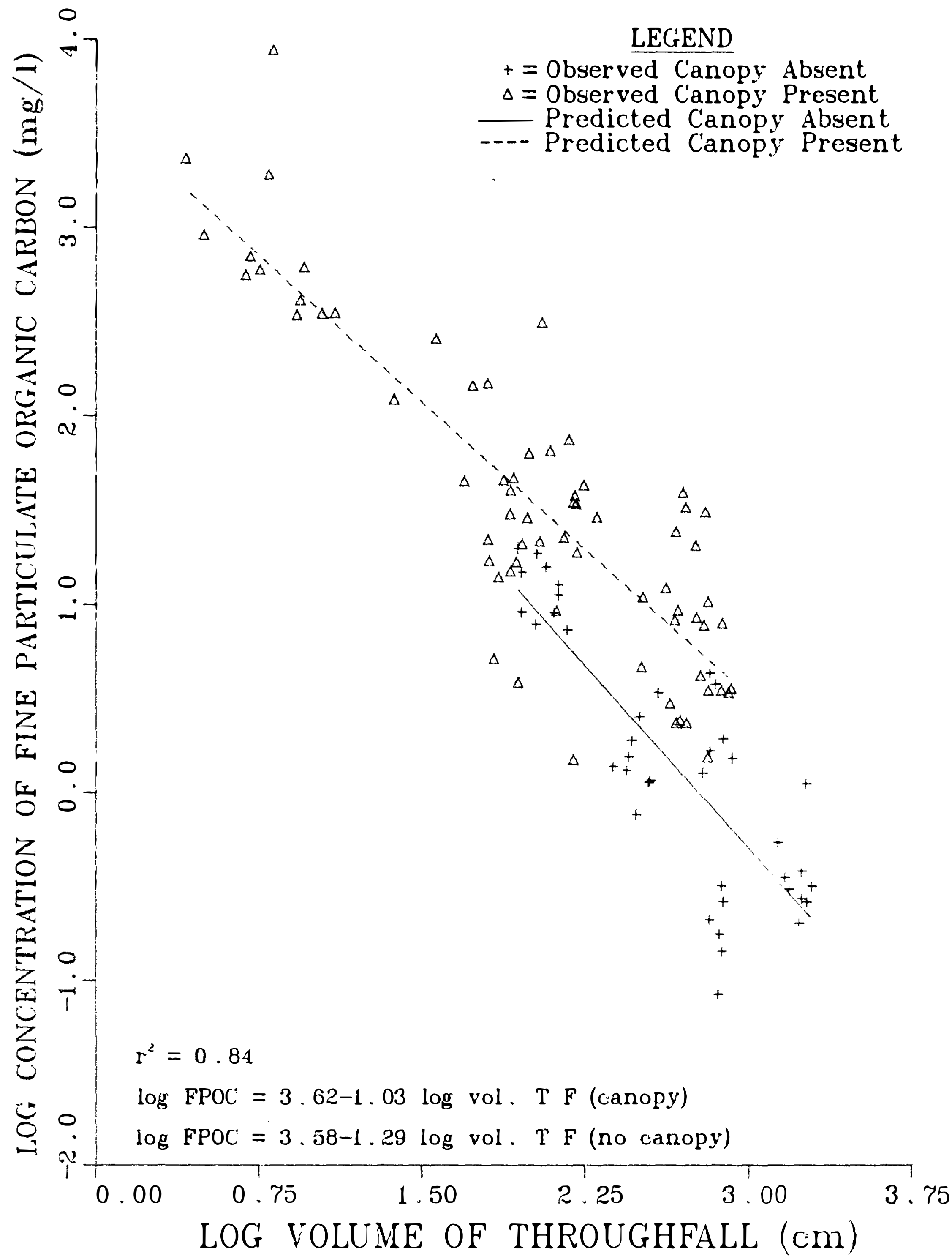

Figure 43. Scattergram Showing the Relationship Between the Logarithm of Concentration of Fine Particulate (<1 mm) Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

For log TOC vs log volume of throughfall, the overall slope and intercept were significantly different from zero, again being negative. The qualitative intercept variable had a coefficient significant only at the 10% level and the quantitative slope variable, log Z_2, was not significantly different from zero, probably due to the opposite effect of presence of canopy on the behavior of DOC and FPOC concentrations. Thus, although there was a trend for overall enrichment of the relationship with the presence of canopy, it was not strong and only marginally significant. The plot of predicted values of log TOC vs log collector volume is shown in Figure 44. Presence of canopy had no appreciable effect on the slope of the overall relationship.

All regressions clearly showed a negative relationship between concentration of organic carbon and volume of throughfall. FPOC showed a stronger negative relationship than DOC, indicating that the concentration of the former declined more rapidly with increasing volumes of throughfall than did the concentration of DOC. The reason for this probably lies in the fact that particulate material, either in the atmosphere or on vegetation surfaces, is depleted rather quickly by rainfall scavenging and by washing of the leaf surfaces. Dissolved material is probably depleted from the atmosphere at a much slower rate. In the canopy, dissolved material can either be washed or leached from leaf surfaces, the latter providing a long lasting source of dissolved material for incorporation into the throughfall. However, the fact that the negative relationship between concentration of FPOC and volume of throughfall was less intense during the growing season indicated that the canopy maintained some reserve of FPOC during this time.

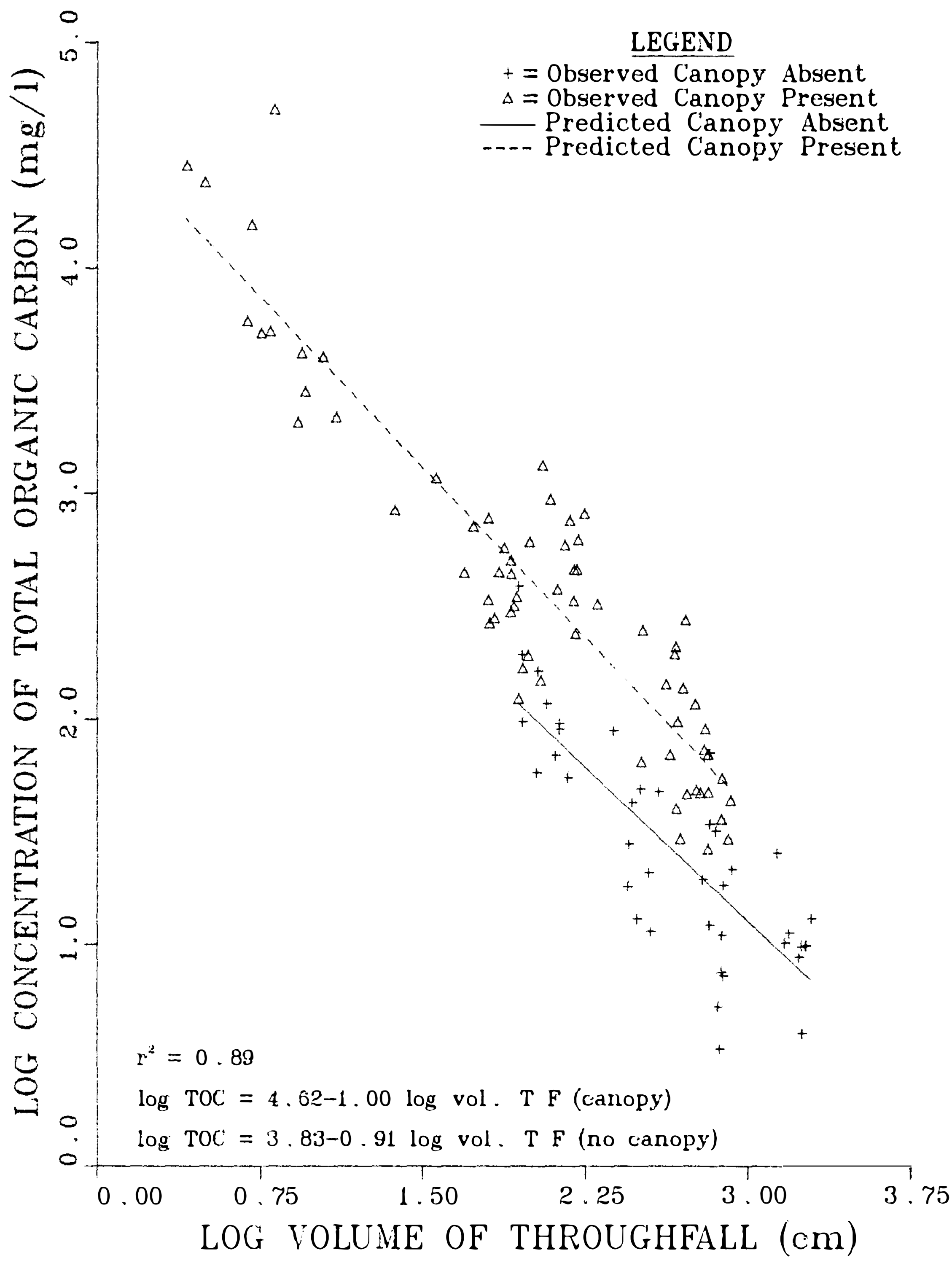

Figure 44. Scattergram Showing the Relationship Between the Logarithm of Concentration of Total (<1 mm) Organic Carbon in Throughfall and the Logarithm of Volume of Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year, Utilizing Qualitative Variables to Incorporate the Effects of Growing vs Dormant Seasons.

During small rains or at the beginning of a larger rain, a large amount of both dissolved and particulate matter is washed from the canopy, after which the supply is essentially exhausted. For dissolved components however, the second source (leaching) continues throughout the rainfall event to some degree. However, diurnal differences in leachability of DOC, associated presumably with photosynthetic activity, do occur. Even taking into account the fact that presence of canopy increased the negative relationship between concentration of DOC and volume of throughfall, the concentration of FPOC still decreased more rapidly with increasing volumes of precipitation during the growing season.

One key to this apparent differential response to presence of canopy for DOC and FPOC can best be seen by consideration of monthly DOC/POC ratios in throughfall and the rainfall regime (Figure 45). The ratio DOC/POC declined from a high in the November - February period (especially December and January) to a lower value during the growing season. Since highest rainfall was associated with these winter months and no month of low rainfall and high DOC concentration occurred during winter, the slope would be less steep than during summer, when several months of relatively low rainfall yielded very high DOC concentrations, and the month with highest rainfall (August) had very low concentrations of DOC. Winter FPOC means were very low (see Figure 28, page 165), especially during months of high throughfall volume. During high rainfall months in summer (August), FPOC concentration followed a similar trend to that for DOC concentration, and was proportionately lower. This was in turn due to proportionately larger inputs of FPOC from the canopy since incident

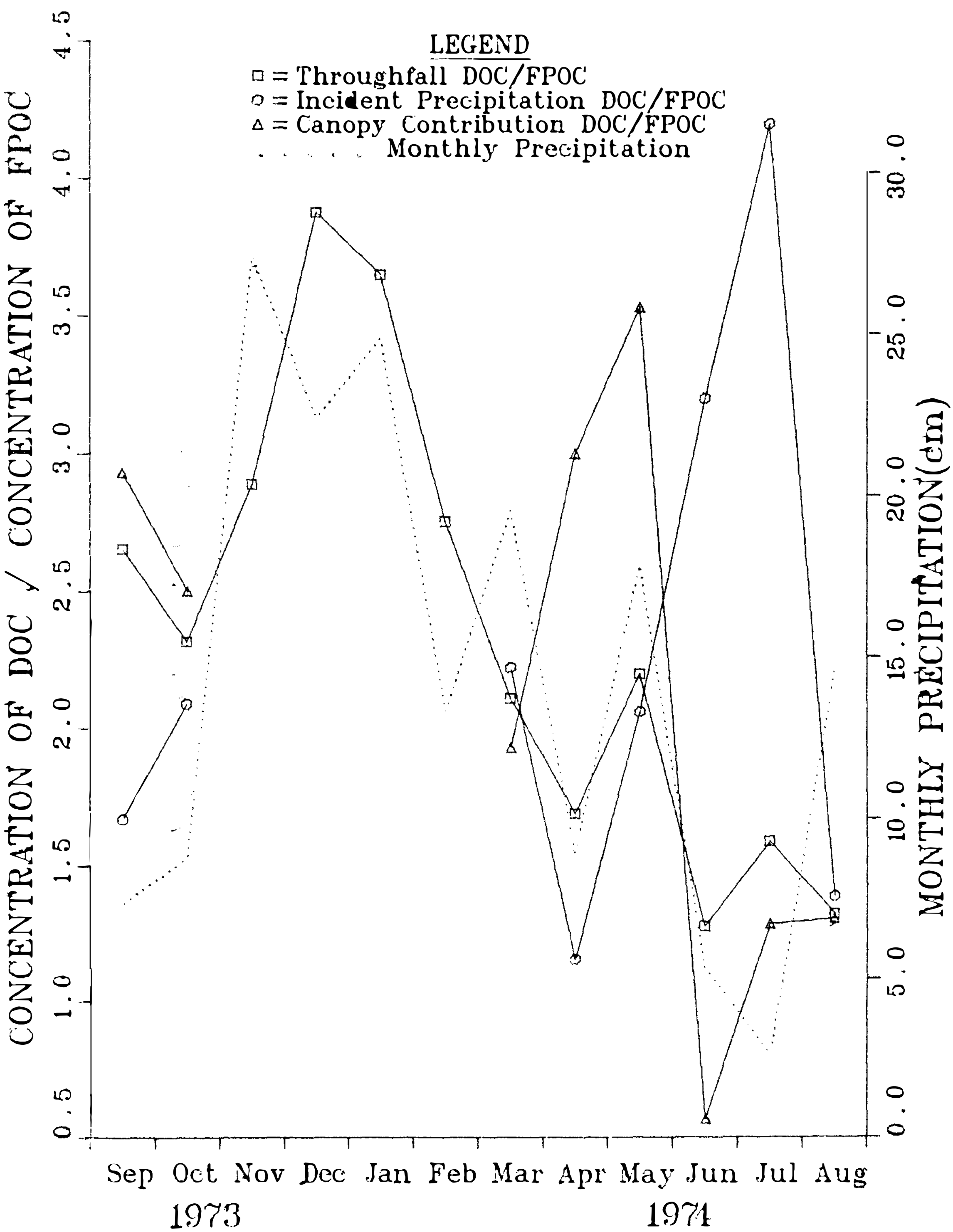

Figure 45. Ratio of Dissolved Organic Carbon to Fine Particulate Organic Carbon (Both Expressed as Either Concentrations or Inputs) in Throughfall, Incident Precipitation, and Canopy Contribution Based on the Monthly Means for the 1973-1974 Water Year.

precipitation DOC/POC ratios were the greatest of the year. For September and October, months of low to intermediate precipitation, the data showed much lower FPOC concentrations than DOC concentrations. The higher concentrations at higher rainfall during the summer must have been of sufficient magnitude to compensate for the obvious elevated FPOC concentrations during months of lowest rainfall. It may be concluded that the extremely low concentrations of FPOC in some winter months during periods of high throughfall yielded an overall steeper negative slope than the high concentrations at low volumes of throughfall during the growing season.

Tamm (1951) presented data showing that concentration of organic matter was inversely related to volume of precipitation for three collection periods from mid-October through November under spruce and pine vegetation. Tukey, Tukey, and Wittwer (1958), who found that intact leaves of bean seedlings can lose up to 4.8% of their dry weight during a 24-hour leaching period, reported that losses increased directly with time but that rate of loss decreased during the latter part of the period. Mecklenberg (1964) and Mecklenberg and Tukey (1964) found that just enough rain to wet a leaf produces leaching, with added rainfall increasing the amount of leaching very little. Thus, rain of a light, intermittent nature should leach more organics than a heavy rain of short duration. Intermittent rain, with accompanying wetting and drying of foliage, increased the wettability of leaves. Attiwill (1966) found that the concentration of inorganic ions in incident precipitation and throughfall decreased exponentially with increasing intensity of rainfall during a collection period. Concentrations in the open were fitted

best to a logarithmic relationship, while those under the canopy (also canopy contribution) fit a semilogorithmic relationship best. Reasons for this change in form of curves expressing the relationship between concentrations and volume of precipitation for throughfall vs incident precipitation were not offered. Eaton et al. (1973) noted that a negative correlation between precipitation volume and concentration of an element in throughfall water was due to a higher degree of leaching during the early part of the storm.

Analysis of Concentration of DOC, FPOC, and TOC in Incident Precipitation vs Collector Volume

For the eight months of data for concentrations of organic carbon in incident precipitation (plotted vs collector volume in Figures 46 to 48) regression analyses were performed, but in this case no analyses were conducted for presence or absence of canopy since only two months of dormant season data were available, and these were marginal months (March and April). While it is true that no canopy was present in the clearings where incident precipitation was monitored, what was really being tested by the qualitative variables was effects of growing season vs non-growing season. Since it has been shown (Went 1960) that it is at least theoretically possible for forest canopy to influence ambient atmospheric organic carbon concentrations, these analyses would have been performed had more data been available for the dormant season. Since no incident precipitation was collected during four leafless months (November - February) only simple regression analyses were performed.

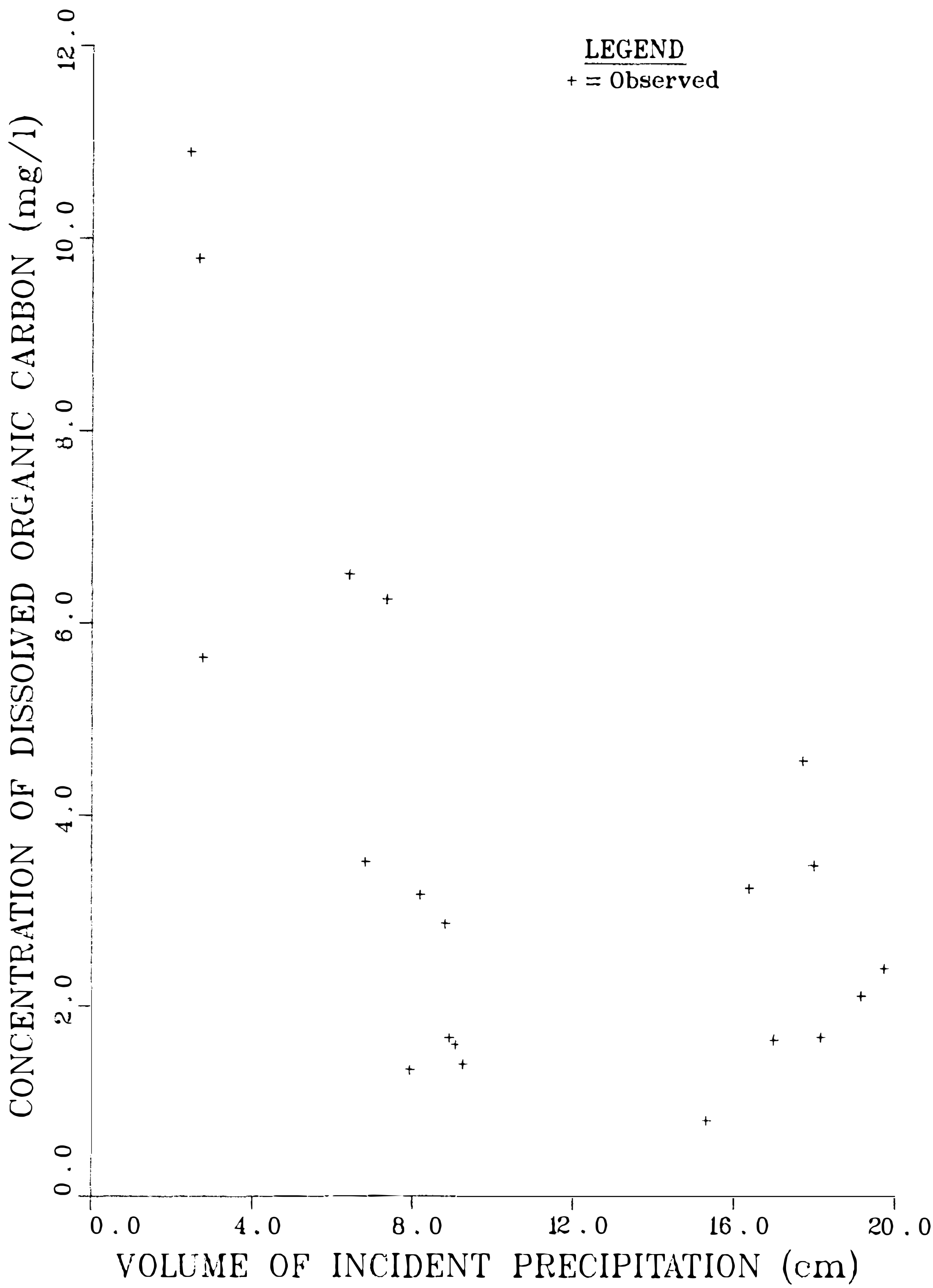

Figure 46. Scattergram Showing the Relationship of Concentration of Dissolved Organic Carbon in Incident Precipitation and Volume of Incident Precipitation for the 1973-1974 Water Year on the West Fork of Walker Branch.

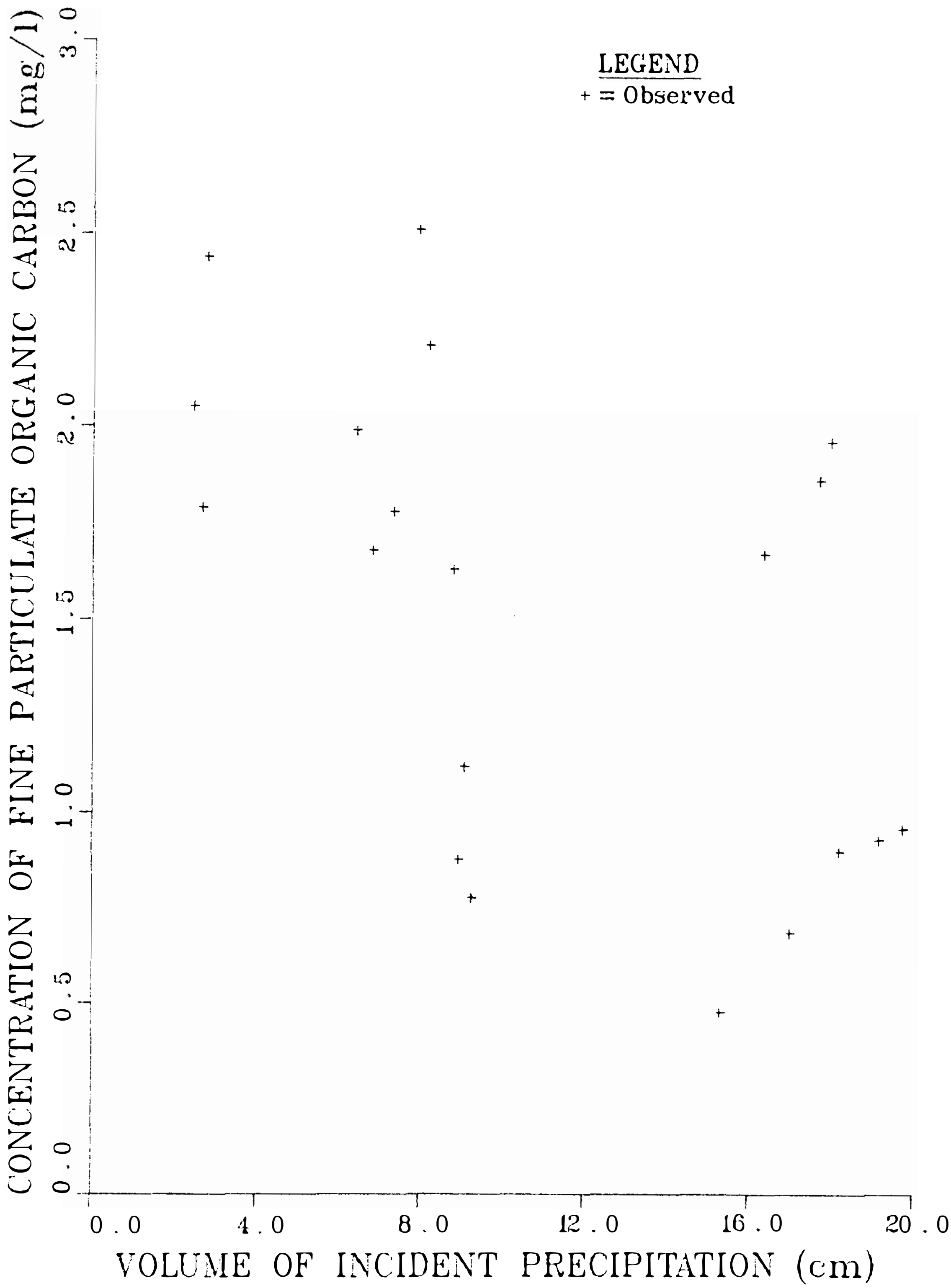

Figure 47. Scattergram Showing the Relationship of Concentration of Fine Particulate (<1 mm) Organic Carbon in Incident Precipitation and Volume of Incident Precipitation for the 1973-1974 Water Year on the West Fork of Walker Branch.

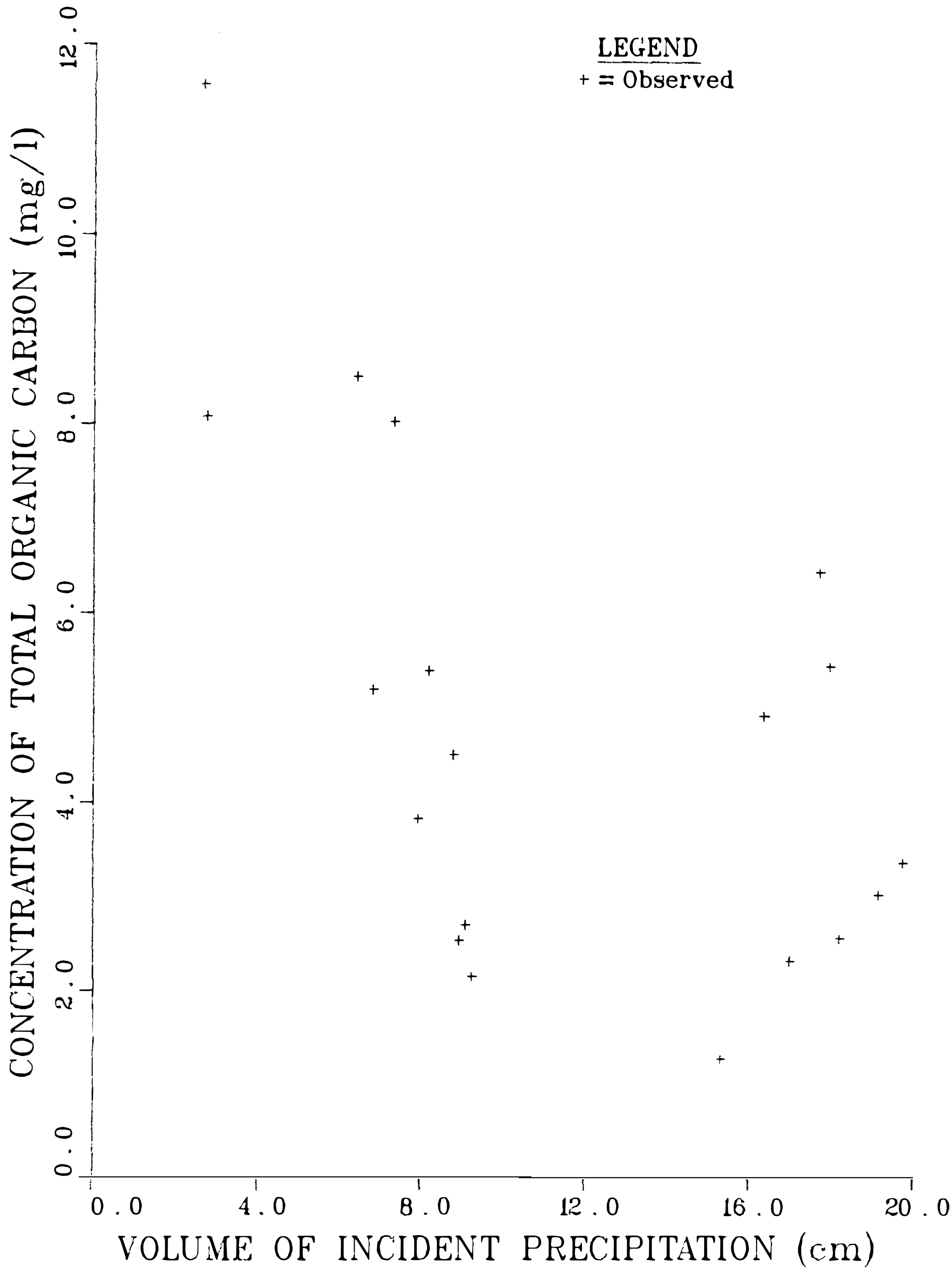

Figure 48. Scattergram Showing the Relationship of Concentration of Total (<1 mm) Organic Carbon in Incident Precipitation and Volume of Incident Precipitation for the 1973-1974 Water Year on the West Fork of Walker Branch.

For all the models run, only the logarithmic relationship provided acceptable fits. The results of these regressions are presented in Table 34. All slopes were significantly different from zero (Pr>T = 0.05), but the relationship was not as well established as that for throughfall, with r^2 values of 0.41, 0.26, and 0.45 for log DOC, log FPOC, and log TOC concentrations, respectively. Thus, while the regressions accounted for a significant portion of the variation of the dependent variables, other independent variables which influenced the behavior of the dependent variables were not included in the analysis. All slopes were negative, indicating a decrease in the concentration of organic carbon with increasing rainfall. Log DOC concentration showed the greatest slope, indicating that the concentration of dissolved material decreased at a faster rate with increasing rainfall than did particulate (or total) organic carbon. This could indicate depletion of DOC in the atmosphere during prolonged main events or months with much precipitation. The fact must be considered that some of the FPOC concentration could be due to dryfall. The predicted values of log DOC, log FPOC, and log TOC concentration vs log of the volume of incident precipitation are shown in Figures 49, 50 and 51, respectively.

Wetselaar and Hutton (1963), working in Australia, where there is a pronounced wet and dry season, found that concentrations of inorganic ions generally decreased during the course of the wet season, and also decreased during the course of a storm, with concentrations inversely related to the amount of precipitation per storm. Visser (1961) showed that during the progress of a storm (in Uganda), most ions were washed out and decreased in concentration in the rainwater. The same thing was

Table 34. Results of Regression Analyses for the Logarithmic Relationship Between Concentration of Organic Carbon (mg/l) in Incident Precipitation and Volume of Incident Precipitation (cm).

Dependent Variable	Independent Variable	r^2	Intercept		Slope	
			Estimate	Pr>T	Estimate	Pr>T
Log DOC	Log Throughfall	0.42	2.63	0.0001	-0.69	0.0015
Log FPOC	Log Throughfall	0.27	1.13	0.0022	-0.36	0.0166
Log TOC	Log Throughfall	0.45	2.85	0.0001	-0.61	0.0012

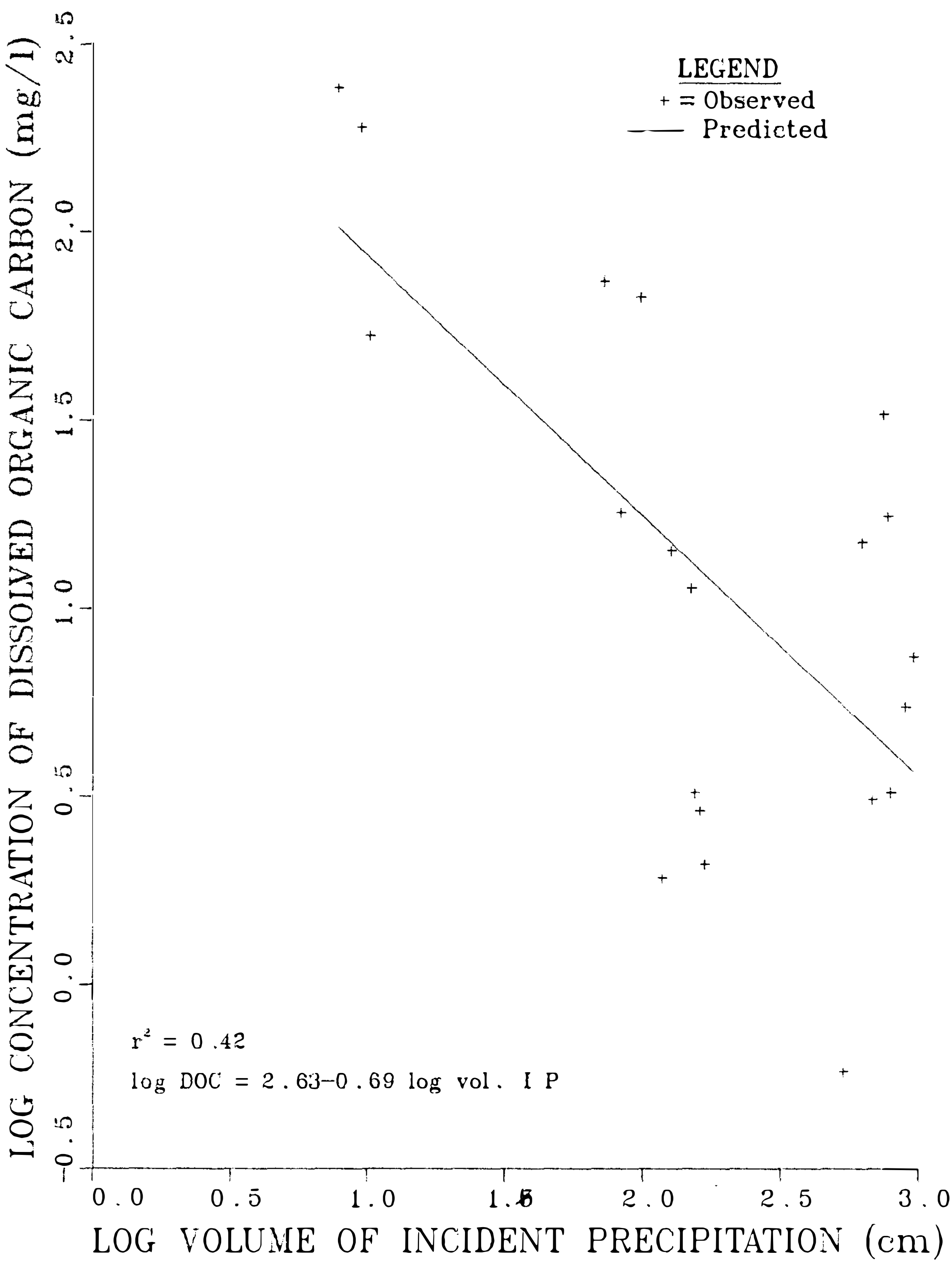

Figure 49. Scattergram Showing the Logarithmic Relationship Between the Concentration of DOC in Incident Precipitation and Volume of Incident Precipitation for the West Fork of Walker Branch for the 1973-1974 Water Year (Eight Months of Data).

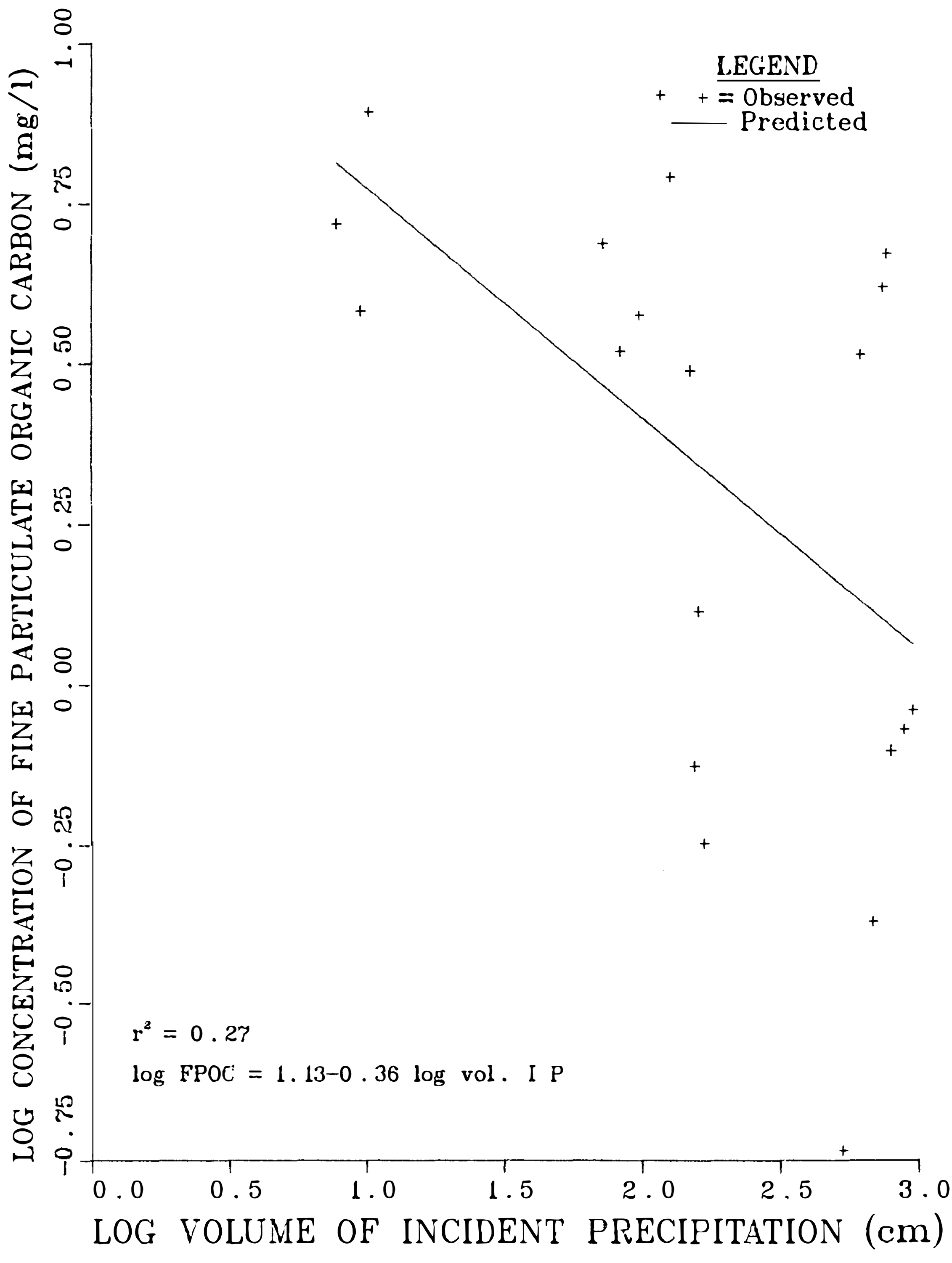

Figure 50. Scattergram Showing the Logarithmic Relationship Between the Concentration of FPOC in Incident Precipitation and Volume of Precipitation for the West Fork of Walker Branch for the 1973-1974 Water Year (Eight Months of Data).

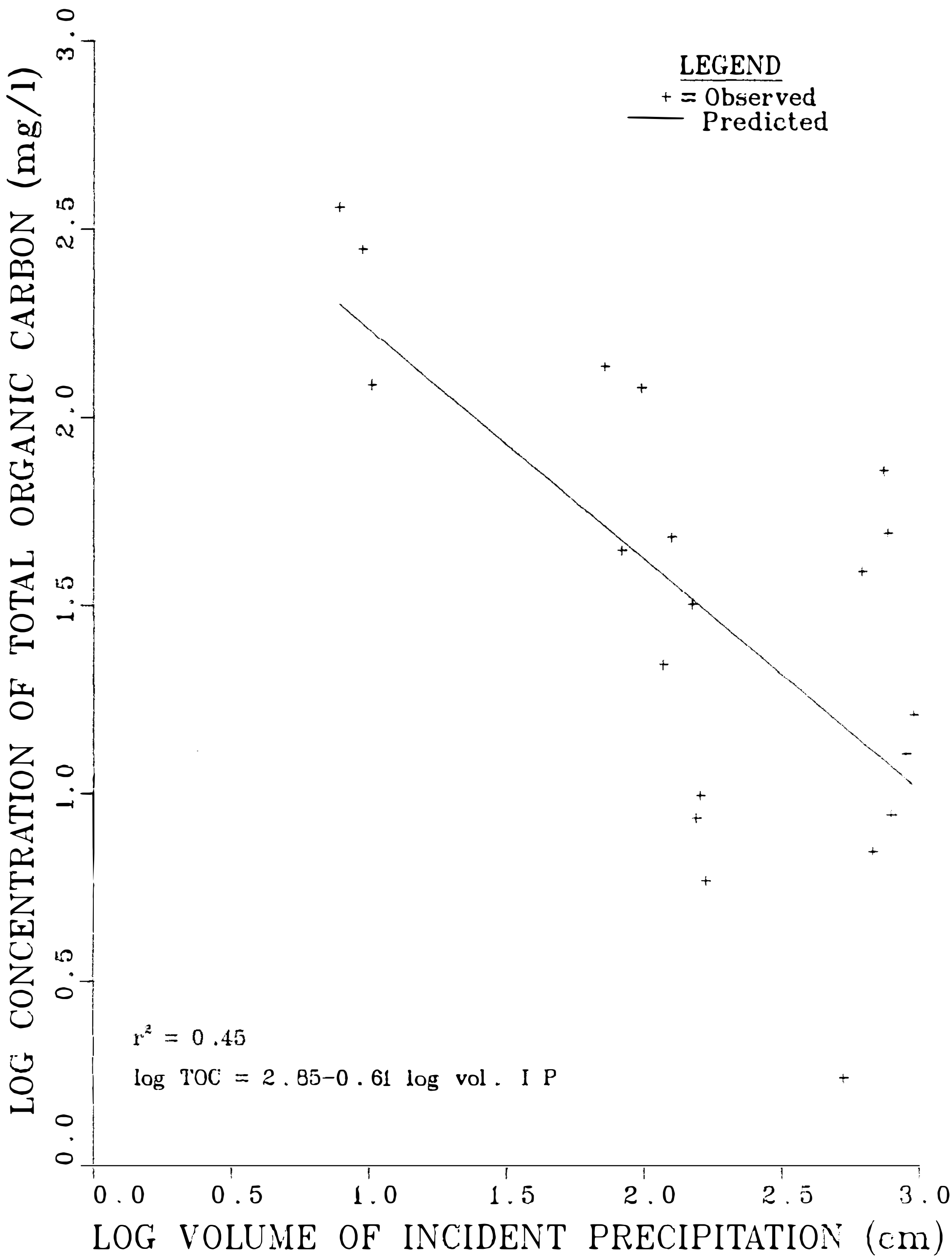

Figure 51. Scattergram Showing the Logarithmic Relationship Between the Concentration of TOC in Incident Precipitation and Volume of Incident Precipitation for the West Fork of Walker Branch for the 1973-1974 Water Year (Eight Months of Data).

seen for successive showers during the wet season, with higher concentrations during the early part of the season.

Munn and Rodhe (1971) reported that monthly mean values for sulphur and chloride (mg/m^2) approach a log distribution (also see Eriksson 1960). Makhon'ko (1967) explained the decreasing concentration of an element during a single rainfall event by washout processes. Sugawara, Oana, and Kayana (1949), and Gorham (1958) have noted that light showering rains usually have much higher concentrations than heavy rainfalls. Dingle and Gatz (1966a) and Gatz (1966) reported an inverse relationship between concentration of pollen in rainfall and rainfall intensity. A number of studies using radioactive particles in the atmosphere (Huff and Stout 1964; Huff 1965; Dingle and Gatz 1966a, 1966b; Gatz 1966; Hall 1965), have shown this inverse relationship between concentrations of contaminants and rainfall intensity.

Huff and Stout (1964) suggested that evaporation of raindrops falling through a relatively dry air at the leading edge of a storm could cause high initial concentrations during a storm. Dust from the ground or lower atmosphere would be collected and deposited in the first rain. Bleeker et al. (1966) felt that the inverse relationship was due to a combination of diffusive capture of aerosols, evaporation of the first rain, and dilution of the load in heavy rain. Gatz and Dingle (1971) attempted to explain the overall negative (but for short periods occasionally positive) correlation of rainfall intensity and concentrations of atmospheric constitutents. They felt raindrop growth and scavenging processes operated to produce the negative correlation, while positive correlation appeared to be due to a predominating advective effect.

From a study of a number of multiple storm events, they concluded that even without substantial evaporative effects, concentration peaks occur early in a storm due to the less effective (smaller) surface to volume ratios of larger drops of heavier rain. Thus, early precipitation of the largest condensation nuclei produces high concentrations at the start of showers, and low concentrations later during the heaviest rain. However, during persistent storms, a much deeper downdraft would lead to greater water loss by evaporation and higher than usual concentrations in the heaviest part of the rain. Hicks (1966), however, proposed that a direct relationship could result from a mid-level entrainment of airborne debris into a severe storm followed by collection of the debris by heavy rain falling in the downdraft.

During the year of this study (September 1973 to August 1974), the monthly distribution of precipitation was somewhat different from the historic average for the Oak Ridge area (see Figure 23, page 131), being for the most part wetter. This was especially true for the leafless period, where only February and April were not substantially above mean monthly values. For the growing season, May and August were above the monthly means, June and July far below, and September and October 1973 were very near the historic monthly means.

The lower than average rainfall in June and July, along with near average readings for September and October, yielded the four months of highest DOC concentrations in throughfall. In contrast, August, which was wetter than normal with a large portion of the monthly rain falling during one four-day period, had DOC concentrations lower than those for April. The same was true for May, with the added factor that most of the

DOC concentrations for this month for throughfall originated in incident precipitation possibly related to the presence of pollen in the ambient air. Thus, during the period when canopy was present, taking into account the seasonal changes in biotic activity, there appeared to be a negative relationship between DOC concentrations in throughfall and volume of throughfall. The coincidence of the period of lowest precipitation (July) with peak or near peak biological activity on the watershed led to the high concentrations of DOC and also FPOC in throughfall, and contributed greatly to the shape of the curve relating concentration to volume of precipitation. The relatively high concentration during April, the month of minimum precipitation for the dormant season, has already been mentioned. Also, February, with second lowest precipitation of the dormant period months, had the second highest concentration of DOC. March, with the third lowest precipitation of dormant period months, had the third highest concentration of DOC. All the remaining months of the leafless season with high volumes of throughfall had concentrations around 2.0 mg/1.

The situation for FPOC was quite similar to that for DOC in most respects, with April and February, the dormant season months, with the lowest and next lowest precipitation, respectively, having the highest and second highest concentrations of FPOC for that season. For the growing season, the same relationship held, with July and June having the first and second highest concentration of FPOC (and lowest volume of throughfall, respectively) and May and August (with the first and second highest volumes of throughfall) the first and second lowest concentrations of FPOC, respectively. September and October, with intermediate volume of throughfall, had the intermediate concentrations of FPOC.

Coincidence of the lowest rainfall with the peak of biological activity and of highest rainfall with the dormant season helped strengthen the apparent negative relationship between concentrations of organic carbon and volume of throughfall as seen within either the dormant or growing season. In a typical year (see Figure 23, page 131), higher throughfall volumes in mid-summer might have reduced concentrations of DOC and FPOC, possibly changing somewhat the shape of the response curve. Possibly, since September and October rainfall was near normal, values for these months could be looked on as typical.

For incident precipitation, the trends for concentration of DOC, while grossly similar to those for throughfall, were less closely tied to volume of precipitation. Thus, while July and June had the first and second highest DOC concentrations, and August the lowest (all based on eight months of data); September, which also had low rainfall, had DOC concentrations lower than those for October or May, months of higher rainfall inputs. March, a dormant season month with high precipitation, had incident precipitation concentrations higher than those of August. April, however, had higher concentrations than March, and in the case of these two months the pattern of increasing concentrations with decreasing precipitation was observed. But here effects of the advent of the growing season must be taken into account.

For FPOC, the relationship between concentration and volume of incident precipitation was not as strong as that involving FPOC and throughfall, especially with regard to the June and July concentrations, which were not higher than those for April and May. However, as each of these pairs of months is compared, the ones with lower precipitation

have higher concentrations. September, with relatively low rainfall, had concentrations as low as those of August and May, months of high rainfall. Attention must be drawn to the fact that these data did not include winter months. Comparing Figures 27 and 28, pages 161 and 165 for DOC and FPOC concentrations in throughfall in winter, it is quite apparent, if we assume that throughfall data are indicative of levels of incident precipitation concentrations, that FPOC declined much more than DOC. The concentrations in incident precipitation for winter would probably have been the lowest of the year. For throughfall, there were no late fall to early winter DOC concentrations as low as the concentrations for September 1973 and August 1974, while for FPOC the means for November, December, and January, months with very high precipitation, had very low concentrations of FPOC (0.49 to 0.72 mg/1), with no other month showing concentrations as low. For February, the concentration was 1.17 mg/1, but February had much less rainfall (13.31 cm).

Thus, it appears that if these data, or preferably concurrent data for incident precipitation, had been used in the analyses for FPOC, the slope of the logarithmic regression would have been steeper, possibly yielding a slope comparable to or greater than that for DOC. Since the log/log relationship for concentration of FPOC in throughfall vs volume of throughfall using the dummy quantitative variables showed that presence of canopy caused the slope of the regression to be less steep, the case for possible greater slope for incident precipitation if the late fall - early winter data had been included is further substantiated.

The lack of late fall - early winter data for concentrations of DOC and FPOC in incident precipitation could also have influenced the

relative magnitude of the slopes of the regression for each variable. In all cases the negative trend was much greater for throughfall. Since the vast majority of incident precipitation measurements were done during the growing season (or in the month directly preceeding or following), the differences in slope of the regression for incident precipitation and throughfall were probably mostly due to the increased levels of organic carbon at low precipitation levels. However, since both DOC and FPOC were expected to be relatively low in winter during periods of high rainfall, the slopes, especially for FPOC, would be expected to be much steeper if a full year's data were available, possibly making them more comparable to those for throughfall.

In general, the seasonal trends for DOC, FPOC, and TOC in throughfall, incident precipitation, and canopy removal were similar (Figures 52 to 54), with lower concentrations for FPOC for all three categories during most of the year. The exception to this occurred during June, when canopy inputs of FPOC were greater than those for DOC (5.10 mg/l as compared to 2.89 mg/l). This occurred despite the higher concentration of DOC in throughfall (8.94 mg/l) as compared to FPOC (6.98 m/l), due to the higher (6.05 mg/l) DOC in incident precipitation (as compared to 1.89 mg/l for FPOC in incident precipitation). The higher concentrations of DOC in incident precipitation are somewhat difficult to explain, but could be due to leaching of water-soluble organics from the particulate material (including pollen) while in the collector.

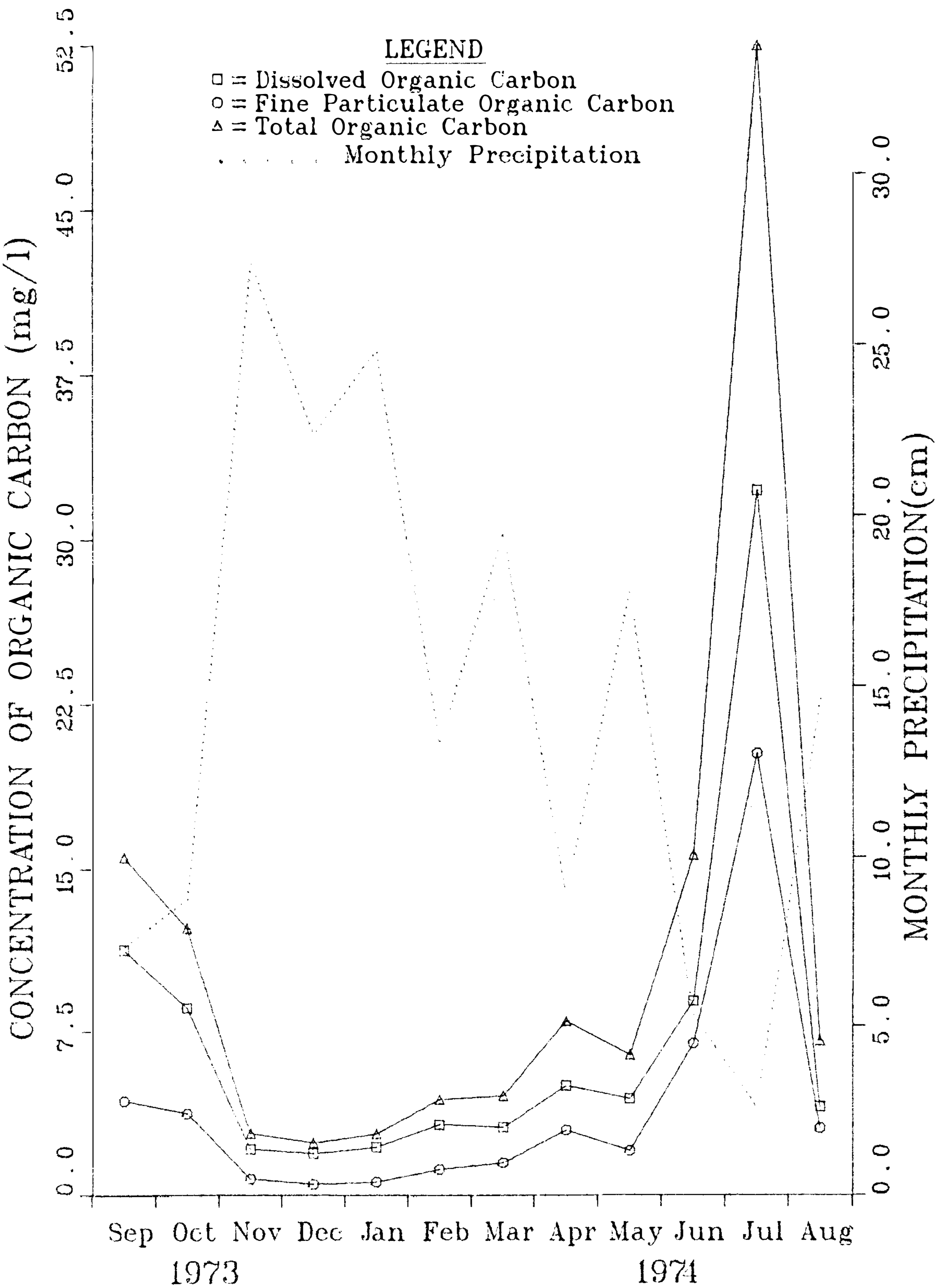

Figure 52. Mean Monthly Concentrations of DOC, FPOC, and TOC in Throughfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

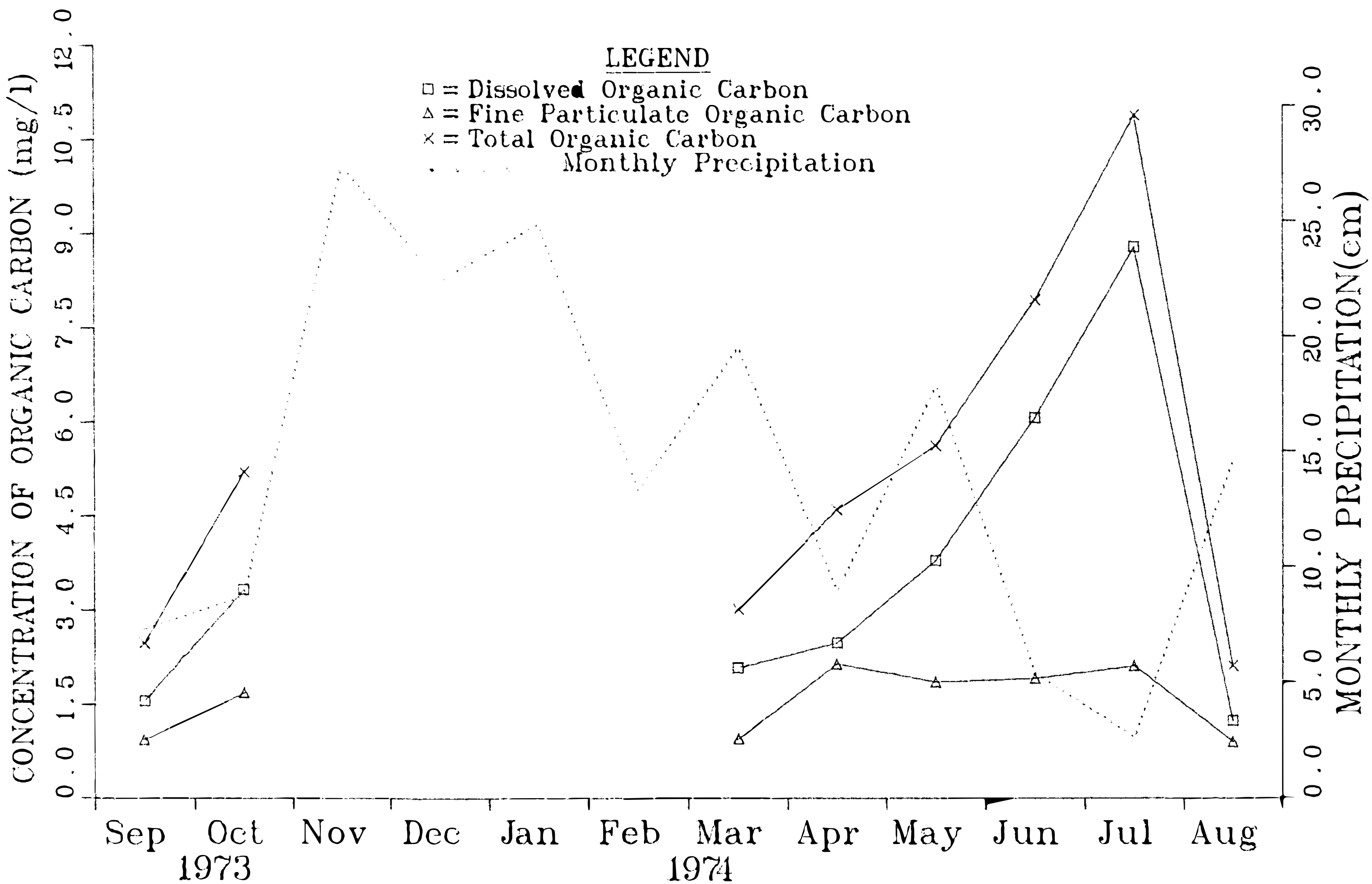

Figure 53. Mean Monthly Concentrations of DOC, FPOC, and TOC in Incident Precipitation for the West Fork of Walker Branch for the 1973-1974 Water Year.

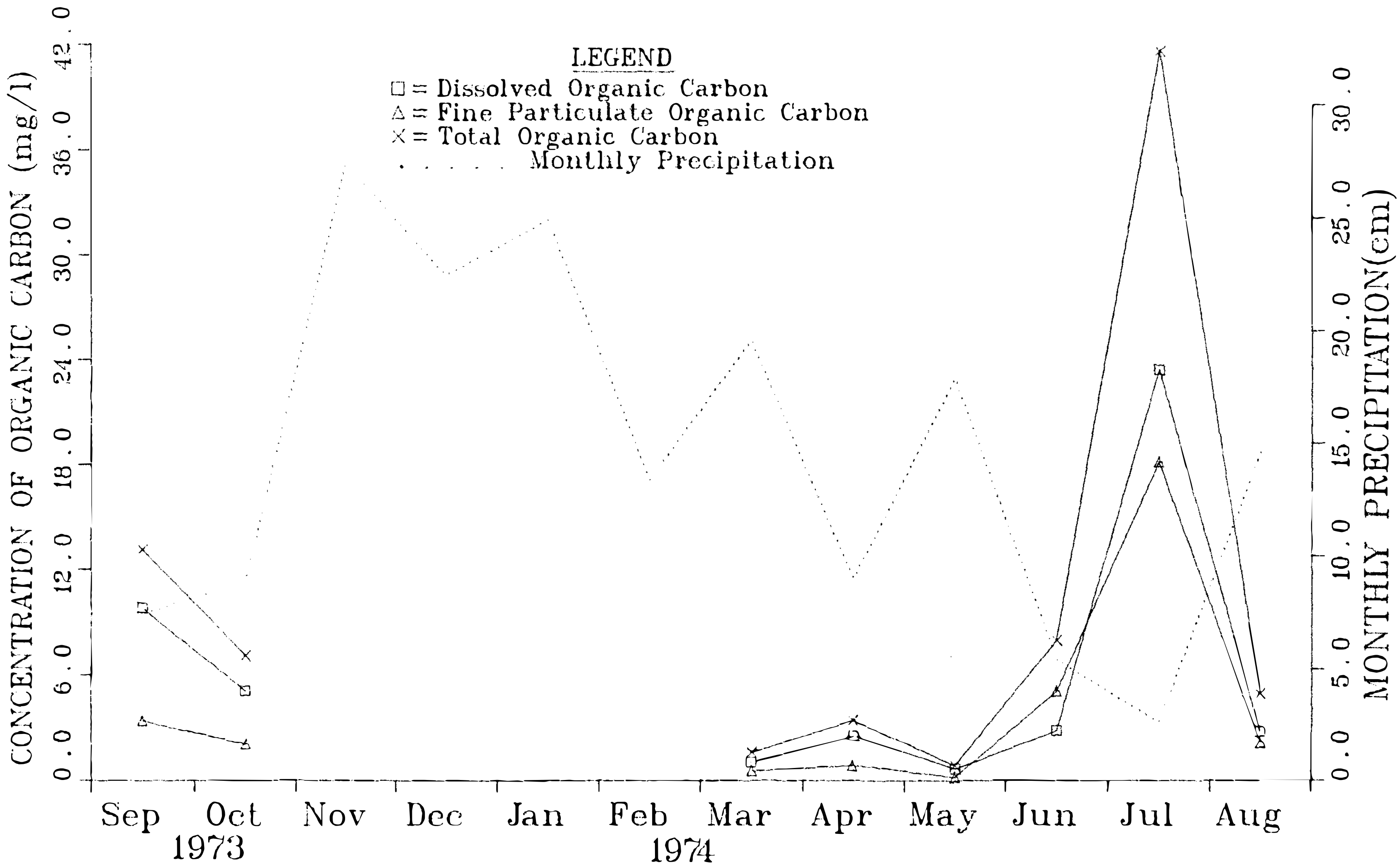

Figure 54. Mean Monthly Concentrations of DOC, FPOC, and TOC in Canopy Contribution for the West Fork of Walker Branch for the 1973-1974 Water Year.

Inputs of Dissolved Organic Carbon

Mean monthly inputs of DOC in throughfall, incident precipitation, and canopy inputs are shown in Figure 55. These means ± one standard error are presented in Table B4, Appendix B. For inputs, which take precipitation volumes into account, different trends are seen when compared to the data for concentrations. No one month showed excessively high throughfall inputs with mean monthly values ranging from 3.32 kg/ha in December to 10.05 kg/ha in September 1973. July, which had by far the highest concentrations of DOC in throughfall, had a dissolved input of 6.77 kg/ha, not unlike those of May, June, August, and also October 1973 (5.36 to 6.37 kg/ha). While the lowest inputs (3.32 and 3.78 kg/ha) were found during some winter months (December and February), similar low values were found in April (3.83 kg/ha). Other months (November, January, and March) during the leafless period showed inputs (5.12 to 5.46 kg/ha) comparable to those of June and October.

For the March through October period, when incident precipitation was monitored, little in the way of a distinct seasonal trend was seen in monthly means for inputs of DOC in incident precipitation. In fact, the lowest incident precipitation inputs were observed in September (1.40 kg/ha), the month of highest throughfall inputs (10.05 kg/ha), indicating canopy leaching/washing. Greatest inputs were found in May (6.55 kg/ha), with June inputs (4.05 kg/ha) similar to those of March (3.93 kg/ha). Values for the remaining months of the growing season ranged from 2.27 kg/ha in August to 2.06 kg/ha for April. The value of 2.40 kg/ha for October may be erroneously high since it is based on only one sample.

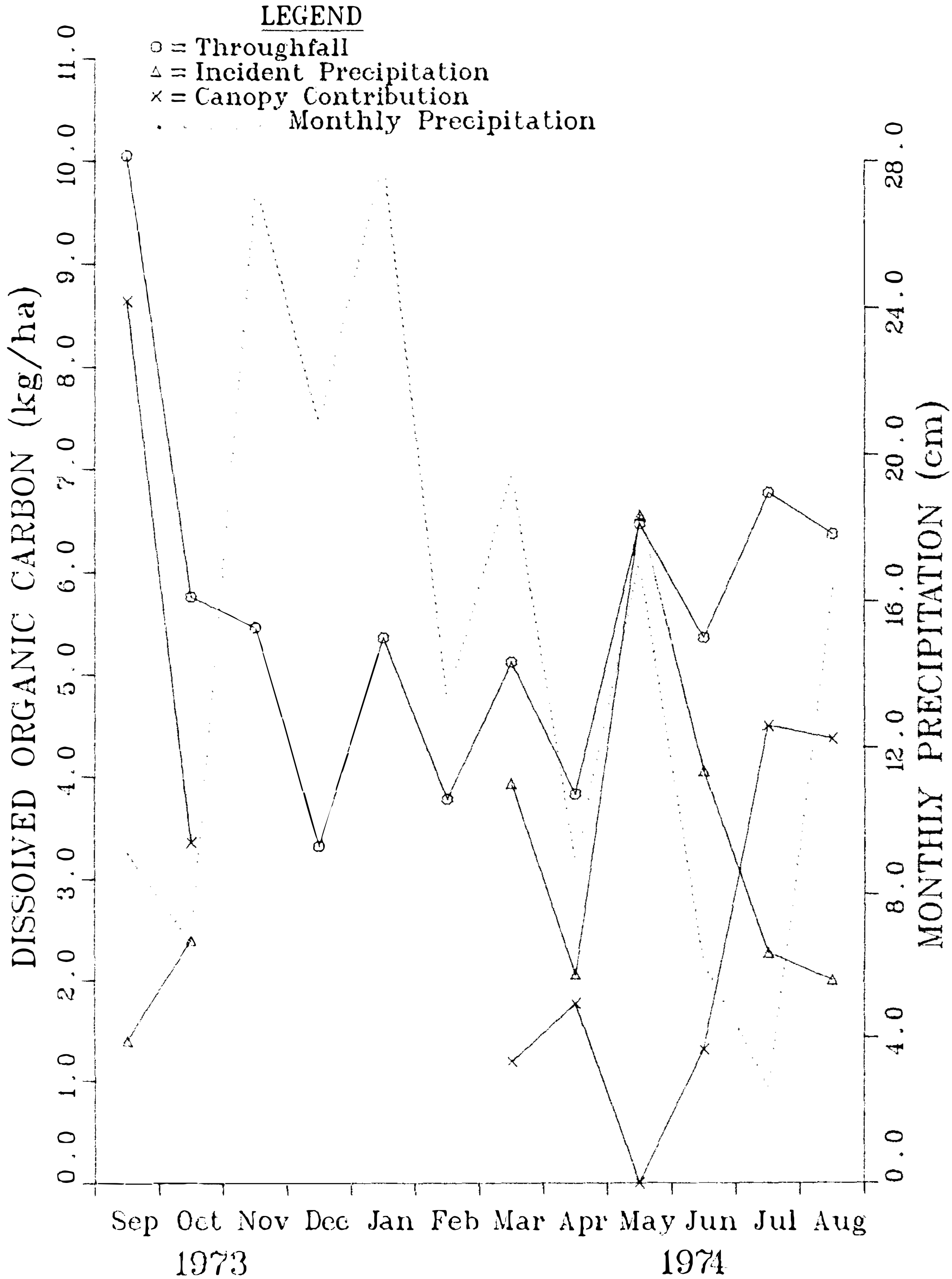

Figure 55. Mean Monthly Input of Dissolved Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

Canopy contribution to DOC inputs for the eight month period of incident precipitation measurement ranged from a high of 8.64 kg/ha in September 1973 to virtually zero (-0.08 kg/ha) in May. This latter value, reflecting net canopy uptake, was due to only small increases in DOC concentration in throughfall over incident precipitation (see Figure 27, page 161) combined with a large amount of interception due to the nature of the precipitation regime (many small storms). The fact that the canopy was newly emergent and insect populations had not yet increased substantially, probably explains the relatively low concentrations of DOC in canopy washing.

Two groups of means are seen for canopy contribution. The July and August 1974 and September and October 1973 canopy inputs of DOC ranges from 3.36 kg/ha (in October) to 8.64 kg/ha (in September), with the July and August inputs similar to each other (4.50 and 4.37 kg/ha respectively). The March through June 1974 period, which includes the negative May inputs, otherwise ranged from 1.19 to 1.77 kg/ha. The enriching effect of the canopy from mid-summer through early fall was evident.

Inputs of Fine Particulate Organic Carbon

Inputs of FPOC in throughfall showed distinct seasonal trends, differing somewhat from those for inputs of DOC. Mean monthly inputs of FPOC in throughfall, incident precipitation, and canopy removal are shown in Figure 56, while Table B5 of Appendix B shows these means ± one standard error. Inputs declined gradually from September 1973 to December 1973 (from 3.82 to 0.85 kg/ha). From the December low, inputs rose consistently during the mid-winter to mid-summer period. From the

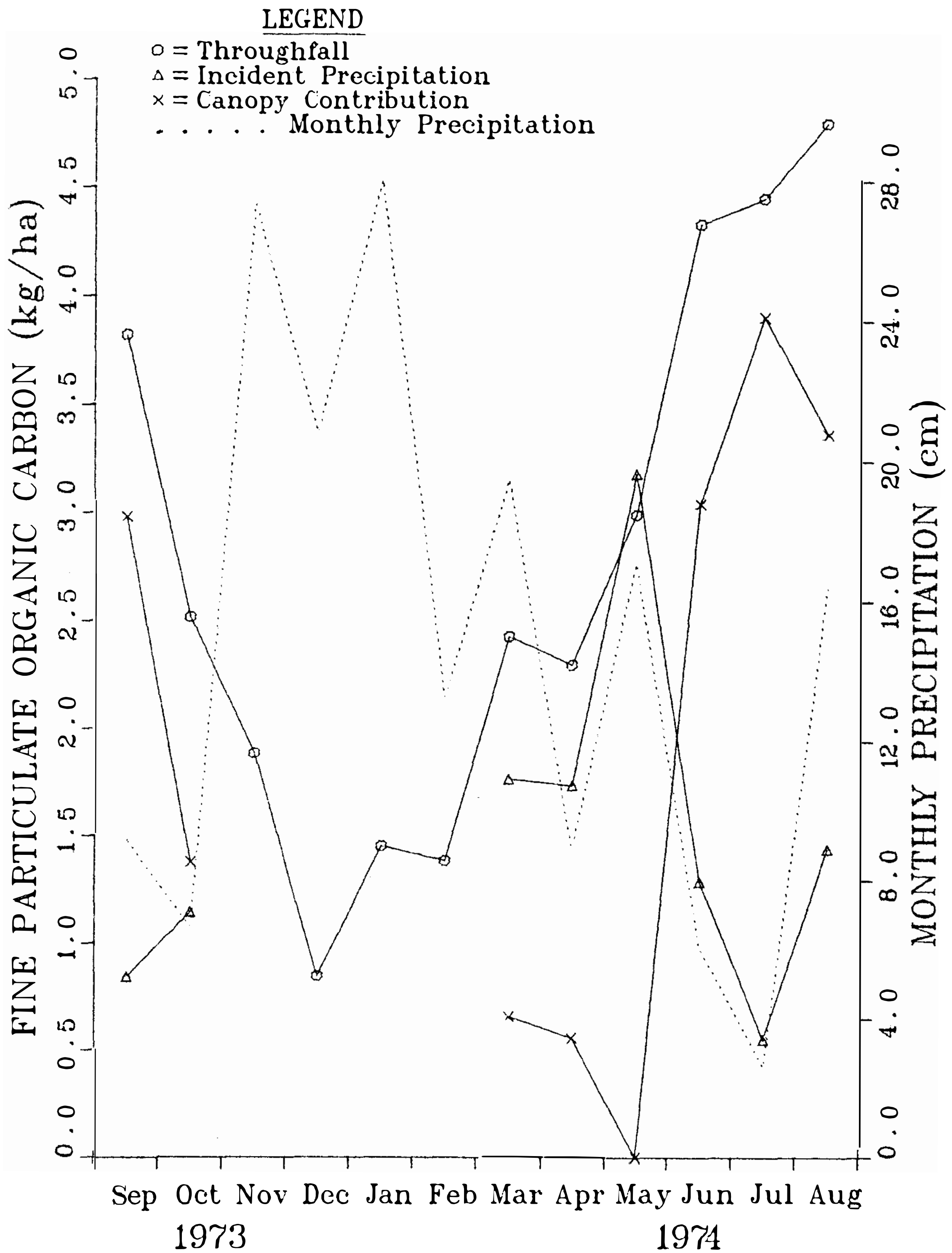

Figure 56. Mean Monthly Input of Fine Particulate (<1 mm) Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

January and February levels (1.46 and 1.39 kg/ha, respectively) and the March to April levels (2.43 and 2.30 kg/ha, respectively) inputs reached 2.99 kg/ha in May, 4.33 kg/ha in June, 4.45 kg/ha in July, and peaked in August (4.80 kg/ha). Whereas DOC inputs were greatest during September 1973, the quantity of FPOC in throughfall during this month was only intermediate.

The 8 months of data for incident precipitation showed inputs ranging between 0.55 kg/ha (July) and 1.77 kg/ha (March), with the exception of May, when an input of 3.18 kg/ha was recorded. Little seasonal trend was evident.

Since the November to February values for throughfall inputs of FPOC were within the range of inputs of FPOC in incident precipitation for most months, and since concentrations of FPOC in throughfall during the winter months were low (0.48 to 1.16 mg/l), throughfall inputs were probably only slightly elevated over those expected for incident precipitation inputs during the winter months.

Except for a negative input in May (-0.19 kg/ha), canopy contributions of FPOC to throughfall varied from 0.56 kg/ha in March and April to 3.90 kg/ha in July. Next highest inputs (2.98 - 3.36 kg/ha) occurred in the periods immediately preceding (June) and following (August 1974 and September 1973) the July peak, with values for all four months quite similar. October 1973 showed somewhat lower inputs (1.38 kg/ha) of FPOC from canopy leaching/washing. July, in addition to showing the highest canopy inputs, had the lowest inputs of FPOC in incident precipitation (0.55 mg/l), while May, with a negative input (net canopy uptake) had the highest incident precipitation inputs (3.18 kg/ha). Otherwise, incident precipitation inputs of FPOC varied between 0.84 and 1.77 kg/ha.

Inputs of Total Organic Carbon

Inputs of TOC in throughfall showed a distinct seasonal trend (Figure 57), although large differences in precipitation volume caused some irregularities. See Table B6 of Appendix B for the standard errors associated with these means. From a December low of 4.17 kg/ha, the monthly means oscillated between 5.17 and 7.55 kg/ha during the February through April period, with the higher values occurring in months with lower precipitation (February and April). In May, TOC input reached 9.48 kg/ha and levels above this were maintained through August. Highest inputs were found in September 1973 (13.87 kg/ha) with inputs declining to 8.28 and 7.34 kg/ha in October and November respectively. In all cases the inputs from DOC were greater than those for FPOC.

A very different situation was seen in the eight months of data for incident precipitation, in which the smallest inputs of TOC occurred during the July through October period (2.24 to 3.54 kg/ha). Due to high throughfall inputs for the late fall to winter months, high inputs of TOC in incident precipitation are assumed for the period. March, April, and June levels (5.70 and 5.67 kg/ha, respectively) are similar to those for the winter season, but the May input (9.73 kg/ha) was the highest of the year. This was due, primarily, to high precipitation volumes accompanying intermediate concentrations of dissolved and particulate organic carbon yielding the highest incident precipitation input of each type for the eight-month period. April inputs (3.81 kg/ha) were similar to that of October. Neumann et al. (1959) found TOC inputs in incident precipitation of 120 - 200 mg/m^2/month for a series of Scandinavian meteorological stations. Assuming that 50% of the organic matter is organic

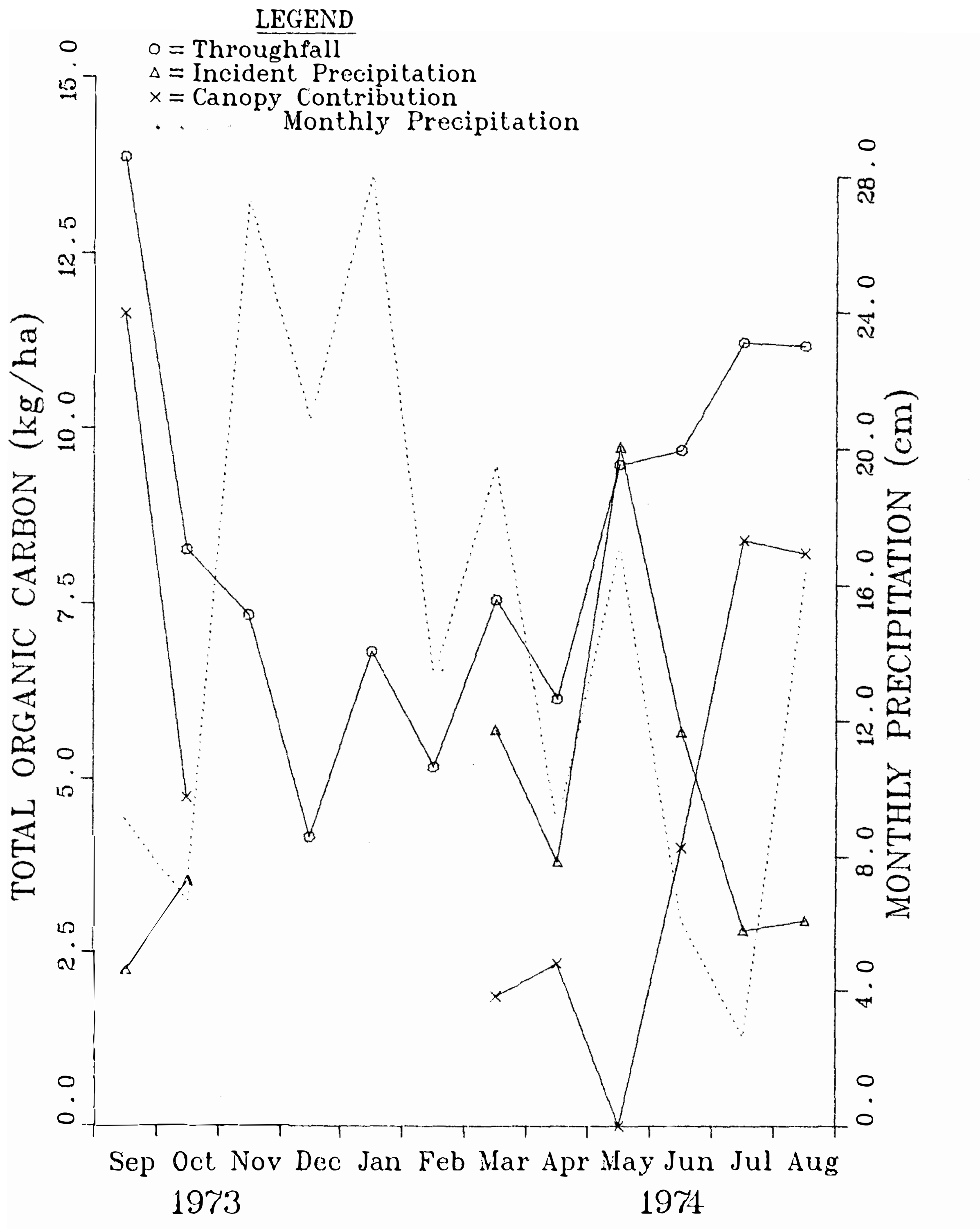

Figure 57. Mean Monthly Input of Total (<1 mm) Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution to the West Fork of Walker Branch for the 1973-1974 Water Year.

carbon, they calculated a yearly input of 4 g/m^2 organic matter. They reported this as being similar to the results of Viro (1953) of 2.74 g organic matter/m^2/yr in Finland.

Net removal from the canopy (throughfall minus incident precipitation) for those months when incident precipitation was monitored (March through October), showed additions from canopy leaching/washing for all months except May. During May, both dissolved and fine particulate uptake occurred (0.08 and 0.18 kg/ha, respectively), and hence a negative total input (-0.25 kg/ha), was observed. Since there was a small net increase in the concentrations of both DOC and FPOC when throughfall and incident precipitation during May are compared, the negative inputs must be explained by other means. Due to the many small rain events during May, (measurable precipitation was recorded on seventeen days), there was a substantial amount of interception. Since the canopy foliage had recently emerged and canopy insect populations had not yet built to substantial levels, there was little increase in concentration of either DOC or FPOC due to canopy contribution. As a result, there was actually a small net uptake by the canopy during May for each form of organic species/carbon (Figures 55 and 56).

Aside from this canopy uptake in May, seasonal trends showed total organic carbon removal increasing from a low of 1.85 kg/ha in March to levels from 8.22 to 11.63 kg/ha during the July through September period. October 1973 levels were near the June 1974 levels (4.74 vs 4.01 kg/ha).

Dalbro (1956) calculated that up to 800 kg/ha/yr of carbohydrates can be leached from apple (*Malus*) foliage. Carlisle et al. (1966a, 1966b) reported inputs of organic matter in incident precipitation and

canopy washing (throughfall minus incident precipitation) of 76.56 and 173.86 kg/ha, respectively for the 1964-1965 year in a sessile oak forest in Great Britain. Of the canopy washing 68.42 kg/ha (39.4%) was soluble carbohydrate. Throughfall values totaled 250.42 kg/ha for the year, of which 30.6% was in incident precipitation and 69.4% was from canopy washing.

For the 1963-1964 year, Carlisle et al. (1966) presented monthly values which showed highest total input (throughfall) and highest canopy removal of organic matter in June through August (67.41 - 100.80 kg/ha and 61.63 - 88.54 kg/ha, respectively). Incident precipitation organic carbon inputs during this time were not particularly high, ranging from 5.78 to 12.26 kg/ha. Low levels of total inputs were found for December through February (6.06 to 8.15 kg/ha) with incident precipitation providing the majority of the input (5.02 - 5.34 kg/ha). Early spring values showed 13.89 kg/ha (March) and 13.37 kg/ha (April) total input, with canopy washing contributing 45.9 and 58.4% of the total for March and April, respectively. May and the period September to November had total inputs ranging from 29.34 to 38.63 kg/ha, with incident precipitation inputs ranging from 8.27 to 9.64 kg/ha for all months except November, which had by far the highest input of organic matter in incident precipitation (22.89 kg/ha) due to large amounts of precipitation and, possibly, the senescent condition of the vegetation (and subsequent release of volatile organics. Although inputs of organic matter due to incident precipitation were lowest in winter, little seasonal trend was apparent. Only two monthly means (June and November) exceeded 10 kg/ha.

A large portion of the 86.74 kg/ha washed from the canopy in August 1963, consisted of soluble carbohydrates (especially melezitose) which the authors attributed to honey dew production. Inputs of carbohydrates for the two study years were 89.18 kg/ha (August 1963 to May 1964) and 68.42 kg/ha (June 1964 - May 1965). Since no carbohydrate was found in incident precipitation, all carbohydrate inputs were attributed to canopy leaching/washing. Reichle et al. (1973) found that aphids returned an estimated 0.5 g carbon/m^2/yr in honeydew for the Liriodendron forest in Oak Ridge, most of which was returned to the soil via leaf washing. This value, equivalent to 5 kg/ha, was much less than that reported by Carlisle et al.(1966).

Results for the two years of work in Great Britain were quantitatively distinct, with total inputs (incident precipitation and canopy washing) of 453.16 and 250.42 kg/ha (ash-free dry weight) of organic matter for 1963-1964 and 1964-1965, respectively, of which 104.33 kg/ha and 76.56 kg/ha were contributed by incident precipitation and 348.83 kg/ha and 173.86 kg/ha washed from the canopy.

In comparison, the data from Walker Branch showed total input of organic carbon in throughfall at 100.90 kg/ha, or approximately 200 kg/ha organic matter. This value is close to the 1964-1965 data from the sessile oak forest. For canopy contributions, assuming none for the leafless period at Walker Branch, the value for the Oak Ridge site was 40.94 kg/ha organic carbon, considerably lower than the values for either year for canopy washing in Great Britain. Inputs via incident precipitation were similar for both forests (assuming incident precipitation equal to throughfall for the November through February period at Walker Branch),

with the yearly total at Walker Branch (59.96 kg/ha) being slightly greater than the 1963-1964 value for the sessile oak forest.

Due to the different precipitation regimes for the Oak Ridge and England sites, seasonal patterns of inputs were quite different, with greatest inputs for the sessile oak forest occurring in summer, when high precipitation levels accompanied high concentrations of organic matter. For Walker Branch, the high concentrations in the summer months were accompanied by low rainfall, and the month with the highest level of throughfall inputs (May) showed incident precipitation inputs actually greater than those in throughfall.

Eaton et al. (1973) studied throughfall under the canopies of three dominant tree species at Hubbard Brook, New Hampshire for the June through October growing season. No incident precipitation data were given for organic matter, and dissolved and very fine particulate forms were not segregated. For the five-month period, total input to the forest floor (calculated from known litterfall values and leaf surface regressions) from incident precipitation plus canopy contribution (leaching/ washing) was 103.94 kg/ha, with individual monthly means being 14.04 kg/ha, 38.10 kg/ha, 27.75 kg/ha, 9.36 kg/ha, and 14.69 kg/ha for the months June through October inclusive. While inputs were closely associated with volumes of monthly precipitation, the fact that June inputs were less than those for October, when the latter month had only two-thirds as much rain, would indicate either a greater washing/leaching of the foliage or a greater concentration in incident precipitation or both.

Fisher and Likens (1973), reporting on calculations made from the same data used by Eaton et al. 1973) for the June through October growing season at Hubbard Brook, found mean throughfall inputs to Bear Brook of 7.2 g/m^2/season or 72 kg/ha/season.

Comparing the Oak Ridge results with those from Hubbard Brook, the 54.23 kg/ha of organic carbon in throughfall for the June to October period are very similar to the 103.94 kg/ha organic matter for the same five months at Hubbard Brook, and are somewhat higher than the 72 kg/ha calculated by Fisher and Likens (1973) from the same data for inputs to Bear Brook.

Based on leaching experiments on southern red oak, live oak, and longleaf pine growing on spodic soils of the North Carolina Coastal Plain, Malcolm and McCracken (1968) estimated that 20 kg/ha per year of organic matter could be contributed to the soil from this source. This value is quite close to the 40.94 kg/ha of organic carbon calculated for throughfall for Walker Branch.

<u>Analysis of Inputs of DOC, FPOC, and TOC in Throughfall and Incident Precipitation vs Volume of Rainfall</u>

Data for inputs of DOC, FPOC and TOC were statistically analyzed according to the procedures of Sokal and Rohlf (1969, pp 428-436) for situations of multiple dependent readings for each value of the independent variable. Since collector volume (representing either throughfall volume or incident precipitation volume) was used to calculate inputs, and a number of replicate samples were taken each month, rainfall values for the corresponding periods (as measured by the three watershed rain

gages and calculated according to the weighted Thiessen method) were used as values of the independent variable.

The first step in these analyses involved one-way ANOVA's with rainfall as the class variable. If results of any of these analyses proved significant (Pr>T = 0.05), subsequent analyses were performed. If no significant differences occurred between classes, the chance for a significant regression coefficient ($\alpha = 0.05$), while remotely possible, was extremely unlikely and the analysis was not continued. Since the ANOVA is insensitive to the relative magnitude of values for the independent variable, several forms of the independent variable were tested for each case in which the initial ANOVA showed a significant F value. The initial ANOVA's were run on several forms of the dependent variable (input) including normal, log, and inverse forms.

Plots of the individual observations for inputs of DOC, FPOC, and TOC for throughfall and incident precipitation vs rainfall are shown in Figures 58 to 60, and Figures 61 to 63, respectively

Results of the ANOVA's are shown in Table 35. For all dependent variables for both incident precipitation and throughfall, significant F values occurred. As a consequence, subsequent analyses were performed for all three forms of the dependent variable (normal, logarithm, and inverse) for both cover types. The following regression models were tested: normal, semilogarithmic, logarithmic, inverse. The procedure involved partitioning the sums of squares within groups into those due to linear regression and those due to deviations from linear regression, with 1 and a-2 degrees of freedom respectively, where a equals the number of classes of the independent variable in the original ANOVA. Mean

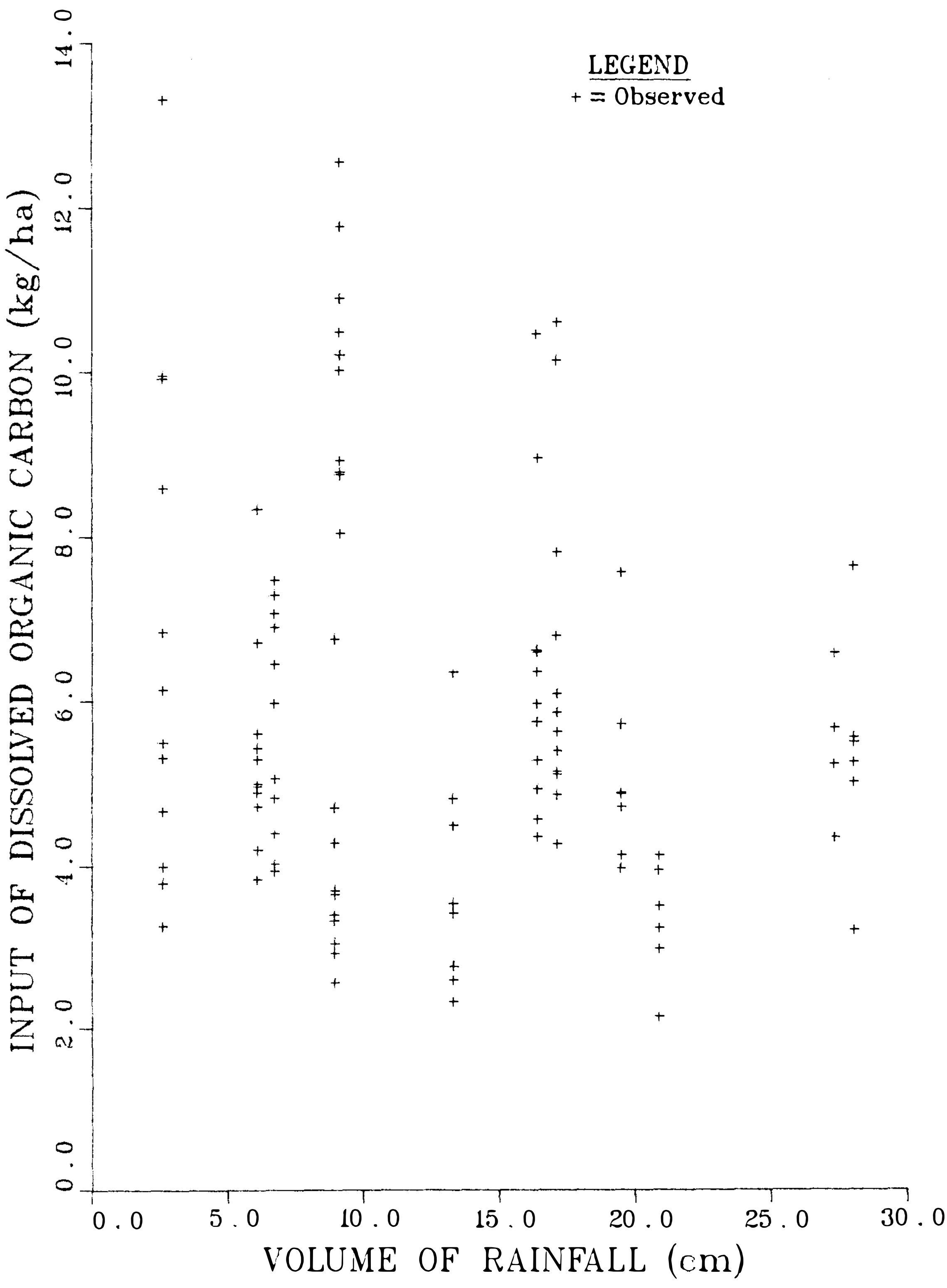

Figure 58. Scattergram Showing the Relationship Between Input of Dissolved Organic Carbon in Throughfall and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

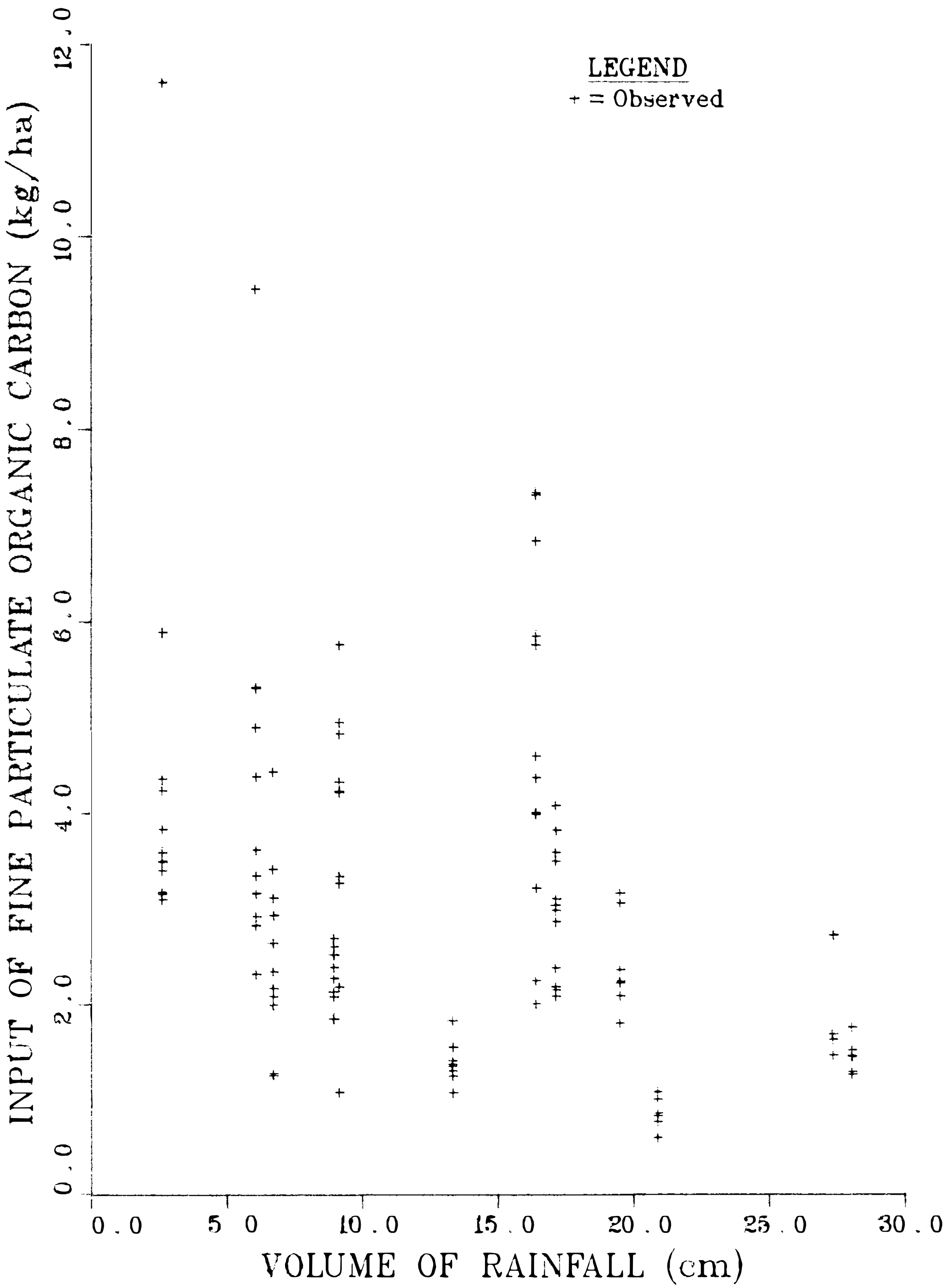

Figure 59. Scattergram Showing the Relationship Between Input of Fine Particulate (<1 mm) Organic Carbon in Throughfall and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

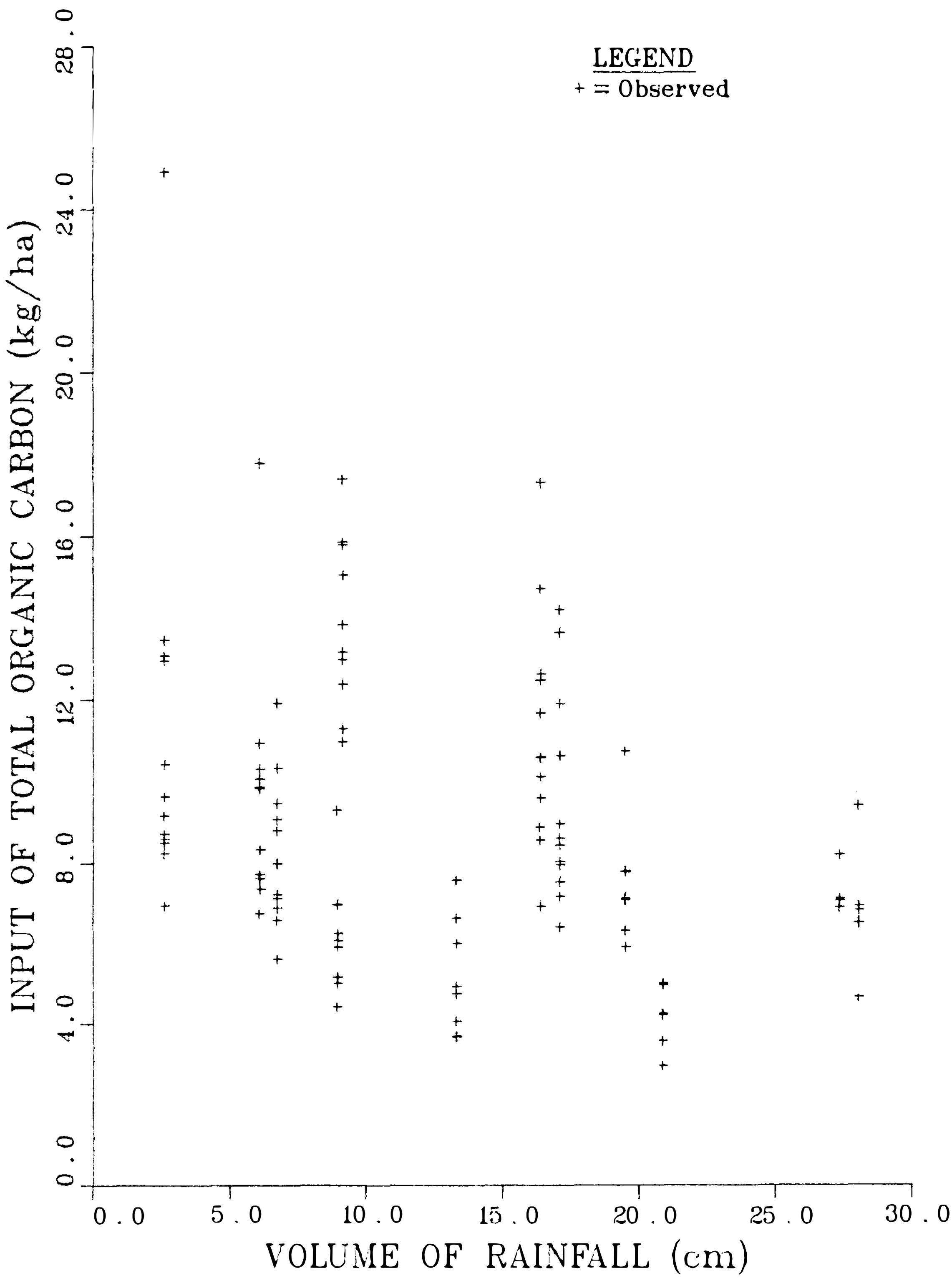

Figure 60. Scattergram Showing the Relationship Between Input of Total (<1 mm) Organic Carbon in Throughfall and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

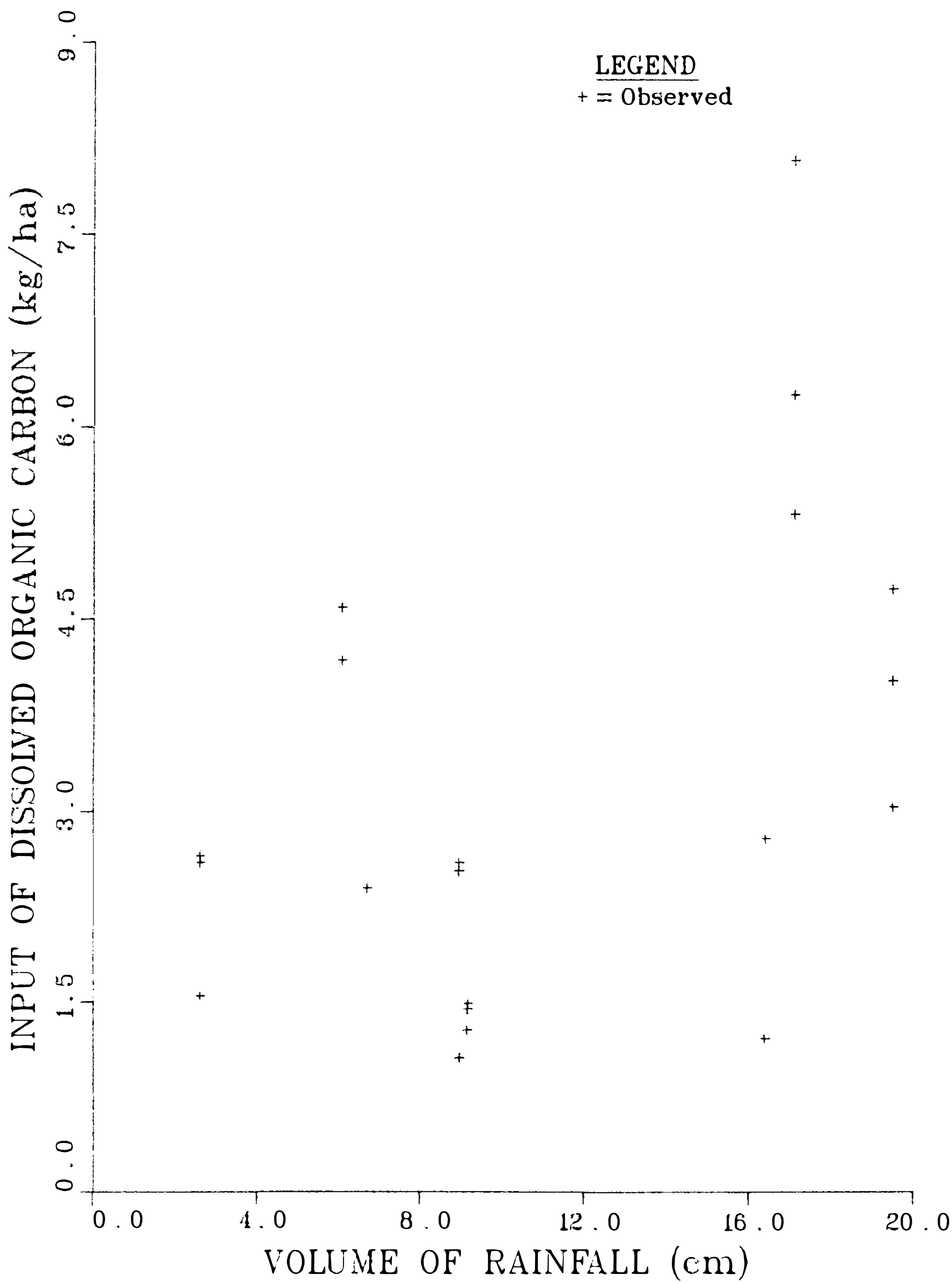

Figure 61. Scattergram Showing the Relationship Between Input of Dissolved Organic Carbon in Incident Precipitation and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

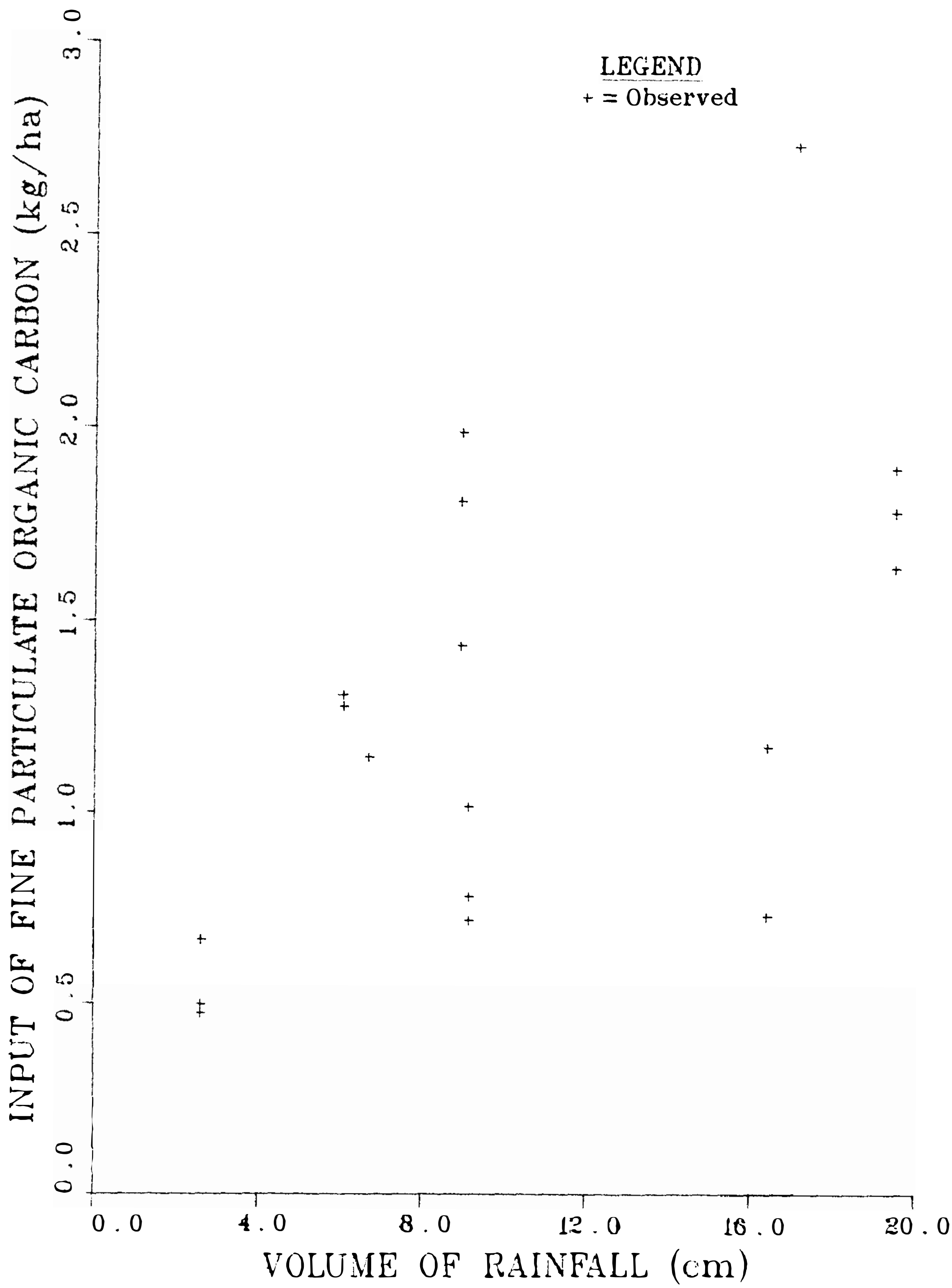

Figure 62. Scattergram Showing the Relationship Between Input of Fine Particulate (<1 mm) Organic Carbon in Incident Precipitation and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

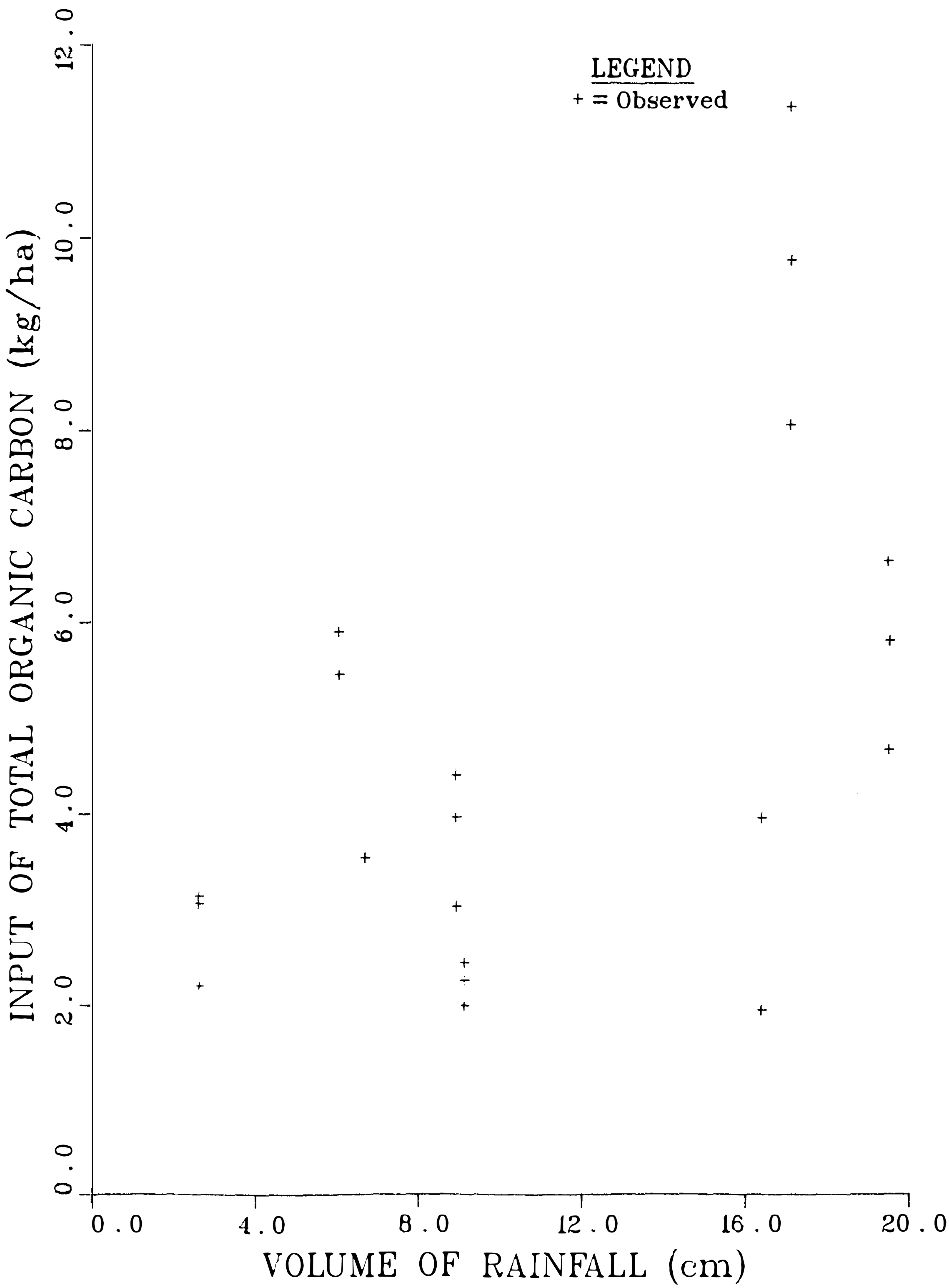

Figure 63. Scattergram Showing the Relationship Between Input of Total (<1 mm) Organic Carbon in Incident Precipitation and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

Table 35. Results of Regression Analyses for Inputs of Organic Carbon in Throughfall and Incident Precipitation and Volume of Rainfall: Initial ANOVA's

Dependent Variable	Independent Variable	Cover Type	F	Pr > F
Input of DOC	Volume of Rainfall	Canopy Present	9.70	0.0001
Input of FPOC	"	"	8.45	0.0001
Input of TOC	"	"	10.41	0.0001
Log Input of DOC	"	"	10.31	0.0001
Log Input of FPOC	"	"	19.03	0.0001
Log Input of TOC	"	"	16.85	0.0001
Input of DOC	Volume of Rainfall	Canopy Absent	10.91	0.0002
Input of FPOC	"	"	11.66	0.0001
Input of TOC	"	"	18.28	0.0001
Log Input of DOC	"	"	7.37	0.0011
Log Input of FPOC	"	"	11.40	0.0001
Log Input of TOC	"	"	14.35	0.0001

square of deviations from regression were tested over the within-group mean square, while mean square due to linear regression was tested over the mean square of deviations from regression. For a given form of the dependent variable, the same error mean square (as derived from the initial ANOVA involving that form of the dependent variable) was used in all tests, no matter what form of the independent variable was used. Deviations from regression were tested at $F_{.05\ (a-2,\ n_i-1)}$ where n_i is the total number of observations in the analysis. Linear regression was tested at $F_{.05\ (1,\ a-2)}$.

Results are shown in Table 36. Of all the relationships tested, only ones involving fine particulate organic carbon in incident precipitation showed a slope significantly different from zero. Regressions with significant slopes included the semilogarithmic, logarithmic, and inverse/forms. The logarithmic relationship is preferred in this case because it resulted in a lower F value for deviations from regression. However, in all cases the deviations from regression were also significant (Table 36). This means that while the regressions explain a significant portion of the within-group sum of squares, heterogeneity of the data is such that certain important environmental (independent) variables have been left out of the model. A plot of individual observations of log of fine particulate organic carbon inputs vs log rainfall are presented in Figure 64, along with the predicted regression line.

If a strong negative relationship between concentration of DOC and volume of throughfall exists, one would expect that the inputs, being a product of the two, would show little relationship to volume of throughfall. The tendency should be for the monthly means to approach a median

Table 36. Results of Regression Analyses for Inputs of Organic Carbon in Throughfall and Incident Precipitation and Volume of Rainfall: Subsequent Analyses

			Cover Type	
Dependent Variable	Independent Variable	Test	Under Canopy	Open
Input of DOC	Volume of Rainfall	1	0.61[ns]	1.88[ns]
Input of FPOC	"	1	3.75[ns]	5.26[ns]
Input of TOC	"	1	1.91[ns]	2.76[ns]
Log Input of DOC	"	1	0.42[ns]	1.40[ns]
Log Input of FPOC	"	1	3.96[ns]	6.89[sd]
Log Input of TOC	"	1	1.65[ns]	2.54[ns]
Input of DOC	1/Volume of Rainfall	1	0.50[ns]	0.69[ns]
Input of FPOC	"	1	3.22[ns]	3.96[ns]
Input of TOC	"	1	1.62[ns]	1.30[ns]
Log Input of DOC	Log Volume of Rainfall	1	0.46[ns]	0.80[ns]
Log Input of FPOC	"	1	3.65[ns]	9.26[sd]
Log Input of TOC	"	1	1.70[ns]	1.92[ns]
Input of DOC	Volume of Rainfall	2	10.05[sd]	9.71[sd]
Input of FPOC	"	2	7.32[sd]	7.24[sd]
Input of TOC	"	2	9.61[sd]	22.31[sd]
Log Input of DOC	"	2	10.84[sd]	7.06[sd]
Log Input of FPOC	"	2	14.99[sd]	6.20[sd]
Log Input of TOC	"	2	15.91[sd]	11.76[sd]
Input of DOC	1/Volume of Rainfall	2	10.15[sd]	11.44[sd]
Input of FPOC	"	2	7.03[sd]	8.19[sd]
Input of TOC	"	2	9.85[sd]	17.53[sd]
Log Input of DOC	Log Volume of Rainfall	2	10.79[sd]	7.68[sd]
Log Input of FPOC	"	2	15.34[sd]	5.23[sd]
Log Input of TOC	"	2	15.86[sd]	12.68[sd]

	Cover Type	
Critical F values:	Under Canopy	Open
[a]Test 1: Deviations due to Regression	4.96	5.99
Test 2: Deviations from Regression	1.91	2.92

[b]ns = not significant; sd = significant difference

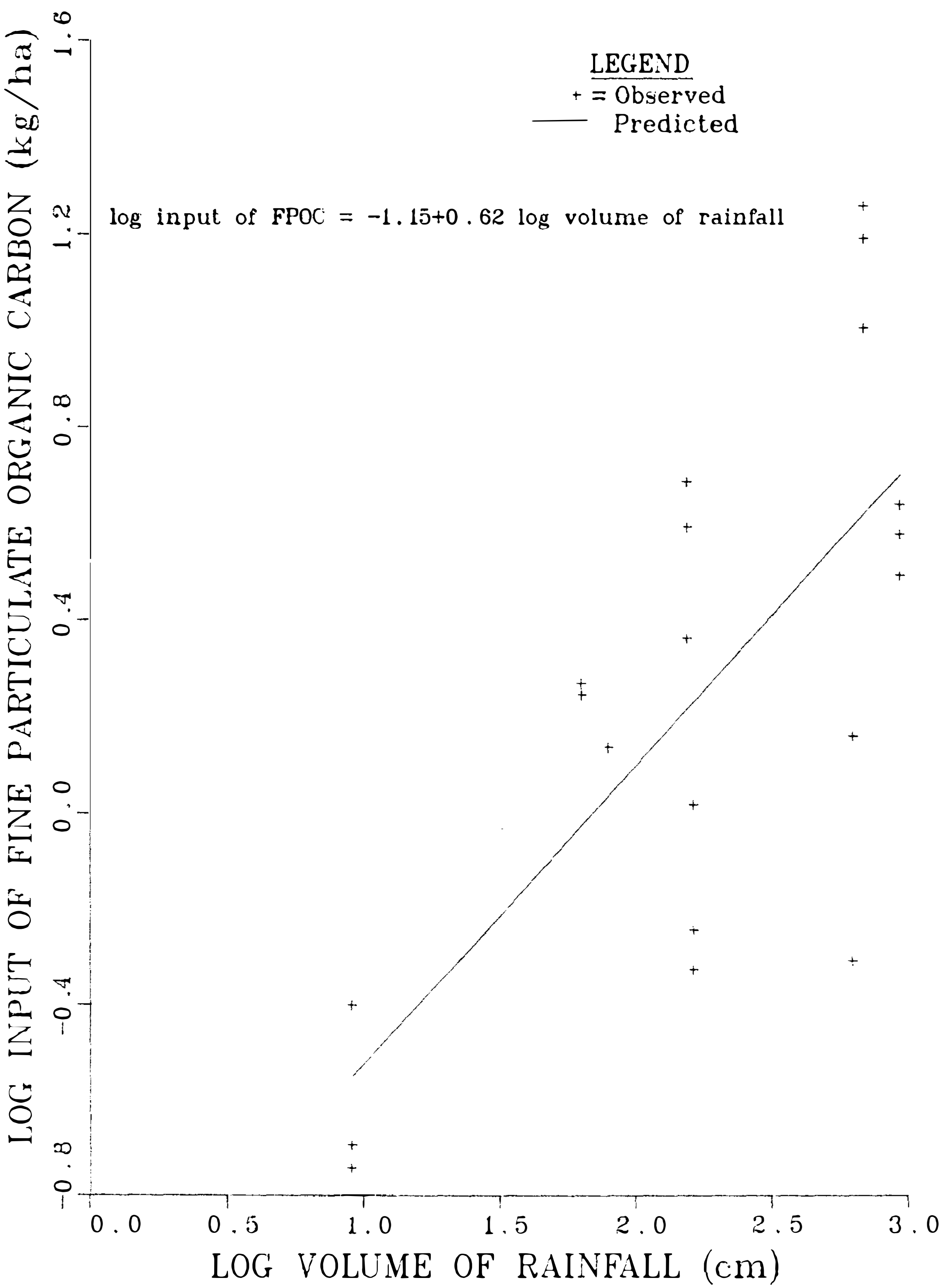

Figure 64. Scattergram Showing the Logarithmic Relationship Between Input of Fine Particulate Organic Carbon (<1 mm) and Volume of Rainfall for the West Fork of Walker Branch for the 1973-1974 Water Year.

value. Such is the case with DOC input in throughfall. Except for the case of September, where the second highest DOC concentration (11.3 mg/l) accompanied a mid-range volume of throughfall and yielded the highest monthly DOC input (10.05 kg/ha), all values were between 3.32 and 6.77 kg/ha, a factor of only two, occurring over greater than an order of magnitude difference in volume of throughfall (2.60 cm to 27.41 cm). Several examples will show independence of DOC input from concentration. Comparing July and August, we find that while concentration differences of eightfold existed, and volume differences of about sixfold existed, the inputs were virtually the same (6.77 vs 6.37 kg/ha for July and August, respectively). May, with even greater rainfall than August, had inputs below those for July and August. A similar situation existed for October and November, in which a precipitation difference of greater than three times yielded input differences of 0.30 kg/ha. The high September values indicated possible significant leaching of the senescing canopy.

The FPOC inputs in throughfall, which showed a greater overall range than DOC inputs (0.85 - 4.80 kg/ha) exhibited a smooth temporal transition from a low in December to a high in August, and a steady decline through November. While the three months (November - January) with throughfall volumes greater than 20 cm had the lowest inputs, when comparing the three months, there was a positive trend between volume and input. However, February, with more than 10 cm less volume of throughfall than January, had virtually the same input; and March, with not quite 20 cm of throughfall, had higher inputs than any of the other dormant season months. Comparing July and August, where a sixfold difference

occurred in volume of throughfall, only a 7% difference in input existed.

For FPOC inputs in incident precipitation, where a range of 0.93 - 2.12 kg/ha concentration was seen for the eight months of data, a somewhat greater range was seen in inputs (0.55 - 3.18 kg/ha). In this case, lowest input was associated with the month of lowest volume of incident precipitation (July), with June, September, and October, with the next lowest volumes of incident precipitation, constituting the set of months with next lowest inputs. However, March and April, which differed by a factor of two in volume of precipitation, had virtually identical inputs, being near the middle of the input range for the eight months. Comparing March with May (the former with the greater amount of rainfall), it is seen that the latter had 54% greater input of FPOC in incident precipitation. Thus, the significant positive relationship with volume of incident precipitation is due largely to the trends during those summer months with lowest precipitation.

For DOC, concentrations in incident precipitation varied from 1.22 to 8.78 mg/l, while inputs ranged from 1.40 to 6.55 kg/ha. For the summer months (June - September), when rainfall varied from 2.6 to 14.6 cm, and concentrations of DOC varied from 1.22 to 8.78 mg/l, inputs ranged from 1.40 to 4.05 kg/ha, with little relation to volume of rainfall. October and April, with similar precipitation volumes, had similar inputs. March, with the highest input of precipitation, had an intermediate input, while May, with the next highest, had the highest inputs. The overall trend then was a slight (not significant) tendency for inputs to be positively related to volume of precipitation.

Total Inputs

Total inputs of dissolved and particulate organic carbon in throughfall were 95.02 kg/ha/yr for the September 1973 through August 1974 period. Of this total, 63.72 kg/ha/yr (two-thirds) was deposited as dissolved organic carbon, with the remaining 31.30 kg/ha/yr (one-third) coming down in fine particulate form.

For the periods of September through October 1973 and March through August 1974 when incident precipitation was also monitored, 72.88 kg/ha/yr organic carbon were deposited as throughfall, with the dissolved and fine particulate fractions accounting for 46.84 and 26.04 kg/ha/yr (64% and 36% respectively).

Incident precipitation inputs during this time (September and October 1973 and March through August 1974) totaled 34.21 kg/ha, with 23.00 kg/ha (two-thirds) and 11.2 kg/ha (one-third) contributed by the dissolved and fine particulate fractions, respectively.

During the eight month period when both throughfall and incident precipitation were monitored, there was a net removal of 38.68 kg/ha from the canopy; of this, 23.84 kg/ha (61.6%) was in dissolved form and 14.84 kg/ha (38.4%) was in fine particulate form. Thus, although more DOC was removed from the canopy than was FPOC, the proportion of FPOC in the total (TOC) increased over that in the incident precipitation.

Throughfall for the November to March period was 22.14 kg/ha, of which a very large fraction (76.2%) was contributed in dissolved form (16.88 kg/ha). Particulate contributions (5.26 kg/ha) amounted to only 23.8% of total input for the period.

DOC and FPOC net removal followed similar trends, with dissolved contribution greater during all months except June, when FPOC constitu-

ted 70% of the net removal. This situation resulted even though DOC concentrations in throughfall were greater than the FPOC concentrations, because incident precipitation levels of DOC were also much higher than those of FPOC. The other extreme was seen in the September through October and the March through April data, where DOC constituted 64.2% to 76.1% of the net removal. July and August values for percent DOC in net removal were 54.5% and 56.5%, respectively.

DOC contributed from 73.4% to 79.6% of the TOC (either concentrations or inputs) in throughfall during the four winter months. In no other month was the proportion of total throughfall input in dissolved form this great, but September and October values (72.6% and 69.8%, respectively) of DOC were close. For the rest of the year, DOC contributed 56.2% to 69.8% of the total, with the lowest values (56.2% to 61.4%) being recorded during early to mid-summer (June to August). During this latter period DOC constituted a greater percentage of total organic carbon in incident precipitation (58.1% to 80.7%) than it did for throughfall, although the percentages for August were quite similar.

During all other months, percentage contributions differed little or there was a distinct increase in dissolved contribution as the rain passed through the canopy. This was particularly evident in April and again in September when a greater than 10% increase in DOC contribution occurred.

On a yearly basis, contributions of DOC to total organic load of throughfall and incident precipitation were 67.1% and 67.2%, respectively. For the eight months of the growing season, the value for throughfall declined to 64.3%, indicating overall greater proportions of fine particulate organic carbon in throughfall during this time as com-

pared to the leafless period. Net removal from the canopy for the growing season was composed of 61.6% dissolved and 38.4% fine particulate organic carbon.

Mid-Summer Trends for 1973

Data for the period July 15 to August 30, 1973, including four collection intervals, are shown in Table 37. For July 15 to July 28, 1973, when a number of small thunderstorms occurred, throughfall concentration was 11.14 mg/l for DOC based on four replicate samples. Total rainfall was 7.21 cm, a value somewhat higher than the historic mean. This DOC concentration compared well with the 1974 trends, being somewhat higher than that for June 1974 (a month with somewhat less rainfall) and virtually identical to that in September 1973 (when a similar amount of rain fell). No FPOC data were available for this period.

For the next three collection periods (July 29 through August 30, 1973), data for DOC and FPOC in both throughfall and incident precipitation were realized. Concentrations of the two organic forms differed in their relationship to volume of rainfall for both throughfall and incident precipitation. For throughfall, FPOC concentration varied inversely with volume of rainfall. DOC concentrations, while lowest in the first storm (with highest rainfall), were higher in the third storm (rainfall of 1.95 cm) than in the second (0.78 cm). DOC concentrations during these last two storms were high (12.44 and 5.88 mg/l), being surpassed only by the 32.23 mg/l DOC in July 1974. FPOC concentrations were lower than in 1974. The low concentrations of both DOC and FPOC in the first storm were consistent with the previously shown negative relationship between organic concentration and volume of rainfall.

Table 37. Summary of Results of Mid-Summer 1973 Sampling for Concentration of Organic Carbon in Throughfall, Incident Precipitation, and Canopy Contribution in the West Fork of Walker Branch.

	Collection Interval				
Carbon Source	7/15-7/28	7/29-8/05	8/06-8/15	8/13-8/30	7/29-8/30
Rainfall Vol. (cm)	7.21	7.04	0.78	1.96	9.78
Throughfall					
Concentration (mg/l)					
DOC	11.14	6.15	12.44	15.88	9.78
FPOC		1.18	3.64	2.96	1.89
TOC		7.33	16.08	18.84	11.12
Relative Contribution					
%DOC		0.84	0.77	0.84	0.83
%FPOC		0.16	0.23	0.16	0.17
Incident Precipitation					
Concentration (mg/l)					
DOC		3.55	6.56	3.88	3.94
FPOC		0.31	0.72	1.27	0.61
TOC		3.86	7.28	5.15	4.55
Relative Contribution					
%DOC		0.92	0.90	0.75	0.87
%FPOC		0.08	0.10	0.25	0.13
Canopy Removal					
Concentration (mg/l)					
DOC		2.60	5.88	12.00	5.29
FPOC		0.87	2.92	1.69	1.28
TOC		3.47	8.80	13.69	6.57
Relative Contribution					
%DOC		0.75	0.67	0.88	0.81
%FPOC		0.25	0.33	0.12	0.19

For incident precipitation, DOC concentration was inversely related to volume of rainfall, while FPOC concentration was higher in the third storm (with 1.96 cm of rainfall) than in the second (with 0.78 cm of rainfall). However, for DOC, the concentration for the first and third storms differed by only 10%, while there was a 3.5-fold difference in volume of rainfall. DOC concentrations in incident precipitation were high (3.55-6.56 mg/l) but, based on the 1974 data, were consistent with volume of precipitation. FPOC concentrations in incident precipitation varied from 0.31 to 1.27 mg/l. These were low values considering the time of year and low volume of precipitation, with that for the first storm being the lowest FPOC concentration in incident precipitation recorded in the study.

Trends for canopy removal followed those for throughfall, with concentrations attributable to this source of 2.60 to 12.00 mg/l for DOC and 0.87 tO 2.92 mg/l for FPOC. For both organic forms, the first storm had the lowest concentrations, but only FPOC showed a consistent inverse trend between concentration and volume of rainfall for all three storms.

For the 31-day period (July 31 to August 30), concentrations of DOC, FPOC, and TOC in throughfall were 9.23, 1.89, and 11.12 mg/l, respectively, with 9.78 cm of precipitation. Based on these data, DOC concentrations were a little lower than expected relative to the 1974 data, the lower values being due to low concentrations associated with the storm of July 29-31, during which most of the rain fell. FPOC concentrations were low considering the volume of precipitation. August 1974, with almost two times as much precipitation, had FPOC concentrations 50% higher.

For incident precipitation for the entire month, DOC concentration was 3.94 mg/l, while FPOC was 0.61 mg/l, for a total mean organic concentration of 4.55 mg/l. This monthly mean for DOC was similar to that for October 1973. However, the FPOC concentration of 0.61 mg/l was the lowest monthly mean concentration for FPOC found during the entire study.

For the 31-day period, canopy contribution was 5.29 mg/l DOC and 1.25 mg/l FPOC, for a total canopy removal of 6.57 mg/l. For this period DOC, as a percent of total organic load, decreased from 87% in incident precipitation, to 83% in throughfall, to 81% for canopy removal. These ratios of DOC to FPOC were among the highest recorded during the study, especially for growing season collections.

These results indicate that monthly mean concentration is not necessarily equivalent to that found during one storm of equal volume. A month with many small storms would be expected to have a higher concentration of organics for all components (throughfall, incident precipitation, canopy removal) than one dominated by one or two major rainfall events. This was previously inferred from the low concentrations in August 1974, when the 5-day storm at the end of the month dominated rainfall for the period. Smaller storm events, fairly equally spaced in time, would allow maximum replenishment of the atmosphere and canopy sources of organic material in incident precipitation and throughfall.

Because the largest storm (July 29 - August 1) had the lowest concentrations of both DOC and FPOC in throughfall, inputs were virtually the same as those for the August 12-30 collection, when rainfall was only about one-third as much. Based on previous results of regression analyses for inputs vs volume of throughfall, these results were expected.

For the three collection periods combined, total throughfall inputs were 10.09, 2.02, and 12.11 kg/ha for DOC, FPOC, and TOC, respectively. DOC inputs were the highest recorded for any one month during the study, being similar to those for September 1973. For FPOC, inputs were lower than for any other month of the growing season.

For incident precipitation, DOC inputs were quite high (4.59 kg/ha) being exceeded only by the monthly mean for May 1974, during which time 17.81 cm of rain fell. FPOC monthly input was 0.69 kg/ha, the lowest monthly mean recorded during the study. For the individual collection intervals, DOC inputs varied with throughfall volume, with the August 5-12 period, with the lowest rainfall (0.78 cm), contributing more DOC than would be expected based on volume of throughfall alone, due to the presence of a considerably higher DOC concentration. FPOC showed less coincidence with the pattern of throughfall volume, with the highest input recorded for the last storm (intermediate volume of throughfall).

Total inputs from canopy removal (6.84 kg/ha) were lower than those for August 1974, due again to the lower contribution by FPOC (1.13 kg/hr). In fact, inputs of DOC were greater in August 1973 than in August 1974 (5.50 kg/ha vs 4.37 kg/ha).

For the individual collections, DOC canopy inputs from the canopy were not related to volume of rainfall, while those for FPOC were directly related. This was so, even though concentration of FPOC was inversely related to volume of precipitation, due to the smaller range of FPOC values (0.87-2.92 mg/l) compared to those for volume of rainfall (0.78-7.04 cm).

Soil Water

Mean concentrations of DOC for each sample period are presented for each cover type in Figure 65. See Table B7, Appendix B, for these means ± one standard error. The discontinuity in the figure for the period encompassing August 16 to November 21, 1973 was due mainly to dry soil with insufficient quantities of soil water being collected to allow for sample analysis; however, the period from October 28 to November 21, 1973, when soil water was present, was not sampled.

With minor exceptions, the monthly mean DOC concentrations for chestnut oak (CO) and oak-hickory (OH) cover types were higher than those for the pine (P) and yellow poplar (YP) cover types. Also seen were higher readings in the mid-summer to mid-winter period for all cover types, with lowest readings (especially for pine and yellow poplar) found during the mid-winter through late spring period. The low value for the oak-hickory type in November should be evaluated with caution, since it was based on only one sample and is not a mean. Yellow poplar and pine mean concentrations were low (1.0 mg/l or less) through the late winter and spring. Lowest means for chestnut oak (0.74 mg/l) and oak-hickory (0.87 mg/l) were found during the February 15 to March 8, 1974 period, these means lower than that for the pine type (0.92 mg/l) for this period. Reasons for low readings for this period for the chestnut oak and oak-hickory forest types were apparently not related to concentration of DOC in throughfall during February, as measured with collectors along the stream channel (see Figure 27, page 161). February mean concentration of DOC in throughfall was 3.22 mg/l, a relatively high value considering the low January and March means. Although the forest type

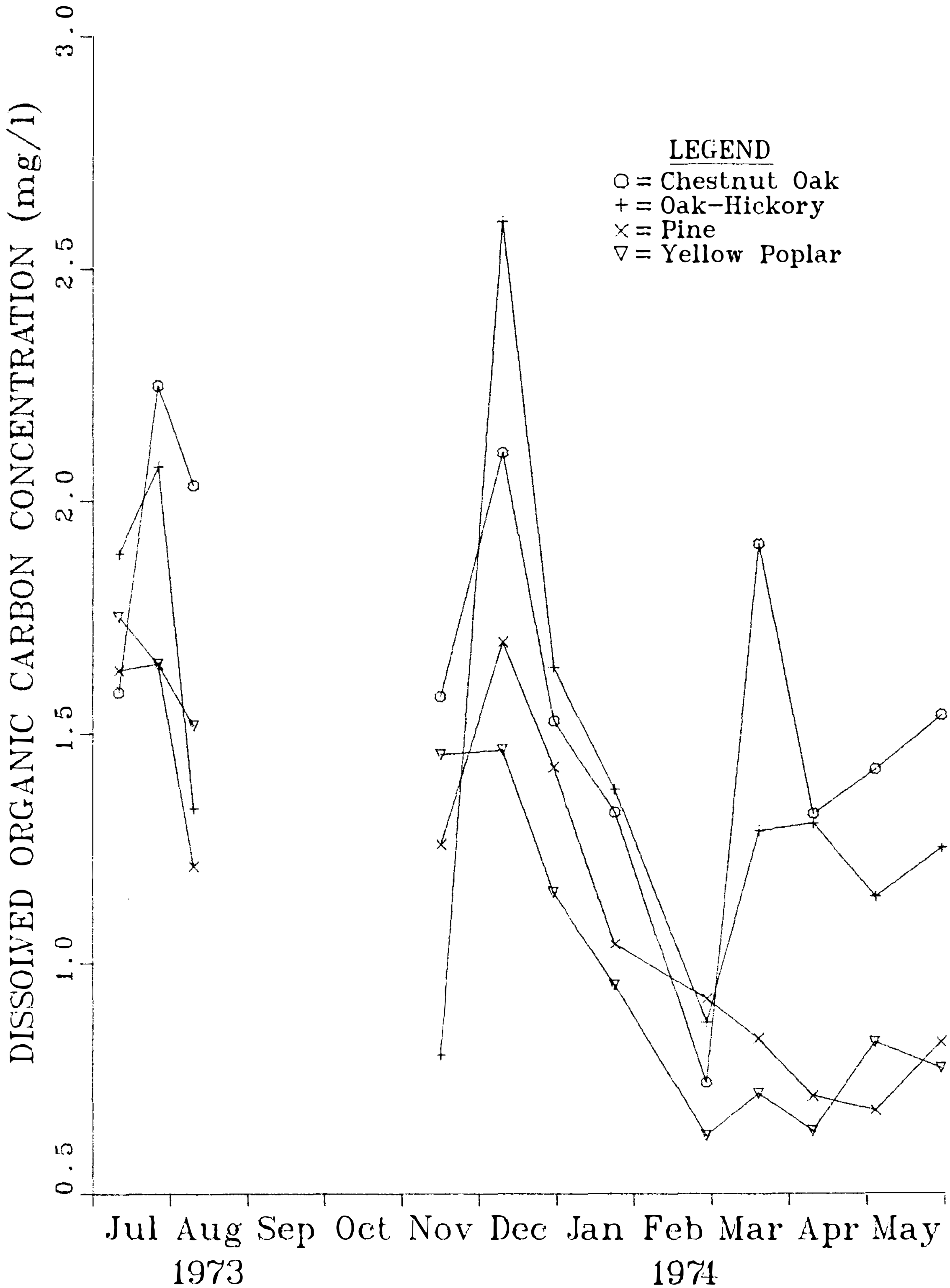

Figure 65. Mean Concentrations of DOC in the Four Forest Types on Walker Branch Watershed for the Collection Periods from July 1973 to Mid-June 1974.

along the stream system is a composite of yellow poplar and the two oak types, differences in winter concentrations between cover types should not be great, and these values should be representative of collections made in any of the deciduous forest types.

Peak DOC concentrations occurred during the last half of July for the chestnut oak and yellow poplar types (2.08 mg/l and 1.75 mg/l, respectively), while the oak-hickory (2.60 mg/l) and pine type (1.70 mg/l) showed peaks in the first half of December. The former interval (late July) corresponded to a period of high throughfall organic carbon (DOC concentrations 11.14 and 6.15 mg/l for the periods July 15 - 28 and July 28 - August 5, respectively), and the latter was the period of lowest rainfall for winter (5.36 cm/20 days). The peak in the pine type at this time was possibly due to retention of foliage in the conifer stand, leading to higher concentrations of DOC in throughfall, while deciduous stands were virtually leafless. However, high concentrations of DOC in soil water in the pine stand did not continue through the dormant season. Henderson et al. (1977a) reported comparatively higher potassium, calcium, and magnesium concentrations in throughfall during the dormant season under the pine cover type.

Overall, organic carbon concentrations were very low with a range of mean concentrations (for all cover types) of 0.62 to 2.60 mg/l, with the second highest mean being 2.25 mg/l. As such, they generally appeared to be independent of concentration of DOC in throughfall.

Data for soil water concentrations were first statistically analyzed using a 2-way factorial ANOVA, with date (of collection) and cover type as main effects. At certain times of the year, soil water was present in only a few of the twenty-four lysimeters, those located in the most

moist plots (generally yellow poplar type). Data for those sampling intervals were not used in the ANOVA, with only those periods yielding at least one observation from each cover type included in the analyses. Data were first tested and found to conform to the criteria for normality, so no transformation was necessary.

Results of the initial ANOVA are presented in Table 38. As can be seen, both main effects were highly significant, with the interaction term not significant (Pr>F = 0.05). Since the interaction term was not significant, the seasonal trends for all cover types were similar, as can be seen in Figure 65, and the ANOVA was run again, with the interaction term left out. In this way, the error mean square for subsequent multiple means tests was determined. Results of this ANOVA are also presented in Table 38.

To determine differences among levels of each main effect (either forest type or date), multiple means procedures (see Kirk 1968) were utilized. All possible pairwise comparisons were made, with the error level set at Pr>T = 0.05 and Tukey's t (0.707 x studentized range) used to determine significance.

Results of the multiple means tests for cover type differences (Table 39) for concentration of DOC show that over all dates, both chestnut oak and oak-hickory were significantly different from both pine and yellow poplar, but chestnut oak was not significantly different from oak-hickory and pine was not significantly different from yellow poplar.

Results of the multiple means tests for date effects are shown in Table 40. With minor exceptions, means fall into two groups. Means for the period July 19, 1973 to January 10, 1974 form one group, with mem-

Table 38. Two-Way Analysis of Variance for Concentration of DOC in Soil Water on Walker Branch Watershed for the Collection Periods from July 1973 to Mid-June 1974, with Date and Cover Type as Class Variables.

Variable	Degrees of Freedom	F	Pr>F
Date	11	7.56	0.0001sd
Cover Type	3	8.39	0.001[sd]
Date/Cover Type Interaction	33	0.72	0.8661[ns]

Note: sd = significant difference; ns = not significant.

Table 39. Results of the Multiple Means Tests for Cover Type Effects (Over All Dates) for Concentration of DOC in Soil Water for the Period July 1973 - June 1974.

	Cover Type		
Cover Type	Oak-Hickory	Pine	Yellow Poplar
Chestnut Oak	1.04^{ns}	5.85^{sd}	5.77^{sd}
Oak-Hickory	--	4.96^{sd}	5.41^{sd}
Pine	--	--	0.42^{ns}

Note: All tests run at studentized range/$\sqrt{2}$ = 2.57, Tukey's test at α = 0.05; Error mean square = 0.356.

Table 40. Results of Multiple Means Tests for Date Effects (Over All Cover Types) for Concentration of DOC in Soil Water on Walker Branch Watershed for the July 1973-June 1974 Period.

	1973				1974						
Date	08/02	08/16	11/29	12/18	01/10	02/15	03/08	03/28	04/19	05/16	06/11
1973											
07/19	-0.92^{ns}	1.50^{ns}	2.95^{ns}	-1.63^{ns}	-2.32^{ns}	-4.43^{sd}	-7.18^{sd}	-4.31^{sd}	-5.93^{sd}	-5.75^{sd}	-5.03^{sd}
08/02	--	2.36^{ns}	3.13^{ns}	-0.65^{ns}	-3.15^{ns}	-5.20^{sd}	-7.83^{sd}	-5.06^{sd}	-6.63^{sd}	-6.46^{sd}	-5.80^{sd}
08/16	--	--	1.21^{ns}	-3.13^{ns}	-0.82^{ns}	-2.92^{ns}	-5.74^{sd}	-2.83^{ns}	-4.41^{sd}	-4.24^{sd}	-3.50^{sd}
11/29	--	--	--	-3.76^{sd}	-0.54^{ns}	-1.16^{ns}	-3.57^{sd}	-1.12^{ns}	-2.38^{ns}	-2.23^{ns}	-1.61^{ns}
12/18	--	--	--	--	-3.95^{sd}	6.08^{sd}	-8.76^{sd}	-5.92^{sd}	-7.58^{sd}	-7.40^{sd}	-6.70^{sd}
1974											
01/10	--	--	--	--	--	2.09^{ns}	4.96^{sd}	2.02^{ns}	3.58^{sd}	3.41^{sd}	2.66^{ns}
02/15	--	--	--	--	--	--	2.99^{ns}	-0.03^{ns}	1.51^{ns}	1.33^{ns}	0.55^{ns}
03/08	--	--	--	--	--	--	--	-2.96^{ns}	-1.56^{ns}	-1.73^{ns}	-2.50^{ns}
03/28	--	--	--	--	--	--	--	--	1.50^{ns}	1.33^{ns}	0.57^{ns}
04/19	--	--	--	--	--	--	--	--	--	-0.18^{ns}	-0.97^{ns}
05/16	--	--	--	--	--	--	--	--	--	--	-0.79^{ns}

Note: Error mean square = 0.356; Tukey's $t_{0.05}$ = 3.27.

bers generally being significantly different from those of the second group, for the period January 10 to June 11, 1974. Means within each group were generally not significantly different from each other.

To determine if any significant relationship existed between the quantity of water passing through the soil profile and organic carbon concentration in each forest type, regressions were performed using volume of infiltration as the independent (class variable) and concentration of DOC as the dependent variable. Volume of infiltration was calculated by summing the daily values for infiltration from outputs of PROSPER (using environmental data from the watershed and from a nearby weather station). Analyses followed the procedures described by Sokal and Rohlf (1969) for regression with more than one observation for the dependent variable for each observation of the independent variable. As such, initial 1-way ANOVA's (one for each cover type) were performed to determine if any significant differences in carbon concentration occurred during the study. If significance was achieved (Pr>T= 0.05), the sum of squares was used in subsequent calculations. If no significance was found, analysis for the particular cover type ceased. Results of initial analyses are presented in Table 41, where significant concentration differences were found for all cover types except chestnut oak.

Analyses were continued for the three other cover types. The sum of squares was partitioned into deviations due to regression and those from regression, and F ratios calculated (Table 42). In no case was any slope significantly different from zero, confirming that there was no significant correspondence between DOC concentration and volume of infiltration.

Table 41. Results of Regression Analyses for Concentration of DOC in Soil Water vs Volume of Infiltration for the Period July 1973 - June 1974: Initial ANOVA's

Dependent Variable	Independent Variable	Cover Type	Mean Square	Error Mean Square	F	Pr>F
DOC	Infiltration	CO	0.700	0.692	1.01	0.4527
DOC	Infiltration	OH	1.209	0.214	5.65	0.0001
DOC	Infiltration	P	0.795	0.228	3.49	0.0010
DOC	Infiltration	YP	1.015	0.400	2.54	0.0012

NOTE: CO = Chestnut Oak
OH = Oak-Hickory
P = Pine
YP = Yellow Poplar

Table 42. Results of Regression Analyses for Concentration of DOC in Soil Water vs Volume of Infiltration for the Period July 1973 - June 1974: Subsequent Analyses

Dependent Variable	Independent Variable	Test[a]	Cover Type[b]		
			OH	P	YP
DOC	Infiltration	1	0.22[ns]	0.003ns	0.26ns
		2	6.08[sd]	3.84[sd]	2.72[sd]
log DOC	Infiltration	1	0.11[ns]	0.43[ns]	0.026[ns]
		2	6.70[sd]	3.55[sd]	3.50[sd]
DOC	1/Infiltration	1	0.001[ns]	0.169[ns]	1.43[ns]
		2	6.21[sd]	3.77[sd]	2.43[sd]
log DOC	log Infiltration	1	0.23[ns]	0.22[ns]	0.96[ns]
		2	6.58[sd]	3.49[sd]	3.20[sd]

	Critical F values:
[a]Test 1: Deviations due to Regression	4.96
Test 2: Deviations from Regression	1.99

[b]CO = Chestnut Oak
OH = Oak Hickory
P = Pine
YP = Yellow Poplar

[c]ns = not significant
sd = significant difference

Although no statistical comparisons are possible between throughfall and soil water DOC concentrations since collection periods differed somewhat, a comparison of monthly mean concentrations of DOC in throughfall and mean concentrations in soil water for similar periods was made. While throughfall DOC concentrations varied (during the months when soil water was collected) from 1.90 to 12.44 mg/l, the highest concentrations of DOC in soil water were only slightly above the lowest concentrations in throughfall. This again, points to the general independence of DOC concentrations in soil water from those in throughfall.

For the period July 19 to August 2, 1973, DOC concentrations in soil water ranged from 1.65 to 2.25 mg/l, while throughfall concentrations averaged 11.14 and 6.15 mg/l, respectively, for the July 15 - 28 and July 28 to August 2, 1973 periods. For the period August 5 - 12, 1973, throughfall DOC concentration was 12.44 mg/l, while concentrations in soil water ranged from 1.21 to 2.04 mg/l. Thus, for these summer periods, soil water had much lower DOC concentrations than throughfall. Actually, the last rainfall event (0.78 cm) with 12.44 mg/l DOC concentration may never have reached the 75 cm layer, due to rapidly drying soil conditions during this period. This was the last collection period of the summer during which enough soil water was available for replicate sampling, giving further indication that, for the period ending on August 16, 1973, most of the recovered water may have been collected during the early stages of the interval, representing the effects of the last portion of the large storm of July 31 to August 1. As such, its residence time in the soil profile would have been longer. Also, the overall concentration of DOC in throughfall during the storm of July 31 to August 1

was not very high (6.15 mg/l), possibly contributing to the lower values for soil water DOC concentrations in water collected during the first two weeks in August. Maier et al. (1976) found total organic carbon concentrations in tile lines (drains) from experimental plots in the Cottonwood River drainage ranging from 0 to 6.5 mg/l, with the average being 3.2 mg/l. Organic carbon losses varied from 0 to 66 kg/ ha/day. They noted indications of a direct relationship between flow rates from the plots and organic carbon concentrations (May to June), which they attributed to residence time of water in the profile, with shorter residence times favoring less decomposition/retention and higher DOC levels.

During the period August 16 to September 28, 1973, the several collections yielded soil water from only a few of the twenty-four plots. For the first interval (August 16 to September 13), samples were available for only the yellow poplar type (two samples), with a mean DOC concentration of 1.26 mg/l. This was somewhat lower than the mean for the previous interval and, compared to throughfall means of 15.88 mg/l for the period August 12-30 and 11.33 mg/l for September, represented an order of magnitude decrease in concentration of DOC. These lower concentrations were probably due to the long period of time the water remained in the profile. The last of August had very little rain, while the first half of September had near "normal" rainfall.

For the last half of September (September 13 - 28), soil water was recovered from one plot for yellow poplar and one plot for oak-hickory, with the concentrations being 0.85 and 1.94 mg/l, respectively. For both plots, concentrations represented a considerable reduction over those in throughfall (mean for September for DOC of 11.33 mg/l).

Unfortunately, soil water samples were not collected for the period from late October to mid-November, the first period for which soil water would have been available for sampling since mid-August. On October 28, a rainfall of 4.82 cm occurred, and three days later another centimeter of rain fell, recharging the watershed. It would be expected, from the available information on organic litter leaching, that high concentrations of DOC in soil water were possible. DOC concentrations in throughfall were fairly high for October (8.59 mg/l), being of the same order of magnitude as the values for June. By October 28, leaf senescence had already progressed substantially, as can be assumed from the weight losses shown in the work of Grizzard et al. (1976). Their data showed substantial pre-abscission decreases (averaging 28%) in dry weights of the leaves of eight deciduous species of trees on Walker Branch watershed. Tulip poplar showed a sharp decline (23%) beginning in early August, consistent with the early leaf fall for this species (late October). Mockernut hickory lost 32%, with almost all the decline after mid-October. Maple lost 51% of its dry weight, again mainly during the last half of October. Black gum lost 62%, all during the first half of October. White oak, which had latest leaf fall of the deciduous species tested, lost most of its weight (approximately 27%) after November 1. Chestnut oak and red oak, with the heaviest leaves, lost much less weight (less than 10%) with the loss occurring during late October. The pine species (loblolly and shortleaf) showed no clear indication of weight loss during autumn, but this may have been due more to the particular age class of needles sampled in the study. This is in contrast to the work of Viro (1955), who showed that conifer (*Pinus* and *Picea*)

needles lost 40-44% of dry weight during yellowing. For the majority of the deciduous species studied by Grizzard et al. (1976), the greatest weight losses occurred during late October. This was also the period of maximum litterfall (see Figure 6, page 57 of this study and Figure 3 of Grizzard et al. 1976). Thus, a large amount of freshly fallen, relatively unleached leaf material was on the forest floor prior to the storm on October 28. For the month of October, relatively little rainfall had been recorded prior to this storm.

A rapid decrease in the amount of water-soluble substances during the initial period of decomposition of litter has been shown by many workers (Waksman et al. 1928, Melin 1930, Watson 1932, Broadfoot and Pierre 1939, Mattson and Koutler-Andersson 1941, Coldwell and Delong 1950, and Viro 1955). Waksman et al. (1928) found sugars, starches, organic acids, and proteins in the water-soluble fraction of leachate from fresh litter during the first few days of leaching. These substances are easily decomposable. Broadfoot and Pierre (1939), who extracted the water-soluble organic matter from the freshly fallen leaves of a number of species, showed a large degree of within-species variation for some species. Beech losses ranged from 5% - 10% of leaf weight, sycamore 8.8% - 10.1%, white oak 10.9% - 14.8%, red oak 13.8%, sugar maple 19.3% - 20.2%, red maple 26.4%, yellow poplar 23.9% - 26.2%, dogwood 17.7% - 20.0%, black walnut 4.7% - 13.9%, and horse chestnut 13.1%. Similar values were found for some species by Plice (1934) and Coile (1937), although the latter found higher mean values for white oak and dogwood.

Nykvist (1959a and b, 1961a and b, 1962) found one-day leaching rates of fresh leaf litter of 16.5% for ash, 12% for alder, 7% for oak, 3.8% for beech, 10.8% for birch, while the conifers *Pinus sylvestris* and spruce lost only 1%. Little additional leaching occurred on subsequent days. He found early leaching of freshly fallen leaves to be independent of microorganisms. Viro (1955) found that the litter of mountain ash showed greatest leaching of organic matter of the species tested, with less from larch and alder. In most cases the bulk of the leachate was removed at the first leaching. He showed that in the early stages leaching accounted for most of the loss of organics, while for the later stages, it accounted for less than 10% of the loss. The percentage of soluble organic matter was larger for broad-leaved plants than for conifers. Mattson and Koutler-Andersson (1944) found highest concentrations of water-soluble organic matter in leaf litter of *Fraxinus excelsior* and lowest in *Pinus sylvestris*, the former having the higher decomposition rate. Similar results were reported by Broadfoot and Pierre (1939), who found a significant correlation between initial water-soluble organic material and percent decomposition after six months. However, multiple correlation results showed that the influence of both water-soluble organic matter and nitrogen on the percent decomposition is exerted largely during the first two months of decomposition (after which excess base content of litter is the determining factor).

These differences in amount of water soluble material leading to different leaching and decomposition rates may partially explain the lower concentrations of DOC in soil water in pine stands. This relates both to leaching while on the tree (as seen by weight loss during senescence), and for the freshly fallen litter.

Thomas (1970), studying leaf decomposition on Walker Branch watershed, attributed weight losses of leaves on land during the first eight weeks mainly to leaching of water-soluble material. These percentage losses were 29.3% for *Acer*, 22.3% for *Liriodendron*, and 6.8% for *Quercus*. Confirmation of these leaching losses was obtained in laboratory streams, where percentages leached in 24 hours were *Acer*, 25.0%; *Liriodendron*, 24.0%; and *Quercus*, 3.7%. An additional 24 hours removed less than 1% of the weight from all species. Gosz et al. (1973), in their study at Hubbard Brook, attributed all weight losses of litter during the first month to leaching. They found weight losses in the order yellow birch > sugar maple > beech. Finally, Anderson (1973a), while studying weight losses in chestnut and beech leaf litter, showed that carbon losses, which were directly proportional to weight losses over a year of decomposition, were primarily due to leaching (75% for chestnut and 100% for beech), with microbial breakdown relatively minor.

Another possible explanation for low DOC concentrations in soil water over the whole year, related to the amount of time water was in contact with the soil proper, is decomposition of the leachate itself. Waksman et al. (1928) and Nykvist (1959) found that the amount of water-soluble organics in leaf leachate decreased with period of decomposition, showing that the water-soluble forms are readily decomposed. Nykvist (1959) stated that two different types of water-soluble organics exist in litter, that from fresh litter and that formed during decomposition (e.g., organic acids). He found that 50% of the organic substances in litter extracts decomposed after 42 days. Similar indications of rapid uptake of DOC by microflora, in this case in the stream

systems, were provided by Hynes et al. (1974) and McDowell and Fisher (1976).

Concentrations were intermediate for the November 29, 1973 collection, with the low value for oak-hickory type based on only one value. A large volume of water passed through the soil profile during this period, associated with the storm of November 27 - 28. While concentrations were low in throughfall (2.08 mg/1), concentrations in the soil water were about two-thirds of this value. Possibly the reason soil water values were not lower was because the water passed through the soil profile so fast that little decomposition and/or uptake by clays in the soil could occur.

The higher concentrations during the period November 29 to December 18, 1973 are somewhat difficult to interpret due to the lack of throughfall data for that specific period. DOC concentrations for the month of December averaged 1.90 mg/1, but this included the large storm of December 25 - 26. Perhaps the concentrations were higher during the earlier part of the month. Another possibility is that there was still an appreciable reserve of water-soluble organics in the leaf litter to contribute to the DOC load. It is interesting to note in this regard that yellow poplar did not show this rise. The litter of this species would be expected to have been thoroughly leached during the previous rains. Also, the results of Grizzard et al. (1976) showed that 23% of the dry weight had been lost from yellow poplar before leaf fall, while for the dominant oaks, an average of only 10% had been lost.

Birch (1958) found that more frequent wetting and drying increased leaching. After the storm of November 27 - 28, there were five days of

no rain, four of which had minimal cloud cover (less than 30%, ORATDL 1973). These days were also relatively warm (maximum temperature 15.5°C) a factor which could also increase leaching and decomposition (Nykvist 1959a, 1961a, 1962, Witkamp 1969).

From this seasonally high value for early December, concentrations steadily declined through the March 28, 1974 sampling collection, with the oak-hickory and chestnut oak forest types exhibiting the lowest values of the year (0.87 and 0.74 mg/l, respectively) during the later March interval. January had a very large amount of rain spread over 19 days of the month, with 100% cloud cover on 24 days and only two days with less than 50% cloud cover. Wind was also at a seasonal low, thus there was little drying of the litter during the period. This, combined with lowering temperatures, led to little leaching of the litter on the forest floor or little decomposition. DOC levels in throughfall averaged 2.19 mg/l for the month, yielding a range of reduction of 25% (oak-hickory) to 47% (yellow poplar) compared to soil water values.

Thomas (1970) reported that the rate of loss of dry matter from leaves of three species (*Acer*, *Liriodendron* sp., and *Quercus* sp.) on land on Walker Branch watershed was very low from the eighth through the twentieth weeks (winter) before accelerating in spring and summer due to more favorable conditions for decomposers. This further substantiates the low rates of leachate contribution to soil water DOC in winter. Quick passage of the large volume of rainfall in January (24.84 cm) prevented much uptake or exchange in the soil profile, however, disallowing further reduction in the DOC concentrations.

February was not as wet as January, but was substantially colder and had only one period of three consecutive days with no measurable rainfall. Thus, the litter material remained wet and cool, with little microbial activity and little leaching. DOC concentrations in throughfall averaged 3.22 mg/l for the month, a relatively high value for the winter months. The lower soil water concentrations (0.62 to 0.92 mg/l) for the period February 16 to March 8, 1973, could have resulted from the fact that rainfall was quite light for the last half of February, with no major storms occurring. Thus, for most of the period, percolating water remained in contact with the soil system for some time. The temperature differential between the litter layer and the soil layer could have yielded differential responses, with colder temperatures at the soil surface leading to inhibition of leaching, while higher temperatures at depth in the profile allowed some decomposition or geochemical exchange.

Beginning in the second week in March, the cover types began to behave divergently. One pair (oak-hickory and chestnut oak) showed general increases in concentrations in soil water for the remainder of the winter and spring, while the pine and yellow poplar types remained low. For the pine stands, the lower DOC levels were probably due to overall slower rates of decomposition along with a less readily available pool of leachable (water-soluble) organic matter.

The differential response for the yellow poplar vs the chestnut oak and oak-hickory types may be explained as follows. Senescing yellow poplar leaves, with high concentrations of water-soluble organic matter, were leached thoroughly during the period of senescence (following

abscission) prior to leaf fall. Since they fell earlier in the year than the oak leaves, they probably also underwent considerable leaching on the forest floor during the time leaf fall was occurring for the oak species. Thus, a large proportion of the initial biomass was probably removed early from the yellow poplar litter, with little soluble organic matter remaining by springtime. Since the overall decomposition rate of tulip poplar is faster than for oaks, the litter layer standing crops should have been smaller at all times.

Broadfoot and Pierre (1939) found that oaks produce litter which decomposes faster than pine litter, but much more slowly than litter of many other hardwoods. They also reported that green needles and leaves decompose considerably faster than mature litter, a difference they attributed at least in part to differences in water-soluble organic matter and other organic constituents. For the oak types, a larger reserve of organic material may have been present in the spring and available for leaching and/or decomposition during this time.

In this regard, the results of Nykvist (1961) and Kowal (1969) are pertinent. They showed that leaching of freshly fallen deciduous leaves leads to accelerated litter breakdown through increased microbial decomposition and palatability to soil animals, which was possibly related to the polyphenol content of the leaves (Edwards and Heath 1963, Heath and King 1964). This may explain why the greater weight loss by decomposition occurred during spring for oak litter, because of their high polyphenol content and a cuticle which resists leaching until it is broken down.

Thomas (1970) noted highest decomposition rates for the three species (Acer rubrum, Liriodendron tulipifera and Quercus alba) he studied on Walker Branch watershed occurred during spring and summer. His data (see Figure 1 of his paper) showed that after initial leaching, decomposition rates as a percent of initial weight, were equivalent for Liriodendron and Quercus. However, since a greater total amount of oak litter would be present, a greater total contribution might be expected. Witkamp and Frank (1969) found that white oak leaves decomposed at a faster rate than alder or sycamore leaves, with peaks of bacterial and fungal populations in the fall and spring. Nykvist (1959a and b; 1961a and b, 1962), who studied litter leaching for a number of deciduous and coniferous species, found that increasing temperatures increased the percent of dissolved organics leached in one day. He found the greatest effect of elevated temperatures in the leaching of oak leaves. Gosz et al. (1973) also found that summer was the period of maximum litter decomposition. They observed that nutrient release from decomposing litter was affected by nutrients in the current falling litter, precipitation, and throughfall. Edwards (1974) found that the seasonal pattern of total CO_2 evolution from the forest floor was a function of temperature in the Liriodendron forest at Oak Ridge. The same temperature dependence has been shown by a number of workers (Froment 1972, Reiners 1968, Wiant 1967, and Garrett and Cox 1973). It is interesting to note that Edwards and Harris (1975) attributed most of the CO_2 evolved in the Liriodendron stand to catabolic processes (primarily root respiration and microbial processing of soil organic matter) below the litter layer. Possibly the relatively low value for litter decomposition is related to the

predominance of leaching early in the year (fall to early spring) and consequent removal of soluble organic matter from the litter of yellow poplar.

Another source of soil organic carbon involves the root system and its associated rhizosphere microflora. Edwards and Harris (1975) reported two peaks for small root (0.5 cm) biomass, one in early March and one in September. They calculated 450 g carbon/m^2/yr small root production, with annual turnover of equal magnitude. They reported total carbon lost annually as CO_2 from the forest floor of 1065 g/m^2, with 42% from decay of dead roots, 35% from root respiration and associated microorganisms, 10.9% from 01 litter, and 9.7% from 02 litter. Thus, the contribution of organic matter to soil water organic carbon from root decay could be substantial, in addition to serving as a substrate for decomposer metabolism.

Barber and Martin (1976) and Martin (1977) also showed that substantial loss of organic material from living plant roots occurs. They found in laboratory experiments that greater soil respiration occurred under non-sterile conditions, but there was no effect on the quantity or quality of the soil organic carbon, indicating that soil microflora both stimulated and decomposed organics from roots. They postulated that root decomposition, involving continual release of low molecular weight organics from degenerating epidermal and cortical tissue and sloughed root cap material, was part of the normal root development. This could be followed by invasion of epidermal and cortical tissue by microflora causing extensive breakdown of cell walls, and finally, decomposition of the endodermal tissue. The term these authors used for the released

organics from extensive cell degeneration was "root lysate." Expressed in terms of total carbon recovered (lysate plus plant weight), the loss of carbon from wheat roots at several temperatures and a range of plant ages was 14.3 - 22.6% with a mean of 17.3%. Griffin et al. (1976) found for axenic peanut plant cultures, 15% of the root carbon was sloughed per week.

Smith (1976) noted considerable variation, both quantitative and qualitative, in the exudate from the root tips of different species of trees studied at Hubbard Brook, with organic acid release generally being greater than release of carbohydrates or amino acids. Betula allegheniensis, which had the greatest diversity of root exudates, also released, per mg of root, approximately three times the amount released by Acer saccharum and two times that released by Fagus grandifolia. For a one year period, Smith calculated loss of organic carbon as 1.64, 2.05, and 0.35 kg/ha/yr for Betula allegheniensis, Fagus grandifolia, and Acer saccharum. These should be looked on as conservative estimates of root exudates. These values are equivalent to between 35 and 25 $g/m^2/yr$, and are an order of magnitude lower than the DOC concentrations found in soil water in this study. Although these values are low, root exudates could serve to maintain the decomposer community in such a state that they could increase rapidly once DOC was introduced into the soil system via throughfall.

In summary, the higher DOC concentrations for oak-hickory and chestnut oak in spring and summer were probably due to increased biological and chemical activity in the soil system coinciding with increased tem-

peratures operating on a reserve pool of leachable organic carbon in the litter of these stands.

A major factor possibly explaining the yellow poplar stands' low soil water DOC concentrations was related to the low slope position of most of the poplar stands. Soils on the lower slopes, moist coves, and bottoms generally had higher moisture content than those on the upper slopes and ridges, being replenished by lateral movement from upslope. Thus, water remained in contact with the soil for a longer period of time, allowing more complete decomposition of the organic matter in the soil water, and removal of organic matter from the soil water by exchange and precipitation processes. This explanation was made more plausible based on the results of Thomas (1970) for leaching of leaf litter on Walker Branch watershed. Leaves collected from the forest floor in July, which presumably had been in residence there since the previous autumn, showed rates of decomposition of 1.8% for <u>Acer</u>, 5.7% for <u>Liriodendron</u> and 1.1% for <u>Quercus</u>. In the laboratory stream, the twentyfour hour water-soluble losses from these leaves were 2.9% for <u>Acer</u>, 5.4% for <u>Liriodendron</u>, and 0.5% for <u>Quercus</u>, 12% - 23% of the rates for freshly fallen leaves. Thus, it would appear that there could have been an appreciable amount of leachable organic carbon in the yellow poplar leaves during summer, although some of this leachate may have ultimately been derived from throughfall. Long residence time of water in the soil profile served to lower substantially the DOC levels in soil water.

The picture that emerged was a soil system more or less continually supplied by the root system of the plants with a source of organic ma-

terial, which in turn supported a microbial community that could consume introduced leaf leachate. In this scenario, the longer the leachate was in the profile, the greater the total removal, until all the labile fractions were removed. The leachate, or components thereof, also attached to the clay micelles where they were subject to further microbial breakdown. Those that were not broken down in the soil water or on the exchange complex or interlaminar spaces were released from the profile.

The period of maximum throughfall concentrations of DOC for both years was included within the period when little or no soil water was recovered at 75 cm. Thus, the same factor (low incident precipitation) that contributed to the high DOC concentrations in throughfall also resulted in the lack of soil water at 75 cm. Although other factors undoubtedly contributed to the cycling phenomenon, this coincidence of low incident precipitation/high concentrations of DOC must have contributed to the average low outputs of organic carbon in the soil water by limiting the amount of water reaching the 75 cm layer. The other factors involved, such as the summer peak in decomposition of soil organic matter and the apparent dependence of DOC concentrations of the soil water on the retention time of water in the profile, would have also considerably lowered the high DOC concentrations once the water reached the soil profile.

Overall, the soil system seemed to regulate the output of dissolved organic carbon from the watershed system. Fisher (1970) pointed out that dissolved organic matter acts like inorganic nutrients, in that fluctuations (upward) in concentration are dampened by the soil system.

Since the pressure tube lysimeters were not necessarily expected to yield a water sample proportional to the total amount of water passing through the profile, the volume recovered could not be used to quantify this flux. To quantify the DOC passing through the soil profile in each cover type, the simulation model PROSPER was used. This model of atmospheric - soil - plant water flow was described by Goldstein and Mankin (1972) and documented by Goldstein et al. (1974). Inputs to the model, including daily readings for solar radiation, mean air temperature and mean atmospheric vapor pressure were provided by the NOAA Townsite Meteorological Station located about 3 km from the watershed, and measured during the study period. Precipitation data were taken from the rain gages on the watershed itself.

Since PROSPER calculates water flow based on a soil model with no topographic expression, its output may not necessarily conform to the soil water regime at all the sites, the latter spread over a wide range of topographic positions. As such, during early summer, when soil water is declining, the model might predict a negative (upward) soil water flux at the 75 cm depth, while sites at lower topographic positions could still experience a positive flux. Since the direction of flow could not be ascertained for individual plots, the concentrations of the recovered water were used to determine the upward transport of organic carbon during those intervals when the model calculated negative soil water fluxes.

Since it is recognized that PROSPER does not take into account differences in water flow in the various plots due to topographic, slope or

aspect differences, the calculated carbon fluxes based on the model outputs for water fluxes should be viewed as approximations.

For each time interval, daily model outputs for fluxes through the second soil layer (60 - 90 cm) were summed, with one value for each sample period used to represent the water flow for all four forest types. Since certain forest types (e.g., pine vs yellow poplar) generally assume divergent topographic positions (see Table 1, page 29), the water fluxes would be expected to be different. Therefore, a certain amount of bias is introduced into the results. However, since mean concentrations for the forest types were all within the range 0.6 - 2.6 mg/l, this bias is probably not serious. Further justification for using one value for water flux was related to the typical topographic position for each forest type. Pine occupied the driest sites, while yellow poplar occupied the wettest sites. Using a mean value for water flux would then represent a compromise between the volumes of water flowing through each type. This mean water flux probably represented a value close to that for the oak-hickory and chestnut oak types which occupied intermediary slope positions.

Water fluxes thus calculated were then multiplied by the concentration for each time interval for each forest type, and the results summed over all dates to get the annual flow of organic carbon from the soil profile for each unit area (ha) of each cover type. Each resulting quantity was then multiplied by the area of the west fork watershed occupied by each forest type, and the resulting values summed across forest types to get the yearly output of DOC from the west fork water-

shed. To include a whole year's data, an additional collection made during June 1973 was included. These were not used in the earlier statistical analyses, because only the west fork collectors were being utilized at the time.

During the study period, the first period of recharged soil conditions (late October through mid-November 1973) was not sampled. Organic carbon concentrations from the period directly following this one (November 21 through November 29, 1973) were used in the PROSPER model for calculation of soil water DOC outputs for this period.

Results of the calculations for outputs of DOC for each forest type are shown in Table 43, along with the percent of each forest type on the west fork subwatershed. Note that 64% of the watershed was classified as being in transition stands because these stands could not be segregated into any particular forest type by the ordination-classification methods employed (Grigal and Goldstein 1971, Goldstein and Grigal 1972). To quantify the organic carbon in soil water for transition stands, it was assumed that these stands were composed of the four forest types in relative proportion to the area of the watershed classified as being in each of the four types.

Due to lack of a significant relationship between quantity of water flowing through the soil system and concentration of DOC, total output of DOC from the soil system varied directly with fluxes occurring during the period from December 19, 1973 to January 10, 1974, the period with maximum flux of water from the 75 cm layer. Other high outputs occurred

Table 43. Calculated Output of DOC in Soil Water from 75 cm Soil Layer Using Fluxes of Water Generated from the Computer Program PROSPER

Collection Interval Begin	End	Flux of Water Past 75 cm Layer (m^3/ha x 100)	Output of DOC (kg/ha)	Output of DOC (kg/W.F.)*
06/12/73	06/28/73	1.052	0.211	8.116
06/28/73	07/19/73	-0.759	-0.133	-5.106
07/20/73	08/02/73	3.061	0.570	21.892
08/03/73	08/16/73	-0.730	-0.108	-4.132
08/17/73	09/13/73	-1.480	-0.218	-8.383
09/14/73	09/28/73	-0.174	-0.027	-1.041
09/29/73	11/20/73	4.577	0.565	21.694
11/21/73	11/29/73	16.365	2.020	77.738
11/30/73	12/18/73	6.156	1.190	45.853
12/19/73	01/10/74	25.527	3.580	137.441
01/11/74	02/15/74	18.477	2.130	81.621
02/16/74	02/08/74	8.528	0.650	25.101
03/09/74	03/28/74	12.037	1.290	49.557
03/29/74	04/19/74	8.131	0.770	29.561
04/20/74	05/16/74	6.129	0.600	23.085
05/17/74	06/11/74	2.010	0.330	12.697
06/12/73	06/11/74	108.900	13.430 (1.34 g/m^2)	515.690

*W. F. = West Fork Subwatershed

when water fluxes were high. Outputs of DOC were proportionally higher than water flux would indicate during the period from November 30 to December 18, 1973, due to peak or high concentrations of DOC at the time. Negative outputs due to upward movement of water in the profile occurred during the period from June 29 to September 28, 1973, except for the July 20 to August 2, 1973 period, during which a relatively large amount of precipitation temporarily reversed the trend of increasing soil water deficits.

Because the same water flux was used for each forest type, outputs of DOC on a yearly basis were proportional to concentration, with the chestnut oak and oak-hickory forest types (16.93 and 14.61 kg/ha, respectively) with higher outputs than the pine and yellow poplar types (12.40 and 11.28 kg/ha, respectively). Thus for the whole year, output of DOC ranged from 1.13 g/m^2 for the yellow poplar type to 1.69 g/m^2 for the chestnut oak type. These values are close to the 1.25 $g/m^2/yr$ found by Edwards (unpublished data) for loss of DOC from the *Liriodendron* forest at Oak Ridge during the 1973-1974 water year.

For the west fork watershed, 515.7 kg of dissolved organic carbon passed through the 75 cm layer for the year, for an average of 13.43 kg/ha/yr or 1.34 $g/m^2/yr$. Compared to the 1.07 kg/m^2 of organic carbon lost via release of carbon dioxide from the soil system in the *Liriodendron* forest (Edwards and Harris 1975), this hydrologic loss is insignificant.

Springflow

Results of analyses of weekly composite spring samples are presented in Figure 66. For FPOC, sampling began on week 45 of 1972 and continued through week 35 of 1974, but filters were analyzed only through early 1974, with the remainder being archived. DOC sampling commenced on week 27 of 1973 and continued through the end of August 1974 (week 35).

Overall, little change was seen in either species of organic carbon over the year. Highest FPOC concentration (0.82 mg/l) was found during week 48 of 1973, the week having the highest weighted concentration in streamflow (7.45 mg/l) due to the large spate of November 26-28. It is the opinion of this investigator that this high concentration may have been due to a flooding of the spring mouth by streamwater during very high storm flows. A large intermittent channel enters Walker Branch several feet above the spring and possibly contributed to the contamination. Even if the spring FPOC concentration is correct, it represents an order of magnitude lower concentration than the weighted stream concentration for the week. Besides this extreme high concentration, no other weekly concentration of FPOC in springflow exceeded 0.45 mg/l, with more than half being 0.25 mg/l or less.

For DOC, peak concentration was 0.59 mg/l, recorded during week 31 of 1973, during which the largest summer storm of the study occurred. Next highest concentration was recorded during week 48 of 1973 (0.56 mg/l), but this may have been due to contamination from stream sources, as discussed above for FPOC. Only nine weekly means were above 0.40 mg/l DOC. About half the readings were below 0.25 mg/l, with little

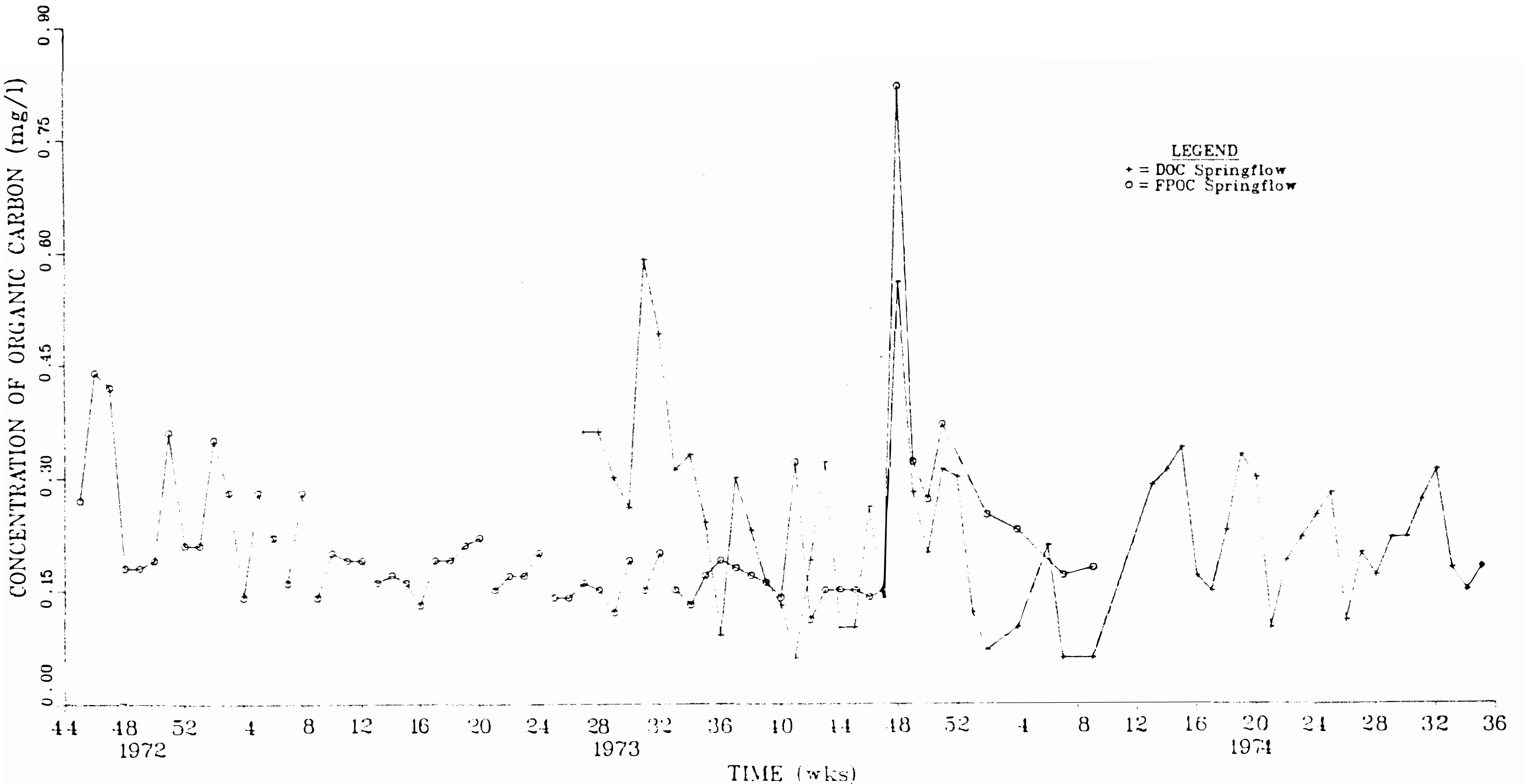

Figure 66. Concentrations of DOC and FPOC in Springflow During the 1972-1973 and 1973-1974 Water Years for the West Fork of Walker Branch.

seasonal trend apparent apart from a slight tendency for the higher concentrations to be associated with periods of higher water inputs to the watershed system, as was the indication for FPOC.

Elwood (in Auerbach et al. 1974, pages 76-77) characterized the major spring systems on the east and west forks of Walker Branch, using the coefficient of variation of hardness (as $CaCO_3$ in mg/l) to differentiate between diffuse-flow and conduit-flow types, with the 10% level being the separation of the two types (Schuster and White 1971). The coefficient of variation for approximately biweekly samples taken over one year for the west fork spring (SW3) was 7.5% compared to 43.1% for the east fork spring, indicating that the former was of the diffuse-flow type, with water flow through small passages (fractures, joints, bedding planes) measuring centimeters or less in diameter, resulting in intimate contact between the bedrock and water as well as longer residence time in the system. The west fork spring showed essentially no seasonal variation in temperature. The east spring was characterized as a conduit-flow system, due to its greater coefficient of variation for hardness and also its greater range of temperatures over the year (10.4% for east fork and 2.0% for west fork). Tracer studies (Auerbach et al. 1973) had previously shown that the effluent from the east spring (SE1) consisted in part of stream water that had entered subterranean channels upstream from the spring. This would help explain the greater variability in the physical and chemical parameters of the east spring. The results indicated that the west spring, being characteristic of diffuse-flow springs, should have maintained a rather stable regime of concentration of chemical effluents. The long residence time of water in the aquifer, plus

the intimate contact of the water with the bedrock system, allowed greater geochemical exchange and biological decomposition. Thus, from the characteristics of the spring aquifer system, one would expect rather invarying organic carbon concentrations in the spring discharge.

The low, relatively invarying concentrations of FPOC and DOC in the spring system at Walker Branch are in agreement with other studies. Odum (1957) found levels of 0.6 - 0.9 mg/l of total organic matter for the water of the upper section of Silver River, flowing from Silver Springs, Florida. Westlake et al. (1972) stated that suspended organic material could scarcely be detected in spring water feeding chalk streams in southern England, with values generally below 0.1 mg/l. The same order of values was found in Bere Heath itself, the stream receiving the spring discharge. Wetzel and Otsuki (1973) found, for groundwater sources emptying into Lawrence Lake (Michigan), POC concentrations at the spring sources were a constant 0.2 mg carbon/l, increasing significantly only during periods of heavy rainfall. A groundwater seep in the lake showed POC concentrations of less than 0.1 mg carbon/l, increasing only slightly during the fall and winter months. Baker et al. (1974) reported on DOC and POC concentrations in chalk springs in England. For POC, concentrations were very low (0.03 - 0.04 mg/l) while for DOC, the range was 0.25 - 0.85 mg/l, similar to that reported by Mackereth (1963) of 0.4 - 0.8 mg/l.

Manny and Wetzel (1973) stated that true groundwater from constant temperature springs contains very little DOM (< 2 mg carbon/l) with subsurface runoff containing higher concentrations of DOM (5-10 mg carbon/l). Wetzel and Otsuki (1973) found DOC concentrations in ground-

water averaging less than 2 mg/l, with minor seasonal fluctuations. Some increase was seen in the fall during periods of high precipitation and groundwater flow. McDowell and Fisher (1976) reported DOM in subsurface water entering Roaring Fork (Massachusetts) of 1.1 mg/l. Maier et al. (1976), for a series of groundwater samples from selected water supply wells, found organic carbon concentrations of 0.5 to 2.0 mg/l (lower limit of detection of equipment). They concluded, assuming groundwater in the region is a result of vertical percolation from the surface, that the low organic carbon levels in groundwater are due to decomposition or retention of the organics in the upper layer of soil. Long residency time favors removal of organics by geochemical and biochemical processes.

Leenheer et al. (1974) collected groundwater samples at 100 sites in 27 states for nonvolatile DOC. DOC concentrations ranged from 0.1 mg/l to 15 mg/l, but the latter value is an outlier. The next highest concentration recorded was 6.8 mg/l, with all but twelve readings less than 2 mg/l and a median value of 0.7 mg/l. DOC concentrations were correlated with specific conductance and alkalinity although the two variables explained only a small portion of the variability. The high values could generally be explained by either natural carbon sources or pollutants. Generally lower means were found for crystalline bedrock than for sedimentary aquifers.

Fisher (1970) stated that at high rates of discharge groundwater samples also show a significantly increased DOM load, suggesting that the site of action is in the soil compartment of the watershed. He reported that concentrations of DOM in groundwater and stream water did

not differ significantly from each other, with groundwater mean of 2.30 mg/l and stream water mean of 2.25 mg/l. This factor simplified the construction of the budget for dissolved organic matter in his study area, since groundwater neither diluted nor enriched stream water.

While a tendency for increasing concentrations of DOC and FPOC with increasing flow has been noted in the results of the present study, the concentrations themselves are considerably lower than those reported by Fisher (1970) and Wetzel and Ozuki (1973) and more in line with those of Baker et al. (1974) and Mackereth (1963). Since springflow concentrations dictate baseflow stream water concentrations in Walker Branch, a large part of the difference in the importance of DOC to the output of organic carbon from the Hubbard Brook vs. Walker Branch watersheds was due to lower baseflow concentrations of DOC in Walker Branch. Also, Fisher (1970) assumed no input of FPOM from the spring, while this has been shown to be qualitatively equivalent to the DOC input at Walker Branch, and on the same order as found by Wetzel and Ozuki (1973).

High concentrations in groundwater reported in the literature were usually associated with known natural or man-made sources. Robinson, Connor and Engelbrecht (1967) extracted organic carbon from groundwater samples with active carbon filters and found, for five small towns in Illinois, DOC concentrations of 1.5 to 7.2 mg/l. Buckley, Hocott, and Taggart (1958) found concentrations of dissolved hydrocarbon gases in some subsurface waters of the Gulf Coast region of the United States up to 1340 mg/l DOC in groundwater obtained from depths to 3000 meters, with increasing concentration generally due to higher solubility with increasing pressures.

Streamflow

Storm Cycles

Analyses of individual storm events throughout the year reveal the complex nature of the response of organic carbon concentrations and outputs to discharge. This response was dependent on presence or absence of a canopy, degree of biological activity in the canopy, baseflow concentrations at the time, standing crop of organic materials in the stream channel (past history), and concentrations of organic materials in incident precipitation. It also depended, to a large degree, on the source of the discharge water, whether from increased baseflow or direct input into the stream channel via precipitation. The source of increased baseflow (lateral transport in the profile or true groundwater) was also a factor. The concentration and loads therefore varied with the particular portion of the hydrograph (ascending or descending limb) under consideration.

The response of a stream or river system to a precipitation event depends, to a large extent, on the size of the drainage system, which determines the degree of land-water interaction. Because Walker Branch is a relatively small headwater stream, with low consistent base flow, storm events have a much greater impact on organic loads than they would in a larger, more open river system. Hydrologic responses to precipitation events were rapid, the first few minutes of a storm event (especially an isolated, intense type) being critical to a proper characterization of amount of discharge of each organic species, especially that of FPOC.

Hydrologically, the simplest storm events occur as summer thundershowers. During summer months, the soil profile is usually relatively dry (see Figure 3, page 36), and when a precipitation event occurs, very little in the way of lateral transport to hydrologic source areas or increased groundwater inputs occur, with most rainfall being held in the canopy, litter, or upper soil layers. Thus, for the most part, storm hydrographs during the summer usually reflect inputs directly to the stream channel, with little sustained increase in baseflow.

Figure 67 shows the hydrographic response and concentrations of DOC and FPOC in streamwater for the period July 14 to July 16, 1973, during which a storm occurred on the afternoon of each day. Rainfall values for July 14, 15, and 16 were 1.29, 1.87, and 1.09 cm, respectively, while discharge values for the three days were 705.2, 769.0, and 745.9 m^3, respectively. Several trends which occurred consistently for storms during the entire year can be noted in this figure. For each storm, the trend was for a very rapid rise of concentration of FPOC, with peak FPOC concentration occurring before the peak in the hydrograph. For July 14, peak concentration (8.00 mg/l) occurred at a discharge of 0.011 m^3/s, while at peak discharge of 0.017 m^3/s, the FPOC concentration was much lower (3.09 mg/l) and clearly on the decline. In fact, the decline had been in progress for the entire twenty-minute period from 1555 to 1615, during which rain was falling and the hydrograph steadily rising. The decline in FPOC concentration continued as the hydrograph declined, returning to base flow levels (0.30 mg/l) approximately four hours after the peak in FPOC concentration.

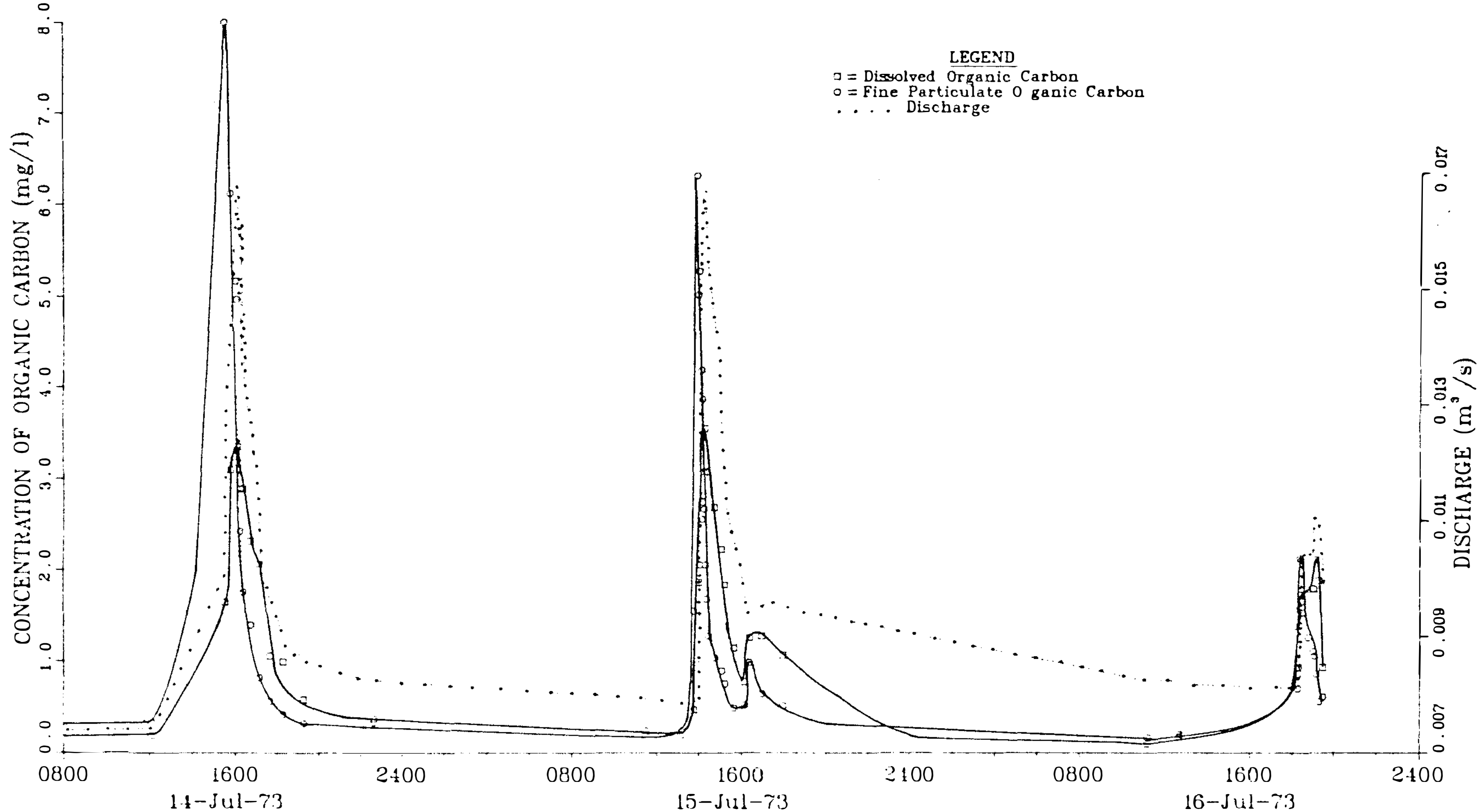

Figure 67. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of July 14-16, 1973.

Maciolek (1966) found microseston dynamics in Convict Creek, California to depend directly on discharge with microseston increasing with initial flows. Kevern and Ball (1969), working in the Red Cedar River, found the most important factor causing organic drift to be an increase in stream discharge. Peak amounts were found during the rise of water level rather than at peak discharge. They cited an earlier work (Tennessee Valley Authority 1940), in which peak sediment movement was found during the rise in stream stage height. They found that during March and April, peak organic drift occurred during discharge increase, after which drift values declined although volume of flow continued to increase. They related this phenomenon to a flushing action which stirred up previously settled drift material and transported it downstream, with the initial rise sweeping the streambed clean. They stressed the importance of frequent sampling during periods of increasing discharge for quantification of particulate load, stating that samples taken at peak discharge often miss the peak of drift concentration. They also noted a rapid decline from peak particulate concentration. Fisher (1970) noted the different response of FPOC during increases in streamflow as opposed to those seen on the descending limb of the hydrograph.

The response of DOC concentration, while also showing an increase with increasing streamflow, mirrored trends in the hydrograph much more closely than did FPOC concentration. DOC concentration peaked at approximately the same time as did the hydrograph, and declined somewhat faster than the decrease in streamflow but not nearly as abruptly as FPOC. As opposed to the peak FPOC concentration of 8.00 mg/l, peak DOC concentration was 3.34 mg/l. Baker et al. (1973), who sampled a spate

on the River Frome for DOC, found that DOC rose to 6 mg/l shortly after the river began to rise, climbed steadily for 10 - 20 hours (to 10 mg/l), and then fell rapidly to near baseflow levels (~2-3 mg/l).

Because of the lack of synchronous behavior for FPOC and DOC, the ratio of DOC/FPOC varied during the July 14 storm event, going from about 0.58 at baseflow, to about 0.33 (extrapolated) during the peak of FPOC concentration, to about 1 during peak DOC concentration, and increasing to between 1.5 and 2.5 during the descending limb as FPOC concentration declined at a more rapid rate than DOC concentration.

Virtually the same trends occurred during the storm events of the next two days with FPOC concentration peaking first (before the peak in the hydrograph) with DOC concentration trends very closely paralleling the hydrograph, declining more synchronously with streamflow. For the major events on July 15 and 16, the ratio of concentration of DOC to FPOC showed the same trend as for the storm on July 14. Here again, lowest ratios were observed during the early part of the storm when FPOC concentration was peaking. As the hydrograph continued to rise, FPOC concentrations declined, while DOC concentrations continued to increase, thus lowering ratios. The largest ratios of concentration of DOC to concentrations of FPOC were found during hydrographic descent, due to FPOC concentration declining at a much faster rate than DOC concentrations.

During the storm of July 15 and 16, peak concentration of FPOC and DOC were 6.31 and 3.54 mg/l, respectively for July 15 and 2.12 and 2.11 mg/l, respectively for July 16. Thus, proceeding through time, the ratio peak concentrations of FPOC/DOC declined from near 3 for July 14, to 1 for July 16, possibly indicating depletion of particulate source components.

The influence of one storm event on another can be seen for the small shower that occurred later in the afternoon of July 15. Prior to this shower, the hydrograph was declining and had not yet reached base-flow levels of discharge or concentrations of organic materials. Since DOC was declining at a slower rate than FPOC prior to this shower, the ratio of DOC concentration to FPOC concentration never fell below 1. Again, however, even in this small shower, the concentration of DOC paralleled discharge, while FPOC concentrations peaked before the peak in discharge.

Because of the temporal trend in the concentration of DOC and FPOC during the storm event, the outputs of dissolved and fine particulate organic carbon (Figure 68) were not synchronous. Peak output for FPOC occurred prior to the peak in the hydrograph, while that for DOC occurred simultaneously with the the hydrograph peak. However, due to peak DOC concentration being associated with higher flows, the ratio of DOC peak output to FPOC peak output was higher than the comparable peak concentration ratio. Thus, for July 14, when peak concentration ratio was 0.33, peak output ratio was 0.61. For July 15 and 16, peak output ratios were 0.85 and 1.15 respectively, as opposed to peak concentration ratios of 0.56 and 1.0.

While the trends for output and concentration of DOC were temporally synchronous, that for FPOC output was dependent on the relative magnitudes of concentration and discharge at the time of peak concentration vs those at peak hydrographic discharge. Thus, for FPOC output, peak discharge occasionally occurred sometime after peak concentration, depending on the interaction of rate of increase in discharge (especially

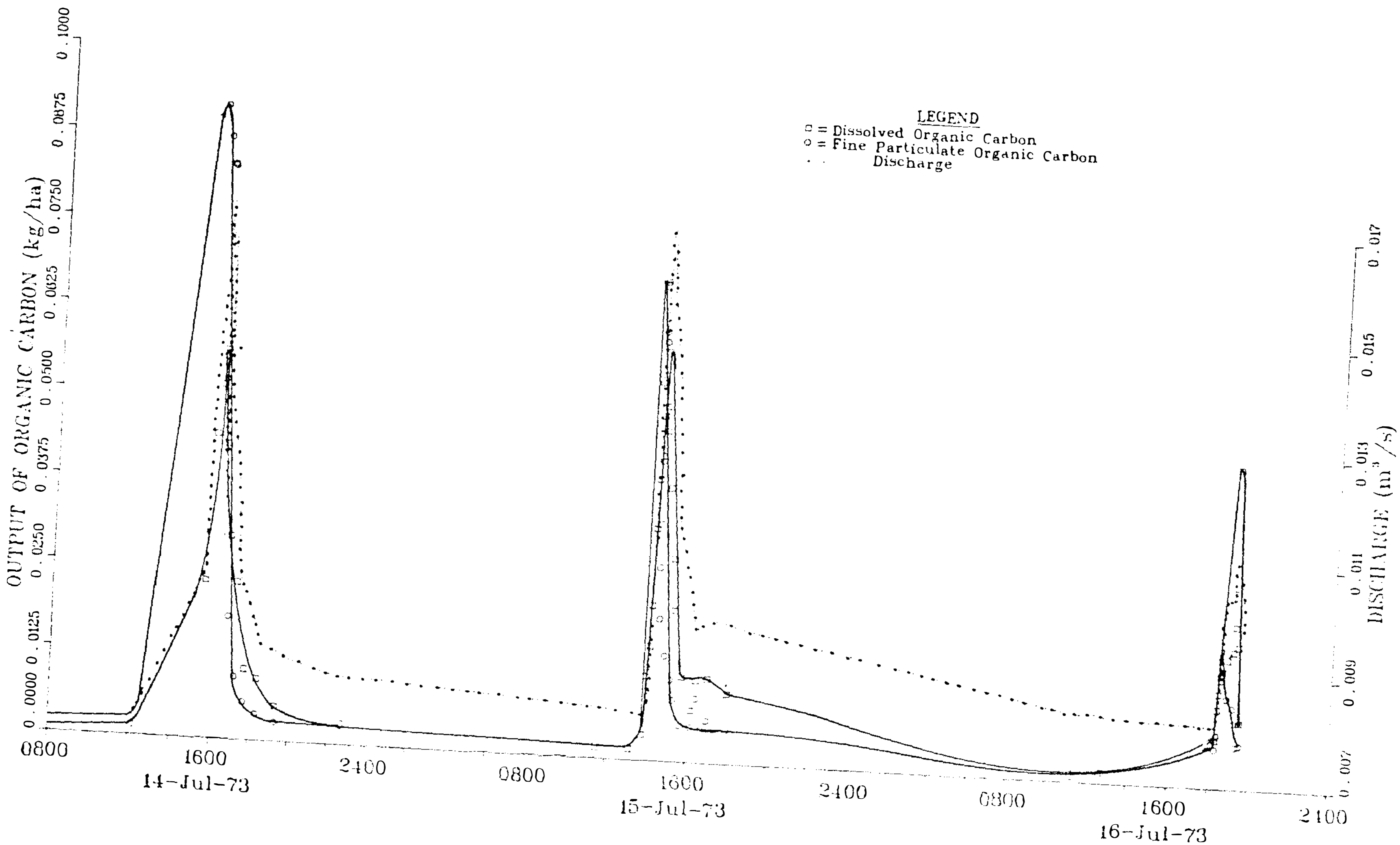

Figure 68. Relationship Between Outputs of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of July 14-16, 1973.

for the period of time when the storm is near peak flow) vs rate of decline in FPOC concentration.

Approximately ten days after these storms, on July 25 and 26, 1973, a similar situation occurred, with thundershowers each afternoon. Similar trends were seen as for the period July 14-16. FPOC concentration and output peaked before those for DOC (Figures 69 and 70), giving trends for ratio DOC concentration (or output)/ FPOC concentration (or output) similar to those for the July 14-16 storms. As occurred during the period July 14 - 16, the ratio of peak concentration of DOC to peak concentration of FPOC decreased from 0.28 for July 25 to 0.52 for July 26. Ratios of peak concentration of DOC/peak concentration of FPOC were comparatively higher (0.30 and 0.63), due to the DOC peak concentration occurring synchronously with that for discharge. All in all, the trends shown in Figures 67-68 and 69-70 are very similar.

While the pattern of increasing or decreasing concentration of DOC and FPOC with hydrographic trends was consistent for most storms during the year, the relative magnitude of DOC and FPOC concentrations and outputs differed considerably. A prime example is found in the period July 19 - 24, 1974, during which time two separate thunderstorms occurred. The storm of July 19 - 20 is shown in Figure 71. There had previously been a long period of drought (1.95 cm rainfall in 42 days), with the days just prior to and including July 19 exhibiting inversion conditions. Peak concentration of DOC was 13.55 mg/l, the highest value recorded during the two-year study. Again, peak concentration of DOC coincided with peak discharge, indicating that maximum quantity of throughfall contribution coincided with peak instantaneous discharge. Compared to

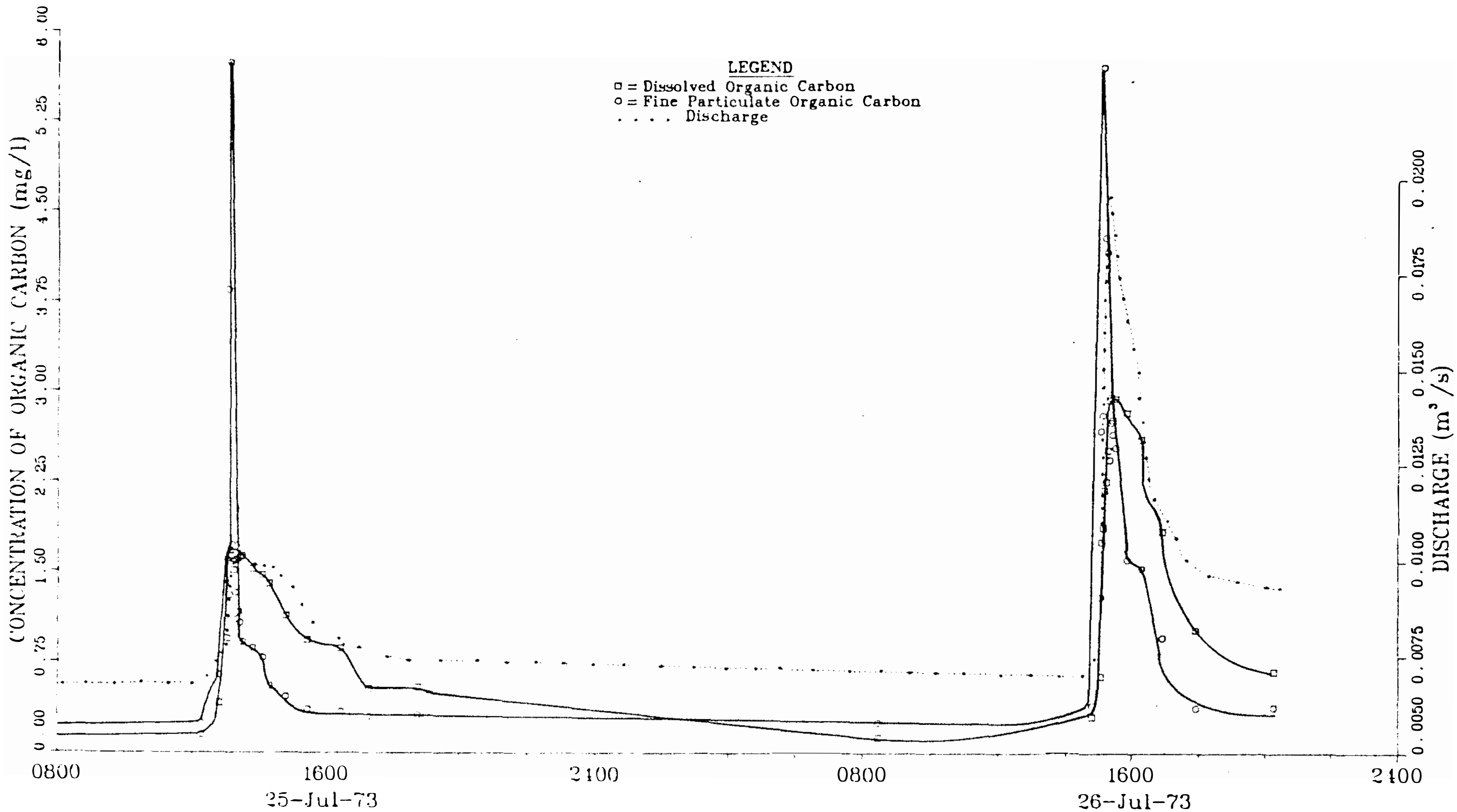

Figure 69. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of July 25-26, 1973.

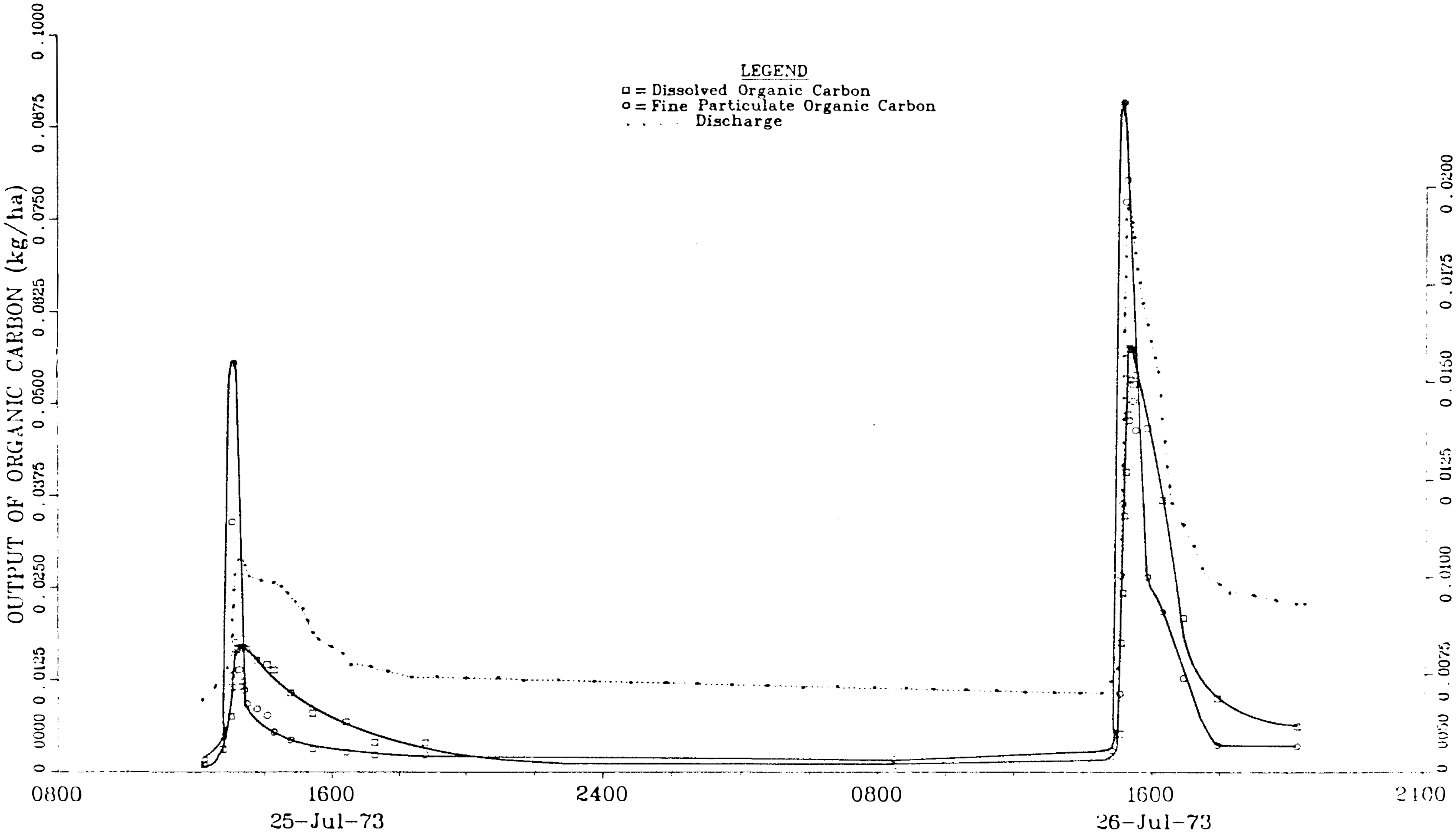

Figure 70. Relationship Between Outputs of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of July 25-26, 1973.

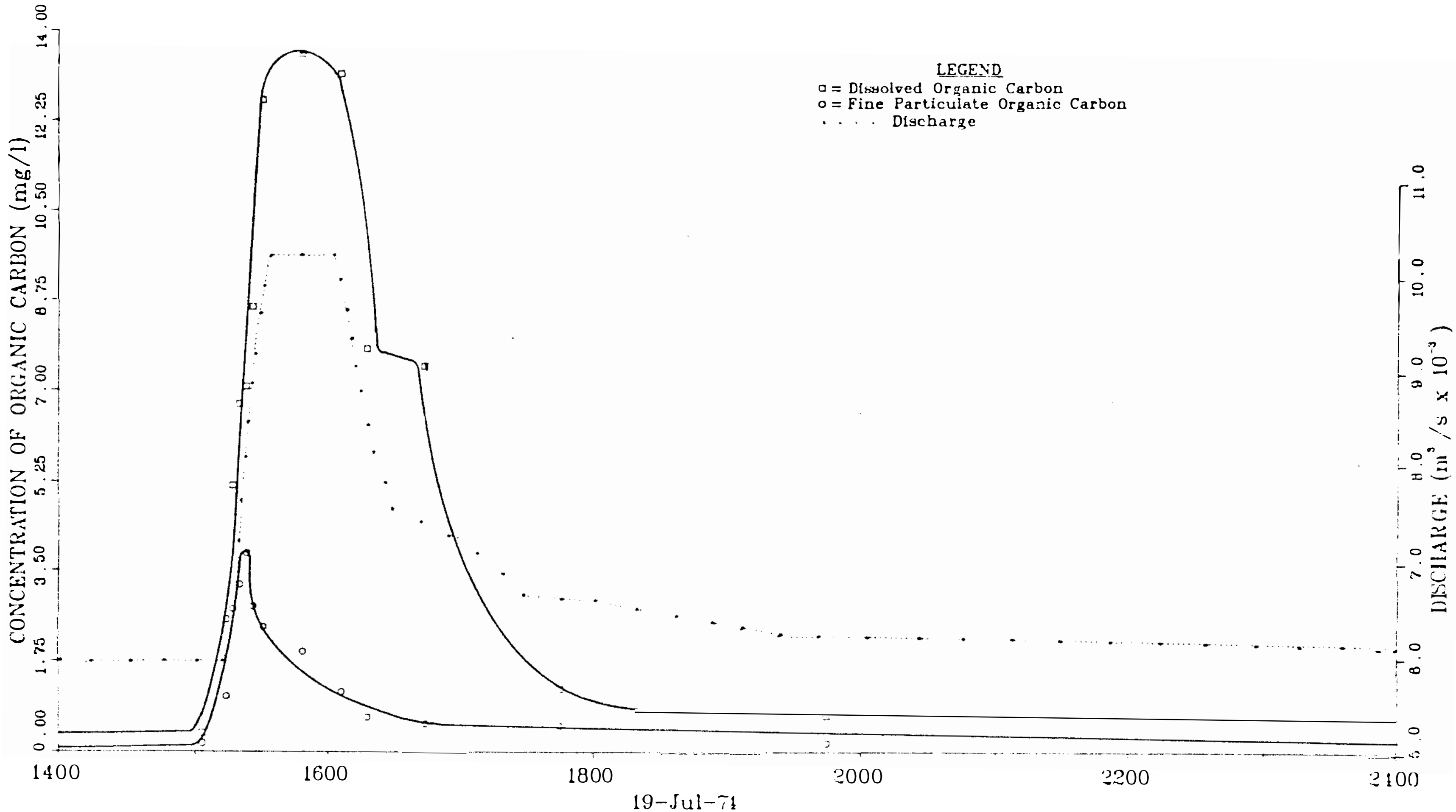

Figure 71. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of July 19, 1974.

baseflow discharge of 5.95 liters, discharge during peak flow was 10.20 liters, slightly less than twice the baseflow. DOC concentration, however, increased almost 38 times over baseflow, with the increase in concentration being 13.19 mg/l. Since throughfall volume contribution was 4.25 l/s at this peak flow, the percent of peak flow due to baseflow was 58%. By multiplying peak concentration (13.55 mg/l) by peak discharge (10.201), total output of DOC can be calculated. By subtracting the output due to baseflow (5.95 l x 0.36 mg/l) from total output, storm output is realized. Dividing this by discharge due to the storm (4.25 l/s) yields the concentration of added water (32.01), which is very close to the monthly mean DOC concentration for throughfall of 32.23 mg/l.

Contrasting this with the data for FPOC, we see a peak concentration of 3.84 mg/l, a 24-fold increase in concentration, but a much smaller absolute increase than for DOC. Therefore, calculation of total concentration of the added water contributing to peak concentration (as above), yields only 8.99 mg/l. Comparing this to measured throughfall inputs of 20.27 mg/l, it can be seen that unlike DOC, FPOC inputs as throughfall may have occurred to a large degree as dryfall of frass and aerosols bouncing off vegetation surfaces (Chamberlain 1966), with less FPOC available in the canopy for input during storm periods. An alternative explanation would be that the rate of increase in streamflow was not sharp enough to keep the added material in suspension.

Comparing the storm of July 19 - 20, 1974 to that for July 24, 1974, the latter storm had a less intense ascending hydrographic limb, with a rainless period sandwiched between precipitation events (Figure 72). For DOC, peak concentration was only 1.31 mg/l, with the peak again syn-

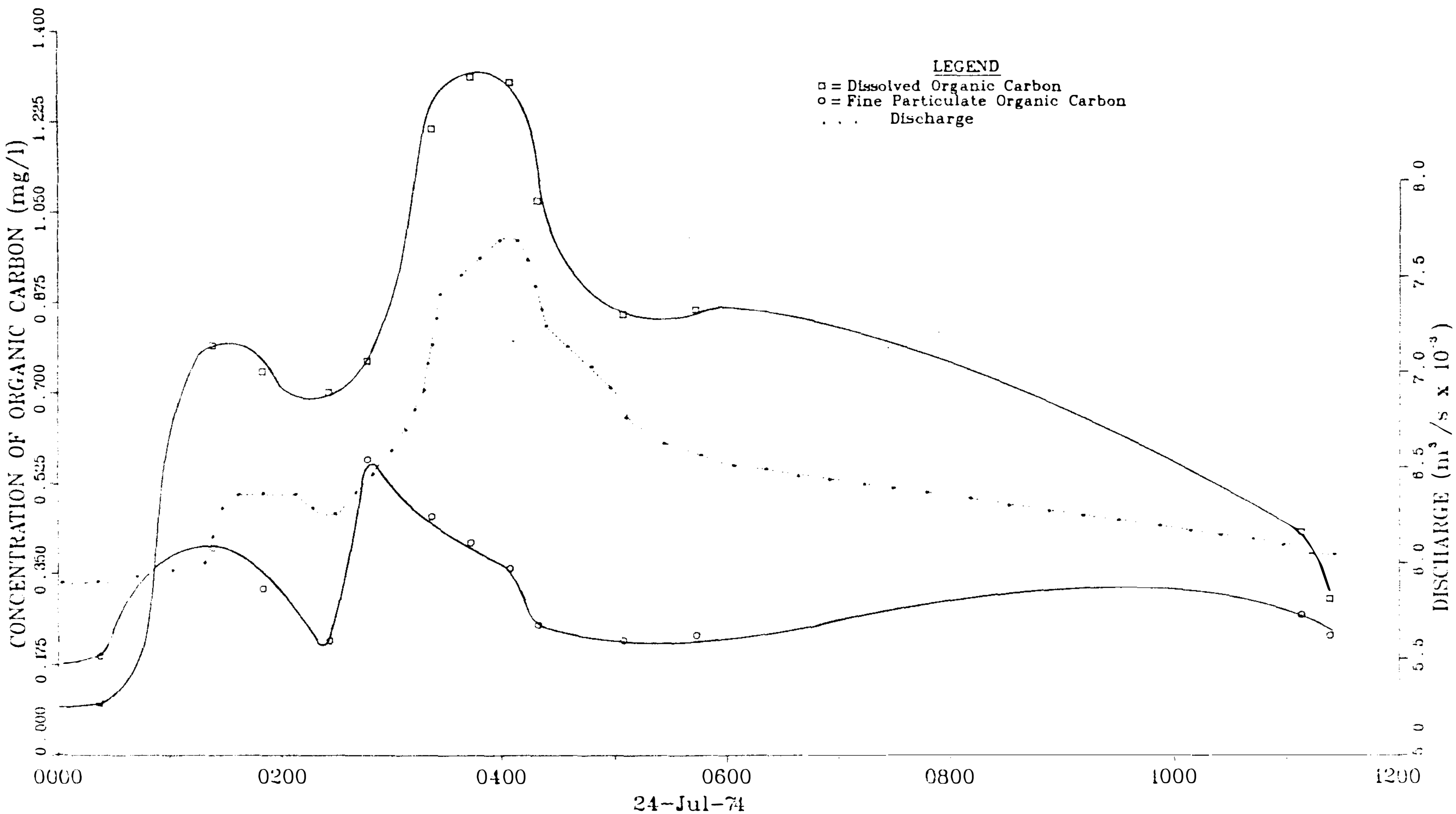

Figure 72. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of July 24, 1974.

chronous with peak discharge. For FPOC, peak concentration was only 0.57 mg/l, occurring prior to peak discharge. Ratio of peak concentrations (DOC/FPOC) was 2.30. At discharge equal to those for peak concentrations of DOC and FPOC for the July 24 storm, DOC concentrations were approximately 7.0 mg/l for July 19, and 1.31 mg/l for July 24, while comparable FPOC values were 2.74 and 0.57 mg/l. There are several possible explanations for this difference. Either the throughfall concentrations were lower for the second storm, or concentrations were related to intensity of precipitation or both factors were operative. For DOC the former was probably the case, while both conditions probably contributed to the FPOC values. Since FPOC must be held in suspension (while DOC does not), the rate of increase in discharge, as well as the rate of disturbance of the shallow stream bottom due to more intense rainfall, contribute to the FPOC loads. Also, more intense rainfall could be more effective in washing canopy material into the stream since aerosol particles are known to adhere rather strongly to leaf surfaces once they became attached. For DOC, biotic uptake in the stream channel, which would be greater during a prolonged storm, is a factor to consider.

The largest summer storm of the twenty-month study period occurred during the July 31 to August 2, 1973 period and the hydrograph is shown in Figure 73, along with concentration data. This complex storm, consisting of four separate precipitation events, had a peak discharge of 0.043 m^3/s. In all cases, FPOC concentration rose and fell much more rapidly than DOC concentration. For example, during the period of 0900 - 1030, FPOC concentration rose, fell, and rose again with changes in the intensity of rainfall, while DOC showed very little change during

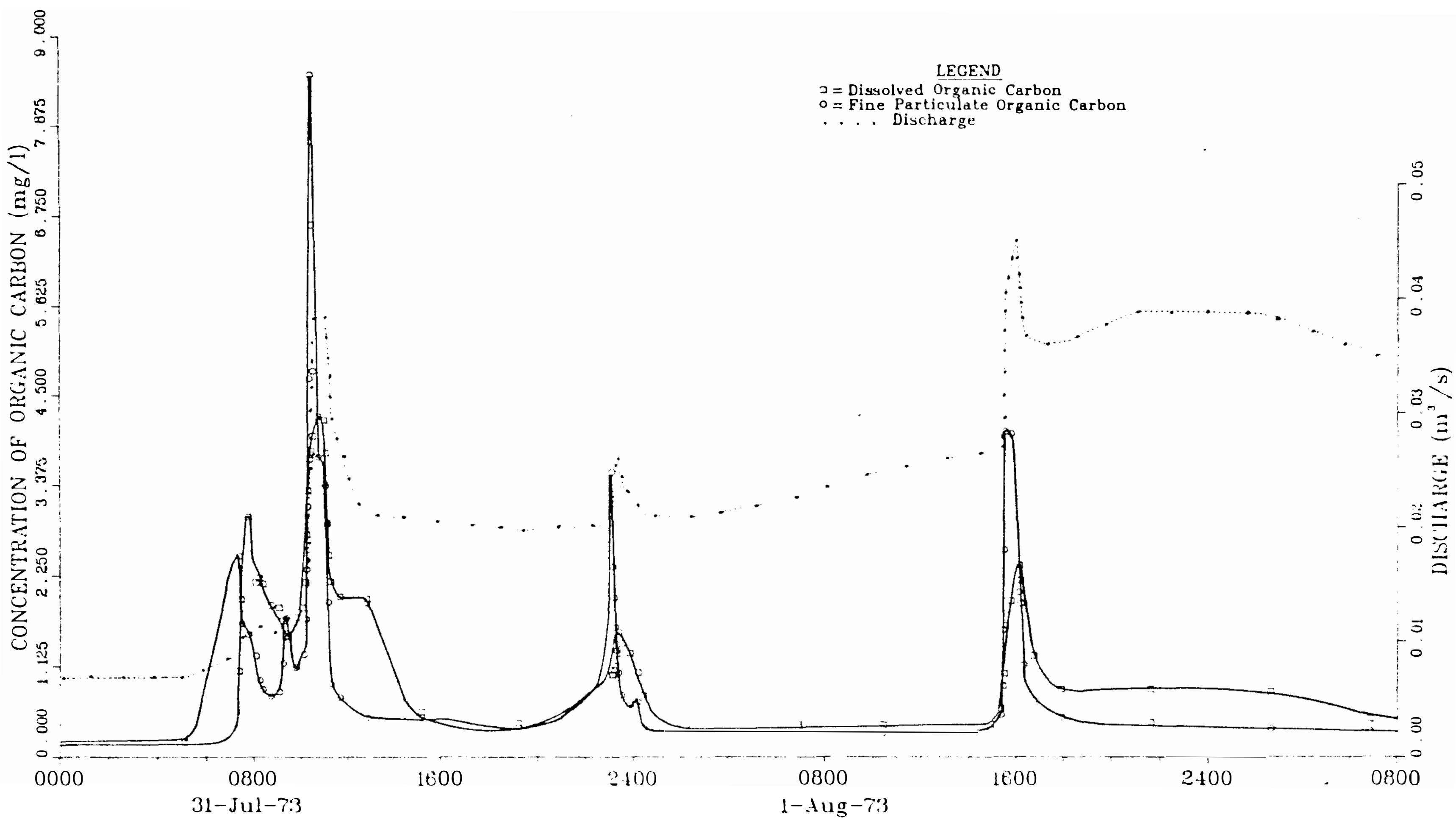

Figure 73. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of July 31-August 1,1973.

the period, again apparently related to the need to keep FPOC in suspension.

While the data showed consistent trends for any ascending or decending limb of the hydrograph, it is obvious, especially from comparison of the various peak concentrations, that little can be explained from discharge alone. FPOC concentration seemed dependent on intensity of precipitation (as exhibited by the rate of change in streamflow) as much as on actual discharge. Also, little in the way of "exhaustion" of FPOC was seen, with the concentration rising rapidly with each ascent of the hydrograph, indicating a within-stream source.

On the other hand, DOC data indicated that there was some exhaustion of the source of DOC throughout the period. If we assume that DOC concentration was related to discharge, then DOC concentration at peak discharge (2.38 mg/l) was about 2 mg/l less than the peak concentration during the next highest peak (1055 - 1100), even though the latter peak was less than the former. However, the lower peak concentration during the 1613 - 1618 period of August 1 may have been partially due to a flow contribution from source areas or soil water (springflow). In either case, the water would be expected to have been substantially lower concentrations of DOC (and FPOC) than direct throughfall inputs.

Throughfall concentrations from the period of July 28 through August 5, 1973, due solely to inputs during this storm, were 6.15 mg/l and 1.18 mg/l for DOC and FPOC, respectively. Concentrations above base flow during this peak of the storm, and attributable to direct input of throughfall to the stream channel, were calculated as 5.11 mg/l DOC, and 11.47 mg/l FPOC. DOC values indicated a contribution at the peak of the

hydrograph from several sources of water (throughfall, soil water, groundwater). This peak flow was not associated with initiation of the rain event; therefore, FPOC concentrations were not due to quick flushing/washing of the canopy. The only feasible alternative source of FPOC was the stream bottom. Since this was the largest storm in several months, organic accumulations in the dry (at baseflow) portions of the channel probably suffered some depletion.

The storm of August 8, 1974 also included two periods of rainfall, with peak flows separated in time by about five hours, and with a return to baseflow levels between the peaks. Comparing the two peaks for FPOC concentration (Figure 74), they again appear to be related to rate of change in streamflow more than to actual rate of discharge, with only a slight indication of depletion of the FPOC source from one storm to the next. Little in the way of depletion can be seen for DOC, although concentrations for the second storm were somewhat lower than those for the first storm. Ratios of peak concentrations of DOC/FPOC for the two storms were near one. Assuming all the hydrographic rise was due to direct input to the stream channel, the peak DOC concentrations were attributable to throughfall DOC concentrations of 4.59 and 4.07 mg/l for the first and second peaks, respectively. Likewise, FPOC concentration increases at peak discharge, attributable to throughfall or stream bottom contributions, involved inputs of 2.27 and 0.81 mg/l, with peak concentration of FPOC indicating a throughfall contribution of 3.59 mg/l. Thus, for FPOC, contributions from throughfall or stream bottom were much less, possibly indicating depletion of either or both of the sources. These concentrations are comparable to the DOC and FPOC concentrations measured

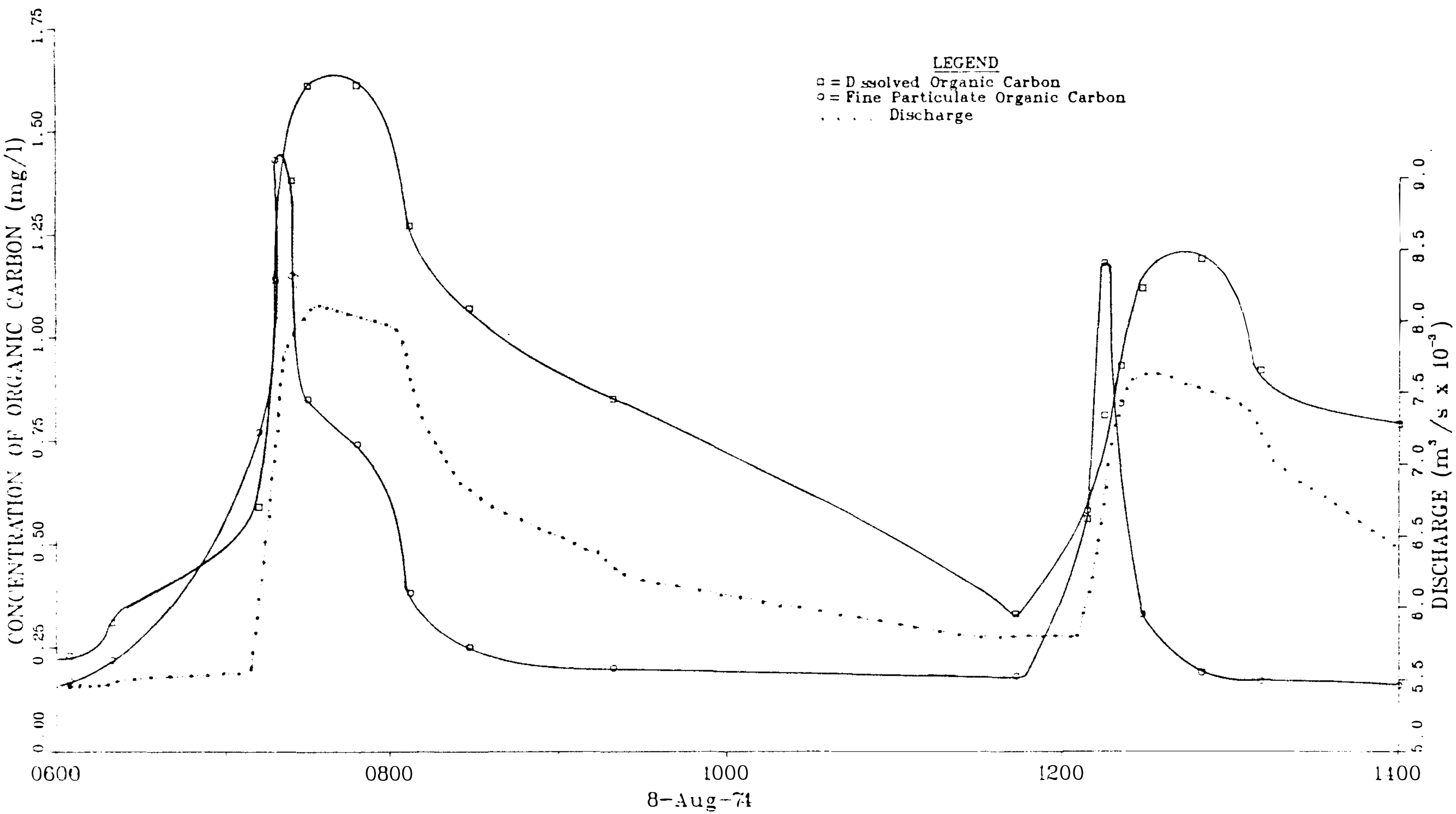

Figure 74. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 8, 1974.

in throughfall for August 1974 of 4.03 and 3.04 mg/l, respectively. The FPOC concentrations indicated little bottom disturbance during this small storm.

This storm can be compared to a somewhat larger event occurring on August 12 - 13, 1973 (Figure 75), for which the ratio of peak DOC to peak FPOC concentration in streamwater was 0.60. In this storm, discharge approximately doubled base flow, while for the storm of August 8, 1974, discharge increased only 50%. Thus, it appears that storms involving larger flows have a tendency for the DOC/FPOC peak concentration ratio to be lower, again indicating the greater response of FPOC to increase in discharge from either the stream bottom or throughfall. This could also explain the decreasing ratio of peak DOC concentrations to peak FPOC concentrations during the series of peak flows associated with the storms of July 31 to August 3, 1973.

The complex storm event of August 21 - 22, 1974 (Figure 76), showed indications of what might at first be considered source depletion for FPOC concentration due to highest concentrations occurring early in the storm. However, the initial peak FPOC concentration (6.08 mg/l) occurred during an intense rise in the hydrograph, indicating that the high concentrations could have been related to streambed contributions which would not be as great during a less intense rise in discharge.

Concentration differences at the two discharge peaks were not indicative of source depletion for DOC. In fact, comparing the peaks for 0600 - 0630 and 0950 - 0955, the concentrations were equivalent, with the latter peak accompanied by much lower streamflow (and hence, lower quantity of canopy contribution). Calculated concentrations due to

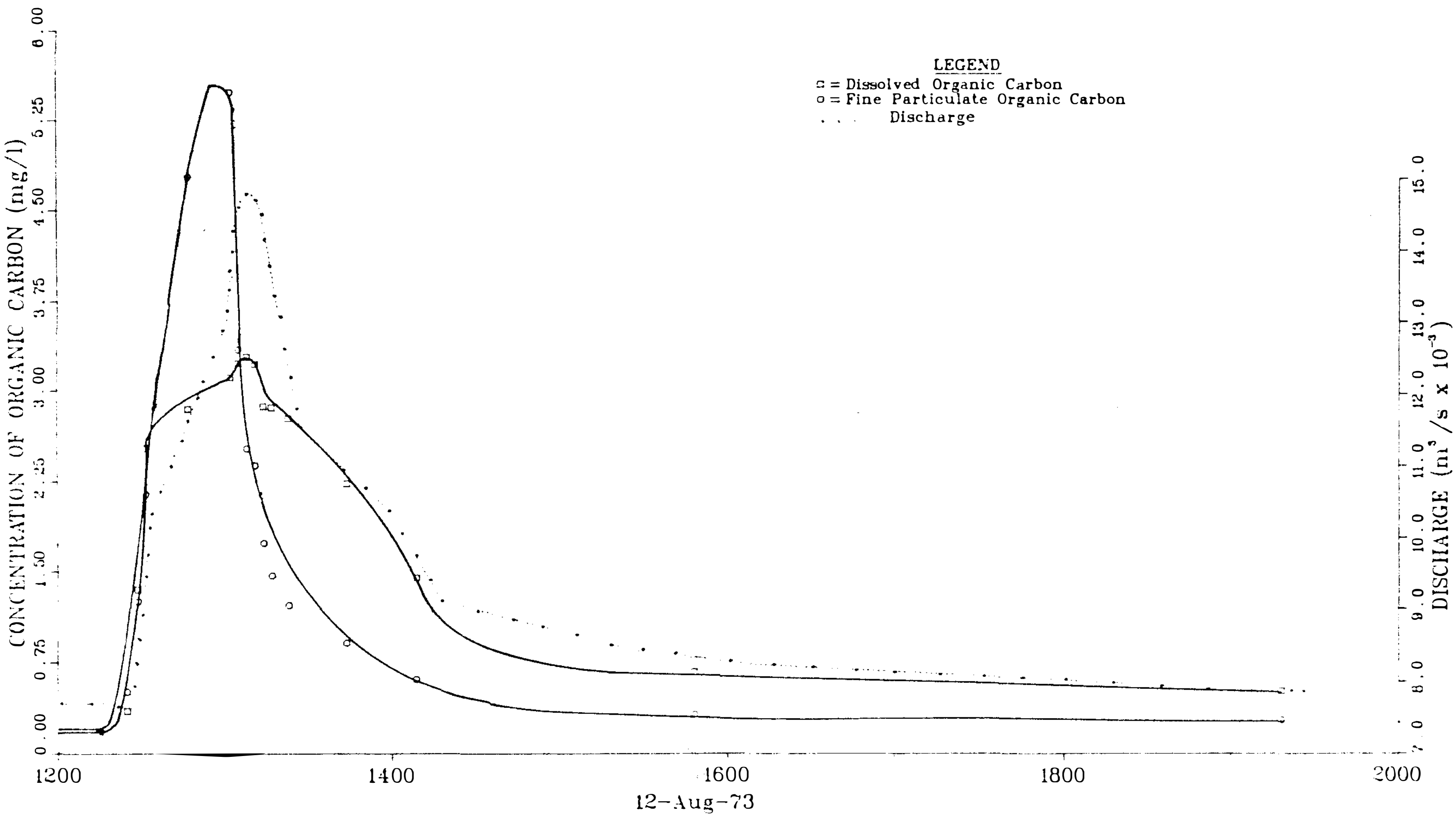

Figure 75. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 12,1973..

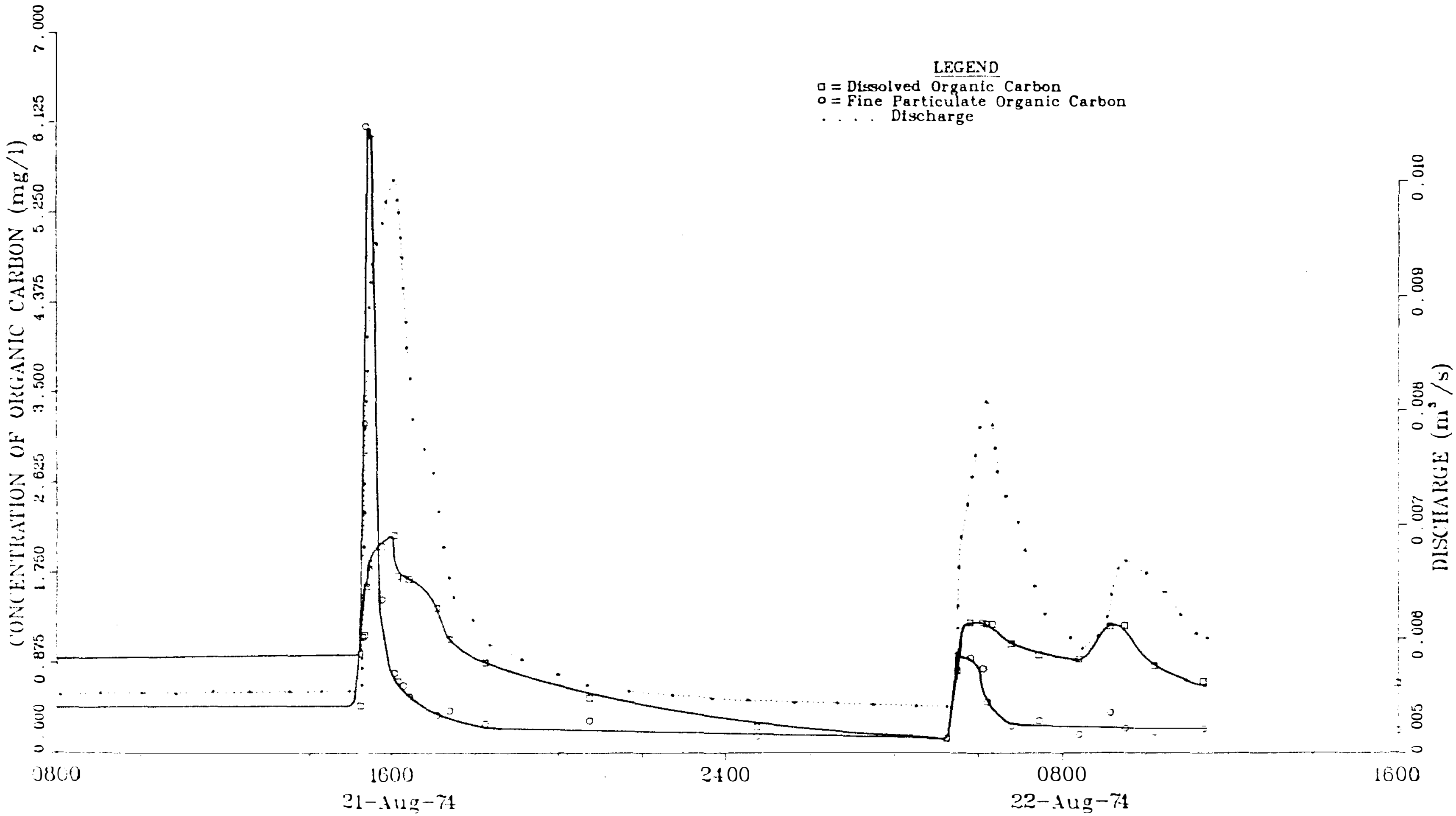

Figure 76. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of August 21-22, 1974.

throughfall inputs (assuming that all increases in discharge and concentration were due to throughfall inputs) would have required throughfall concentrations of 4.19, 2.99, and 5.11 mg/l for the three successive peaks.

During the five-day period from August 28 to September 1, 1974, rain fell every day. The resulting series of storm events and DOC concentrations are shown in Figures 77-81 one assumes that all the increases in streamflow were due to precipitation input to the stream channel, some indications were present for depletion of the DOC source, but they were not clear cut. Concentrations in input water were estimated at 4.60 mg/l for the first peak (1410 - 1420 on August 28), 4.05 mg/l for the second peak (1710 - 1715 on August 29), 2.21 mg/l for peaks at 1735 - 1750 on August 30 and 1505 - 1515 on August 31, and 3.50 mg/l for the peak on September 1 at 0255 - 0300. FPOC concentration once again appeared due to the rate of intensity of hydrographic rise. Comparing peak concentrations for the first portion of the storm (1410 - 1420 on August 28), it can be seen that a concentration of 1.12 mg/l was associated with an increase in the hydrograph of 14% over base flow, while for the sampling interval 1645 - 1650 on August 29, peak concentration of FPOC in streamflow was 3.83 mg/l, associated with an increase in discharge of 35%, with mean discharge for both sampling intervals being approximately 0.007 m^3/s. While an overall increase in discharge over base flow was involved in the dynamics of FPOC, the main factor seemed to be the rate of increase in discharge over the interval, indicating that it was a function of rainfall intensity. These values were 0.0004 m^3/s increase/5 minute interval for the 1410 - 1420 period, and

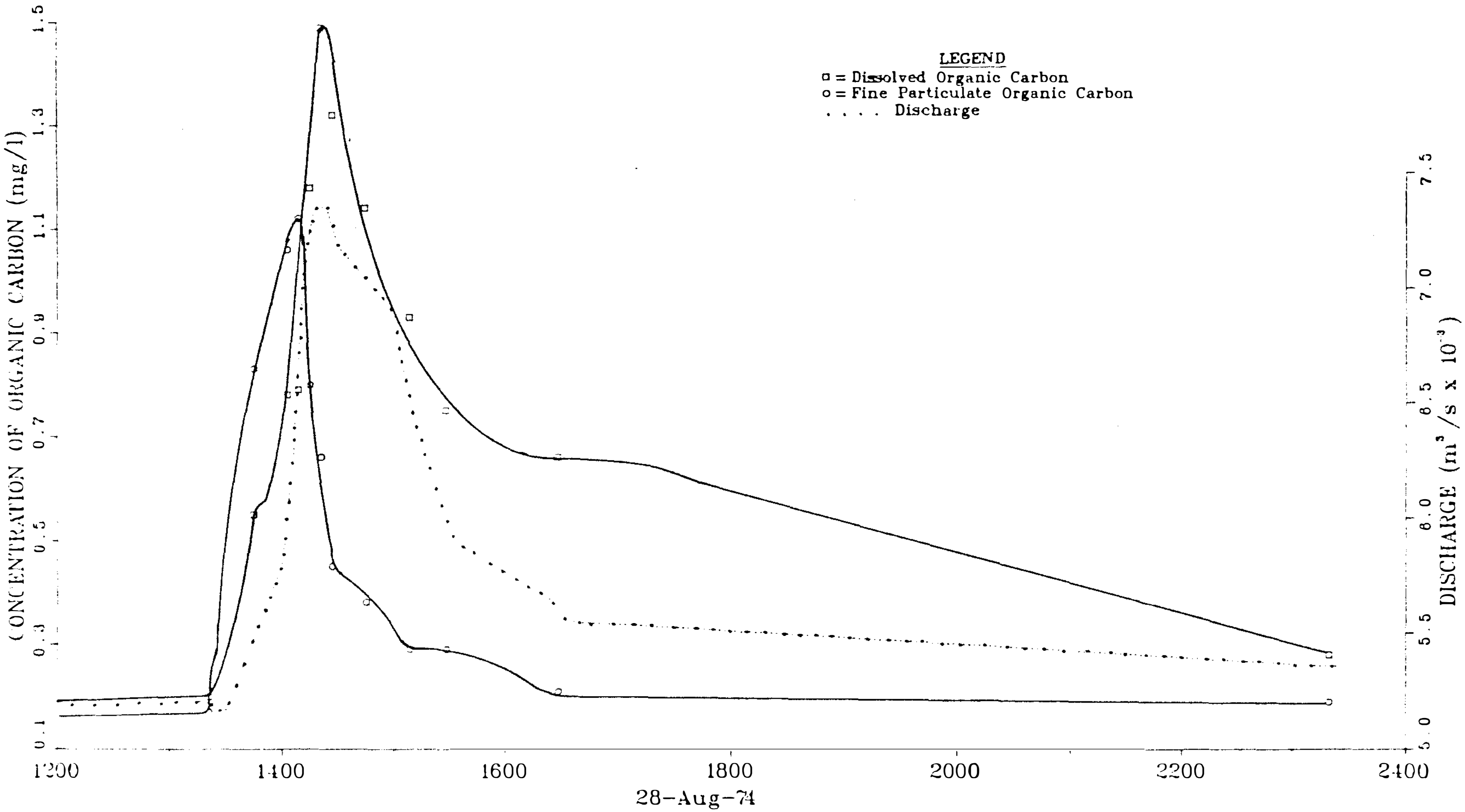

Figure 77. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 28, 1974.

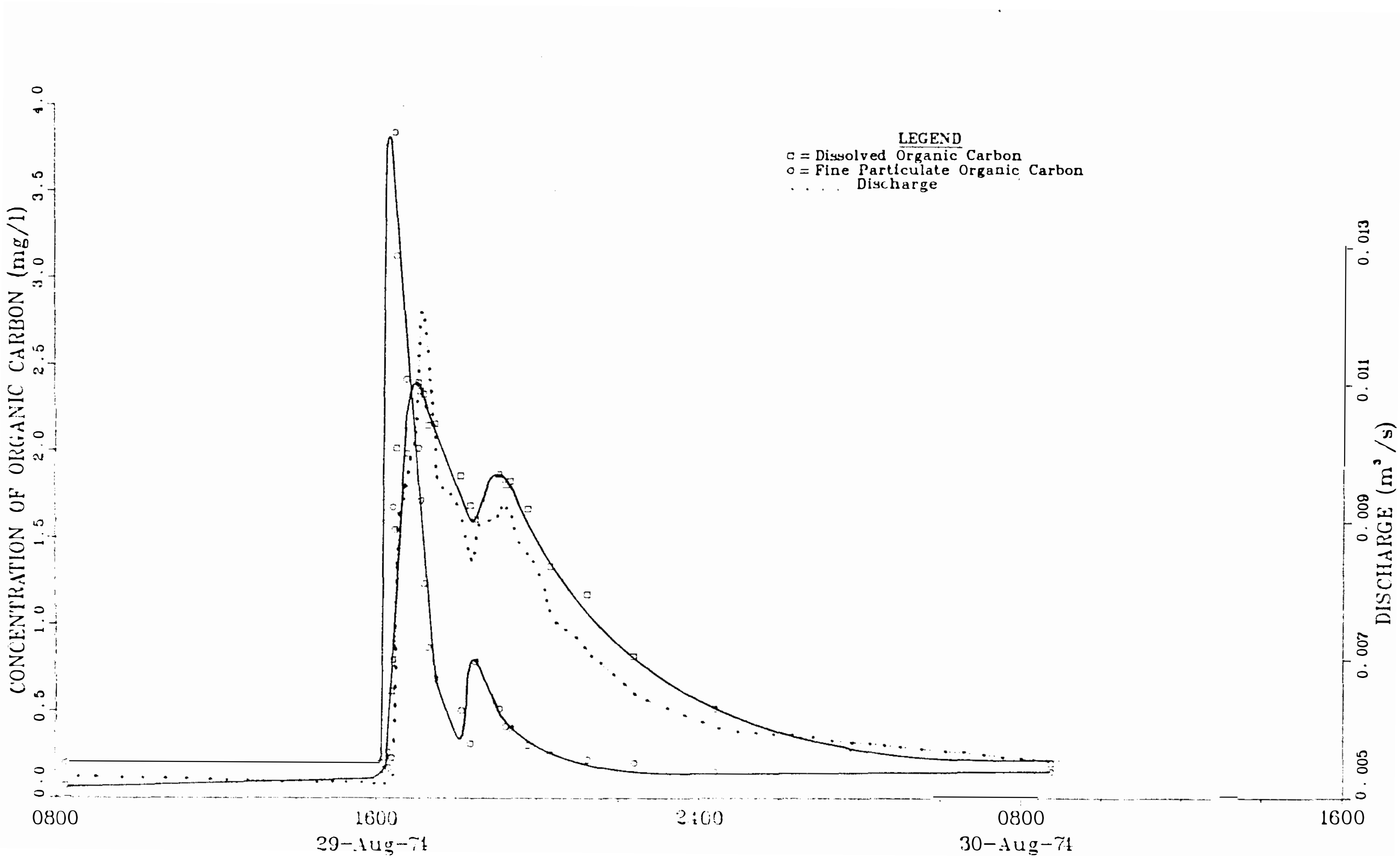

Figure 78. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 29, 1974.

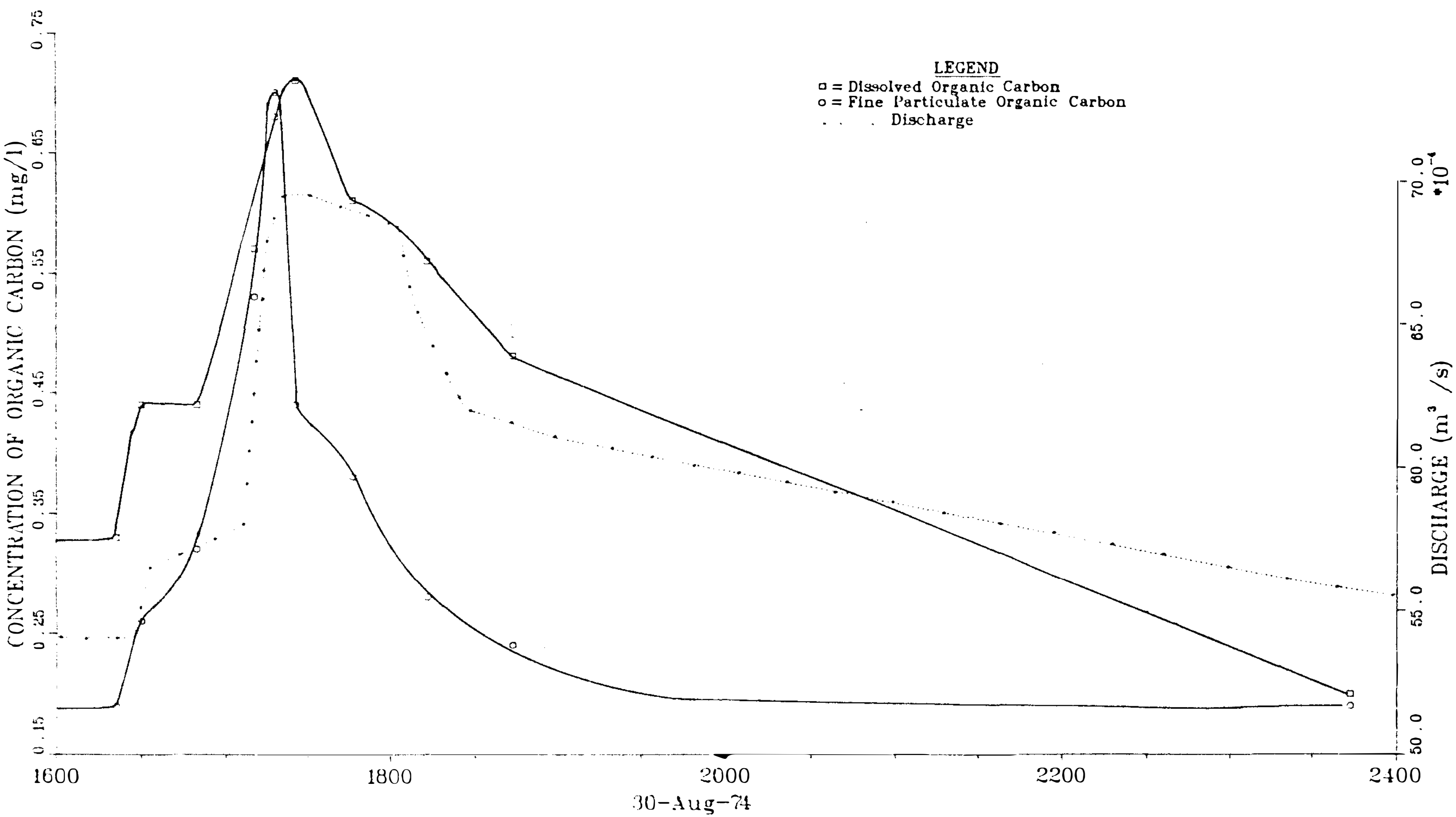

Figure 79. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 30, 1974.

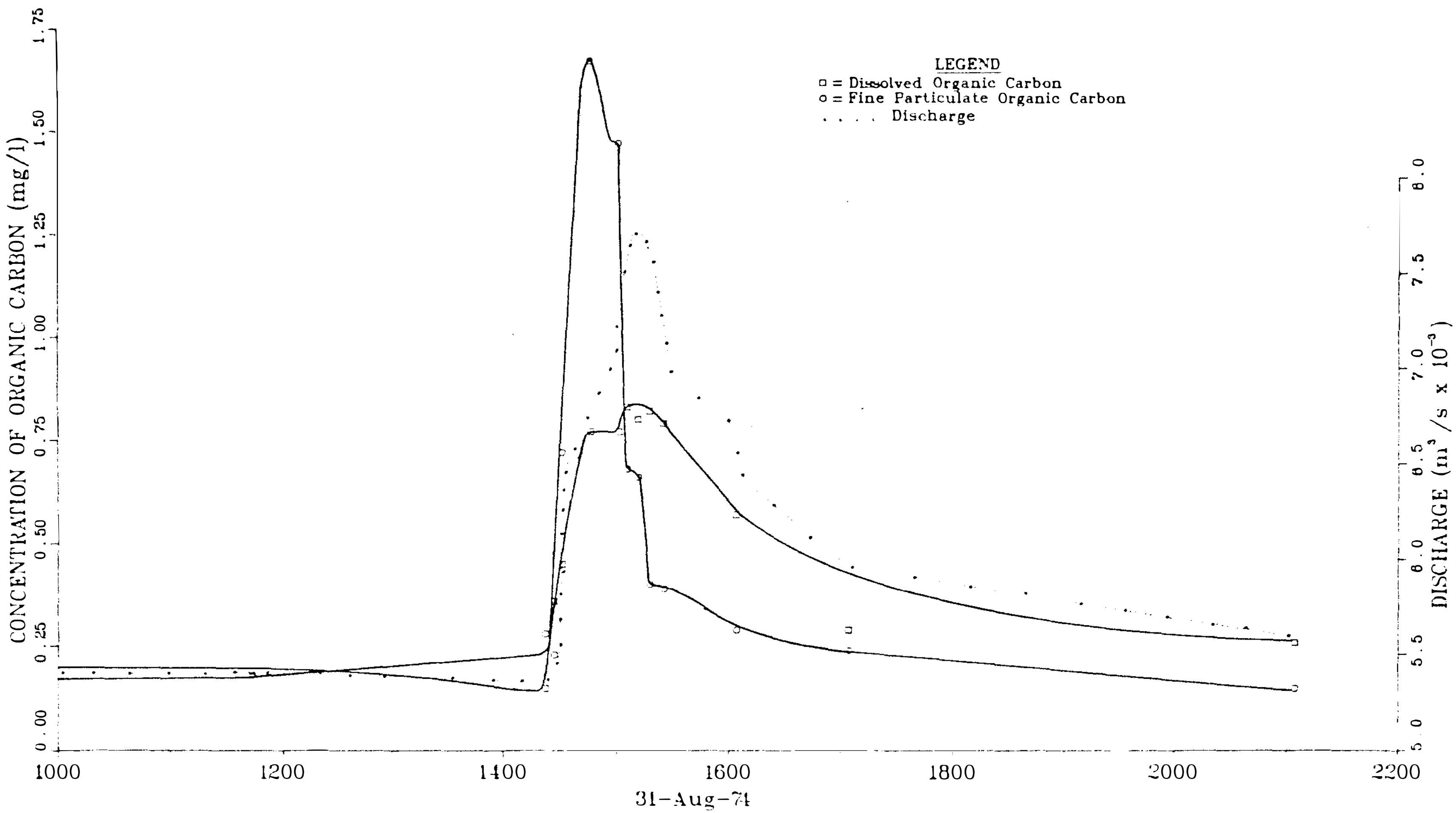

Figure 80. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of August 31, 1974.

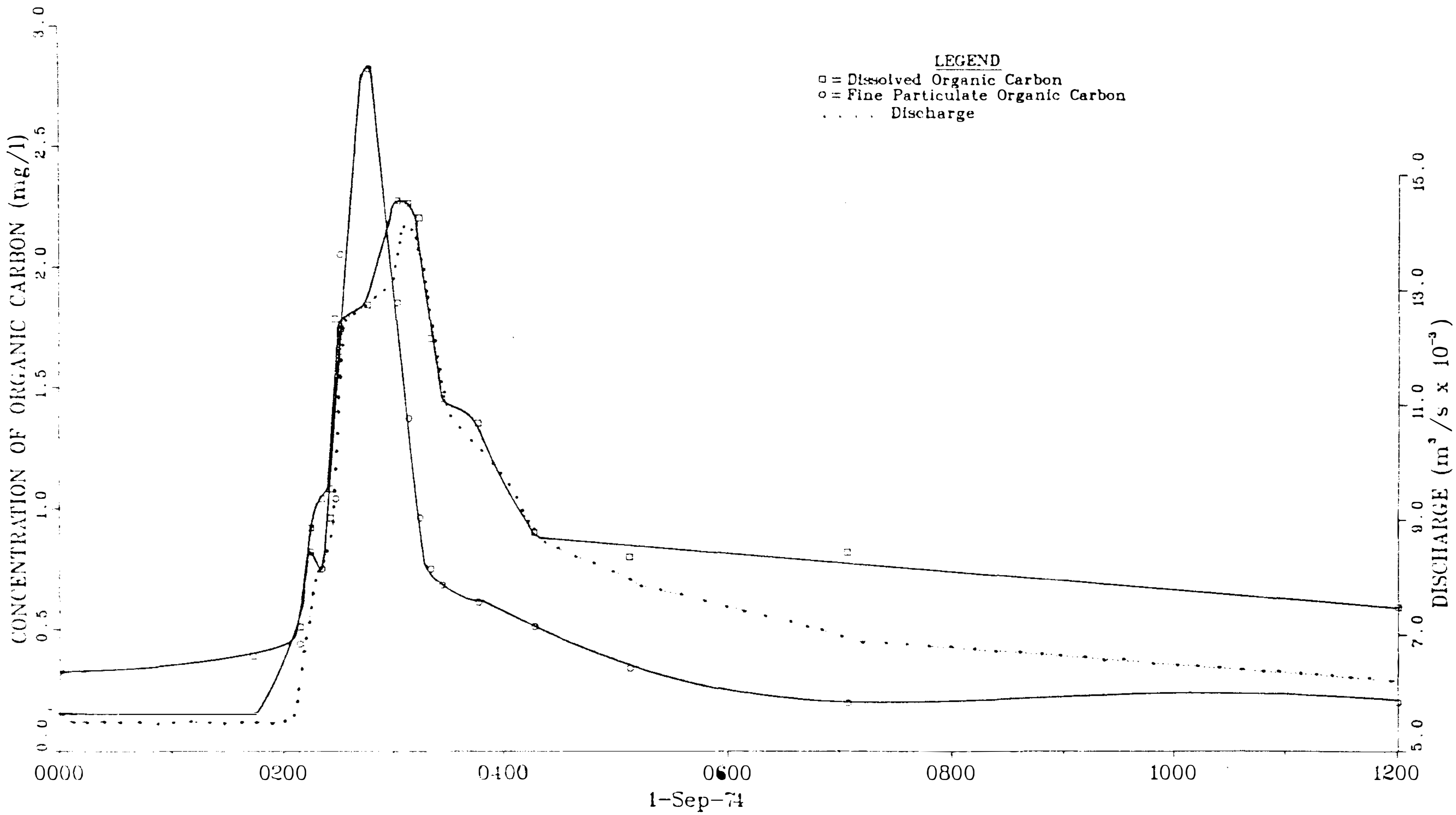

Figure 81. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of September 1, 1974.

0.0020 m^3/s increase/5 minute interval for 1645 - 1650, a difference of 4.6 times greater increase in discharge during the period of peak concentration of FPOC in the August 29 storm. Thus, peak FPOC concentrations in subsequent storms did not show indications of depletion, but were more expressive of the intensity of water input to the stream, with this general relationship holding for all three peaks. The behavior of FPOC with relation to the hydrograph (decreasing concentrations while the hydrograph was increasing), makes the relationship between FPOC and rate of increase in streamflow more convincing. Throughfall probably introduced a given amount of particulate organic material into the stream system (or raised it off the bottom from raindrop impact), and this particulate matter was in an unstable state with regard to suspension and fell out quickly. Thus, it was only for the short period when rain was falling intensely that concentrations were raised. Unless this high intensity input, bottom disturbance, and hydrographic acceleration continued, concentrations declined sharply as the organic material settled to the bottom. An alternative explanation might be that heavy rain was more efficient at canopy washing than less intense rain, especially for FPOC. Generally, these concentrations of DOC and FPOC attributable to increases in discharge agreed with concentrations of DOC and FPOC in throughfall, which were low in August 1974 (monthly means of 4.03 and 3.04 mg/l for DOC and FPOC respectively). Thus, during these smaller storms the major factor in increasing FPOC concentrations seemed to be throughfall additions.

A small shower (0.51 cm of rainfall), extending over a two-hour period on September 9, resulted in the hydrograph and concentration data

shown in Figure 82. An increase in discharge of 23% at peak flow resulted in a tenfold increase in concentration of DOC (and a twelve fold increase in output of DOC). This would correspond to a concentration of throughfall input of 13.76 mg/l if all water input and increase in DOC were due to throughfall input to the stream channel. Consistent with other results, the FPOC concentration peaked before DOC concentration, and was declining during the peak in the hydrograph. Ratio of peak concentration of DOC to FPOC was 1.72. Throughfall for September had DOC concentration of 11.33 mg/l, indicating possible leaching of a senescing canopy. The small size of the storm and the suspected leaching of dissolved material from the foliage contributed to the high peak concentration ratio of DOC to FPOC.

The main reasons for the general sharp increase in streamflow concentrations of DOC and FPOC were low ambient (baseflow) concentrations along with the small size of the stream system. Even a small rain causes a discernible rise in discharge, and a moderate shower can double discharge. High concentrations of DOC and FPOC in throughfall (11.30 and 4.27 mg/l, respectively, in September 1973), up to two orders of magnitude higher than concentrations in streamflow, were responsible for major increases in concentrations of organic carbon, especially the dissolved form. This was particularly so in smaller, less intense showers.

A larger, more complex storm occurred on September 17, 1973, (Figure 83) consisting of two storm events. The first storm, showing a higher peak discharge and more rapid rise in the hydrograph, had a ratio of peak DOC concentration to peak FPOC concentration of 0.58, while the second, a less intensive storm, had a peak ratio of 0.82, with no

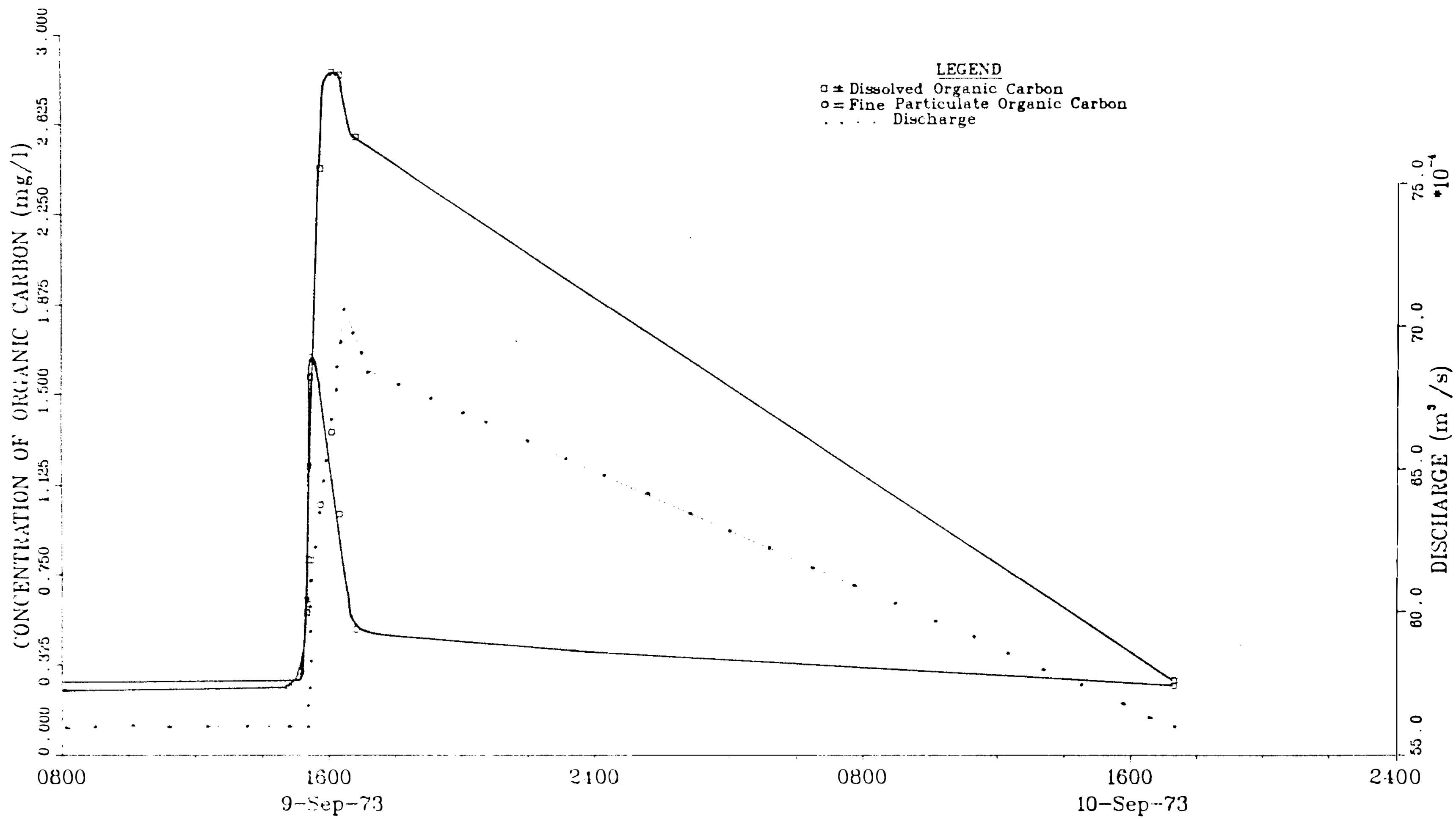

Figure 82. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of September 9-10,1973.

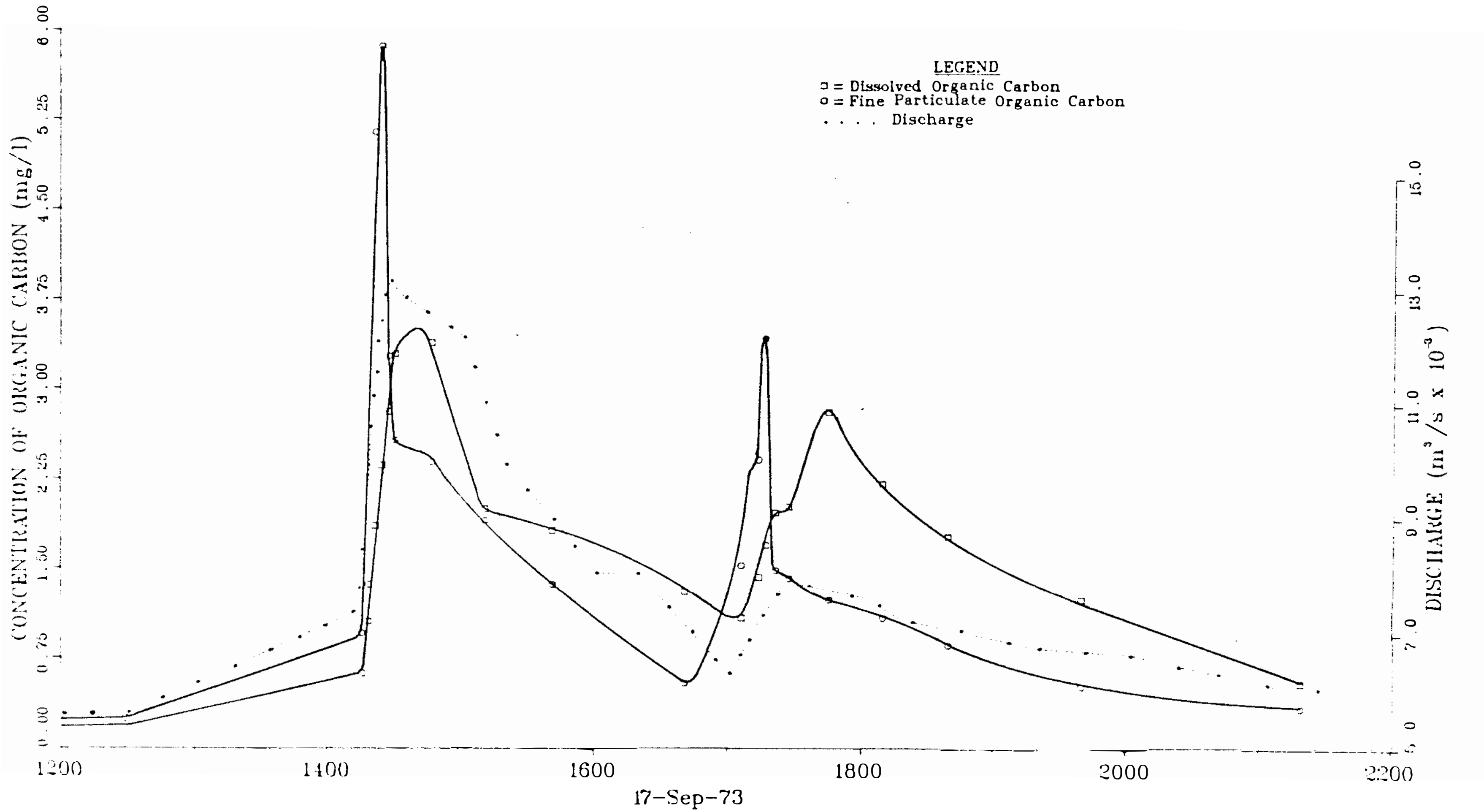

Figure 83. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of September 17, 1973.

indication of depletion of source of DOC. In fact, just the opposite trend could be inferred from the data. Again, FPOC concentrations were apparently related to intensity of rainfall, peaking during the most intensive rise of the hydrograph and responding to rainfall events (1700 - 1800) much more rapidly than DOC.

The storm series of September 29 through October 1, 1973 (Figure 84) showed three separate peaks. FPOC concentrations were again most related to intensity of hydrographic rise. Peak concentration of DOC (3.84 mg/l) would represent a throughfall input of 7.54 mg/l if all flow increases were due to throughfall inputs. The second DOC peak can likewise be calculated as resulting from an input increase of 7.3 mg/l. These compare relatively well with the mean DOC concentrations for September and October of 11.33 and 8.59 mg/l, respectively.

The larger storm of October 28, 1973 (Figure 85) began with a higher baseflow concentration of DOC due to leaching of the large input of leaf litter entering the stream at the time. Peak DOC concentrations were 4.45 mg/l, representing a throughfall input containing 6.31 mg/l DOC. FPOC concentration did not peak as fast as during the summer months, perhaps because the canopy was depleted of FPOC due to lack of insect activity at this time (as seen from the lack of frass fall at this time), with the increase in FPOC concentration having been more dependent on incident precipitation levels of FPOC.

Soon after the major inputs of litterfall ceased, a large storm, the largest ever recorded at Walker Branch watershed, completely flushed the system. The storm actually occurred over a period of several days (Nov 26-28), with two major and several minor peaks (Figure 86). Of

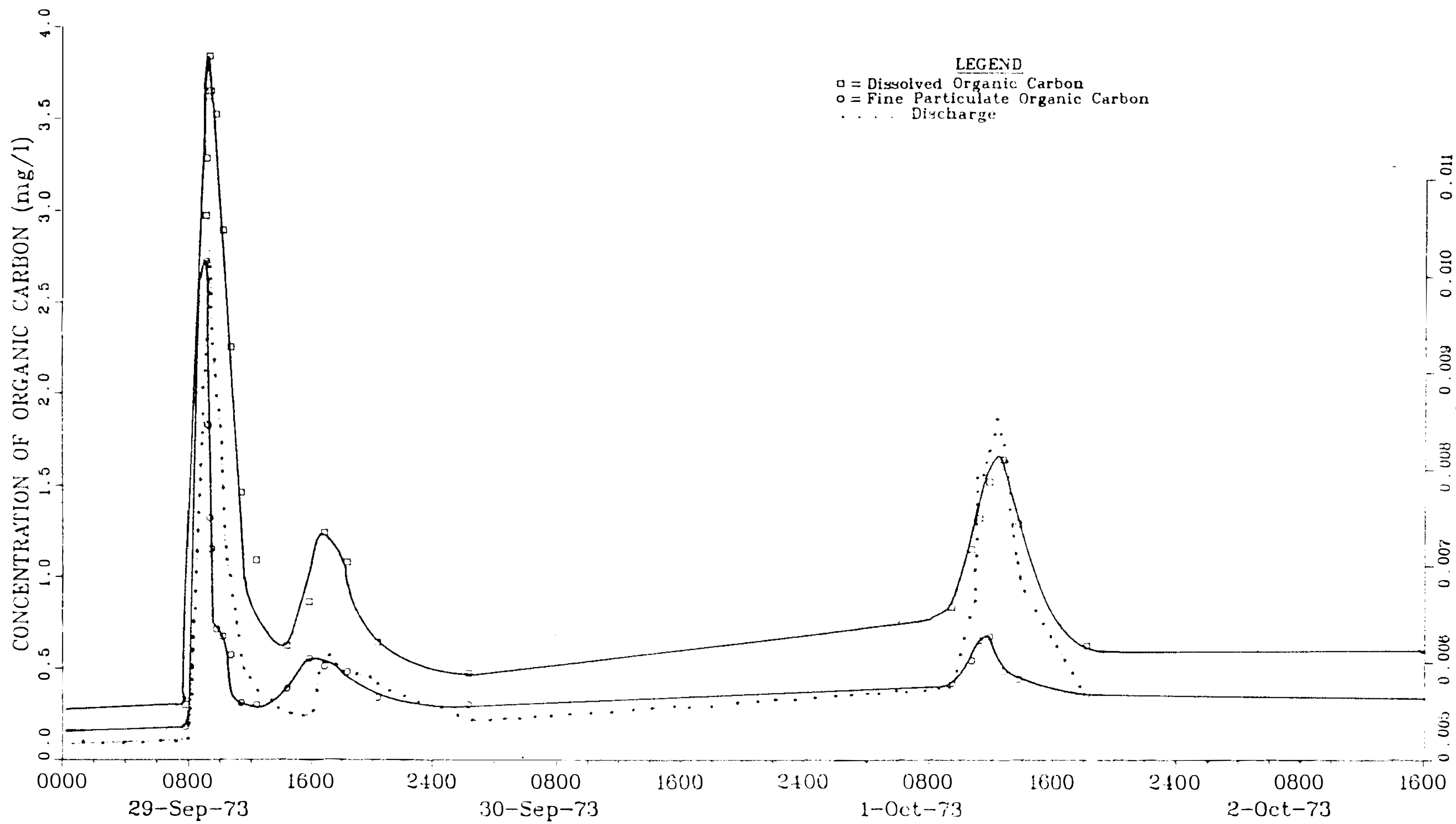

Figure 84. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of September 29 - October 1, 1973.

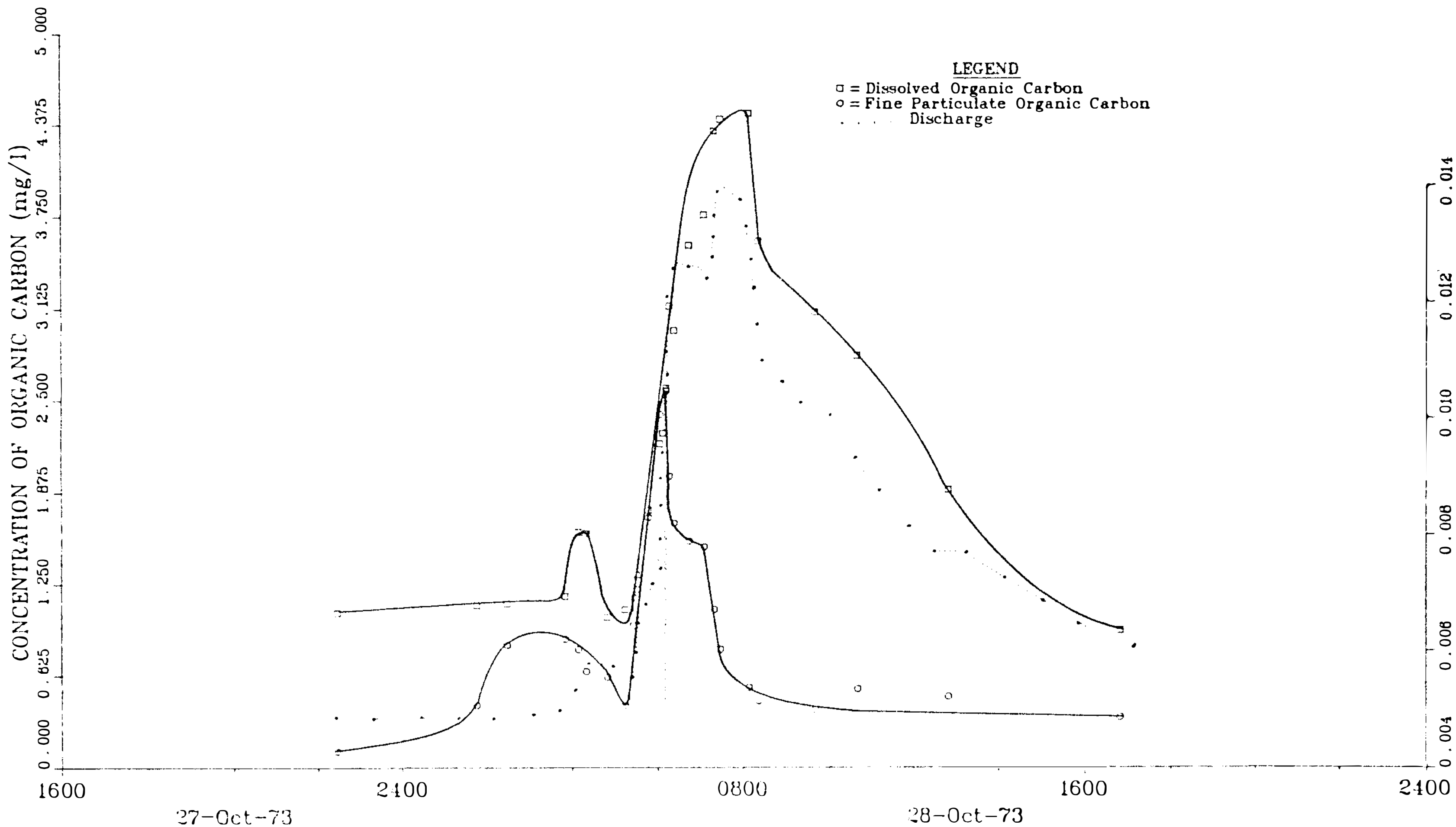

Figure 85. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of October 28, 1973.

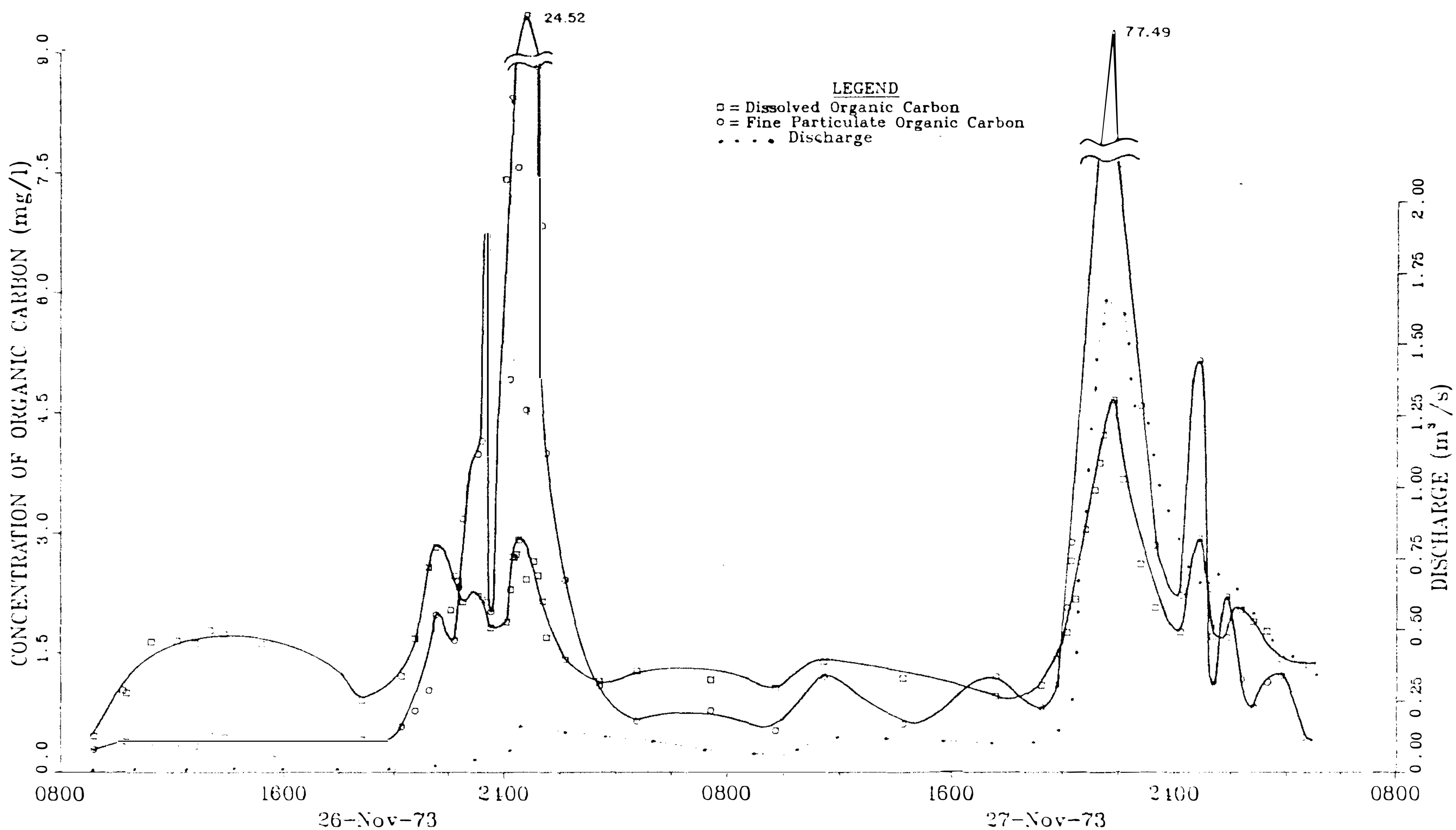

Figure 86. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of November 26-28, 1973.

special note was the DOC/FPOC ratio and the relative responsiveness of DOC vs FPOC with regard to changes in streamflow. Since autumn litterfall was virtually over at this time, most of the FPOC must have come from the stream system and surrounding landscape. Throughfall concentrations for November averaged 2.08 and 0.72 mg/l for DOC and FPOC, respectively (see Figure 52, page 222). Since peak concentrations of DOC and FPOC were greater than these values (for FPOC, two orders of magnitude greater), the source was other than the throughfall water itself. Breakup of leaf packs in the stream with release of trapped dissolved and fine particulate matter contributed to stream concentrations. Also important were inputs from intermittent flow areas (variable source areas), where no water had flowed for almost six months, and where large amounts of litterfall and blow-in had accumulated.

A second factor complicating interpretation of the pattern of DOC and FPOC concentration was the obvious contribution of water from sources other than direct input to the stream channel by rainfall. Because of the large amount of rain falling during this time, large inputs of water from lateral flow in the soil profile (feeding variable source areas), as well as from increased spring flow, would be expected to modify the pattern of DOC and FPOC concentrations compared to the previous summer or early fall storms.

A comparison of the various peaks is instructive in ascertaining the relative behavior of DOC and FPOC with flow. During the initial small rise (1018 - 1225, November 26) ratio of peak DOC to peak FPOC concentration was 4:1. This high ratio can be related to throughfall inputs for the month, which had a ratio of 2.89, indicating minimum

disruption of the stream bottom along with some settling of FPOC inputs due to the slow rise of the hydrograph.

During the next hydrographic ascent (peaking around 0100 on November 27), the ratio was 0.12, indicating the shift in emphasis to FPOC discharge at these higher flows. FPOC concentrations were 17.55 - 24.52 mg/l, the highest found on the watershed up to that time. The reason for the low ratio was that DOC concentration was dependent on either throughfall inputs, springflow inputs, or lateral flow - variable source area inputs, the latter two having lower concentrations than throughfall. Another source for DOC was interstitial water in the stream system, but the storage capacity of the substrate system was minor compared to the great volume of water passing through the system. Thus, DOC concentration (and input) did not increase above a level comparable to throughfall concentration. FPOC on the other hand, increased greatly during the major storm due to the large (newly acquired) amount of organic material already in the perennial and intermittent stream system.

A similar situation is seen for the very large peaks on November 27, between 2100 and 2200, where DOC/FPOC ratio was 0.06. This peak flow (1.63 m^3/sec) represented the greatest flow ever recorded on the west fork watershed. Highest concentrations recorded during the study were found during this time, ranging from 68.09 mg/l to 77.49 mg/l. During the major peak, FPOC concentration was greatest near peak flow, while for smaller storms, peak FPOC concentrations usually occurred sometime before peak flow. In this case, there were added sources, the streamside litter layer and source areas. These were undoubtedly the sources for the high concentration of FPOC, as the peak flow of the

previous day had removed most of the organic material from the stream channel (perennial flow and a portion of intermittent flow sections) itself. This would also explain the higher concentrations of DOC for this peak (as compared to the peak flow of the previous day), as flowing water entrained large amounts of relatively unleached and unwashed organic material present in the litter. Headwater extension into intermittent channels where flow was rare was possibly the major source for much of the organic carbon. The litter layer on these source areas and streamside forest floor had probably accumulated a large amount of readily dissolvable organic material from catabolic biological processes, thus yielding DOC concentrations in streamflow somewhat greater than those in throughfall.

In the case of both peak flows, FPOC responded much more quickly to changes in streamflow than did DOC, with order of magnitude changes occurring within a one-half hour period.

Figure 87 shows the response for DOC and FPOC during the storm (December 4) following the major storm event just described. As can be seen, the stream system was relatively unresponsive to a doubling of flow (0.011 to 0.021 m^3/s), with DOC showing almost no increase, and FPOC with peak concentration of only 0.54 mg/l. This resulted from prior removal of reserves of DOC and FPOC from the stream channel plus the thorough washing and leaching of the entire terrestrial watershed system during the late November storm along with presumably low concentrations of organic carbon in throughfall.

Approximately a week later another fairly substantial storm event occurred (Figure 88), with flows increasing from 0.008 m^3/s to an

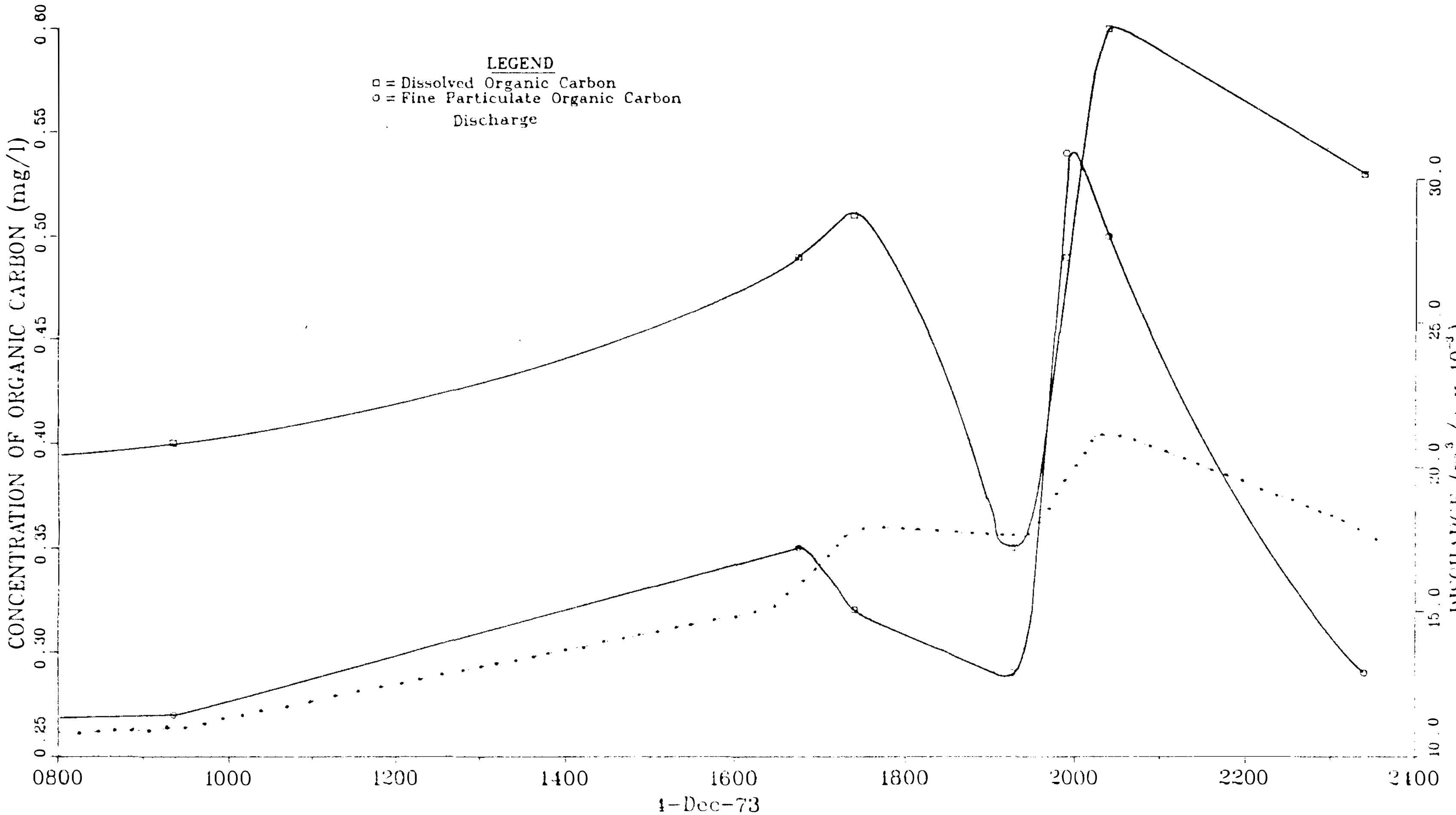

Figure 87. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of December 4, 1973.

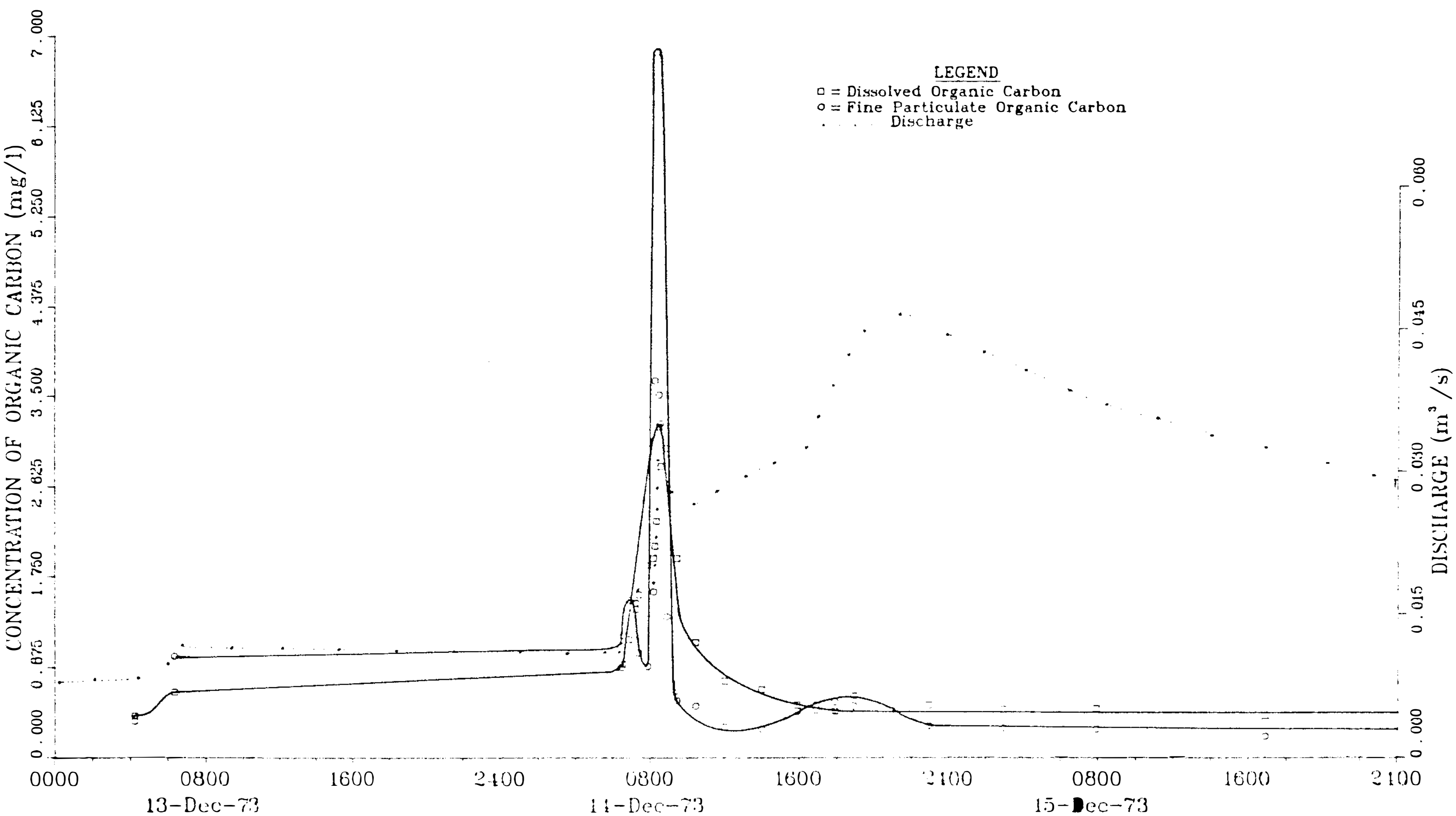

Figure 88. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of December 14, 1973.

initial peak (December 13, 0845 - 1900) of 0.031 m^3/s a four-fold increase. Somewhat surprisingly, fairly high concentrations of DOC and FPOC were found, with peak concentrations of DOC and FPOC being 3.20 and 6.84 mg/l, respectively, for a ratio of 0.47. Mean concentrations in throughfall for the month were 1.90 and 0.47 mg/l for DOC and FPOC, respectively. Since the stream system was thoroughly flushed of organic matter at the time of this storm, the concentrations above baseflow must be explained by higher throughfall concentrations during this storm than for the rest of the month. Since there was a very large storm on December 26, 1973, which was accompanied by low concentrations of DOC and FPOC, this reasoning is probably correct. Also, the December 4 storm had very low organic concentrations in throughfall based on concentrations in streamflow (Figure 87), a fact which would contribute to a low monthly mean for throughfall DOC concentration. Soil water data (see Figure 65, page 258) showed the first half of December with the highest DOC concentration of the year for the pine and oak-hickory types, adding further evidence for relatively higher DOC concentrations during this period in throughfall.

Another point relating to this December 13 hydrograph was the occurrence of the second peak (~ 2100) during a period of no rain. This delayed behavior, often seen in storms of moderate size during periods of saturation of the watershed system, was due to delayed inputs from source areas and groundwater, originally fed by the precipitation event, but involving some water previously stored in the soil water/bedrock system. During this hydrographic rise, a small but discernible increase occurred in FPOC concentrations, while little increase was seen for DOC. This

was related to the relative sources of FPOC and DOC. For FPOC, the increase in concentration most probably represented material being lifted off the stream bottom by the increasing flow, although springflow increases in FPOC may have also occurred. For DOC, little increase in concentration was seen, due to the fact that the sources for DOC were strictly within the soil water or groundwater, and these have been shown to be quite low in DOC (see Figures 65 and 66, pages 258 and 288, respectively). As seen in a later storm, the relative behavior of DOC and FPOC during these "non-rain" hydrographic rises was dependent on the quantity of organic material in the stream channel, and the relative magnitude and intensity of the rainless rise as compared to the preceding rise, the latter being due mainly to direct channel input of water via throughfall. The timing of the two events was also important. If the rise had been delayed long enough for DOC concentrations to decrease from peak concentration, then DOC concentrations would have remained relatively constant during the rise, or would even have increased slightly. If the groundwater rise had come before DOC concentrations declined from the peak, then an actual decrease in DOC would have been seen .

Another large storm event occurred on December 25 - 26, 1973 (Figure 89). As can be seen by comparing Figure 88 and 89, the increase in discharge was greater for the storm of December 25 than for that of December 13, but DOC concentrations remained much lower, never reaching 2.0 mg/l. This coincided with the mean DOC concentration for the month for throughfall of 1.90 mg/l. FPOC concentrations, on the other hand, reached a peak of 13.21 mg/l during the period of most intense hydrographic rise, at a discharge rate (0.29 m^3/sec) only 39% of peak dis-

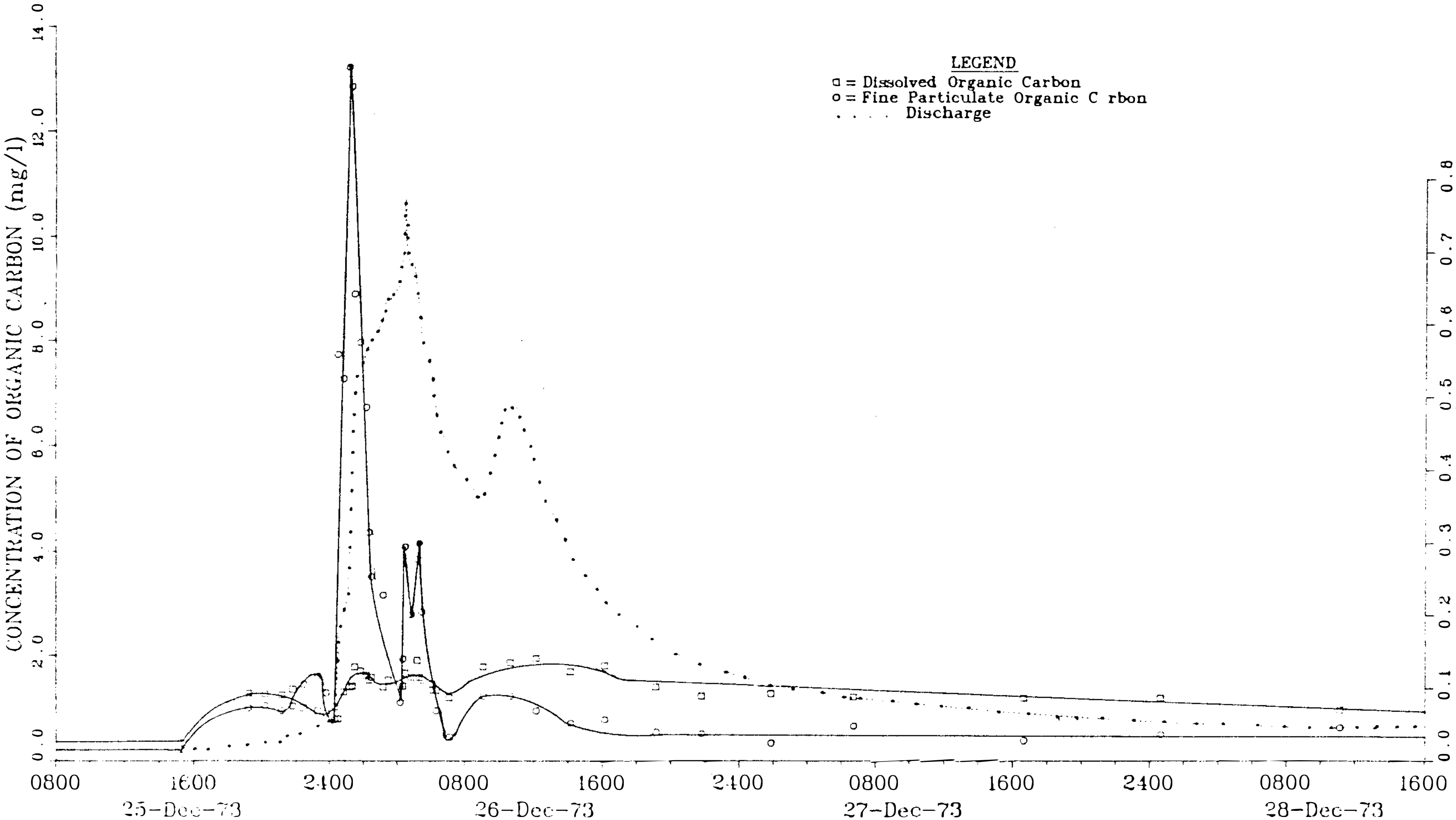

Figure 89. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of December 25-26, 1973.

charge. Again, FPOC concentration was most responsive to rates of change in discharge, while DOC concentration showed a smoother progression through time. Compared to the storm of November 26 - 28, where peak concentration of FPOC and discharge were much more synchronous, the difference could be explained by the fact that highest concentrations of FPOC during the earlier storm were due to bank overflow and flushing of the litter layer along the low-lying slope positions. For the latter storm, with substantially lower peak discharge, the highest flows did not encounter this litter layer, thus FPOC concentration behavior was more like that for a typical storm, which does not overflow the banks.

A similar result was seen for the storm of January 28, 1974 (Figure 90), during which FPOC reached a peak concentration of greater than 3 mg/l, while DOC concentration never exceeded 1.0 mg/l. Since peak FPOC concentration represented an input of water with 10.45 mg/l FPOC, the obvious conclusion is that much of this increase in FPOC came from the stream substrate itself, since throughfall values for January showed both DOC and FPOC concentrations quite low (2.19 and 0.60 mg/l, respectively). Data for inputs to the stream system in litter fall and blow-in showed no significant inputs during January. In fact, due to the lack of strong winds during the period, blow-in was at a six-month low (see Figures 10 and 11, pages 75 and 76). In this storm, the secondary rise (occurring from 1500 to 2050 on January 28) showed a decrease in DOC and very little increase in FPOC concentration, the latter due to the small overall rise and the slow rate of increase in discharge. A similar situation with regard to this secondary rise was seen in the storm of February 5 1973 (Figure 91).

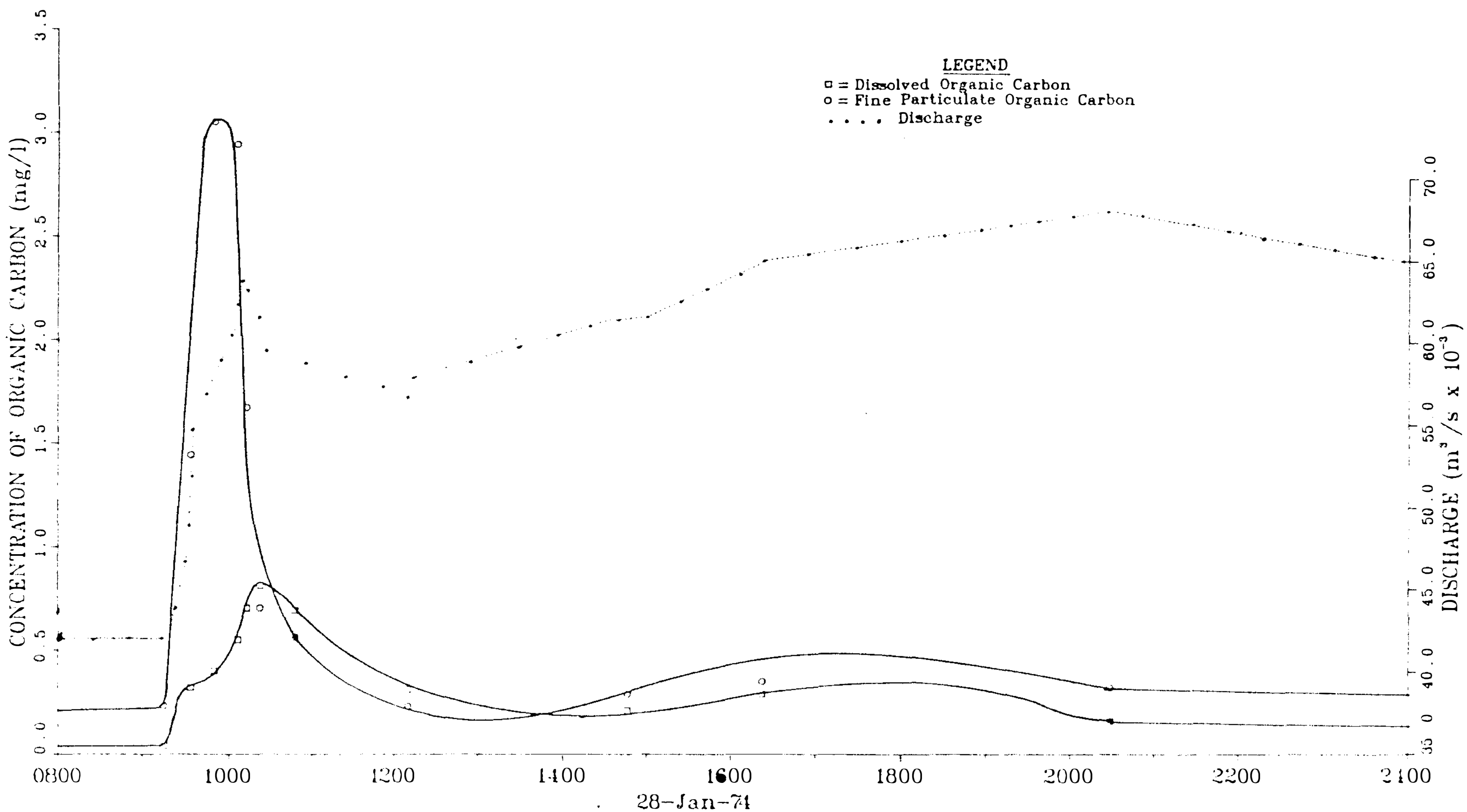

Figure 90. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of January 28, 1974.

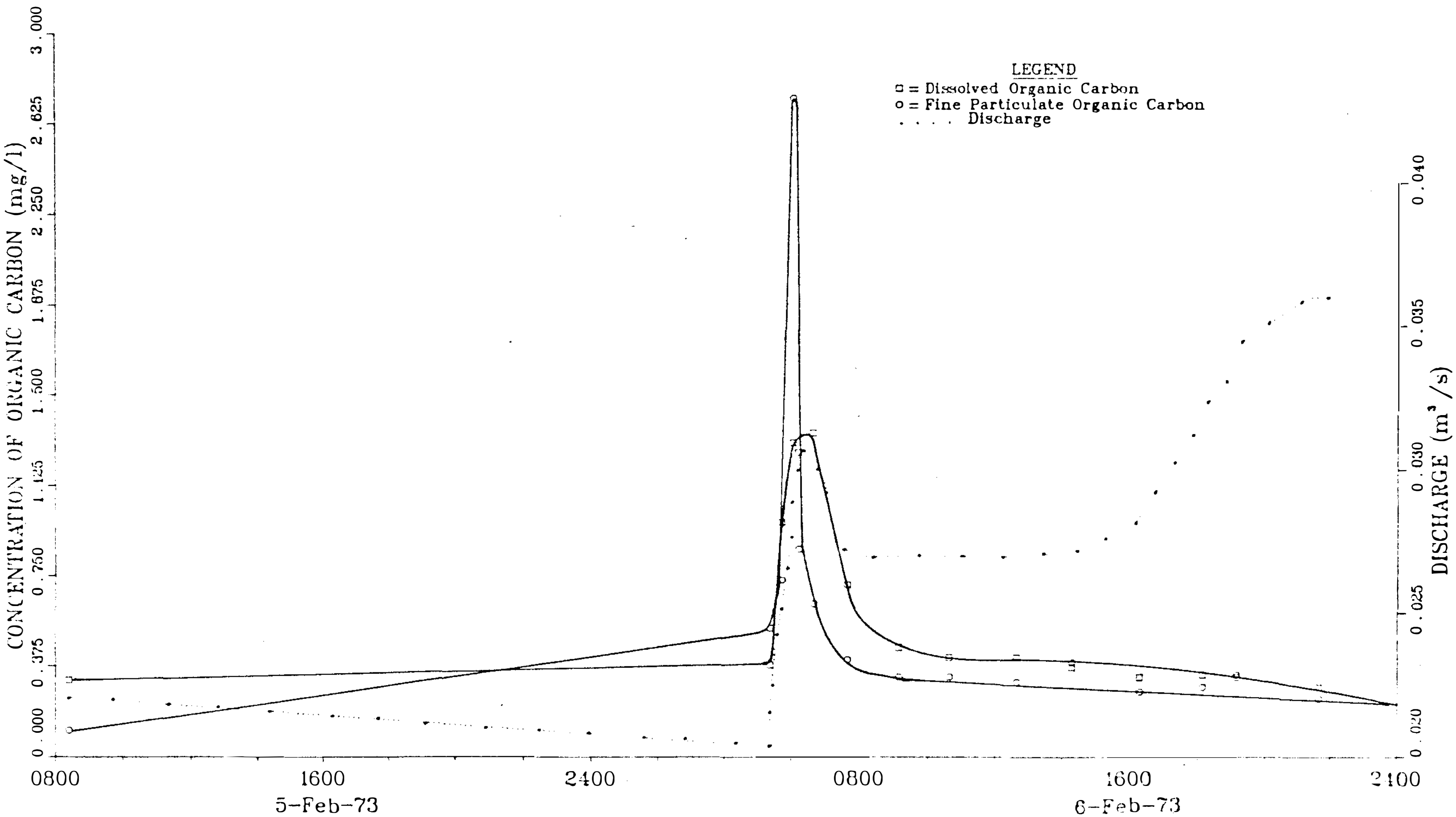

Figure 91. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of February 5, 1973.

The storm of March 15-17 1973 (Figure 92) showed the results of a large groundwater/soil water input to the stream system. Approximately 4.5 cm of rain had fallen over a three hour period prior to cessation of rainfall at about 0900. This extended heavy rainfall had time to filter through the watershed system, and from 0900 to 1130, with insignificant rainfall, streamflow rose from 0.053 to 0.130 m^3/sec. Since much of this increase was due to input from source areas and lateral flow through the soil profile to the intermittent flow sections of the stream system, where substantial quantities of organic material had been accumulating, concentrations of FPOC increased greatly, while DOC continued to decline through the period. Maciolek (1966) stated that much of the detrital increase during rising (spring) flows was due to moblization of organic matter (partly humidified) as seston from areas of fall and winter deposition (pools). He also noted peak concentrations before peak discharge. It is interesting to note that the behavior of FPOC during this period of rise paralleled that during periods of hydrologic rise due to direct channel input, in that FPOC concentration was again most closely associated with the rate of change of discharge. Based on these observations, it would appear that the work necessary to suspend or keep in suspension FPOC, can only be accomplished at high rates of increase in discharge. The similarity between this "no-rain" portion of the hydrograph and springflood due to snow melt in more northern watersheds is noted. Since the concentration of DOC in groundwater and soil water is apparently dependent on residence time in the soil/bedrock subsystem, DOC concentration did not decline dramatically from throughfall levels, as water passed through the soil/ bedrock system relatively rapidly. It

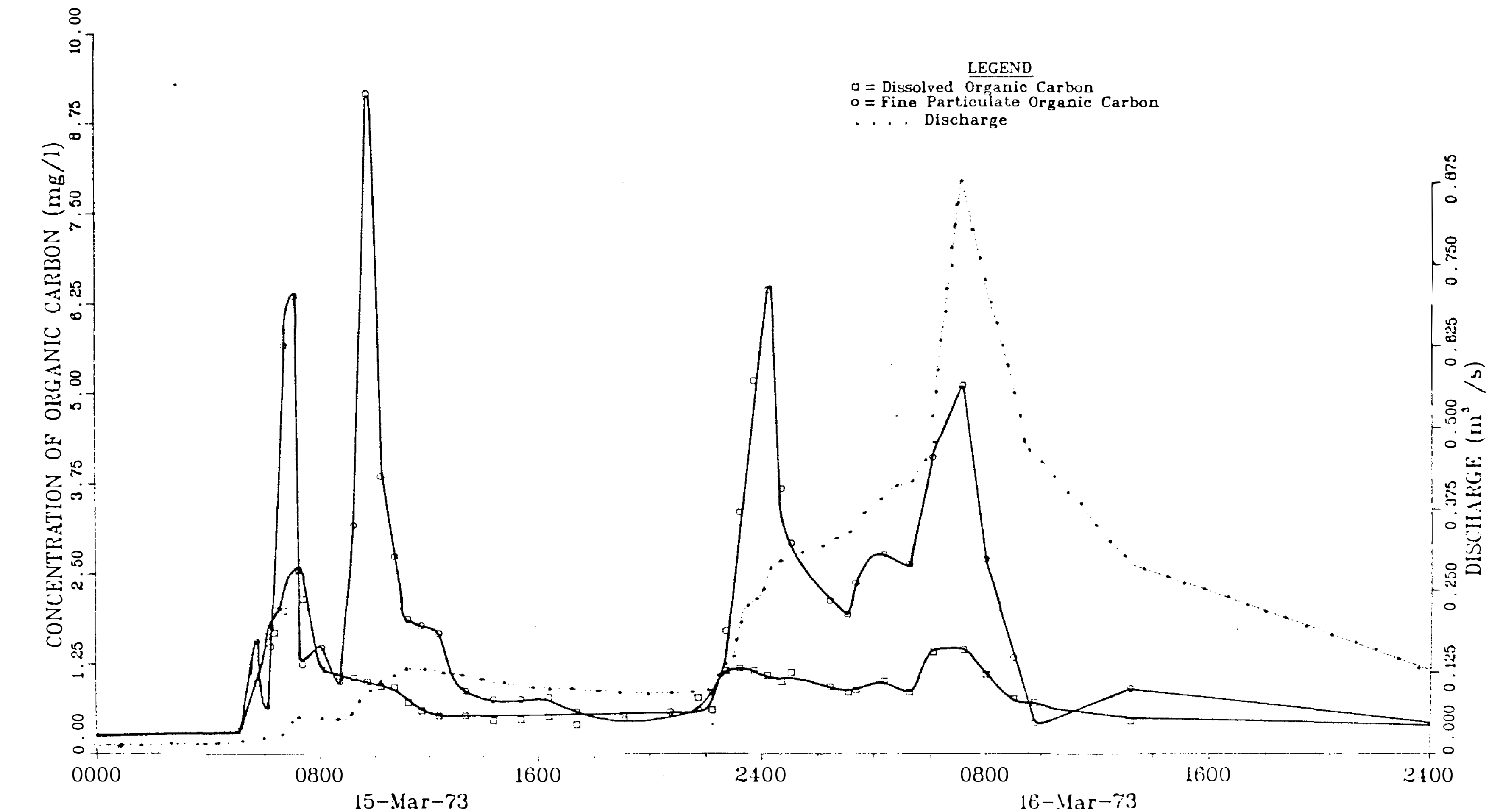

Figure 92. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of March 15-16, 1973.

is interesting to note that both DOC and FPOC concentrations were greater during this smaller event than for the major storm on March 16. During this latter event, FPOC concentrations followed their characteristic trend of rising and falling rapidly with rates of change in discharge. As with other large storm events, FPOC concentrations were substantially higher than those for DOC, but because the previous storm (on March 15) had removed much of the organic material from the system, FPOC concentrations were not exceptionally high.

Another large storm, occurring on March 19 - 21, 1974 (Figure 93), showed peak concentrations of 31.17 mg/l FPOC and 1.99 mg/l DOC, for a ratio of DOC/FPOC of 0.06. The DOC concentrations during the peak of the storm were lower than that during an earlier, smaller peak, due primarily to the source of increased streamflow. It is assumed that the larger peak on March 21 had a significant groundwater/ soil water contribution, while the former had very little, with most inputs coming from direct channel input of precipitation. The concentrations of DOC in streamflow were somewhat less than the mean for DOC concentration for the month for throughfall. Throughfall concentrations for March 1974 averaged 3.10 and 1.48 mg/l for DOC and FPOC, respectively. This helps substantiate the claim that a significant input of groundwater of lower DOC concentration was occurring.

A late April storm series covering the period April 24 to May 3, 1973 is presented in Figure 94 and 95. Even though newly emerged canopy was present, this series still exhibited characteristics of winter storms. Peak DOC concentrations barely exceeded 2.0 mg/l, while FPOC concentrations of 6.45 mg/l were observed. DOC concentrations were higher during earlier peaks than during the major peaks, due to ground-

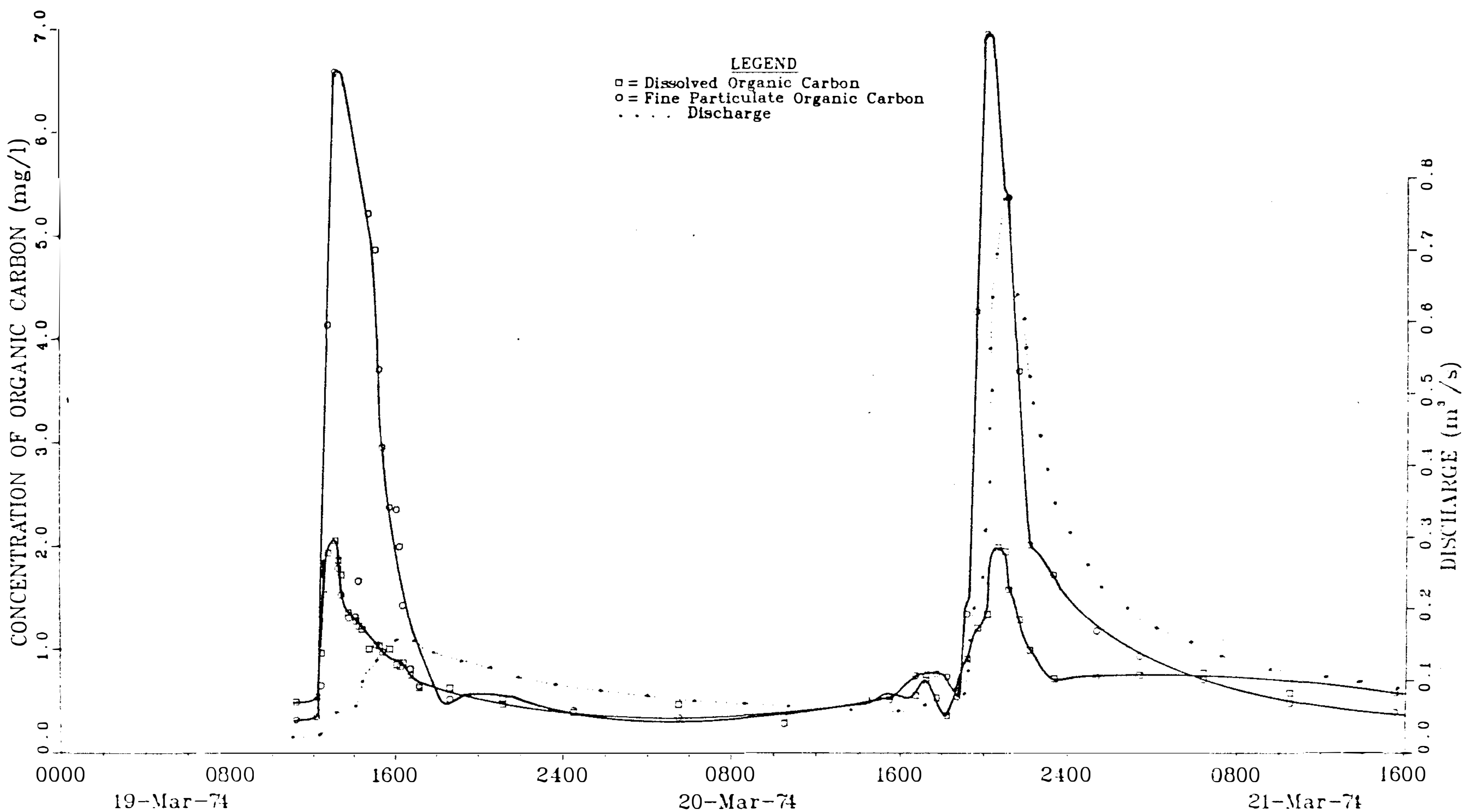

Figure 93. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of March 19-21,1974.

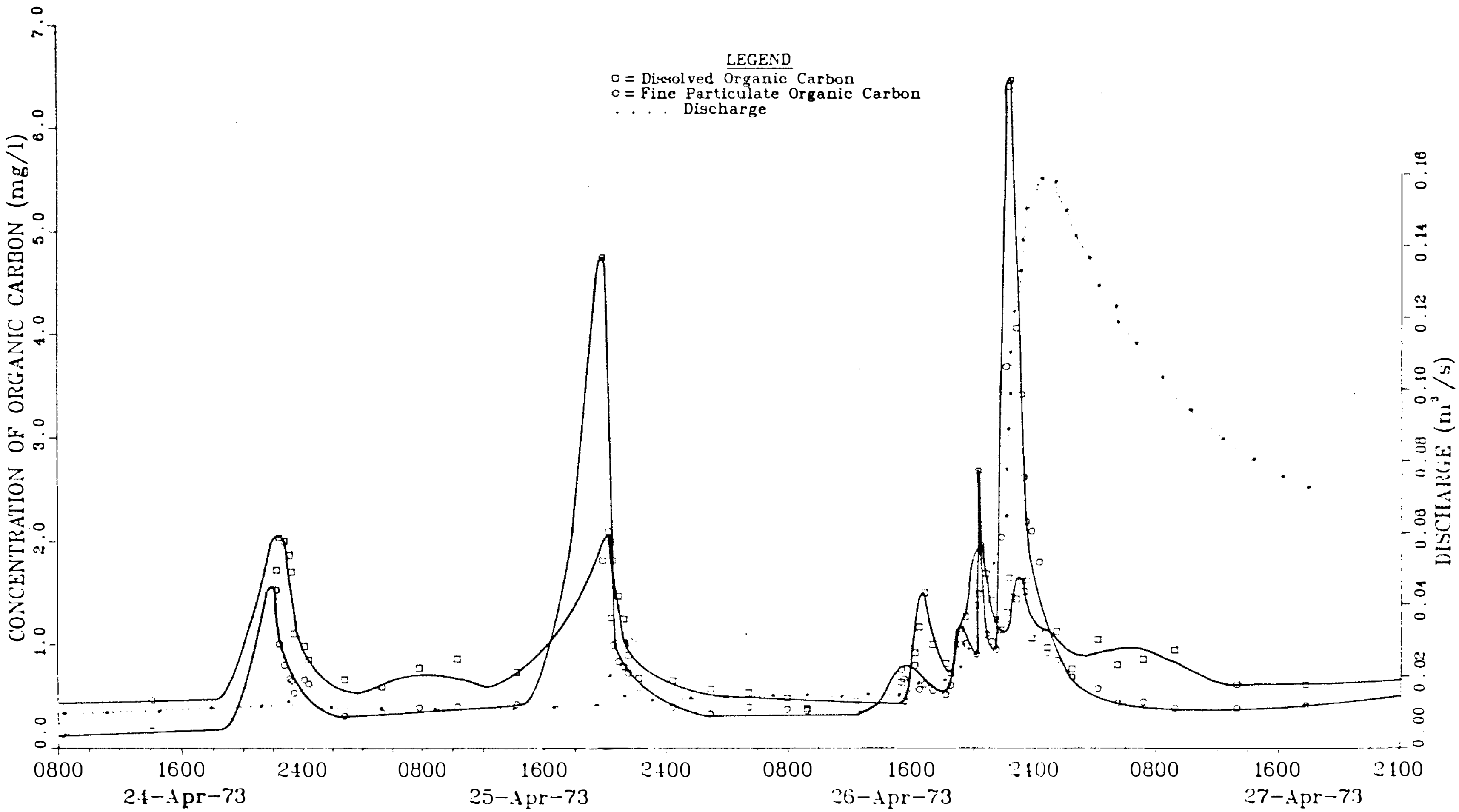

Figure 94. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storms of April 24-27, 1973.

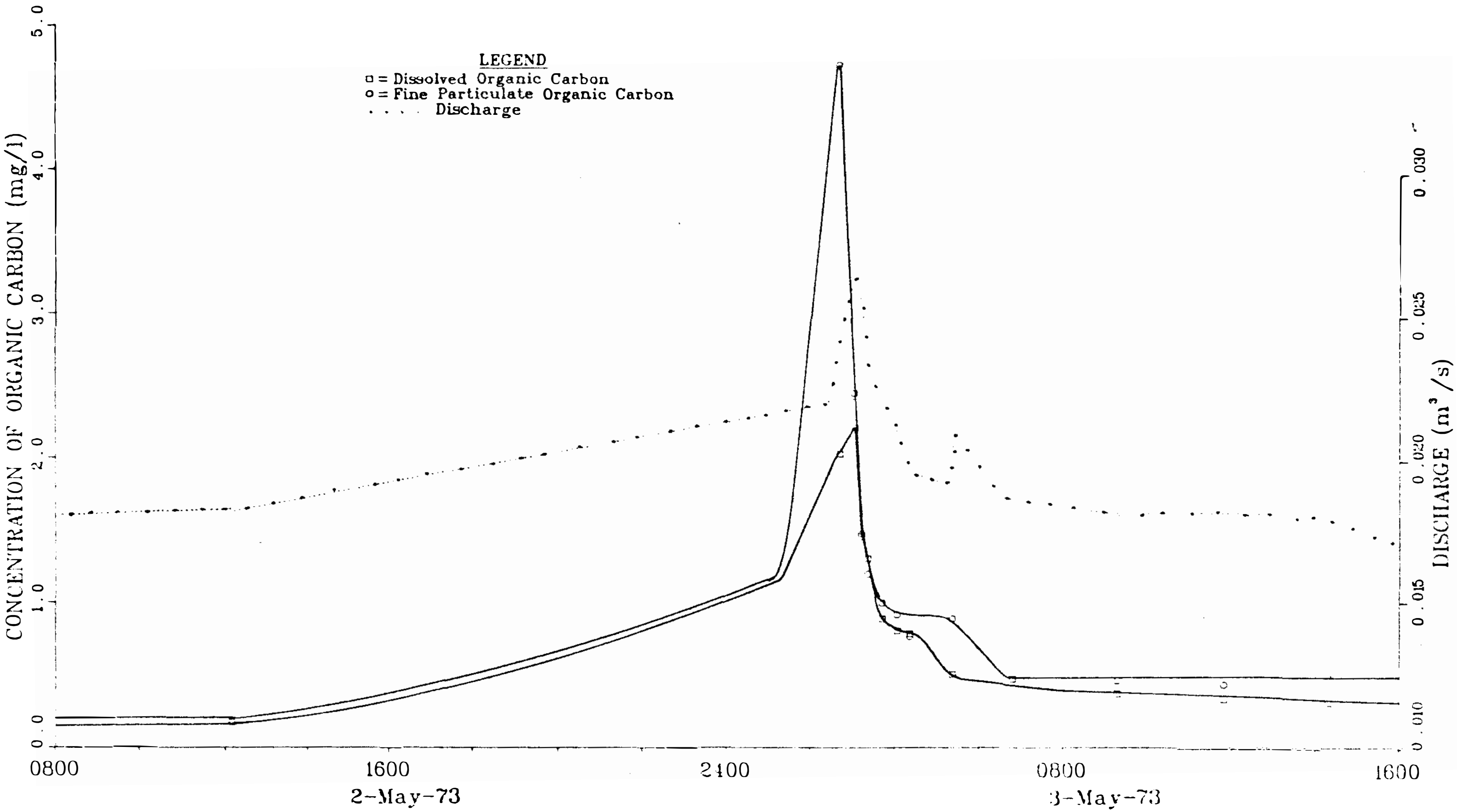

Figure 95. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of May 3, 1973.

water/soil water inputs during the latter peaks, in addition to possible depletion of the dissolved source in the atmosphere or canopy. It is interesting to note that, for the entire series, the highest DOC concentration (2.20 mg/l) was found during the relatively small storm of May 3, but here again FPOC peak concentrations were approximately twice those of DOC. The source for the substantial increase in FPOC during the latter storm may have been organic debris in the channel or canopy wash, both resulting from flowering occurring in the canopy at the time. Much of this material was easily broken down by physical and chemical means to fine fragments. Another source could have been pollen. Also, substantial blow-in occurred during the previous month, with sufficient time for some within-system biological and physical processing.

A few days later, another storm occurred (May 8, 1973), and this initial storm was followed two days later by a second storm of smaller magnitude and duration (Figures 96). Note the lower concentrations of FPOC during the early part of this May 8 storm than during the one for May 3, discussed above, at comparable flow rates. The difference again appears to be due to the rate of increase in discharge. The early part of the storm of May 8 showed a somewhat slower rise than did that of May 3. Also note, that for this early rise, the ratio of peak concentration of DOC to peak concentration of FPOC was greater than one. During the period 1925-1955 on May 8, streamflow rise was intense compared to that for May 3, and still the peak FPOC concentration was lower for May 8. However, in this case the ratio DOC/FPOC concentration was less than one (0.66).

Note also the increasing concentration of FPOC with increasing discharge for the period 2110-2255. This was a period similar to the storm

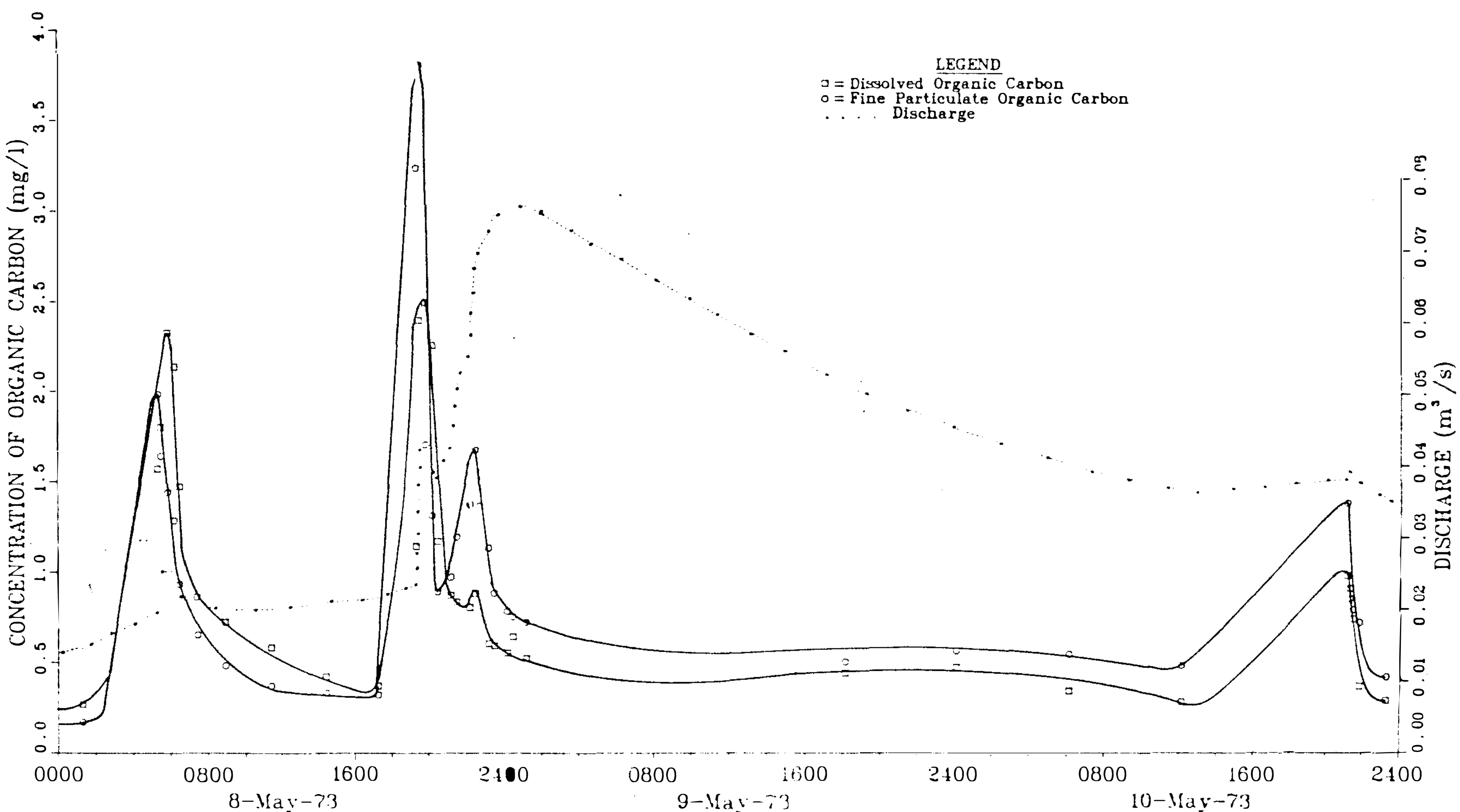

Figure 96. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of May 8-10, 1973.

of March 15, 1973, where discharge increase was due, not to rain falling in the stream channel, but to increasing springflow and soil water inputs to the channel. In this case, as with March 15, the rate, magnitude, and timing of the increased flow were sufficient to cause a mobilization of FPOC from the substrate of the stream channel (perennial and intermittent). No discernible increase in DOC was seen during this delayed rise.

The storm of May 23, 1973 (Figure 97) showed somewhat higher peak concentrations of DOC (and FPOC) than storms earlier in the spring, especially when total input due to throughfall is considered. The peak DOC concentration of 3.90 mg/l was equivalent to a throughfall input of 8.4 mg/l. The FPOC peak (5.82 mg/l) was very high in relation to change in streamflow (20%), and was indicative of a larger reservoir of FPOC in either the stream channel or throughfall. While throughfall values are not available for May 1973, the May 1974 throughfall concentrations were 4.44 and 2.02 mg/l for DOC and FPOC, respectively. Thus, the streambed is seen as the probable source for the majority of the FPOC concentration increase. Since a considerable amount of blow-in and litterfall occurred during the spring period, there was probably a modest supply of FPOC in the streambed.

A return to summer conditions was seen in the storm of June 19 to June 20, 1973 (Figure 98). No significant precipitation events had occurred for a period of almost two weeks prior to this storm. Considering the increase in discharge, the increase in concentration of FPOC in the early stages of this storm was quite significant, with the 10.03 mg/l concentration recorded for the interval 2155-2200 equivalent to an input of $\sim$ 61 mg/l over baseflow, while peak DOC concentrations

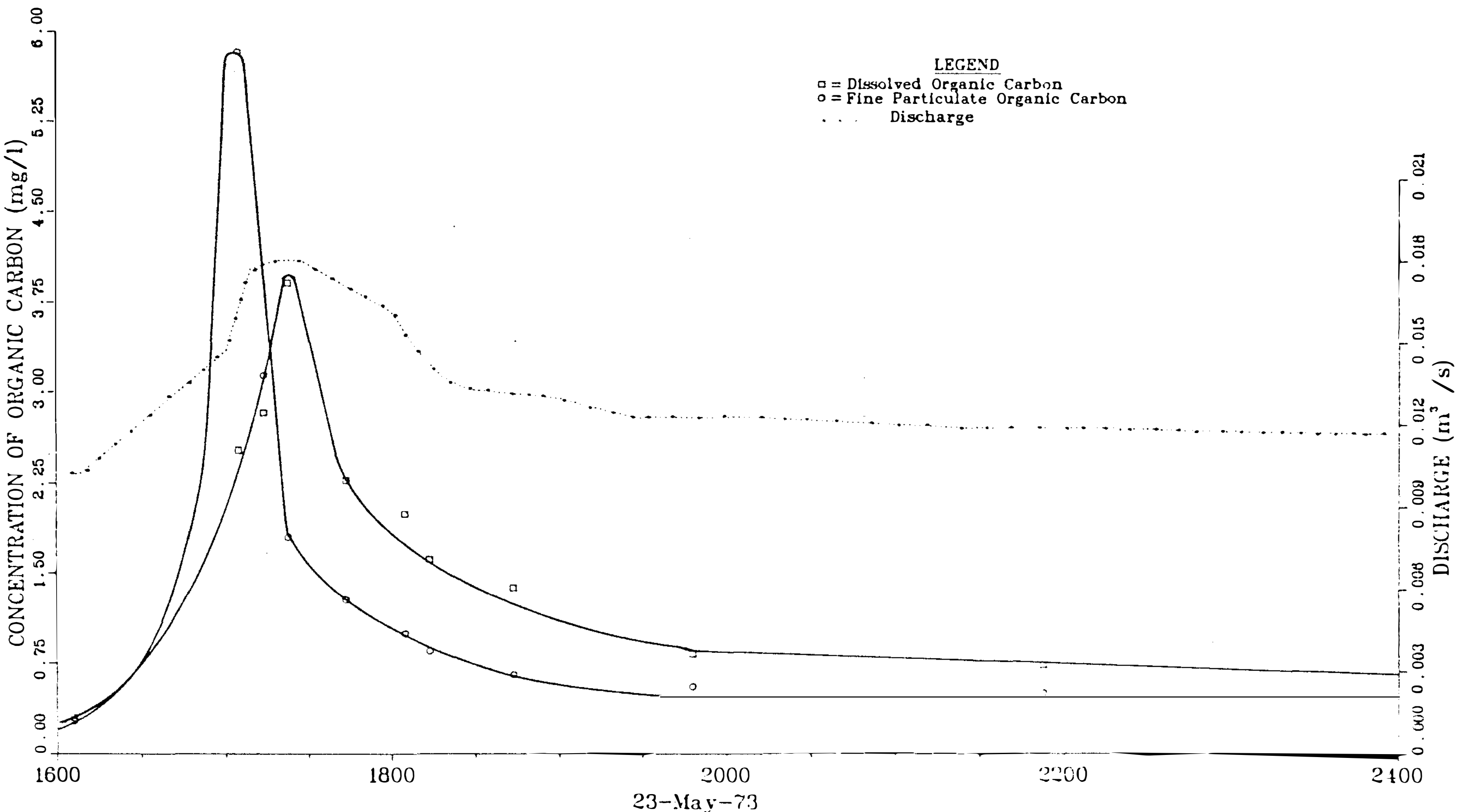

Figure 97. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of May 23, 1973.

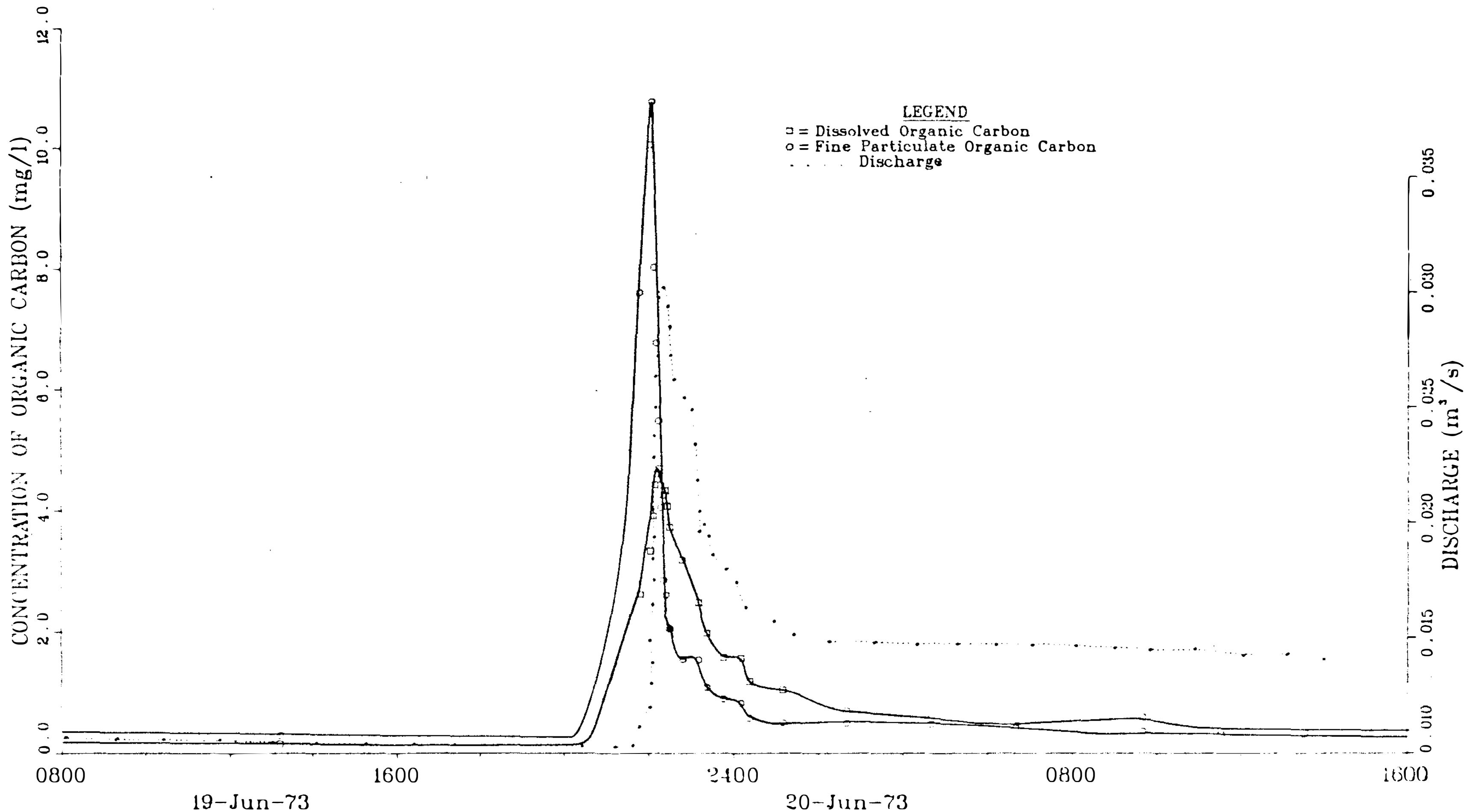

Figure 98. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of June 19-20, 1973.

(4.68 mg/l for the interval 2220-2225) represented an input of water with 7.2 mg/l DOC. Although no throughfall data are available for June of 1973, the June 1974 data showed 8.94 and 6.98 mg/l, respectively, for DOC and FPOC concentrations. Thus, while it appears that a large part of the DOC concentration increase can be attributed to throughfall, the large initial increase in FPOC concentration (at low discharge) must mean either quick washing of the canopy or input from the streambed. Since there was a large storm on May 27, 1973, which flushed most of the spring litterfall fruit out of the system, it is assumed that much of the increase in FPOC concentration during the June storm came from the throughfall.

The storm of June 27-28 is shown in Figure 99. Except for the minor peak early on June 27, this storm was similar to the previous (June 19) in that baseflows and peak discharges were comparable. However, in the later storm, FPOC concentrations were not as high, even though the rate of change and magnitude of discharge were similar in both. This would indicate that the canopy had not yet had a sufficient period to recover its FPOC load through insect activity or aerosol impaction. Peak DOC concentrations were similar in the two storms (4.68 vs 4.14 mg/l), indicating little change in the reservoir of DOC available as input during storm periods. This could be related to the fact that DOC is not depleted from the canopy as quickly as FPOC, since it is leached as well as washed from the canopy. However, since the stream substratum can serve as a source for FPOC, there is also the possibility that the differential behavior of FPOC was unrelated to condition of the canopy during that time.

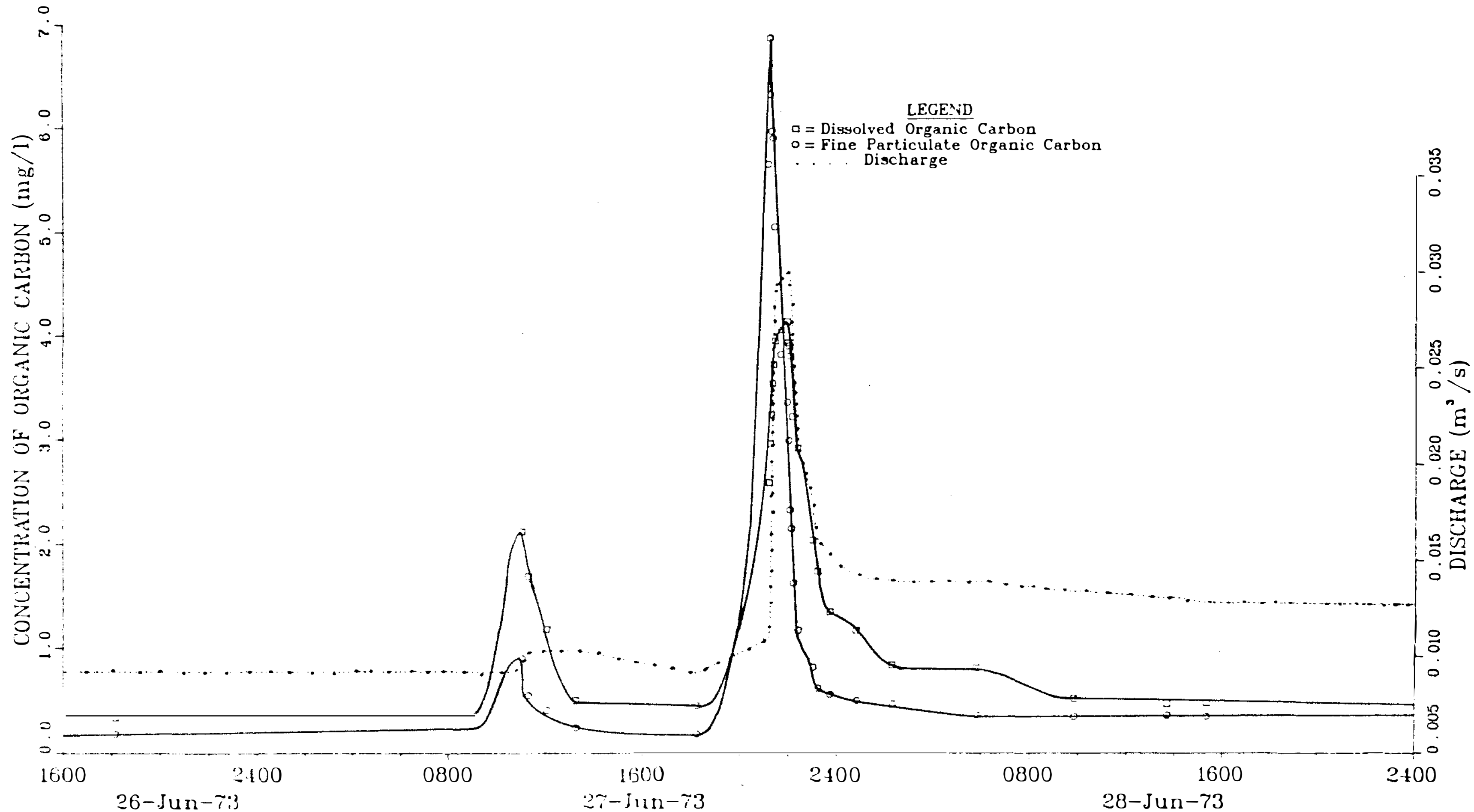

Figure 99. Relationship Between Concentrations of DOC and FPOC in Streamflow and Discharge on the West Fork of Walker Branch for the Storm of June 27-28, 1973.

Regression Analyses of the Relation of DOC and FPOC Concentrations in Grab Samples and Discharge

As a result of in-depth analyses of the behavior of DOC and FPOC concentration in individual storm cycles, it became apparent that there were characteristics of the normal hydrologic response of these organic species that negated any great amount of the variability being explained by discharge alone.

Regardless, a series of linear regressions, based on both transformed (logarithmic) and untransformed values for both the independent and dependent variables, were run to discern, among other things, possible seasonal factors that would compound the interpretation of the behavior of organic carbon as discharge increased and subsided. Once the behavior of DOC and FPOC was firmly established by detailed investigation of individual storm cycles throughout the year, the results of the regressions, including the poor fit found for many sortings of the data, were more readily explainable.

For the total data set (1559 observations), results of regression analyses (Table 44) showed DOC concentration to be very weakly related to discharge, with the semilogarithmic relationship showing the strongest trend (r^2 = 0.04). Slope was positive (1.28), indicating that the small amount of variation in concentration of DOC explained by discharge exhibited a direct relationship.

For FPOC, the best fit was with a normal (untransformed), relationship (r^2 = 0.30), with a slope of 13.35. Since the normal regression for DOC concentration vs discharge also showed slope significantly different from zero, a comparison can be made between it and the slope of

Table 44. Results of Regression Analyses for Relationship of Instantaneous Concentrations of DOC and FPOC and Instantaneous Ratio DOC/FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974.

Dependent Variable	Independent Variable	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.03	1.04	0.0001	1.16	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.30	0.57	0.0001	13.35	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	0.05	1.65	0.0001	-1.80	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.04	-0.38	0.0001	1.29	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.19	-0.67	0.0001	3.21	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	0.13	0.28	0.0001	-1.88	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	0.02	0.10	0.1859	0.12	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	0.19	1.04	0.0001	0.40	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	0.19	-0.93	0.0001	-0.29	0.0001

the normal relationship for FPOC. The slope for FPOC is thirteen times that for DOC (1.15) indicating its much greater responsiveness to increased streamflow, with the relationship dominated by the very high concentrations of FPOC during the largest storms. DOC concentration did not respond accordingly.

Fisher (1970) found that FPOC concentration vs discharge was best fit with a third order quadratic equation, indicating steep increases in concentration at highest levels of discharge, with little increase (or a minor decrease) at lower discharge levels. MacKay and Kalff (1969) found no significant correlation between discharge and allochthonous organic drift. Weber and Moore (1967) found no seasonal pattern for concentration of DOC, with no relationship to discharge. Concentration of POC was, however, positively related to river discharge. Fisher (1970), who found no significant difference in DOC concentration along Bear Brook in New Hampshire, and no seasonal variation apart from that associated with discharge, reported DOC significantly correlated with discharge, with best fit found with the logarithmic regression.

For ratio concentration (or output) of DOC to concentration (or output) of FPOC, an r^2 value of 0.19 was found for the logarithmic regression, with the negative slope (-.0.30) significantly different from zero. This reflects the greater importance of FPOC at higher discharges, with a decrease in the rate of change in ratio as discharge increases. Lowest ratios of DOC to FPOC (0.06) were found at peak discharges.

As can be seen from an understanding of the behavior of DOC and FPOC concentrations during individual storm events, many factors obviously influence concentration response to changes in discharge. Sea-

sonal and month to month differences (volume of baseflow, presence or absence of canopy, seasonal input of organic debris to the stream) are evident, but year to year differences are possible depending on the particular hydrologic sequence for the water year, and particularly the occasion of very high discharges. Thus, further analyses to segregate these factors and also to discern seasonal responses was made.

Results of the regressions for concentrations of DOC and FPOC vs discharge for the data sorted by year, by season, and by month are shown in Tables 45, 46 and 47, respectively.

For 1973 (Table 45), the untransformed regression for DOC had a slope (1.22) significantly different from zero, but the r^2 value was only 0.05, indicating that 95% of the variation of concentration was not explained by variation in discharge. No better fit was obtained with the semilogarithmic or logarithmic regressions.

For 1974 (Table 45) , the slope for the normal regression for DOC was not significantly different from zero, with the slope for the logarithmic regression barely significant (Pr >T = 0.05). Less than 1% of the variation in concentration of DOC is explained by the independent variable. Also, the slope is negative, indicating that overall for 1974 the concentration of DOC decreases with increasing discharge.

The different response of DOC concentration to discharge for the two years can best be explained by the fact that the 1973 data encompassed the whole year, while that for 1974 did not include the autumn period. As such, the generally high concentrations associated with high flows in late autumn of 1973 were not represented in 1974. The high flows in 1974 occurred in winter and were accompanied by relatively

Table 45. Results of Regression Analyses for Relationship of Instantaneous Concentrations of DOC and FPOC and Instantaneous Ratio DOC/FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Year).

Dependent Variable	Independent Variable	Year	r^2	Intercept		Slope	
				Estimate	Pr>T	Estimate	Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	1973	0.05	1.13	0.0001	1.22	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	1973	0.29	0.73	0.0001	12.89	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	1973	0.06	1.58	0.0001	-1.48	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	1973	0.05	-0.26	0.0001	1.21	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	1973	0.19	-0.53	0.0001	2.93	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	1973	0.14	0.25	0.0001	-1.67	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	1973	0.04	0.40	0.0001	0.15	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	1973	0.21	1.26	0.0001	0.43	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	1973	0.18	-0.86	0.0001	-0.27	0.0001
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	1974	<0.01	0.90	0.0001	-0.23	0.7530
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	1974	0.40	0.12	0.1921	16.85	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	1974	0.06	1.88	0.0001	-4.51	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	1974	0.01	-0.65	0.0001	0.94	0.0693
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	1974	0.19	-1.03	0.0001	4.83	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	1974	0.16	0.38	0.0001	3.94	0.0001
Log DOC (mg/l)	Log Discharge (m^3)	1974	0.01	0.92	0.0001	-0.08	0.0445
Log FPOC (mg/l)	Log Discharge (m^3)	1974	0.10	0.18	0.2308	0.26	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	1974	0.23	-1.15	0.0001	-0.34	0.0001

lower concentrations than occurred during summer thunderstorms at lower discharges. In general, sorting DOC data by year did little to improve the fit of the data set.

For FPOC concentration (Table 45), all regressions showed a significant portion of the variability attributable to discharge, with the normal relationship showing the best fit (r^2 values of 0.29 for 1973 and 0.40 for 1974). In contrast to a slope near 1 for DOC concentration vs discharge for 1973, slopes for FPOC concentration vs discharge were 12.89 for 1973 and 16.85 for 1974, again showing the much greater response of FPOC to high discharge than DOC. This was related to the different sources of the two organic species, which placed an upper limit on DOC concentrations owing primarily to the inverse relationship between organic concentration and volume of precipitation and the lack of standing crops of DOC within the stream system.

Ratio of concentration of DOC to concentration of FPOC vs discharge (Table 45), showed slopes significantly different from zero for all relationships tested ($Pr > T = 0.001$), with the logarithmic regression explaining the most variation (r^2 values of 0.18 and 0.23 for 1973 and 1974, respectively). Slopes were negative and similar (-0.27 and -0.34 for 1973 and 1974, respectively), indicating that increasing streamflow greatly increases the dominance of the particulate component of the load.

Regressions by season (Table 46) over the two years (1973 - 1974) showed that all dependent variables (concentration DOC, concentration FPOC, and ratio) had significant relationships with discharge. For DOC, best fits were seen in the normal relationships for fall, spring, and

Table 46. Results of Regression Analyses for Relationship of Instantaneous Concentrations of DOC and FPOC and Instantaneous Ratio DOC/FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Season).

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.19	1.23	0.0001	1.39	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.36	0.36	0.4655	15.77	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Fall	0.11	2.08	0.0001	-1.72	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.13	-0.08	0.2194	1.05	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.37	-0.52	0.0001	2.66	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Fall	0.22	0.44	0.0001	-1.60	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	Fall	0.18	0.82	0.0001	0.22	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Fall	0.44	1.59	0.0001	0.51	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Fall	0.23	-0.77	0.0001	-0.29	0.0001
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.12	0.51	0.0001	1.25	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.34	0.04	0.7324	12.22	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Winter	0.13	1.51	0.0001	-2.74	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.01	-0.87	0.0001	1.98	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.33	-1.17	0.0001	5.07	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Winter	0.24	0.28	0.0001	-3.17	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	Winter	0.07	-0.06	0.6378	0.21	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Winter	0.37	1.31	0.0001	0.67	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Winter	0.32	-1.39	0.0001	-0.46	0.0001

Table 46. (Continued)

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Spring	0.05	0.91	0.0001	1.54	0.0001
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Spring	0.15	0.93	0.0001	8.36	0.0001
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Spring	0.08	1.36	0.0001	-1.72	0.0001
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Spring	0.08	-0.53	0.0001	2.01	0.0001
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Spring	0.20	-0.66	0.0001	3.97	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Spring	0.10	0.13	0.0012	-1.94	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	Spring	0.07	0.43	0.0037	0.23	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Spring	0.26	1.50	0.0001	0.53	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Spring	0.18	-1.07	0.0001	-0.30	0.0001
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Summer	0.05	0.96	0.0001	50.13	0.0001
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Summer	0.14	0.38	0.0003	72.34	0.0001
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Summer	0.02	2.19	0.0001	-31.81	0.0011
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Summer	0.10	-0.50	0.0001	44.70	0.0001
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Summer	0.17	-1.04	0.0001	59.82	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Summer	0.02	0.53	0.0001	-14.64	0.0015
Log Conc DOC (mg/l)	Log Discharge (m^3)	Summer	0.19	-4.25	0.0001	0.91	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Summer	0.28	4.91	0.0001	1.13	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Summer	0.02	-0.60	0.0622	-0.21	0.0024

winter data, while for summer, the logarithmic relationship gave the best fit. In any case, only a small portion of the variability was accounted for by regressions (maximum 20% in fall). Slope values for the untransformed data varied from 1.24 for winter to 1.54 for spring. The relatively small slopes were due to no canopy being present for most of the period, along with the negative relationship between DOC concentration and volume of throughfall.

McDowell and Fisher (1976) found concentration of dissolved organic matter (DOM) positively correlated to discharge throughout their autumn study period. Hobbie and Likens (1973) reported that fall samples showed DOC concentrations best correlated with flow, with summer values almost as high as those for fall. They found that spring concentrations were not correlated with flow, and spring and winter concentrations were low (generally less than 0.5 mg/l).

Since the regression for DOC vs discharge (untransformed data) for the summer data had a slope significantly different from zero, it is interesting to compare this with slopes for the other seasons, even though only 5% of the variability of DOC was explained. The slope (50.13) is 30 - 40 times higher than that for the other seasons, indicating the great effect of canopy on intensity of DOC behavior vs discharge. For the logarithmic relationship for DOC concentration vs discharge in summer ($r^2 = 0.19$), the relationship showed a slope of 0.91, indicating a sharper rise at low flows, with slowly decreasing slopes as discharge increased. This well represents the situation in summer, where small increases in flow due to throughfall inputs caused large increases in DOC load, while during longer rains, with associated higher flows, DOC

concentration showed relatively smaller increases. Highest flows of summer, occurring during the storm of July 31 - August 1, 1973, were accompanied by substantially lower concentrations of DOC than many smaller storms at peak flows, due to lower concentrations of organic carbon in throughfall.

For FPOC, all forms of the regression tested for each season showed slopes significantly different from zero (Table 46). Generally, best fits were obtained with the logarithmic relationship (r^2 = 0.44, 0.37, 0.26, and 0.28 for fall, spring, and summer data, respectively), with slopes ranging from 0.51 and 0.53 for fall and spring, respectively, to greater than one (1.13) for summer. The estimated winter slope was 0.67, intermediate between fall and spring slopes on the one hand, and summer slopes on the other. For logarithmic regressions, the linearized slopes indicate that behavior was different for summer compared to the other seasons. The slope greater than one for summer indicated that, as discharge increased, concentration of FPOC increased at faster rates, but since the slope was near one (1.13) this trend was not strong. For other seasons with slopes less than one, the rate of increase in concentration declined as discharge increased, with indications of an upper limit. This difference is most related to the lack of very high flows during summer and overall high concentrations of FPOC in streamflow during small to moderate storms due to presence of canopy and high FPOC levels in throughfall. From baseline levels to peak discharge in the storm of November 26-28, concentration of FPOC and DOC increased about 270-fold and 4-fold, respectively, while discharge increased 270-fold. This should be compared to increases during the early part of some summer

storms when FPOC and DOC increased 50- to 100-fold, while discharge increased less than 2-fold.

Since all regressions for FPOC vs discharge showed slopes significantly different from zero, a comparison of slopes for FPOC concentrations vs discharge for the untransformed data for the four seasons is appropriate. The slope for summer (72.34) was by far the greatest, reflecting the sharp increase in concentration of FPOC with relatively small rises in discharge, along with the absence of very high flows during summer. For the remaining seasons, the order of slope values (decreasing) was fall > winter > spring. The fact that spring had the smallest slope value (8.36) is indicative of the lack of canopy influence, plus the fact that the stream system was relatively depauperate of organic material during both spring periods of the study. This would also explain why autumn data showed greater slopes than winter data. Even though highest concentrations occurred at highest flows, the increase in FPOC did not keep up with increases in discharge, thereby explaining the higher slope during summer than fall.

For ratio of concentration of DOC to concentration of FPOC, best fits for all seasons except summer (which had the poorest overall fit) were obtained with the logarithmic regressions, with r^2 values of 0.23, 0.19, and 0.32 for the fall, spring, and winter seasons respectively (Table 46). All slopes were negative with the slope for winter (-0.46) being greatest. Slopes for the fall and spring seasons were quite similar (-0.29 and -0.30, respectively). These data emphasize the prevalence of particulate organic carbon as a component of organic load at higher flow rates, especially in winter when canopy is absent. Trends for winter

showed the steepest decline in ratio as flows increased, reaching a lower plateau than regressions for data for the other seasons, due to low concentrations of FPOC in incident precipitation during this period along with the "flushed" condition of the stream system.

For summer, no form of the relationship showed r^2 >0.02, indicating that 98% of the variability of the ratio during summer was attributable to factors other than discharge. Best fit came from the normal regression, with a slope of -31.81, an order of magnitude greater than the slope for any other season for this form of the regression.

For data sorted by month (Table 47), logarithmic relationships explained the greatest amount of variability in DOC and FPOC concentration in most cases. The normal regressions gave the best fit for the months of May, June, and October for DOC (r^2 values of 0.29, 0.42, and 0.90, respectively) with slopes of 2.12, 131.03, and 412.35, respectively. The October r^2 value for concentration vs discharge was the highest found for concentration vs discharge in the study. The large positive slopes for June and October were indicative of high canopy contributions associated with moderate increases in discharge along with absence of very high flows.

The semilogarithmic relationship showed the best fit for DOC concentrations vs discharge for January, February, and April, with r^2 values of 0.05, 0.17, and 0.08, respectively. For January, this was the only form of the regression with slope significantly different from zero (Pr >T = 0.027). January and April slopes were positive (1.80 and 1.48, respectively), while that for February was negative (-22.91), indicating an entirely different behavior during February, with decreasing concentrations associated with increasing discharge.

Table 47 Results of Regression Analyses for Relationship of Instantaneous Concentrations of DOC and FPOC and Instantaneous Ratio DOC/FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Month).

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Jan	0.02	0.49	0.0001	0.56	0.1353
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Jan	0.07	0.36	0.0001	1.74	0.0028
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Jan	0.08	1.53	0.0001	-2.86	0.0045
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Jan	0.05	-0.94	0.0001	1.80	0.0267
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Jan	0.16	-1.33	0.0001	4.28	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Jan	0.04	0.23	0.0080	-1.74	0.0420
Log Conc DOC (mg/l)	Log Discharge (m^3)	Jan	0.01	-0.55	0.0230	0.09	0.2620
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Jan	0.23	0.34	0.1500	0.45	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Jan	0.14	-0.80	0.0007	-0.30	0.0001
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Feb	0.10	0.64	0.0001	6.73	0.0004
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Feb	<0.01	0.33	0.0001	-0.46	0.8069
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Feb	0.18	2.48	0.0001	-30.24	0.0001
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Feb	0.17	-0.34	0.386	-22.91	0.0001
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Feb	<0.01	-1.36	0.0001	1.92	0.5698
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Feb	0.24	1.00	0.0001	-24.22	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	Feb	0.13	-3.53	0.0001	-0.70	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Feb	0.01	-0.82	0.0440	0.14	0.2370
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Feb	0.23	-2.61	0.0001	-0.81	0.0001

Table 47. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Mar	0.11	0.67	0.0001	1.04	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Mar	0.34	0.28	0.3192	13.10	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Mar	0.18	1.39	0.0001	-2.35	0.0001
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Mar	0.13	-0.58	0.0001	1.48	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Mar	0.35	-0.69	0.0001	4.20	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Mar	0.36	0.18	0.0032	-3.08	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	Mar	0.18	0.27	0.0265	0.24	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Mar	0.44	1.70	0.0001	0.66	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Mar	0.54	-1.50	0.0001	-0.47	0.0001
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Apr	0.06	0.68	0.0001	3.24	0.0073
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Apr	0.17	0.38	0.0046	12.06	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Apr	0.10	1.71	0.0001	-6.34	0.0005
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Apr	0.08	-0.66	0.0001	5.38	0.0019
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Apr	0.19	-1.11	0.0001	11.07	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Apr	0.11	0.43	0.0001	-5.47	0.0002
Log Conc DOC (mg/l)	Log Discharge (m^3)	Apr	0.04	0.25	0.4270	0.20	0.0230
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Apr	0.19	1.25	0.0008	0.54	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Apr	0.16	-0.94	0.0002	-0.32	0.0001

Table 47. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	May	0.29	0.64	0.0001	2.12	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	May	0.16	1.05	0.0004	0.06	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	May	0.08	1.04	0.0001	-0.90	0.0002
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	May	0.24	-0.77	0.0001	2.43	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	May	0.30	-0.59	0.0001	3.66	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	May	0.07	-0.16	0.0165	-1.23	0.0002
Log Conc DOC (mg/l)	Log Discharge (m^3)	May	0.21	0.47	0.0018	0.30	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	May	0.38	1.57	0.0001	0.55	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	May	0.18	-1.12	0.0001	-0.26	0.0001
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jun	0.42	-0.57	0.0166	131.03	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jun	0.18	-0.62	0.1423	130.10	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Jun	0.02	1.79	0.0001	-18.69	0.1069
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jun	0.26	-1.52	0.0001	85.87	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jun	0.30	-1.85	0.0001	91.31	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Jun	<0.01	0.32	0.0194	-4.85	0.5470
Log Conc DOC (mg/l)	Log Discharge (m^3)	Jun	0.21	4.90	0.0001	1.20	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Jun	0.25	5.10	0.0001	1.30	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Jun	<0.01	-0.15	0.7800	-0.09	0.4600

Table 47. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jul	0.07	0.91	0.0012	75.86	0.0002
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jul	0.25	0.04	0.8500	116.91	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Jul	0.03	2.40	0.0001	-46.09	0.0140
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jul	0.20	-0.66	0.0001	67.19	0.0001
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Jul	0.31	-1.28	0.0001	89.27	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Jul	0.04	0.57	0.0001	-19.33	0.0087
Log Conc DOC (mg/l)	Log Discharge (m^3)	Jul	0.28	5.65	0.0001	1.21	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Jul	0.43	7.03	0.0001	1.59	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Jul	0.05	-1.19	0.0208	-0.34	0.0029
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Aug	0.03	0.99	0.0001	19.80	0.0255
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Aug	0.05	0.60	0.0001	30.94	0.0024
Coc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Aug	0.03	2.16	0.0001	-25.67	0.0250
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Aug	0.03	-0.45	0.0002	22.06	0.0114
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Aug	0.08	-0.96	0.0001	87.91	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Aug	0.02	0.50	0.0001	-11.03	0.0958
Log Conc DOC (mg/l)	Log Discharge (m^3)	Aug	0.09	2.41	0.0001	0.56	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Aug	0.15	2.74	0.0001	0.71	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Aug	0.01	-0.33	0.5100	-0.15	0.1500

Table 47. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Sep	0.42	-0.60	0.0243	266.41	0.0001
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Sep	0.44	-1.04	0.0001	264.78	0.0001
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Sep	<0.01	1.911	0.0010	-13.53	0.7560
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Sep	0.41	-1.85	0.0001	244.87	0.0001
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Sep	0.54	-2.32	0.0001	252.07	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Sep	<0.01	0.46	0.0340	-4.91	0.8540
Log Conc DOC (mg/l)	Log Discharge (m^3)	Sep	0.49	11.07	0.0001	2.25	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Sep	0.58	10.45	0.0001	2.20	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Sep	<0.01	0.74	0.5000	0.07	0.7700
Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Oct	0.90	-1.48	0.0001	412.35	0.0001
Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Oct	0.32	-1.76	0.4155	123.68	0.0001
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	Oct	0.18	0.11	0.8970	331.65	0.0033
Log Conc DOC (mg/l)	Discharge (m^3 x 10^3)	Oct	0.46	-2.47	0.0001	319.93	0.0001
Log Conc FPOC (mg/l)	Discharge (m^3 x 10^3)	Oct	0.38	-1.88	0.0001	169.43	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	Oct	0.19	-0.69	0.1020	162.99	0.0032
Log Conc DOC (mg/l)	Log Discharge (m^3)	Oct	0.50	13.46	0.0001	2.27	0.0001
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Oct	0.42	6.60	0.0001	1.45	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Oct	0.18	6.93	0.0018	1.29	0.0035

Table 47. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/1)	Discharge ($m^3 \times 10^3$)	Nov	0.43	1.36	0.0001	1.53	0.0001
Conc FPOC (mg/1)	Discharge ($m^3 \times 10^3$)	Nov	0.40	0.71	0.5229	18.92	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Nov	0.17	2.29	0.0001	-1.64	0.0001
Log Conc DOC (mg/1)	Discharge ($m^3 \times 10^3$)	Nov	0.23	0.17	0.0200	0.83	0.0001
Log Conc FPOC (mg/1)	Discharge ($m^3 \times 10^3$)	Nov	0.36	-0.31	0.0430	2.38	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Nov	0.29	0.51	0.0001	-1.53	0.0001
Log Conc DOC (mg/1)	Log Discharge (m^3)	Nov	0.36	1.01	0.0001	0.22	0.0001
Log Conc FPOC (mg/1)	Log Discharge (m^3)	Nov	0.50	2.02	0.0001	0.61	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Nov	0.40	-1.03	0.0001	-0.40	0.0001
Conc DOC (mg/1)	Discharge ($m^3 \times 10^3$)	Dec	0.19	0.90	0.0001	1.24	0.0001
Conc FPOC (mg/1)	Discharge ($m^3 \times 10^3$)	Dec	0.23	0.87	0.0037	5.43	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Dec	0.15	1.54	0.0001	-1.30	0.0002
Log Conc DOC (mg/1)	Discharge ($m^3 \times 10^3$)	Dec	0.26	-0.34	0.0001	1.46	0.0001
Log Conc FPOC (mg/1)	Discharge ($m^3 \times 10^3$)	Dec	0.38	-0.66	0.0001	3.08	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Dec	0.22	0.31	0.0012	-1.60	0.0001
Log Conc DOC (mg/1)	Log Discharge (m^3)	Dec	0.34	0.66	0.0001	0.27	0.0001
Log Conc FPOC (mg/1)	Log Discharge (m^3)	Dec	0.40	1.29	0.0001	0.51	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Dec	0.18	-0.61	0.0005	-0.24	0.0001

The logarithmic relationship gave the best fit for the DOC concentration data for March (r^2 = 0.18, slope = 0.24) and, with the exception of October, all other months from July through December. Values for r^2 ranged from 0.09 in August to 0.49 in September, with r^2 values for the remaining months varying from 0.34 to 0.49. Slopes ranged from 0.22 and 0.27 in November and December, respectively, to 0.56 in August and 1.21 and 2.25 in July and September, respectively, with slopes greater than one indicating that the rate of increase in concentration of DOC increased as discharge increased. Those less than one show the opposite effect, resulting from DOC concentration characteristically reaching a plateau with increasing discharge during major (November and December) or prolonged (August) storm events.

For FPOC concentration vs discharge, the logarithmic relationship gave the best fit in all months for which there was a significant relationship. For these months, r^2 values were generally highest in the fall to early winter period (0.58, 0.42, 0.50, and 0.40 for the months from September through December, respectively). High r^2 values (0.38 - 0.43) were also found in March, May, and July, while those for January, April, June, and August were lower (0.15 - 0.25). Slopes showed clear seasonal trends, ranging from 0.45 to 0.66 for January and March through May, and were also less than one in August, November, and December (0.71, 0.60, and 0.51, respectively). Slopes greater than one were found in June (1.30), July (1.59), September (2.20), and October (1.45), the four periods of highest throughfall FPOC concentrations (see Figure 28, page 165) along with flows that were neither sustained nor very large.

FPOC concentration for the month of February showed no form of the regression with concentration significantly related to discharge. This was the only month for which no significant relationship was found.

To summarize, the generally poor relationship between organic carbon concentration and discharge was somewhat improved when data were sorted by season or month, but a large amount of variability remained embedded in the very form of the discharge response, especially so for FPOC, for which peak discharge and peak concentration did not often coincide. Distinct differences in seasonal response were evident for each organic type. Somewhat similar trends are indicated for both forms on a seasonal basis. Comparatively steeper (positive) slopes were generally found in regressions for FPOC, indicating its greater rate of increase as streamflow increases. At least part of the decrease in concentration of organic carbon during higher discharges can be explained by the inverse relationship between organic carbon concentration and volume of incident precipitation or throughfall (see Figures 30-32, pages 181 to 183, respectively).

Results of the various regressions for ratio of concentration of DOC to concentration of FPOC vs discharge (Table 47) showed only two regressions (logarithmic for March and November) with r^2 values of 0.40 or greater. June and September data showed no significant portion of the variability of the ratio explained by variations in discharge. The logarithmic relationship was also the best fit for January (0.14), April (0.16), May (0.18), and July (0.05). Of those months in which the logarithmic form proved the best fit, largest (negative) slopes were found during March (-0.47), with November (-0.40), July (-0.34), April (-0.32)

and January (-0.31) greater than -0.30 and May with a slope of -0.26. Since all logarithmic regressions except June and September proved significant, and since logarithmic fits were nearly as good as the other forms for most months, a further comparison of slopes is warranted. Steepest significant slopes for logarithmic regressions were found during October (1.29) and February (-0.81). October was the only month for which a significant positive slope was found. Lowest significant negative slope was found for August (-0.15). A comparison of the two months with highest positive and negative slopes gives some insight into the extremes in behavior of organic carbon. During October, only two significant storm events occurred, with the one on October 28-29 showing the greater hydrographic rise. For all samples taken during the storm, only two showed DOC/FPOC rates less than one, and here the differences were minor. During peak flow, DOC concentration was at a peak (4.45 mg/l), while FPOC had already decreased to 0.54 mg/l from a peak of 2.56 mg/l. Thus, ratios were consistently near or above 1, increasing greatly as discharge reached peak flow for the month. Also, baseflow concentrations of DOC remained high after hydrographic recession, probably due to the leaching of leaf material which was freed from the canopy during the storm by raindrop impact. The slope greater than one for the October data was indicative of leaching of DOC from the senescent canopy.

For February, FPOC peak concentrations were closely associated with peak flows because the major hydrographic peaks were associated with delayed "non-rain" increases in discharge. As has been shown in the discussion of individual storm events, this delayed rise may be accompanied by an increase in FPOC concentration due to suspension of material

from the stream bottom. Since this streamflow represented a dilution of any direct throughfall input, DOC concentration in the streamwater should have been low. While peak flows had low DOC/FPOC ratios, a smaller storm occuring on February 22, 1974 raised the streamflow relatively little, but resulted in DOC concentrations of 1.40 mg/l compared to peak FPOC concentrations of 0.65 mg/l for FPOC, the latter occurring before peak flow. Thus, the two months, divergent with respect to both canopy cover (and hence, throughfall) and hydrologic regime, yielded entirely different responses to discharge for FPOC and DOC concentrations.

The normal relationships gave the best fit for August (r^2 = 0.03, slope = -25.67) and October(r^2 = 0.16, slope = 331.65), the latter being the only month when there was a positive relationship between ratio and discharge. The semilogarithmic relationship gave best fit for February (r^2 = 0.24) and December (r^2 = 0.22). Slopes were negative and greater in February (-24.22 vs -1.00).

<u>Regression Analyses of the Relation of DOC and FPOC Output from Grab Samples and Discharge</u>

For the entire data set, results of the various regression analyses are presented in Table 48 for output of dissolved and particulate organic carbon vs discharge. Highest r^2 value for DOC vs discharge (0.80) was seen for the linear relationship. For output of FPOC, best fit was achieved with the logarithmic relationship (r^2 = 0.74), with a slope of 1.40. The different behavior indicated the greater importance of fine particulate outputs at highest flow rates due to different sources for FPOC and DOC. The fact that DOC output was linearly related

Table 48. Results of Regression Analyses for Relationship of Instantaneous Outputs of DOC and FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974.

Dependent Variable	Independent Variable	r^2	Intercept		Slope	
			Estimate	Pr>T	Estimate	Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	0.79	-0.06	0.0001	2.42	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	0.31	-0.64	0.0001	16.16	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	0.48	-4.54	0.0001	7.42	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	0.52	-4.83	0.0001	9.30	0.0001
Log Output DOC (g)	Log Discharge (m^3)	0.67	0.10	0.1859	55.86	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	0.74	1.04	0.0001	65.99	0.0001

to discharge indicated that changes in DOC concentration were relatively unimportant in determining increases in output with increasing discharge. These results were consistent with results of the regressions for concentration vs discharge. An increasing slope for the logarithmic regression of FPOC output vs discharge was consistent with FPOC concentration being positively related to discharge.

Although the normal regression did not give as good a fit for output of FPOC vs discharge ($r^2 = 0.31$) as the logarithmic forms, the slope was significantly different from zero, so a comparison with that for DOC output vs discharge is possible. Compared to the slope of 2.45 for DOC output, that for FPOC was 16.51, indicating a much greater increase of FPOC output with discharge. This was most probably related to the behavior at highest flow rates. The poorer fit for FPOC output vs discharge was most likely related to the fact that peak concentration (and often peak output) did not coincide with peak discharge, even within a given storm.

Regressions for the output of dissolved and fine particulate organic carbon by year are shown in Table 49. While all forms of the regression showed slopes significantly different from zero, the output of DOC vs discharge was most closely approximated with the linear relationship, with a similar portion of the variability in DOC output for the two years (r^2 values of 0.81 and 0.82 for 1973 and 1974, respectively) explained by variations in discharge. For the 1973 water year, a slope of 2.57 was found, while for the eight months of 1974, the slope was 1.29. Again, lack of late summer and fall data accounted for much of the difference in the response for the two years, since otherwise the two

Table 49. Results of Regression Analyses for Relationship of Instantaneous Outputs of DOC and FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Year).

Dependent Variable	Independent Variable	Year	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge (m^3 x 10^3)	1973	0.81	-0.06	0.0001	2.35	0.0001
Output FPOC (kg)	Discharge (m^3 x 10^3)	1973	0.31	-0.71	0.0001	16.59	0.0001
Log Output DOC (g)	Discharge (m^3 x 10^3)	1973	0.50	-4.36	0.0001	6.89	0.0001
Log Output FPOC (g)	Discharge (m^3 x 10^3)	1973	0.53	-4.64	0.0001	8.59	0.0001
Log Output DOC (g)	Log Discharge (m^3)	1973	0.72	0.40	0.0001	1.15	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	1973	0.74	1.26	0.0001	1.43	0.0001
Output DOC (kg)	Discharge (m^3 x 10^3)	1974	0.82	-0.02	0.0001	1.29	0.0001
Output FPOC (kg)	Discharge (m^3 x 10^3)	1974	0.43	-0.35	0.0001	12.03	0.0001
Log Output DOC (g)	Discharge (m^3 x 10^3)	1974	0.45	-5.03	0.0001	10.94	0.0001
Log Output FPOC (g)	Discharge (m^3 x 10^3)	1974	0.56	-5.43	0.0001	15.14	0.0001
Log Output DOC (g)	Log Discharge (m^3)	1974	0.55	-0.92	0.0001	0.92	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	1974	0.72	1.20	0.2308	1.25	0.0001

years were hydrologically similar, especially during the winter and spring months. However, the lack of numerous small storms during late spring and summer, accompanied by a prolonged rainfall event in late August 1974, during which concentrations were low, were also factors.

For data sorted by year, best fits for FPOC output were obtained with the logarithmic relationship, with r^2 values of 0.74, and 0.72 for 1973 and 1974, respectively. For the 1973 year, the slope of the regression was 1.43, while for the eight months of 1974, the slope was 1.25. These results are consistent with those found for the overall data set, with year-to-year differences due to the same factors discussed above for DOC.

Results of the regressions for seasonal output of DOC and FPOC on discharge are shown in Table 50. For all regression forms tested, a significant portion of the variation in the dependent variable was explained by the independent variable. Best fits were seen for all seasons for output of DOC with a normal relationship, with r^2 values varying from 0.47 for summer, to 0.85 - 0.90 for fall, winter, and spring. All slopes were positive with the order (decreasing slope) being fall > summer > spring > winter. This order reflected the influence of presence or absence of canopy, periodicity of high flows, and occurrence of antecedent storm events. Patterns are consistent with those from the total data set and the data sorted by year.

For fine particulate organic carbon, the logarithmic relationship proved the best fit for all seasons, consistent with the pattern for the total data set and yearly data. Just as with output of DOC, the summer season showed the lowest r^2 value (0.58) with those for fall (0.87),

Table 50. Results of Regression Analyses for Relationship of Instantaneous Outputs of DOC and FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Season).

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Fall	0.85	-0.12	0.0001	2.99	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Fall	0.38	-1.74	0.0080	22.88	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Fall	0.58	-4.12	0.0001	5.67	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Fall	0.62	-4.54	0.0001	7.25	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Fall	0.87	0.82	0.0001	1.22	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Fall	0.87	1.59	0.0001	1.51	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Winter	0.85	-0.03	0.0001	.127	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Winter	0.34	-0.38	0.0001	8.36	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Winter	0.58	-4.49	0.0001	8.73	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Winter	0.61	-4.82	0.0001	11.82	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Winter	0.72	-0.06	0.6378	1.21	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Winter	0.79	1.31	0.0001	1.67	0.0001

Table 50. (Continued)

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Spring	0.89	-0.03	0.0001	1.79	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Spring	0.48	-0.08	0.0152	4.79	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Spring	0.57	-4.61	0.0001	9.51	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Spring	0.57	-4.74	0.0001	11.57	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Spring	0.70	0.43	0.0037	1.23	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Spring	0.75	1.50	0.0001	1.53	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Summer	0.47	-0.01	0.0001	2.32	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Summer	0.46	-0.01	0.0001	2.65	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Summer	0.36	-5.87	0.0001	109.00	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Summer	0.43	-6.41	0.0001	124.36	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Summer	0.51	4.25	0.0001	1.91	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Summer	0.58	4.91	0.0001	2.51	0.0001

winter (0.79), and spring (0.75) being higher. Steepest slopes were found during summer (2.13), while slopes for the other three seasons varied from 1.51 to 1.67, with winter having the steepest slope. The fact that all slopes were greater than one would indicate that, during all seasons, rate of increase in FPOC output increased with increasing discharge. Presence of canopy along with lack of very high flow rates contributed to the highest slope during summer, while the lack of synchronous behavior of FPOC concentration and peak discharge contributed to the lower r^2 values as compared to those for DOC output.

Results of the various monthly regressions for relationship of output of DOC and FPOC vs discharge are shown in Table 51. For output of DOC, no form of the regression for February data showed a significant portion of the variability explained by the independent variable. For all other months, the normal relationship showed the best fit. Lowest r^2 values were found during the summer months, with June, July, August, and September having values of 0.68, 0.57, 0.46, and 0.72, respectively. The r^2 values for other months were equal to or greater than 0.84, with the months from October through January showing r^2 values greater than 0.90. Of these, December was the highest with 0.98, indicating that virtually all of the variability of the DOC output was explained by discharge due to consistent inputs (meteorological).

Slopes were greatest in certain spring, summer, and fall months, with greatest slopes in October (5.86), June (4.61), September (3.83), November (3.50), and July (3.43). Lowest slope values were in January (0.71), due to a well-flushed stream system and low concentrations of DOC in throughfall. Except for November, months with greatest slopes

Table 51. Results of Regression Analyses for Relationship of Instantaneous Outputs of DOC and FPOC to Instantaneous Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Month).

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Jan	0.92	-0.01	0.0001	0.71	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Jan	0.72	-0.01	0.0111	0.77	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Jan	0.66	-4.62	0.0001	11.45	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Jan	0.59	-5.14	0.0001	14.76	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Jan	0.65	0.55	0.0230	1.09	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Jan	0.76	0.34	0.1516	1.44	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Feb	0.01	0.01	0.0001	0.05	0.3452
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Feb	0.16	<0.01	0.3793	0.27	0.0001
Log Output DOC(g)	Discharge ($m^3 \times 10^3$)	Feb	0.01	-4.73	0.0001	4.52	0.3510
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Feb	0.35	-5.77	0.0001	29.77	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Feb	0.03	-3.53	0.0001	0.30	0.0705
Log Output FPOC (g)	Log Discharge (m^3)	Feb	0.44	-0.82	0.0441	1.14	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Mar	0.88	-0.04	0.0001	1.37	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Mar	0.37	-0.54	0.0045	9.66	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Mar	0.61	-4.16	0.0001	7.57	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Mar	0.61	-4.24	0.0001	10.19	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Mar	0.86	0.28	0.0265	1.24	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Mar	0.83	1.69	0.0001	1.66	0.0001

Table 51 (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Apr	0.84	-0.01	0.0001	1.21	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Apr	0.46	-0.03	0.0066	2.03	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Apr	0.61	-4.96	0.0001	24.22	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Apr	0.59	-5.41	0.0001	29.98	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Apr	0.62	0.25	0.4270	1.20	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Apr	0.65	1.25	0.0008	1.54	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	May	0.90	-0.05	0.0001	1.85	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	May	0.45	-0.08	0.3476	4.86	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	May	0.76	-4.72	0.0001	9.28	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	May	0.68	-4.54	0.0001	10.56	0.0001
Log Output DOC (g)	Log Discharge (m^3)	May	0.83	0.47	0.0018	1.30	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	May	0.83	1.57	0.0001	1.55	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Jun	0.68	-0.04	0.0001	4.61	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Jun	0.39	-0.04	0.0001	4.17	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Jun	0.52	-6.77	0.0001	149.03	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Jun	0.55	-7.09	0.0001	154.51	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Jun	0.47	4.91	0.0001	2.20	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Jun	0.51	5.10	0.0001	2.30	0.0001

Table 51. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Jul	0.58	-5.48	0.0001	3.48	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Jul	0.59	-0.02	0.0001	3.99	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Jul	0.46	-5.98	0.0001	130.65	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Jul	0.53	-6.58	0.0001	152.64	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Jul	0.57	5.65	0.0001	2.21	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Jul	0.67	7.03	0.0001	2.59	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Aug	0.46	<0.01	0.6437	1.39	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Aug	0.38	-0.01	0.0103	1.65	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Aug	0.31	-5.82	0.0001	83.36	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Aug	0.38	-6.33	0.0001	94.59	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Aug	0.44	2.42	0.0001	1.56	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Aug	0.50	2.74	0.0001	1.71	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Sep	0.72	-0.02	0.0001	3.83	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Sep	0.55	-0.02	0.0001	3.64	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Sep	0.59	-7.67	0.0001	362.71	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Sep	0.70	-8.14	0.0001	370.22	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Sep	0.67	11.07	0.0001	3.25	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Sep	0.75	10.46	0.0001	3.20	0.0001

Table 51. (Continued)

Dependent Variable	Independent Variable	Month	r^2	Estimate	Pr>T	Estimate	Pr>T
Output DOC (kg)	Discharge (m^3 x 10^3)	Oct	0.94	-0.03	0.0001	5.77	0.0001
Output FPOC (kg)	Discharge (m^3 x 10^3)	Oct	0.56	-0.01	0.0006	1.88	0.0001
Log Output DOC (g)	Discharge (m^3 x 10^3)	Oct	0.61	-8.34	0.0001	441.51	0.0001
Log Output FPOC (g)	Discharge (m^3 x 10^3)	Oct	0.63	-7.76	0.0001	291.19	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Oct	0.65	13.46	0.0001	3.73	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Oct	0.67	6.59	0.0001	2.45	0.0001
Output DOC (kg)	Discharge (m^3 x 10^3)	Nov	0.91	-0.16	0.0024	3.47	0.0001
Output FPOC (kg)	Discharge (m^3 x 10^3)	Nov	0.47	-2.68	0.0880	29.81	0.0001
Log Output DOC (g)	Discharge (m^3 x 10^3)	Nov	0.59	-3.67	0.0001	4.56	0.0001
Log Output FPOC (g)	Discharge (m^3 x 10^3)	Nov	0.59	-4.09	0.0001	6.04	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Nov	0.95	1.01	0.0001	1.22	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Nov	0.88	2.02	0.0001	1.61	0.0001
Output DOC (kg)	Discharge (m^3 x 10^3)	Dec	0.98	-0.02	0.0053	1.61	0.0001
Output FPOC (kg)	Discharge (m^3 x 10^3)	Dec	0.56	-0.06	0.5380	3.81	0.0001
Log Output DOC (g)	Discharge (m^3 x 10^3)	Dec	0.79	-4.08	0.0001	7.22	0.0001
Log Output FPOC (g)	Discharge (m^3 x 10^3)	Dec	0.77	-4.43	0.0001	8.90	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Dec	0.92	0.66	0.0001	1.27	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Dec	0.86	1.29	0.0001	1.51	0.0001

generally had highest concentrations of DOC in throughfall. The high slope value for November was attributable to the quick passage of throughfall through the watershed system, allowing little uptake by the soil/bedrock system.

For output of FPOC, all forms of the regression tested for all months had slopes significantly different from zero and for the most part, were best explained by the logarithmic relationship between FPOC and discharge. The one exception was June, where the semilogarithmic form had a slightly higher r^2 value than that for the logarithmic relationship. Slope for the semilogarithmic relationship for June was 12.30, with an r^2 value of 0.55. For the sake of slope comparisons, the logarithmic relationship (r^2 of 0.51) for June will be used.

The r^2 values for the logarithmic relationships varied from a high of 0.88 and 0.86 for November and December, to 0.44, 0.50, and 0.51 for February, August, and June, respectively. October (0.65), April (0.65), and July (0.66) also had low r^2 values. Other values were 0.75 (September), 0.76 (January), and 0.83 for March and May. For October especially, much less of the FPOC output data could be fitted to a curve than could the DOC output data. Highest slope values were found during summer and early fall, with August (slope = 1.71) being the only month during this period with a slope less than 2.0. Highest slope value was found in September (3.20), with those for June, July, and October being similar to each other (2.29 to 2.50). It would thus appear that presence of canopy plays a large role in the dynamics of the behavior of FPOC output, especially when storm events of small magnitude are involved. The low slope for August was related to the prolonged storm event of August 28 - September 2, when FPOC concentrations were low.

Regression Analyses of the Relationof Weighted Weekly Concentrations of DOC and FPOC and Weekly Discharge

Results of the regression analyses for weighted weekly concentration of DOC and FPOC and the ratio of concentration of DOC to concentration of FPOC vs weekly discharge for the entire study are shown in Table 52. Note that discharge in the normal and semilogarithmic regressions is in $m^3 \times 10^3$, while for the logarithmic relationship, discharge is in m^3.

Generally poor fits were found, with the normal regression showing the best fit for DOC ($r^2 = 0.23$), and the semilogarithmic regression yielding the best fit for FPOC ($r^2 = 0.42$) and ratio of concentration of DOC to concentration of FPOC ($r^2 = 0.24$). All regressions tested, except the logarithmic regression for DOC, showed a significant portion of the variation in the dependent variable explained by the independent variable. For the normal regressions, DOC had a slope of 0.01 and FPOC had a slope of 0.04 indicating that FPOC concentration increased at a faster rate than did DOC concentration. For the logarithmic regressions, the slope for FPOC was 0.04, while that for DOC was 0.02. Slopes for ratio were negative, in accordance with results for the previous analyses.

Results of regressions for the 1973 and 1974 weekly weighted mean concentrations of DOC and FPOC are presented in Table 53. The 1973 and 1974 data may not be completely comparable because of the absence of observations from fall 1974. The normal regression gave the best fit for DOC for 1973 ($r^2 = 0.36$), and the semilogarithmic regression gave the best fit for the 1973 and 1974 data for FPOC (r^2 values of 0.45 and 0.41, respectively) and ratio ($r^2 = 0.26$ and 0.20, respectively). No form of regression tested for DOC concentration in 1974 showed slope

Table 52. Results of Regression Analyses for Relationship of Weighted Weekly Concentrations of DOC and FPOC and Weighted Weekly Ratio DOC/FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974.

Dependent Variable	Independent Variable	r^2	Intercept		Slope	
			Estimate	Pr>T	Estimate	Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.24	0.27	0.0001	0.01	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.35	-0.07	0.5252	0.04	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	0.15	1.55	0.0001	-0.02	0.0002
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.12	-1.27	0.0001	0.02	0.0011
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	0.42	-1.66	0.0001	0.04	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	0.24	0.40	0.0001	-0.02	0.0001
Log Conc DOC (mg/l)	Log Discharge (m^3)	0.04	-2.22	0.0010	0.12	0.0824
Log Conc FPOC (mg/l)	Log Discharge (m^3)	0.23	-4.85	0.0001	0.40	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	0.19	2.63	0.0001	-0.28	0.0001

Table 53. Results of Regression Analyses for Relationship of Weighted Weekly Concentrations of DOC and FPOC and Weighted Weekly Ratio DOC/FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Year).

Dependent Variable	Independent Variable	Year	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/1)	Discharge (m^3 x 10^3)	1973	0.36	0.30	0.0001	0.01	0.0001
Conc FPOC (mg/1)	Discharge (m^3 x 10^3)	1973	0.43	-0.10	0.5214	0.06	0.0001
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	1973	0.15	1.61	0.0001	-0.02	0.0043
Log Conc DOC (mg/1)	Discharge (m^3 x 10^3)	1973	0.21	-1.14	0.0001	0.02	0.0007
Log Conc FPOC (mg/1)	Discharge (m^3 x 10^3)	1973	0.49	-1.58	0.0001	0.04	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	1973	0.26	0.44	0.0001	0.02	0.0001
Log Conc DOC (mg/1)	Log Discharge (m^3)	1973	0.11	-2.95	0.0007	0.23	0.0151
Log Conc FPOC (mg/1)	Log Discharge (m^3)	1973	0.30	-5.67	0.0001	0.51	0.0001
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	1973	0.18	2.71	0.0010	-0.28	0.0020
Conc DOC (mg/1)	Discharge (m^3 x 10^3)	1974	0.10	0.24	0.0001	<0.10	0.0629
Conc FPOC (mg/1)	Discharge (m^3 x 10^3)	1974	0.33	0.07	0.3221	0.02	0.0004
Conc DOC/Conc FPOC	Discharge (m^3 x 10^3)	1974	0.15	1.44	0.0001	-0.02	0.0219
Log Conc DOC (mg/1)	Discharge (m^3 x 10^3)	1974	0.05	-1.43	0.0001	<0.01	0.2110
Log Conc FPOC (mg/1)	Discharge (m^3 x 10^3)	1974	0.41	-1.77	0.0001	0.03	0.0001
Log (Conc DOC/Conc FPOC)	Discharge (m^3 x 10^3)	1974	0.20	0.33	0.0039	-0.02	0.0071
Log DOC (mg/1)	Log Discharge (m^3)	1974	0.01	-1.38	0.1022	0.01	0.9510
Log FPOC (mg/1)	Log Discharge (m^3)	1974	0.21	-3.84	0.0001	0.27	0.0061
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	1974	0.20	2.45	0.0054	-0.26	0.0072

significantly different from zero. Aside from this, all other trends for slopes were similar to those for the entire data set. Slopes for 1973 regressions were generally greater, due possibly, at least in the case of FPOC and ratio, to the high concentrations associated with the large storm of November 26, 1973. Results are also consistent with "grab" sample results reported above.

The various regressions expressing the relationship between weekly concentration of DOC and FPOC and ratio DOC/FPOC discharge by season are shown in Table 54. For two seasons, fall and winter, the forms of regression for DOC giving best fit were the same (normal) as those for the total data set and yearly data.

Slope for DOC concentration for fall for the normal regression was less than that for FPOC concentration (0.02 vs 0.09), but greater than that for DOC for winter (0.005), with the latter barely significant ($Pr > T = 0.05$).

For two seasons (spring and summer) there was no form of the regression yielding slopes significantly different from zero for DOC or ratio DOC/FPOC, indicating that, on a weekly basis, no significant portion of the variations of DOC concentration or the ratio of DOC/FPOC was explained by discharge for spring and summer. This was probably due to the fact that small storm events had a proportionally greater effect on weekly DOC concentration when canopy was present, but had little effect on discharge. Thus, some weeks with small increases in discharge had elevated DOC concentrations.

Summer and winter data for FPOC concentration were best explained with the normal regression (r^2 values of 0.41 and 0.56, respectively).

Table 54. Results of Regression Analyses for Relationship of Weighted Weekly Concentrations of DOC and FPOC and Weighted Weekly Ratio DOC/FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Season).

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.78	0.36	0.0009	0.02	0.0001
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.68	-0.21	0.6146	0.09	0.0005
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Fall	0.30	1.98	0.0001	0.03	0.0520
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.52	-0.97	0.0001	0.03	0.0053
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Fall	0.89	-1.60	0.0001	0.05	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Fall	0.49	0.63	0.0053	0.03	0.0081
Log Conc DOC (mg/l)	Log Discharge (m^3)	Fall	0.37	-3.90	0.0120	0.37	0.0283
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Fall	0.71	-8.04	0.0001	0.81	0.0003
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Fall	0.44	4.14	0.0094	-0.44	0.0314
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.16	0.26	0.0001	0.01	0.0407
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.53	-0.08	0.4560	0.02	0.0001
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Winter	0.23	1.69	0.0001	0.02	0.0127
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.10	-1.40	0.0001	0.01	0.1083
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Winter	0.56	-1.92	0.0001	0.04	0.0001
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Winter	0.30	0.52	0.0042	0.02	0.0036
Log Conc DOC (mg/l)	Log Discharge (m^3)	Winter	0.04	-3.05	0.1032	0.20	0.3049
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Winter	0.43	-8.50	0.0001	0.75	0.0003
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Winter	0.003	5.45	0.0028	-0.56	0.0013

Table 54 (Continued)

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Spring	0.15	0.21	0.0248	0.01	0.0521
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Spring	0.12	0.10	0.6240	0.03	0.0853
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Spring	0.08	1.47	0.0001	0.02	0.1594
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Spring	0.12	-1.47	0.0001	0.03	0.0829
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Spring	0.22	-1.84	0.0001	0.05	0.0153
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Spring	0.11	0.37	0.0481	0.02	0.0987
Log Conc DOC (mg/l)	Log Discharge (m^3)	Spring	0.12	-4.24	0.0195	0.34	0.0814
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Spring	0.18	-6.31	0.0094	0.55	0.0331
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Spring	0.06	2.06	0.1962	0.30	0.2179
Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Summer	0.14	0.22	0.0101	0.03	0.0810
Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Summer	0.41	0.12	0.0109	0.30	0.0013
Conc DOC/Conc FPOC	Discharge ($m^3 \times 10^3$)	Summer	0.04	1.53	0.0001	0.06	0.3612
Log Conc DOC (mg/l)	Discharge ($m^3 \times 10^3$)	Summer	0.07	-1.40	0.0001	0.06	0.2435
Log Conc FPOC (mg/l)	Discharge ($m^3 \times 10^3$)	Summer	0.28	-1.75	0.0001	0.10	0.0112
Log (Conc DOC/Conc FPOC)	Discharge ($m^3 \times 10^3$)	Summer	0.03	0.36	0.1166	0.04	0.4320
Log Conc DOC (mg/l)	Log Discharge (m^3)	Summer	0.03	-3.06	0.2718	0.23	0.4851
Log Conc FPOC (mg/l)	Log Discharge (m^3)	Summer	0.24	-6.06	0.0046	0.57	0.0217
Log (Conc DOC/Conc FPOC)	Log Discharge (m^3)	Summer	0.06	3.00	0.2295	-0.34	0.2595

The slope for summer (0.30) was an order of magnitude greater than in winter (0.02).

Best fits for the fall (r^2 = 0.89) and spring (r^2 = 0.22) data were found with the semilogarithmic regressions for concentration of FPOC, with both seasons with similar slopes (0.05). The better fit in the autumn data was due to the greater influence of large flows in fall and winter, and less confounding with high FPOC concentrations at lower flows (with peak FPOC concentration not necessarily coinciding with peak discharge for the particular storm events).

For the fall and winter data, the ratio DOC/FPOC vs discharge was best explained by the semilogarithmic regression with r^2 values of 0.49 and 0.30, respectively. Slope for fall (-0.03) was steeper than for winter (0.02), indicating the great importance of the high flows in autumn on the ratio.

<u>Regression Analyses of the Relation of Weekly Output of DOC and FPOC and Weekly Discharge</u>

In contrast to the situation for concentration of organic carbon, a large portion of the variability of the output of DOC and FPOC was explained by regressing the weekly output (calculated from weighted weekly concentrations) on the weekly discharge. Three forms of regression were tested; results are shown in Table 55 for the entire study period. Note that the units for both output (kg or g) and discharge (m^3 or m^3 x 10) vary from form to form.

Best fits for output based on all data combined were with the semilogrithmic regressions for both DOC (r^2 = 0.75) and FPOC (r^2 = 0.83).

Table 55. Results of Regression Analyses for Relationship of Weighted Weekly Outputs of DOC and FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974.

Dependent Variable	Independent Variable	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	0.64	-4.91	0.0002	0.94	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	0.41	-18.58	0.0009	2.52	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	0.83	7.05	0.0001	0.08	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	0.74	6.65	0.0001	0.10	0.0001
Log Output DOC (g)	Log Discharge (m^3)	0.74	-2.22	0.0010	1.13	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	0.78	-4.85	0.0001	1.40	0.0001

Slope for FPOC was 0.01, greater than that for DOC (0.08) indicating that output of DOC increased at a slower rate than output of FPOC as discharge increased. This slope difference was probably related to data from larger storms, where FPOC became much more important than DOC.

Results of the regressions expressing the relationship between weekly output of DOC and FPOC by year are shown in Table 56. For DOC, the semilogarithmic and logarithmic relationships did not show appreciable improvement of fit as compared to the normal regressions for DOC, which had r^2 values of 0.74 and 0.80 for 1973 and 1974, respectively, with the slope for 1973 much steeper (1.17 vs 0.46), due primarily to the fact that the summer of 1973 was wetter, yielding numerous small to medium-sized thunderstorms which produced high concentrations of both DOC and FPOC in streamwater and high output per unit volume of discharge. The better fit for FPOC was probably due to the effects of large storm events.

Slopes for output of DOC for the normal regressions were less than those for FPOC for either year (3.28 and 0.97 for 1973 and for 1974, respectively). For FPOC outputs, the 1973 and 1974 data were fit best with the semilogarithmic relationship, with r^2 values of 0.82 and 0.90, respectively, and with slopes similar for the two years (0.01).

For output of DOC and FPOC vs discharge by season, results of the various regression analyses are shown in Table 57. For output of DOC, best fit during all seasons except spring was with the normal regression, with r^2 values of 0.95, 0.80, and 0.85 for fall, summer, and winter, respectively. For spring, the fit was slightly better with the semilogarithmic regression ($r^2 = 0.65$) although the normal form was satisfactory

Table 56. Results of Regression Analyses for Relationship of Weighted Weekly Outputs of DOC and FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Year).

Dependent Variable	Independent Variable	Year	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	1973	0.74	-5.87	0.0010	1.17	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	1973	0.50	-23.04	0.0051	3.28	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	1973	0.74	7.20	0.0001	0.07	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	1973	0.82	6.76	0.0001	0.10	0.0001
Log Output DOC (g)	Log Discharge (m^3)	1973	0.79	-2.95	0.0007	1.23	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	1973	0.79	-5.67	0.0001	1.51	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	1974	0.80	-1.76	0.0108	0.46	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	1974	0.46	-6.46	0.0401	0.98	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	1974	0.84	6.42	0.0001	0.08	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	1974	0.90	6.49	0.0001	1.10	0.0001
Log Output DOC (g)	Log Discharge (m^3)	1974	0.79	-1.38	0.1022	1.01	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	1974	0.86	-3.84	0.0001	1.27	0.0001

Table 57 Results of Regression Analyses for Relationship of Weighted Weekly Outputs of DOC and FPOC to Weekly Discharge in the West Fork of Walker Branch for January 1973 through August 1974 (Data Sorted by Season).

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Fall	0.95	-6.29	0.0256	1.73	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Fall	0.69	-25.47	0.2765	5.24	0.0005
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Fall	0.91	7.07	0.0001	0.08	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Fall	0.97	6.44	0.0001	0.10	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Fall	0.89	-3.90	0.0120	1.37	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Fall	0.93	-8.04	0.0001	1.81	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Winter	0.85	-4.58	0.0012	0.64	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Winter	0.71	-18.34	0.0008	1.59	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Winter	0.69	7.52	0.0001	0.05	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Winter	0.85	7.00	0.0001	0.08	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Winter	0.63	-3.05	0.1032	1.195	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Winter	0.81	-8.50	0.0001	1.750	0.0001

Table 57 (Continued)

Dependent Variable	Independent Variable	Season	r^2	Intercept Estimate	Intercept Pr>T	Slope Estimate	Slope Pr>T
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Spring	0.51	-2.27	0.1546	0.61	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Spring	0.38	-5.18	0.1145	0.96	0.0008
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Spring	0.65	6.80	0.0001	0.10	0.0001
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Spring	0.66	6.43	0.0001	0.10	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Spring	0.69	-4.24	0.0195	1.34	0.0001
Log Output FPOC (g)	Log Discharge (m^3)	Spring	0.63	-6.31	0.0094	1.55	0.0001
Output DOC (kg)	Discharge ($m^3 \times 10^3$)	Summer	0.80	-1.55	0.0004	0.74	0.0001
Output FPOC (kg)	Discharge ($m^3 \times 10^3$)	Summer	0.91	-1.56	0.0001	0.68	0.0001
Log Output DOC (g)	Discharge ($m^3 \times 10^3$)	Summer	0.51	6.22	0.0001	0.20	0.0002
Log Output FPOC (g)	Discharge ($m^3 \times 10^3$)	Summer	0.73	5.87	0.0001	0.30	0.0001
Log Output DOC (g)	Log Discharge (m^3)	Summer	0.42	-3.06	0.2718	1.23	0.0012
Log Output FPOC (g)	Log Discharge (m^3)	Summer	0.70	-6.06	0.0046	1.57	0.0001

(r^2 = 0.51). For the normal regressions, the steepest slope was found during fall (1.73), while for the other seasons, slopes were similar (0.61 to 0.74) and less than one, indicating that output of DOC was increasing at a slower rate than discharge. The larger slopes for fall were primarily the result of large storms in November and December 1973, for which weekly output of DOC was positively correlated with discharge.

For FPOC outputs, three seasons (fall, spring, and winter) show the semilogarithmic regression as giving best fit (r^2 values of 0.97, 0.66, and 0.85 for fall, spring, and winter, respectively). Slopes were similar for fall and spring (0.10), greater than those in winter (0.08), but less than those in summer (0.30), where a satisfactory semilogarithmic relationship was also seen (r^2 = 0.73). Best fit for summer was with normal form (r^2 = 0.91). The slope associated with summer for FPOC output (0.68) was the smallest for all the normal regressions for the four seasons for FPOC, due to the general lack of significant storm events during the summer which would influence weekly discharge. This yielded many different outputs, both high and low, at relatively the same discharge. Also, as summer proceeded, baseflows declined but throughfall concentrations increased, giving a trend for declining discharge but increasing concentrations (and hence, outputs on a unit volume basis) especially in the smallest storms.

Dynamics of DOC and FPOC in Streamflow Based on Weighted Weekly Concentrations

The weighted average weekly concentrations and weekly outputs of DOC and FPOC, along with discharge, are plotted in Figures 100 and 101, respectively. Highest weekly concentrations occurred during the forty-eighth week of 1973, the week in which the storm with largest peak flow of the study period occurred. Weighted weekly concentrations were 1.87 mg/l for DOC and 7.45 mg/l for FPOC, (total 9.32 mg/l). The low ratio (0.25) of DOC to FPOC concentration was due to several factors. First, the storm occurred soon after peak leaf fall, a time when the stream was well stocked with organic debris. Also, throughfall concentrations recorded for November were relatively low (2.08 mg/l and 0.72 mg/l for DOC and FPOC, respectively), indicating that the majority of the FPOC concentration came from within the stream system. However, the close approximation of weighted average streamflow concentrations to those for throughfall, combined with the small amount of DOC resident in the stream system, point to throughfall as being the major source of DOC during this week. This data best expressed the differential behavior of DOC and FPOC in streamflow. The ratio of DOC/FPOC of 0.25 can be compared to the DOC/FPOC ratio of 0.86 for the fifty-second week of 1973. In this latter case, a significant storm event also occurred, but since the storm of the forty-eighth week had alread occurred, washing the vast majority of the particulate organic material not only out of the stream system, but also from the adjacent forest floor, there was little reserve present to contribute to FPOC loads. Since DOC was more dependent on

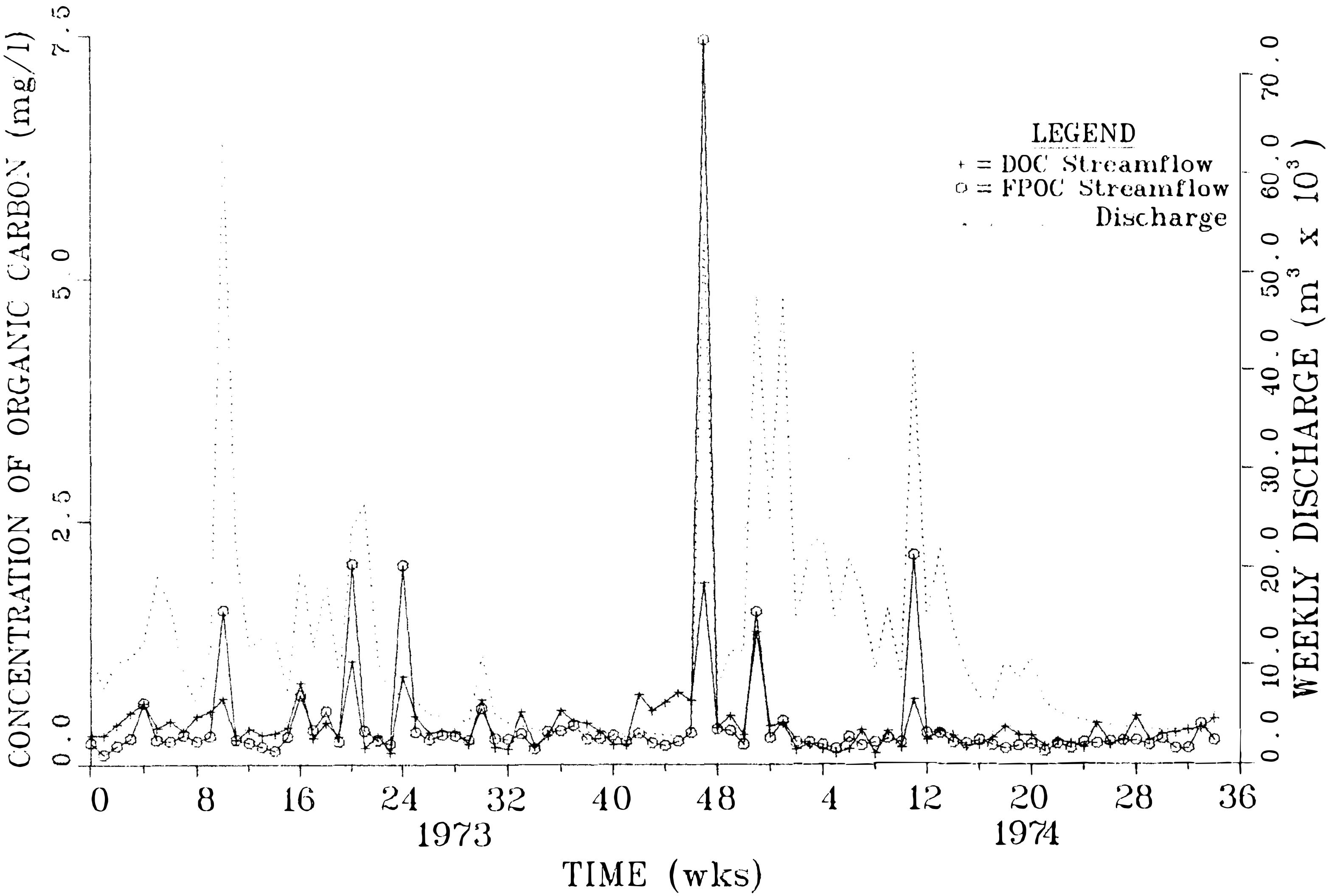

Figure 100. Weighted Weekly Concentrations of DOC and FPOC in Streamflow on the West Fork of Walker Branch for the Period January 1, 1973 through August 31, 1974.

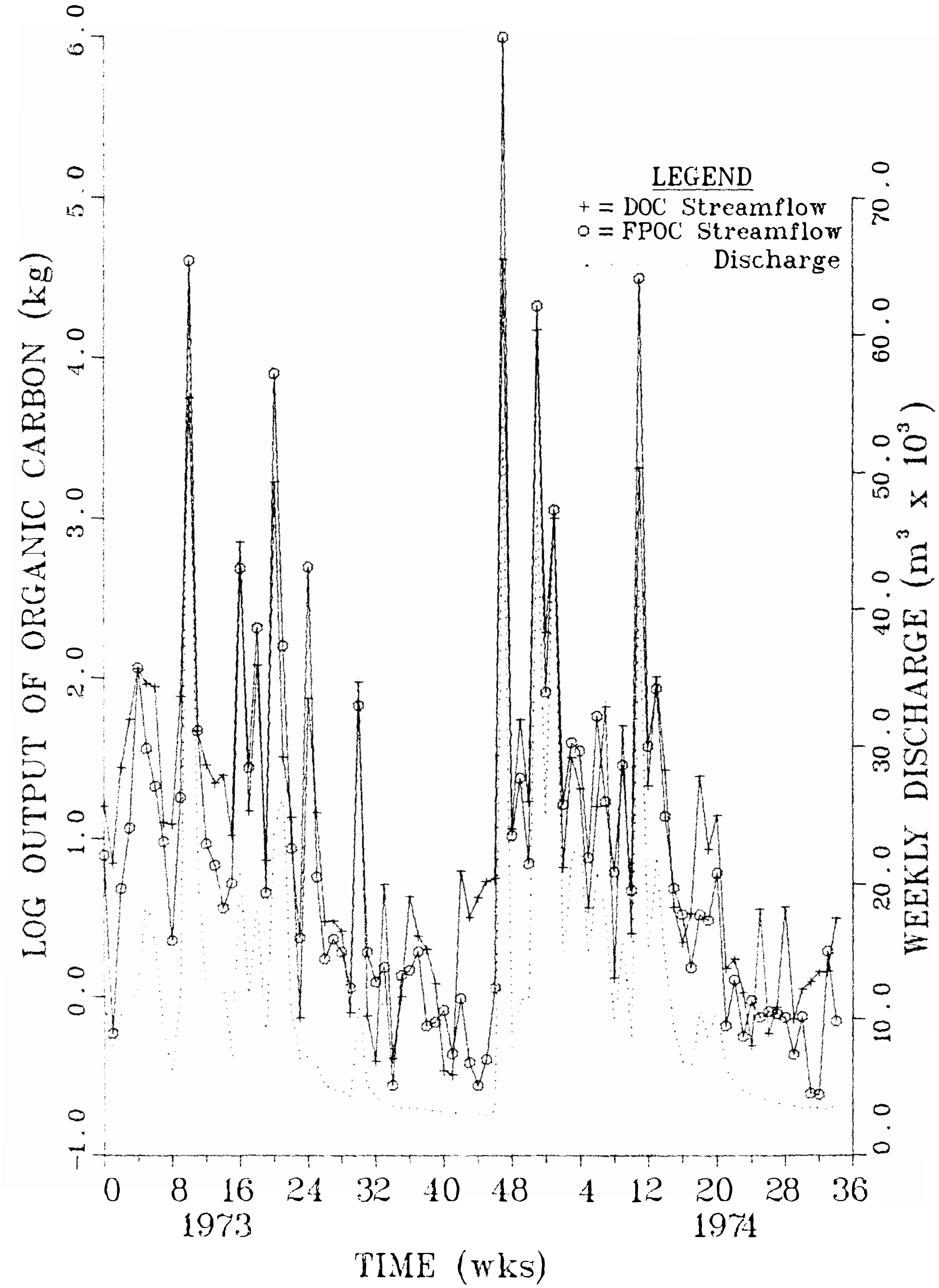

Figure 101. Weekly Outputs of DOC and FPOC in Streamflow on the West Fork of Walker Branch for the Period January 1, 1973 through August 31, 1974.

throughfall during major storm events, its weighted concentration did not decrease as much as did the concentration of FPOC.

Several other comparisons are pertinent. For the twelfth week of 1974, during which another major storm event occurred, the ratio of DOC to FPOC was lower (0.31). This was a period when canopy was not yet present, but significant inputs of organic material had occured due to blow-in (see Figures 10 and 11, pages 75 and 76). Thus, the stream system had been partially replenished with particulate organic matter which it subsequently exported during the high discharge event. The higher ratio (compared to the storm of November 27) was also due to peak discharge being lower.

Similar situations are seen for 1973 during the eleventh, twenty-first, and twenty-fifth weeks. In each case, large storm events acting on a stream system somewhat replenished with FPOC yielded higher FPOC than DOC concentrations due to the lack of a reserve stock of DOC in the system. Main reserves of DOC in the watershed system, aside from that contained in the biota, were found in the soil water/groundwater system, but as has been shown, organic carbon concentrations were very low, being responsible for the low baseflow concentrations of both DOC and FPOC.

The one summer week (week 31 of 1973) during which a large storm event occurred showed a situation somewhat different from that for the fall, winter and spring seasons. It should be kept in mind when looking at the data of week 31 that this storm was much smaller than other major storms, but was the largest summer storm event of the study. Average weighted concentration for week 31 was 0.66 mg/l for DOC and 0.57 mg/l

for FPOC. Throughfall values for this storm (See Table 37, page 253), showed very low concentration of FPOC (1.18 mg/l, about 16% of the total organic load). This storm did not exceed the stream banks, and since another large storm had occurred about two months earlier (May 27) flushing most of the spring litterfall and blow-in from the system, FPOC concentrations in streamflow were low, yielding a concentration ratio of of DOC to FPOC of 1.16 for the week. This was the only week with average FPOC concentrations exceeding 0.50 mg/l, for which the ratio concentration DOC to concentration FPOC was greater than one.

Weekly average concentrations, along with results of analyses of the storm series and regressions for ratio concentration DOC/concentration FPOC, indicated quite clearly that peak discharge favored proportionally greater concentrations of FPOC, with highest peak concentrations generally observed during steepest hydrographic ascent.

This increase in FPOC concentrations relative to DOC concentrations has been observed in other studies. Hobbie and Likens (1973) stated that concentration of FPOC is highly dependent on stream discharge rates and recent rainfall events. Brooks (1970) found POC concentrations in the Brazos River in Texas directly related to river discharge. He stated that DOC concentration is far more independent of streamflow than POC concentration. Whereas DOC concentrations were generally greater during baseflow, during several hydrographic peaks, ratios of DOC/POC decreased to 0.50 and 0.25. An interesting point in Figure 5 from Brooks (1970) is that the lowest ratio (0.25) shown occurred during a sharp rise in the hydrograph, the peak being lower than that of the previous rise, which was much less intense. This conforms well to results of the

present study, where FPOC concentration appeared to be more related to intensity of hydrographic ascent than to absolute increase in discharge.

Nelson and Scott (1962) found the DOM (dissolved and colloidal)/POM ratio to be two to ten times greater than the POM load at low to moderate flows, and at times the POM was twice the DOM fraction at high flows. Weber and Moore (1967) found DOC/POC ratios of from 0.56:1 to 11.0:1 in the Little Miami River near Cincinnati, Ohio, with values greater than 5:1 occurring in winter during low streamflow, and lowest values during periods of high runoff.

Because of the very low concentrations of DOC and FPOC in stream water under low flow conditions on Walker Branch during most of the year, ratios of DOC concentration (or output) to FPOC concentration (or output) varied greatly under these flow conditions.

Baseflow concentrations during the study year on Walker Branch varied from 0.1 mg/l to 0.4 mg/l for both DOC and FPOC, with no particular seasonal trend apparent. These low and relatively invariable baseflow concentrations were controlled by springflow and represented groundwater contributions. In virtually all cases where average weighted weekly concentrations were greater than this, a significant storm event occurred.

The one exception to this trend was seen during the forty-third to forty-seventh weeks. During this period DOC baseflow concentrations were higher than for the rest of the year, varying between 0.55 and 0.73 mg/l. These increased concentrations were most associated with the leaching of organic material recently deposited in the stream system. Since flow rates were generally at a yearly low, no increase was seen in

concentrations of FPOC. Highest ratios of DOC/FPOC for the study were seen at this time (2.0 - 3.3).

Fisher and Likens (1972) reported mean DOM and fine POM concentrations of 2.34 and 0.26 mg/l, both increasing with increasing discharge. Highest concentration of FPOM was 3.02 mg/l, recorded during an intense storm in July 1969. For DOM, Fisher (1970) found ranges for stream water in Bear Brook of 0.76 to 7.56 mg/l.

The forty-third week constituted the last full week in October. Litterfall data (see Figure 6, page) showed maximum leaf fall centered around the first of November. Thus the increases in DOC concentration in the stream system and the period of maximum leaf fall coincided well.

McDowell and Fisher (1976) found DOM from 1.02 mg/l to 7.25 mg/l on Roaring Fork, Massachusetts for 77 days in autumn, with highest nonstorm value of DOM during peak litterfall. Weighted average DOM concentration for the autumn period was 2.2 mg/l, similar to that for the tributaries.

Grab samples taken during this interval (weeks 43 - 47) on Walker Branch under baseflow conditions showed considerable variation from day to day. For example, a sample taken on November 6, 1973 had DOC concentration of 0.11 mg/l, while ones taken on November 9 and 13 had DOC concentrations of 1.45 and 0.85 mg/l, respectively. A sample taken on November 15, 1973 had DOC concentration of 0.28 mg/l. Thus, the data again indicate a rapid response for DOC cycling. Litterfall was not temporally consistent during the autumn, but varied from day to day depending on species involved and on ambient meteorological conditions.

On Walker Branch, composite springflow samples taken during the same period (weeks 43 - 47) showed DOC concentrations of 0.10 to 0.32 mg/l (see Figure 66, page 288), much lower than the 0.55 to 0.73 mg/l for weighted average stream concentration. This is further evidence that the source of elevated DOC levels was within the stream itself.

Another factor adding to the day to day variability in DOC concentrations in stream water during leaf fall involves the relatively rapid leaching of leaf material. Thomas (1970), who attributed weight losses of leaves on land on Walker Branch watershed during the first eight weeks mainly to leaching of water-soluble material, confirmed these leaching losses in laboratory streams using spring water at 15°C, where the percent leached in 24 hours was 25.0% for Acer, 24.0% for Liriodendron, and 3.7% for Quercus. An additional 24 hours removed less than 1% of the weight from all species.

Other investigators working on stream systems have noted similar rapid response. Egglishaw (1969) noted that leaves collected from beech trees in September lost 12.7% of their dry weight in 24 hours of leaching in a laboratory stream. McConnell (1968) reported that, in arid regions, fallen leaves remained chemically preserved during the winter and spring seasons, during which time they were redistributed by winds, accumulating in dry water courses. With the sudden onset of the rainy season in July, the first two or three floods of the season carried most of the accumulated watershed litter into the impoundments. He reported six-hour leaching rates (24-25°C) of 1.56% (of total dry weight) for carbohydrates in oak leaves, increasing to 3.72% after 24 hours. No

further increase was seen. For phenolics, the six-hour value was 0.56%, increasing to 1.50% after 24 hours.

Suberkropp et al. (1976) found that weight loss was more rapid for pignut hickory (Carya glabra) than white oak (Quercus alba) in a Michigan stream. Weight loss was rapid during the initial two weeks for hickory (18.4%) and constituted a large portion of the total reducing sugar and polyphenol loss. Since these forms are among the most soluble constituents of leaves, leaching was probably responsible.

Petersen and Cummins (1974) found rapid weight loss (leaching) of leaves of several species of forest trees in a Michigan stream, with white oak the lowest (5.16%), while Salix lucida (22.74%) and Cornus (27.20%) were highest. Carya glabra was also low, losing 10.37% of the dry weight in 24 hours. Comparing the leaching rates at three temperatures (4°C, 8°C, and 17°C), they found no significant differences.

McDowell and Fisher (1976) found rapid leaching in Roaring Fork, Massachusetts for autumn-shed leaves, with beech slowest (after three days, 3% leached), possibly due to the tough cuticle. They reported this as close to the value of 3.4% found by Saito (1957) for leaching of beech leaves in cold water. For gray birch leaves and maple leaves, McDowell and Fisher (1976) found that 19% and 22%, respectively, were leached after three days. These values are similar to those reported by Gosz et al. (1973) of 15% for yellow birch and sugar maple. In laboratory experiments, the 24-hour leaching rate was 10% for gray birch (McDowell and Fisher 1976). Hayden (1973) reported 23% loss from Acer saccharum after 24 hours in a laboratory stream.

Not only are leaching rates rapid, but the process is further complicated by uptake of the released organics by stream (benthic) microflora. Bretthauer (1971) noted that peptides and amino acids are water-soluble and are washed out of autumn-shed leaves very quickly. Disappearance of the leached amino acids was rapid, with 75% gone after one week and 90% gone after five weeks. Similar decomposition rates have been shown by Brehm (1967) and Schurmann (1964) in lakes. Wetzel and Manny (1972), who leached hickory and maple leaves in experimental streams, found that rapid uptake of leaf leachate occurred. They observed rapid leaching of DOC, with maximum concentrations of 35.6 mg carbon/ liter 30 hours after introduction. Bacterial populations responded quickly (within 48 hours), with almost a two-thirds reduction in DOC during the first 80 hours of the experiment. They reported 0.58 mg/l/hr uptake for DOM in their artificial stream. They also showed that DOM uptake by decomposers had two phases, corresponding to a labile fraction (halflife of two days) and a refractory component (with a half-life of 80 days), with 20% of the leachate being refractory. These workers attributed the uptake to bacteria in the water column, not on the substrate.

Fisher and Likens (1973) calculated that input of DOM in Bear Brook, New Hampshire equaled export, indicating that DOM uptake in the stream was equal to DOM released in the stream by leaching of litter. Barlöcher and Kendrick (1973) reiterated the findings of Sladeckova (1963) that, for many fungi, organic material serves as effective substrate for attachment, with most nutrients coming from the water column (dissolved). Howarth and Fisher (1976) reported that microbes associa-

ted with the stream substrate can remove appreciable quantities of DOM from the water column. Hynes et al (1974) reported on leaf leachate uptake studies in a small hardwater stream in Ontario. Sterile leachates of sugar maple were added to the stream over a 20 minute period, raising DOM concentration of the water from 4 to 40 mg/l. They sampled downstream over a long period of time, and their results showed that up to 75% of the added leachate disappeared from the water column within one hour and a distance of 30 meters. Other leachates showed the same effects.

McDowell and Fisher (1976) found, for the period September 16 to November 9, 1974, that DOM exported in excess of hydrologic input was only 18% (refractory) of total input from leaf leaching. During the study period, DOM uptake by the stream system was 1.1 mg/l, with maximum uptake at 3.5 mg/l during the peak litterfall period, or 88 mg/l/hr. DOM uptake during the autumn was 53 mg/m^2. They found, for several of the autumn collection periods, that input of DOM exceeded output due to uptake of DOM by the benthic bacteria, with DOM uptake ranging from 1% to 57% of total DOM input and 6% to 117% of leachate input. For the entire autumn season, DOM uptake was equivalent to 33% of total DOM input and 77% of leachate release. For DOM, 58% of the input occurred by hydrologic paths and 42% was released in the stream as leachate.

Lock and Hynes (1976), using maple leaf leachate in Speed River (Ontario) water with ambient DOC concentrations of 15-20 mg/l, found that over four days the concentration of DOC dropped a significant amount (80%) due to particle formation. Using well water (DOC concentration 3-4 mg/l) adjusted for hardness, a 20% loss of DOC occurred the

first day (significantly different from the control), while little further change was seen. Indications were for greater particle formation effect using natural waters with low ambient DOC. No explanation for this was given. No greater uptake effects were seen for October as compared to July. They found that when leachates were added to sediment cores, significant changes occurred in DOM levels, falling to 15% of the initial level in one day and 2% by the second day.

In this regard, it is pertinent to note the results obtained by Nelson et al. (1969) and Elwood and Nelson (1972), where rapid uptake of released P^{32} by the benthic microflora was seen. In these studies highest standing crops of microflora were found in autumn after leaf fall, due to the excess substrate provided by the allochthonous organic material. They showed that very little P^{32} was taken up by freshly fallen leaves, with the P^{32} concentration being most dependent on length of time the leaves had been in the creek. Other studies (Ball and Hooper 1963, Garder and Skulberg 1966) have shown similar phenomena, including the observation that uptake by inorganic sediments is minor compared to that taken up by the aufwuchs.

Recent studies have indicated that uptake by microflora may not be the only mechanism responsible for conversion of DOC to FPOC in stream systems. Hynes et al (1974) stated that formation of particles by complexing of DOM with divalent metals, e.g. humus/metal complexes (Schnitzer 1969), are probably found in streams. Within one hour after introduction, sterile leaf/water cultures showed precipitates similar to detritus found in the field. Infrared spectroscopy indicated a great similarity between detritus and metal/organic complexes of known weight

of fulvic acid. Greater variablilty was seen comparing the laboratory precipitates and the fulvic acid complexes, possibly due to the lack of aging for the laboratory material. Thus, although biotic uptake is probably the predominant form of uptake, other more esoteric factors could be operating simultaneously.

Although not reported in this paper, upstream-downstream determinations were made periodically throughout the 1973-1974 water year. Grab samples were taken over a 30 minute period sequentially from: 1) spring SW3; 2) Walker Branch - west fork, 15 meters below spring SW3; 3) at the intake to the composite sampler, approximately 30 meters above the weir. Spring SW3 empties into Walker Branch about midway along its perennial flow section ($\sim$ 185 meters above the weir). The rationale behind the timing and the sequence of sampling was to approximate the travel of a unit mass of water emerging from the spring to the stilling basin.

Results of three such sampling periods are shown in Table 58. For the October 29 sampling, both DOC and FPOC concentrations showed the same pattern of increase from spring to stream. In addition, DOC concentrations showed a difference between upstream and downstream measurements, indicating further increase in DOC load, presumably due to leaching of the freshly fallen litter. This was the period of maximum litterfall on the watershed. The midrange DOC concentration measured 15 meters below the spring indicated dilution of the streamwater DOC concentrations by lower concentrations in springflow. Flow above SW3 was relatively sluggish during this low flow period in autumn, allowing a long period of contact between a water mass emerging from the headwater spring (about 400 meters above the weir, see Figure 2, page 26) and the leaf material in the channel.

Table 58. Results of Three Upstream-Downstream Samplings for Concentration of DOC and FPOC on the West Fork of Walker Branch During the Autumn of 1973.

Date	Time	Location*	DOC	FPOC
10/29	1800	a	0.21	0.16
	1805	b	0.42	0.21
	1820	c	0.54	0.24
11/6	1130	a	0.11	0.17
	1140	b	0.11	0.17
	1200	c	0.11	0.18
11/15	0930	a	0.25	0.10
	0940	b	0.21	0.18
	1000	c	0.28	0.14

*Location: a--at spring SW3, 180 m above weir
b--west fork, 15 m below SW3
c--west fork, 30 m above weir.

Comparing these results to those for November 6 and November 15, 1973 one and two weeks later, respectively, a very different trend was seen. No difference was seen for any of the parameters for the November data except inorganic carbon, which reached equilibrium with atmospheric carbon dioxide in its passage down the stream from its underground origins. DOC and FPOC remained in very low concentrations, with values being virtually identical for all three locations.

The data further point to the erratic behavior of DOC levels in Walker Branch during this period of leaf fall, with high ambient levels of DOC not present on a sustained basis throughout the period. This points to relatively quick leaching of the litter, with higher concentrations due to large inputs of litter on a particular day.

From results of the upstream-downstream studies conducted over the year, along with results of grab and composite samples taken at the spring and weir, it is quite evident that baseflow concentrations of DOC and FPOC in the stream are primarily controlled by inputs from the spring system.

The present study has shown that leaves are blown into the stream through much of the winter to early spring period. However, these leaves have been on the forest floor for many months and are well leached before their introduction. Thomas (1970) collected autumn-shed leaves from the forest floor of Walker Branch watershed in July and leached them in a laboratory stream. The 24-hour water-soluble losses from these leaves were 2.9% for *Acer*, 5.4% for *Liriodendron*, and 0.5% for *Quercus*, these values being 12-20% of those for freshly fallen leaves. Because the quantity of windblown leaves represented only about 20% of

that of litterfall (see earlier discussion), and because blow-in was distributed over a long period of time, this small amount of leaching would probably not noticeably affect stream DOC levels.

Generally higher concentrations of DOC and therefore DOC/FPOC have been reported from other studies. Manny and Wetzel (1972) indicated that the ratio of DOC to POC in hardwater streams in Michigan was 10:1 on a sustained basis over a 15 month period. Seki et al (1969) used the ratio of soluble to particulate organic carbon of 7:1 in the Nanaimo River, British Columbia. Hynes et al (1974) indicated that Speed River (Ontario) water had DOC concentrations on the order of 20 mg/l. Owens and Edwards (1964) found soluble organic carbon concentrations of between 2.6 and 14 mg/l. However, the streams represented by these data are larger than Walker Branch, with a higher degree of autochthonous primary production.

For small watersheds, the data are more comparable. Hobbie and Likens (1973), on the basis of few analyses, attempted to characterize the output of DOC and FPOC from two contrasting Hubbard Brook watersheds. They reported low concentrations of DOC in both the forested and clearcut watersheds, with most values falling between 0.3 and 2.0 mg carbon/ liter. Highest values were found during the same storm studied by Fisher (1970), occurring on July 29, 1969 (3.1 and 4.8 mg carbon/l for the forested and clearcut watersheds, respectively. The range reported in their study is about one order of magnitude, although not too much can be said about DOC behavior since sampling was far from adequate. It is difficult to believe that a DOC concentration of 3.1 mg/l could represent peak concentration in the forested stream, especially since

throughfall values for DOM for the summer months at Hubbard Brook have been shown to be high (18-28 mg/l organic matter) (Eaton et al. 1973), and these streams are very small. However, their argument concerning the relative increase of DOC output to increase in streamflow (10^3-10^4 for the latter) is pertinent and is confirmed by the present study. Their conclusion that the clearcut watershed had higher output of DOC, based primarily on the greater discharge may represent a serious error if results of the present study, which indicate the dependence of DOC concentration on throughfall concentration, are indicative of conditions at Hubbard Brook.

The overall range of DOC concentrations found in this study was greater than that found in most other studies, one reason being the much lower DOC baseflow concentrations reported on Walker Branch. Under baseflow conditions concentrations were quite constant. Baker et al. (1974) found ranges of concentrations of DOC during baseflow in English streams of 0.41 mg/l to 2.75 mg/l for the River Piddle (chalk stream) and 0.72 to 5.58 mg/l for the River Frome (Tertiary sands, Jurassic limestone and chalk). Indications were that chalk streams had lower DOC concentrations, less than 2 mg/l for unpolluted chalk streams, while for streams draining acid heath land concentrations were significantly higher (3 5.5 mg/l).

Baseflow values of FPOC at Walker Branch are more in line with those in the literature. McDowell and Fisher (1976) reported lowest concentrations of FPOM in Roaring Fork, Massachusetts of 0.04 mg/l. Maciolek (1966) reported microseston values at baseflow of 0.3 mg/l. Maciolek and Tunzi (1968) studied the microseston (< 350 μm) dynamics in

Laurel Creek, California. They found that headwater and seepage sources contributed 0.5 mg/l dry weight of mainly organic detritus. Reiners et al. (1955) found, for the upper basin of Convict Creek, that microseston did not exceed 1 mg/l and were dependent on the level of discharge of phytoplankton from oligotrophic lakes in the drainage system. Downstream, just before entering Convict Lake, the microseston had decreased to 0.1 mg/l and was almost all detritus. Seki et al. (1969) reported POC concentrations of 0.2 mg/l in the Nanaimo River in British Columbia. Fisher (1970) found (as taken from the graph he presented in Figure 5 of his thesis) no concentration of FPOM (< 1mm) greater than 1 mg/l over a range of almost three orders of magnitude of discharge, with most values around 0.1 mg/l. Hobbie and Likens (1973) reported, also for Hubbard Brook streams, no concentration of FPOC over 1 mg/l.

However, the range generally reported in other studies was far less than that for Walker Branch. Maciolek (1966) reported a range of microseston concentrations of 0.3 mg/l to 2.1 mg/l, the latter measured in late spring prior to peak runnoff (from snowmelt). Baker et al. (1973) reported a range of POC under baseflow conditions for the English chalk stream, River Piddle of 0.71 - 6.83 mg/l and 0.31 - 2.23 mg/l for the River Frome. The high value for the River Piddle was an outlier, with the next highest concentration being 2.30 mg/l under baseflow conditions. However, they reported that concentrations of 0.2 to 50 mg/l POC have been found in streams of the River Frome. McDowell and Fisher (1976) reported autumn FPOM concentrations in the range 0.04 - 3.2 mg/l in Roaring Fork, Massachusetts, with highest concentrations during storms.

Minshall (1967) stated that particulate organic matter, in the size range studied (4-158 μm), is predominantly detrital in nature, especially in small streams. He sampled a Kentucky springbrook monthly for 15 months and found that the content of POM suspended in the water was generally lowest at the most upstream station (ranging from 0.03 to 0.75 g/l), increasing downstream, indicating some production in the stream itself. Most values fell in the range 0.11 to 0.18 mg/l.

For larger rivers, concentrations are higher, at least in part due to autochthonous production. Birge and Juday (1926) reported concentrations of suspended organic matter in the Wisconsin River at Prairie du Sac Dam for November and July, respectively, of 1.02 and 2.6 mg/l.

Nelson and Scott (1962) found values for total organic matter in the Middle Oconec River in Georgia ranging from 8 to 47 mg/l, with the majority of values in the 10 to 20 mg/l range.

Nelson (in Auerbach et al. 1967) reported further on the organic matter levels in the Middle Oconee River in the Georgia Piedmont. This river, with drainage area at the site of sampling of 9.86×10^4 ha, had a shifting sand bottom, and thus primary production was very low. He found seasonal changes in particulate organic matter (POM) concentration, with average values of 4.25 and 11.5 mg/l for the winter and summer seasons, respectively. The dissolved load, which showed no seasonal variation, averaged 15.3 mg/l, somewhat higher than the POM levels in summer. Of the total dissolved solids load, 29% was organic matter, while organics constituted only 13% of the particulate fraction.

Because of low baseflow concentrations of DOC and FPOC in the present study, (0.1 - 0.4 mg/l for each species), changes in concentration,

even during small summer showers and moderate rains in the dormant season were at least an order of magnitude. Fisher (1970), discussing the various ways allochthonous particulate organic material can enter the stream system, pointed out that a light shower can cause a ninefold increase (0.04 to 0.93 mg/l) in concentration of FPOC, with little change in discharge, due to high organic leaching/washing from the canopy.

For Walker Branch, this type of rise would represent a minimal value, especially during the growing season. The range of concentrations for the entire study period for DOC was from 0.05 mg/l to 13.55 mg/l, the latter occurring at a discharge of 0.01 m^3/sec. This represents greater than a two order of magnitude change in DOC concentration for an approximate doubling of streamflow. For FPOC, peak concentration and peak discharge coincided well, with highest concentrations of 68-77 mg/l during the peak (1.60-1.63 m^3/sec) of the November 28 storm. These values approach a three order of magnitude change in FPOC concentration (770-fold based on baseflow concentrations of 0.1 mg/l), while discharge increased 271-fold over baseflow. These results show that the highest FPOC concentration was most dependent on peak flows, while that for DOC was not. During the peak flow of November 28, DOC concentrations averaged 4.4 mg/l, with higher concentrations recorded during many smaller storms. In addition to this very large peak concentration of FPOC, smaller storms produced FPOC concentrations over 10 mg/l at proportionally much lower flows and, as shown in many cases, before peak discharge. It is felt that the coincidence of peak flow and peak FPOC concentration during the November 28 storm was due to the added factor of bank overflow and scouring of streamside litter.

One study reporting comparable ranges of FPOM was discussed by Hynes et al. (1974), who found levels of POM in streamflow varying from a low of less than 1 mg/l to a high of 60 mg/l, with fluctuations of this magnitude found in summer thunderstorms in hardwater streams in the Waterloo, Ontario area.

Hobbie and Likens (1973), whose data agreed with that of Fisher (1970), found a strong relationship between FPOC and discharge, but stated that, overall, FPOC was relatively unimportant in the total organic matter exported, as 2-16 times more DOC than FPOC was lost in stream output for various periods. They stated that FPOC estimates would have been improved considerably by increased sampling, with more emphasis on periods of highest flow (10% of the year). Random or monthly sampling could entirely miss peak flows with their greatly increased FPOC loads. At least in small streams, FPOC concentration is very responsive to changes in rate of discharge, with large changes in concentration occurring over a short period of time. Fisher (1970) presented a storm series including the largest storm of his study at Hubbard Brook Experimental Forest (see Figure 6, page 74 of his thesis). This storm was also discussed by Hobbie and Likens (1973). Because no samples were taken on the ascending limb of the hydrograph, but only at the peak, the curves for discharge and FPOM concentration rise and fall synchronously, with peak concentration and peak discharge coinciding. A rapid fall in FPOM concentration occurred during each descending limb. Overall concentrations of FPOM for the two storms at a given streamflow were not the same, with the storm with greatest peak discharge (> 100 l/sec) occurring first (July 29) and having somewhat higher FPOM concen-

trations (3.02 mg/l vs ~1.4 mg/l). The author compared a series of four points at 4 l/s discharge, the values for FPOM being extrapolated from baseflow to peak flow (no intermediate data points). While results of the present study agree with his observation of far greater concentrations on the ascending limb, it is the feeling of this writer that the lack of data points on the ascending limb render any other comparisons meaningless. The present study showed that FPOC concentrations rise on the ascending limb with a rapidity greater than their decline on the descending limb. In fact, on the ascending limb, a decline in concentration of FPOC occurred in most cases long before peak streamflow, with concentration being more related to rate of change in discharge than to actual discharge. If output values for Bear Brook as calculated by Fisher (1970) and for several smaller Hubbard Brook streams by Hobbie and Likens (1973) are based on such infrequent samplings, the importance of FPOC could be greatly underestimated, since they may have completely missed peak concentrations even during a particular storm. Another point with reference to Figure 6 of Fisher (1970) is the higher FPOC concentration during the greater peak flow. Comparing the two peaks of discharge, it can be seen that the rate of change in flow during the first rise was greater than during the second. The higher peak flow during the first storm may have been due to the higher rate of change in streamflow rather than to the absolute size of the peak. Thus, any calculation of yearly discharge using regressions based on concentration at peak flow would lead to an obvious underestimate.

From results of weekly average concentrations, it is apparent that relative magnitude of DOC and FPOC concentrations for the year were most

dependent on relative frequency of major storm events, which favored FPOC.

It has been noted that the storm of November 26 occurred soon after the majority of leaf fall (see Figure 6, page 57). While the timing of this event was somewhat unusual, being earlier than expected, it is characteristic of the Oak Ridge area for peak flows to occur during late fall through early spring. In 1972, just as this study was beginning, a large storm event occurred (December 8 - 10). The fact that peak flows occur during the late fall to early spring results from a combination of factors, including the low evapotranspiration during the period, plus the precipitation regime for the area (see Figure 23, page 131), which shows high sustained monthly precipitation inputs during the entire December through March period.

DOC concentration was apparently most dependent on throughfall inputs (and the rate at which these pass through the soil/aquifer system), while FPOC concentrations were controlled more by standing crops in the system itself. This was especially true in the dormant season. Results of throughfall and incident precipitation analyses showed that incident precipitation was responsible for the majority of the input on an annual basis.

Weighted mean concentrations over each of the two years, calculated from weekly weighted average concentrations, were 0.67 and 0.32 mg/l for DOC during 1973 and 1974, respectively, and 1.28 and 0.45 mg/l for FPOC for 1973 and 1974, respectively. McDowell and Fisher (1976) reported a flow-weighted average concentration for FPOM (<1.0 mm) of 0.16 mg/l for Roaring Fork, Massachusetts, with that for tributaries 0.10 mg/l. These data were for a 77 day fall period with no extremely high discharge.

The results for 1973 showed mean yearly concentrations of DOC and FPOC to be approximately two and three times greater, respectively, than those for 1974. The two years' data were not directly comparable, however, since data for 1974 included only the first nine months. Thus, the high DOC concentrations expected in fall 1974 and observed in fall 1973 were not included. Also not included in the 1974 data were storms equivalent to those in fall 1973, especially one in late November of 1973, where highest concentrations of FPOC occurred. This storm dominated the behavior of FPOC on a yearly basis, and the higher concentrations of FPOC, relative to other concentrations of FPOC and to all concentrations of DOC, were primarily responsible for the high mean yearly concentration of FPOC. Excluding this storm from the data, the yearly concentrations of FPOC for 1973 would have been 0.67 mg/l, about one-half that with the storm included. For DOC, omitting this storm from the data set would reduce the DOC concentration 0.55 mg/l for the year, a decrease of only 18%. However, this would be an artificial exercise, since responses of organic carbon, especially FPOC, were dependent to a great extent on antecedent storm events. Thus, had the November storm not occurred, the December storm would have had elevated concentrations of organic carbon, especially concentrations of FPOC.

Hobbie and Likens (1973) presented data for June 1968 to May 1969 (see their paper, Table 1), from which concentrations of FPOC and DOC can be calculated. For the deforested watershed, concentrations were 0.22 mg/l and 0.42 mg/l for FPOC and DOC, respectively, while for the undisturbed watershed concentrations were 0.16 and 0.95 mg/l for FPOC and DOC, respectively. The FPOC values were very close to those calcu-

lated by Fisher (1970) for FPOM and DOM on Bear Brook of 0.26 mg/l and 2.34 mg/l, respectively.

Maciolek (1966) estimated that microseston averaged 0.67 mg/l for the year of his study on Convict Creek, California, with concentrations varying directly with discharge. This direct relationship resulted in seasonality of microseston discharge varying with streamflow. However, the increase in concentration between high and low flows was only fivefold, while discharge varied thirtyfold. Little diurnal pattern was seen in microseston dynamics. He concluded that without lacustrine contribution microseston would have been greater than three-fourths detritus.

Weekly output of DOC and FPOC in streamflow in Walker Branch are shown in Figure 101. Like concentrations, outputs for the year were dominated by events of week 48, when the major peak flow event in the watershed's history of operation occurred. During this week, when 9% of the total yearly output of water occurred, 25% of the yearly output of DOC and 52% of the yearly output of FPOC occurred. For the total weekly output of 504.8 kg, DOC contributed 20% (101.2 kg) of the total, with FPOC (403.6 kg) contributing 80% of the output. The week with highest water output of the year (week 11 of 1973), during which another significant storm event occurred, had an FPOC output (100.09 kg) of only 25% of that of week 48. The importance of the timing of storm events and antecedent conditions are clearly shown here because week 11 had overall discharge of 1.16 times that of week 48. In late 1972 (week 49), after leaf fall, a large storm also occurred which flushed the vast majority of leaf material from the system. Week 52 of 1973 had FPOC output of

75.55 kg, only 19% that of week 48, while water output was 89% of that that for week 48. Thus, the lower output of FPOC in the later storms can be related to timing of the storm along with the magnitude of peak flow.

For DOC output, a comparison of week 48 of 1973 with weeks 11 and 52 shows that the output during week 11 (42.14 kg) was 42% of that of week 48, while for week 52 the DOC output (65.20 kg) was 64% of that for week 48. The lower proportion of DOC output in these storms was primarily due to timing of the events. With throughfall inputs relatively constant during fall and winter (2-3 mg/l), the higher concentrations of DOC in week 48 were related to some degree to entrainment of leachable litter from the stream bottom and adjacent banks. Note however, that the percent output of DOC in these later storms, compared to the storm of week 48 of 1973, was much higher than that for FPOC.

Although data for throughfall and incident precipitation were not available for March 1973, the low concentration of DOC in streamwater during the week can be attributed to low DOC inputs in throughfall, plus little contribution from litter leaching due to cold temperatures in March. The values for week 52 of 1973 are very instructive. In this case, where most FPOC had been previously been flushed from the drainage system, DOC became much more important, contributing 46% of the total weekly output.

Because of the positive relationship between organic carbon concentration and discharge, an even stronger positive trend was seen for outputs. Weekly outputs of FPOC above 10 kg were observed only during those weeks when flow greater than 2.0×10^4 m^3 occurred. The reverse

was not true. There were many weeks when discharge exceeded 2.0×10^4 m^3 with output less than 10 kg, indicating that output may be more related to peak instantaneous discharge than cumulative weekly discharge. Another consideration, related to the antecedent flow conditions, is that for several weeks (especially week 12 of 1973) the high weekly discharge was associated with hydrographic recession following a major storm at the end of a previous week. This would help explain the lower outputs for these weeks since low concentrations, especially for FPOC, accompanied hydrologic recession.

The twenty-first week of 1973 had the second highest weekly concentration of TOC for the study period (3.11 mg/l); however, due to considerably less water discharge during the week, output of TOC was only 21.28 kg. The higher TOC concentration was due mainly to higher FPOC concentration associated with presence of canopy.

Lowest weekly outputs were recorded during week 35 of 1973 (end of August - first of September) when 1.24 kg was exported, consisting of 49% DOC and 51% FPOC. Only 0.07 cm of rain was recorded for the week. Next lowest exports were recorded on week 42 (third week in October) when 1.3 kg was exported, consisting of 47% DOC and 53% FPOC. The flow during this week was 2960 m^3, the third lowest weekly flow of the calendar year. No rainfall was recorded during the week. Lower weekly flows were recorded during weeks 45 and 46 (2954 and 2843 m^3, respectively), but due to higher DOC concentration from leaching of fallen litter, total output was greater. Also contributing to higher DOC concentrations was the fact that 1.60 and 0.51 cm of rain fell during weeks 45 and 46, respectively. However, FPOC outputs were still very low

during this time, due to the low flow regime. FPOC outputs during week 45 were similar to those found during week 35, together constituting the lowest FPOC outputs of the year.

Three weeks besides week 48 had weekly total output greater than 100.0 kg, with the storm of week 11 of 1973 and week 52 having very similar outputs (142.50 and 140.76 kg, respectively). While the former had highest weekly water discharge for the study period, it also had lower concentrations of DOC. The twelfth week of 1974 had output of 117.29 kg, with FPOC concentrations approximately three times greater than DOC (TOC concentration 2.80 mg/l).

The results show that lowest outputs of both DOC and FPOC occurred when three conditions were met: low rates of discharge, little or no rain, and small reserves of leachable or transportable organic debris in the stream channel. Groundwater concentrations of organics were low during these conditions due to the long residence time of water in the aquifer system. Throughfall, which has been shown to contain sizeable fractions of organic material, did not pass through the soil system during this period, since the soil was very dry (see Figure 65, page 258). Most throughfall was held in the soil profile during this time, where organic concentrations were rather quickly reduced. Water falling directly into the stream channel contributed most of the increase in discharge during this time.

Table 59 summarizes the data for DOC and FPOC in streamflow on the west fork of Walker Branch. For the 1973 calendar year, average TOC concentration was 1.95 mg/l of which, DOC was 0.66 mg/l and FPOC was 1.28 mg/l. Based on a discharge of 6.01×10^5 m^3, total output of TOC

Table 59. Summary of Data for Concentrations and Outputs of DOC, FPOC, and TOC in Walker Branch for Various Periods from January 1973 through September 1974.

Interval	Discharge (m^3)	Concentration (mg/l)			Output (kg)			Output (kg/ha)		
		DOC	FPOC	TOC	DOC	FPOC	TOC	DOC	FPOC	TOC
1973 (Jan-Dec)	6.01×10^5	0.66	1.28	1.95	400.3	770.9	1191.2	10.42	20.08	30.50
1973 (Sep-Dec)	1.71×10^5	1.15	2.91	4.06	196.3	499.0	695.3	5.11	12.99	18.10
1974 (Jan-Aug)	4.21×10^5	0.32	0.45	0.77	133.7	187.0	321.6	3.49	4.89	8.37
1973-1974 Water Year	5.92×10^5	0.56	1.16	1.72	330.0	686.9	1016.9	8.59	17.88	26.47

(DOC + FPOC) was 1171.17 kg, of which 400.27 kg (34.2%) was DOC and 770.90 kg (63.8%) was FPOC.

For the September through December period of 1973, during which two major storm events occurred, average DOC and FPOC concentrations were 1.15 and 2.91 mg/l, respectively, for a TOC concentration of 4.06 mg/l. Based on a discharge of 1.71 x $10^5 m^3$, DOC and FPOC outputs were 196.3 and 499.0 kg. respectively, for a total output of 694.3 kg. For the nine months of 1974, average DOC concentration was 0.77 mg/l, of which 0.32 mg/l was DOC and 0.45 mg/l was FPOC. Total output for the period, based on a discharge of 4.21 x $10^5 m^3$, was 321.58 kg, of which 41.5% was dissolved and 58.4% was in particulate form. Thus, the 1973-1974 water year (September 1973 through August 1974), with a discharge of 5.92 x 10^5 m^3, had DOC and FPOC concentrations of 0.56 and 1.16 mg/l, respectively, for a TOC concentration of 1.72 mg/l. Outputs for the year were 330.0 and 686.9 kg for DOC and FPOC, respectively, for a total output of 1016.9 kg.

The September through December period, with 29% of the discharge, had 68.3% of the organic carbon output for the 1973-74 water year. This included 72.6% of the FPOC output for the year and 59.5% of the DOC output for the year. These results show the great importance of major storm events on organic carbon outputs, especially for FPOC. The great similarity in the outputs for the 1973 calendar year and the 1973-1974 water year were mostly due to the large outputs in Fall 1973, which were included in both time periods.

Egglishaw and Shackley (1971) compared total discharge of organic matter during a February increasing hydrograph (seven times base flow)

with low flow output during July and found a 35-45 times greater total output during the February sampling period.

Fisher (1970) noted that, since DOM and POM increase in concentration with discharge, high flows discharge a disproportionately large amount of the organic material. Hobbie and Likens (1973) observed that Fisher's (1970) data for FPOM transport in Bear Brook showed that almost all of the annual total of FPOM was transported during periods of high streamflow. Their data showed 87% of total FPOC export for October 1967 through May 1968 occurring during March to May. From June 1968 through May 1969, 86% of the FPOC output in W-2 occurred in April. Their results should be examined with some caution, since the highest concentrations were estimated from regressions based on data from much lower flows (e.g., the measured values fell between 1 and 99 g/l while they estimated 345 g/l).

Expressed on a unit area basis, the outputs of DOC, FPOC, and TOC were 10.42, 20.08, and 30.50 kg/ha, respectively, for the 1973 calendar year, and 8.59, 12.89, and 26.48 kg/ha, respectively, for the 1973-1974 water year. Hobbie and Likens (1973) presented values for the output of DOC and FPOC (< 1 mm) for several small watersheds (W-2 and W-6) at Hubbard Brook, New Hampshire. For June 1968 through May 1969, DOC, FPOC, and TOC were 4.84, 2.58, and 7.42 kg/ha, respectively, for the deforested W-2 watershed, and 1.45, 8.51, and 9.96 kg/ha, respectively, for the W-6 (undisturbed and forested) watershed. The values for Hubbard Brook watersheds, which had a somewhat lower discharge (115.95 and 89.72 cm, respectively, for W-2 and W-6) than the west fork of Walker Branch during the 1973-1974 water year (153.1 cm), were only about one-third of those for Walker Branch.

Several explanations for these differences are possible. First, the Hubbard Brook values were based on a very small number of samples (one per month) and could well be in error by several fold, especially with regard to FPOC outputs. Also, the hydrologic regime for the June 1968 through May 1969 period at Hubbard Brook showed no catastrophic flows, with only the normal spring high flows due to snowmelt. Walker Branch, on the other hand, experienced a number of severe storm events during the 1973 and 1974 years. Due to the close relationship between output of organic carbon and discharge, along with the positive relationship between FPOC concentration and discharge, the high flows had a major impact on organic carbon transport. The effect of greater discharge rates at Hubbard Brook can be seen in the data of Hobbie and Likens (1973) for the June 1969 through October 1969 period (four months), when organic carbon outputs were 6.71 and 4.44 kg/ha for W-2 and W-6, respectively. The output for W-2 was almost equivalent to the output for the entire previous year on this catchment. Data for these four months also indicated very low outputs of FPOC. The FPOC data may well represent a considerable underestimate, based on the known complexity of the response of FPOC to discharge.

CHAPTER VI

SYNTHESIS

Table 60 shows a comparison of the organic carbon inputs (kg/ha) to the forest floor of Walker Branch watershed. Litterfall dominated the inputs, contributing 95.9% of all organic carbon reaching the forest floor. Throughfall, which contributed 4.1% of the total input, was dominated by organic carbon fixed external to the watershed (59.3%), with canopy removal contributing 40.73% of the throughfall. Of the total input to the forest floor, organic carbon fixed external to the watershed comprised 2.4%, while organic carbon produced within the watershed contributed 97.6% of the total.

Dissolved organic carbon losses in groundwater were 1.34 $g/m^2/yr$, or 13.43 kg/ha. If it is assumed that these dissolved losses represent the only organic flux of carbon from the soil system, and if the forest floor is considered to be near steady state, then the DOC losses in groundwater represent 0.6% of the total input to the forest floor, indicating that the vast majority of the organic carbon leaves the forest floor in the inorganic form, the result of catabolic processes in the litter and soil compartments. When root respiration and root decay are taken into account, this relative loss of organic carbon from the soil profile becomes very small. Edwards and Harris (1975) found that root respiration and decay contributed greater than 75% of the total CO_2 loss from the soil system in a mixed deciduous forest in the Oak Ridge area.

Table 60. Organic Carbon Inputs (kg/ha) to the Forest Floor of Walker Branch Watershed.

Source	Inputs (kg/ha)	Relative Contribution (%)
Incident Precipitation (External)	56.3	2.4
Canopy Removal (Internal)	38.7	1.7
Throughfall (IP + CR)	95.0	4.1
Litterfall (Internal)	2221.5	95.9
Total	2316.5	100.0

Table 61 shows a comparison of direct channel inputs of organic carbon (kg/ha) to the west fork of Walker Branch. Litterfall dominated the inputs, contributing 74.4% of the total organic carbon to the stream channel, followed by blow-in, with 22.5% of the total inputs. Throughfall contributed only 3.2% of the total. Comparing externally vs internally fixed organic carbon inputs, incident precipitation, the only external source, contributed 1.9% of the total, with organic carbon fixed directly on the watershed contributing 98.1% of the total.

Elwood and Nelson (1972) estimated net periphyton production (AFDW) in Walker Branch west fork to range from 16 to 22 mg/m^2/day or an average of 20.7 mg/m^2/day (7.56 g/m^2/yr). Assuming 50% organic carbon, annual net periphyton production was 3.78 g C/m^2. When this is compared to the particulate allochthonous inputs (including litterfall, blow-in and throughfall but not springflow) of 292.74 g organic carbon/m^2/yr, autochthonous inputs constituted only 1.3% of total organic carbon inputs to the stream system. If dissolved inputs (via throughfall and springflow) and springflow inputs of FPOC were included, the value for the relative contribution of periphyton to the total organic carbon budget would be even lower. This adds confirmation to earlier speculation (Auerbach et al. 1970) concerning the heterotrophic nature of Walker Branch. The value derived in this study for relative autochthonous inputs is very close to that found in Bear Brook, New Hampshire by Fisher and Likens (1972).

Table 62 (from Henderson et al. 1977b) presents streamflow (in cm) for the east and west fork subwatersheds of Walker Branch for the 1970-1976 period. When streamflow is thus expressed, the greater area-

Table 61. Organic Carbon Inputs (kg/ha) to the West Fork of Walker Branch.

Source	Inputs (kg/ha)	Relative Contribution (%)
Incident Precipitation (External)	56.3	1.9
Canopy Removal (Internal)	38.7	1.3
Throughfall (IP + CR)	95.0	3.1
Litterfall (Internal)	2221.5	74.4
Blow-In (Internal	670.9	22.5
Total	2987.4	100.0

Table 62. Comparison of Area-Equivalent Streamflow (cm) from the East and West Forks of Walker Branch Watershed for 1970-1976.

	Streamflow Discharge (cm)	
Water Year*	East Branch	West Branch
1970-71	52.3	108.5
1971-72	50.5	102.6
1972-73	90.8	151.6
1973-74	92.0	153.1
1974-75	61.8	115.9
1975-76	38.0	81.9
Six-Year Average	64.2	118.9

*A water year extends from September 1 to August 31 of the following calendar year.

Source: Henderson et al., 1977.

equivalent discharge on the west fork subwatershed is apparent, being twice that for the east fork during some years. This problem has long hindered endeavors to utilize Walker Branch in the paired watershed context. When the two subwatersheds are taken as a unit, area-equivalent discharge is very close to the expected amount. Thus it has long been hypothesized that the west fork subwatershed is receiving water via interbasin transfer from the east fork subcatchment.

Progress in quantifying this transfer has recently been made. Huff et al. (1977) used a computer code (Huff and Begovich 1976), based on the hydrographic separation technique of Hewlett and Hibbert (1967) to distinguish quick (storm) flow and delayed (base) flow for the watershed. They found that quick flow, on a unit area basis, was not significantly different for the two forks of Walker Branch (Table 63) and concluded that about 30% of the delayed flow originating on the east fork is transferred to the west fork each year, accounting for virtually all of the observed difference in discharge.

Values for monthly transfer of water, given in Huff et al. (1977) for the study period, were combined with average springflow concentrations of DOC and FPOC to yield monthly transfers of DOC and FPOC from the east to west fork subwatersheds (Table 64). Because of the relatively invarying nature of springflow organic carbon concentrations, interbasin organic transfers varied with the quantity of water transferred, yielding highest amounts during the late fall through early spring period.

As can be seen from Table 64, the data series for DOC and FPOC concentrations overlapped, but were not entirely synchronous. The FPOC

Table 63. Calculated Monthly Quick Flows on East and West Forks of Walker Branch for the 1971-1972 through the 1974-1975 Water Years.

	Water Year									
Month	71-72		72-73		73-74		74-75		Average	Standard Error
					East Fork of Walker Branch (Flow in cm)					
Oct	0		0.13		0		0		0.03	± 0.06
Nov	0		0.26		9.86		0.01		2.53	± 4.89
Dec	0.74		8.78		8.21		1.52		4.81	± 4.27
Jan	2.42		0.78		6.90		1.94		3.01	± 2.68
Feb	0.68		0.50		1.34		0.82		0.84	± 0.36
Mar	1.54		11.46		6.03		11.29		7.58	± 4.75
Apr	0.01		2.34		0.38		0		0.68	± 1.12
May	0.19		7.94		0.87		0		2.25	± 3.81
Jun	0		0.03		0		0.79		0.20	± 0.39
Jul	0		0.04		0		0		0.01	± 0.02
Aug	0.01		0.09		0		0		0.02	± 0.04
Sep	0		0		0		0.02		0.005	± 0.01
Average	0.47	±0.78	2.70	±4.16	2.80	±3.78	1.37	±3.20	1.83	± 2.38
Sum	5.6		32.4		33.6		16.4		22.0	±13.4
					West Fork of Walker Branch (Flow in cm)					
Oct	0.02		0.11		0.02		0.03		0.04	± 0.44
Nov	0.01		0.26		10.31		0.07		2.66	± 5.10
Dec	0.89		8.86		8.44		1.41		4.90	± 4.34
Jan	2.37		0.61		6.72		1.94		2.91	± 2.65
Feb	0.57		0.28		1.09		0.79		0.68	± 0.34
Mar	1.47		12.15		5.83		10.97		7.60	± 4.92
Apr	0.07		2.10		0.32		0		0.62	± 1.00
May	0.20		7.54		0.84		0.03		2.15	± 3.61
Jun	0.03		0.09		0.01		0.81		0.21	± 0.40
Jul	0.07		0.15		0		0.01		0.06	± 0.07
Aug	0.03		0.24		0.04		0.02		0.08	± 0.10
Sep	0.03		0.01		0.02		0.06		0.03	± 0.02
Average	0.48	±0.75	2.70	±4.27	2.80	±3.87	1.34	±3.10	1.83	± 2.39
Sum	5.7		32.4		33.6		16.1		22.0	±13.4

Table 64. Calculated Transfer (kg) of Organic Carbon from the East to West Fork Subwatersheds of Walker Branch Based on Excess Flow (m^3) on the West Fork as Calculated from Hydrologic Data of Huff et al. (1977) and Weighted Weekly Concentrations of DOC and FPOC in Springflow.

Year	Month	Excess Flow West Fork (m^3)	Concentration DOC (mg/l)	Transfer DOC (kg)	Concentration FPOC (mg/l)	Transfer FPOC (kg)
1973	Apr	14807.8			.15	2.22
	May	15692.6			.19	2.98
	Jun	13223.5			.16	2.16
	Jul	9986.8			0.15	1.50
	Aug	10266.4			0.16	1.63
	Sep	7821.6	0.20	1.56	0.17	1.33
	Oct	7449.1	0.18	1.34	0.18	1.34
	Nov	7985.4	0.15	1.20	0.15	1.20
	Dec	13900.4	0.33	4.59	0.40	5.56
1974	Jan	20910.7	0.10	2.09	0.24	5.02
	Feb	18533.5	0.14	2.59	0.17	3.15
	Mar	18253.5	0.14	2.59	0.17	3.15
	Apr	15110.9	0.32	4.84		
	May	11664.3	0.24	2.80		
	Jun	9148.9	0.22	2.01		
	Jul	8962.2	0.22	1.97		
	Aug	8240.6	0.21	1.73		
Apr 1973-Mar 1974		1.47×10^5		30.01		
73-74 Water Year		1.59×10^5				31.38

record extended from the first week of 1973 through March 1974, while the DOC record encompassed the 1973-1974 water year. The April 1973 through March 1974 portion of the FPOC data record was used to calculate the yearly transfer of FPOC. The two time periods (April 1973 through March 1974 and September 1973 through March 1974) were very similar, with both including the major storm events of November and December 1973, as well as the major storm event in March 1974. There was less than a 2% difference in streamflow for the two periods (5.92×10^3 vs 6.01×10^3 m^3) and a 7.5% difference in volume of water transfer (1.47×10^5 vs 1.59×10^5 m^3) with the April 1973 - March 1974 period having the higher values for both streamflow and water transfer. Thus, the FPOC data could represent a 5-10% overestimate of organic transfer compared to that for DOC. Regardless, the transfers of DOC and FPOC were very similar (0.78 vs 0.82 kg/ha for DOC and FPOC, respectively) for a total transfer of 61.38 kg/ha, representing 6% of the total uncorrected output (uncorrected for basin transfer) of organic carbon from the west fork subwatershed.

A summary of inter- and intrabasin transfers of organic carbon on the west fork subcatchment of Walker Branch watershed for the 1973-1974 water year is shown in Table 65. Incident inputs of organic carbon (dissolved and fine particulate) were 56.34 kg/ha. This value should be looked on as a maximum, since it was assumed that during the November through February period (when incident precipitation was not monitored) canopy contribution was zero, with incident precipitation being equal to throughfall. The eight months of canopy contribution were 38.68 kg/ha, as calculated from the difference in inputs in throughfall and incident

Table 65. Fluxes of Organic Carbon on the West Fork Subwatershed of Walker Branch Watershed for the 1973-1974 Water Year.

	DOC		FPOC		TOC	
Type of Flux	(kg/ha)	(kg/W.F.)	(kg/ha)	(kg/W.F.)	(kg/ha)	(kg/ha)
Incident Precipitation (Input)	39.9	1531.4	16.5	632.1	56.3	2163.5
Canopy Removal	23.8	915.5	14.8	569.9	38.7	1485.3
Throughfall (IP + CR)	63.7	2446.8	31.3	1201.9	95.0	3648.8
Soil Water	13.4	515.7	-	-	-	-
Streamflow (uncorrected output)	8.6	330.1	17.9	686.8	26.5	1016.9
Transfer from East Fork	-0.8	30.0	-0.8	31.4	-1.6	61.4
Streamflow (output corrected for intrabasin transfer)	7.8	300.1	17.1	655.4	24.9	955.5
Input - Output	32.1	1231.3	- 0.6	-23.4	31.5	1207.9

Note: W.F. = West Fork Subwatershed

precipitation for the March through October period. Throughfall, as measured over the 12 month period, was 95.02 kg/ha.

Output of TOC in streamflow was 26.48 kg/ha, but when the inter-basin transfer of 1.60 kg/ha is taken into account, loss of TOC from within the west fork subwatershed was 24.89 kg/ha. Comparing meteorological input with geological output, 31.45 kg/ha (equivalent to 56% of the input) was retained, with an amount equivalent to 44% lost from the system. This retention represents uptake in the soil/bedrock/aquifer system, and when the amount of organic carbon reaching the forest floor (throughfall) is compared to the output, an even greater uptake (70.13 kg/ha) in the geological subsystem is observed. Further, when consideration is given the fact that much of the output is due to throughfall directly to the channel, the retentive capacity of the terrestrial system becomes more apparent.

For the entire subwatershed, 2163.5 kg of organic carbon was introduced from the atmosphere, and was supplemented with 1485.3 kg of organic carbon from canopy contribution, for a total in throughfall of 3648.8 kg, of which 955.54 kg of TOC was exported from the system in streamflow. This would represent an uptake in the system of 1207.9 kg of organic carbon introduced by the atmosphere.

When DOC and FPOC fluxes are compared (Table 65), a striking difference in behavior is apparent. FPOC actually showed a negative net balance between input and output (-23.37 kg/subwatershed). Thus, the net retention of DOC is greater than that for TOC (32.06 kg/ha or 1231.3 kg/subwatershed). While much more DOC than FPOC was received in incident precipitation (39.88 vs 16.46 kg/ha or 1531.4 vs 632.1 kg), the

percent of FPOC of the total output (69%) approximated that of DOC for total inputs (71%). It should be noted that the 1973-1974 water year was extremely wet, probably contributing to the dominance of FPOC in geological outputs. FPOC outputs were overwhelmingly dominated by major storm events, especially the late November storm which occurred during maximum stream load of particulate organic carbon (POC), with bank overflow washing away large quantities of POC from the adjacent forest floor. This streamside litter stratum did not contain a DOC reserve nearly as large as that for FPOC, as seen by the much lower DOC concentrations during peak storm flows. It therefore appears that the watershed system is more resistant to loss of dissolved outputs than those in the particulate form during catastrophic flow events, due to the low pools of DOC in the non-living components of the watershed system.

CHAPTER VII

SUMMARY

Leaf fall to the west fork of Walker Branch (g organic matter (AFDW)/m^2/day) showed two peaks, a major one during mid-October to mid-November (6.78 g/m^2/day) and a minor peak (0.37 g/m^2/day) during July and August, the latter possibly due to extremely dry conditions during early summer, leading to early abscission of some leaves. Trends and quantities of leaf fall were very similar to those found in previous studies on the watershed.

The majority of fall of fruits and reproductive parts occurred during two periods, mid-September to the end of November, and April through May (0.24 g/m^2/day). The autumn peak was bimodal, with the highest rate of input (0.44 g/m^2/day) occurring during the last half of September, and the peak during November similar in magnitude to the spring peak. Minor temporal and quantitative differences were observed in comparing these results with those of previous work on the watershed.

Inputs of twigs also occurred mainly during two periods, with a single major peak occurring from the last half of October through November (daily input rate varying from 0.16 to 0.22 g/m^2/day) and a bimodal trend in the spring, with peaks (each 0.15 g/m^2/day) coinciding with either periods of maximum wind speeds (March) or high fruitfall (May). Trends were similar to those previously reported for the watershed, although the spring peak occurred earlier in the present study.

Frass fall began in June and peaked in July (0.15 $g/m^2/day$) before declining precipitously in August, the decline possibly associated with the very dry conditions during early summer. This trend was apparently dissimilar to that of the previous summer, as indicated by the September 1973 sampling, where frass fall during the first half of the month equalled that for July 1974. The variable nature of the populations of canopy insects in the Oak Ridge area had previously been documented.

Litterfall (> 1 mm) contributed 222.1 g/m^2 organic carbon to the west fork of Walker Branch during the 1973-1974 water year with 179.1 g/m^2 (80.6%) as leaves, 25.0 g/m^2 (11.3%) as fruits and reproductive parts, 12.5 g/m^2 (5.6%) as twigs, and 5.5 g/m^2 (2.5%) as frass.

A bimodal trend was apparent for blow-in of leaves to the west fork of Walker Branch for both northeast- and southwest-facing slopes, but the magnitude of the inputs and the relative size of the two peaks differed for the two aspects, although they were temporally coincident. For northeast-facing slopes, the autumn peak was larger than the spring peak (for 45-60% slopes, 0.71 vs 0.14 g/m streambank/day), while for southwest-facing slopes, the spring peak, which was more closely associated with periods of strong winds, was larger than that in autumn (for 45-60% slopes, 5.32 g/m streambank/day). The low inputs in mid-winter from both aspects was coincident with wet conditions and low winds, especially in January. In general, the inputs increased with increasing slope, except for the high inputs for the 15-30% slope class during fall for the southwest-facing slopes (1.50 g/m streambank/day) and during fall and spring for northeast-facing slopes (0.42 and 0.30 g/ m streambank/ day). These high inputs were attributable to proximity of the land with

these slopes to points of confluence of the drainage system, where funnelling of incident wind was apparent.

Even though the strong winds were predominantly from the southwest, southwest-facing slopes virtually always had higher leaf inputs, due to eddy formation as the winds passed over the ridges bordering the drainage system. Very little blow-in of leaves occurred from May through August, due in part to the lack of strong winds incident to the watershed, but also due to the influence of forest cover. Significant aspect and slope class differences were seen for virtually all months when appreciable amounts of blow-in occurred. Significant aspect and date differences occurred for all slope class except benches, while significant slope class differences were found for southwest-facing slopes, and significant date differences were seen for both aspects.

Lateral transport of fruits and reproductive parts was quantitatively similar for the two aspects, with a major peak in early fall (0.4-0.5 g/m streambank/day). Statistical analyses showed that both date and slope class exhibited significant differences with no confounding interaction. Significant date differences were associated with the high values for September and October, while inputs from the steepest slopes were significantly higher than from the other slope classes. Results indicated that lateral transport of fruits and reproductive parts was not directly associated with aeolian factors.

Lateral transport of twigs from northeast-facing slopes was variable and low throughout the year (most values were 0.02 g/m streambank/ day or less), while for southwest-facing slopes a pattern was discernible, with the steepest slopes having highest inputs (six monthly means

for the two steepest slope classes were greater than 0.05 g/m streambank/day); most means were higher than those for the corresponding slope classes for northeast-facing slopes. Peak lateral transport of twigs coincided well with peaks for leaves, indicating that either an aeolian forcing factor was operative (February and March) or litterfall was high (November).

Data for lateral transport of frass showed trends very similar to those for frass fall, with peaks in September 1973 (0.008 g/m streambank/day) for the steepest northeast-facing slopes) and July 1974 (0.003 g/ m streambank/day) with low values in August. However, several unique trends were noted, including a peak in November for the southwest-facing slopes and a constant low input during winter and spring, when frass fall was 0. These inputs were coincident with peaks of blow-in of leaves, including high values for the 15-30% slope class during November, indicating that frass material was transported attached to leaves. Aspect differences were only marginally significant and significant slope class effects were evident only during September, with the steepest slopes having the greatest inputs.

Yearly inputs of organic carbon via lateral transport to the west fork of Walker Branch for the 1973-1974 water year were (in g C/m^2) 42.9 for leaves, 7.1 for fruits and reproductive parts, 2.0 for twigs, and 0.1 for frass, for a total of 52.1 g C/m^2 of stream channel.

The study took place during a period of greater than normal rainfall and streamflow and was characterized by severe storm events occurring sporadically from late fall through late winter of both the 1972-1973 and 1973-1974 water years, with the former also experiencing a large

storm at the end of May. The summers for the two years were quite different, with numerous thunderstorms during the summer of 1973, and a pronounced dry spell from late spring through early summer of 1974. Streamflow was at seasonally low levels during the latter part of the summer and the early to mid-fall period of both years. Although it is recognized that the study was performed during years of high rainfall and discharge, the general climatic regime of the Tennessee Valley, coupled with the small size of the watershed system, indicated that disruptive spates can be expected at least once every few years.

Standing crops of leaf material on four habitat types in Walker Branch during the 1973-1974 water year showed large seasonal differences, with substantial increases during early to mid-fall during peak leaf fall, followed by a precipitous decline in the December sampling due to effects of the large storm of late November. Standing crops remained low (0.35-33.85 g/m^2) for the remainder of the study year due to intermittent storm events during winter and spring which washed away leaf material introduced to the stream system via blow-in, and little input to the stream system occurred during summer. Consistent habitat type differences occurred, with the order (decreasing) being dry gravel stream gravel dry bedrock bedrock pools. This indicated that organic matter in the dry habitats underwent less biological and physical depletion than that in the habitat types permanently covered with water, and the gravel substrate was better able to retain organic matter than the bedrock.

Standing crops of fruits and reproductive parts also showed an October peak (2.00 g/m^2 for the gravel types) with a large decline seen

in the December samples associated with the late November storm. A second peak (1.35-2.62 g/m^2) was seen during June for all habitat types except the dry bedrock. The dry gravel habitat type was significantly higher in standing crop than any other habitat type.

The pattern for twig standing crops was similar to that for fruits, with fall and late-spring to summer peaks, and a precipitous decline seen in the December 2 samples. All significant differences for dates were associated with December, February, and April, the three months with lowest means. The two gravel habitat types were significantly higher than the two bedrock types, indicating the effectiveness of the gravel substrate in retaining twig inputs.

For total organic matter, highest standing crops were found during the November 4, 1973 sampling (62.76 -273.32 g/m^2) and lowest during the February 7 sampling (0.55 -13.21 g/m^2). Leaf contributions were greatest during autumn, increasing during the litterfall season (90% for all habitat types during the November 4 sampling) and being lower during winter.

Concentration of DOC (mg/l) in incident precipitation and throughfall showed clear seasonal patterns. Throughfall values ranged from 1.90 mg/l in December to 32.32 mg/l in July, with the next highest mean being 11.33 mg/l in September 1973, and generally low concentrations found during the leafless season. Incident precipitation values (eight months' data), paralleling those for throughfall, were highest in July (8.78 mg/l), with only the low September value (1.55 mg/l) showing a divergence from the throughfall pattern. The September values for throughfall and incident precipitation, yielding large values for canopy

removal (9.78 gm/l), were indicative of canopy leaching. Lowest values for canopy removal (0.66-2.89 mg/l for March and June, respectively) were indicative of little leaching/washing from the newly emergent vegetation.

FPOC concentration in throughfall and incident precipitation closely paralleled those for DOC with an extremely high July mean for throughfall (20.27 mg/l), and much lower means (0.49-6.98 mg/l) for the rest of the year. Values for the leafless period were below 1.50 mg/l, and means for three months (November to January) were below 0.75 mg/l. For the eight months of data for FPOC concentration in incident precipitation, means ranged from 0.88 to 0.93 mg/l for September 1973 and March and August 1974 to 1.83 to 2.12 mg/l for April through July. Concentration of FPOC in incident precipitation did not increase during summer to the extent that throughfall concentrations did, this being especially true for July (2.09 mg/l).

Canopy contributions to FPOC concentration in throughfall closely parallelled FPOC levels in throughfall due to the rather unchanging nature of FPOC concentration in incident precipitation, with highest contributions (18.18 mg/l) in July. The March through May period showed the smallest contributions from the canopy (0.19 -0.85 mg/l), due to the fact that the vegetation was newly emergent and insect populations were still low.

Results from Walker Branch for total organic carbon in throughfall were comparable to those found by Carlisle et al. (1966, 1967) in Great Britain; however, canopy contributions in the latter study were generally higher, due to greater canopy insect activity and heavy epiphytic growth.

Compared to results of summer throughfall studies at Hubbard Brook (Eaton et al. 1973), Walker Branch data was more variable, being more closely linked to volume of precipitation.

DOC, FPOC, and TOC concentrations in throughfall were all significantly related (negatively) to volume of throughfall, with the inverse and logarithmic regressions providing the best fits (r^2 values of 0.66, 0.55, and 0.67 for DOC, FPOC, and TOC, respectively, for inverse and 0.79, 0.75, and 0.82 for DOC, FPOC, and TOC, respectively, for the logarithmic regression), with FPOC showing the largest slopes. Use of qualitative slope and intercept variables to discern the effects of presence or absence of canopy generally improved the fit of the data, with overall higher concentrations and steeper slopes prevalent for DOC during the growing season. For FPOC concentration, slopes were significantly lower during the growing season, indicating that FPOC showed less tendency to decline with increasing throughfall volumes. The different behavior of DOC and FPOC was attributed to the very low concentrations of FPOC during some winter months of high rainfall.

While the data fit the logarithmic relationship well, it should be remembered that the low precipitation in July, leading to the very high concentrations in incident precipitation and throughfall, was abnormal, with July usually being one of the wettest months.

For incident precipitation, only the logarithmic regressions provided acceptable fits (r^2 values of 0.42, 0.27, and 0.45 for DOC, FPOC, and TOC, respectively) with the slope (negative) steepest for DOC. Results were consistent with those previously reported.

Because of the negative relationship between organic carbon concentration and volume of throughfall or incident precipitation, no one month showed excessively high inputs. Monthly means ranged from 3.32 kg/ha for December to 10.05 kg/ha for September 1973, with July (next highest inputs) at 6.77 kg/ha. Lowest incident precipitation inputs occurred during September (1.40 kg/ha), the month of highest throughfall inputs. Highest incident precipitation inputs were found in May (6.55 kg/ha), yielding a negative (-0.08 kg/ha) canopy contribution for the month. In general, canopy contributions were low during spring and higher during the July through October period, with the peak in September (8.64 kg/ha).

For FPOC, inputs showed seasonal pattern, with values declining from September 1973 to December 1973 (from 3.82 to 0.85 kg/ha) and then rising to an August high of 4.80 kg/ha. For the eight months of incident precipitation data, inputs ranged from 0.55 kg/ha in July, to 1.77 kg/ha in March, except for May which had an input of 3.18 kg/ha. Little seasonal trend was evident. Canopy contribution was negative (-0.19 kg/ha) in May, indicating canopy uptake, while for the seven months, values ranged from 0.56 kg/ha in March and April to 3.90 kg/ha in July, with other high inputs during the summer months.

Total input of organic carbon in throughfall was 100.90 kg/ha, similar to inputs in the sessile oak forest in Great Britain for 1964-1965 year (Carlisle et al. 1967). Canopy contributions at Walker Branch were lower (40.94 kg/ha for eight months), while inputs via incident precipitation were similar (59.96 kg/ha) for the two studies. The results for throughfall inputs of TOC at Walker Branch for June through October were similar for the two studies. The results for inputs of TOC

in throughfall at Walker Branch for the June - October period were comparable to those found by Eaton et al (1973) at Hubbard Brook for the same five months.

Statistical analyses of inputs of organic carbon in throughfall and incident precipitation revealed only FPOC in incident precipitation was significantly (positive) related to volume of rainfall, with the logarithmic form of the regression giving the best fit. Deviations from regression were also significant. Lack of significant relationship between inputs and volume of rainfall was explained mainly by the significant (negative) relationship between concentration and volume of throughfall or incident precipitation.

Total input of DOC and FPOC in throughfall was 95.02 kg/ha for the 1973-1974 water year with approximately two-thirds deposited as DOC and one-third as FPOC. Net canopy removal was 38.68 kg/ha for eight months (September through October 1973 and March through August, 1974), with relative contributions of DOC and FPOC similar to those for throughfall. Incident precipitation inputs for the eight months period was 34.21 kg, again with about two-thirds entering as DOC and one-third as FPOC. DOC had the highest relative contribution in winter (73-80%) because of very low FPOC concentrations. Highest relative contributions of FPOC were in early to mid-summer.

Comparing results for summer 1974 with those for the intense sampling in mid-summer 1973 revealed that the 1973 period had lower FPOC concentrations. No clear trend emerged from the data except for concentration to be weakly (negatively) related to volume of rainfall. Results showed that one large storm had quite different effects on organic carbon

concentration and inputs than a series of smaller storms which, cumulatively, have the same volume of rainfall.

Organic carbon concentrations in soil water at the 75 cm layer were low, with collection means varying from 0.62 to 2.60 mg/l. Peak DOC concentrations occurred during the last half of July for the chestnut oak (CO) and yellow poplar (YP) types (2.08 and 1.78 mg/l, respectively), while the oak-hickory (2.60 mg/l) and pine (P) types (1.70 mg/l) showed peaks in the first half of December. The former period corresponded to a period of high throughfall organic carbon and the latter to lowest rainfall off the winter. Analysis of data by two-way ANOVA revealed significant date and cover type effects. Over all dates, the CO and OH cover types had significantly higher means than the YP and P types, but within each group, the cover types were not significantly different. Low means for the pine type were attributed to low standing crops of leachable organics, while for the YP type, the low topographic position led to prolonged contact of soil water with soil matrix, allowing uptake of DOC by the soil system. Means for dates fell into two groups, with the period July 19, 1973 to January 10, 1974 forming a group with generally higher means than the second group (January 10 - June 11, 1974). No significant relationship was found between DOC concentration and volume of infiltrate, the latter calculated from the computer code PROSPER. Water fluxes past the 75 cm soil layer, as calculated by PROSPER, were utilized to calculate the flux of organic carbon from the 75 cm soil layer. This flux amounted to a loss of 1.34 g/m^2/year, similar to other results from the Oak Ridge area. Compared to the loss as CO_2 due to catabolic processes in the soil, the organic losses are insignificant.

Springflow concentrations of DOC and FPOC were relatively invariable and low during the study indicating a reduction in concentration as the water passed from the soil profile through the aquifer matrix. Highest concentrations of FPOC occurred during the week of the large November storm (0.82 mg/l) with the DOC concentrations during this time (0.53 mg/l) almost as high as the 0.59 mg/l recorded during the thirty-first week of 1973, during which the largest summer storm of the study period occurred. Most DOC and FPOC concentrations were below 0.25 mg/l. The consistently low concentrations were due to a combination of factors, including the seasonality of precipitation and the fact that the spring is the diffuse flow type, allowing prolonged, intimate contact between the groundwater and the aquifer matrix. Concentrations of DOC and FPOC were consistent with published data.

The simplest storm events occurred in summer, with the hydrographic rise being due to direct channel input of throughfall. Because of dry soil conditions and high evapotranspiration, most water falling on the forest floor was utilized in the soil profile, yielding little to groundwater. During summer storms, the concentration of DOC in throughfall, combined with the amount of water entering the stream, determine the DOC concentrations in streamflow, with an upper limit dictated by the negative relationship between volume of throughfall and concentration. For similar reasons, an upper limit is placed on the concentration of FPOC in stream water, but an added factor, mobilization of detrital standing crop in the stream itself, adds to the FPOC load. Thus, DOC concentration (and output) in streamflow closely paralleled the hydrograph, while for FPOC, concentrations increased dramatically at the first of a storm

or during any sharp rise in the hydrograph. FPOC concentrations characteristically peaked before peak discharge, while for DOC peak discharge and peak concentration were synchronous. Peak streamflow concentration of DOC was 13.55 mg/l found in a summer thunderstorm in July 1974, after a prolonged dry period. Peak FPOC concentration (66.77 mg/l) occurred during the November 27 storm, coincident with the highest flows recorded during the study, due to particulate contributions from source areas, from the stream channel itself, and from the adjacent low-lying forest floor. Peak DOC concentrations during this storm were little higher than throughfall values for the month. In many storms during the winter and spring, a second rise was seen due, not to direct channel input of precipitation, but to increased groundwater flow from a previous storm. During such a rise DOC concentrations remained low or decreased, while FPOC concentrations increased if the rise in the hydrograph was sharp enough. The data revealed that FPOC was more dependent on antecedent hydrologic conditions than was DOC, due to the different sources of organic material.

Regression analyses of the relation of organic carbon concentrations and outputs based on data from grab samples and weighted weekly average concentrations and weekly outputs revealed generally somewhat better fits for FPOC concentration, and good fits for outputs of both DOC and FPOC. Slopes for FPOC were generally greater than those for DOC. Ratio of DOC/FPOC vs discharge showed negative slopes for virtually all sortings of the data, again indicating the greater importance of FPOC at higher flows. For FPOC concentration data based on grab samples, best fits were seen with the logarithmic relationship, with highest slopes in

summer, due to the lack of very high flows during this period. For the weighted weekly concentrations, best fits for FPOC were found with the semilogarithmic regression. Best fits for DOC were with the normal regression, with only summer data showing a better fit with a logarithmic regression. Based on weighted weekly concentrations, two seasons, spring and summer, showed no form of the regression yielding slopes significantly different from zero for DOC concentration. Outputs of FPOC vs discharge were best fitted with a logarithmic relationship for grab samples and a semilogarithmic form of weekly outputs. Three seasons (fall, spring and winter) had the semilogarithmic regression giving best fit (r^2 values of 0.97, 0.66, and 0.85, respectively), with slopes for all three months lower than those for summer. However, summer data was fit best with a normal regression ($r^2 = 0.91$). The normal regression fit the DOC output data best with r^2 values of 0.95, 0.80, and 0.85 for fall, summer, and winter, respectively, and 0.65 for spring.

Highest weighted weekly concentrations of DOC and FPOC during the study period (1.87 and 1.45 mg/l, respectively) occurred during the forty-eighth week of 1973, during which the storm with the largest peak flow of the study occurred. Also, the ratio of DOC/FPOC, based on weighted weekly concentrations was the lowest of the study (0.25), indicating the dominance of FPOC at higher flows. High FPOC concentrations were due to maximum standing crops of organic carbon in the stream prior to the storm and entrainment of the streamside litter layer. Ratio of DOC/FPOC was low during all major storms, indicating the great importance of FPOC at higher flow rates. The large summer storm (week 31 of 1973) had DOC concentrations greater than those for FPOC due in part to low levels of FPOC in incident precipitation.

Baseflow concentrations were low (0.1-0.4 mg/l) for both DOC and FPOC during the entire year, with the exception of the forty-third to forty-seventh weeks, when within-system leaching of the large autumn litterfall inputs led to elevated DOC levels (0155 to 0.73 mg/l). FPOC concentrations remained low during this time due to the low discharge. Because of the low baseflow levels and small size of Walker Branch, concentration ranges during this study were great (2-3 orders of magnitude) for both DOC and FPOC. Weighted mean concentration, highly dependent on the occurrence of major storm events, were 0.67 and 0.32 mg/l for DOC during 1973 and 1974, respectively.

Outputs for 1973 were dominated by the events of week 48, when 9% of the total yearly discharge transported 25% of the yearly output of DOC and 52% of the yearly output of FPOC, with FPOC contributing 80% (403.6 kg) of the output. Lowest weekly outputs were recorded during week 35 of 1973 (1.24 kg total) due to absence of rainfall events, little freshly fallen litter in the stream, and low discharge.

For the 1973 calendar year, total output (DOC and FPOC) was 1171 kg (30.50 kg/ha), 63.8% FPOC and 34.2% DOC. For the 1973-1974 water year, outputs were 1017 kg (26.48 kg/ha), 32.5% DOC and 67.5% FPOC. These values are 2-3 times higher than those recorded at Hubbard Brook (Hobbie and Likens 1973), due to insufficient data at the New Hampshire site and also the occurrence of catastrophic flows at Walker Branch during the study period.

Total inputs to both the forest floor and to the west fork of Walker Branch were dominated by litterfall (95.9% and 74.4%, respectively), with throughfall contributing 4.1% and 3.2%, respectively. A maximum value

for autochthonous producers in Walker Branch was 1.3% of the total organic input, confirming the heterotrophic nature of the stream ecosystem. Interbasin transfer from the east fork to west fork, calculated by hydrographic separation techniques and springflow concentrations of FPOC and DOC was approximately 1.6 kg/ha or 61.4 kg for the entire west fork catchment, respectively, 6% of the total output. Comparing meteorological inputs and geological outputs, DOC and FPOC behaved dissimilarly, with FPOC showing a negative net balance (-23.4 kg) indicating greater output than input. Total uptake by the watershed system was 1207.9 kg of organic carbon introduced by the atmosphere.

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APPENDICES

APPENDIX A

Table A1. Mean Daily Input of Leaves (± One Standard Error) Via Litterfall to the West Fork of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

Date of Collection	Mean Input ($\bar{x}$) (g/m^2)	$\bar{x}$ + One Standard Error	$\bar{x}$ - One Standard Error
09/15/73	1.469	1.635	1.303
10/02/73	2.069	2.226	1.912
10/16/73	3.702	3.958	3.446
11/02/73	6.168	6.583	5.753
11/16/73	7.465	7.952	6.978
12/02/73	1.573	1.747	1.399
01/01/74	0.056	0.066	0.046
02/01/74	0.015	0.017	0.013
03/01/74	0.019	0.022	0.016
04/01/74	0.030	0.034	0.026
05/01/74	0.029	0.032	0.026
06/01/74	0.050	0.057	0.043
07/01/74	0.053	0.058	0.048
08/01/74	0.396	0.441	0.355
09/01/74	0.283	0.314	0.252

Table A2. Mean Daily Input of Fruits and Reproductive Parts (± One Standard Error) Via Litterfall to the West Fork of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

Date of Collection	Mean Input $(\bar{x})$ (g/m^2)	$\bar{x}$ + One Standard Error	$\bar{x}$ - One Standard Error
09/15/73	0.055	0.079	0.031
10/02/73	0.438	0.617	0.259
10/16/73	0.279	0.407	0.151
11/02/73	0.366	0.529	0.203
11/16/73	0.269	0.327	0.211
12/02/73	0.208	0.239	0.177
01/01/74	0.053	0.059	0.047
02/01/74	0.011	0.014	0.008
03/01/74	0.031	0.043	0.019
04/01/74	0.051	0.063	0.039
05/01/74	0.259	0.276	0.242
06/01/74	0.211	0.232	0.190
07/01/74	0.064	0.079	0.049
08/01/74	0.053	0.067	0.039
09/01/74	0.095	0.131	0.059

Table A3. Mean Daily Input of Twigs (± One Standard Error) Via Litterfall to the West Fork of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

Date of Collection	Mean Input ($\bar{x}$) (g/m^2)	$\bar{x}$ + One Standard Error	$\bar{x}$ - One Standard Error
09/15/73	0.034	0.052	0.016
10/02/73	0.049	0.067	0.031
10/16/73	0.043	0.061	0.025
11/02/73	0.223	0.309	0.137
11/16/73	0.210	0.313	0.107
12/02/73	0.154	0.215	0.093
01/01/74	0.023	0.030	0.016
02/01/74	0.011	0.017	0.005
03/01/74	0.014	0.018	0.010
04/01/74	0.150	0.192	0.108
05/01/74	0.054	0.066	0.420
06/01/74	0.150	0.203	0.097
07/01/74	0.035	0.052	0.018
08/01/74	0.024	0.031	0.017
09/01/74	0.056	0.070	0.042

Table A4. Mean Daily Input of Frass (± One Standard Error) Via Litterfall to the West Fork of Walker Branch for the Fifteen Collection Periods of the 1973-1974 Water Year.

Date of Collection	Mean Input ($\bar{x}$) (g/m^2)	$\bar{x}$ + One Standard Error	$\bar{x}$ - One Standard Error
09/15/73	0.149	0.166	0.132
10/02/73	0.079	0.090	0.068
10/16/73	0.019	0.023	0.015
11/02/73	0.000	---	---
11/16/73	0.000	---	---
12/02/73	0.000	---	---
01/01/74	0.000	---	---
02/01/74	0.000	---	---
03/01/74	0.000	---	---
04/01/74	0.000	---	---
05/01/74	0.000	---	---
06/01/74	0.000	---	---
07/01/74	0.053	0.064	0.042
08/01/74	0.148	0.168	0.128
09/01/74	0.015	0.019	0.011

Table A5. Mean Daily Rate (g/m Streambank) of Input of Leaf Material (with 95% Confidence Limits) Via Blow-In from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.*	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.03851	0.10378	-0.02289	0.06214	0.12023	0.00706
11/02/73	0.10204	0.18670	0.02341	0.25521	0.44130	0.09316
12/02/73	0.16901	0.86967	-0.26907	0.41626	0.79575	0.11696
01/01/74	0.00737	0.02089	-0.00596	0.13928	0.30816	-0.00779
02/01/74	0.00082	0.00106	0.00058	0.01323	0.02491	0.00169
03/01/74	0.01147	0.03632	-0.01277	0.13675	0.28874	0.00269
04/01/74	0.02348	0.05473	-0.00683	0.30012	0.69072	-0.00024
05/01/74	0.00493	0.01153	-0.00163	0.07423	0.10021	0.04887
06/01/74	0.00656	0.01114	0.00200	0.01103	0.02529	-0.00303
07/01/74	0.00262	0.00608	-0.00083	0.00519	0.00923	0.00117
08/01/74	0.01929	0.04709	-0.00778	0.00822	0.01455	0.00193
09/01/74	0.00268	0.00470	0.00067	0.01795	0.04684	-0.01013
	-------30-45% Slopes-------			-------45-60% Slopes--------		
10/02/73	0.07231	0.10175	0.04366	0.12373	0.19801	0.05415
11/02/73	0.23117	0.33315	0.13699	0.35544	0.61130	0.14021
12/02/73	0.48237	0.73104	0.26943	0.71346	1.25684	0.30091
01/01/74	0.07626	0.12555	0.02913	0.09468	0.17235	0.02217
02/01/74	0.00858	0.01641	0.00081	0.03796	0.08505	-0.00709
03/01/74	0.06002	0.10766	0.01444	0.10257	0.16554	0.04301
04/01/74	0.10414	0.20500	0.01173	0.14862	0.31704	0.00174
05/01/74	0.04047	0.06314	0.01829	0.04581	0.07668	0.01583
06/01/74	0.00421	0.00635	0.00208	0.00787	0.01544	0.00036
07/01/74	0.00312	0.00533	0.00091	0.00781	0.01278	0.00286
08/01/74	0.02816	0.05759	-0.00045	0.03156	0.05764	0.00613
09/01/74	0.01584	0.02448	0.00728	0.02438	0.04840	0.00091

*C.L. = 95% Confidence Limit

Table A6. Mean Daily Rate (g/m Streambank) of Input of Leaf Material (with 95% Confidence Limits) Via Blow-In from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	Benches			15-30% Slopes		
10/02/73	0.06577	0.18512	-0.04157	0.05340	0.07346	0.03371
11/02/73	0.32244	0.87109	-0.06533	0.35844	0.58696	0.16282
12/02/73	0.26073	3.27422	-0.62813	1.49872	2.97921	0.56905
01/01/74	0.02353	0.05807	-0.00989	0.72760	1.30747	0.29345
02/01/74	0.01347	0.04071	-0.01305	0.07948	0.16485	0.00036
03/01/74	0.08084	0.37286	-0.14907	0.40186	0.81179	0.08468
04/01/74	0.11811	0.38755	-0.09901	0.60107	1.31822	0.10577
05/01/74	0.09249	0.22901	-0.02886	0.32543	0.45461	0.20773
06/01/74	0.01139	0.02342	-0.00050	0.00773	0.01456	0.00095
07/01/74	0.00477	0.01354	-0.00392	0.01017	0.01821	0.00220
08/01/74	0.00782	0.01737	-0.00164	0.02169	0.04002	0.00369
09/01/74	0.02076	---	---	0.02053	0.03730	0.00403
	30-40% Slopes			45-60% Slopes		
10/02/73	0.09715	0.14105	0.05493	0.22922	0.35530	0.11486
11/02/73	0.60726	0.91197	0.35111	0.89354	1.26568	0.58253
12/02/73	0.92546	1.48580	0.49142	1.35032	2.71865	0.48549
01/01/73	0.20742	0.41899	0.02740	1.19383	1.93796	0.63818
02/02/74	0.03867	0.07359	0.00488	0.13555	0.23202	0.04664
03/01/74	0.66407	1.43011	0.13950	2.24300	3.47262	1.35143
04/01/74	1.84702	4.93856	0.36489	5.32392	8.62732	3.15401
05/01/74	0.33037	0.61091	0.09869	1.29393	2.52092	0.49453
06/01/74	0.01029	0.01584	0.00474	0.06291	0.11658	0.01183
07/01/74	0.01557	0.03319	-0.00174	0.04504	0.10978	-0.01592
08/01/74	0.04576	0.09630	-0.00244	0.06803	0.12400	0.01485
09/01/74	0.01638	0.02332	0.00949	0.03111	0.05192	0.01071

Table A7. Results of Three-Way ANOVA's for Blow-In Data for the West Fork of Walker Branch for the 1973-1974 Water Year, with Date, Slope Class, and Aspect as Class Variables.

Statistical Parameter	Leaves	Fruits and Reproductive Parts	Twigs	Frass
Mean Square	0.131	0.008	0.001	0.001
Mean Square Error	0.008	0.007	<0.001	<0.001
F	15.82	1.11	2.26	2.25
Pr>F	0.0001	0.2371	0.0001	0.0001
Data				
F	36.57	2.11	3.36	7.47
Pr>F	0.0001	0.0181	0.0002	0.0001
Slope Class				
F	42.45	5.80	6.02	5.74
Pr>F	0.0001	0.0008	0.0006	0.0008
Aspect				
F	144.48	0.04	11.62	3.73
Pr>F	0.0001	0.8342	0.0007	0.0538
Date/Slope Class Interaction				
F	4.39	1.31	1.34	2.41
Pr>F	0.0001	0.1212	0.1014	0.0001
Date/Aspect Interaction				
F	14.86	0.33	1.26	0.86
Pr>F	0.0001	0.9779	0.2426	0.5844
Slope Class/Aspect Interaction				
F	23.77	0.22	5.63	0.13
Pr>F	0.0001	0.8839	0.0009	0.9370
Date/Slope Class/Aspect Interaction				
F	4.73	0.18	1.44	0.54
Pr>F	0.0001	1.0000	0.0546	0.9843

Table A8. Mean Daily Rate of Input (g/m Streambank) of Fruits and Reproductive Parts Via Blow-In (with 95% Confidence Limits) from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	Benches			15-30% Slopes		
10/02/73	0.00039	0.00133	-0.00055	0.03007	0.12430	-0.04535
11/02/73	0.00171	0.00554	-0.00201	0.02275	0.06899	-0.02149
12/02/73	0.00590	0.01031	0.00150	0.02523	0.05276	-0.00158
01/01/74	0.00737	0.02038	-0.00547	0.01836	0.04588	-0.00844
02/01/74	0.00113	0.00330	-0.00104	0.00379	0.00681	0.00078
03/01/74	0.00171	0.00422	-0.00079	0.00134	0.00260	0.00001
04/01/74	0.00232	0.00829	-0.00361	0.00343	0.00897	-0.00208
05/01/74	0.00879	0.01752	0.00012	0.00587	0.01017	0.00159
06/01/74	0.00650	0.02230	0.00906	0.00091	0.00161	0.00020
07/01/74	0.00068	0.00236	-0.00099	0.00711	0.02211	-0.00787
08/01/74	0.00016	0.00065	-0.00034	0.00031	0.00054	0.00008
09/01/74	0.00256	0.01074	-0.00556	0.00141	0.00410	-0.00127
	30-45% Slopes			45-60% Slopes		
10/02/73	0.16892	0.38331	-0.01224	0.53685	1.83032	-0.16550
11/02/73	0.03934	0.11895	-0.03538	0.27074	0.93224	-0.16430
12/02/73	0.02435	0.05969	-0.00980	0.01355	0.02638	-0.00087
01/01/74	0.01560	0.04602	0.01394	0.00413	0.00778	0.00051
02/01/74	0.00169	0.00387	-0.00048	0.00102	0.00197	0.00008
03/01/74	0.00113	0.00210	0.00017	0.00214	0.00379	0.00049
04/01/74	0.00215	0.00413	0.00018	0.00121	0.00191	0.00050
05/01/74	0.00955	0.01962	-0.00043	0.02580	0.04950	0.00262
06/01/74	0.00432	0.00636	0.00228	0.06492	0.19887	-0.05406
07/01/74	0.00437	0.00903	-0.00027	0.01744	0.05334	-0.01724
08/01/74	0.02250	0.07671	-0.02890	0.19581	0.41684	0.00927
09/01/74	0.01232	0.03851	-0.01320	0.14860	0.52479	-0.13479

Table A9. Mean Daily Rate of Input (g/m Streambank) of Fruits and Reproductive Parts Via Blow-In (with 95% Confidence Limits) from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.03521	0.15343	-0.07089	0.03148	0.10956	-0.04112
11/02/73	0.01994	0.05161	-0.01079	0.05921	0.17559	-0.04565
12/02/73	0.12016	0.50804	-0.16796	0.03582	0.08534	-0.01144
01/01/74	0.01844	0.03829	-0.00103	0.01013	0.01815	0.00218
02/01/74	0.00241	0.00457	0.00026	0.00252	0.00260	0.00044
03/01/74	0.00428	0.00999	0.00141	0.00218	0.00463	-0.00027
04/01/74	0.09064	0.39932	-0.14994	0.00418	0.00674	0.00162
05/01/74	0.04832	0.10170	-0.00248	0.02121	0.03647	0.00617
06/01/74	0.00801	0.01467	0.00137	0.00549	0.01108	-0.00007
07/01/74	0.00281	0.00587	-0.00024	0.00325	0.00736	-0.00085
08/01/74	0.01563	0.06089	-0.02771	0.00172	0.00135	0.00009
09/01/74	0.00020	0.00066	-0.00026	0.00003	0.00008	-0.00002
	-------30-45% Slopes-------			-------45-60% Slopes--------		
10/02/73	0.04310	0.11742	-0.02628	0.35057	1.69686	-0.32363
11/02/73	0.02195	0.06102	-0.01568	0.45484	2.48907	-0.39335
12/02/73	0.05235	0.11308	-0.00506	0.10100	0.27441	-0.05059
01/01/74	0.01371	0.02154	0.00597	0.03191	0.06708	-0.00211
02/01/74	0.06059	0.16401	-0.03364	0.00238	0.00443	0.00034
03/01/74	0.00835	0.01359	0.00414	0.00726	0.01230	0.00224
04/01/74	0.00641	0.01012	0.00272	0.00533	0.01051	0.00117
05/01/74	0.04182	0.07372	0.01086	0.03000	0.05802	0.00185
06/01/74	0.00709	0.01398	0.00025	0.02163	0.05275	-0.00763
07/01/74	0.00357	0.00459	0.00156	0.02396	0.07041	-0.02239
08/01/74	0.00089	0.00181	-0.00002	0.04208	0.14857	-0.05372
09/01/74	0.00271	0.00690	-0.00145	0.02327	0.06640	-0.01811

Table A10. Mean Daily Rate of Input (g/m Streambank) of Twigs Via Blow-In (With 95% Confidence Limits) from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.00002	0.00010	-0.00005	0.00017	0.00052	-0.00020
11/02/73	0.00023	0.00096	-0.00050	0.00035	0.00088	-0.00019
12/02/73	0.00000	---	---	0.01764	0.06090	-0.02386
01/01/74	0.00040	0.00135	-0.00056	0.01064	0.03063	-0.00896
02/01/74	0.00383	0.00160	-0.00084	0.00241	0.00536	-0.00054
03/01/74	0.00100	0.00385	-0.00185	0.00653	0.01682	-0.00359
04/01/74	0.04854	0.16224	-0.05403	0.02188	0.06983	-0.02392
05/01/74	0.00694	0.02474	-0.01056	0.00950	0.01872	0.00037
06/01/74	0.00253	0.00751	-0.00244	0.00543	0.01689	-0.00589
07/01/74	0.00000	---	---	0.00145	0.00341	-0.00049
08/01/74	0.00161	0.00673	-0.00349	0.00334	0.00998	-0.00324
09/01/74	0.00122	0.00513	-0.00267	0.00004	0.00013	-0.00005
	-------30-45% Slopes-------			-------45-60% Slopes--------		
10/02/73	0.00363	0.01017	-0.00286	0.01403	0.03323	0.00482
11/02/73	0.00341	0.01131	-0.00443	0.00074	0.00206	-0.00058
12/02/73	0.01544	0.03083	0.00028	0.01104	0.03506	-0.01242
01/01/74	0.01445	0.04846	-0.01846	0.00044	0.00111	-0.00024
02/01/74	0.00237	0.00567	-0.00092	0.01778	0.05986	-0.02262
03/01/74	0.00738	0.02155	-0.00658	0.00256	0.00470	0.00043
04/01/74	0.02617	0.06951	-0.01542	0.00704	0.01556	-0.00141
05/01/74	0.00409	0.01068	-0.00246	0.01539	0.03542	-0.00426
06/01/74	0.00208	0.00470	-0.00053	0.00804	0.02587	-0.00948
07/01/74	0.00020	0.00044	-0.00005	0.00034	0.00098	-0.00031
08/01/74	0.00195	0.00498	-0.00107	0.00088	0.00204	-0.00028
09/01/74	0.00027	0.00090	-0.00037	0.00122	0.00411	-0.00166

Table A11. Mean Daily Rate of Input (g/m Streambank) of Twigs (with 95% Confidence Limits) Via Blow-In from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.00008	-0.00320	-0.00017	0.00126	0.00284	-0.00032
11/02/73	0.00672	0.01970	-0.00610	0.00651	0.00173	-0.00041
12/02/73	0.00158	0.01781	-0.01448	0.00679	0.01417	-0.00054
01/01/74	0.00174	0.00436	-0.00087	0.00284	0.00613	-0.00043
02/01/74	0.00269	0.00069	-0.00015	0.00153	0.00333	-0.00026
03/01/74	0.00985	0.02492	-0.00500	0.00088	0.00211	-0.00035
04/01/74	0.00877	0.02847	-0.01056	0.03318	0.08641	-0.01744
05/01/74	0.03694	0.15289	-0.06735	0.01290	0.02438	0.00155
06/01/74	0.00404	0.01572	-0.00751	0.00020	0.00069	-0.00028
07/01/74	0.00004	0.00017	-0.00089	0.00166	0.00328	0.00004
08/01/74	0.00004	0.00016	-0.00008	0.00478	0.01383	-0.00420
09/01/74	0.00015	0.00064	-0.00033	---	---	---
	-------30-45% Slopes-------			-------45-60% Slopes--------		
10/02/73	0.00286	0.00562	-0.00049	0.07741	0.22344	-0.05119
11/02/73	0.00598	0.01360	-0.00158	0.00814	0.01745	-0.00107
12/02/73	0.03980	0.09388	-0.01161	0.17288	0.46214	-0.05916
01/01/74	0.03569	0.10681	-0.03084	0.01837	0.03895	-0.00180
02/01/74	0.00076	0.00183	-0.00032	0.01041	0.01901	0.00188
03/01/74	0.13276	0.34016	-0.04255	0.02839	0.07127	-0.01278
04/01/74	0.06493	0.15181	-0.01447	0.16483	0.36182	-0.00367
05/01/74	0.00983	0.01564	0.00407	0.06642	0.14160	-0.00334
06/01/74	0.00975	0.02471	-0.00500	0.02172	0.05123	-0.00693
07/01/74	0.00063	0.00134	-0.00007	0.00138	0.00302	-0.00025
08/01/74	0.00054	0.00180	-0.00073	0.00630	0.01730	-0.00457
09/01/74	<0.00100	0.00015	-0.00004	0.00539	0.01030	0.00050

Table A12. Mean Daily Rate (g/m Streambank) of Input of Frass (with 95% Confidence Limits) Via Blow-In from Northeast-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

Date	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.00062	0.00169	-0.00046	0.00007	0.00015	-0.00002
11/02/73	0.00002	0.00009	-0.00005	0.00012	0.00024	---
12/02/73	0.00035	0.00155	-0.00085	---	---	---
01/01/74	0.00037	0.00083	-0.00008	0.00013	0.00039	-0.00013
02/01/74	0.00015	0.00041	-0.00012	0.00005	0.00013	-0.00004
03/01/74	0.00000	---	---	0.00000	---	---
04/01/74	0.00048	0.00202	-0.00105	0.00000	---	---
05/01/74	0.00110	0.00414	-0.00193	0.00023	0.00047	-0.00002
06/01/74	0.00015	0.00061	-0.00032	0.00002	0.00006	-0.00001
07/01/74	0.00011	0.00034	-0.00012	0.00024	0.00068	-0.00019
08/01/74	0.00015	0.00041	-0.00012	0.00091	0.00020	-0.00002
09/01/74	0.00000	---	---	0.00007	0.00015	-0.00002
	-------30-45% Slopes--------			-------45-60% Slopes--------		
10/02/73	0.00246	0.00518	-0.00002	0.00778	0.01244	0.00312
11/02/73	0.00014	0.00031	-0.00003	0.00048	0.00098	-0.00001
12/02/73	0.00039	0.00098	-0.00021	0.00015	0.00039	0.00009
01/01/74	0.00000	---	---	0.00000	---	---
02/01/74	0.00051	0.00161	-0.00060	0.00015	0.00033	-0.00004
03/01/74	0.00036	0.00012	-0.00005	0.00005	0.00012	-0.00001
04/01/74	0.00000	---	---	0.00000	---	---
05/01/74	0.00051	0.00101	0.00001	0.00057	0.00106	0.00009
06/01/74	0.00029	0.00060	-0.00002	0.00054	0.00139	0.00030
07/01/74	0.00020	0.00267	-0.00024	0.00065	0.00128	0.00003
08/01/74	0.00012	0.00312	-0.00087	0.00171	0.00452	-0.00111
09/01/74	0.00017	0.00023	---	0.00047	0.00135	-0.00041

Table A13. Mean Daily Rate (g/m Streambank) of Input of Frass (with 95% Confidence Limits) Via Blow-In from Southwest-Facing Slopes to the West Fork of Walker Branch for the Monthly Collections During the 1973-1974 Water Year.

	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.	$\bar{x}$	$\bar{x}$ + C.L.	$\bar{x}$ - C.L.
	----------Benches----------			-------15-30% Slopes--------		
10/02/73	0.00096	0.00291	-0.00097	0.00025	0.00076	-0.00026
11/02/73	0.00091	0.00201	-0.00020	0.00006	0.00014	-0.00003
12/02/73	0.00075	0.01032	-0.00087	0.00028	0.00088	-0.00031
01/01/74	0.00007	0.00031	-0.00016	0.00000	---	---
02/01/74	0.00015	0.00041	-0.00012	0.00028	0.00062	-0.00005
03/01/74	0.00000	---	---	0.00004	0.00012	-0.00005
04/01/74	0.00000	---	---	0.00004	0.00014	0.00005
05/01/74	0.00060	0.00016	-0.00035	0.00016	0.00039	-0.00007
06/01/74	0.00000	---	---	0.00029	0.00085	-0.00027
07/01/74	0.00030	0.00069	-0.00009	0.00019	0.00045	-0.00008
08/01/74	0.00160	0.00313	0.00007	0.00316	0.00981	-0.00345
09/01/74	0.00051	0.00212	-0.00111	0.00002	0.00006	-0.00001
	-------30-45% Slopes-------			-------45-60% Slopes--------		
10/02/73	0.00522	0.01115	-0.00067	0.00580	0.01451	-0.00285
11/02/73	0.00029	0.00063	-0.00005	0.00158	0.00327	-0.00010
12/02/73	0.00130	0.00224	-0.00037	0.00213	0.00534	-0.00107
01/01/74	0.00017	0.00059	-0.00025	0.00017	0.00043	-0.00009
02/01/74	0.00015	0.00034	-0.00004	0.00012	0.00030	-0.00006
03/01/74	0.00000	---	---	0.00004	0.00009	-0.00002
04/01/74	0.00000	---	---	0.00001	0.00004	-0.00002
05/01/74	0.00019	0.00036	0.00001	0.00050	0.00104	-0.00005
06/01/74	0.00051	0.00110	-0.00008	0.00094	0.00234	-0.00046
07/01/74	0.00122	0.00221	0.00022	0.00247	0.00506	-0.00011
08/01/74	0.00156	0.00355	-0.00043	0.00280	0.00571	-0.00011
09/01/74	0.00001	0.00004	-0.00001	0.00015	0.00030	-0.00001

Table A14. Mean Standing Crops ($\bar{x}$) of Leaves (with 95% Confidence Limits) in the West Fork of Walker Branch for the Eight Collection Periods of the 1973-1974 Water Year.

Date of Collection	Habitat Type*	$\bar{x}$ (g/m^2)	$\bar{x}$ + 95% C.L.	$\bar{x}$ - 95% C.L.
02/07/74	1	4.009	10.582	1.166
02/07/74	2	6.571	25.465	1.166
02/07/74	3	0.352	2.123	-0.415
02/07/74	4	1.391	10.715	-0.512
04/15/74	1	11.698	22.409	5.888
04/15/74	2	30.560	55.493	16.631
04/15/74	3	4.282	18.831	0.407
04/15/74	4	1.996	6.117	0.261
06/21/74	1	4.707	10.223	1.902
06/21/74	2	16.364	35.366	7.291
06/21/74	3	2.175	13.043	-0.282
06/21/74	4	2.825	9.349	0.414
09/04/74	1	13.337	23.526	7.381
09/04/74	2	33.846	53.177	21.412
09/04/74	3	2.864	26.604	-0.459
09/04/74	4	20.522	44.164	9.256
09/08/73	1	23.380	45.260	11.849
09/08/73	2	37.117	142.080	9.154
09/08/73	3	9.311	18.025	4.588
09/08/73	4	13.108	72.053	1.725
10/05/73	1	64.993	99.814	42.199
10/05/73	2	106.905	141.479	80.720
10/05/73	3	6.201	37.379	0.351
10/05/73	4	42.445	78.939	22.612
11/04/73	1	180.578	251.099	129.785
11/04/73	2	256.023	327.214	200.274
11/04/73	3	61.867	325.244	11.114
11/04/73	4	187.042	238.812	146.448
12/03/73	1	8.537	17.695	3.866
12/03/73	2	11.576	43.918	2.521
12/03/73	3	0.550	3.305	-0.442
12/03/73	4	4.917	88.650	-0.605

*1--Stream Gravel
2--Dry Gravel
3--Bedrock Pools
4--Dry Bedrock

Table A15. Results of Two-Way ANOVA's for Standing Crop Data for the West Fork of Walker Branch for the 1973-1974 Water Year, with Date and Habitat Type as Class Variables.

Statistical Parameter	Leaf Weight		Fruit Weight		Twig Weight	
	With Interaction	Without Interaction	With Interaction	Without Interaction	With Interaction	Without Interaction
Mean Square	3.185	9.45	0.317	0.668	1.43	3.781
Mean Square Error	0.263	0.259	0.183	0.18	0.487	0.474
F	12.11	36.53	1.73	3.70	2.94	7.97
Pr>F	0.0001	0.0001	0.0016	0.0001	0.0001	0.0001
Date						
F	31.63	42.27	1.99	3.83	3.25	6.17
Pr>F	0.0001	0.0001	0.0558	0.0006	0.0026	0.0001
Habitat Type						
F	22.81	24.60	2.62	3.22	11.73	12.06
Pr>F	0.0001	0.0001	0.0505	0.0028	0.0001	0.0001
Date/Habitat Type Interaction						
F	0.77		0.82		0.64	
Pr>F	0.7604		0.6993		0.8898	

Table A16. Mean Standing Crops ($\bar{x}$) of Fruits and Reproductive Parts (with 95% Confidence Limits) in the West Fork of Walker Branch for the Eight Collection Periods of the 1973-1974 Water Year.

Date of Collection	Habitat Type*	$\bar{x}$ (g/m^2)	$\bar{x}$ + 95% C.L.	$\bar{x}$ - 95% C.L.
09/08/73	1	0.00000	---	---
09/08/73	2	0.00000	---	---
09/08/73	3	0.41200	3.2327	-0.52896
09/08/73	4	0.11763	0.5219	-0.17923
10/05/73	1	1.23373	3.0993	0.21716
10/05/73	2	2.05158	9.8528	-0.14197
10/05/73	3	0.00000	---	---
10/05/73	4	1.09761	7.8754	-0.50425
11/04/73	1	2.33721	5.1977	0.79694
11/04/73	2	2.15136	8.8064	0.01271
11/04/73	3	0.19992	0.9901	-0.27653
11/04/73	4	1.71588	11.3396	-0.40225
12/03/73	1	0.15393	0.2654	0.05230
12/03/73	2	0.82841	1.4154	0.38407
12/03/73	3	0.00000	---	---
12/03/73	4	1.11515	3.0159	0.11393
02/07/74	1	0.49339	1.1335	0.04533
02/07/74	2	1.11531	4.5302	-0.19090
02/07/74	3	0.00000	---	---
02/07/74	4	0.64336	3.9246	-0.45160
04/15/74	1	0.37601	0.9619	-0.03490
04/15/74	2	0.31500	0.6496	0.04827
04/15/74	3	0.00000	---	---
04/15/74	4	0.15641	0.5601	-0.14282
06/21/74	1	1.34926	3.8290	0.14288
06/21/74	2	2.62178	6.1982	0.82231
06/21/74	3	0.48911	3.4975	-0.50696
06/21/74	4	0.09271	0.3976	-0.14569
09/04/74	1	0.41422	1.2415	-0.10773
09/04/74	2	1.69658	5.2979	0.15459
09/04/74	3	2.08188	22.1573	-0.58985
09/04/74	4	0.22414	0.7037	-0.12043

*1--Stream Gravel
2--Dry Gravel
3--Bedrock Pools
4--Dry Bedrock

Table A17. Mean Standing Crops ($\bar{x}$) of Twigs (with 95% Confidence Limits) in the West Fork of Walker Branch for the Eight Collection Periods of the 1973-1974 Water Year.

Date of Collection	Habitat Type*	$\bar{x}$ (g/m^2)	$\bar{x}$ + 95% C.L.	$\bar{x}$ - 95% C.L.
09/08/73	1	3.9893	16.080	0.45741
09/08/73	2	15.1200	143.651	0.79641
09/08/73	3	0.0000	---	---
09/08/73	4	2.2201	18.846	-0.47752
10/05/73	1	8.7524	28.045	2.27453
10/05/73	2	4.9150	16.378	1.01329
10/05/73	3	0.2409	0.812	-0.15004
10/05/73	4	7.1236	32.359	0.97827
11/04/73	1	11.1877	25.601	4.58390
11/04/73	2	15.1494	68.8308	2.73477
11/04/73	3	0.6919	6.2842	-0.60700
11/04/73	4	1.9790	20.5717	-0.58860
12/03/73	1	0.7003	2.2043	-0.09780
12/03/73	2	0.8047	3.0863	-0.20299
12/03/73	3	0.0000	---	---
12/03/73	4	0.4972	3.5905	-0.51168
02/07/74	1	1.7109	5.013	0.22218
02/07/74	2	3.1260	13.565	0.16884
02/07/74	3	0.1377	0.628	-0.20476
02/07/74	4	0.0638	0.263	-0.10403
04/15/74	1	2.4080	6.576	0.53302
04/15/74	2	6.5419	25.917	1.11322
04/15/74	3	0.2452	1.289	-0.32255
04/15/74	4	0.7492	6.379	-0.58535
06/21/74	1	7.1229	20.790	2.02812
06/21/74	2	12.0887	36.154	3.61091
06/21/74	3	4.0101	29.240	-0.16992
06/21/74	4	0.1863	0.615	-0.12846
09/04/74	1	9.5130	23.161	3.57437
09/04/74	2	15.2843	45.157	4.74512
09/04/74	3	1.8688	10.248	-0.26811
09/04/74	4	2.0207	12.269	-0.31232

*1--Stream Gravel
2--Dry Gravel
3--Bedrock Pools
4--Dry Bedrock

APPENDIX B

Table B1. Mean Monthly Concentrations of Dissolved Organic (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

		Mean DOC Concentration (mg/1)	
Year	Month	Throughfall	Incident Precipitation
1973	Sep	11.33 ± 0.51	1.55 ± 0.09
	Oct	8.59 ± 0.64	3.52
	Nov	2.08 ± 0.17	--
	Dec	1.90 ± 0.18	--
1974	Jan	2.19 ± 0.27	--
	Feb	3.22 ± 0.46	--
	Mar	3.10 ± 0.30	2.06 ± 0.21
	Apr	5.02 ± 0.61	2.46 ± 0.57
	May	4.44 ± 0.51	3.77 ± 0.41
	Jun	8.94 ± 0.60	6.05 ± 0.34
	Jul	32.23 ± 5.36	8.78 ± 1.60
	Aug	4.03 ± 0.39	1.22 ± 0.43

Table B2. Mean Monthly Concentrations of Fine Particulate (<1 mm) Organic Carbon (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

Year	Month	Mean Concentration FPOC (mg/l)	
		Throughfall	Incident Precipitation
1973	Sep	4.27 ± 0.50	0.93 ± 0.10
	Oct	3.71 ± 0.38	1.68
	Nov	0.72 ± 0.11	--
	Dec	0.49 ± 0.04	--
1974	Jan	0.60 ± 0.04	--
	Feb	1.17 ± 0.07	--
	Mar	1.47 ± 0.12	0.93 ± 0.02
	Apr	2.97 ± 0.15	2.12 ± 0.26
	May	2.02 ± 0.16	1.83 ± 0.09
	Jun	6.98 ± 0.88	1.89 ± 0.11
	Jul	20.27 ± 3.23	2.09 ± 0.19
	Aug	3.04 ± 0.36	0.88 ± 0.30

Table B3. Mean Monthly Concentrations of Total (<1 mm) Organic Carbon (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

		Mean TOC Concentration (mg/1)	
Year	Month	Throughfall	Incident Precipitation
1973	Sep	15.53 ± 0.81	2.47± 0.16
	Oct	12.31 ± 0.80	5.20
	Nov	2.80 ± 0.09	--
	Dec	2.39 ± 0.20	--
1974	Jan	2.79 ± 0.30	--
	Feb	4.39 ± 0.50	--
	Mar	4.56 ± 0.39	2.99 ± 0.23
	Apr	8.00 ± 0.73	4.58 ± 0.45
	May	6.46 ± 0.65	5.60 ± 0.44
	Jun	15.65 ± 1.35	8.27 ± 0.24
	Jul	52.51 ± 7.73	10.87 ± 1.45
	Aug	7.07 ± 0.62	1.80 ± 0.53

Table B4. Mean Monthly Input of Dissolved Organic Carbon (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

		Mean DOC Input (kg/ha)	
Year	Month	Throughfall	Incident Precipitation
1973	Sep	10.05 ± 0.46	1.40 ± 0.07
	Oct	5.76 ± 0.41	2.40
	Nov	5.46 ± 0.47	--
	Dec	3.32 ± 0.30	--
1974	Jan	5.36 ± 0.58	--
	Feb	3.78 ± 0.48	--
	Mar	3.12 ± 0.46	3.93 ± 0.49
	Apr	3.83 ± 0.38	2.06 ± 0.51
	May	6.47 ± 0.59	6.55 ± 0.81
	Jun	5.36 ± 0.37	4.05 ± 0.35
	Jul	6.77 ± 0.89	2.27 ± 0.36
	Aug	6.37 ± 0.51	2.00 ± 0.79

Table B5. Mean Monthly Input of Fine Particulate (<1 mm) Organic Carbon (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

Year	Month	Mean FPOC Input (kg/ha)	
		Throughfall	Incident Precipitation
1973	Sep	3.82 ± 0.44	0.84 ± 0.09
	Oct	2.52 ± 0.28	1.15
	Nov	1.89 ± 0.29	--
	Dec	0.85 ± 0.07	--
1974	Jan	1.46 ± 0.07	--
	Feb	1.39 ± 0.08	--
	Mar	2.43 ± 0.19	1.77 ± 0.08
	Apr	2.30 ± 0.10	1.74 ± 0.16
	May	2.99 ± 0.20	3.18 ± 0.23
	Jun	4.33 ± 0.60	1.20 ± 0.02
	Jul	4.45 ± 0.69	0.55 ± 0.06
	Aug	4.80 ± 0.53	1.44 ± 0.50

Table B6. Mean Monthly Input of Total (<1 mm) Organic Carbon (± One Standard Error) in Throughfall and Incident Precipitation to the West Fork of Walker Branch for the 1973-1974 Water Year.

		Mean TOC Input (kg/ha)	
Year	Month	Throughfall	Incident Precipitation
1973	Sep	13.87 ± 0.67	2.24 ± 0.13
	Oct	8.28 ± 0.55	3.54
	Nov	7.34 ± 0.30	--
	Dec	4.17 ± 0.33	--
1974	Jan	6.83 ± 0.62	--
	Feb	5.17 ± 0.51	--
	Mar	7.55 ± 0.59	5.70 ± 0.57
	Apr	6.14 ± 0.44	3.81 ± 0.40
	May	9.48 ± 0.74	9.73 ± 0.96
	Jun	9.69 ± 0.91	5.67 ± 0.22
	Jul	11.22 ± 1.39	2.81 ± 0.30
	Aug	11.17 ± 0.82	2.95 ± 1.01

Table B7. Mean Concentrations of DOC (± One Standard Error) in the Four Forest Types on Walker Branch Watershed for the Collection Periods from July 1973 to Mid-June 1974.

Collection Interval		Chestnut Oak		Oak-Hickory		Pine		Yellow Poplar	
Begin	End	Mean (mg/l)	Standard Error	Mean (mg/l)	Standard Error	Mean (mg/l)	Standard Error	Mean (mg/l)	Standard Error
07/02/73	07/19/73	1.59	0.21	1.89	0.23	1.64	0.15	1.75	0.25
07/20/73	08/02/73	2.25	0.82	2.08	0.30	1.65	0.31	1.65	0.44
08/03/73	08/16/73	2.04	0.34	1.34	0.06	1.21	0.16	1.52	0.35
08/17/73	11/29/73	1.58	0.33	0.80	--	1.26	0.29	1.46	0.26
11/30/73	12/18/73	2.11	0.34	2.60	0.29	1.70	0.32	1.47	0.32
12/19/73	01/10/74	1.53	0.21	1.64	0.12	1.43	0.13	1.16	0.16
01/11/74	02/15/74	1.33	0.47	1.38	0.31	1.04	0.12	0.95	0.26
02/16/74	03/08/74	0.74	0.18	0.87	0.20	0.92	0.33	0.62	0.20
03/09/74	03/29/74	1.91	0.55	1.29	0.11	0.84	0.18	0.72	0.25
03/30/74	04/19/74	1.33	0.36	1.31	0.13	0.71	0.13	0.63	0.15
04/20/74	05/16/74	1.42	0.34	1.15	0.10	0.68	0.08	0.83	0.17
05/17/74	06/11/74	1.54	0.31	1.26	0.11	0.83	0.20	0.77	0.20

VITA

Charles Edward Comiskey was born in Newark, New Jersey on December 5, 1944. He lived most of his early life in Hillside, New Jersey, where he attended the local elementary schools. He graduated from Hillside High School in June 1962. The following September, he entered Seton Hall University and received the B. A. degree with a major in Biology in June 1966. He enrolled in the University of Tennessee Graduate School in September 1966, and was a graduate assistant in the Department of Zoology and Entomology until September 1968, at which time he accepted a University of Tennessee Non-Service Fellowship for the academic year 1968-1969. In March 1969, he resigned the Non-Service Fellowship, accepting a National Defense Education Act Title IV Fellowship.

He received his Master of Science degree in Zoology in Winter 1970, with thesis research on the ichthyofauna of the Big South Fork of the Cumberland River System.

He subsequently enrolled in the newly-formed Graduate Program in Ecology, working toward the degree of Doctor of Philosophy. Field and laboratory work related to his dissertation was supported by an Oak Ridge Associated Universities Pre-Doctoral Research Participantship in the Environmental Sciences Division of Oak Ridge National Laboratory.

He is a member of the Freshwater Biological Association (United Kingdom) and the American Society of Limnology and Oceanography.

He is married to the former Ethel Jane Goodman and now resides in Knoxville. He is presently employed by Science Applications, Inc. of Oak Ridge, Tennessee.