BUFFALO NATIONAL RIVER ECOSYSTEMS

PART II

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FINAL REPORT

BUFFALO NATIONAL RIVER ECOSYSTEMS PART II

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INTRODUCTION

The priorities were established for the Buffalo National River Ecosystem Studies through meetings and correspondence with Mr. Roland Wauer and other personnel of the Office of Natural Sciences, Southwest Region of the National Park Service. These priorities were set forth in the appendix of contract no. CX 700050443 dated May 21, 1975 and summarized below.

Priority 1 - Water Quality Analysis - This phase of the study involved physico-chemical analysis and phycological studies of the river water and represented an extension of the previous two contracts except for the addition of turbidity measurements and chlorophylls analysis.

Priority 2 - Analysis of Fecal Contamination - The objective of this phase of the study was to determine the magnitude and source of fecal contamination in selected river sections.

Priority 3 - Geochemistry of Sediments and Water - The purpose of this phase of the study was to determine whether anomalous high heavy metal concentrations are due to tailing and ore piles from old mine sites or whether they are the result of natural contributions due to metals present in the rocks.

Priority 4 - Hydrogeologic Characteristics - The purpose of this phase of the study was designed to provide information on the characteristics of the groundwater resources of the watershed and on the relationship between alteration of the local environment and river hydrology.

Priority 5 - Vegetation on Selected Sites - The purpose of this phase of the study was to identify and locate the vegetation types present in areas of most immediate interest to the management of the river.

Priority 6 - Resource Capacity - The purpose of this phase of the study was to provide information on the use-activity pattern along the river.

In accordance with these priorities the following report is submitted as a final report for contract no. CX 700050443.

WATER QUALITY ANALYSIS AND MONITORING

The algal flora of the Buffalo River was studied throughout the period of July, 1974 to December, 1975. Determinations were made at regular intervals of a set of physico-chemical variables which may be supposed to influence algal growth and water quality. The seasonal aspects of the algal populations as they occurred during this research period are discussed in detail. General patterns have repeated themselves and may be expected to continue to do so if the habitats are maintained. Future plans for river research include a more concentrated study of productivity of the periphyton community. These studies will be based on those methods which prove most successful. This report reviews various analytical techniques, field trials and applicability to the Buffalo National River.

Physico-Chemical

Temperature and conductivity were measured in the field with a YSI Conductivity meter. Oxygen concentrations were measured on water samples taken from the river in glass bottles using a modified Winkler analysis. Water samples for chemical analysis were collected in plastic bottles. In the laboratory, turbidity was measured using a Hach Analytical Nephelometer Model 2100A, on unfiltered water samples. Ammonia was measured on unfiltered water samples using direct or standard addition methods with the Orion Specific Ion Probe. Samples of river water were filtered through

Millipore filters and refrigerated overnight. Nitrate-nitrogen was determined by the ultraviolet standard method (American Public Health Association, 1971). Orthophosphate was measured by the ammonium molyldate procedure, also a standard method. Silica concentrations were determined by diluting water samples 1:4 and measuring according to the heteropoly blue standard.

Primary Productivity

Productivity studies were carried out using artificial substrates of standard glass microscope slides, plastic "whirl pacs", simulated concrete rocks, and glass plates. These various materials were positioned in the river in such a manner so that they would be available for algal colonization and growth. Carbon-14 uptake experiments carried out in August, 1975 according to the standard procedures. Diurnal or diel oxygen measurements were made using a YSI Oxygen meter standardized by a modified Winkler titration except where extremely cold temperatures prevented the operation of the meter. Direct titration was used under cold conditions.

In order to measure chlorophyll concentrations it is necessary to filter a known volume (1 liter) of river water onto a glass fiber filter. The algal cells that had been suspended in this river water become trapped on this filter. Then the filters are lypholized. After this desication process, pigments are extracted from the filters in a known volume of acetone. Using spectrophotometric methods described in

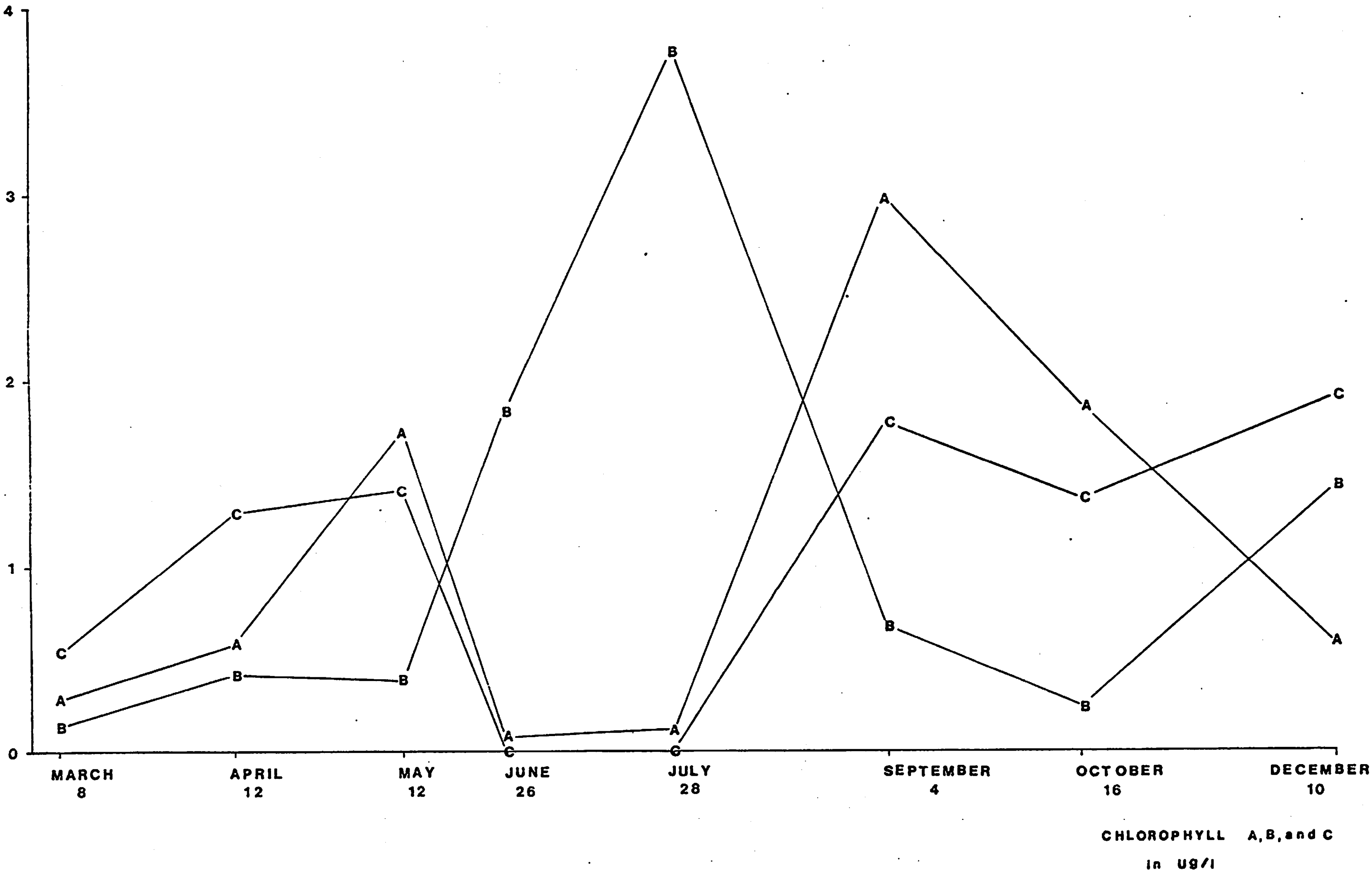
(Meyer, 1971), the concentrations of Chlorophyll A, B and C are determined. A similar method was used in determining chlorophyll concentrations of the artificial substrates.

Results and Discussion

Stream algal flora is usually lacking true phytoplankton and the Buffalo River examplifies this condition (Meyer, 1974). The majority of the algae is periphytic. By taking plankton tows and observing the samples, it becomes clear that the usual algal forms found free floating in the river are dislodged periphytic organisms and thus are tychoplanktonic. This pausity of euplankton is supported by the chlorophyll data (Table 1). Starting with the March 8, 1975 sampling, chlorophyll analysis was instituted as a regular part of the sampling regime. The generally low concentration values of these pigments in ug/l illustrate the scarcity of phytoplankton. Abundances were often below detection limits as is shown by zero values in the table. There is an interesting increase in the concentration of chlorophyll B in June and July of 1975 (Fig. 1). At that time masses of free floating Spirogyra were evident at most stations on the river and can account for that high value. Chlorophyll B to Chlorophyll A ratio is extremely high in the Conjugatophyceae (Table 3). In June of that year, at some of the stations there was slight development of a truly planktonic flora in the still pools. Species of the order Volvocales (Table 3) are usually part of this plankton (Table 2). Eudorina eglans was found in a pool at Jasper and also at the Hasty station. This same event was noted for the summer of 1974 but to a greater extent. Then there were greater numbers of planktonic species found in still pools throughout the summer and into October as long as quiet water persisted. Planktonic genera included many flagellates; chrysophytes such as

FIG. 1

MEAN CHLOROPHYLL VALUES VS. TIME



Mallomonas alpina, Mallomonas helvetica, Synedra petersenii and Anthophysa vegetans. Euglenophyta included Trachlomonas hispida and Phacus orbicularis. The Pyrrhophyta found as euplankters were Peridinium sp. and Ceratium. Chlorophyta in the summer plankton was predominately Chlamydomonas petryi and Eudorina eglans. Typical summer algal flora has also included Spirogyra during the period studied. Once still pools and quiet water, with the only significant water movement limited to riffles, became established Spirogyra spp. became predominant. From these pools it was washed out into the main stream. This observation is similar to findings reported in a study concerning a Michigan stream where pools acted as centers of dispersal for Spirogyra (Blum, 1959).

There were several species of Spirogyra, few were observed in fruiting stages needed for taxonomic determination. One of these was Spirogyra hymenae which was observed with zygospores and conjugation tubes in the December, 1975 sample. Only one species of Spirogyra was forced to conjugate in the laboratory; this was Spirogyra orientalis. After subjecting a culture to darkness, cool temperatures and a concentrated CO_2 atmosphere for a few days, fruiting structures developed. Attempts to force other species of Spirogyra to conjugate were never successful.

Spirogyra was abundant at most stations in the summer months and although much reduced the population lasted until late fall to winter during the years sampled. In late December and early January it finally disappeared from the stream system. Spirogyra has established itself as a regular aspect of the summer flora on the river.

Another important summer event was the growth of large beds of Justica Americana (water willow) in the water. As these vascular phanaerogams became established so did the epiphytic algal population which depended on them. Epiphytes are therefore, limited by the distribution of a suitable habitat; the higher plant.

This axium is applicable to the Buffalo River ecosystem, so that algae epiphytic on water willow are similar from station to station. These included; Calothrix minima, Phormidium Ambiguum, Stigeoclonum nanum, Oscillatoria geminata, macroscopic colonies of Choleochaete scutata and associated metaphytic genera such as Cosmarium and Scenedesmus.

Other important epiphytes do not depend on vascular plants but on large filamentous algae. Filaments of Oedogonium or Cladophora may harbor extensive epiphytic assemblages. These may include; Chamaesiphon, Aphanochete, Epithemia, Gomphonema, Cymbella, Synedra, Cocconeis, Diatoma and others. Characium ambiguum has been found on filaments of Mougeotia as an epiphyte. Growth of the supporting plant could be essential to the epiphyte if they are restricted to this relationship. Epiphytes on those filamentous algae are present year around in the case of Oedogonium or as long as those supporting plants are available, in the case of Cladophora which shows periodicity in that it is available only in the summer months. As in the case of epiphytes on Justica, their association is seasonal because the beds of water willow have usually dissappeared completely by late September.

Seasonal succession on the Buffalo National River is very complex. Very few events stand out as clearly as the summer events discussed above (Table 2). Autumn, for instance, seems to be a transitional stage with no dominant algal flora or unique species. With the loss of leaves in the surrounding forest and increased rainfall, this is a period of high runoff and rising water levels. Higher turbidity readings are typical of these high water periods. Epilithic populations are the major ones at this season but with swiftly flowing water this periphyton is often scoured off of the rocks. Algae typically encountered in the fall includes remnants of the summer population, the ubiquitous Oedogonium, and cyanophytes of the Chroococcales, Chamaesiphonales, and Oscillatoriales (Table 3).

Winter has an algal association which is predominated by diatoms. This can be viewed macroscopically as golden colored gelatinous coatings on rocks in the stream which develops from December to January. This winter predominance of Bascillariophyceae is also reflected in the high chlorophyll C values at that season (Fig. 1). The most important components of this winter algal association are the pennate diatoms such as Achnanthes, Cymbella, Navicula and Nitzschia. Associated with them in lesser numbers are the green Ankistrodesmus, the desmids; Cosmarium, Closterium and Stauradesmus and the filamentous bluegreen alga, Oscilatoria.

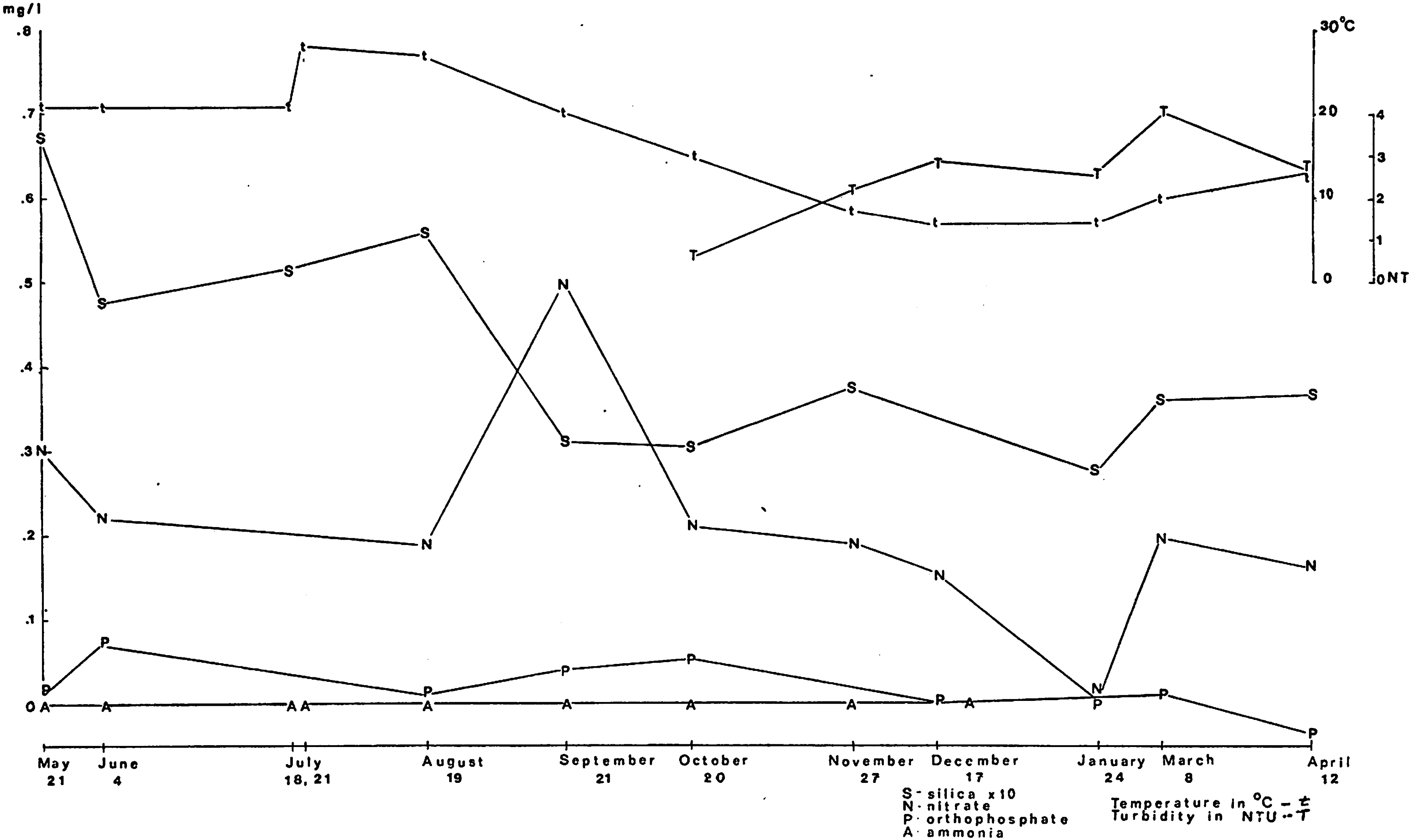
In March there is an early spring period of transition typically being dominated by high, swift waters that scours away the winter diatom populations. Occationally in quieter more sheltered areas such as that encountered at Boxley, there is development of large green gelatinous colonies of Tetraspora. At the majority of the stations the only non-diatom algae encountered were bluegreens.

Strangely enough no seasonal pattern as to the occurrence of red algae develops (Table 2). Traditionally fresh water red algae have been classified as the type of algae that might be found in cool, clean waters. The Buffalo River is a warm water stream with summer temperatures ranging up to 32°C. Red algae of different genera have been found infrequently at Boxley, Ponca, Pruitt, Hasty, Gilbert, Highway 14, and Rush in every season. The only stations where red algae have not been found were Jasper and Buffalo Point. Those can probably be classified as generally disturbed sites which never develop very extensive epilithic floras.

Water quality parameters monitored were phosphate, nitrate, silica temperature, oxygen, turbidity and conductivity. Graphs and discussion of chemical and physical parameters can be found in Buffalo National River Ecosystems, Part I, for the period through 1974 (Rippey and Meyer, 1975). For chemical and physical data through December, 1975 refer to the accompanying tables. A complete discussion of chemical and physical parameters as they relate to seasonal algal populations will be included in a Masters of Science Thesis by one of the authors (LLR). Conductivity was first included in the sampling regime in October, 1975 so there is not enough data at this time to make conclusive statements concerning the seasonal pattern of conductivity. Filterable ortho-phosphate persists at low levels throughout the year with slight fluctuations but never exceeding a mean value of 0.1 mg./liter (Fig. 2 and 3). Although there is no real quantitative algal data at this time, ortho-phosphate traditionally shows a negative correlation with algal abundance. Nitrate-N concentrations for the previous reporting period showed a peak value of 0.5 mg./liter in September (Fig. 2). This increased nitrate concentration was thought to have initiated the summer to winter assemblage succession. In the current reporting period the fall peak is not so pronounced as in 1974 but there is a concentration peak of 0.4 mg./liter in early December (Fig. 3). This is probably due to a sparse epilithic population which has lower nitrate utilization. Silica levels continue to be relatively high and the data reflects the algal populations. Mean concentrations of silica are reduced by large diatom populations such as the winter epilithic bascillariophytes.

FIG. 2

Mean Values of Chemical and Physical Data vs. Time



(Source: Rippey & Meyer. 1975)

FIG. 3

MEAN VALUES OF CHEMICAL AND PHYSICAL DATA VS. TIME

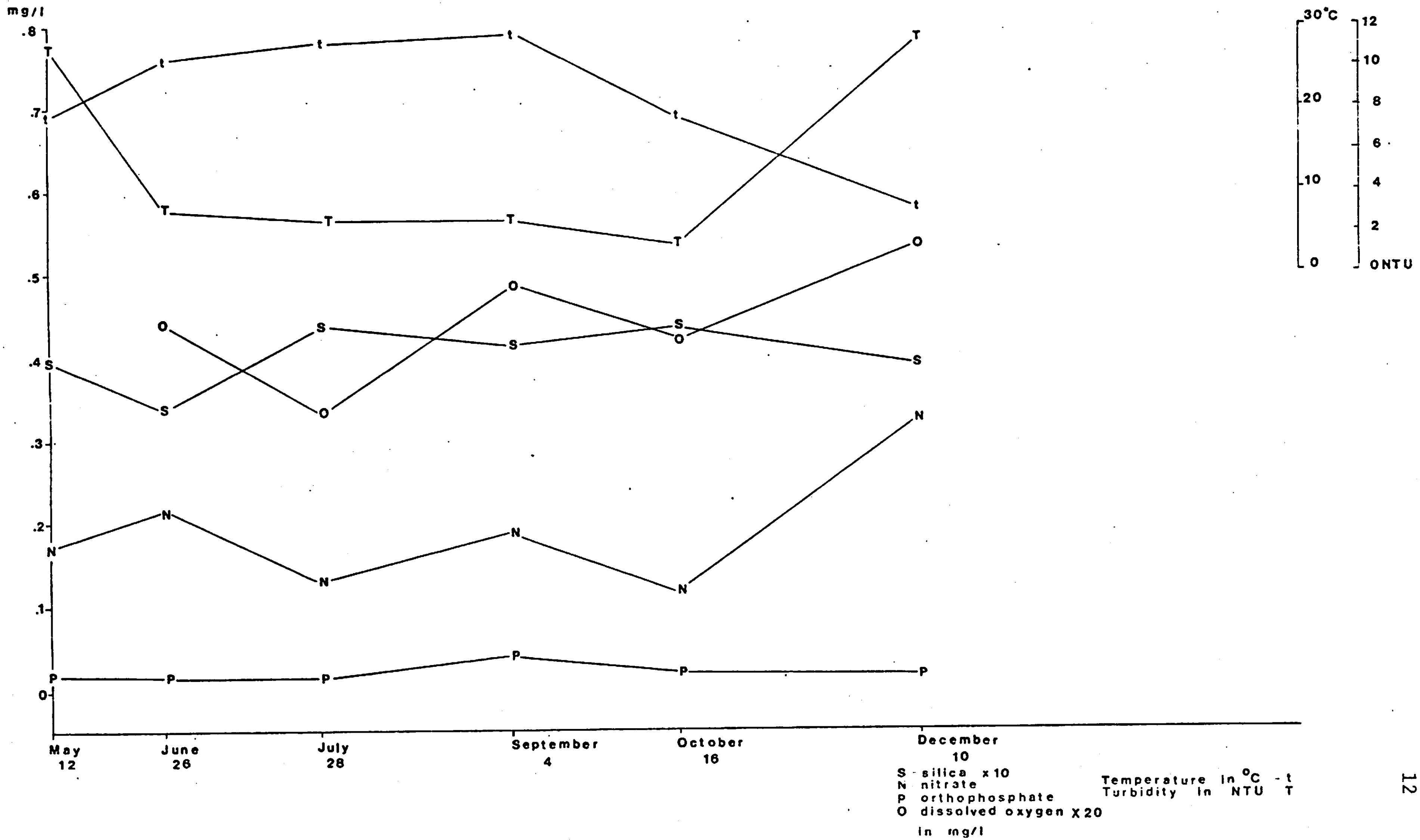
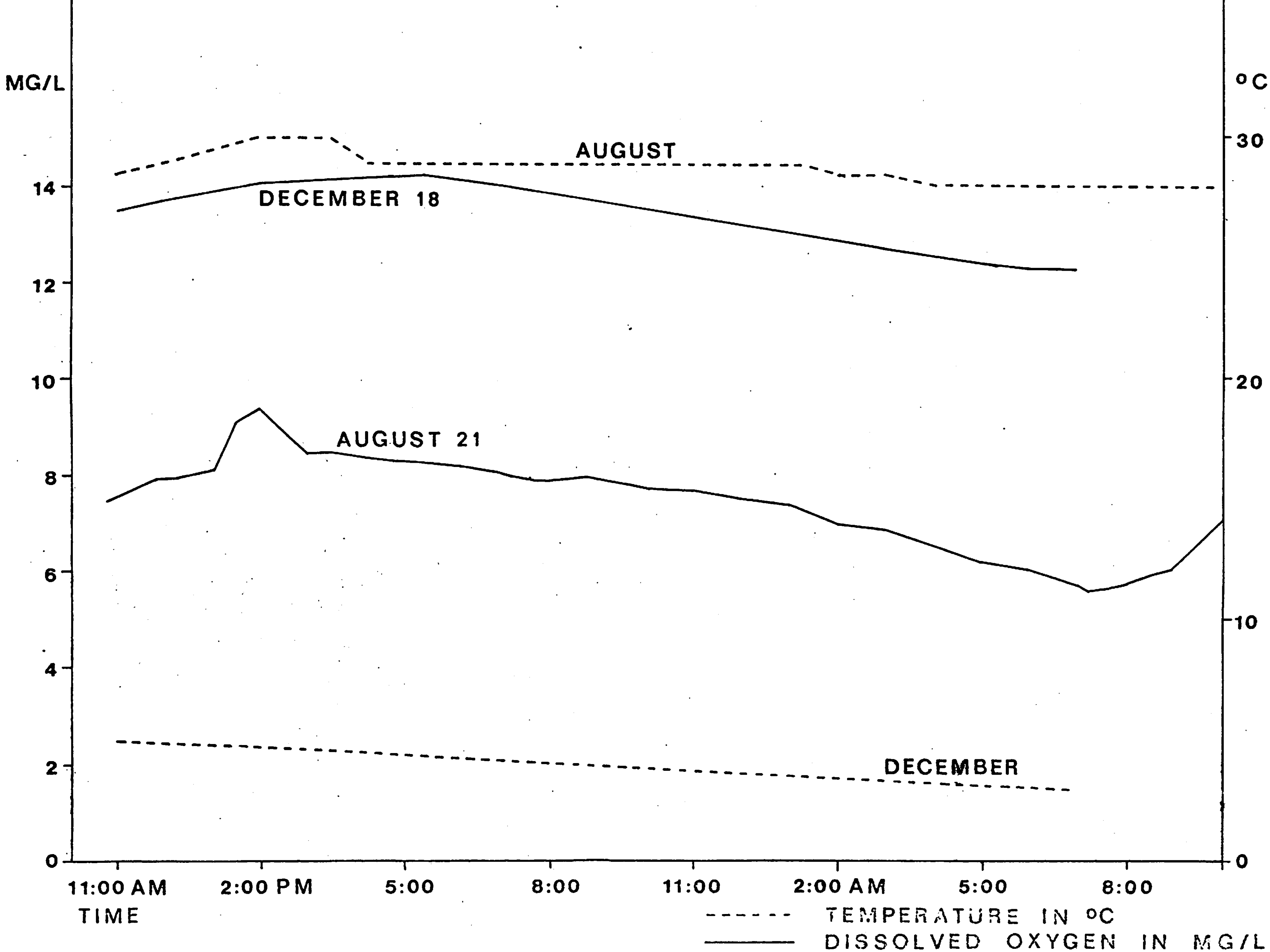


FIG 4

SEASONAL DIEL OXYGEN PROFILES



Water temperature in the Buffalo is influenced by atmospheric temperatures but due to the thermal properties of water, the changes are moderate (Fig. 2 and 3). The concentrations of dissolved oxygen in the Buffalo River is the result of atmospheric exchange in accordance with the gas laws and algal productivity (Fig. 3). The question of dissolved oxygen resulting from photosynthetic activity is best approached with diel oxygen curves (Fig. 4). The oxygen concentrations are further discussed under the "Productivity" section. Turbidity is generally low in the river water but its increase reflects increased flow of sediment laden waters from either runoff or upstream regions of the river. These values are typically lowest in the summer when the flow is most reduced (Fig. 2 and 3).

Productivity

A major portion of the research effort was directed at assessing techniques and methods for quantifying the primary producers and establishing a procedure for determining rates of productivity. These quantitative values are important in recognizing initial perturbations on the natural flora prior to severe damage to the algal community. Methods for establishing productivity rates have been successfully developed for the euplanktonic subcommunity but much innovative effort is required for the development of an approach for the epilithic and epiphytic subcommunity. Work done on the Buffalo River was directed toward developing a quantitative estimation of the distribution of algae. It is accepted that research from this quantitative approach would give a great deal of more well defined information but there are a number of problems inherent to such a quantitative approach. First, in order to assess an algal population it is necessary to know the area that is available to its growth. In a limmetic situation this is much more simplistic because volumes of water available to plankton growth can easily be calculated. It is a standard physiological procedure to speciate and enumerate, "count" algae from samples of a known volume taken from a known depth in a lake. In small order rivers like the Buffalo, the algal flora is periphytic and it is difficult to calculate true surface areas of the natural substrates that are available for colonization and growth. The rough irregular surfaces of the substrate provides a greater true colonizing area than is represented by aerial dimension. Most researchers substitute an artificial substrate with a known surface area.

Throughout the late spring, summer and fall of 1975 a series of experiments were conducted on the Buffalo in order to determine the best quantitative experimental approach. The first experiments utilized artificial substrates of two different materials, glass and plastic. These substrates were implanted in the river for an inculation period of a month and then recovered for analysis. Descriptions of these devices can be found in previous reports, but briefly the plastic device consisted of a "whirl pac" sampling bag filled with sand or gravel indigenous to the site where it was to be placed to render it as inconspicuous as possible. The glass device consisted of a standard slide box with the side panels removed to allow water to flow through. A number of slides were placed in the holder in the usual manner and the whole box was taped closed and mounted on a retaining stake. Then the slides could be positioned at the desired depth and orientation in the water.

The first major problem encountered with these and other substrates is that foreign looking objects in the river arouse attention and are often removed by the curious well intentioned visitors to the river. Substrates in no way parallel either quantitatively or qualitatively the natural substrates. Glass substrates recovered at Gilbert showed predominantly Cocconeis, a genus which was present on natural substrates but did not out number all other genera. Some other genera found on glass substrates Oedogonium, Choleochaete and Lyngbya did not occur at all on natural substrates at the Gilbert station at that time (July 28, 1975). Similar results were found with the glass substrates from the Highway 14 station. There Cocconeis was still the major alga colonizing glass slides. In that case there were no non-diatom algae found on the artificial substrates while natural substrates supported eight other orders of algae. Involving other investigations of the growth of benthic algae on artificial substrates, it has been reported that:

1. Species normally present in populations on natural substrates may be stimulated to grow at different times of the year on artificial surfaces.
2. Species growing on glass slides may not be the same as those growing on natural surfaces.
3. Some of the species characteristic of the winter population fail to develop for some reason, so that glass slides are only measuring part of the community.

These observations on the quality of periphyton growth (Tippett, 1970) on artificial substrates probably reflect problems encountered with such devices wherever they are used. At best, artificial substrates can only be used as a comparison showing relative changes in flora from one station to another within equivalent time blocks.

Since one of the reasons for the loss of those artificial substrates may have been the current, a more substantial type of artificial substrate was fashioned. The design of this substrate was meant to facilitate the in situ measurement of productivity with carbon-14. These substrates consisted of a plate glass square anchored to a concrete block by straps of rubber tubing. Three of these were positioned in the river, at Ponca, Highway 14 and Rush in early August. Later that same month only one of these substrates was recovered from the river. On August 21, 1975, a carbon-14 uptake study was done on the glass plate remaining at the Rush station. This was done by strapping open bottom B.O.D. bottles of known volume onto the glass plate. One these bottles was clear glass, the other was made light tight with black paint and reflective foil. After the bottles were affixed to the plate _in situ_, a small amount of sodium carbonate (14C) was introduced to each and the bottles were stoppered. Incubation took place during the four hours around solar noon. At the end of this time the entire apparatus was removed from the water. Bottle contents were poured into a waste bottle. Then, the algae from the area under each bottle was washed and scraped onto a Millipore filter and hand vacuumed while washing with several aliquots of distilled water to remove the carbon-14 not incorporated into the cells. Filters were put into plastic vials to be transported back to the lab and later analyzed for carbon fixation. All the substrates for the performance of such a test cannot be maintained at other stations. The method appears to be aviable approach but will require further testing. Also recovery of the substrate to carry out this test requires a bit of submarine work which is complicated by strong currents and low water temperature.

Problems with artificial substrates abound. Among the most poignant complaints are that they look foreign in the river thus are subject to human disturbance, and that they support uncharacteristic algal populations. So if qualitative data is to be collected the type of artificial substrate must be more like the natural rock but with an easily measured surface area. Concrete rocks seemed to meet these specifications so on October 16, 1975 four concrete cylinders (approx. 5 cm. high and 7.2 cm. in diameter) were placed in the stream bed at five sampling sites. At the next sampling expedition, on the tenth of December, two sets of these substrates were located. Most of the work scraping and washing the algae onto glass fiber filters can be done in the field with a hand vacuum pump so that the "rocks" can be cleaned of periphyton and replaced in the stream for the next sampling. Two of these rocks were used for chlorophyll analysis from a known area and the other two provided biomass data as dry weight corrected for extraneous particulate matter. Again it would be desirable to have more stations represented in this quantitative work but high water made it impossible to find the substrates at other stations. From both chlorophyll concentrations and biomass data it seems that substrates at the Pruitt station harbor more algae than those at Ponca. These "rocks" are currently undergoing further testing.

To measure relative productivity from station to station or from season to season without the inconvenience of leaving materials in the field would indeed be an ideal experimental method. On the basis of the fact that periphyton populations enhance the dissolved oxygen in the water when they photosynthesize in the daytime and deplete it when they respire, a set of diel oxygen measurements were conducted. The first diel oxygen measurement was done in August, 1975 and the second was done in December of that year. Using the data obtained from these studies a seasonal comparison can be made of similar points on the river. The summer water temperatures ranged from 28-32°C and the oxygen levels ranged between 9.5 mg./liter at noon and 5.6 mg./liter at dawn. The December water temperatures ranged between 3 and 5°C and oxygen concentrations were from 12.3 and 14.2 mg./liter (Fig. 4). There is an increased soluability of gasses in water at lower temperatures which accounts for the greater magnitude of the December oxygen concentrations. These high values may also be enhanced by the more rapid flow rates of the river in December which also has the effect of incorporating more atmospheric oxygen into the water. The importance in comparing these studies is to see the differences in the high noon and low dawn oxygen values. These represent the amount of oxygen in the water due to photosynthetic activity. There is not as much oxygen in the water in December due to photosynthesis as in the summer (1.9 compared to 3.9). Sparse epilithic algal populations may also be evidence of this low comparative photosynthetic activity.

Table 1

BUFFALO NATIONAL RIVER
PHYSICO-CHEMICAL PARAMETERS

Stations

1	Boxley
p	Ponca
2	Pruitt
3	Jasper
4	Hasty
5	Gilbert
6	Highway 14
7	Buffalo Point
8	Rush

Temperature in Celcius.

Turbidity in N.T.U.

Oxygen, Silica, Soluable Ortho-Phosphate-P, Nitrate N, in milligrams/liter.

Chlorophylls in micrograms/liter.

Concentrations below detection limits reported as 0.

No Data indicated by ****.

BUFFALO RIVER PHYSICAL CHEMICAL DATA

SURVEY DATE 09-21-74

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	18.0	****	*****	3.680	0.030	0.496	*****	*****	*****
PONCA	19.0	****	*****	2.675	0.017	0.378	*****	*****	*****
PRUITT	19.0	****	*****	3.545	0.032	0.771	*****	*****	*****
JASPER	20.0	****	*****	3.206	0.054	0.574	*****	*****	*****
HASTY	20.0	****	*****	3.410	0.062	0.692	*****	*****	*****
GILBERT	22.0	****	*****	2.499	0.072	0.751	*****	*****	*****
HWY-14	22.0	****	*****	3.370	0.016	0.280	*****	*****	*****
BUFF.PT	22.0	****	*****	2.934	0.024	0.280	*****	*****	*****
RUSH	22.0	****	*****	3.070	0.063	0.241	*****	*****	*****

SURVEY DATE 10-21-74

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	15.0	****	0.53	2.565	0.115	0.000	*****	*****	*****
PONCA	17.0	****	0.86	2.665	0.125	0.201	*****	*****	*****
PRUITT	15.0	****	0.80	2.920	0.142	0.280	*****	*****	*****
JASPER	20.0	****	0.91	3.125	0.000	0.280	*****	*****	*****
HASTY	16.0	****	0.47	2.390	0.158	0.162	*****	*****	*****
GILBERT	16.0	****	0.89	3.585	0.128	0.260	*****	*****	*****
HWY-14	14.0	****	0.39	3.140	0.121	0.162	*****	*****	*****
BUFF.PT	14.0	****	0.39	3.070	0.117	0.182	*****	*****	*****
RUSH	14.0	****	0.29	3.765	0.113	0.162	*****	*****	*****

SURVEY DATE 11-27-74

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	8.0	****	5.50	3.653	*****	0.178	0.000	*****	*****
PONCA	8.0	****	3.50	3.498	*****	0.179	*****	*****	*****
PRUITT	9.0	****	1.25	3.653	*****	0.119	*****	*****	*****
JASPER	9.0	****	1.10	3.807	*****	0.159	*****	*****	*****
HASTY	9.0	****	1.00	3.776	*****	0.199	*****	*****	*****
GILBERT	9.0	****	1.50	3.498	*****	0.277	*****	*****	*****
HWY-14	9.0	****	2.00	3.962	*****	0.218	*****	*****	*****
BUFF.PT	10.0	****	2.00	3.653	*****	0.159	*****	*****	*****
RUSH	10.0	****	1.40	4.039	*****	0.179	*****	*****	*****

BUFFALO RIVER PHYSICAL CHEMICAL DATA

SURVEY DATE 12-17-74

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	5.0	####	5.25	3.807	0.000	0.000	#####	#####	#####
PONCA	6.3	####	4.20	3.421	0.000	0.199	#####	#####	#####
PRUITT	6.0	####	3.00	3.003	0.000	0.218	#####	#####	#####
JASPER	6.0	####	2.50	3.266	0.000	0.199	#####	#####	#####
HASTY	7.0	####	3.00	3.343	0.000	0.000	#####	#####	#####
GILBERT	7.0	####	2.00	2.956	0.000	0.159	#####	#####	#####
HWY-14	7.0	####	1.70	3.421	0.000	0.238	#####	#####	#####
BUFF.PT	7.0	####	1.80	3.498	0.000	0.179	#####	#####	#####
RUSH	7.0	####	1.90	3.668	0.000	0.179	#####	#####	#####

SURVEY DATE 01-24-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	6.0	####	4.00	6.477	0.018	0.000	#####	#####	#####
PONCA	6.0	####	3.10	2.191	0.017	0.000	#####	#####	#####
PRUITT	6.0	####	2.40	2.030	0.001	0.000	#####	#####	#####
JASPER	7.0	####	2.70	2.119	0.002	0.000	#####	#####	#####
HASTY	7.0	####	1.90	2.191	0.008	0.000	#####	#####	#####
GILBERT	7.0	####	1.60	2.280	0.005	0.001	#####	#####	#####
HWY-14	7.0	####	1.48	2.369	0.003	0.003	#####	#####	#####
BUFF.PT	7.0	####	1.70	2.369	0.004	0.003	#####	#####	#####
RUSH	38.0	####	3.80	2.566	0.006	0.003	#####	#####	#####

SURVEY DATE 03-08 75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	9.0	####	5.90	2.873	0.007	0.187	0.000	0.410	0.000
PONCA	9.0	####	4.50	3.251	0.005	0.205	0.230	0.000	0.000
PRUITT	9.0	####	7.50	3.382	0.013	0.241	0.200	0.240	0.680
JASPER	10.0	####	3.70	3.775	0.011	0.169	0.700	0.000	0.000
HASTY	10.0	####	4.20	3.746	0.012	0.205	0.670	0.150	0.000
GILBERT	10.0	####	3.00	3.382	0.007	0.187	0.430	0.060	1.690
HWY-14	10.0	####	2.90	3.659	0.010	0.205	0.000	0.000	0.000
BUFF.PT	11.0	####	3.00	3.673	0.009	0.223	0.210	0.330	0.000
RUSH	11.0	####	1.50	4.546	0.005	0.133	0.230	0.000	0.000

BUFFALO RIVER PHYSICAL CHEMICAL DATA

SURVEY DATE 04-12-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	9.0	****	4.20	3.703	0.011	0.072	0.200	0.150	1.780
PONCA	9.5	****	3.90	3.615	0.010	0.034	0.790	1.450	1.300
PRUITT	13.0	****	3.50	3.572	0.018	0.110	1.040	0.860	2.630
JASPER	12.5	****	2.20	4.270	0.024	0.083	0.690	0.000	1.920
HASTY	14.0	****	3.50	3.804	0.020	0.072	0.930	0.000	0.000
GILBERT	14.0	****	1.50	3.324	0.015	0.053	0.650	0.650	0.000
HWY-14	14.0	****	1.35	3.353	0.015	0.038	0.230	0.000	2.110
BUFF.PT	15.5	****	1.20	3.415	0.012	0.053	0.000	0.000	0.000
RUSH	14.0	****	2.45	3.964	0.012	0.034	0.840	0.620	1.950

SURVEY DATE 05-12-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	19.0	****	10.00	4.266	0.017	0.125	0.000	0.680	0.000
PONCA	18.0	****	10.00	4.075	0.016	0.163	1.020	1.190	3.410
PRUITT	19.0	****	17.50	4.046	0.017	0.182	1.510	0.860	0.250
JASPER	20.0	****	9.10	4.046	0.018	0.125	0.870	0.300	1.180
HASTY	20.0	****	19.00	4.163	0.021	0.355	1.360	0.000	0.220
GILBERT	20.0	****	12.00	3.753	0.014	0.240	1.300	0.360	2.870
HWY-14	20.0	****	9.00	3.621	0.015	0.163	2.230	0.000	2.490
BUFF.PT	19.0	****	7.50	3.812	0.013	0.086	3.370	0.150	0.000
RUSH	20.0	****	8.50	3.914	0.012	0.086	4.030	0.030	2.200

SURVEY DATE 06-26-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	25.0	7.1	1.25	2.975	0.006	0.077	0.180	0.739	0.000
PONCA	24.0	8.4	1.65	2.770	0.012	0.184	0.333	1.893	0.000
PRUITT	25.5	7.2	2.40	2.920	0.006	0.206	0.000	2.070	0.000
JASPER	22.8	8.7	20.00	3.230	0.030	0.483	0.000	2.070	0.000
HASTY	26.8	8.4	2.25	3.345	0.014	0.184	0.000	1.744	0.000
GILBERT	26.8	9.2	1.90	3.395	0.007	0.270	0.000	2.070	0.000
HWY-14	28.8	10.1	1.50	3.820	0.020	0.206	0.000	1.242	0.000
BUFF.PT	28.8	9.7	2.20	3.280	0.007	0.142	0.000	1.656	0.000
RUSH	29.0	10.4	2.00	4.230	0.007	0.163	0.254	3.135	0.000

SURVEY DATE 07-[illegible]-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	****	****	*****	*****	*****	*****	*****	*****	*****
PONCA	25.2	7.5	7.50	3.590	0.005	0.132	0.000	4.494	0.000
PRUITT	27.0	10.3	1.50	3.675	0.001	0.172	0.000	4.582	0.000
JASPER	27.0	5.0	2.75	3.575	0.012	0.132	0.000	4.582	0.000
HASTY	28.5	4.2	3.00	4.195	0.018	0.152	0.031	3.489	0.000
GILBERT	29.0	11.0	1.60	4.590	[illegible]	0.112	0.000	5.675	0.000
HWY-14	30.0	6.3	1.50	4.715	[illegible]	0.092	0.942	4.139	0.000
BUFF.PT	30.0	4.1	1.80	4.715	0.026	0.112	0.000	1.656	0.000
RUSH	30.0	5.0	1.00	5.410	0.014	0.112	0.000	1.507	0.000

SURVEY DATE 09-04-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
BOXLEY	****	****	*****	*****	*****	*****	*****	*****	*****
PONCA	27.0	8,4	1,70	4.240	0.030	0.242	3.480	0,000	0.000
PRUITT	29.0	8.4	3.40	4.540	0.040	0.163	2.812	[illegible]	2.021
JASPER	29.0	8.8	2.10	4.730	0.070	0.242	3.593	0.000	2.711
HASTY	30.0	8.6	7.00	4.540	0.030	0.124	2.668	0.239	1.982
GILBERT	30.0	12.5	1.30	5.220	0.030	0.222	1.073	0.554	1.853
HWY-14	32.0	12.0	[illegible]	4.710	[illegible]	0.144	7.201	1.988	3.374
BUFF.PT	[illegible]	[illegible]	[illegible]	3.750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RUSH	31.0	9.2	1.70	[illegible]	0.040	*****	0.647	0,799	0.000

SURVEY DATE 10-[illegible]6-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
PONCA	17.0	7.4	0.98	4.470	0.014	0.141	1.508	0.682	2.446
PRUITT	19.0	7.8	1.90	4.315	0.011	0.141	3.596	0.000	1.611
HASTY	19.0	8.5	2.50	4.550	0.008	0.121	3.596	0.000	1.611
GILBERT	20.0	9.6	1.00	4.535	0.023	0.082	0.609	0.711	2.044
HWY-14	20.0	10.1	1.00	4.375	0.035	0.102	0.899	0.000	0.403
RUSH	20.0	9.0	2.50	3.935	0.017	0.082	0.928	0.000	0.000

SURVEY DATE 12-10-75

STATION	TEMP	D.O.	NTU	SILICA	ORTHO PHOS	NITRATE	CHLOROPHYLL A	CHLOROPHYLL B	CHLOROPHYLL C
PONCA	7.0	10.5	7.90	0.938	0.000	0.211	0.409	0.562	0.262
PRUITT	7.0	11.0	9.25	0.705	0.013	0.229	0.087	1.539	3.777
GILBERT	9.0	10.8	12.00	0.721	0.026	0.380	1.015	1.185	3.406
HWY-14	9.0	11.2	14.00	0.705	0.042	0.380	0.760	1.776	2.073
RUSH	9.0	11.0	14.00	0.833	0.031	0.417	0.533	2.041	0.000

Table 2

TEMPORAL DISTRIBUTION OF ALGAE

Sampling Station	
1	Boxley
p	Ponca
2	Pruitt
3	Jasper
4	Hasty
5	Gilbert
6	Highway 14
7	Buffalo Point
8	Rush

SAMPLE DATE	21 Oct. 74									21 Sept. 74									19 Aug. 74								24 Jul. 74							1 Jul. 74		
	8	7	6	5	4	3	2	P	1	8	7	6	5	4	3	2	P	1	8	7	6	5	4	3	2	P	8	7	6	5	4	3	2	4	3	P
CHLOROPHYCEAE																																				
Volvocales					X				X				X						X				X	X						X					X	X
Tetrasporales									X														X	X			X			X	X					X
Chlorococcales	X				X				X	X										X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ulotrichales																														X						
Chaetophorales	X		X				X		X		X							X			X	X			X	X	X	X	X	X	X	X	X		X	
Cladophorales	X		X							X	X		X							X												X	X	X	X	X
Oedogonales	X	X	X	X	X		X		X	X	X		X			X		X	X	X	X	X			X	X	X	X		X	X	X	X			X
Charales																																				
CONJUGATOPHYCEAE																																				
Zygnematales	X	X	X		X		X		X	X	X		X	X		X		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Desmidales					X		X		X	X			X						X	X			X	X				X	X	X		X	X	X	X	X
Mesotaeniales																														X		X				
EUGLENOPHYCEAE	X	X																					X													X
PYRRHOPHYCEAE									X															X												X
XANTHOPHYCEAE			X																																	
CHRYSOPHYCEAE																					X														X	X
CYANOPHYCEAE																																				
Chroococcales			X	X		X	X		X										X	X	X	X	X			X	X	X		X	X	X	X	X	X	X
Chamaesiphonales	X									X			X								X									X	X				X	
Oscillatoriales	X	X	X	X	X	X	X		X	X		X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RHODOPHYCEAE														X																X						
BACILLARIOPHYCEAE																																				
Centrales	X	X	X	X	X	X	X	X	X	X	X			X		X		X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X
Pennales	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SAMPLE DATE	28 July 75									16 June 75									12 May 75									12 Apr. 75								
	8	7	6	5	4	3	2	p	1	8	7	6	5	4	3	2	p	1	8	7	6	5	4	3	2	p	1	8	7	6	5	4	3	2	p	1
CHLOROPHYCEAE																																				
Volvocales														X	X																					
Tetrasporales					X					X							X								X	X	X									
Chlorococcales			X	X	X	X	X	X		X	X	X	X	X	X	X	X			X						X										
Ulotrichales																		X											X				X		X	
Chaetophorales						X		X		X	X		X	X	X	X	X	X		X		X														
Cladophorales						X		X				X																X					X	X	X	X
Oedogonales	X	X	X		X					X	X	X	X		X		X						X			X										
Charales			X																																	
CONJUGATOPHYCEAE																																				
Zygnematales		X	X	X	X	X	X	X		X	X	X			X	X	X	X		X			X			X	X						X			X
Desmidales							X									X	X	X	X		X	X	X	X	X	X	X		X			X			X	X
Mesotaeniales																																				
EUGLENOPHYCEAE																																				
PYRRHOPHYCEAE																																				
XANTHOPHYCEAE																																				
CHRYSOPHYCEAE	X		X			X		X							X																					
CYANOPHYCEAE																																				
Chroococcales	X		X	X	X					X								X	X	X	X	X	X	X	X			X					X			
Chamaesiphonales			X																																	
Oscillatoriales	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
RHODOPHYCEAE	X											X	X			X																				X
BACILLARIOPHYCEAE																																				
Centrales			X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Pennales	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SAMPLE DATE	8 Mar. 75									24 Jan. 75									17 Dec. 74									27 Nov. 74								
	8	7	6	5	4	3	2	P	1	8	7	6	5	4	3	2	P	1	8	7	6	5	4	3	2	P	1	8	7	6	5	4	3	2	P	1
CHLOROPHYCEAE																																				
Volvocales																																				
Tetrasporales							X		X																										X	
Chlorococcales			X				X		X						X	X				X		X		X							X				X	
Ulotrichales																	X	X	X							X										
Chaetophorales								X		X	X	X				X	X	X	X							X		X	X	X			X			
Cladophorales				X	X		X					X	X				X																			
Oedogonales										X								X								X	X					X	X			
Charales																																				
CONJUGATOPHYCEAE																																				
Zygnematales																X	X	X						X	X		X						X			
Desmidales	X			X	X	X	X	X	X		X	X	X	X	X	X	X	X		X		X	X	X	X	X	X				X			X	X	X
Mesotaeniales																								X		X										
EUGLENOPHYCEAE																																				
PYRRHOPHYCEAE																																				
XANTHOPHYCEAE																																				
CHRYSOPHYCEAE																																				
CYANOPHYCEAE																																				
Chroococcales						X			X							X	X	X							X											
Chamaesiphonales																																				
Oscillatoriales		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X		X		X	X	X	X	X
RHODOPHYCEAE																X		X																		
BACILLARIOPHYCEAE																																				
Centrales	X	X	X	X	X	X	X	X	X			X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Pennales	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SAMPLE DATE	4 Sept. 75									16 Oct. 75						10 Dec. 75				
	1	p	2	3	4	5	6	7	8	p	2	4	5	6	8	p	2	5	6	8
CHLOROPHYCEAE																				
Volvocales											X									
Tetrasporales										X										
Chlorococcales		X	X	X	X	X	X	X		X	X	X								
Ulotrichales																				
Chaetophorales		X	X	X	X	X	X			X	X	X	X		X					
Cladophorales		X					X		X				X	X	X			X		
Oedogonales		X	X	X	X	X	X	X	X	X			X	X	X					X
Charales							X							X						
CONJUGATOPHYCEAE																				
Zygnematales		X	X	X		X	X	X	X	X										X
Desmidales										X	X				X					
Mesotaenales																				
EUGLENOPHYCEASE																				
PYRRHOPHYCEAE																				
XANTHOPHYCEAE																				
CHRYSOPHYCEAE				X		X			X											
CYANOPHYCEAE																				
Chroococcales			X		X			X		X	X		X	X	X	X	X		X	
Chamaesiphonales		X				X			X						X					
Oscillatoriales		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
RHODOPHYCEAE											X		X	X	X					
BACILLARIOPHYCEAE																				
Centrales			X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Pennales		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 3

Buffalo National River Algal Species

Organisms listed alphabetically under order, class and division.

BUFFALO NATIONAL RIVER ALGAL SPECIES LIST

- CHLOROPHYCEAE
  - VOLVOCALES
    - CHLAMYDOMONAS ANGULOSA DILL.
    - CHLAMYDOMONAS PETRYI GOROSHANKIN
    - EUDORINA ELEGANS EHRENBERG
    - GONIUM SOCIALE (DUJ.) WARMING
    - SPONDYLOSIUM PYGAEUM RABENHORST
  - TETRASPORALES
    - APIOCYSTIS BRAUNIANA NAEGELI
    - GLEOCYSTIS BOTRYOIDES (KUTZ.) NAGELI
    - GLEOCYSTIS MAJOR
    - GLEOCYSTIS VESICULOSA NAGELI
    - SPHAEROCYSTIS SCHROETERI CHODAT
    - TETRASPORA GELATINOSA (VAUCH.) DESVAUX
  - CHLOROCOCCALES
    - ANKISTRODESMUS FALCATUS (CORDA) RALFS
    - CHARACIUM AMBIGUUM HERMANN
    - COELASTRUM RETICULATUM (DANG.) SENN.
    - CRUCIGENIA IRREGULARIS WILLE
    - CRUCIGENIA TRAPEDIA (KIRCH.) W. & G.S. WEST
    - KIRCHNERIELLA LUNARIS (KIRCHNER) MOBIUS
    - PEDIASTRUM BORYANUM (TURP) MENEGHINI
    - PEDIASTRUM DUPLEX MEYEN
    - PEDIASTRUM SIMPLEX (MEYEN) LEMMERMAN
    - PEDIASTRUM TETRAS (EHR.) RALFS
    - SCENEDESMUS ABUNDANS (KIRCH) CHODAT
    - SCENEDESMUS ACUMINATUS (LAG.) CHODAT
    - SCENEDESMUS BIJUGA (TURP) LAGERHEIM
    - SCENEDESMUS BIMORPHOUS (TURP.) KUTZING
    - SCENEDESMUS BRASILIENSIS BOHLIN
    - SCENEDESMUS INCRASSATULUS BOHLIN
    - SCENEDESMUS OBLIQUUS (TURP.) KUTZING
    - SCENEDESMUS OPOLIENSIS P. RICHTER
    - SELANASTRUM WESTII G.M. SMITH
    - SORASTRUM SPINULOSUM NAEGELI
  - ULOTRICHALES
    - ULOTHRIX TENERRIMA KUTZ
    - ULOTHRIX ZONATA (WEBER & MOHR) KUTZING
  - CHAETOPHORALES
    - APHANOCHAETE POLYCHAETE (HANSG.) FRITSCH
    - APHANOCHAETE REPENS A. BRAUN
    - CHAETOPHORA ATTENUATA HAZEN
    - COLEOCHAETE DIVERGENS PRINGSHEIM
    - COLEOCHAETE ORBICULARIS PRINGSHEIM
    - COLEOCHAETE SCUTATA BREB.
    - GOMONTIA HOLDENII COLLINS
    - GONGROSIRA DEBARYANA RABENHORST
    - STIGEOCLONUM NANUM KUETZING
    - STIGEOCLONUM TENUE (AGARDH) KUTZING
  - CLADOPHORALES
    - BASICLADIA CHELONUM (COLLINS) HOFFMAN & TILDEN
    - CLADOPHORA FRACTA (DILLW.) KUETZING
    - CLADOPHORA GLOMERATA (L.) KUETZING
    - RHIZOCLONIUM HIEROGLYPHICUM (C.A. AGARDH) KUTZ.
  - OEDOGONALES
    - BULBOCHAETE PYGMEA PRINGSHEIM
    - BULBOCHAETE SP. DE BARY
    - OEDOGONIUM SP. LINK
  - CHARALES
    - CHARA FRAGILIS DESVAUX

CONJUGATOPHYCEAE
ZYGNEMATALES
MOUGEOTIA GOTLANDICA (CLEVE) WITTROCK
MOUGEOTIA SP. AGARDH
SPIROGYRA HYMENAE BRITTON & SMITH
SPIROGYRA SP. LINK
DESMIDALES
COSMARIUM COSTATUM NORDST.
COSMARIUM DEPRESSUM WEST&WEST
COSMARIUM BOTRYTIS MENEGHINI
COSMARIUM CUCUMIS CORDA
COSMARIUM GALERITUM NORDST.
COSMARIUM GRANATUM BREB.
COSMARIUM NOTABILE BREB.
COSMARIUM OCHTHOIDES WEST & WEST
COSMARIUM PSEUDOBROOMEI WOLLE
COSMARIUM PSEUDOPROTUBERANS KIRCH.
COSMARIUM PYRAMIDATUM BREBISSON
COSMARIUM QUADRATUM IRENEE-MARIE
COSMARIUM SUBIMPRESSULUM CEDERCREUTZ & GRONBLAD
COSMARIUM TAXICHONDRUM LUND
COSMARIUM TENUE ARCH.
COSMARIUM TURPINII BREBISSON
CLOSTERIUM ABRUPTUM (LYNGB.) BREBISSON
CLOSTERIUM ACEROSUM (SCHRANK) EHRENBERG
CLOSTERIUM LUNULA NITZSCH.
CLOSTERIUM MONILIFERUM EHRENB.
CLOSTERIUM PARVULUM NAG.
CLOSTERIUM PSEUDODIANAE ROY
CLOSTERIUM TUMIDUM JOHNSON
CHLOROPHYCEAE PENIUM MARGARITACEUM (EHR.) BREB.
PENIUM MARGARITACEUM (EHR.)BREB.
STAURADESMUS PUNCTULATUM BREB
MESOTAENIALES
CYLINDROCAPSA CONFERTA W. WEST
CYLINDROCAPSA GEMINELLA WOLLE
EUGLENOPHYCEAE
EUGLENALES
EUGLENA ACUS EHREN.
PHACUS ORBICULARIS HUBNER
TRACHLOMONAS ABRUPTA DEFLANDRE
TRACHLOMONAS HISPIDA (PERTY) STEIN
PYRRHOPHYCEAE
PERIDINALES
CERATIUM HIRUDINELLA (O.F.M.) SCHRANK
PERIDINIUM SP. EHRENBERG
XANTHOPHYCEAE
HETEROSIPHONALES
VAUCHERIA LONGIPES COLLINS
CHRYSOPHYCEAE
CHRYSOMONADALES
DINOBRYON CAMPANULOSTIPITATUM AHLSTROM
DINOBRYON DIVERGENS IMHOF
MALLOMONAS ALPINA PASHER & RUTTNER
MALLOMONAS HELVETICA
SYNURA PETERSENII KORSH
OCHROMONADALES
ANTHOPHYSA VEGETANS (MULL.) STEIN
CYANOPHYCEAE
CHROOCOCCALES
ANACYSTIS MONTANA (LIGHTFOOT) DROUET & DAILY

ANACYSTIS THERMALIS (MENEGHINI) DROUET & DAILY
APHANOCAPSA ELACHISTA WEST & WEST
APHANOCAPSA PULCHRA (KUTZ.) RABENHORST
APHANOTHECE CONFERTA RICHTER
CHROOCOCCUS GIGANTEUS W. WEST
CHROOCOCCUS MINUTUS (KUTZ.) RABENH.
CHROOCOCCUS MULTICOLORATUS WOOD
CHROOCOCCUS VARIUS A. BRAUN
ENTOPHYSALIS CONFERTA DROUET & DAILY
ENTOPHYSALIS RIVULARIS (KUETZING) DROUET
GLEOCAPSA ALPICOLA (LYNG.) BORNET
GLEOCAPSA GLOMERATA KUTZ.
GLOECAPSA GRANOSA (BERK.) KUTZING
GLOECAPSA NIGRESCENS KUETZING
GLEOCAPSA POLYDERMATICA KUTZING
GOMPHOSPHERIA WICHURAE (HILSE.) DR. & DA.
MERISMOPEDIA CONVOLUTA BREB.
MERISMOPEDIA GLAUCA (EHR.) NAG.
MERISMOPEDIA MAJOR G.M. SMITH
MERISMOPEDIA PUNCTATA MEYEN
MERISMOPEDIA TENUISSIMA LEMM.
MICROCYSTIS INSERTA WEST
PLEUROCAPSA MINOR HANSG.
POLYCYSTIS AERUGINOSA KUTZ.
POLYCYSTIS FIRMA (KUTZ.) DR. & DAILY

CHAMAESIPHONALES

CHAMAESIPHON INCRUSTANS GRUN.
CHAMAESIPHON REGULARIS GEITLER

OSCILLATORIALES

ANABAENA CONFERVOIDES REINSCH
BEGGIATOA ARACHNOIDEA (AG.) RBH.
CALOTHRIX BRAUNII BORNET & FLAHAULT
CALOTHRIX JULIANA BORN &FLAH.
CALOTHRIX MINIMA FREMY
CALOTHRIX PARIETINA (NAG.) THURET
DICHOTHRIX BAUERIANA (GRUN.) BORN & FLAH.
FISCHERELLA AMBIGUA (NAG.) GOMONT
GLOETHECE CONFLUENS NAG.
LYNGBYA BIRGEI G.M. SMITH
LYNGBYA DIGUETI GOM.
LYNGBYA HIERONYMUSII LEMMERMANN
LYNGBYA LUTA (AGARDH) GOMONT
LYNGBYA MAJOR MENEGHINI
MICROCOLEUS SOCIATUS W. & G.S. WEST
NOSTOC ENTOPHYTUM BORN. & FLAH.
NOSTOC PUNCTIFORME (KUTZ.) HARIOT
NOSTOC SPHAERICUM VAUCH.
OSCILLATORIA AMPHIBIA AGARDH
OSCILLATORIA ANGUSTISSIMA WEST & WEST
OSCILLATORIA BREVIS KUTZ.
OSCILLATORIA GEMINATA MENEGHINI
OSCILLATORIA LIMOSA (ROTH.) AG.
OSCILLATORIA PRINCEPS VAUCHER
OSCILLATORIA PROLIFICA (GREVILLE) GOMONT
OSCILLATORIA TENUIS AG.
PHORMIDIUM AMBIGUUM GOMONT
PHORMIDIUM INUNDATUM KUETZING
PHORMIDIUM NAVEANUM GRUNOW
PHORMIDIUM RETZII (AGARDH) GOMONT
SCYTONEMA TOLYPOTHRICHOIDES KUTZING
SPIRULINA MAJOR KUTZ.

SPIRULINA PRINCEPS WEST & WEST
STIGONEMA TOMETOSUM (KUTZ.) HIERONYMUS
TOLYPOTHRIX CONGLUTINATA BORZI
TOLYPOTHRIX DISTORTA KUETZING
TOLYPOTHRIX TENUIS KUTZING
TRICHODESMIUM LAUCUSTRE KLEBAHN

RHODOPHYCEAE

NEMALIONALES

ASTEROCYSTIS RAMOSA (THWAITES) GOBI.
ADOUINELLA VIOLACEA KUTZ.
CHROODACTYLON RAMOSUM (THWAITE) HANSG.
COMPSOPOGON COERULEUS (BALBIS) MONTAGNE
COMPSOPOGONOPSIS LEPTOCLADOS KIRSH.
LEMANEA AUSTRALIS AIKINSON

BACILLARIOPHYCEAE

ACHNANTHES HAUCKIANA GRUNOW
ACHNANTHES INFLATA KUTZ.
ACHNANTHES LANCEOLATA BREB.
ACHNANTHES MINUTISSIMA KUTZ.
AMPHIPLEURA PELUCIDA KUTZ.
CALONEIS VENTRICOSA (EHR,) MEIST
COCCONEIS DISCULUS SCHUM.
COCCONEIS PEDICULUS EHR.
COCCONEIS PLACENTULA EHR.
COCCONEIS RUGOSA SOV.
COCCONEIS SCUTELLUM EHR.
CYMATOPLEURA CAMPLODISCUS BAIL.
CYMATOPLEURA ELLIPTICA (BREB.) W. SMITH
CYMATOPLEURA SOLEA (BREB.) W. SMITH
YMBELLA AFFINIS KUTZ.
CYMBELLA LAEVIS NAEG.
CYMBELLA PROSTRATA (BERKELEY) CLEVE
CYMBELLA SINUATA GREGORY
CYMBELLA TUMIDA (BREB.) VON HUERCK
CYMBELLA TURGIDA (GREGORY) CLEVE
CYMBELLA VENTRICOSA KUTZ.
DIATOMA VULGARE BORY.
DIPLONEIS OSTRACODARUM (PANT.) JUR.
EPITHEMIA ARGUS KUTZ.
EPITHEMIA SOREX KUTZ.
EPITHEMIA TURGIDA (EHR.) KUTZING
EUNOTIA ARCUS EHR.
EUNOTIA PECTINALIS (O.F. MULL.) RABH.
FRAGILLARIA BREVISTRIATA GRUN.
FRAGILARIA CAPUCINA DESMAZIERWS
FRAGILARIA CROTONENSIS KITTON
FRAGILLARIA INTERMEDIA GRUNOW
FRUSTULIA RHOMBOIDES (EHR.) DE TONI
FRUSTULIA VULGARIS THWAITES
GOMPHONEMA ACUMINATUM EHR.
GONPHONEMA ANGUSTATUM (KUTZ.) RABH.
GONPHONEMA AUGUR EHR.
GONPHONEMA CONSTRICTUM EHR.
GONPHONEMA OLIVACEUM (LYNG.) KUTZ.
GYROSIGMA KUTZINGII (GRUN.) CLEVE
GYROSIGMA SCALPROIDES (RABH.) CLEVE
GYROSIGMA SPENCERII (QUEK.) GRIFF. & HENFR.
HANTZSCHIA AMPHOIXYS (EHR.) GRUN.
MASTIGLLIA BRAUNII GRUN.
MERIDION CIRCULAIRE AG.
NAVICULA BACILLUM EHR.

NAVICULA BICEPHALA
NAVICULA COCCONEIFORMIS GREG.
NAVICULA COMMUTATA (GRUN.) A. SCHMIDT
NAVICULA CONTENTA GRUN.
NAVICULA CRYPTOCEPHALA KUTZ.
NAVICULA EXIGUA (GREGORY) O. MILLER
NAVICULA GASTRUM (EHR.) DONK.
NAVICULA GUATAMALENSIS CL. & GRUN.
NAVICULA HALOPHILLA (GRUN.) CL.
NAVICULA HUNGARICA GRUN.
NAVICULA PENNATA PANT.
NAVICULA PEREGRINA (EHR.) KUTZ.
NAVICULA PLACENTULA EHR.
NAVICULA PUPULA KUTZ.
NAVICULA PYGMEA KUTZ.
NAVICULA RADIOSA KUTZ.
NAVICULA REINHARDTII GRUN.
NAVICULA SUBTILISSIMA CL.
NAVICULA VIRIDULA KUTZ.
NEDIUM AFFINE (EHR.) PFITZ.
NEDIUM APICULATUM REIM
NEDIUM DUBIUM (EHR.) CLEVE
NITZSCHIA ACICULARIS W. SMITH
NITZSCHIA DENTICULA GRUN.
NITZSCHIA DISSIPATA (KUTZ.) GRUN.
NITZSCHIA FILIFORMIS (W. SMITH) HUST.
NITZSCHIA FONTICOLA GRUN.
NITZSCHIA HOLSATICA HUST.
NITZSCHIA LACUNARUM HUST.
NITZSCHIA PALEA (KUTZ.) W. SMITH
NITZSCHIA PARADOXA CLEVE & GRUN.
NITZSCHIA PARVULA LEVIS
NITZSCHIA SIGMOIDEA (EHR.) W. SMITH
NITZSCHIA TABELLARIA (GRUN.) CLEVE & GRUN.
PINNULARIA ABAUJENSIS (PANT.) ROSS
PINNULARIA BREBISSONI (KUTZ.) RABH.
PINNULARIA GIBBA EHR.
PINNULARIA MICROSTAURON (EHR.) CL.
PINNULARIA SUDETICA HILSE
PLEUROSIGMA DELICATULUM W. SMITH
RHOPHALODIA GIBBA (EHR.) MULLER
STAURONEIS CRUCICULA (W. SMITH) DONK.
STAURONEIS OBTUSA LAGERST
STAURONEIS PHOENICENTERON (NITZ.) EHR.
STAURONEIS SMITHII GRUN.
SURIRELLA ANGUSTATA KUTZ.
SURIRELLA BISERIATA BREB.
SURIRELLA BRIGHTWELLI
SURIRELLA OVALIS BREB.
SURIRELLA OVATA KUTZ.
SURIRELLA ROBUSTA EHR.
SURIRELLA SPLENDIDA EHRB. MIK.
SURIRELLA TENERA GREGORY
SYNEDRA ACTINASTROIDES LEMM.
SYNEDRA ACUS KUTZ.
SYNEDRA TABULATA (AG.) KUTZ.
SYNEDRA ULNA (NITZ.) EHRENBERG
CYCLOTELLA ATOMUS HUST.
CYCLOTELLA GLOMERATA BACHMANN
MELOSIRA CRENULATA KUTZ.
MELOSIRA VARIANS AGARDH
STEPHANODISCUS ASTREA (EHR.) GRUN.

ANALYSIS OF FECAL CONTAMINATION

A study was conducted in order to determine the magnitude and source of fecal contamination in a selected section of the Buffalo National River. This was considered to be important because, during previous sampling studies, some locations in the river system were found to contain high concentrations of fecal bacteria.

The Arkansas Water Quality Standard for surface water suitable for primary contact recreation states: "Based on a minimum of not less than five samples taken over not more than a 30 day period, the fecal coliform content shall not exceed a log mean of 200/100 ml. nor shall more than ten percent of the total samples during any 30 day period exceed 400/100 ml" (Arkansas Department of Pollution Control and Ecology, 1973).

Procedures

In order to compare the results of this study with the Arkansas Water Quality standards, ten separate sampling trips were taken to the Buffalo National River within a 30 day period between July 16 and August 12. During each trip samples were collected and analyzed for fecal coliforms, fecal streptococcus and turbidity in a stretch of the river between Pruitt and Hastey, Arkansas. Figure 5 shows the location of the study area.

Table 4 gives the location of each of the sampling stations. Stations B1, B2, B3, MC and LB were each sampled ten times during the study. Stations A1 through A10 and C1 through C4 were sampled only once during a float trip taken on August 5. The A samples were

Note: The log mean L of a set of N numbers X_1, X_2, X_3, ---, X_N is the N the root of the product of the numbers. This is the same as the geometric mean.
$L = \sqrt[N]{X_1 X_2 X_3 --- X_N}$

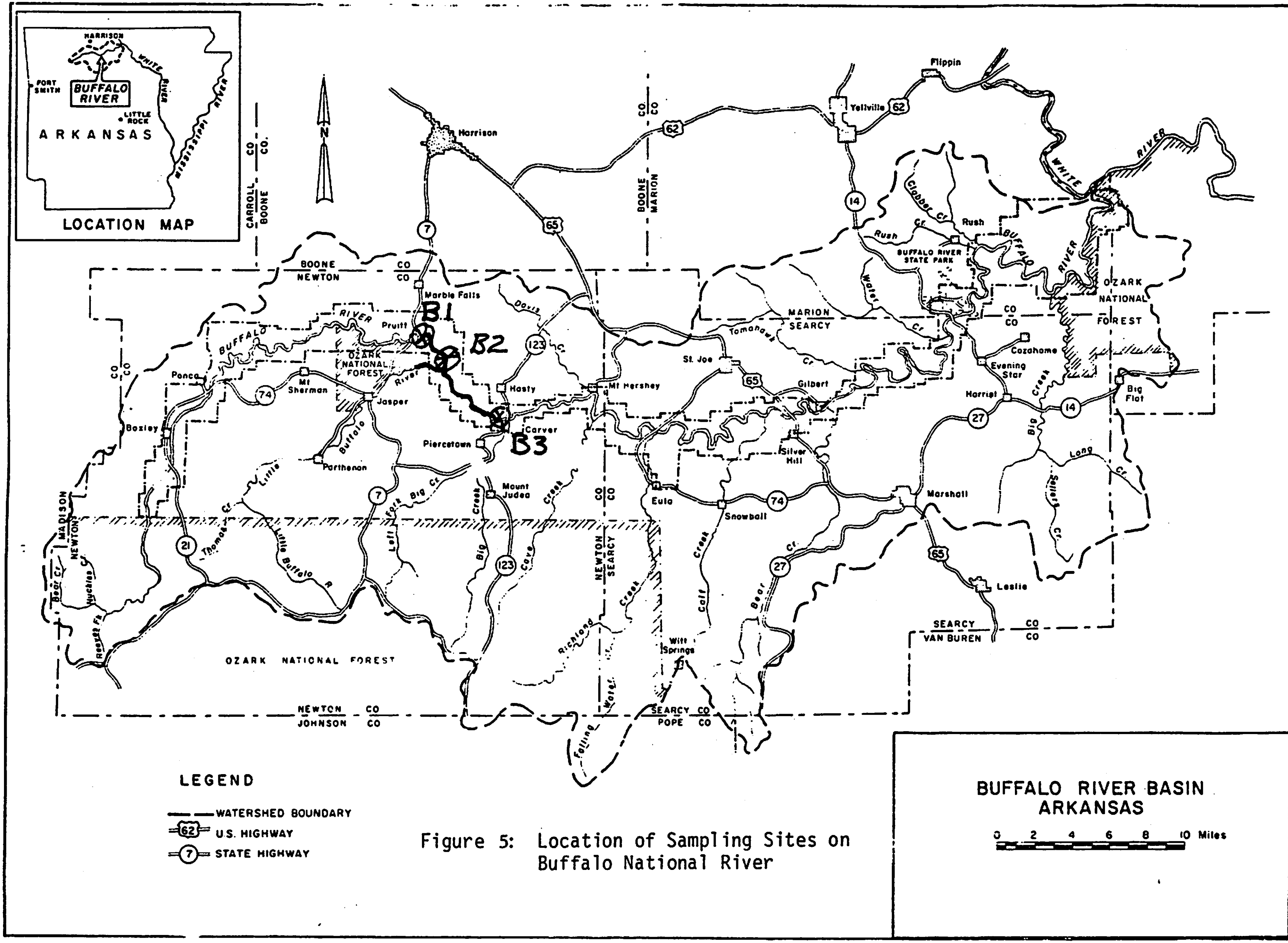


Figure 5: Location of Sampling Sites on Buffalo National River

TABLE 4

SAMPLE LOCATIONS

SAMPLE NUMBER	SAMPLE LOCATION	RIVER MILE
B1	Buffalo River at Pruit above confluence with Mill Creek	103
B2	Buffalo River	101
B3	Buffalo River at Hastey low water bridge	96
MC	Mill Creek above Confluence with Buffalo River	103
LB	Little Buffalo River approximately 1.5 miles upstream from confluence with Buffalo River	99
A1	Same as B1	103
A2	Buffalo River ½ mile below B1	102.5
A3	Buffalo River 1 mile below B1	102
A4	Same as B2	101
A5	Buffalo River ½ mile below B2	100.5
A6	Buffalo River 1 mile below B2	100
A7	Buffalo River 100 yds above confluence with Little Buffalo	99
A8	Buffalo River ½ mile below A7	98.5
A9	Buffalo River ½ mile above B3	96.5
A10	Same as B3	96

TRIBUTARY SAMPLE	TRIBUTARY LOCATION	RIVER MILE
C1	Same as MC	103
C2	Creek on East Bank 3/4 mile below B1	102
C3	Little Buffalo River	99
C4	Creek on East Bank 3/4 mile below C3	98

taken in the Buffalo National River and the C samples were taken in tributaries just upstream from the confluence with the Buffalo River.

Sampling consisted of collecting water in two autoclaved polypropylene bottles. These bottles were stored in a styrofoam chest until they were returned to the lab. One of the bottles was used for turbidity measurements immediately upon returning to the lab. The second bottle was stored in a refrigerator for bacterial analysis. The bacteria samples were processed within twelve hours after returning to the lab. Turbidity was measured using a model 2100A turbidimeter manufactured by Hach Chemical Company. Fecal coliform and fecal streptococcus concentrations were measured according to the membrane filter procedure as set forth in Standard Methods (American Public Health Association, 1971). The concentrations of fecal bacteria are reported as number of organisms per 100 ml. of water.

Results

The fecal coliform and fecal streptococcus concentrations for stations B1, B2, B3, MC and LB are shown in Tables 6 and 7. Fecal coliform concentrations for the Buffalo and Little Buffalo rivers are shown graphically in Figure 6. All concentrations in the Buffalo river were less than 400 coli per 100 ml. and the log mean concentrations for all were less than 200 coli per 100 ml. The fecal coliform concentrations on Mill Creek and the Little Buffalo are shown on Figure 7. The concentrations on Mill Creek are generally higher than the other stations and exceeded 400 coli per 100 ml. on both August 5 and 6th. However, the log mean is still less than 200 coli per 100 ml.

Fecal Coliform - Fecal Streptococcus ratios are shown in Table 5.

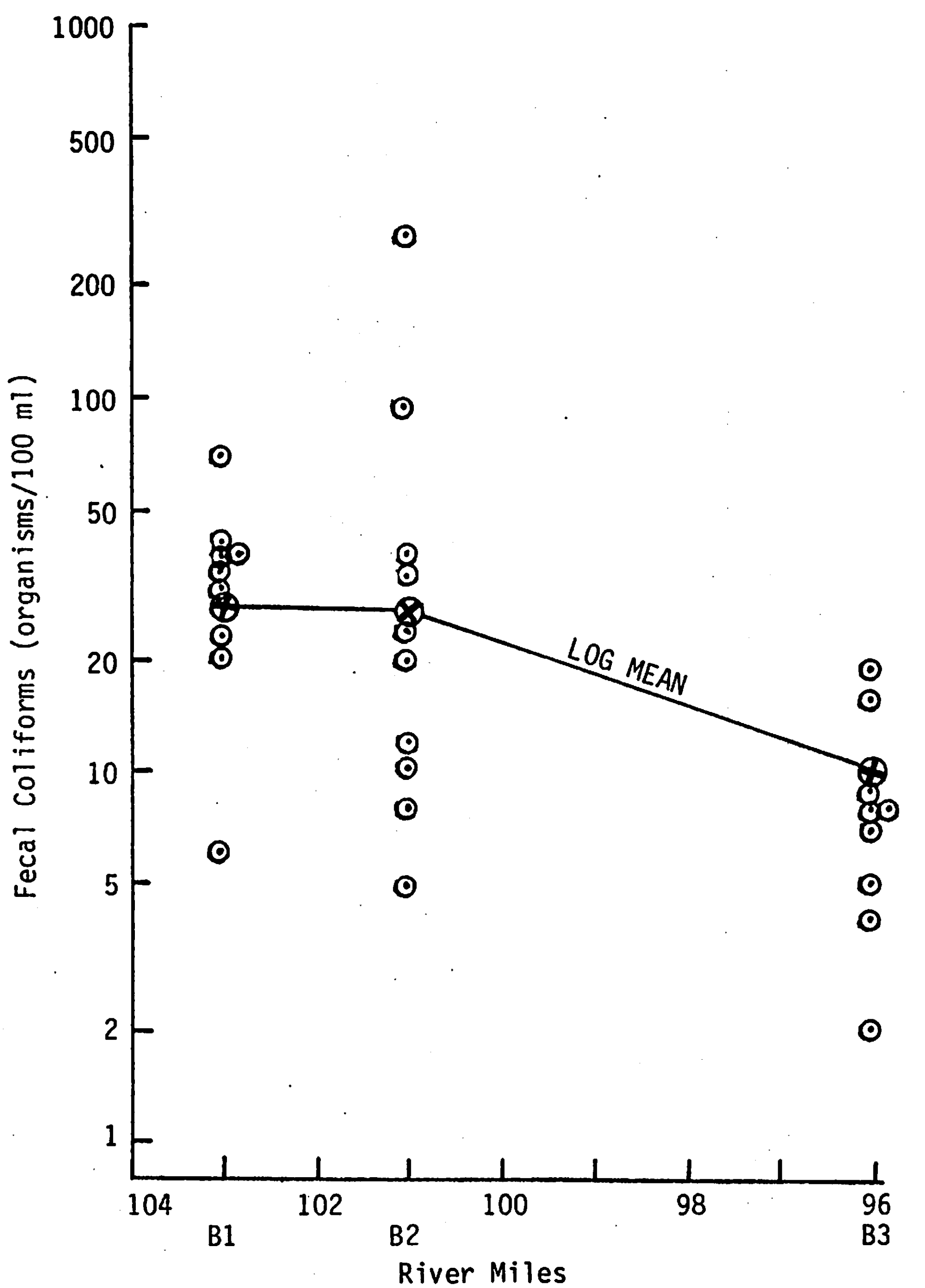


Figure 6: Fecal Coliform Concentrations on Buffalo River (16 July - 12 Aug, 1975)

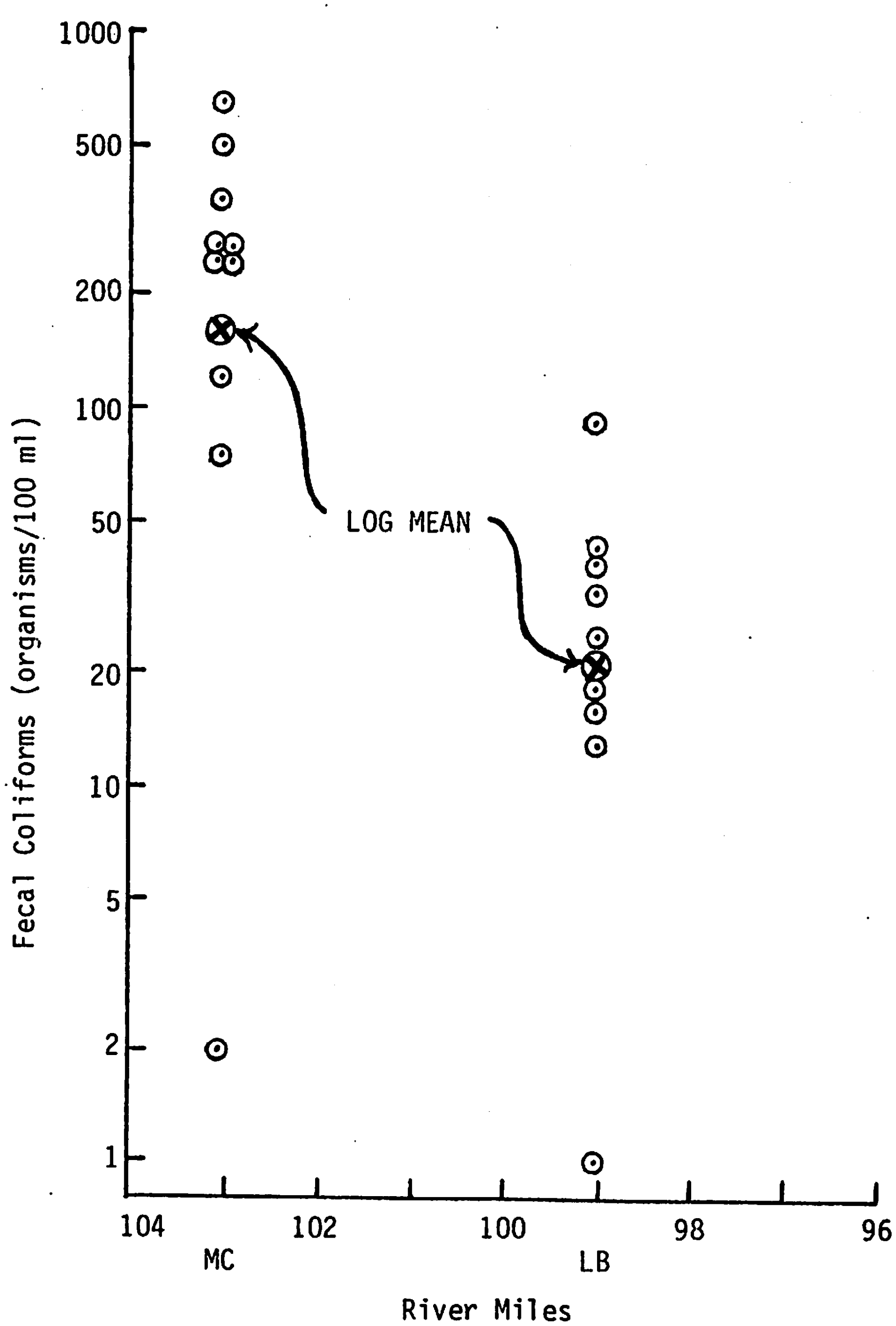


Figure 7: Fecal Coliform Concentrations on Little Buffalo and Mill Creek (16 July-12 Aug, 1975)

TABLE 5

FECAL COLIFORM - FECAL STREPTOCOCCUS RATIO

Sample Date	SAMPLE NO.				
	B1	B2	B3	MC	LB
16 July 75	-	0.6	-	1.8	0.8
18 July 75	-	-	-	-	-
21 July 75	0.8	0.8	-	0.4	0.8
23 July 75	0.9	0.5	-	0.9	0.6
28 July 75	-	0.4	-	1.9	1.7
30 July 75	1.6	0.8	-	0.7	1.2
3 Aug 75	0.6	0.5	-	0.4	0.5
5 Aug 75	0.8	-	-	2.9	-
10 Aug 75	2.8	2.8	-	2.9	0.5
12 Aug 75	0.9	1.2	-	1.1	1.8
Average	1.2	1.0	-	1.4	1.0

Only concentrations of organisms of 10 or greater were used in the calculation because of the lack of accuracy of the lower values. The average ratios were all less than 1.5 and only four of the 32 calculated values were larger than 2.0

Water containing ratios of fecal coliform to fecal streptococcus greater than 4 are assumed to be contaminated by human feces, while ratios less than 1 generally indicate non-human animal contamination (3). Therefore, it appears that most of the contamination in the test area of the river was of non-human origin.

Turbidity in the river is shown on Table 8. All the measured turbidities were less than 10 JTU and the average turbidity at all stations was less than 5. These turbidity values are all low.

The results of samples taken during the float trip on August 5 are shown numerically in Table 9 and graphically in Figure 8. In general, the fecal coliform concentrations showed a decreasing trend in the downstream direction and the concentrations for the tributaries were higher than in the main river. These observations are also apparent in the full study as shown in Figure 6 and Figure 7. Two of the three tributaries sampled had fecal concentrations in excess of 400 coli/100 ml. However, all other concentrations were relatively low.

Discussions of Results

The fecal coliform concentrations in the Buffalo National River and in the Little Buffalo River were generally lower during the sampling period than concentrations measured during previous studies. Furthermore, all of the fecal coliform - fecal streptococcus concentrations were low, indicating predominately non-human contamination.

TABLE 6

FECAL COLIFORM CONCENTRATIONS (organisms/100 ml)

Sample Date	SAMPLE NO.				
	B1	B2	B3	MC	LB
16 July 75	20	12	2	120	25
18 July 75	-	5	7	2	-
21 July 75	38	34	4	76	16
23 July 75	23	24	8	270	19
28 July 75	6	10	8	260	40
30 July 75	34	20	9	260	33
3 Aug 75	70	280	5	360	41
5 Aug 75	40	8	16	660	1
10 Aug 75	31	95	19	500	13
12 Aug 75	39	38	5	270	91
Log Mean	28	25	7	160	20

TABLE 7

FECAL STREPTOCOCCUS CONCENTRATIONS (organisms/100 ml)

Sample Date	SAMPLE NO.				
	B1	B2	B3	MC	LB
16 July 75	2	20	2	68	33
18 July 75	3	15	4	63	8
21 July 75	47	42	10	210	21
23 July 75	25	44	29	308	31
28 July 75	19	24	13	140	23
30 July 75	21	25	9	370	27
3 Aug 75	120	530	35	820	82
5 Aug 75	47	21	2	230	26
10 Aug 75	11	34	5	170	24
12 Aug 75	41	33	18	240	51

TABLE 8

TURBIDITY (FTU)

Sample Date	SAMPLE NO.				
	B1	B2	B3	MC	LB
16 July 75	2	1	3	3	2
18 July 75	3	2	3	4	4
21 July 75	2	2	2	3	3
23 July 75	2	2	3	2	3
28 July 75	2	2	2	2	3
30 July 75	2	2	2	2	3
3 Aug 75	3	8	1	9	3
5 Aug 75	2	2	2	5	2
10 Aug 75	2	3	2	3	2
12 Aug 75	2	3	2	9	3
Average	2.3	2.7	2.3	4.2	2.8

TABLE 9

SAMPLES TAKEN AT FLOAT TRIP ON 5 AUG., 1975

Sample #	River Mile	Fecal Coliforms (organisms/100ml)	Fecal Streptococcus (organisms/100ml)	Fecal Coliform Fecal Streptococcus Ratio
A1	103	40	47	0.8
A2	102.5	100	62	1.6
A3	102	17	38	0.5
A4	101	8	21	-
A5	100.5	26	23	1.1
A6	100	11	12	0.9
A7	99	36	21	1.7
A8	98.5	27	10	2.7
A9	96.5	5	10	-
A10	96	16	2	-
Tributary Sample #				
C1	103	660	230	2.9
C2	102	1100	940	1.2
C3	99	1	26	-
C4	98	77	21	3.7

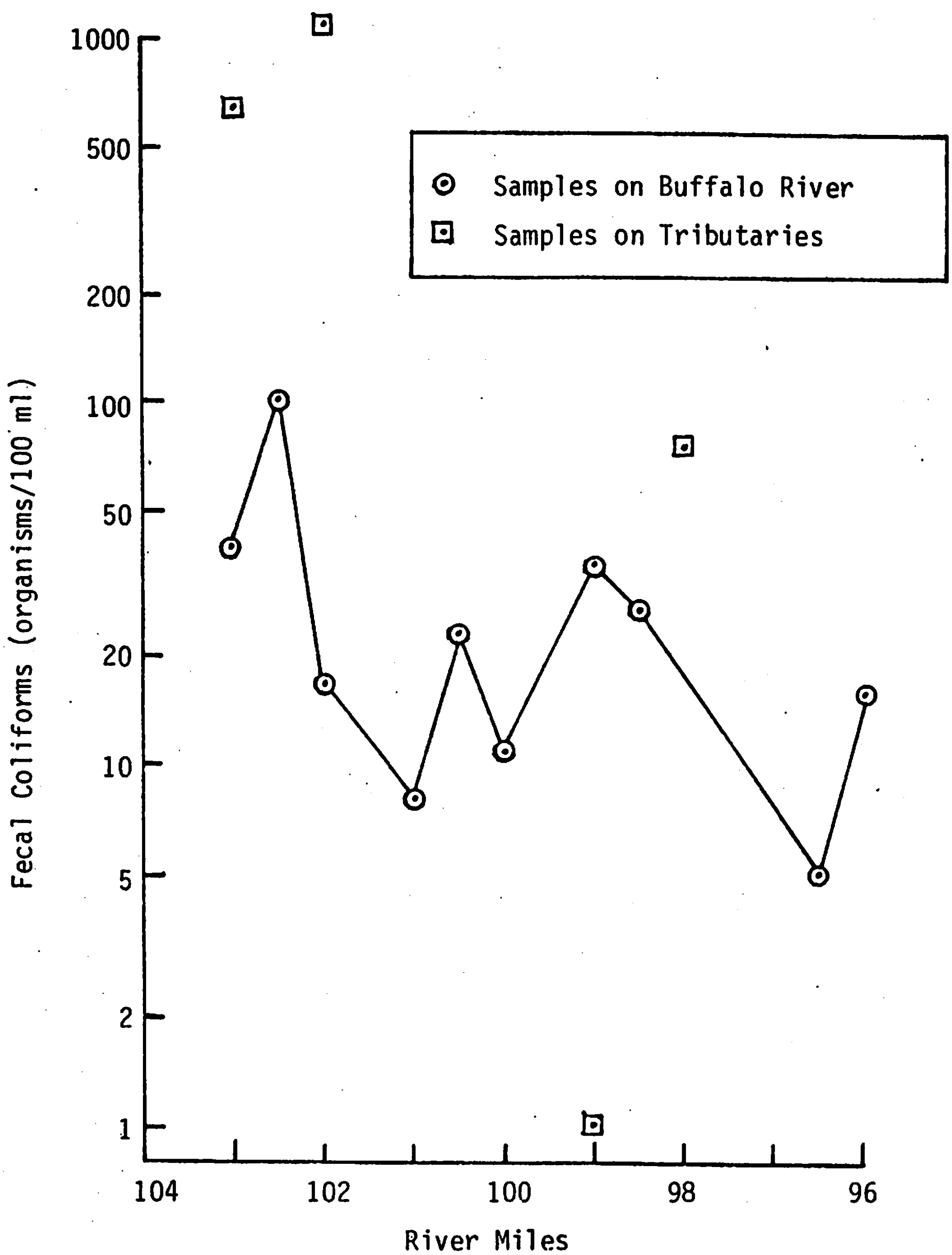


Figure 8: Fecal Coliform Concentrations on Buffalo River and Tributaries (5 Aug, 1975)

One possible explanation for these results in the installation of a sewage treatment plant at Jasper, Arkansas, on the Little Buffalo. This treatment plant was not in operation during previous studies and its installation could have effectively reduced the human contribution of contamination to the Little Buffalo and in the Buffalo River below the confluence with the Little Buffalo.

Comparison with Other Surface Waters

Much of the surface and shallow ground waters in the Arkansas Ozarks contain fecal coliform bacteria. Frequently, measurements in excess of 200 coli/100 ml are recorded. For example, the following data is available for fecal contamination on the Caddo River at Glenwood, Arkansas for the period of September, 1974 to February, 1975. The Caddo River is located in the Ouachita Mountains in Southern Arkansas. The value of fecal contamination for the period mentioned above were: 3170, 30, 20, 26, 4, 40. The first data point is obviously related to a storm event and the other data represent base or low flow data. The log mean value of these six values is 17.0 which compares to values of 28, 25, and 7 for the Buffalo River. However, notice that the log mean value for Mill Creek is considerably higher, being 160.

GEOCHEMISTRY OF SEDIMENT AND WATER

Bottom Sediments, Sample Collection and Preparation

A canoe float trip was taken May 13-16, 1975 on the Buffalo River from Ponca to Highway 65 Bridge. A total of 54 bottom sediment samples - 25 from the river and 29 from the tributaries - were collected (Table 10). These samples were taken from river mile 121.6 to 59.7. Samples were collected from stations shown in Figure 9 May 13, July 18, September 19-20, and December 10. Samples were also collected from tributaries in the Ponca and Rush areas July 18-19. The samples were collected near shore in relatively shallow water. They were dried and sieved through a 95 mesh nylon screen. One gram of the -95 mesh material was treated with 2 ml of aqua regia for 13 hours, diluted to 50 ml and analyzed by atomic absorption spectrometry according to recommendation of Perkin-Elmer Corporation (1970).

Broad Sampling

In general, the metal content of the sediments continues to reflect the geology of the river, (Table 11), Steele, et al., 1975). Sodium (Fig. 10) and potassium (Fig. 11) background levels remained about the same, increasing upstream as a result of the shale environment. The average level for new samples for sodium showed a slight decrease from previous values at Station 2, but still fell well within the range previously reported. The potassium level showed a definite increase at Station 1, from a previous average of about 220 ppm to a new average of 240 ppm.

Table 10. Location of samples for close sampling of the upper part of the Buffalo River. Samples from the main stream of the Buffalo River are indicated by BR, all other samples are from tributaries.

Sample Number		Location Description	Miles from White River
F-1	BR	Bee Bluff	121.6
F-2		Beech Creek	119.1
F-3	BR	Jim Bluff	118.1
F-4		Sneed Creek	117.1
F-5	BR	Lick Ford	115.6
F-6		Bear Creek	114.2
F-7		Clemmons Hollow	112.8
F-8	BR	Camp Orr	112.6
F-9		Shop Creek	111.8
F-10	BR	1.0 mile above Erbie Ford	110.1
F-11		Cecil Creek	109.1
F-12		Webb Branch	108.9
F-13		Conard Fissure	107.5
F-14	BR	0.3 miles below Conard Fissure	107.2
F-15		Sawmill Hollow	103.9
F-16		Brown Cemetery	103.2
F-17	BR	Pruitt	100.9
F-18		Mill Creek	100.4
F-19		Little Buffalo River	97.0
F-20	BR	Lost Hill	96.7
F-21		Unnamed Creek 0.8 miles above Hasty low water bridge	94.3
F-22		Sheldon Branch	92.7
F-23	BR	0.1 miles below Sheldon Branch	92.6
F-24		Elm Spring	90.9
F-25	BR	Carber	89.8
F-26		Big Creek	89.6
F-27		Hancock Hollow	87.5
F-28	BR	0.6 miles below Hancock Hollow	86.9
F-29		Lick Creek	86.5
F-30	BR	0.4 miles below Lick Creek	86.1
F-31	BR	1.0 miles above Davis Creek	84.0
F-32		Davis Creek	83.0
F-33		Mill Branch	82.9
F-34	BR	1.0 miles below Mt. Hersey	81.9
F-35		Cave Creek	80.6
F-36		Cane Branch	79.1
F-37		Small Creek 1.3 miles below Cave Branch	77.8
F-38	BR	1.5 miles below Cave Branch	77.6
F-39	BR	2.4 miles below Cave Branch	76.7
F-40	BR	Richland Valley	75.8
F-41		Roughedge Hollow	75.7
F-42		Richland Creek	74.5
F-43		Jamison Creek	73.2
F-44	BR	1.9 miles below Richland Creek	72.6
F-45	BR	White Ford	70.0

Table 10 Continued

F-46		Creek at Slay Cemetery	68.2
F-47	BR	2.9 miles below White Ford	67.1
F-48		Rocky Hollow	65.4
F-49	BR	Red Bluff	65.1
F-50	BR	Arnold Bend	63.2
F-51		Calf Creek	61.6
F-52	BR	0.3 miles below Calf Creek	61.3
F-53		Mill Creek	60.8
F-54	BR	Buck Point	59.7

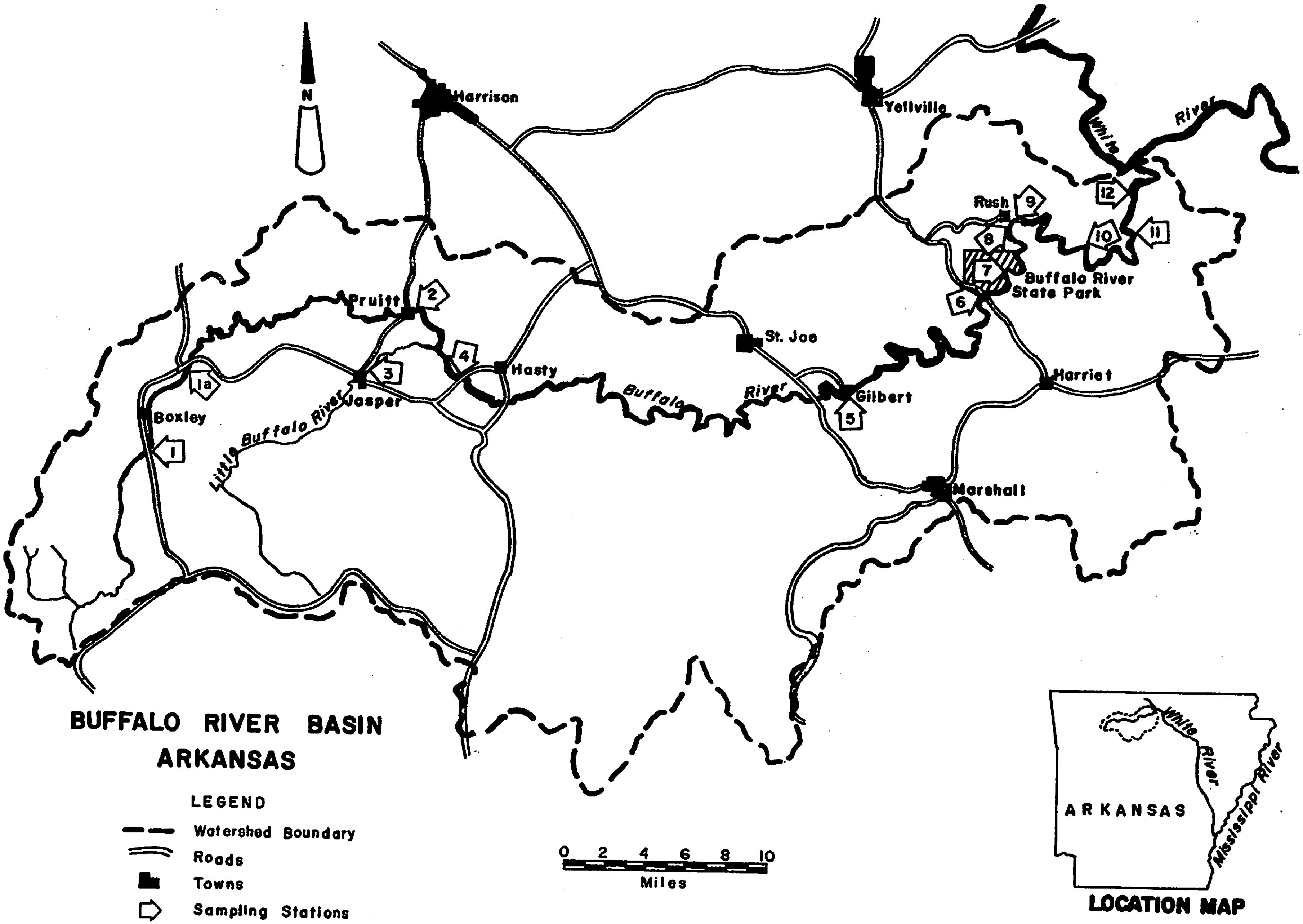


Figure 9. Location of sample stations.

Table 11 Bottom sediment data for seven stations on the Buffalo River (ppm except Fe which is weight percent). River miles in in ( ).

Station	Col. Date	Na	K	Ca	Mg	Fe	Co	Cr	Ni	Cu	Zn	Cd	Pb	Mn
1	M	14	169	555	436	2.08	9	15	16	5	36	1.1	17	700
Boxley	J	-	-	-	-	-	-	-	-	-	-	-	-	-
(130)	S	40	302	682	625	4.84	15	35	29	13	75	0.7	22	1355
	D	26	249	683	600	4.19	18	24	27	10	64	0.3	23	1168
Average		27	240	640	554	3.70	14	25	24	9	58	0.7	21	1074
1A Ponca (120)	J	15	105	2625	183	1.06	6	12	15	1	31	0.5	4	346
2	M	13	117	898	404	1.20	6	12	14	3	44	1.1	9	713
Pruitt	J	15	262	5150	606	2.71	11	14	17	7	74	1.1	20	591
(101)	S	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	12	135	1463	400	1.51	8	13	15	4	54	0.6	14	478
Average		13	171	2504	470	1.81	8	13	15	5	57	0.9	14	594
4 Hasty (94.1)	S	19	184	1113	363	1.76	8	14	19	5	46	0.6	25	419
5	M	13	87	683	163	0.81	5	13	13	2	30	0.7	13	144
Gilbert	J	11	107	1425	218	0.84	7	11	10	2	32	0.7	6	71
(55.2)	S	11	104	947	218	0.99	7	10	10	4	35	0.5	13	258
	D	7	104	1815	203	0.86	5	10	14	3	34	0.8	14	301
Average		11	101	1218	201	0.88	6	11	12	3	33	0.7	12	194
7	M	9	101	1200	486	0.73	4	10	10	2	56	0.7	15	242
Buffalo	J	12	128	7575	521	0.89	7	12	8	3	97	0.7	6	215
Pt.	S	-	-	-	-	-	-	-	-	-	-	-	-	-
(31.4)	D	3	64	1072	159	0.62	5	9	10	2	36	0.4	7	229
Average		8	92	3282	389	0.75	5	10	9	2	63	0.5	9	229
8 Rush (23.3)	S	20	77	9400	1688	0.79	8	9	10	6	658	3	13	186

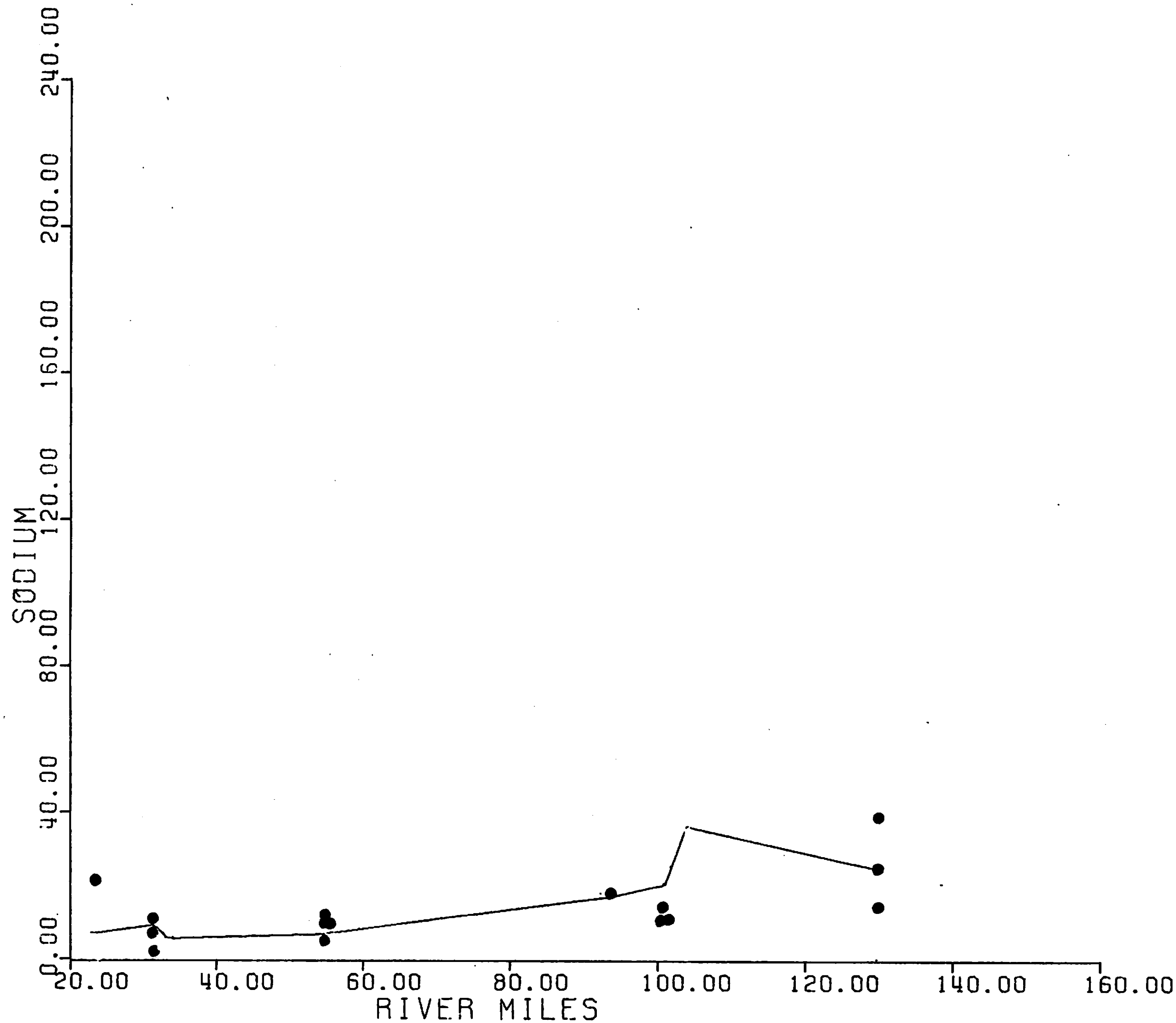


FIGURE 10 NA VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

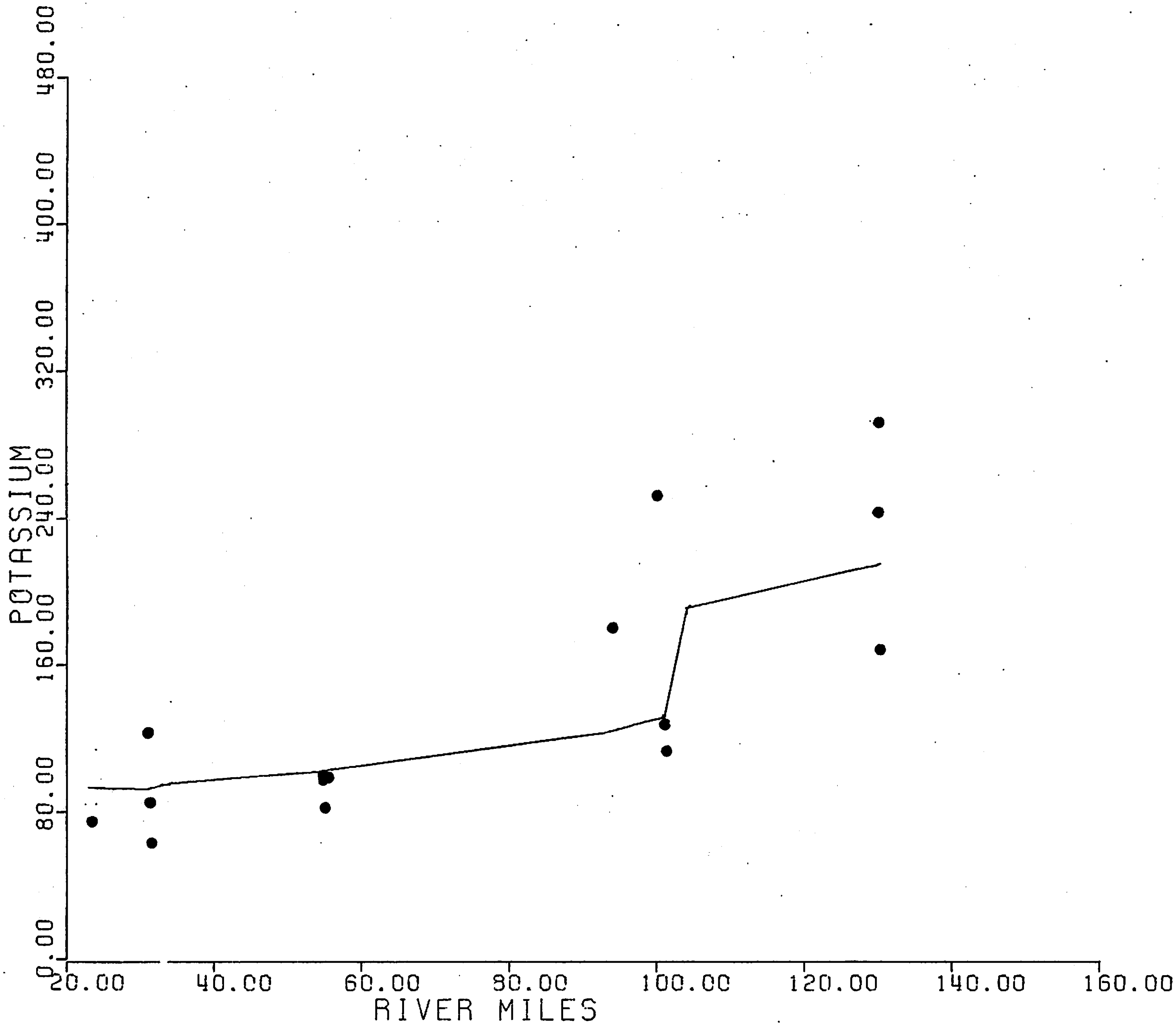


FIGURE 11. K VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

Iron continued to show an increase in concentration upstream, as did the iron - associated elements, Cu, Co, Ni, Cr and Mn (Figs. 12-17). Comparison of 1974 and 1975 data showed several variations. Iron, copper and manganese showed a decrease in average concentrations at Station 5 (Figs. 12, 13 and 17). Nickel and chromium showed an increase in average concentrations at Station 5 (Figs. 15 and 16). The average level for cobalt at Station 5 remained the same as previously reported (Steele, et al, 1975). All of the iron and iron-associated elements showed definite increases in concentration over those values previously reported for Station 1, possibly indicative of increased contribution of clay and shale particles at this location.

The concentrations of calcium and magnesium continued to show a slight increase downstream, a reflection of increased limestone and dolomite in this region. There were no significant changes in the background levels for the new samples as compared to previously reported values. Zinc and cadmium background levels for the new samples remained consistent with previously reported data (Steele, et al, 1975) with no anomalous values being recorded. Lead, however, showed very high concentrations at Station 5, and higher than average readings at Stations 1, 2, 4 and 8. The readings at Stations 1 and 2 reflect the geology of the river, but the high concentration of lead at Station 5 cannot be accounted for at this time.

<u>Close Sampling</u>

Data for close sampling of river miles 121.6 to 59.7 are presented in Table 12 and several individual element trends are discussed below.

1. Sodium

This element averaged about 12 ppm, with a high of 27 ppm and a low of

Table 12. Bottom sediment data for close sampling of the Buffalo River and tributaries. All values are in ppm except Fe which is in weight percent. Sample locations are given in Table 1.

Sample	Na	K	Ca	Mg	Fe	Co	Cr	Ni	Cu	Zn	CD	Pb	Mn
F-1	20	248	2525	1178	3.30	9	23	18	6	117	2.40	51	508
F-2	19	203	12825	1230	1.50	12	12	19	8	86	0.55	34	1996
F-3	5	122	475	463	1.86	5	13	5	3	71	1.30	13	433
F-4	24	171	31500	1003	2.13	12	9	20	7	41	0.80	18	1352
F-5	8	145	1200	608	1.95	10	12	15	6	85	9.8	21	362
F-6	22	198	4325	1000	2.88	10	20	13	6	73	0.71	19	5.3
F-7	15	193	1755	735	2.29	8	17	12	6	74	1.85	10	508
F-8	58	445	60500	968	4.82	19	22	32	11	82	2.80	30	1085
F-9	9	122	900	530	1.46	8	15	14	4	55	0.52	7	390
F-10	15	187	873	630	1.95	4	14	6	6	67	0.41	12	522
F-11	26	280	9000	968	1.70	16	15	35	10	76	2.02	31	1773
F-12	19	283	9375	445	2.13	17	62	19	9	71	0.55	27	2088
F-13	41	233	166750	380	0.49	31	7	34	9	23	2.95	41	1752
F-14	13	146	1200	500	1.85	6	14	23	8	57	1.30	10	467
F-15	11	108	1513	323	1.11	7	10	8	5	67	0.39	9	145
F-16	23	202	2140	628	2.23	10	6	5	6	68	0.46	8	616
F-17	11	143	693	365	1.61	7	15	10	2	54	0.42	0	229
F-18	11	85	31200	436	0.50	2	7	11	4	43	1.41	25	431
F-19	11	187	1893	363	1.70	4	16	5	6	46	1.30	12	463
F-20	15	157	1375	401	1.19	7	14	15	5	48	0.29	6	329
F-21	24	200	22000	1073	0.90	8	11	16	5	36	0.97	26	865
F-22	19	336	1225	563	2.68	12	19	22	8	67	0.42	13	819
F-23	7	107	565	235	1.02	5	12	8	2	39	0.00	6	170
F-24	18	156	2410	280	1.34	10	15	12	3	46	0.51	0	272
F-25	9	149	2625	463	1.24	8	12	12	3	44	0.42	5	359
F-26	35	327	5625	503	2.28	11	19	15	9	52	0.80	12	714
F-27	14	256	4625	600	1.08	13	11	12	6	58	0.42	15	757
F-28	27	254	15850	1313	1.99	6	19	11	6	56	1.30	8	1003
F-29	25	356	6175	563	1.73	8	16	25	11	119	1.35	10	272
F-30	14	117	1605	483	1.35	5	10	10	4	59	0.40	12	349
F-31	11	72	873	335	1.09	8	15	13	5	48	0.59	10	390
F-32	32	168	24200	1620	0.54	6	7	17	6	403	4.08	0	437
F-33	31	149	21375	1385	0.30	8	5	9	5	145	1.52	5	259
F-34	7	153	1538	463	1.04	6	16	13	4	44	1.30	1	390
F-35	19	219	6525	1165	1.45	10	14	21	7	108	0.55	18	497
F-36	20	190	6250	1000	1.11	6	11	12	6	50	1.85	19	302
F-37	19	284	6275	1208	1.60	9	17	8	7	115	1.64	18	640
F-38	21	120	9075	1038	0.39	5	17	12	15	2285	0.92	3	261
F-39	16	220	2140	578	1.56	9	13	9	6	57	0.55	13	659
F-40	18	133	1665	600	1.04	6	12	71	4	100	0.79	18	374
F-41	30	213	653	385	0.56	8	6	8	14	24	0.20	8	437
F-42	13	192	763	295	1.44	9	18	17	6	54	1.47	2	377
F-43	28	209	2383	673	1.60	8	14	15	8	73	0.39	32	422
F-44	23	172	1473	430	1.54	5	16	16	3	53	1.30	14	597
F-45	16	108	653	265	1.04	7	11	20	5	49	1.47	9	218
F-46	22	312	3725	395	2.24	12	20	13	8	90	0.93	14	1142
F-47	7	124	965	366	1.09	12	13	13	4	45	0.62	0	198
F-48	14	211	4750	401	1.55	6	16	21	5	61	1.45	11	623
F-49	7	118	515	198	0.99	8	12	3	3	45	1.88	8	259
F-50	4	105	435	235	0.88	6	10	3	2	36	0.46	0	216

Table 12 Continued

Sample	Na	K	Ca	Mg	Fe	Co	Cr	Ni	Cu	Zn	Cd	Pb	Mn
F-51	15	179	2750	1905	1.12	13	10	12	7	33	0.40	15	497
F-52	7	112	1655	295	0.95	2	10	14	5	33	1.18	3	218
F-53	22	196	40500	563	0.91	7	11	10	5	80	2.28	12	609
F-54	11	157	1803	295	1.15	6	16	12	4	43	0.67	6	216

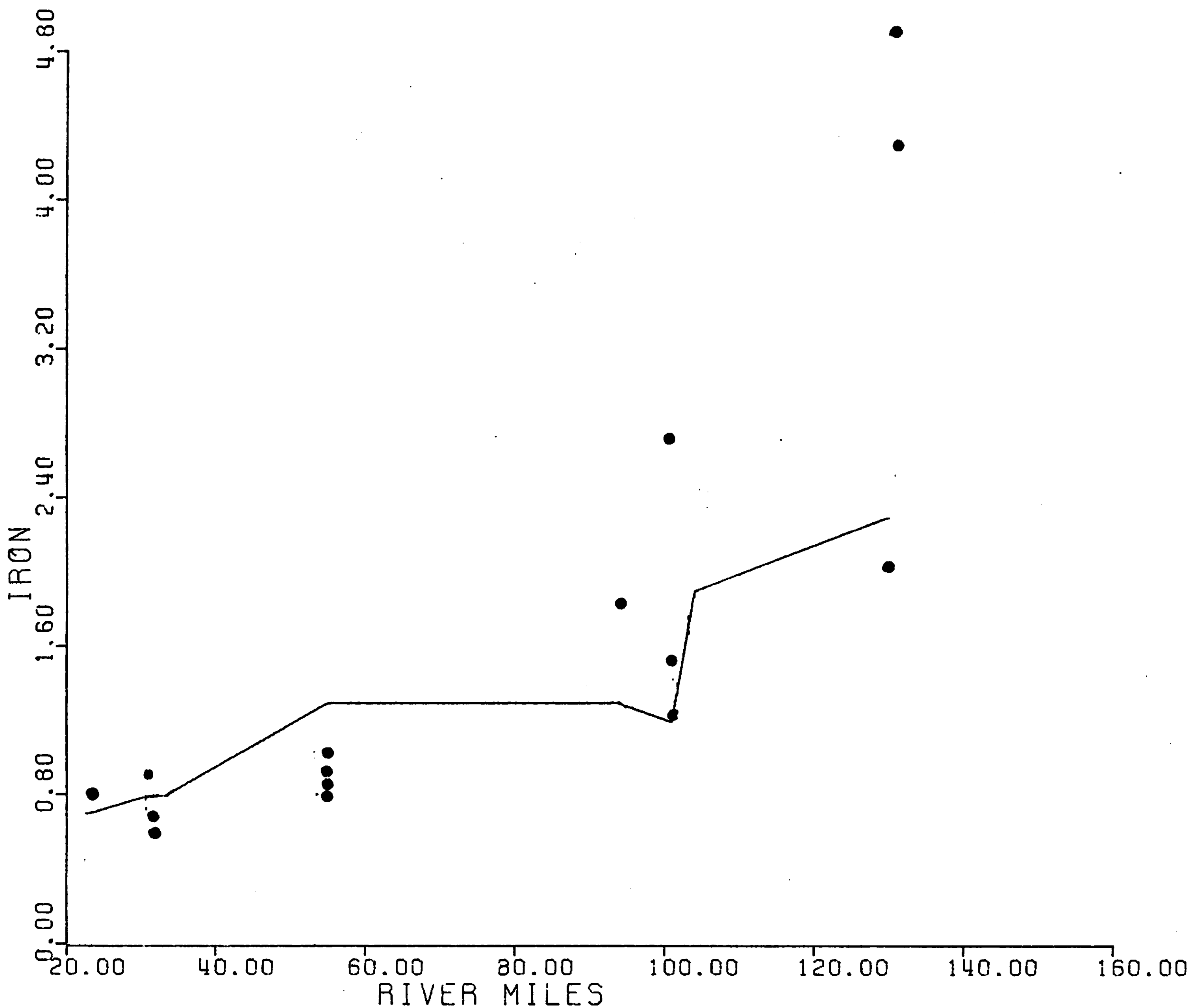


FIGURE 12. FE VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

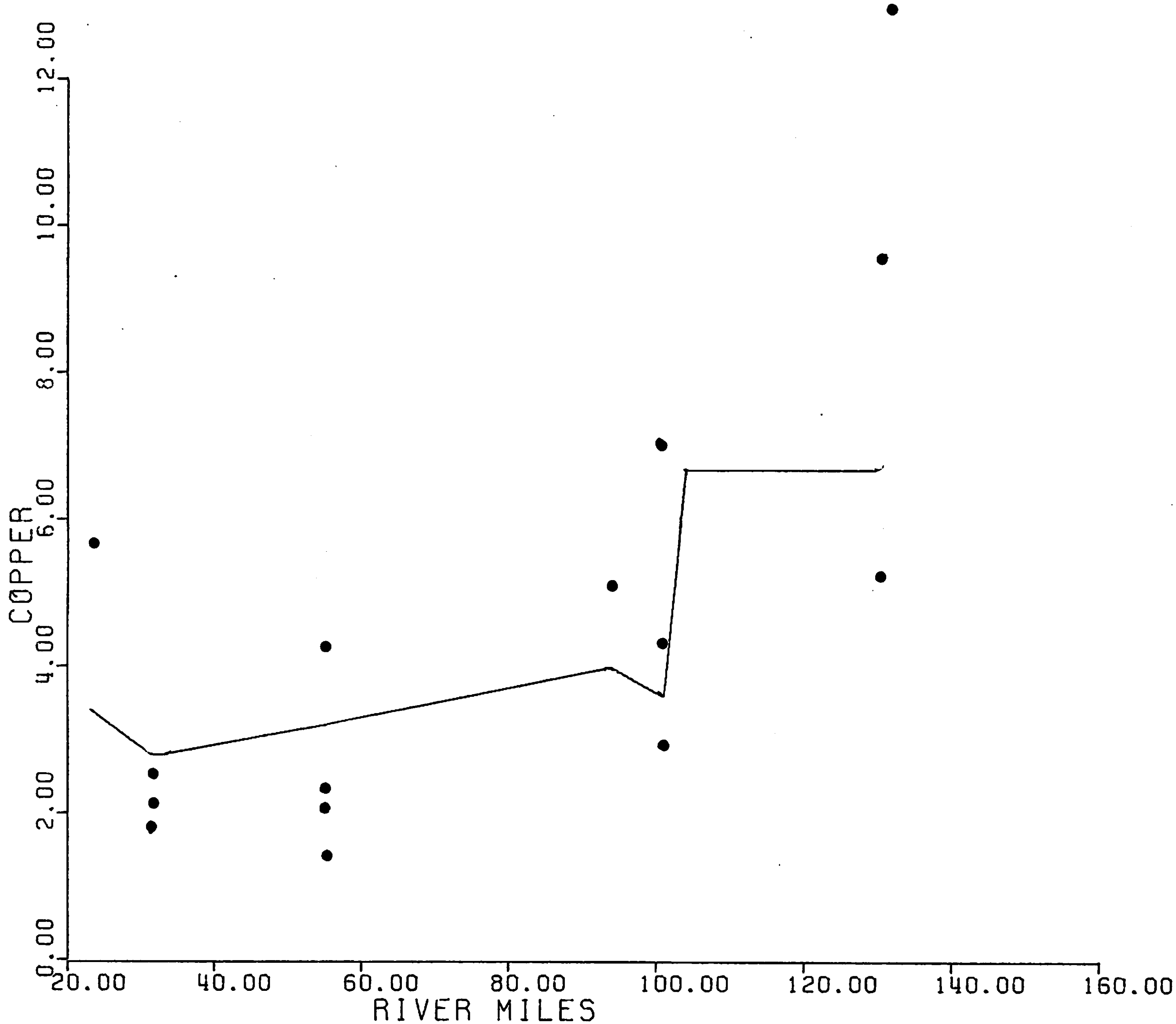


FIGURE 13. CU VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

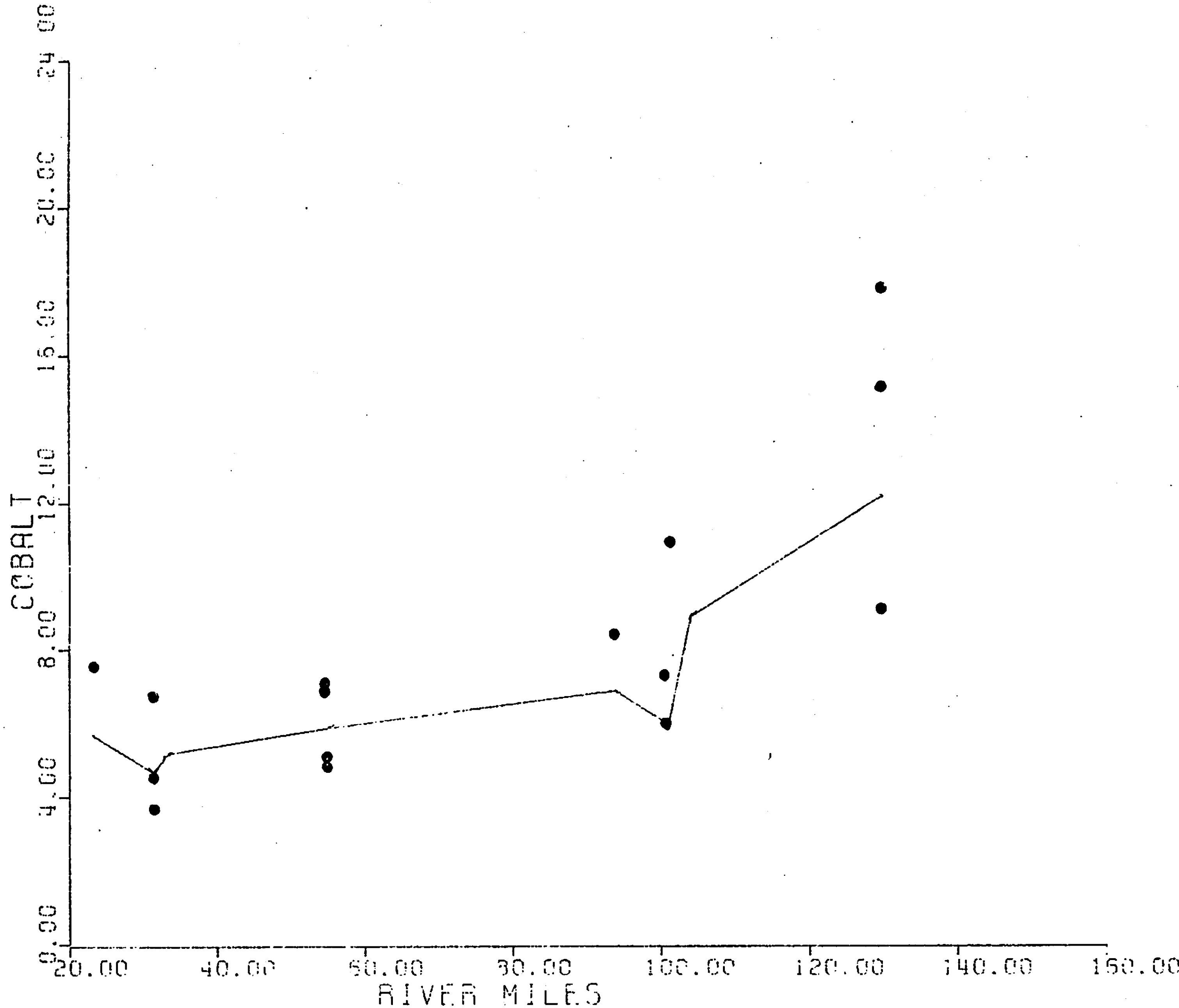


FIGURE 14 . CO VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

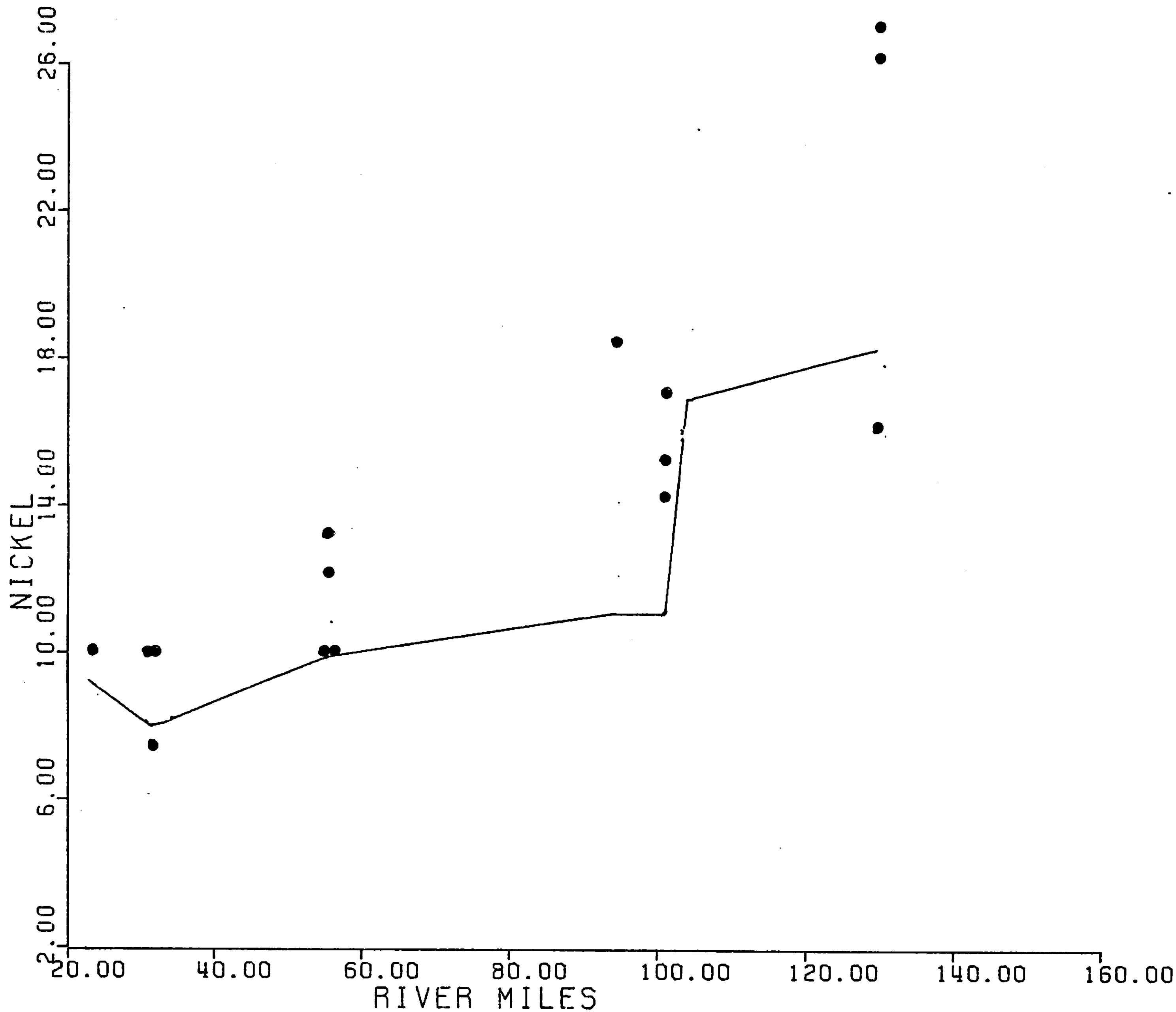


FIGURE 15. NI VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

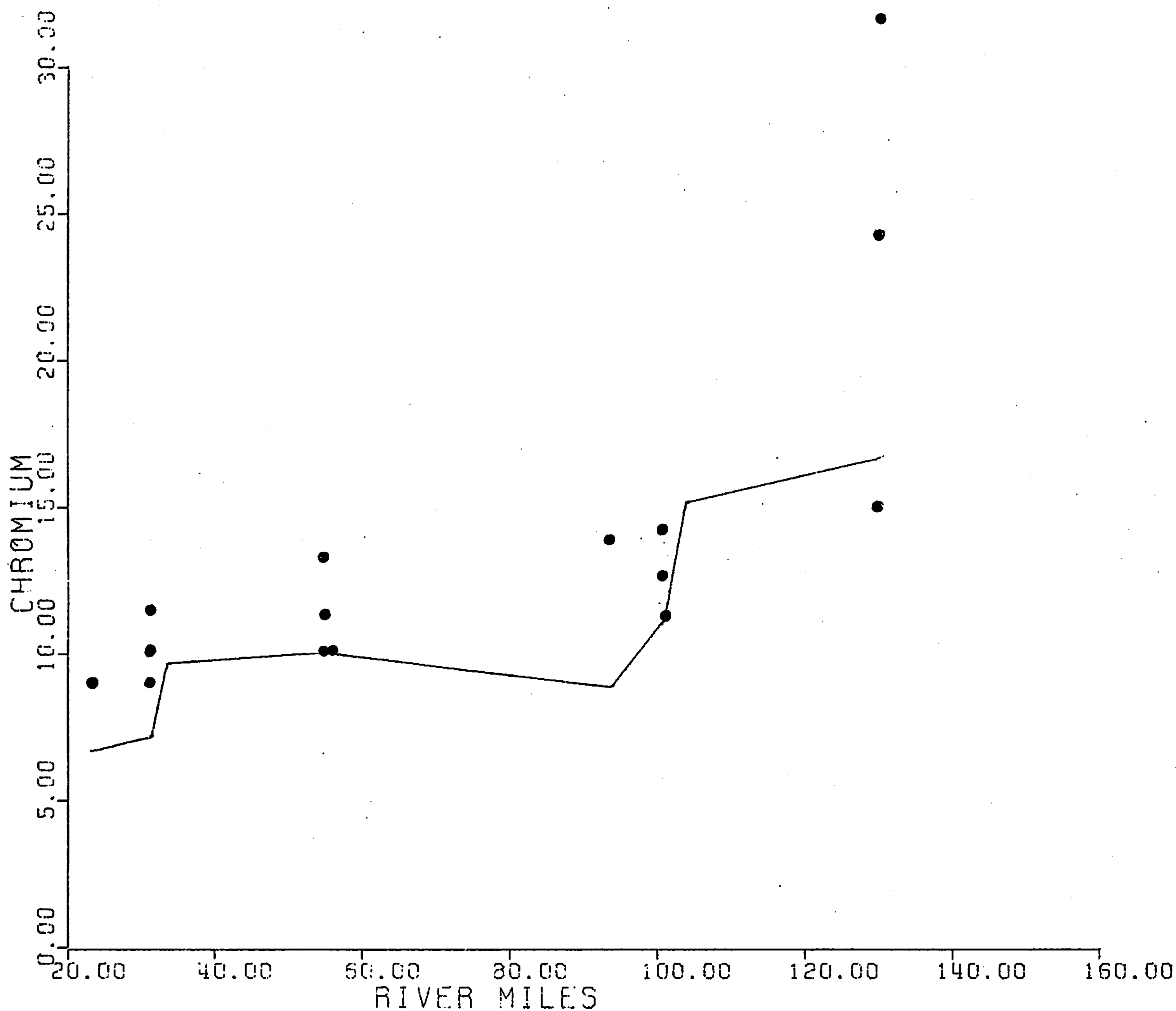


FIGURE 16. CR VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

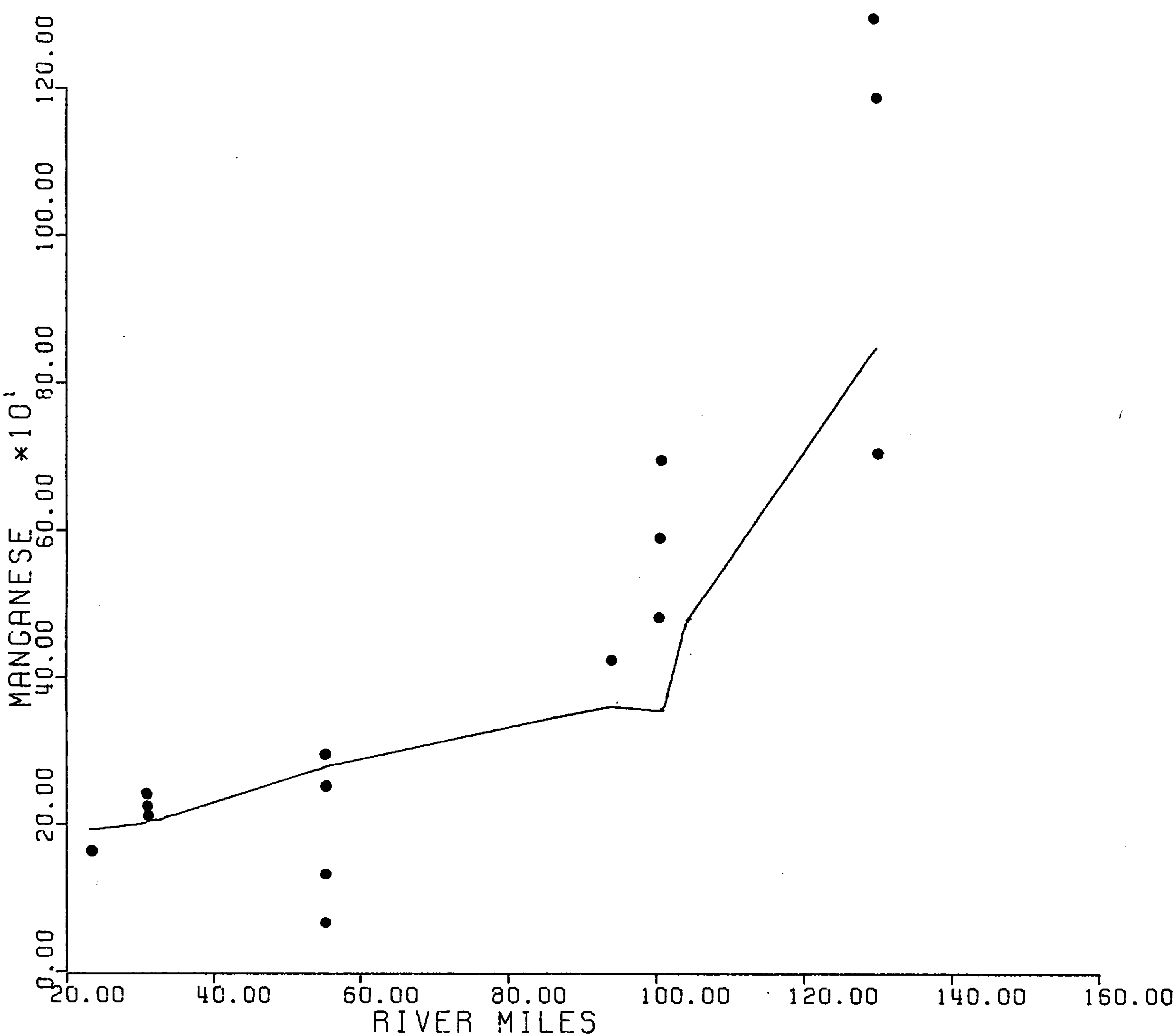


FIGURE 17. MN VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

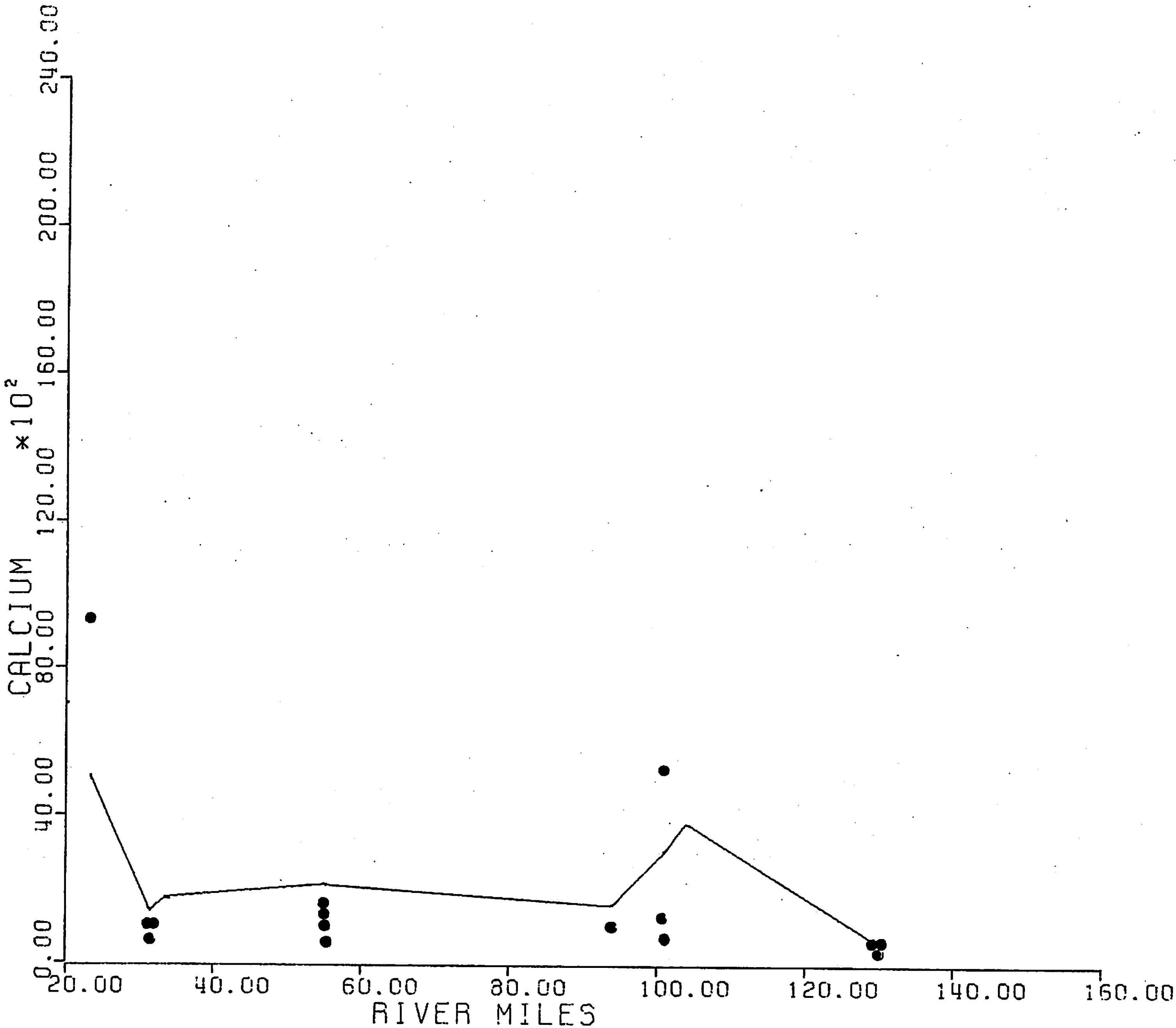


FIGURE 18. CA VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

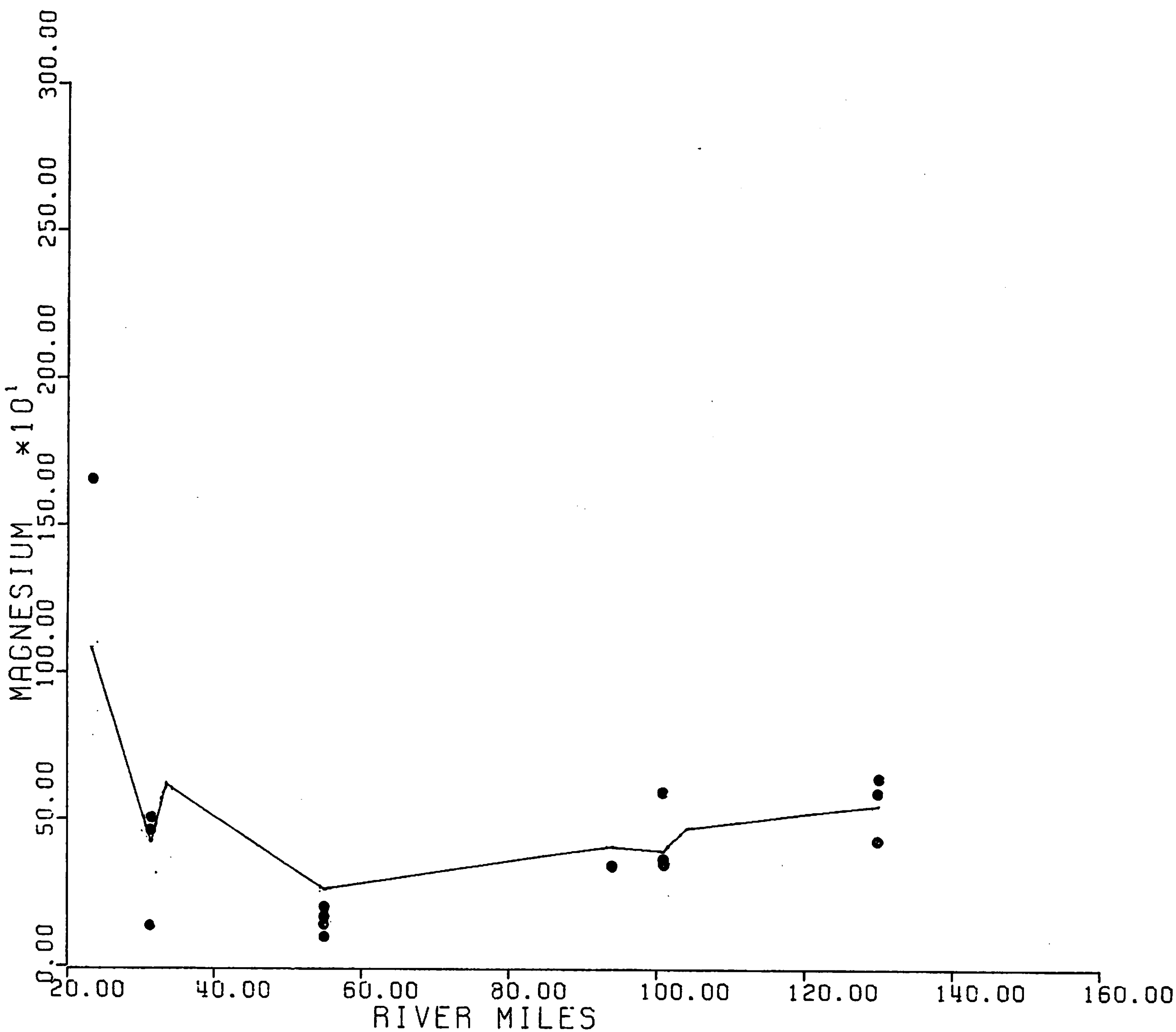


FIGURE 19. MG VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

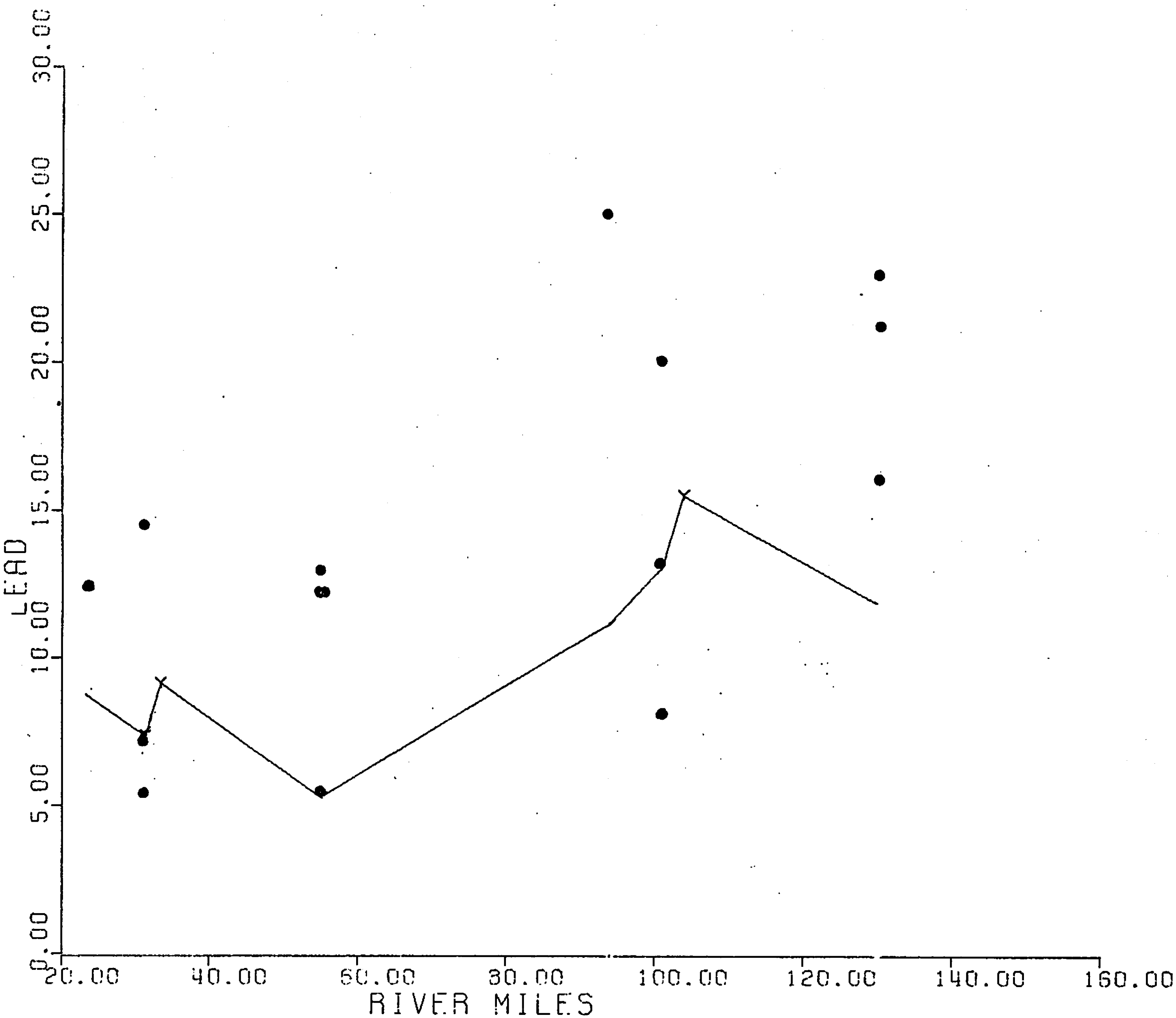


FIGURE 20. PB VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

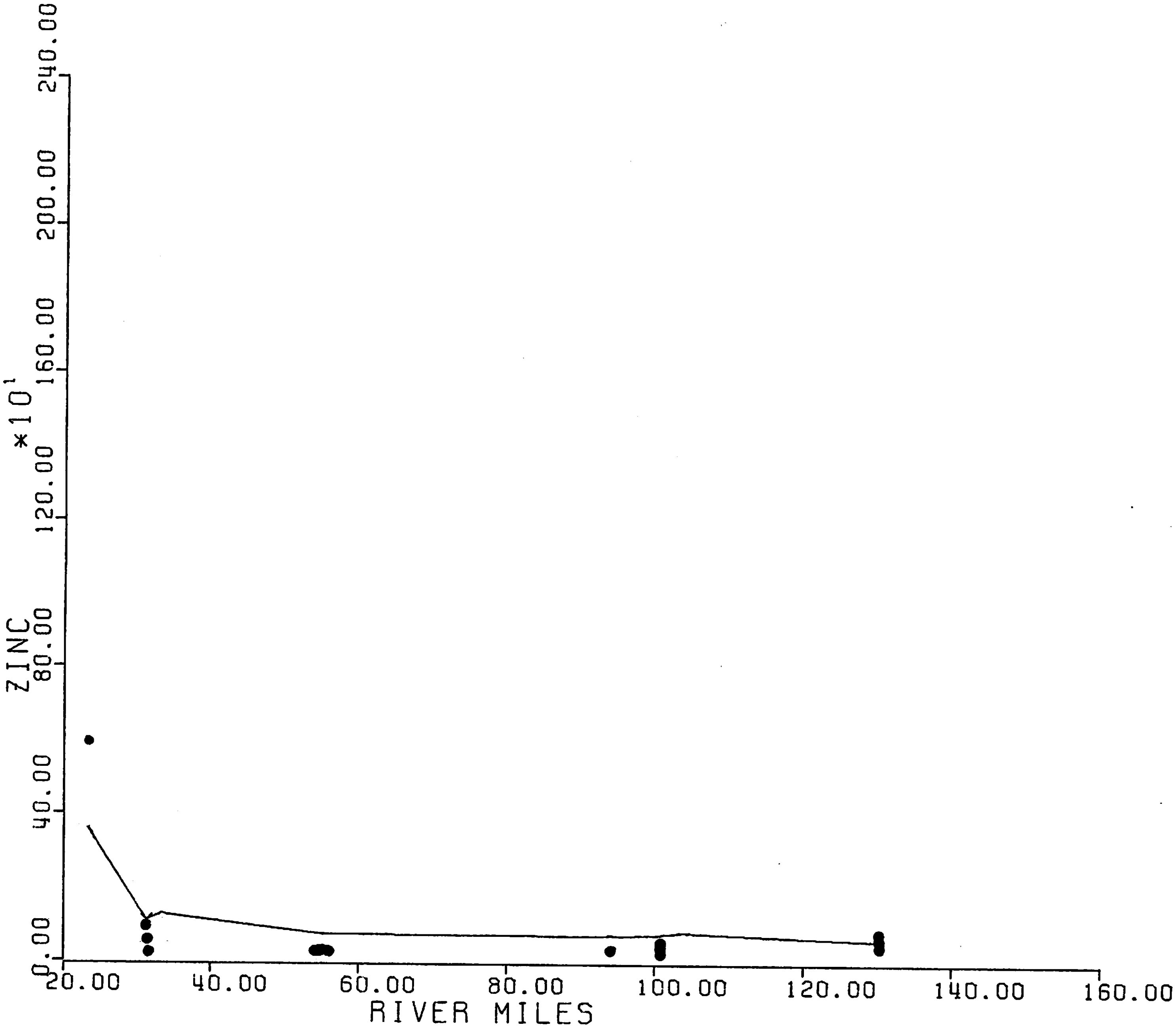


FIGURE 21. ZN VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

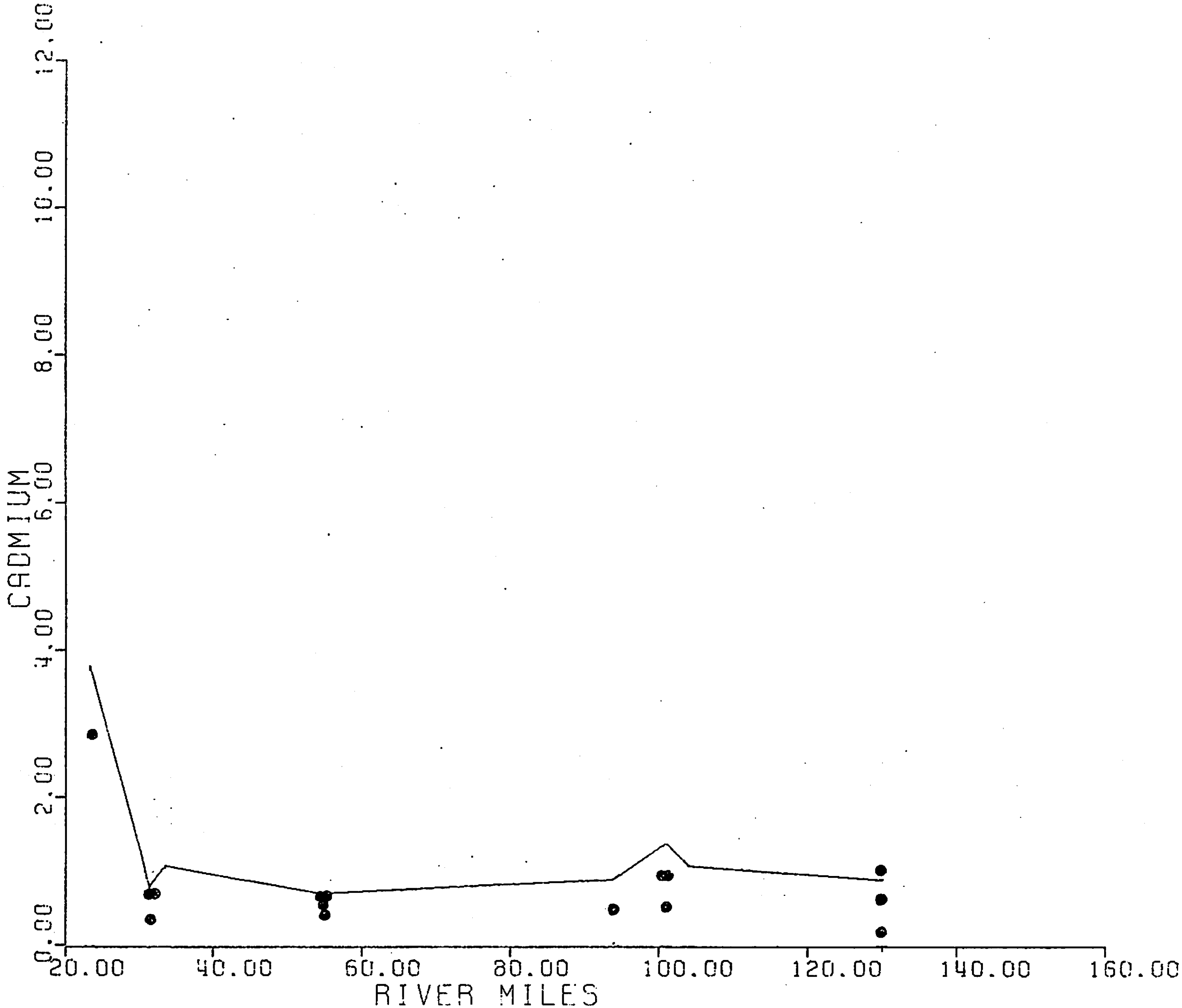


FIGURE 22. CD VS RIVER MILES (BOTTOM SEDIMENTS).
AVERAGE VALUES FOR 1974 INDICATED BY LINE AND 1975 DATA BY POINTS.

4 ppm. No anomalous values occurred. The 12 ppm average does not exceed the expected background level for sodium.

2. Magnesium

Downstream the amount of extractable magnesium showed a general decrease, from 1178 ppm at Bee Cliff to 198 ppm at Red Bluff. Two high peaks occurred, one 0.6 miles below Hancock Hollow and the other 1.5 miles below Cane Branch (see Fig. 23). The average value for magnesium over the section of river sampled was about 450 ppm. The two peaks probably reflect increased contact with dolomitic rock in these areas.

3. Calcium

The average extractable calcium content of the sediments remained fairly steady over the river, with the exception of two high values recorded at the same locations as were the two high values for magnesium. A plot of calcium versus magnesium along the river (Fig. 23) shows a strong correlation between the two, thus indicating that much of the calcium and magnesium found in the sediments is a reflection of the dolomite and limestone units in the region.

4. Copper

Extractable copper shows a slight general decrease down river, from 6 ppm at Bee Cliff to 4 ppm at Buck Point. A high value of 15 ppm was recorded 1.5 miles below Cane Branch, but this is an anomalous value. Disregarding this value, the concentrations range from 8 ppm 0.3 miles below Conard Fissure to 2 ppm at Arnold Bend. The gradual decrease downriver is probably due to a reduction in the amount of shale found downstream, since shale is known to contain more of the heavy metals and iron than other sedimentary rock types.

5. Nickel

Nickel showed a wide variation in concentration along the river, and no general trend could be discerned. This in itself is unusual, since nickel

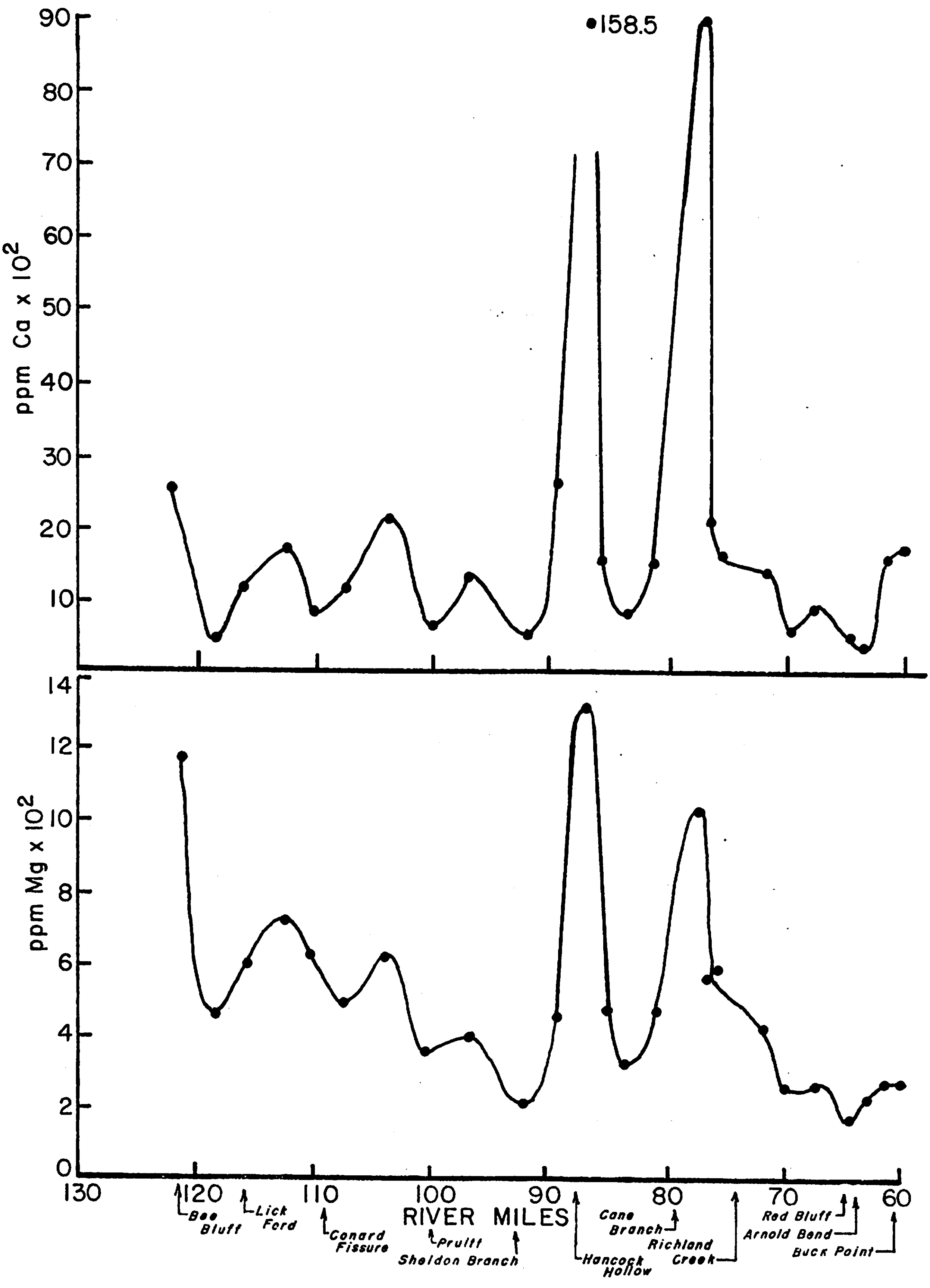


Figure 23. Calcium and magnesium versus river miles. Confluence of Buffalo River with White River is at zero river miles.

would be expected to follow the general pattern set by copper and other iron-associated elements. An anomalous value of 71 ppm was recorded at Richland Valley, and several other high values were recorded further down the river, all of which could be considered higher than would be expected for that region. The higher values upstream are probably due to the greater frequency of shale in the drainage area upstream.

6. Chromium

This element showed a general decrease downstream, ranging from 23 ppm at Bee Cliff to 16 ppm at Buck Point, with average concentrations decreasing from 18 ppm upstream to 10 ppm in the lower section of the river. This decrease again reflects the higher shale content of the rocks upstream. No anomalous values were recorded.

7. Cadminum

Cadmium showed a rapid decrease in concentration between Bee Cliff and Sheldon Branch, dropping from 2.4 ppm at the former to 0 ppm at the latter, with only 2 peaks in between (Fig. 24). One of these peaks, at Lick Ford, was 9.8 ppm, far higher than any other value ever recorded for cadmium anywhere along the entire length of the river. High values for zinc were also recorded at this sample location (Fig. 24) which may be indicative of localized mineralization. This possibility is supported by the close correlation of cadmium and zinc concentrations immediately downstream reflect a common source. Cadmium is associated with sulfide ores in the area.

From the low value of 0 ppm below Sheldon Branch, the cadmium content increases to an average of about 1 ppm, and remains fairly constant thereafter.

8. Lead

There is a gradual decrease of lead going downstream with a low value of 0 ppm at Pruitt and a somewhat higher than average value of 18 ppm at Richland

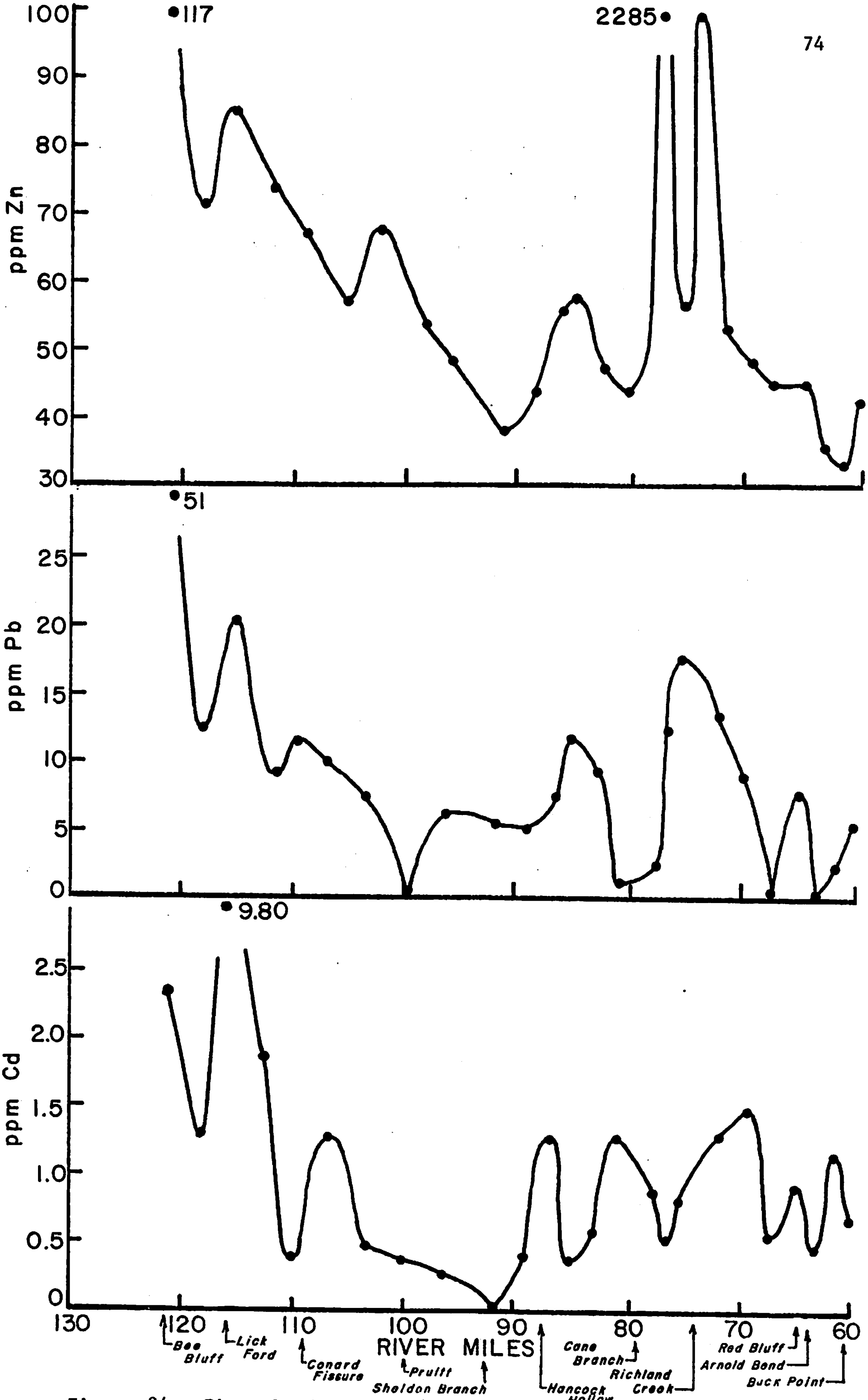


Figure 24. Zinc, lead and calcium versus river miles. Confluence of Buffalo River with White River is at zero river miles.

Valley. The average concentration ranges from about 20 ppm upstream to about 7 ppm in the lower region of the river (Fig. 24). The higher values upstream are probably the result of the known lead deposits in that region.

9. Zinc

Zinc concentrations showed a definite decrease downstream, from 117 ppm at Bee Cliff to 43 ppm at Buck Point (Fig. 24). An intermediate low of 39 ppm was recorded at below Sheldon Branch, and two high peaks were recorded further downstream, 2285 ppm below Cane Branch and 100 ppm at Richland Valley.

10. Manganese

Manganese shows a general decrease in concentration going downstream, from 508 ppm at Bee Cliff to 216 ppm at Buck Point. Several intermediate high values occurred, most notably 0.6 miles below Hancock Hollow (1003 ppm) 2.4 miles below Cane Branch (659 ppm), and 1.9 miles from Richland Creek (597 ppm). A plot of manganese versus iron along the river (Fig. 25) shows a strong correlation between the two.

11. Iron

Iron showed a general decrease in concentration downstream, with values ranging from a high of 3.3 wt. % at Bee Cliff to 1.15 wt. % at Buck Point (Fig. 25). This again is thought to be due to the greater shale occurrence upstream. Shale contains more iron and iron related sediments than do other rock types in the area, and the general decrease in most of these elements downstream can be related to the fact that there are more fine particles of shale and clay from the shale upstream, plus the fact that the groundwater drainage upstream is in contact with more shale. These two factors would tend to increase the heavy metal content of the sediments in this area.

Tributaries

A total of 29 samples were collected from various tributaries from river

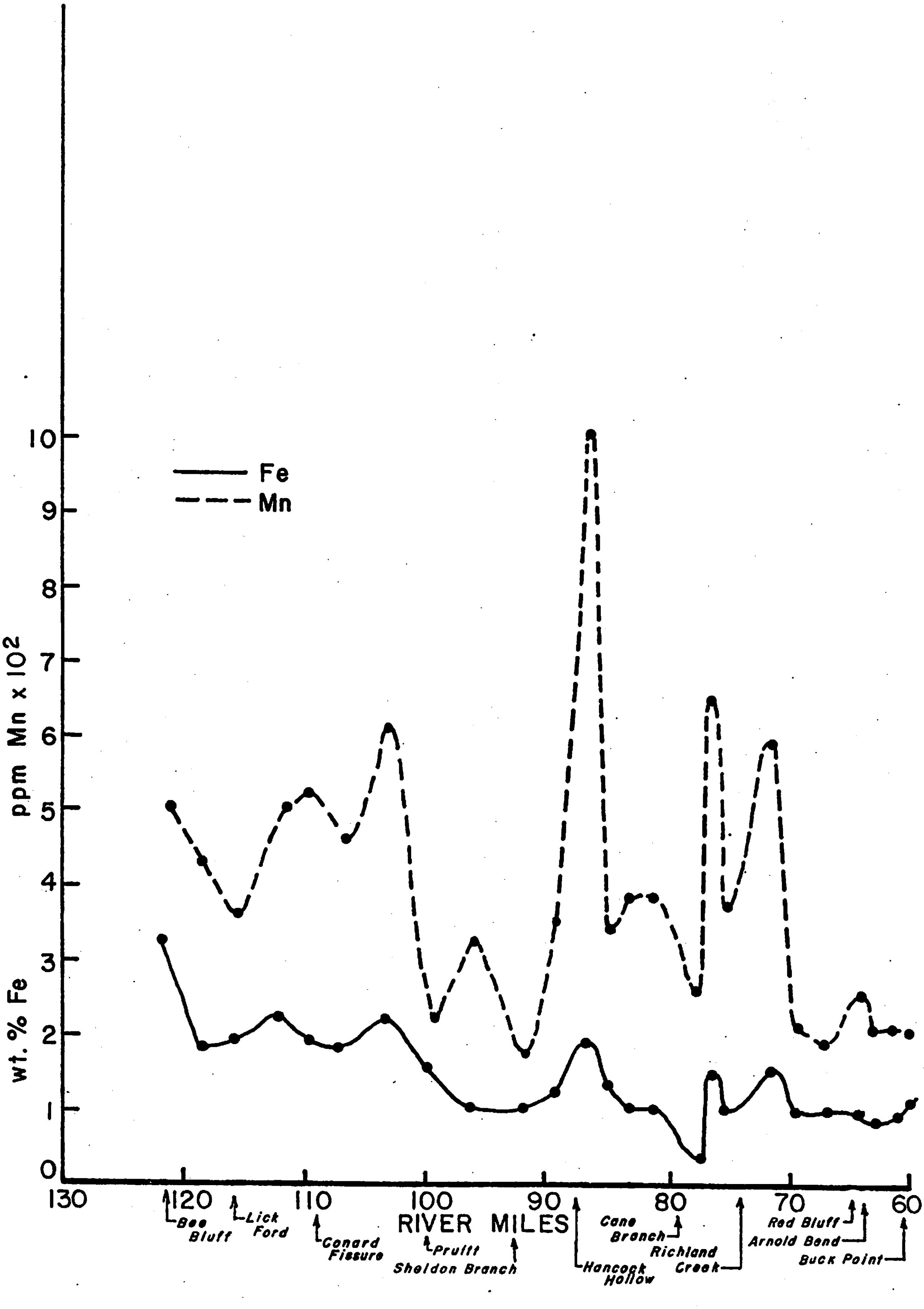


Figure 25. Manganese and iron versus river miles. Confluence of Buffalo River with White River is at zero river miles.

mile. Most of them have significantly higher concentrations of trace metals than did the Buffalo River (Table 12). No correlation could be made between anomalous highs along the Buffalo River and concentrations in nearby tributaries. High values in the tributaries appeared to have little or no effect upon the concentrations in the river below the confluences. This may be due to the rapid diluting effects of the river, as reported by Steele, et al (1975).

In summary, the following elements were analyzed in the -95 mesh fraction of the bottom sediments: Na, K, Ca, Mg, Fe, Co, Cr, Ni, Cu, Zn, Cd, Pb and Mn. These analyses are summarized in Tables 2 and 3. The element concentrations exhibit trends along the river as shown in Figures 2-17 and trends generally correlate well with the geology of the river. Sodium and K values increase downstream where feldspar (rich in Na and K) is present in sandstone. Iron and the iron associated metals (Cu, Co, Cr and Mn) increase in concentration downstream probably due to precipitation and to sorption by the precipitated Fe oxide coating on sediment grains. An interesting exception to this is Ni, which varies widely in concentration, with no discernable trends. Calcium and Mg decreased in concentration downstream, with occasional simultaneous increases to high values, indicative of the presence of limestone and dolomitic rocks in those regions. Tributaries showed consistently higher concentrations of all trace elements studied, but no apparent correlations of these high concentrations to anomalously high values in the river proper could be made.

Detailed Investigation in Two Mining Areas

Bottom sediment samples were collected from Ponca Creek - Adds Creek on July 18, 1975 and Clabber Creek on July 19, 1975. These two tributaries are in mineralized zones and were sampled in an attempt to define the source of anomalous element values associated with these streams. Elemental concentrations in the streams reflect the mineralization of the area. In the Ponca mining district lead and zinc ores have been removed while in the Rush mining district, through which Clabber Creek flows, zinc ores were mined. Cadmium is closely associated with zinc ores. These three important metals-lead,zinc and cadmium-have been plotted in Figs. 26-31. These figures show

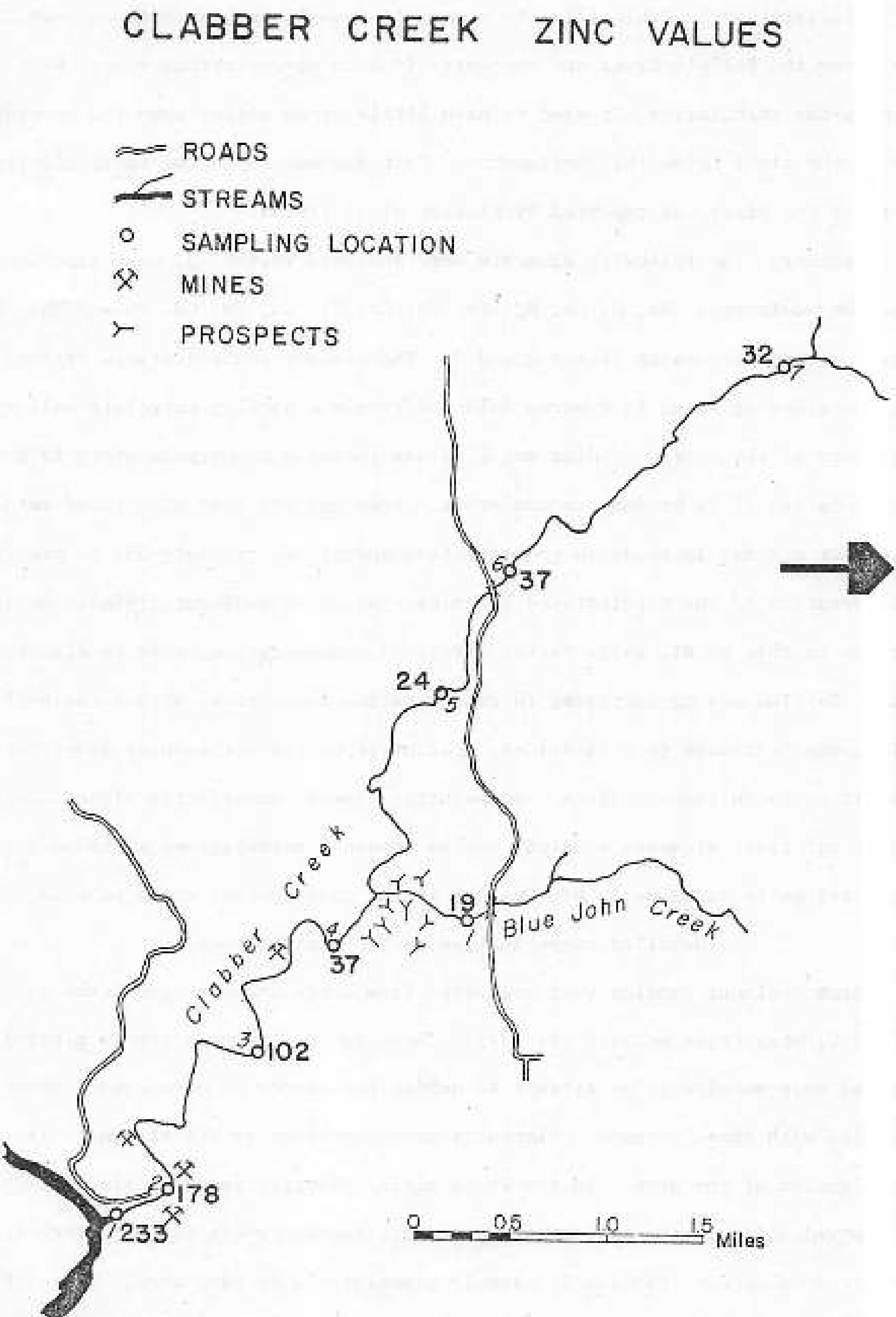


Figure 26. Zinc concentration of bottom sediments from Clabber Creek. Values in ppm.

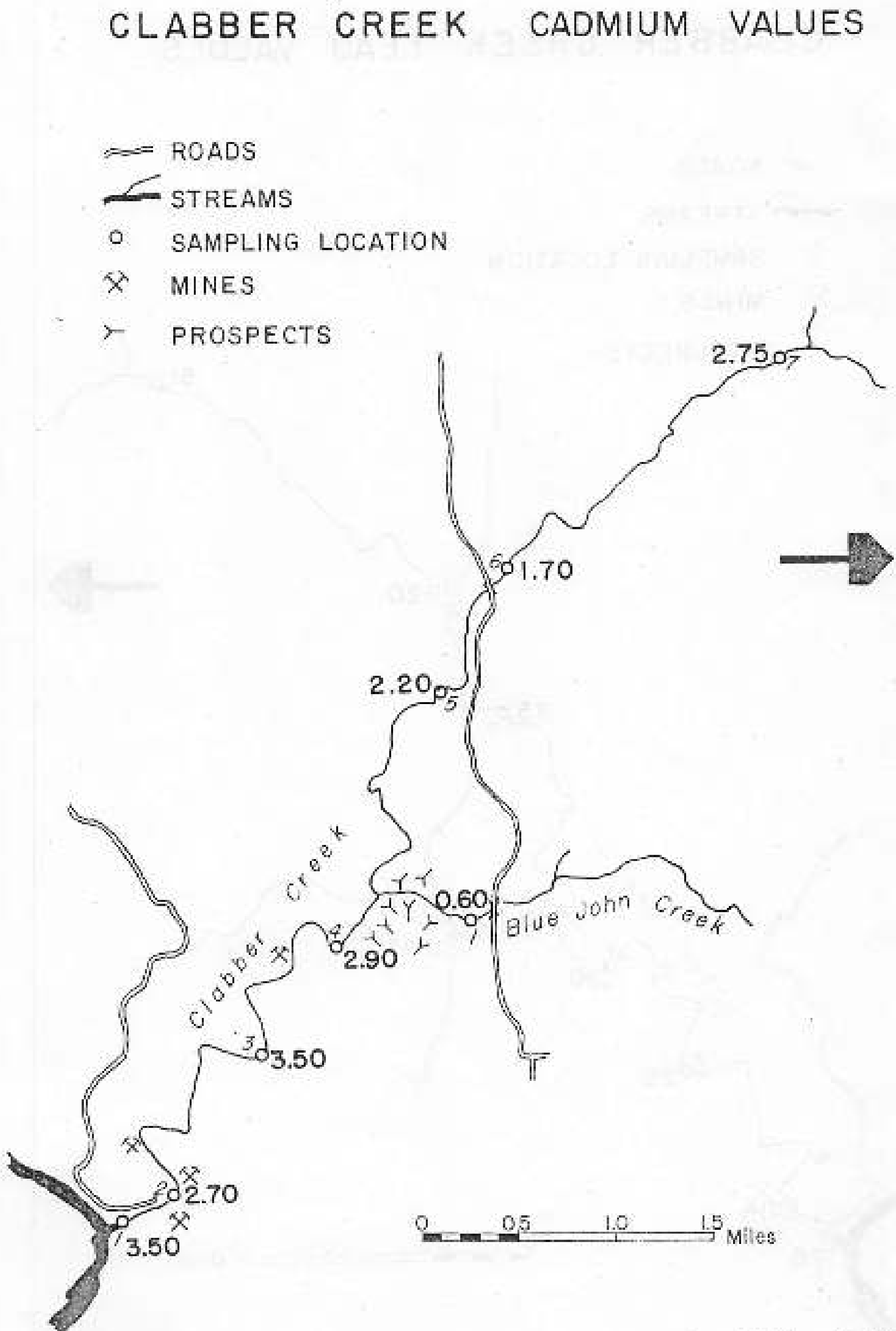


Figure 27. Cadmium concentration of bottom sediments from Clabber Creek. Values in ppm.

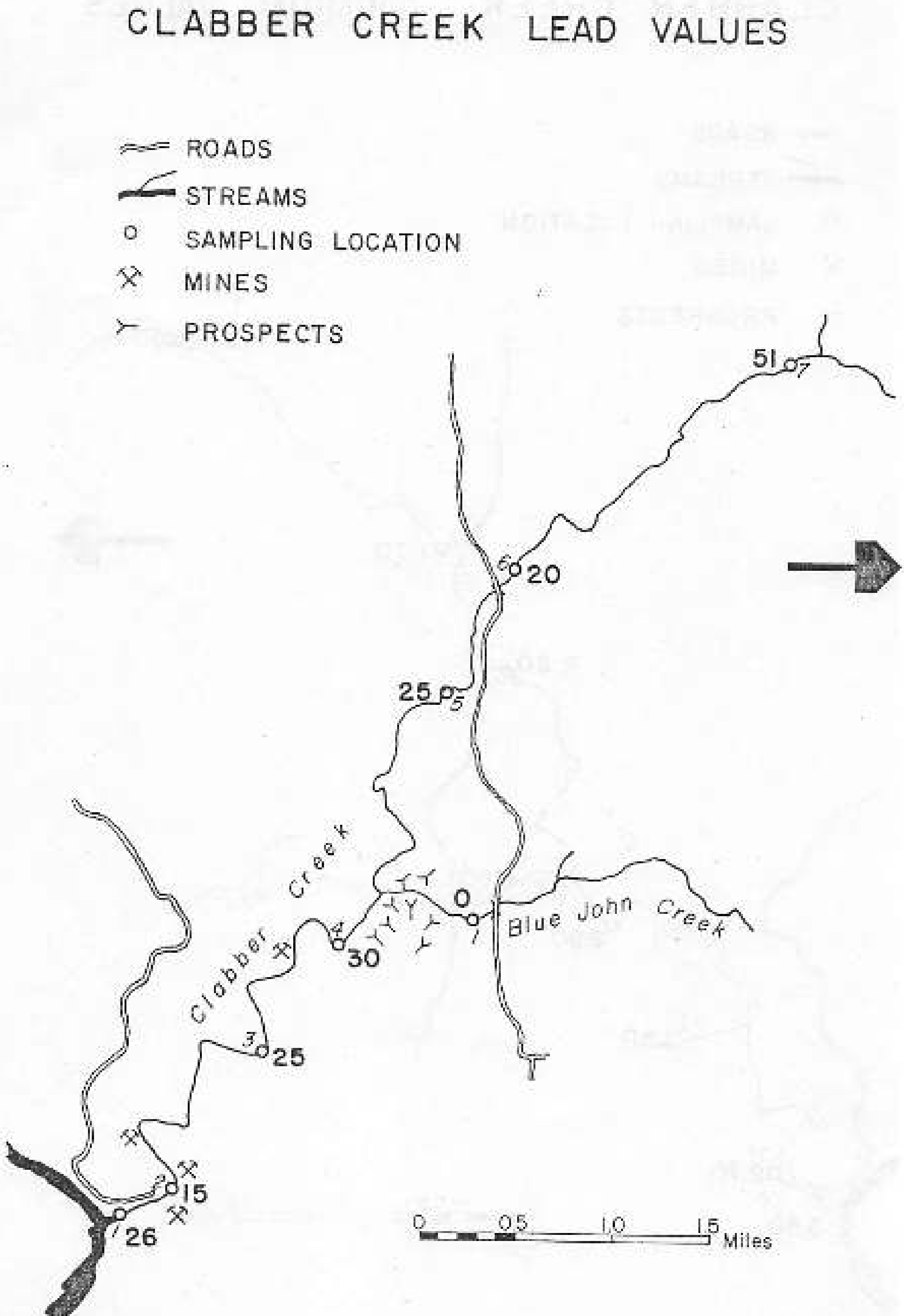


Figure 28. Lead concentration of bottom sediments from Clabber Creek. Values in ppm.

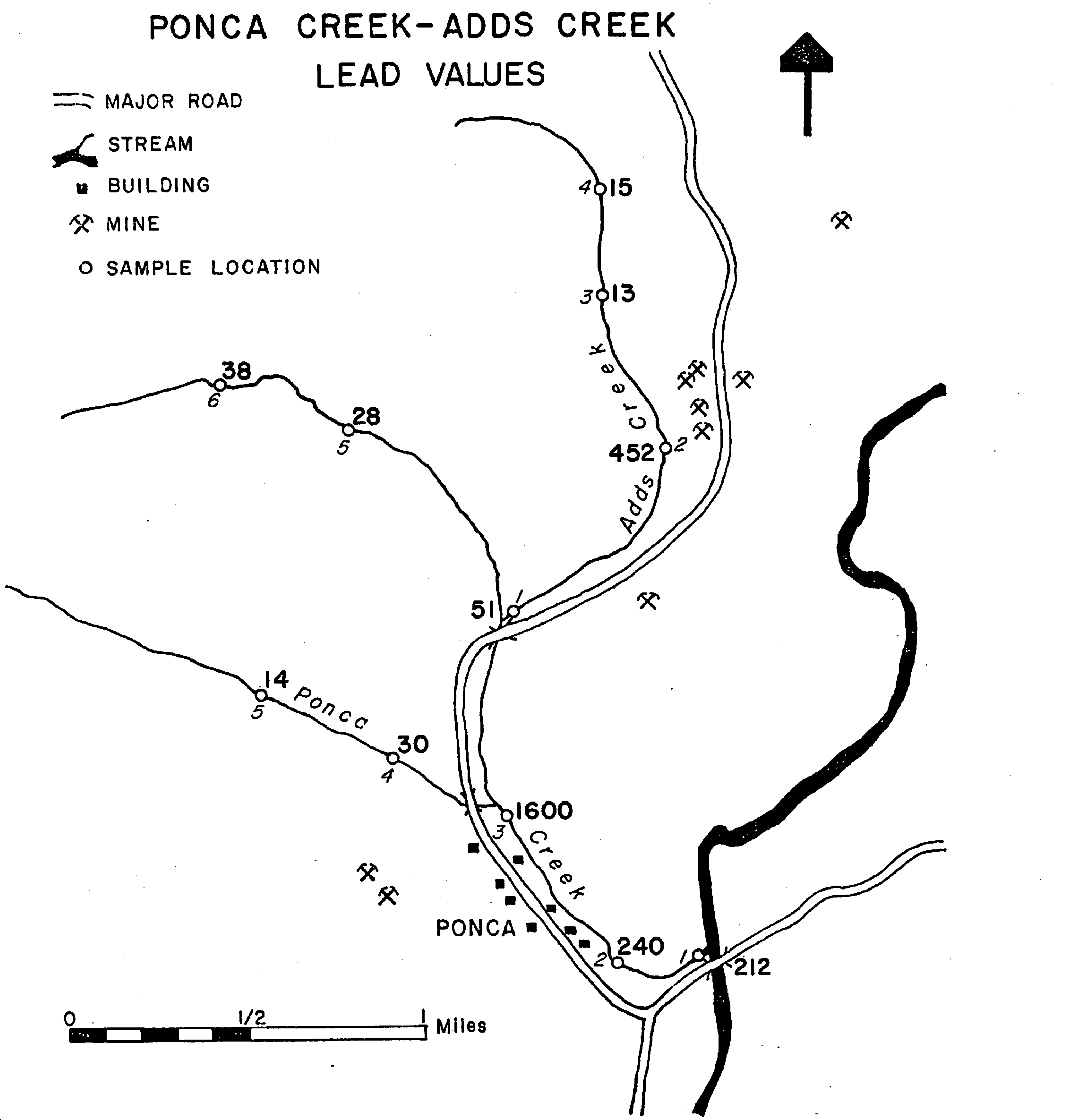


Figure 29. Lead concentration of bottom sediments from Ponca and Adds Creeks. Values in ppm.

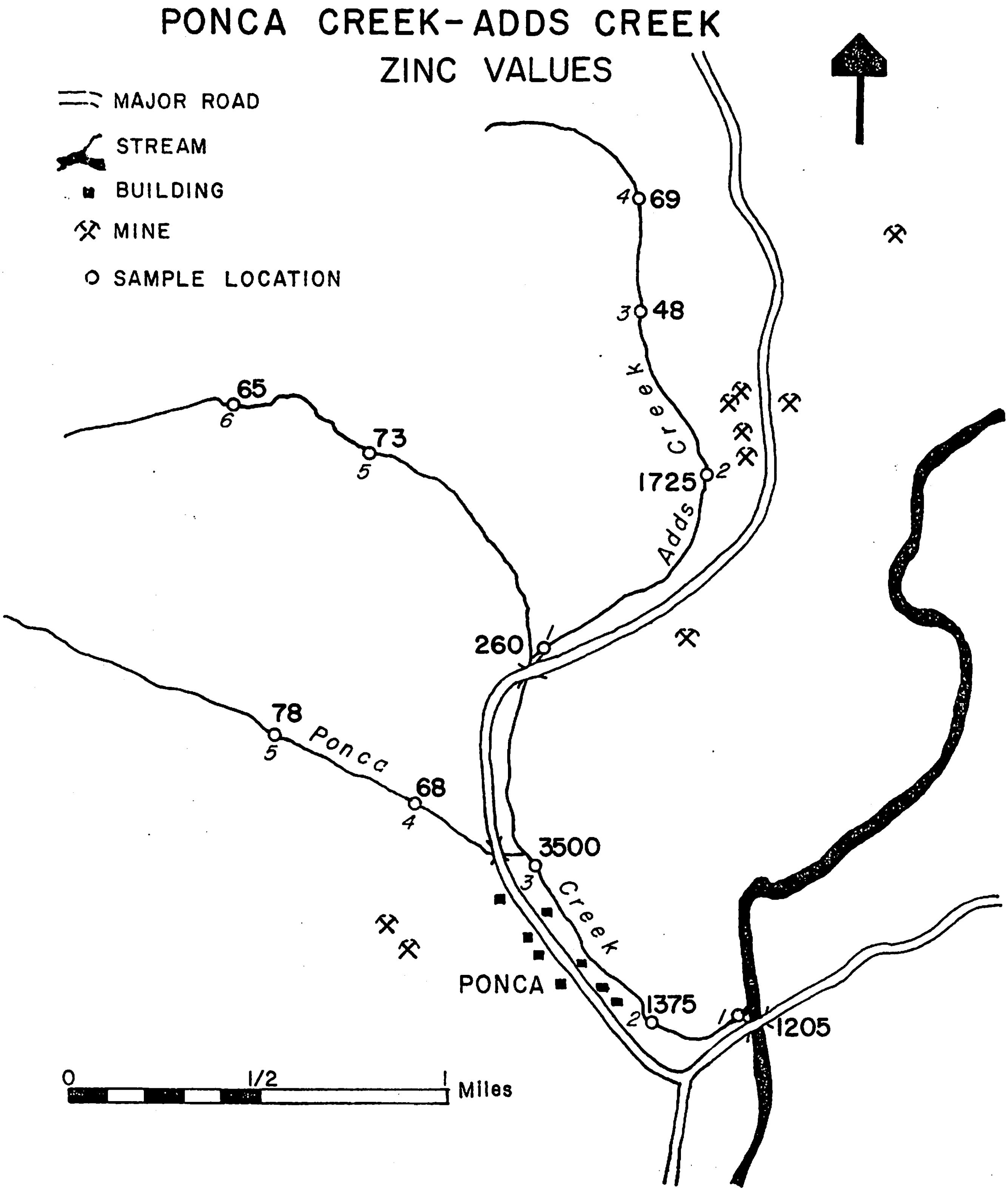


Figure 30. Zinc concentration of bottom sediments from Ponca and Adds Creeks. Values in ppm.

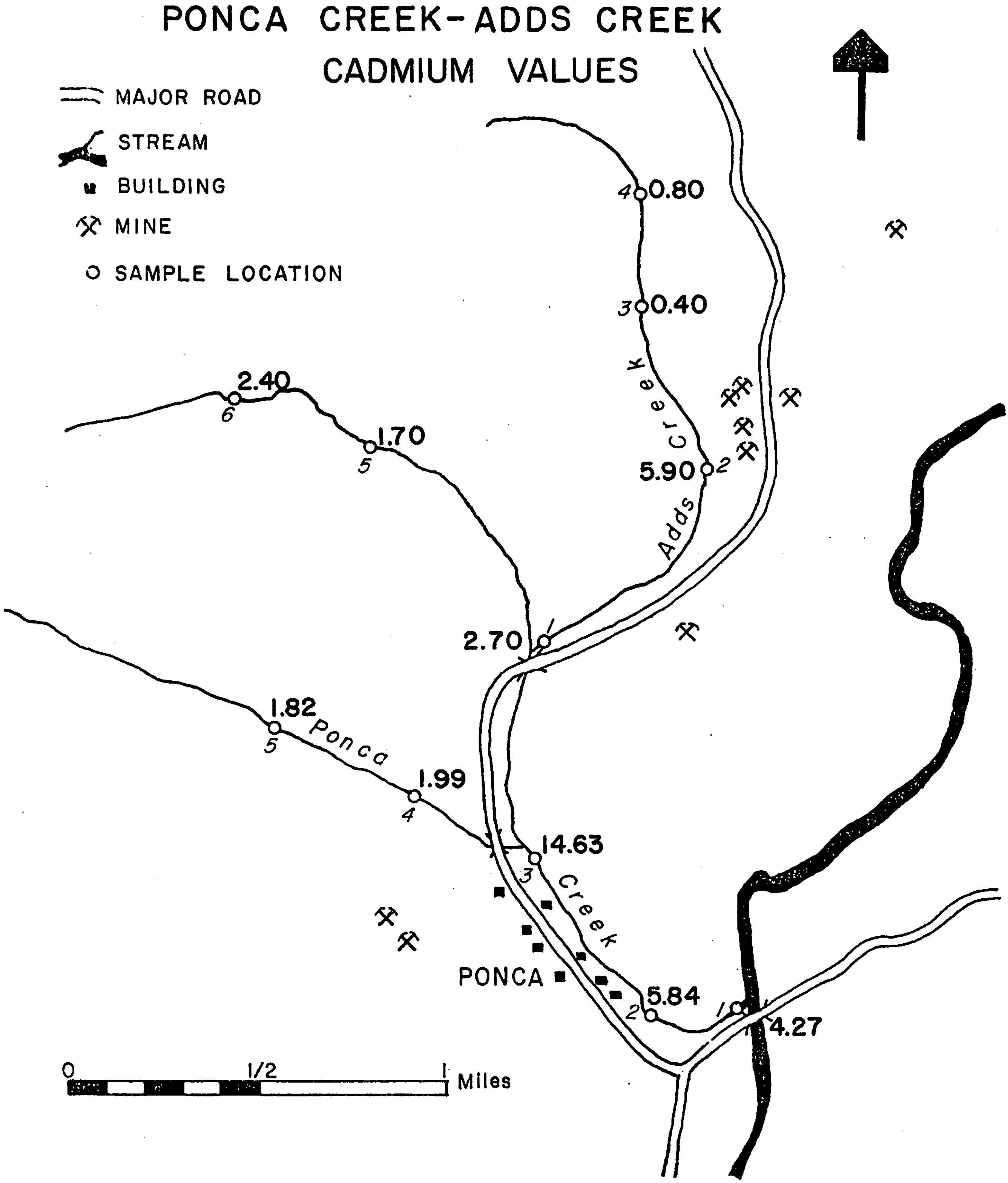


Figure 31. Cadmium concentration of bottom sediments from Ponca and Adds Creeks. Values in ppm.

the streams in relationship to known mines and prospect sites. The other 10 elements which have been analyzed (Table 13 and 14) show no trends along the streams nor association with mineral deposits and therefore have not been illustrated.

Zinc analysis of bottom sediment from Clabber Creek shows that the upper part of the stream has a background level about 30 ppm. Increase in the zinc concentrations occur downstream where mineralization is indicated by the mines of the area (Fig. 26). The increase in values between Sample 1 location and Sample 2 location on Clabber Creek is attributed to the influence of the Leader Mine on the east side of Clabber Creek (in Leader Hollow).

Cadmium generally follows the increased zinc with higher values downstream (Fig. 27). The absence of high lead values is due to the lack of lead mineralization in the area (Fig. 28). The low zinc values in the vicinity of Blue John Creeks show why none of the prospects had been developed (Fig. 26).

The Ponca City area has major lead mineralization; however, some zinc ores have been produced. The two ore minerals are generally found in the same horizons and the trends for lead and zinc are similar. In the Ponca area the upper reaches of the stream reflects background levels (Figs. 29-31). Downstream higher values are encountered where the stream crosses mineralized zones. Sample location, Adds 2, immediately below the mines shows very high values for lead, zinc and cadmium. Dilution reduces the anomalous concentrations at Sample location, Adds 1, almost to background levels (Figs. 29-31). Sample locations, Ponca 4 and 5, have low values; however, Ponca 3, which is located immediately below the junction Adds Creek with Ponca Creek, has the highest values of any location on the stream system. Between Ponca 4 and Adds 1 and Ponca 3 an anomalously high concentration of zinc and lead is introduced (Figs. 29 and 30). The source of the elements could be from the old

Table 13. Bottom sediment data for samples collected in Ponca Creek area. All values are in ppm except Fe which is in weight percent. See Figure 18 for sample locations.

Sample	No.	Na	K	Ca	Mg	Fe	Co	Cr	Ni	Cu	Zn	Cd	Pb	Mn
Ponca	1	31	282	37500	464	1.09	16	14	25	9	1205	4.27	212	1496
Ponca	2	28	322	16200	366	2.64	17	12	28	11	1375	5.84	240	1701
Ponca	3	5	66	5900	154	1.26	6	8	16	6	3500	14.63	1600	653
Ponca	4	47	403	55000	1471	3.85	20	17	38	11	68	1.99	30	1829
Ponca	5	43	423	44600	1155	3.61	25	17	42	12	78	1.82	14	2727
Adds	1	25	272	3575	322	2.55	28	7	48	11	260	2.70	51	1853
Adds	2	83	557	5525	323	3.18	19	10	38	17	1725	5.90	452	799
Adds	3	24	162	343	227	3.25	20	18	28	7	48	0.40	13	1583
Adds	4	27	350	1343	161	3.58	20	12	29	9	69	0.80	15	1456
Adds	5	37	262	5500	414	5.05	26	15	33	10	73	1.70	28	2786
Adds	6	52	295	65500	902	3.62	31	10	36	9	65	2.40	38	4327

Table 14. Bottom sediment data for samples collected in Clabber Creek area. All values are in ppm except Fe which is in weight percent. See Figure 21 for sample locations.

Sample	No.	Na	K	Ca	Mg	Fe	Co	Cr	Ni	Cu	Zn	Cd	Pb	Mn
Clabber	1	42	174	73750	6303	0.55	11	14	21	9	223	3.50	26	708
Clabber	2	39	175	58000	7240	0.56	11	12	19	9	178	2.70	15	620
Clabber	3	43	179	80000	4943	0.52	14	4	16	10	102	3.50	25	754
Clabber	4	52	260	89250	8708	0.69	17	5	19	10	37	2.90	30	1059
Clabber	5	52	218	49500	9421	0.68	11	5	23	9	24	2.20	25	1176
Clabber	6	44	283	32000	8003	0.74	11	16	24	10	37	1.70	20	299
Clabber	7	36	151	70500	5023	0.46	11	2	14	7	32	2.75	51	328
Blue John	1	26	136	21950	4398	0.41	8	3	8	9	19	0.60	0	185

Ponca City Mine workings which are located about one quarter mile west of Ponca City. Another possible source of the anomaly could be the leaching of disseminated mineralization in the area by ground water which is introduced into the stream at this point. Downstream from Ponca 3 the elemental values decrease due to the dilution by non-unique sediments.

These two streams reflect the mineralization of the area. The origin of the anomalous values have been shown to be related, at least in part, to mining in the area. Dilution of anomalous concentrations take place quickly in the Ponca area.

Dissolved Material Sample Collection and Preparation and Element Variation

Water samples were collected on 5/13/75, 7/18/75, 9/19-20/75, and 12/10/75 from seven stations shown in Figure 9. Approximately 200 ml of water was passed through a 0.45 μm filter and collected in a polyethylene bottle. Ten drops of 1:1 nitric acid were added per 100 ml of filtered water. The filters were prewashed in the laboratory in 1:1 HCl for 30 minutes, and rinsed with distilled, deionized water prior to the collection trip.

A procedure of chelation with diethydithiocarbamate and extraction by methyl isobutyl ketone was used to concentrate Cd, Co, Cu, Cr, Ni, Mn, Fe, Zn and Pb before analysis by atomic absorption spectrometry. This organic procedure is modified from Nix and Goodwin (1970) and is given in Steele, et al (1975). Calcium, magnesium, sodium and potassium were analyzed by standard atomic absorption spectrometry methods. Water data is given in Tables 15and 16.

The trends of major and minor element variation along the Buffalo River

Table 15. Dissolved material. All values in ppb except Na, K, Ca and Mg which are in ppm. Numbers in () are river miles from confluence with White River. For Collection Dates: M = May 13 J = July 18 S = September 19-20 D = December 10.

Station	Col. Date	Na	K	Ca	Mg	Fe	Mn	Co	Cr	Ni	Cu	Zn	Cd	Pb
1 Boxley (130)	M	1.11	0.64	3.73	0.33	26	6	1	<1	<1	<4	3	<1	<5
	J	-	-	-	-	-	-	-	-	-	-	-	-	-
	S	1.68	1.13	5.38	0.73	<1	1	<1	<1	<1	<2	<6	<1	<5
	D	1.26	0.60	3.12	0.41	<1	1	<1	<1	<1	<6	<10	<1	<5
1a Ponca (120)	A	2.23	1.21	15.11	1.26	17	11	<1	<1	<1	<9	<10	<1	<5
2 Pruitt (101)	M	1.31	0.70	7.32	0.65	25	7	1	<1	<1	17	<6	<1	<5
	J	2.31	1.03	16.91	1.67	8	3	1	<1	<1	<10	<6	<1	<5
	S	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	1.47	0.86	8.78	0.85	<2	4	<1	<1	<1	<6	<6	<1	<5
4 Hasty (94.1)	S	1.42	1.45	10.29	0.87	22	7	<1	<1	<1	<6	<6	<1	<5
5 Gilbert (55.2)	M	1.44	0.88	9.66	0.70	25	6	<1	<1	<1	<2	<6	<1	<5
	J	1.80	0.97	16.00	1.30	12	9	2	<1	<1	<10	<6	<1	<5
	S	2.23	1.13	19.35	1.80	7	<3	<1	<1	<1	<9	<6	<1	<5
	D	1.67	0.90	10.29	0.85	<1	<1	1	<1	<1	<9	<6	<1	<5
7 Buffalo Pt. (31.4)	M	1.54	0.87	11.61	0.87	18	5	<1	<1	<1	<2	<6	<1	<5
	J	1.95	0.99	15.79	1.59	8	8	<1	<1	<1	<10	<6	<1	<5
	S	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	1.65	0.92	10.95	0.93	<1	1	<1	<1	<1	<9	<6	<1	<5
8 Rush (23.3)	S	2.34	1.00	18.22	2.61	11	9	<1	<1	<1	132	61	<1	<5

Table 16. Average values for dissolved material per station and per collection date for the Buffalo River. All values are in ppm. River miles in ( ).

Station	Na	K	Ca	Mg	Fe	Mn
1 Boxley (130)	1.57	0.90	6.84	0.68	0.011	0.005
2 Pruitt (101)	1.63	1.01	10.83	1.01	0.014	0.005
5 (55.2)	1.79	0.97	13.83	1.16	0.011	0.005
7 Buffalo Pt. (31.4)	1.87	0.95	14.14	1.50	0.009	0.006
7-13-75	1.35	0.77	8.08	0.64	0.024	0.006
7-18-75	2.07	1.05	15.95	1.46	0.011	0.008
9-20-75	1.92	1.18	13.31	1.50	0.010	0.005
12-10-75	1.51	0.82	8.29	0.76	0.001	0.002

are those noted for 1974. Calcium, magnesium, sodium and potassium concentrations increase downstream (Fig. 32), and iron and manganese decrease downstream (Fig. 33). As reported earlier (Steele, et al., 1975), the water concentrations generally correlate with changes in the major rock-types in the Buffalo River Valley. Other element concentrations were below detection and could not be compared with those for 1974. Calcium and magnesium values for 1975 are approximately one half those for 1974. Sodium and potassium values for 1975 are about 20 percent greater than for 1974 (Fig. 32). Iron values are similar for the two years. Although there is a slight difference (about 3 ppb) for the manganese values, they can be considered as equal for the two years (Fig. 33) .

As in 1975, calcium, magnesium, sodium, and potassium exhibit seasonal fluctuations (Fig. 34) with the greatest concentration during late summer. The 1974 seasonal patterns correlated with the flow pattern, with greatest concentration during low flow for the river (Steele, et al., 1975). This correlation was explained as the basis of the lack of dilution by rain and also as the result of the concentration of these elements by evapotranspiration. The seasonal patterns for the two years are similar, however, calcium and magnesium values are lower for 1975 (Fig. 34). Iron values appear to be slightly higher for 1975. However, no acid was added to the samples collected during December which probably allowed much of the iron and manganese in solution to be precipitated. Both the iron and the manganese patterns are similar to those for 1974 with the exception of the December samples (Fig. 35). The manganese values are approximately constant. High values for iron occur during the spring of 1974 and 1975 and correlate with high flow (Steele, et al., 1975). The iron is probably from surface runoff. Humic acids in the soil probably aid in dissolving iron.

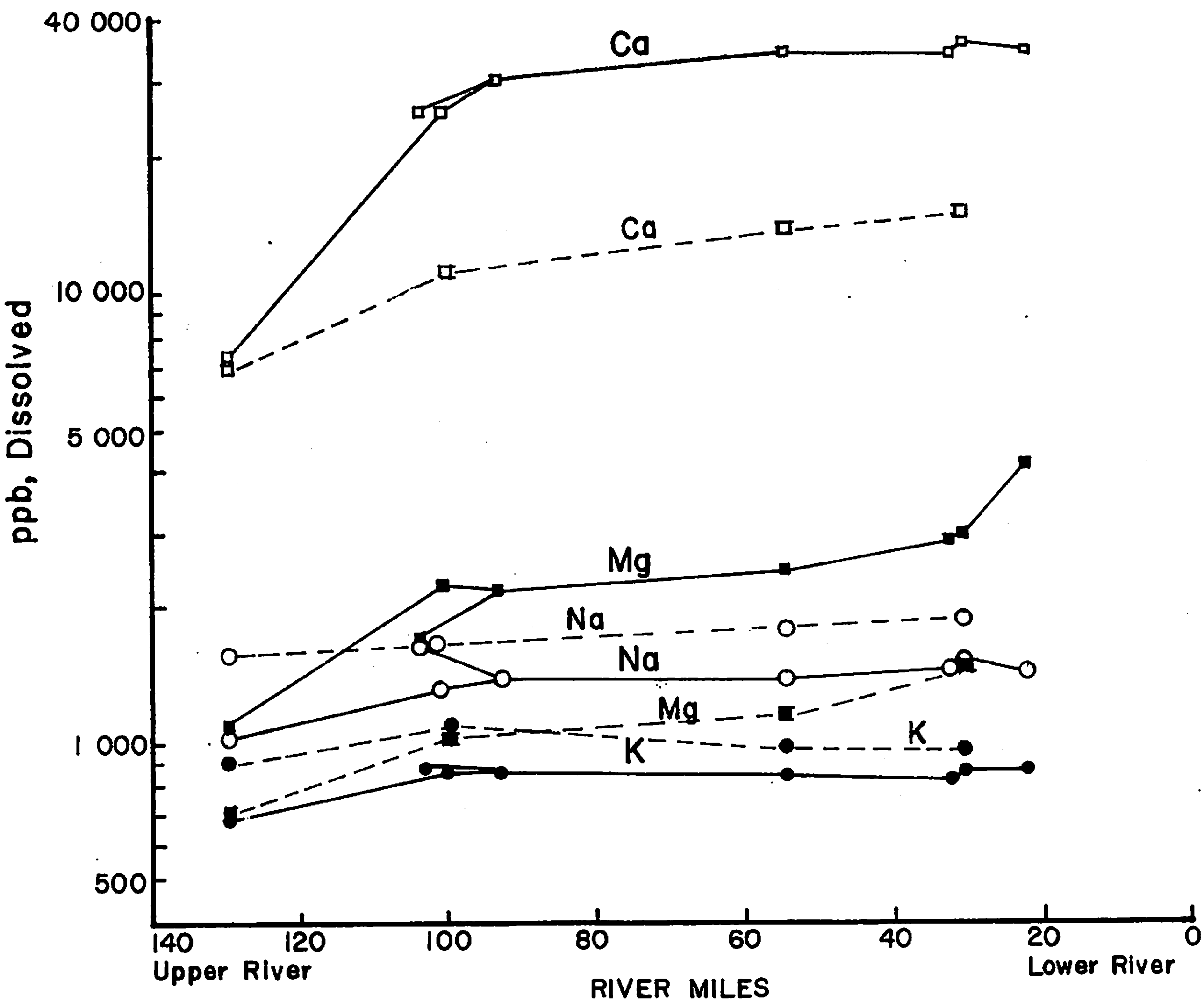


Figure 32. Dissolved river load (major elements) vs river miles. Average values for each station plotted. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

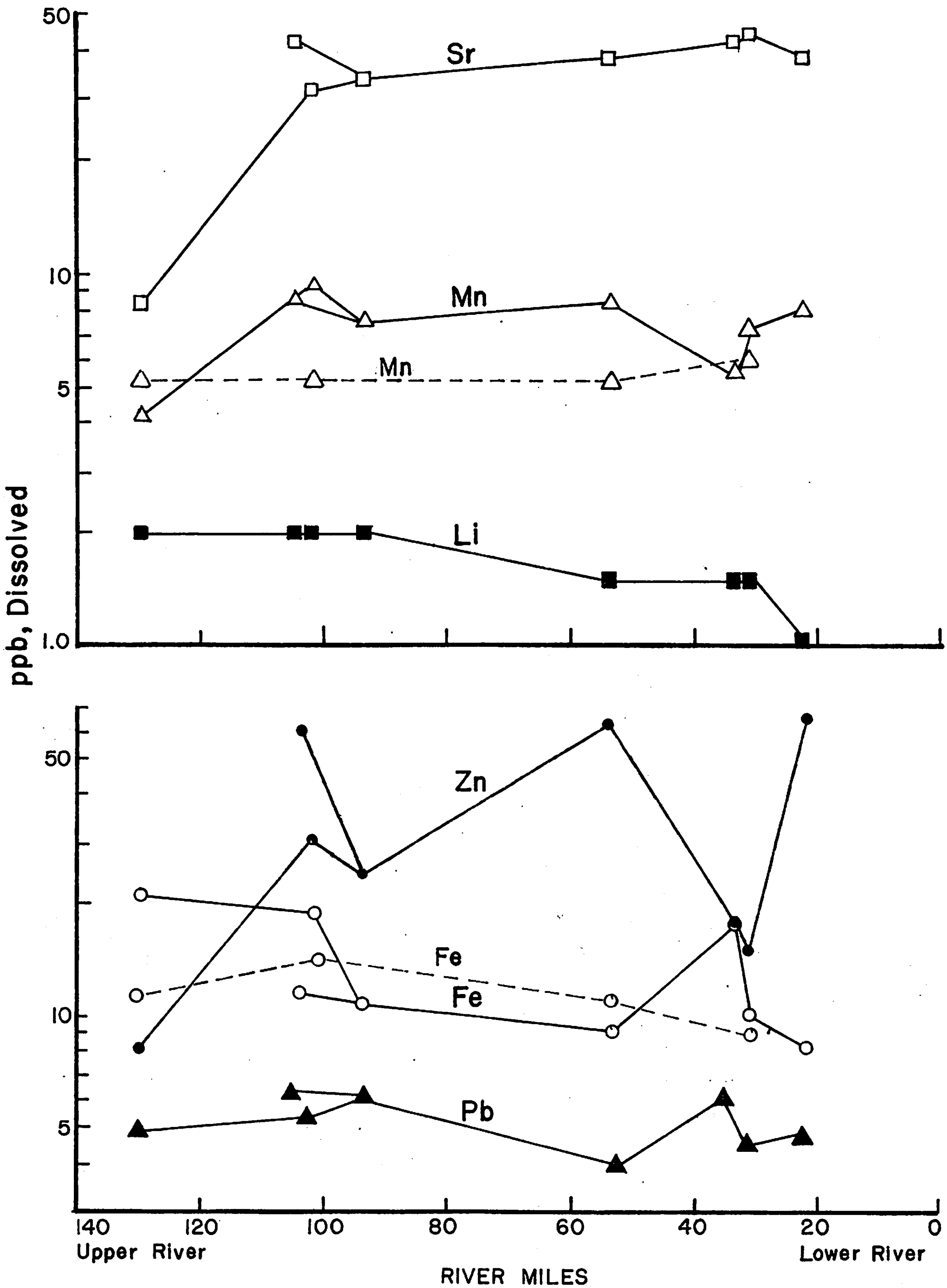


Figure 33. Dissolved river load (minor elements) vs river miles. Average values for each station plotted. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

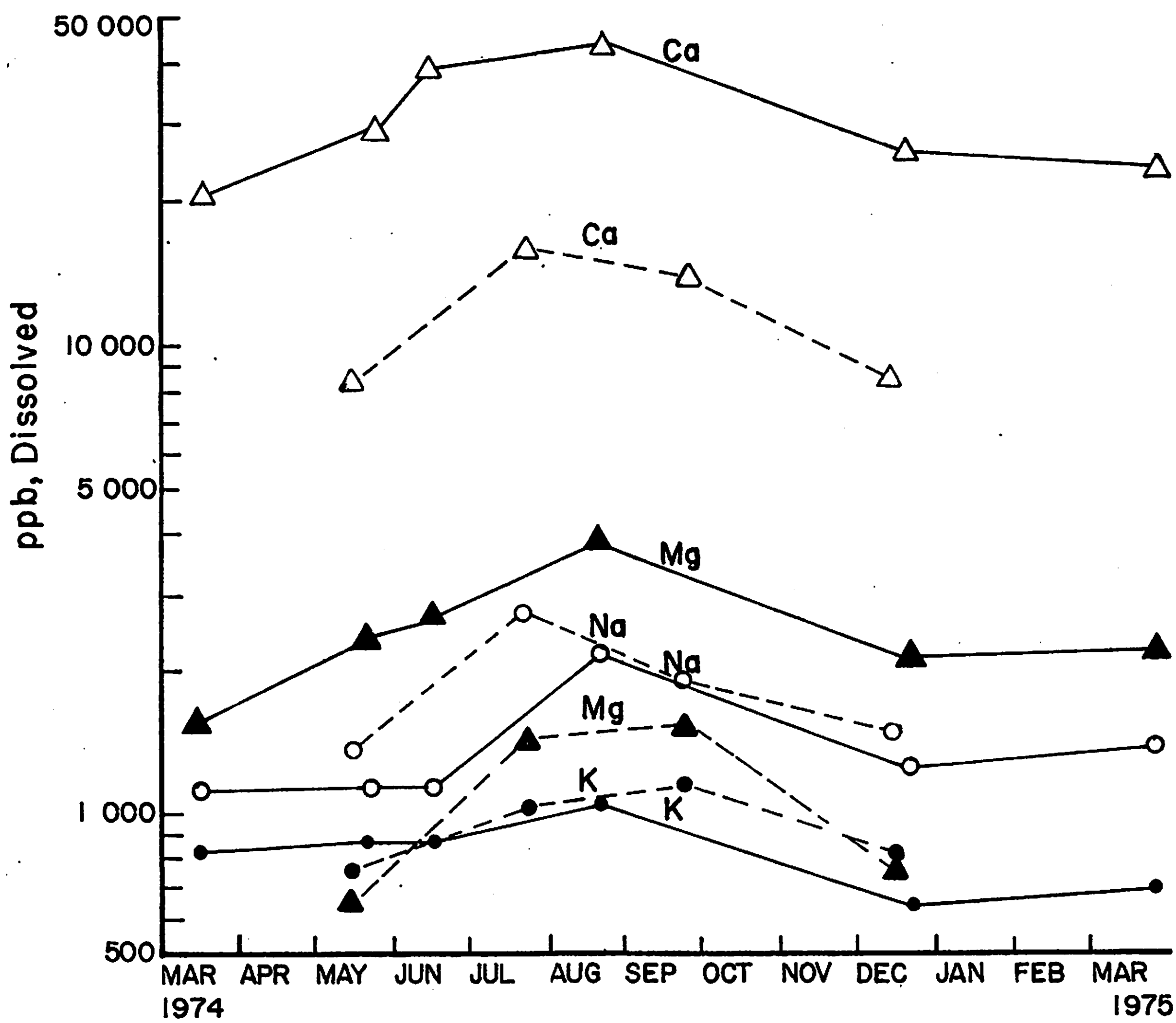


Figure 34. Dissolved river load (major elements) vs month of collection. Points are average values for eight stations. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

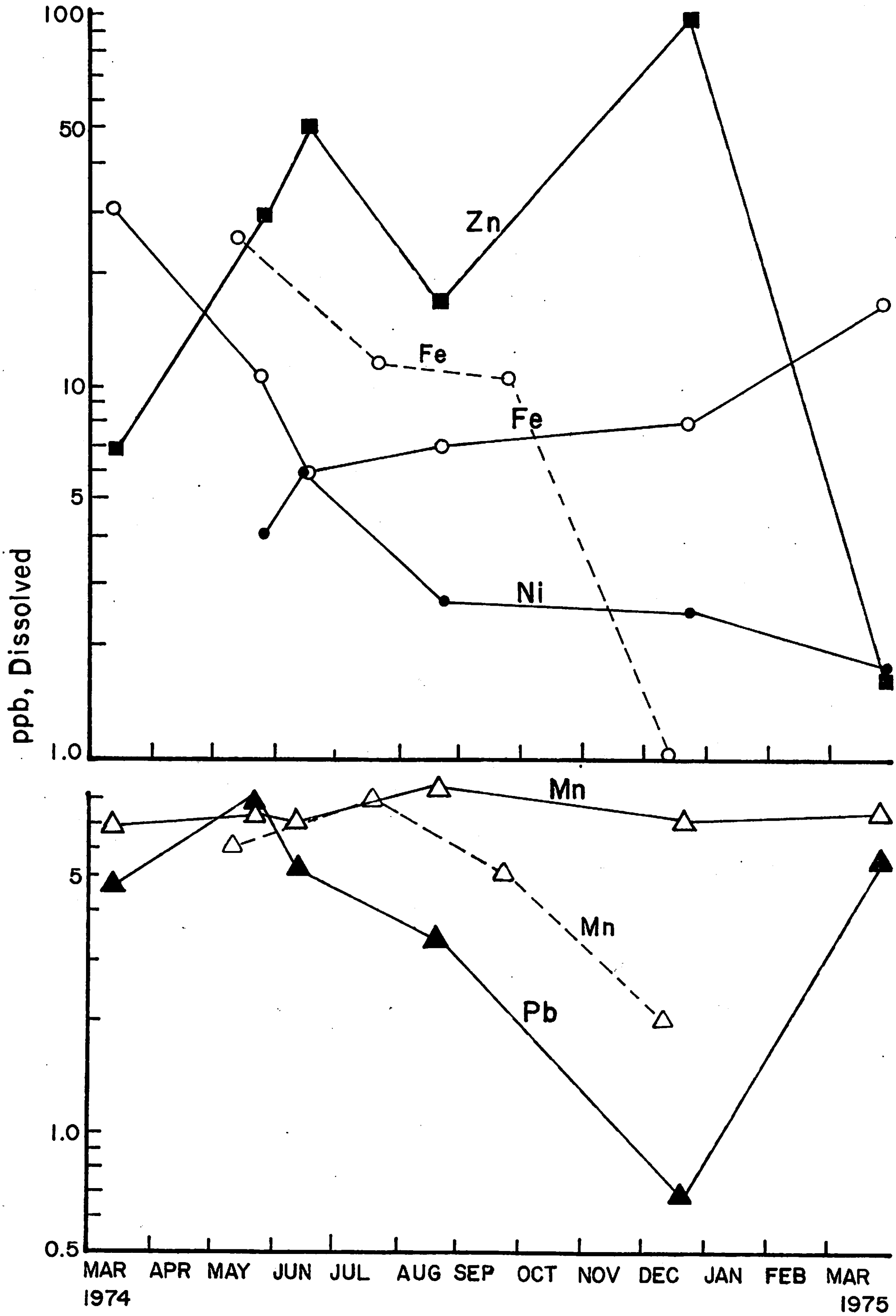


Figure 35. Dissolved river load (minor elements) vs month of collection. Points are average values for eight stations. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

The discrepancies between the 1974 and the 1975 data could be due to chance differences in sampling conditions. However, differences in flow rates is most likely.

Suspended Sediments Sample Collection and Preparation and Element Variation

Suspended sediments were collected from seven stations shown in Figure 9 and also from Ponca, Rush and Clabber Creeks on 5/13/75, 7/18/75, 9/19-20/75 and 12/10/75. One half to one liter of water was filtered in the field through a 0.45 m Millipore filter using a hand operated vacuum pump. The filters were prewashed for 30 minutes in 1:1 HCl and rinsed in distilled, deionized water in the laboratory prior to the collection trip. After filtration the filters were returned to the laboratory and placed in a 25 ml Erlenmeyer flask with 2 ml of concentrated HCl overnight. The extractant was then diluted to 25 ml and the filter rinsed several times in distilled, deionized water. The sample was then analyzed by atomic absorption spectrometry. The atomic absorption technique used was the same as that for the bottom sediments. Sodium, potassium, calcium, magnesium, iron and manganese were determined. The blanks for the 0.45 m filters were very high, making the sodium and potassium data essentially useless (Table 17).

The concentration of elements in the suspended sediments is quite low (Table 17 and summarized in Table 18); however, it is greater than that for 1974 (Table 18). The concentration of elements in the water generally exceeds that in the suspended sediments, except in the case of iron and manganese. Generally, there is about 20-60 times as much suspended iron per liter of water as dissolved iron and about 2-25 times as much suspended manganese per liter of water as dissolved manganese (Tables 16, 18 and 19). Station 1 (Boxley) has the largest Zn concentrations, probably because of the greater amount of clay particles derived from the shale in the area and the lowest Ca values

Table 17. Suspended material. All values in parts per billion (µg per liter of of water). Numbers in ( ) under Station column are river miles from confluence with the White River. For Collection Dates: M = May 13, J = July 18, S = September 19-20, D = December 10.

Station	Collection date	Na	K	Ca	Mg	Fe	Mn	Zn
1	M	63	63	61	131	275	5	40
Boxley	J	-	-	-	-	-	-	-
(130)	S	111	63	80	24	525	8	190
	D	35	25	26	10	300	5	20
1A Ponca (120)	J	63	63	45	3	75	13	< 1
2	M	63	63	34	109	300	8	6
Pruitt	J	63	63	27	4	300	18	8
(101)	S	-	-	-	-	-	-	-
	D	35	25	46	12	400	5	30
4 Hasty (94.1)	S	63	8	271	90	2250	82	46
5	M	63	63	110	30	687	18	12
Gilbert	J	63	63	85	6	<10	11	19
(55.2)	S	63	63	198	10	1650	215	5
	D	35	25	54	14	325	8	15
7	M	63	63	63	13	300	10	5
Buffalo Pt.	J	63	63	72	7	30	9	26
(31.4)	S	-	-	-	-	-	-	-
	D	35	25	70	14	350	13	10
8 Rush (23.3)	S	63	63	29	6	100	5	5

Table 18. Average values for suspended material (<0.45 μm) per station and per collection date for the Buffalo River. All values are in ppb (i.e. μg per liter of water). River miles in ( ).

Station	Ca	Mg	Fe	Mn	Zn
1 Boxley (130)	53	42	294	8	63
2 Pruitt (101)	103	54	812	113	23
5 Gilbert (55.2)	112	15	667	63	13
7 Buffalo Pt. (31.4)	59	10	195	9	12
5-13-75	67	71	390	10	16
7-18-75	57	5	103	13	13
9-20-75	144	33	1131	78	62
12-10-75	49	13	344	8	19

because of the lack of significant carbonate rocks in the area (Table 18). There are no systematic trends for element concentration in the suspended material, either along the river or with season.

Ratios for dissolved to suspended load are different for 1974 and 1975 (Table 19) and some also have different trends (Figs. 36 and 37). The ratio of dissolved magnesium to the concentration of magnesium in suspended material gives an accentuated increase downstream for 1975 data (Fig. 36). The trends for iron (Fig. 37) are similar for the two years. Although data is limited, rainfall (i.e. runoff and flow) is the controlling factor.

Table 19. Ratio of average dissolved material concentration to average suspended material concentration for the Buffalo River. River miles given in ( ).

Station	Ca	Mg	Fe	Mn
1 Boxley (130)	129	16.2	0.037	0.63
2 Pruitt (101)	105	18.7	0.017	0.04
5 (55.2)	123	77.3	0.016	0.08
7 Buffalo Pt. (31.4)	240	150	0.046	0.67
5-13-75	121	1.6	2.4	0.38
7-18-75	280	14.2	0.8	0.62
9-20-75	92	1.3	0.1	0.08
12-10-75	169	2.2	0.1	0.11

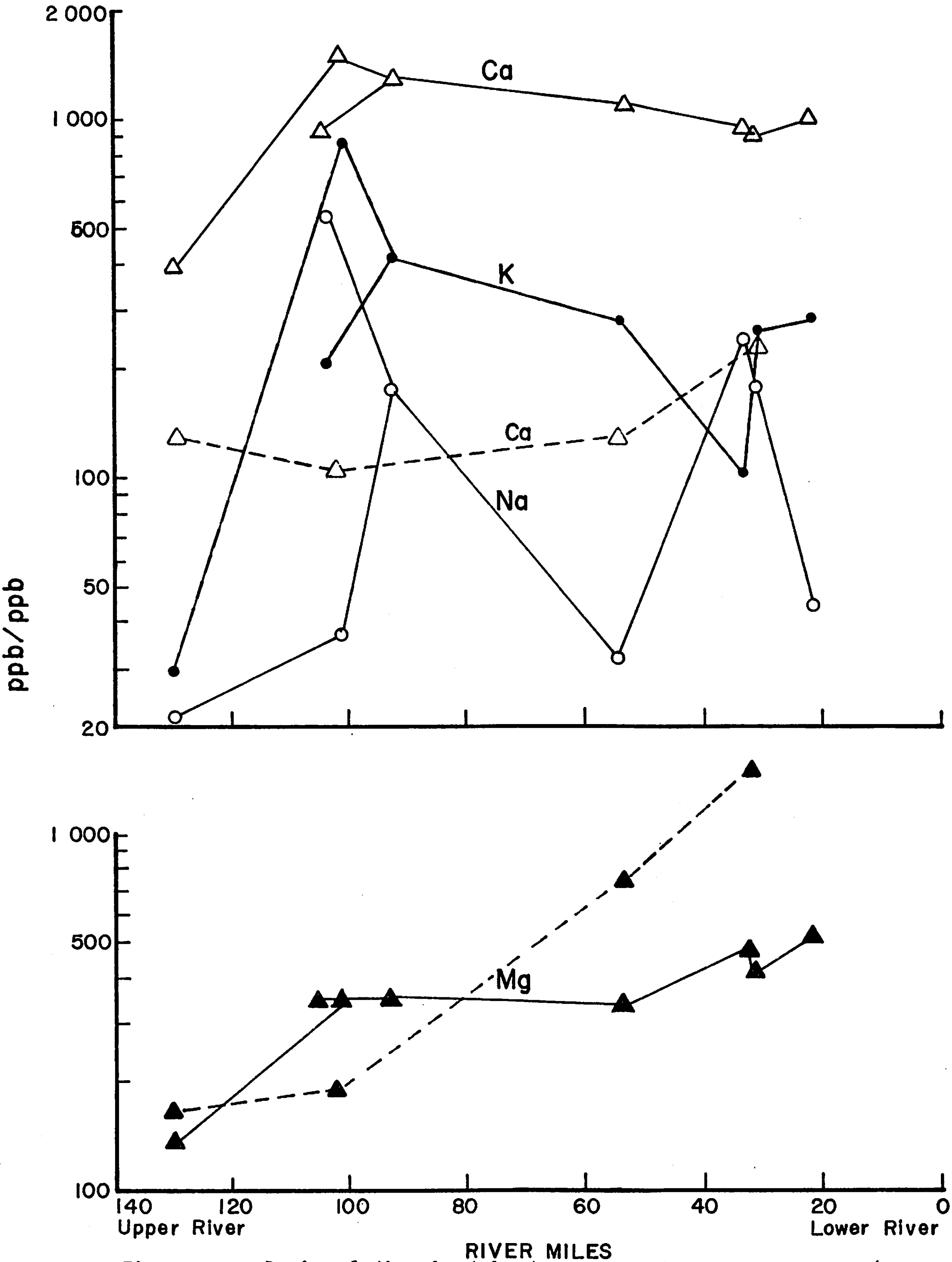


Figure 36. Ratio of dissolved load to suspended load of river (major elements) vs river miles. Average values for each station plotted. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

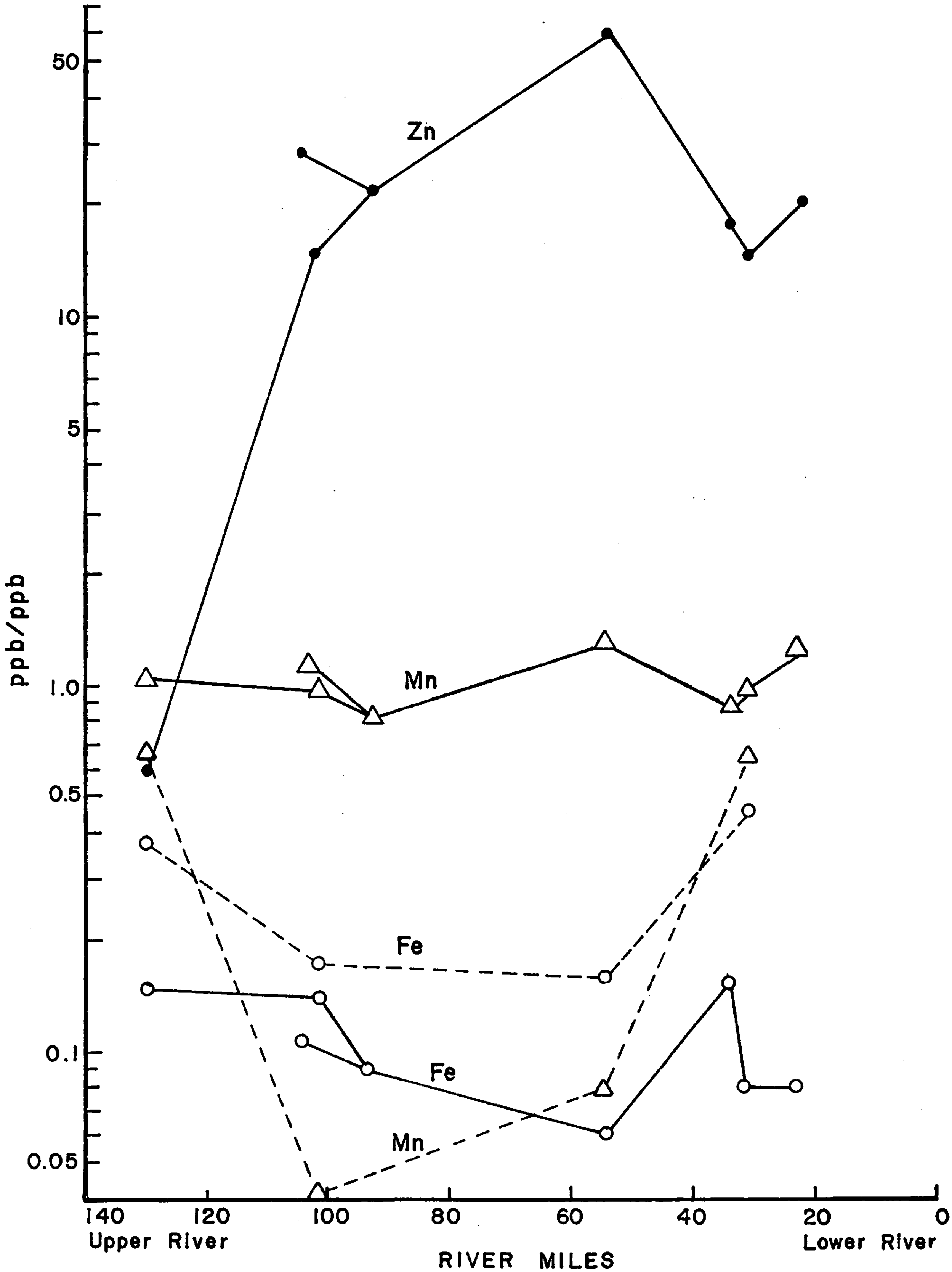


Figure 37. Ratio of dissolved load to suspended load of river (minor elements) vs river miles. Average values for each station plotted. Data for 1974 is indicated by solid lines and that for 1975 by dashed lines.

HYDROGEOLOGIC CHARACTERISTICS

Previous Investigation

Hydrologic investigation of the ground and surface water in the Buffalo River basin has been limited. Baker (1955) briefly discussed possible water-bearing stratigraphic units in northern Arkansas. The United States Army Corps of Engineers (1964) studied the hydrology of the surface water in the Buffalo River basin in preparation for the construction of a dam(s) on the Buffalo River. Lamonds and Stephens (1969) furnished general water resource data for the Ozark Plateaus of Arkansas. Lamonds (1972) discussed the hydrologic characteristics and water quality of the Ozark Plateaus province of northern Arkansas, which pertain in part to the Buffalo River basin. Trace elements in the sediments of the Buffalo River were investigated by Wagner (1974) and Steele and Wagner (1975). Melton (1975) studied in detail the geohydrology of the Roubidoux Formation and the Gasconade Formation in southern Missouri and northern Arkansas.

The U.S. Army Corps of Engineers (1964), in an interim report on the Buffalo River basin, provided information on the economic, sociological, and environmental aspects of the area. Smith (1972) described the aesthetic qualities of the Buffalo River country. Information pertaining to the establishment of the Buffalo National River, an environmental statement, and a wilderness study of the Buffalo River basin were provided by the Department of Interior through the National Park Service (1974).

The Basin

The study area, the Buffalo River basin, is in north-central Arkansas (Figure 38). The basin encompasses the greater part of Newton and Searcy Counties and smaller areas of Baxter, Marion, Boone, Pope, Stone, and Van Buren Counties. Irregular in shape, the basin is bounded roughly by the west longitude lines 92° 20' to 93° 30' and the north latitude lines 35° 40' to 36° 13'.

The Buffalo River basin is elongate, approximately 70 by 22 miles, and the major axis is east-west. The basin encompasses 1,338 square miles. It is in the region known as the Ozark Plateaus province of the Interior Highlands, which consists of three plateaus separated by steep, irregular escarpments (see discussion of physiography, page 105). The plateaus are deeply dissected and as a result the area is rough and mountainous. There is almost no flat land either in the stream valleys or on the divides. The basin is generally heavily forested, although some land is used for agriculture. Soils in the limited flood plains of valleys are sandy and silty loams, whereas cherty loams and clays cover the slopes. The soils on the slopes are thin and easily eroded.

The drainage pattern consists of the main stream, the Buffalo River, and 64 generally short, perennial and intermittent tributaries entering from both sides at regular intervals. The two largest tributaries are the Little Buffalo River and Big Creek which have drainage areas of 142 and 138 square miles, respectively.

The Buffalo River originates in the Boston Mountains in southwest Newton County and flows eastward along a winding course to its

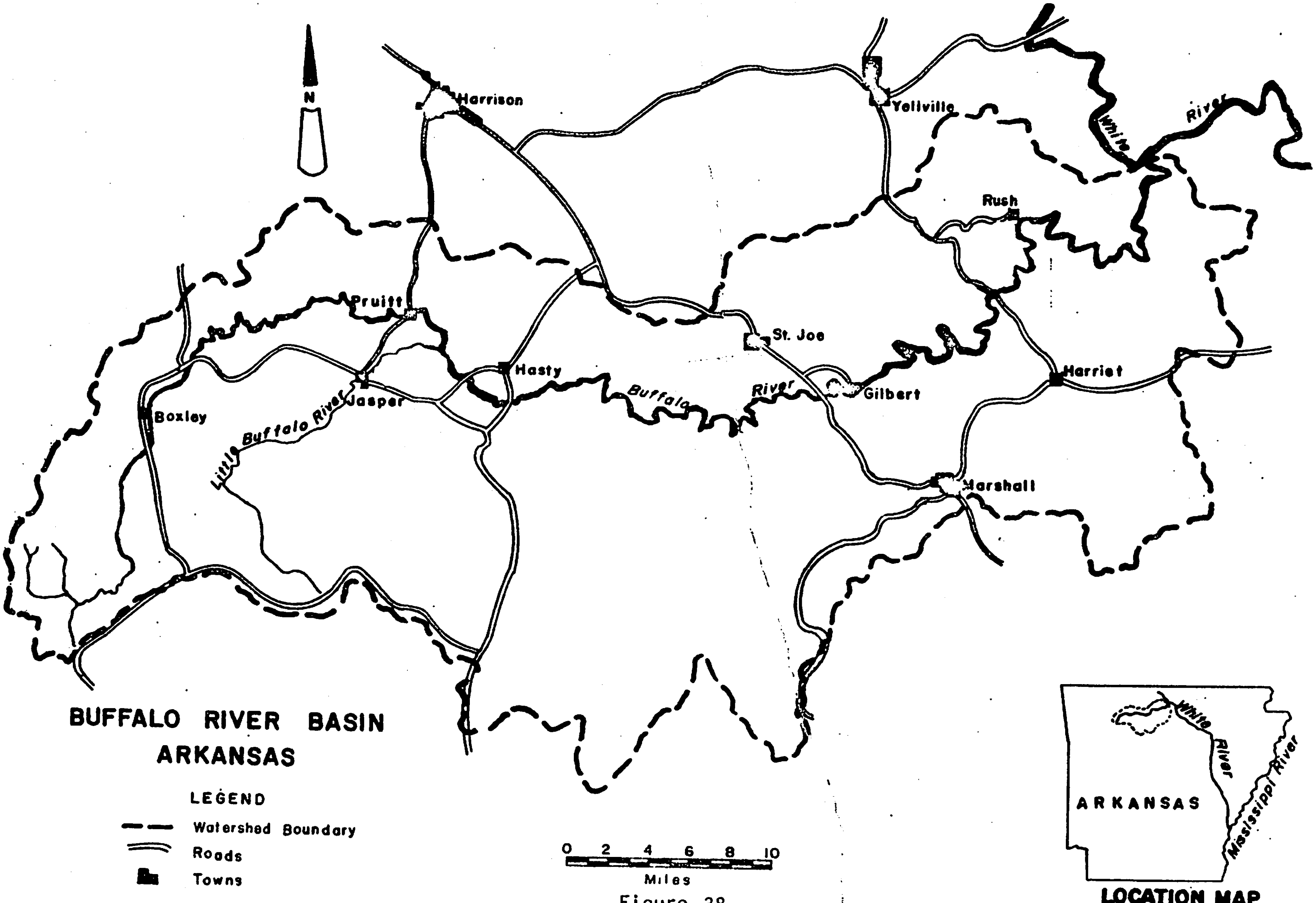


Figure 38

Source: Steele and Wagner (1975).

confluence with the White River, a distance of approximately 148 miles. The river has entrenched itself below the plateau surfaces; as a result, it runs through a narrow, relatively deep valley which has steep rock bluffs on the outside of the river bends and more gentle slopes on the inside of the bends. Narrow elongate flood plains border the stream on the inside of the bends. The river is characterized by quiet pools separated by short shoals. The channel is stable, as the river flows on a veneer of gravel and boulders and in places on bedrock. Steep stream slopes characterize the upper reaches of the Buffalo River, ranging from 40 to 15 feet per mile above Pruitt; but the slope averages less than 4 feet per mile along the lower 100 miles of the river.

The Buffalo National River was authorized by Act of Congress (Public Law 92-237) on March 1, 1972. This act insured that the Buffalo would remain a free-flowing stream and created a linear National Park along the lower 132 miles of the river. The Buffalo National River occupies 11 percent of the Buffalo River basin. In addition, 22 percent of the basin is within the Ozark National Forest. Thus, one third of the basin is under Federal administration. The basin is rural and sparsely populated with only about 13,000 people. The largest towns are Marshall and Jasper with populations of 1,100 and 360, respectively.

Physiography

One of the most significant aspects of the physical environment is topography, because it determines how and at what cost the land is used. Topography is an evolutionary phenomenon, the result of geologic and climatic conditions and the duration of time. The basic geologic matrix is acted upon by tectonic forces and the dynamic forces of air, temperature, and water. The result of these interacting forces, the configuration of the landscape, determines to some extent how the land is used by mankind. Moreover, topography is related to hydrology and land use because it in part determines the strata that are present at the surface and the dpeth of aquifers in the subsurface.

Topographically, Arkansas is divided nearly equally from northeast to southwest into two physiographic provinces. The eastern and southern part of the state is a comparatively low undulating plain - the Gulf Coastal Plain; northern and western Arkansas is included in the Interior Highlands, a region of considerable relief composed of Paleozoic rocks. The Interior Highlands in Arkansas is divided into two provinces. On the south is the Ouachita province which contains the Ouachita Mountains and the Arkansas Valley regions. North of the Ouachita province is the Ozark Plateaus which can be subdivided into the Salem Plateau, the Springfield Plateau, and the Boston Mountains. The physiographic provinces in the Buffalo River basin are shown in Figure 39.

The northernmost of the three Ozark Plateaus sectors, the Salem Plateau, is also the lowest with surface elevation ranging from approximately 250 feet above sea level on the east to 1250 feet on the west. The Salem Plateau is composed at the surface of Ordovician limestone and dolomite (Powell and Cotter Formations) dipping gently southward. It has been eroded extensively and consequently the topography is exceedingly rough. Only the north-

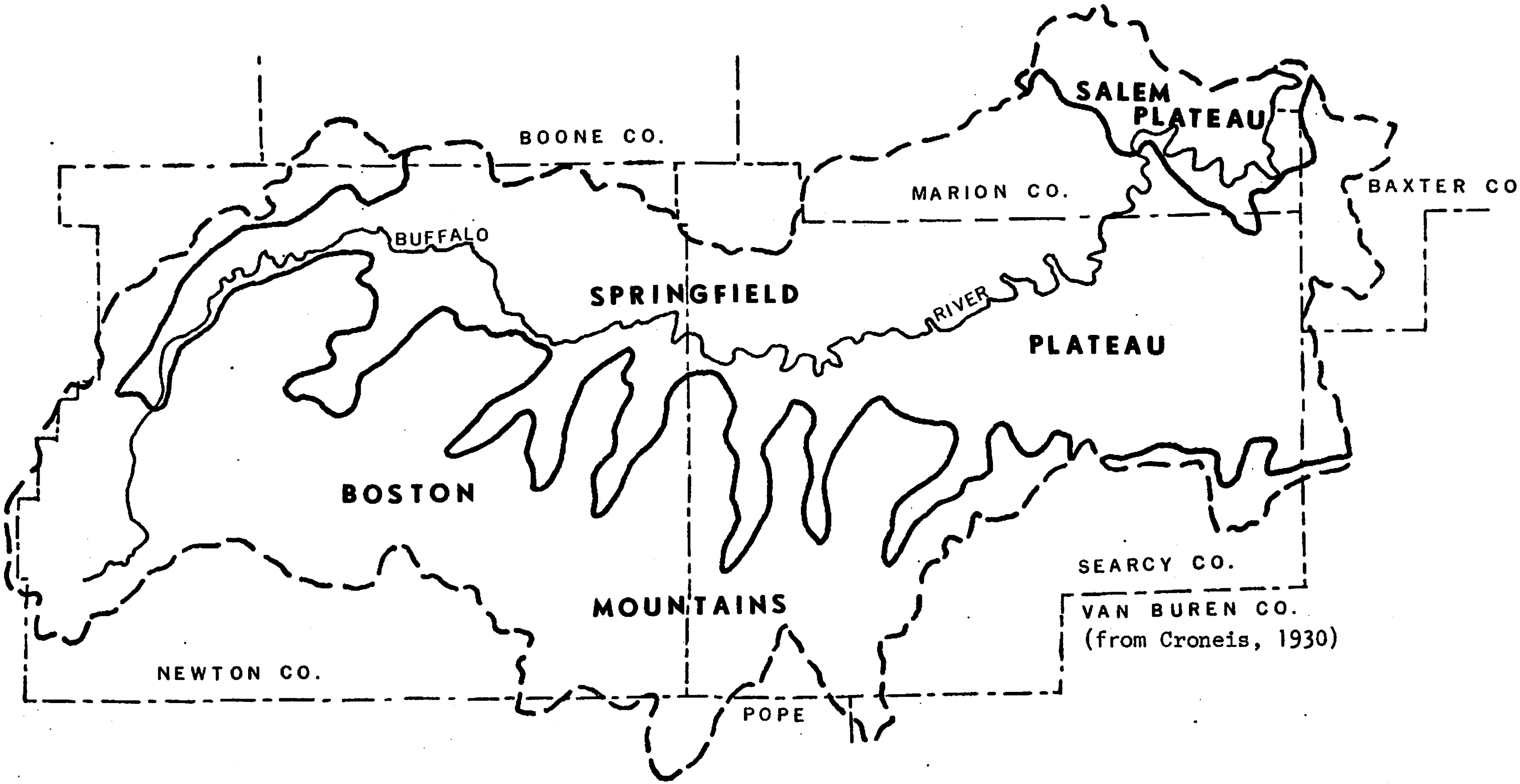


FIGURE 39. PHYSIOGRAPHIC PROVINCES OF THE BUFFALO RIVER BASIN

easternmost part of the Buffalo River basin is within the Salem Plateau.

Above and south of the Salem Plateau is the Springfield Plateau. It is separated from the lower plateau by the sinuous, northfacing Eureka Springs Escarpment, which has a maximum height of about 400 feet on the west and becomes progressively less prominent eastward. The major part of the Springfield Plateau is between 1000 and 1500 feet above sea level, but erosional remnants commonly rise 250 to 750 feet above the plateau surface. The plateau varies from a gently undulating surface to deeply dissected terrain. The surface is composed of resistant Mississippian strata with a slight regional dip to the south. Much of the northern and eastern Buffalo River basin is in this region.

On the south the Boston Mountains rise above the Springfield Plateau. The prominent north-facing Boston Mountain Escarpment attains a maximum relief of 800 feet. Streams have deeply serrated the escarpment, making it irregular with many outliers on the plateau below. The southern slope of the mountains descends less abruptly to the Arkansas Valley. The mountains are actually a deeply dissected plateau that has all but been destroyed by erosion (Quinn, 1958). Many of the mountain tops are flat and are 1900 to 2200 feet above sea level; remnants rise several hundred feet more above the ancient plateau. Maximum elevation is about 2400 feet. Narrow, steep-sided ravines between 500 and 1250 feet deep are common. In places, the slope is broken by vertical cliffs caused by the alternation of resistant and soft beds of rock. The surface rocks of the Boston Mountains are of Pennsylvanian age. The western and southern part of the Buffalo River basin is in this region.

Climate

The climate of the Buffalo River basin is humid-continental, characterized by long hot summers and relatively mild short winters. These seasons are separated by distinct springs and falls. Extremes of temperature of 114 degrees Fahrenheit and -23 degrees Fahrenheit have been recorded within the basin. The average annual temperature is 58 degrees Fahrenheit.

Precipitation averages 48.6 inches annually. This average is based on the records of eleven stations in or adjacent to the basin. Precipitation is slightly greater in the Boston Mountains than on the Springfield and Salem Plateaus. Although the distribution is relatively uniform throughout the year, amounts generally are slightly greater during the spring months April to June. December, January, and February are usually the driest months. Table 20 shows the average monthly and annual precipitation. In spite of the fairly uniform monthly distribution of precipitation, runoff is affected seasonally; flows are greatly reduced during the late summer and early fall. On the basis of records dating back to 1900, the greatest annual precipitation was 82.3 inches in 1927 and the least measured was 23.0 inches in 1963. The average annual snowfall is about 12 inches, occurring from November through March.

Moderately intense local storms, accompanied by heavy rainfall, occur within the basin. Although these storms are most likely in the spring, they can happen at any time of year. Flooding sometimes occurs as the result of these storms. Drought conditions are common in the Buffalo River basin and affect the streamflow.

Table 20.

DISTRIBUTION OF AVERAGE MONTHLY AND ANNUAL PRECIPITATION

Month	Average Precipitation (inches)	Percent of Average Annual Precipitation
January	3.4	7.0
February	3.1	6.4
March	3.8	7.8
April	5.2	10.7
May	5.9	12.1
June	4.4	9.1
July	4.2	8.6
August	4.3	8.9
September	3.9	8.0
October	3.6	7.4
November	3.3	6.8
December	3.5	7.2
Annual	48.6	100.0

Source: U.S. Army Corps of Engineers (1964).

Stratigraphy

Rocks underlying the Buffalo River basin range in age from Precambrian to early Pennsylvanian, as shown by the generalized stratigraphic section (Table 21). The sedimentary section is approximately 5,000 feet thick. The pre-Atoka succession is composed mainly of limestone, dolomite and shale and increases in thickness to the south and southeast; the Atoka rocks are dominantly interbedded sandstone and shale units that increase in thickness to the south (Sheldon, 1954). Sub-surface rocks include the Precambrian basement, Upper Cambrian and Lower Ordovician rocks up to and including the Jefferson City Dolomite. Surface exposures within the basin range from the Lower Ordovician Cotter Formation through the Lower Pennsylvanian Atoka Formation. The geologic map, Figure 40 shows the general distribution of strata related to major time-stratigraphic units. Numerous periods of erosion interrupted deposition of the Paleozoic sedimentary succession (Frezon and Glick, 1959). Most of the interruptions in deposition were minor and the resulting unconformities are of only local significance (Caplan, 1960). Because of these erosional effects, the sedimentary section is considerably different from place to place in regard to thickness, character and the occurrence of particular units.

Ordovician, Silurian, Devonian, Mississippian and lower Pennsylvanian rocks crop out in the basin and dip gently southward under the cover of the Atokan age strata of the Boston Mountains (Frezon and Glick, 1959). In general, progressively older formations

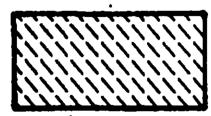
TABLE 21. STRATIGRAPHIC SECTION OF NORTH ARKANSAS

System	Formation	Member	Thickness in Feet	Remarks
PENNSYLVANIAN	Hartshorne ss.		55-160	
	Atoka fm.		4392-4635	Surface thicknesses ranging from 1,500 to 9,400 feet are reported by Croneis (1930, p. 118).
	Bloyd sh. (Morrow group)		0-628	Kessler ls., Brentwood ls., and Prairie Grove member of Hale fm. thicken and grade into sandstone southeastward where the equivalents have generally been included in the Atoka fm.
		Kessler limestone member	0-105	
		Brentwood limestone member	0-90	
	Hale fm. (Morrow group)	Prairie Grove member	70-307	Cane Hill member approximately equivalent to Jackfork sandstone in White, Cleburne, and Jackson Counties.
		Cane Hill member	0-745	
MISSISSIPPIAN	Pitkin ls.		0-219	Pitkin limestone grades into a black shale sequence included in the Fayetteville shale in Pope, Van Buren, and Cleburne Counties.
	Fayetteville sh.		43-297	
	Batesville ss. Ruddell sh. Moorefield fm.		7-457	Batesville ss., Ruddell sh., and Moorefield fm. generally cannot be differentiated in well samples.
	Boone fm.		52-388	Stanley shale in wells 1 and 2 in White County and in well 1 in Jackson County appears to represent all Mississippian rocks, including the Boone fm. and the Chattanooga sh.
MISS. AND DEV.	Chattanooga sh.		0-70	
DEVONIAN	Penters chert		0-260	
SILURIAN	Lafferty ls. St. Clair ls. Brassfield ls.		0-254	Silurian rocks are generally not differentiated in well samples.
ORDOVICIAN	Cason sh.		0-57	
	Fernvale ls.		0-108	
	Kimmswick ls. Plattin ls.		0-400	Rocks below Fernvale ls. and above St. Peter ss. are generally included in Plattin ls. due to correlation uncertainties in wells.
	Joachim dol.		0-117?	
	St. Peter ss.		0-158	St. Peter ss. and Everton fm. are generally correlated with the Simpson group of Oklahoma.
	Everton fm.		0-1180	
	Powell dol.		0-210	Ordovician rocks below the Everton fm. are generally correlated with the Arbuckle group of Oklahoma.
	Cotter dol.		357-400	
	Jefferson City dol.		365-433	
	Roubidoux fm.		134-231	
	Gasconade dol.		360-460	
CAMBRIAN	Eminence dol. Bonneterre dol. Lamotte ss.		307-350(?) 0- 60(?) 0- 35	Lamotte ss. is correlated with Reagan ss. of Okla.
PRE-CAMBRIAN				

(from Sheldon, 1954)

LEGEND

Atoka Formation



Bloyd Shale

Hale Formation

Pitkin Limestone

Fayetteville Shale

Batesville Sandstone

Ruddell Shale

Moorefield Formation

Boone Formation

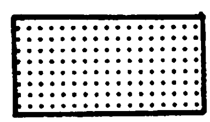
Chattanooga Shale

Penters Chert

Lafferty Limestone

St. Clair Limestone

Brassfield Limestone



Cason Shale

Fernvale Limestone

Plattin Limestone

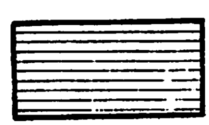
Joachim Dolomite

St. Peter Sandstone

Everton Formation

Powell Dolomite

Cotter Dolomite



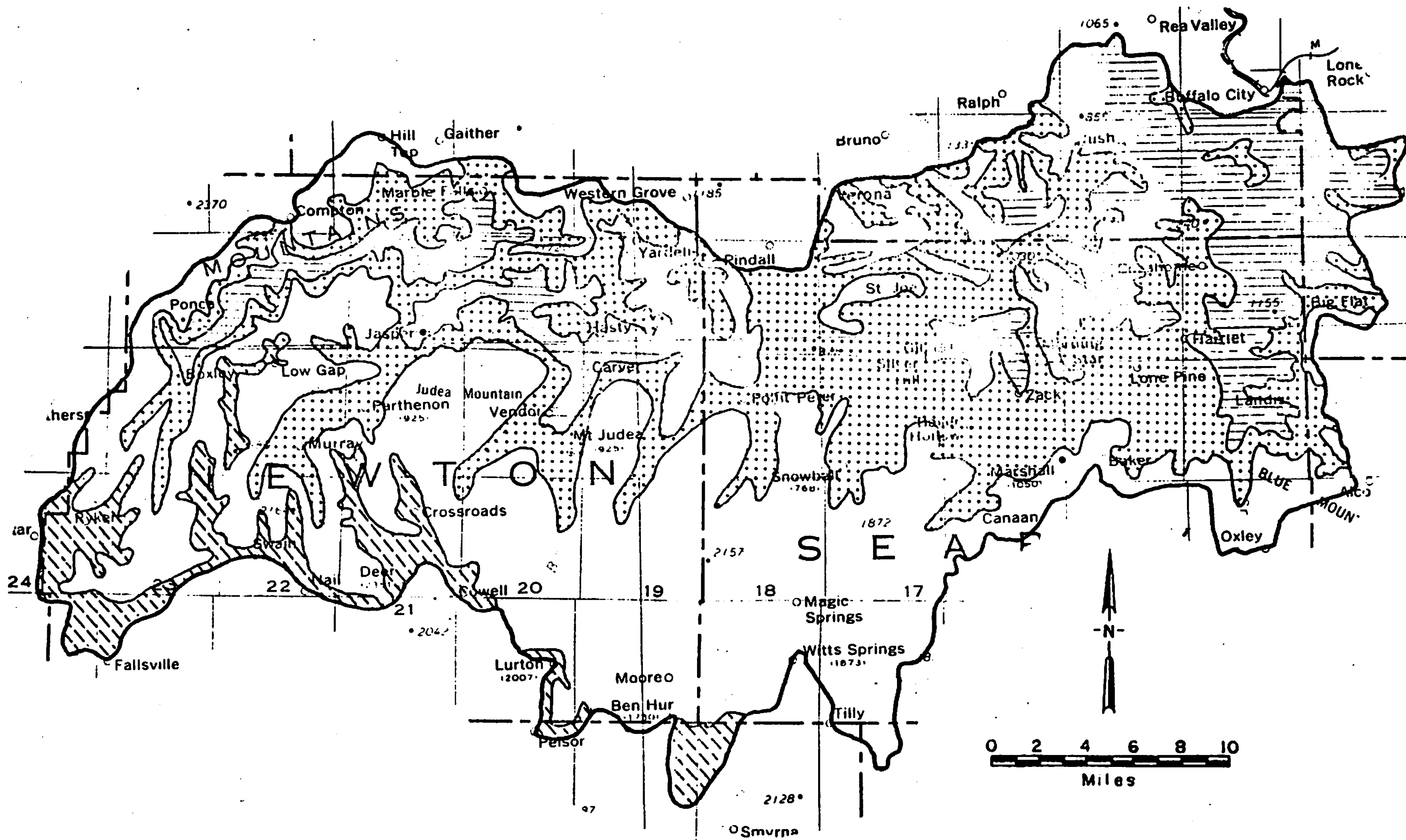


FIGURE 40. GEOLOGIC MAP OF THE BUFFALO RIVER BASIN
After Lamonds (1972).

(Ordovician) crop out toward the northern boundary of the basin. Exceptions are mainly where the Buffalo River and its larger tributaries have deeply incised the landscape exposing the older strata below; and where isolated outliers of younger rocks rise above the Springfield Plateau.

Pre-Cambrian

Current well data is insufficient to allow a detailed account of the nature and distribution of the Precambrian basement rock. Precambrian rock exposed in the St. Francois Mountains of southern Missouri are of three general types: rhyolites, granites, and basic intrusives of gabbroic composition (State of Missouri, 1967). There is some similarity between the Missouri Precambrian and that of Arkansas in that the five wells which penetrate the Precambrian in northern Arkansas have encountered granite and rhyolite (Frezon and Glick, 1959).

Cambrian System

Little is known concerning the Cambrian age rock present in the subsurface of the Buffalo River basin as relatively few wells penetrate these depths and no Cambrian strata are exposed. Because of their prohibitive depth and because of the lack of knowledge pertaining to them the Cambrian strata will be considered only briefly.

The Upper Cambrian formations, the Lamotte Sandstone, Bonneterre Dolomite and the Eminence Dolomite are present in the subsurface. Outcrops of all three are common in portions of southeast Missouri. They are not exposed in Arkansas. The basal unit, the Lamotte Sandstone, lies unconformably on the Precambrian basement. According to Caplan (1960), it is fine to coarse-grained, white to yellow in color and composed of subangular to rounded quartz grains. The loosely cemented rock is occasionally dolomitic and often arkosic. As described by Caplan (1960), this sandstone grades upward into a zone of arenaceous, glauconitic, pyritic, finely granular to medium-crystalline, light-gray dolomite - the Bonneterre Dolomite. Above the Bonneterre Dolomite is the Eminence Dolomite composed chiefly of fine to coarse-crystalline, light-gray dolomite that contains relatively abundant white to light-gray, dense chert (Caplan, 1960). The Eminence is the uppermost Cambrian Formation in northern Arkansas.

Ordovician System

Gasconade Formation

The Gasconade Formation in Arkansas is present only in the subsurface and lies unconformably on the Eminence Dolomite. According to Caplan (1960), the Gasconade Formation is basically finely granular to medium-crystalline, light colored dolomite that contains light gray or blue-gray dense chert. Below the Buffalo River basin, the interval increases in thickness from approximately 320 feet in northwest Newton County to 660 feet in southeastern Searcy County.

The Gunter Member of the Gasconade Formation occurs at the base of the succession. The Gunter is generally regarded as white to light-gray sandstone consisting of loosely cemented fine to coarse, subangular to rounded, frosted quartz grains which may contain thin sandy or silty dolomite beds (Caplan, 1960). The unit thickens regionally to the south and southeast. Thicknesses of 20 to 40 feet are characteristic in Arkansas.

Roubidoux Formation

The Roubidoux Formation rests unconformably on the Gasconade. It does not crop out in the Buffalo River basin. Caplan (1960) considers the Roubidoux to consist of sandstone and dolomite with associated chert. Sandstones found throughout the formation are composed of fine to medium, angular to rounded, frosted quartz grains which are white to light-gray in color. They are loosely cemented by silica or calcareous material. Chert occurs in some sections. The dolomite is finely granular to medium-crystalline, light colored and cherty or sandy in parts. Chert present in the Roubidoux is generally light in color and dense (Caplan, 1960).

In northern Arkansas, the Roubidoux Formation ranges in thickness from approximately 180 feet to 300 feet. Below the Buffalo River basin the thickness increases from 200 feet in northwestern Newton County to 300 feet in southeastern Searcy County.

Jefferson City Dolomite

The Jefferson City Dolomite lies disconformably on the Roubidoux Formation. Croneis (1930) describes these beds as consisting of gray, finely-granular to medium-crystalline dolomite with considerable chert alternating with chert-free, fine-grained, thin-bedded dolomite which is lighter in color. Caplan (1960) states that minor beds of sandy dolomite, sandstone and greyish-green shale are present in the subsurface.

The Jefferson City Dolomite does not crop out in the Buffalo

River basin. However, it is the oldest formation exposed in northern Arkansas. The thickness in Arkansas ranges from approximately 100 feet to approximately 496 feet.

Cotter Dolomite

The oldest formation that crops out in the Buffalo River basin, the Cotter Dolomite is exposed at the surface in the northeast corner of the basin in Marion and Baxter Counties. Two kinds of interbedded dolomite are present according to Croneis (1930): a fine-grained, white to buff, earthy variety known as "cotton rock"; and a more massive, medium-grained, gray variety. Although these dolomites are dominant, the unit also includes chert and thin layers of sandstone and shale (Cady, 1922).

The Cotter-Jefferson City contact is disconformable. In thickness the Cotter Dolomite ranges up to 527 feet.

Powell Dolomite

Resting disconformably on the Cotter Dolomite is the Powell Limestone. A thickness of up to 223 feet is known; however, the Powell within the Bufaflo River basin is locally absent. Where it is entirely missing, the overlying Everton Formation rests unconformably on the Cotter Dolomite.

The Powell Dolomite consists of granular to medium-crystalline, silty and shaly dolomite which is light-to-dark-gray or brown-to-black in color. Occasional thin beds of dolomitic sandstone or sandy dolomite are present. Thin dolomitic limestone beds, dolomitic shales and a basal conglomerate are also present in some places (Caplan, 1960).

Everton Formation

The Everton Formation is widely distributed within the Buffalo River basin, and is well exposed along the Buffalo River and its larger tributaries. The formation disconformably overlies the Powell Dolomite or, where the Powell is absent, the Cotter Dolomite. In the eastern part of the basin, the Everton is overlain disconformably by the St. Peter Sandstone; whereas, in the west, where the St. Peter and the upper part of the Everton have been removed by erosion, younger rocks such as the Plattin Limestone, Sylamore Sandstone or the Boone Formation overlie the Everton. Thickness varies, usually averaging about 400 feet in well exposed sections along the Buffalo River. The Marshall, Arkansas water well penetrated 600 feet of rock assigned to the Everton Formation (Sheldon, 1954). The thickness of the unit increases to southeast in the subsurface (Frezon and Glick, 1959).

Lithologically, Shum (1974) described the Everton as a complex of intertonguing dolomite, limestone and sandstone. He recognized four formal and three informal members. Complex stratigraphy and facies changes are common as the result of local unconformities and fluctuating environmental systems.

St. Peter Sandstone

The St. Peter Sandstone is present as a continuous unit underlying the eastern two-thirds of the Buffalo River basin. Outcrops are almost continuous along the Buffalo River from northwestern Newton County eastward. It is absent west of eastern Newton County (McKnight, 1935). A thickness of 136 feet was reported by McKnight near Rush, Arkansas, but the thickness is commonly less as the result of local truncation by erosion. A thickness of 45 feet was reported from the Marshall, Arkansas water well by Sheldon (1954).

The St. Peter Sandstone is composed of massive, friable sandstone with occasional dolomite and shale beds near the top. The white to cream sandstone consists of fine to medium, well-rounded, frosted quartz grains cemented with calcium carbonate (Maher and Lantz, 1953). The St. Peter rests disconformably on the Everton Formation. In the eastern part of the Buffalo River basin, the St. Peter Sandstone is conformably overlain by the Joachim Limestone (Giles, 1930); to the west where the Joachim is missing, it is unconformably overlain by younger Ordovician and Mississippian Formations.

Joachim Dolomite, Plattin Limestone, Fernvale Limestone and Cason Shale

Post-St. Peter Ordovician rocks outcrop discontinuously from central Newton County to the eastern margin of the Buffalo River basin. In ascending order this section is represented by the Joachim Dolomite, Plattin Limestone, Fernvale Limestone and the Cason Shale. Each is separated from the overlying formation by an unconformity. Their distribution and thickness is irregular but, in general, thickness increases to the southeast (Frezon and Glick, 1959).

Lithologically, the Joachim Dolomite is composed of gray, fine-grained dolomite. The Plattin Limestone is olive-gray, dense limestone and the Fernvale is characterized by medium-crystalline, light-gray, fossiliferous limestone. Greenish-gray to dark-gray dolomitic shale is typical of strata of the Cason Shale (Glick and Frezon, 1965).

Silurian System

Brassfield Limestone, St. Clair Limestone and Lafferty Limestone

The strata of Silurian age have been divided in ascending order into the Brassfield Limestone, St.Clair Limestone and the Lafferty Limestone. Croneis (1930) regards the Brassfield as light-gray, granular to coarsely-crystalline, fossiliferous limestone. The St. Clair consists of highly fossiliferous, coarse-grained, light-gray to pinkish-gray limestone. The Lafferty Limestone is a thin-bedded, earthy, red to gray limestone (Croneis, 1930). The St. Clair and Lafferty Limestones are commonly undifferentiated because of the limited occurence of the Lafferty (Maher and Lantz, 1953).

Silurian rocks are present in the subsurface in roughly the southern half of the Buffalo drainage basin and their distribution here is known to be sporadic (Frezon and Glick, 1959). Outcrops of Silurian age are discontinuous and often locally absent. Thickness increases to the south. The Brassfield Limestone unconformably overlies the Cason Shale and where it is absent the St. Clair rests unconformably on the Cason Shale. The Brassfield-St. Clair contact is an unconformity, whereas the St. Clair-Lafferty contact is conformable.

Devonian System

Penters Chert

The Penters Chert is present in the subsurface below the Buffalo River basin only in the extreme southern portion of the basin in southern Newton and Searcy Counties. According to Frezon and Glick (1959), the thickness in the basin increases from a truncated edge in the north to approximately 50 feet in the south.

The Penters Chert is composed of light-gray to black chert interbedded with thin lenses of gray, crystalline dolomite and limestone. It unconformably overlies rocks ranging in age from Middle Ordovician (Everton) to Silurian (Lafferty Limestone) and is unconformably overlain by the Chattanooga Shale or the Boone Formation (Frezon and Glick, 1959).

Chattanooga Formation

Frezon and Glick (1959) describe the Chattanooga Formation as a black, carbonaceous, fissile shale that includes a thin basal sandstone unit called the Sylamore Sandstone Member. The Sylamore Sandstone is composed of fine to medium-grained quartz sand. The thickness of the Sylamore is usually less than two feet; the Chattanooga Shale in the basin is less than ten feet thick.

The Chattanooga Shale is not present in the Buffalo drainage basin east of western Newton County although the Sylamore Sandstone or its approximate equivalent is persistant to the east (Frezon and Glick, 1959). The Chattanooga Shale is overlain by the St. Joe Member of the Boone Formation. The contact in some places, generally to the west, is gradational; in others, generally to the east, it is unconformable. It unconformably overlies the Penters Chert or successively older formations north of the limits of that formation.

Mississippian System

Boone Formation

The Boone Formation is nearly continuous across the Buffalo River basin. It composes most of the surface of the Springfield Plateau where outcrops are extensive. The unit is absent only in that part of the basin known as the Salem Plateau where it has been removed by erosion. The thickness of the Boone increases from the south toward Boone County. It is generally over 350 feet thick. However, local anomalies exist as the result of post-Boone erosion producing irregular topography (Frezon and Glick, 1959). Sheldon (1954) reported that the Marshall, Arkansas water well contained 375 feet of Boone strata and 400 feet of exposed strata have been reported by Croneis (1930) near Ponca, Arkansas.

Frezon and Glick (1959) consider the Boone Formation to be composed of two units. The lower, the St. Joe Member, is a light-gray to reddish-brown, finely-crystalline, crinoidal limestone less than 100 feet thick. The thicker, upper unit is gray, medium-crystalline, fossiliferous limestone with abundant chert, some of which is interbedded. The Boone, in places, is conformable with the underlying Chattanooga Formation; where this condition does not exist it rests unconformably on the truncated edges of Ordovician, Silurian and Devonian rocks.

The Boone Limestone is readily soluble in water and is extensively fractured; caves, solution channels and sink holes are common. Upon weathering, the Boone produces a mantle of chert rubble. The soils produced are characteristically red due to the presence of iron oxide and have a high clay content.

Moorefield Formation, Ruddle Shale and the Batesville Sandstone

This succession in ascending order consists of the Moorefield Formation, the Ruddle Shale and the Batesville Sandstone. Frezon and Glick (1959) describe the Moorefield as consisting of silty limestone and dark-gray shale, the Ruddle as gray fissile shale and the Batesville as silty lime sandstone. All three are conformable with each other, but unconformable with the underlying Boone Formation.

This sequence increases in thickness to the east and southeast. However, the thickness of each formation varies locally and in places may be altogether absent. These Mississippian rocks have been removed in the northern one-third of the Buffalo drainage basin. The Moorefield Formation and Ruddell Shale are absent west of Searcy County. The more extensive Batesville Sandstone persists across the southern two-thirds of the basin.

Fayetteville Formation

The Fayetteville Formation is composed of black, carbonaceous, fissile, fossiliferous shale containing numerous clay-ironstone concretions. Near the top, in the west, a sandstone unit known as the Wedington Member occurs. The Wedington is a prominent, brown, fine-grained quartz sandstone. The Fayetteville Formation is continuously present in the southern portion of the Springfield

Plateau and the Boston Mountains and its outliers; thus it exists in the southern and western parts of the Buffalo River basin.

The Fayetteville Shale is variable in thickness, ranging from 10 to 400 feet. In general, thickness increases to the south (Croneis, 1930). The Wedington Member is four feet thick at St. Joe, Arkansas and is absent east of that point. It increases in thickness to the west. The Fayetteville Formation is conformable with the Batesville Sandstone and is overlain disconformably by the Pitkin Limestone.

Pitkin Limestone

The Pitkin Limestone is present across the southern and western portion of the Buffalo River basin in the southern Springfield Plateau and the Boston Mountains and its outliers. To the north, it has been removed by erosion. Its thickness generally ranges between ten feet and 100 feet and usually averages approximately 50 feet (Croneis, 1930).

It is composed of massive, bluish-gray, fossiliferous limestone. As stated previously, the Pitkin rests disconformably on the Fayetteville Formation although at places the contact is conformable. It is overlain both disconformably and conformably by the Pennsylvanian Hale Formation (Croneis, 1930).

Pennsylvanian System

Morrow Group

The Morrow Group is divided into two formations, the Hale Formation and the overlying Bloyd Shale. The Hale Formation with its highly diverse composition is divisible into two distinct units. The lower unit, the Cane Hill Member, is characterized by shale, calcerous, silty sandstone, siltstone and shale; the upper unit, the Prairie Grove Member, is massive, cross-bedded sandstone with lenses of fossiliferous limestone (Henbest, 1953).

In Washington County, Arkansas, the Bloyd Shale can be subdivided in ascending order into the Brentwood Limestone Member, an interbedded interval of sandy limestone and shale; the Woolsey Member, a terrestrial sequence containing a coal seam; the Baldwin Coal; the Dye Shale Member, a black fissile shale; the Kessler Limestone Member, a gray, fossiliferous limestone; and the Trace Creek Shale Member, another sequence of black fissile shale (Henbest, 1953). East of Washington County in the Buffalo drainage area these members are not recognized.

The Morrow Group crops out continuously in the Boston Mountains and is present in the subsurface. It is present in the western and southern part of the Buffalo River basin. Rocks of the Hale Formation unconformably overly the Pitkin Limestone or, where the Pitkin is absent, the Fayetteville Shale. The Hale-Bloyd contact is conformable. The Bloyd Shale is unconformably overlain by the Atoka Formation, or where the Bloyd has been removed by pre-Atoka erosion the Atoka rests unconformably on the Hale Formation. The thickness of the Morrow Group increases to the south, ranging from less than 100 feet in Boone County to approximately 350 feet in southern Newton and Searcy County.

Atoka Formation

The Atoka Formation forms the higher elevations of the Boston

Mountains and its outliers. Alternating beds of sandstone and shale compose the Atoka. Atokan sandstones are variable in character but dominantly they are medium-grained and light to dark-brown in color. The shales are ordinarily black. Approximately seventy-five per cent of the formation is composed of shale (Croneis, 1930). The Atoka increases in thickness to the south from 0 to approximately 1,000 feet within the Buffalo River basin.

Structure

Structurally the Buffalo River basin is situated on the south flank of the Ozark dome. This dome induces a regional homoclinal dip to the south. The orientation of the strata below the Buffalo drainage area is a reflection of the Precambrian basement complex. The northern part of the basin is located on the northern Arkansas structural platform and the strata dips approximately one-fourth degree to the south. At the northern edge of the Arkoma basin in central Newton and Searcy Counties, the dip steepens to a maximum of 5 degrees to the south (Chinn and Konig, 1973). The regional dip is modified locally by folds, faults and subsidence structures with the basin.

The majority of faults trend east-west although some have an approximate northwest-southeast strike. These faults are all normal, generally high angle and have small vertical displacements. Most faults are downthrown on the south side of the fault trace (Croneis, 1930). Quinn (1959) recognized several north-south striking faults. These nearly vertical faults are strike-slip faults. Among the larger more extensive faults are the St. Joe fault, the Rush Creek faults and the Buffalo faults. Smaller less extensive faults are numerous. Numerous linears traversing the Buffalo River basin are visible from Earth Resource Technology Sattelite (ERTS-1) imagery and high altitude photography, but have not been mapped.

The orientation of the folds has no definite structural plan. The folds are small and might more accurately be described as small flextures. They decrease in intensity toward the north away from the Arkansas River Valley. Folded strata in the basin is often the result of local subsidence due to the solutioning of carbonate strata at depth.

Ground water, as defined here, is water in the zone of saturation. Thus, ground water is water below the water table that moves in response to differences in potential or head; it does not include water that is between the land surface and the zone of saturation, the zone of aeration. The physical properties of rock influence the characteristics of ground water. More accurately, it is the stratigraphy and structure of the rock which provide the hydrologic framework for ground water.

The way water is held in the zone of saturation, its mode of accretion to this zone, its movement, the ways in which it leaves, the quantities, and the quality are the subjects of this section. In this report, the water-bearing rocks, aquifers, are considered in two parts: the shallow aquifer system, which is defined as those rock units above and including the Cotter Formation; and the deep aquifer system, which includes those rock units below the Cotter Formation. This division of the aquifers into shallow and deep is arbitrary in the sense that hydrologically these systems are not separate entities; rather they are intricately connected with one another. However, the division is practical in that the hydrologic characteristics of the two systems are not similar. Also, because the stratigraphic sequence is essentially undisturbed, the depth below the surface of the shallow and deep aquifers is fairly predictable. Whereas the shallow aquifers are exposed at or near the surface, the deep aquifers are present only in the subsurface and some are buried at considerable depth.

Shallow Aquifer System

Lithologically, the rocks of the shallow aquifer system are dominantly limestone, dolomite, sandstone, and shale. In the limestone and dolomite ground water is in secondary openings along bedding planes, fractures, and solution openings. Thus, the availability of water from carbonate rocks depends upon the degree of fracturing and solutioning which the rocks have undergone and the extent to which the resultant openings are interconnected. Secondary openings are most numerous near the surface and decrease in number with depth.

In sandstone, ground water is in voids between grains; therefore, availability is largely a measure of porosity and permeability. Shale generally is impervious to the movement of water and usually is not a source of supply.

The shallow aquifer system is artesian (Will Schell, 1975, President Arkansas Water Well Drillers Association). Ground water is confined under relatively impermeable strata; it rises in wells and secondary openings to some level above the aquifer in response to the hydrostatic pressure forming the piezometric surface. Despite artesian conditions, the hydrostatic pressure in the shallow aquifer system is not great; water rises in wells, but no flowing well has been drilled. The piezometric surface in the Buffalo River basin forms a subdued reflection of the topography. The lowest piezometric surfaces are in the Buffalo River valley and its tributary valleys and intersect the flowing streams; the highest piezometric surfaces are at higher elevations along stream divides. The potentiometric surface map (Figure 41) indicates the hydrodynamic gradient of the shallow aquifer system. Regionally, the hydrodynamic gradient is from the higher elevations toward the Buffalo River and its larger tributaries. The potentiometric surface map was constructed by contouring the piezometric levels (distance above mean sea level) recorded in wells in the area.

Most wells in the shallow aquifer system are less than 250 feet deep. Yields are usually less than 10 gallons per minute and rarely exceed 25 gallons per minute.

Data concerning water wells within and adjacent to the Buffalo River basin were obtained from the Arkansas Geological Commission and the United States Geological Survey. The data have been assimilated and are summarized in Table 22. Sufficient data are not available for an in-depth interpretation of the ground water hydro-

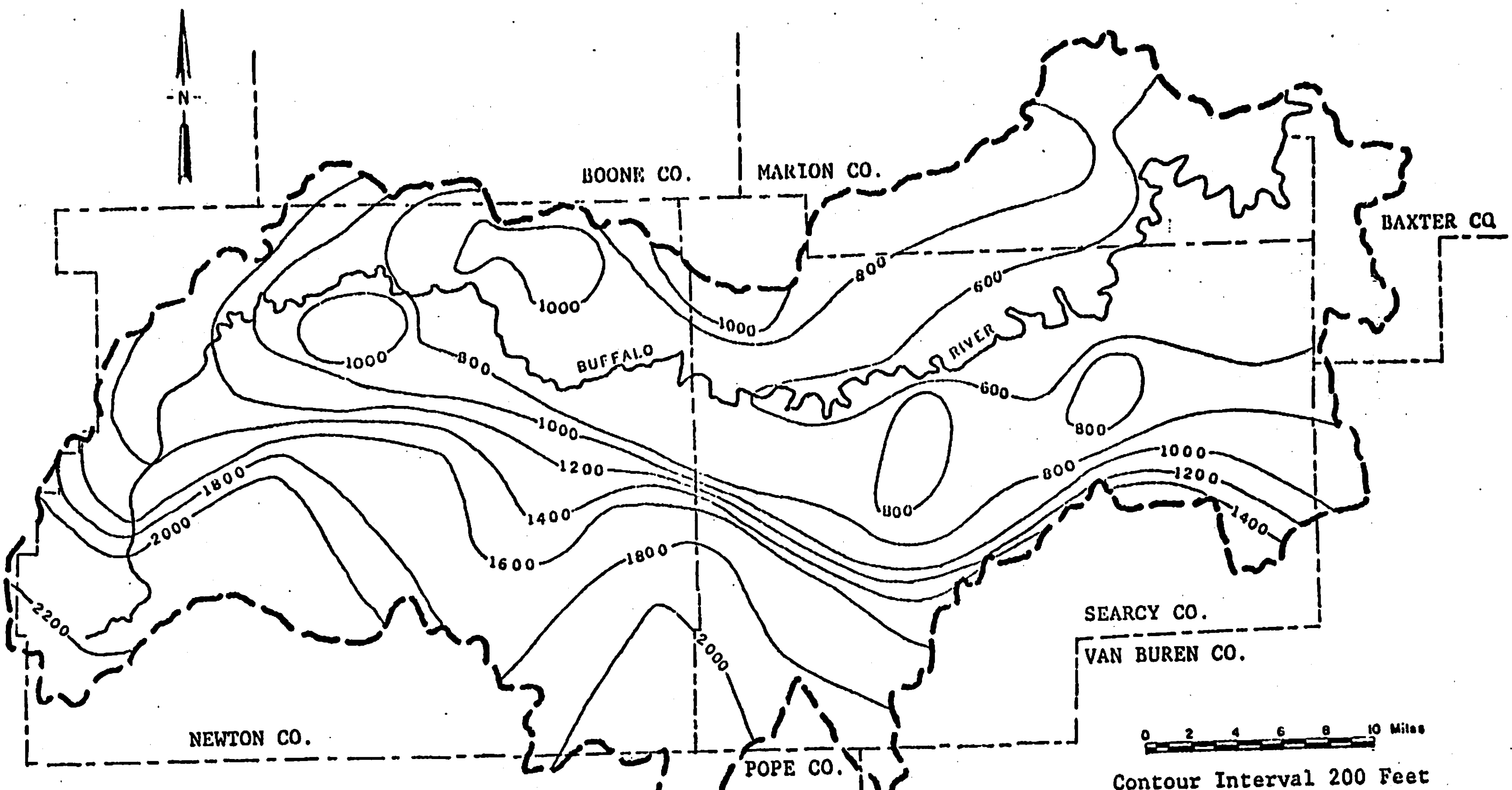


FIGURE 41, POTENTIOMETRIC MAP SHOWING ELEVATION OF POTENTIOMETRIC SURFACE

Table 22
SUMMARY OF WELL DATA
AGC-Arkansas Geological Commission
USGS-United States Geological Survey

Map Number Plate__	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
1	18N16W-34dcb	Marion	1974	400	950	350	600	5	59	AGC
2	18N16W-35acc	Marion	1974	320	1000	150	850	60	63	AGC
3	18N15W-23baa	Marion	1973	400	960	340	620	5	57	AGC
4	18N15W-32dbb	Marion	1973	75	700	20	680	15	18	AGC
5	18N15W-33cca	Marion	1974	360	760	140	620	9	63	AGC
6	18N13W-32dbb	Baxter	1974	169	750	85	665	12	34	AGC
7	17N21W-1ccd1	Boone	-	71	1320	62	1258	-	-	USGS
8	17N21W-12aca	Boone	1973	700	1400	435	965	2	12	AGC
9	17N21W-12bbd	Boone	1971	450	1363	270	1093	4	19	AGC
10	17N20W-7cba	Boone	1973	475	1400	360	1040	4	12	AGC
11	17N20W-7dbb1	Boone	-	140	1250	72	1178	-	-	USGS
12	17N20W-9acb1	Boone	1953	250	1195	37	1158	-	-	USGS
13	17N20W-9bcd1	Boone	1968	208	1230	105	1125	-	-	USGS
14	17N20W-10acd	Boone	1973	109	1102	40	1062	6.6	44	AGC
15	17N20W-10bdc	Boone	1972	175	1100	30	1070	16.6	60	AGC
16	16N20W-13bda	Boone	1973	560	1380	330	1050	5	-	AGC
17	17N20W-16adc	Boone	1972	290	1160	150	1010	70	29	AGC

Table 22. (continued)

Map Number Plate	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
18	17N20W-21bca1	Newton	-	2576	1344	358	987	222	500	USGS
19	17N20W-27bdc	Newton	1973	625	1410	410	1000	2	29	AGC
20	17N20W-30bad	Newton	1972	400	1000	150	850	5	26	AGC
21	17N20W-31acd	Newton	1970	205	988	115	865	15	48	AGC
22	17N19W-24cad	Newton	1973	295	1080	90	990	2	21	AGC
23	17N19W-25bba	Newton	1973	125	1100	30	1070	2	47	AGC
24	17N19W-25ccc	Newton	1972	520	1130	140	990	4	51	AGC
25	17N19W-26bad	Newton	1973	250	1150	140	1010	7.5	66	AGC
26	17N18W-35dcc	Searcy	1972	485	1280	185	1095	5	32	AGC
27	17N16W-16bda	Marion	1973	935	1060	235	825	5	146	AGC
28	17N15W-3bcc	Marion	1905	146	450	142	308	-	-	AGC
29	17N15W-13bdc	Marion	1904	140	450	20	430	-	-	AGC
30	17N15W-18dcd	Marion	1974	280	1120	200	920	8	126	AGC
31	17N15W-18ddb	Marion	1973	600	1100	300	800	3	152	AGC
32	17N15W-22adc	Marion	1973	670	990	200	790	4	68	AGC
33	17N15W-29cba	Marion	1973	895	925	140	785	2	-	AGC
34	17N15W-30dac	Marion	1973	500	980	250	730	3	128	AGC
35	17N15W-30dca	Marion	1974	700	950	260	690	0.5	60	AGC
36	16N22W-21ccc	Newton	1970	145	1080	75	1005	30	-	AGC
37	16N21W-20abb	Newton	1971	127	2000	97	1903	3	21	AGC

Table 22. (continued)

Map Number Plate__	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
38	16N21W-34abc1	Newton	1962	190	880	58	832	150	40	USGS
39	16N20W-4cbb1	Newton	1946	179	1065	83	982	-	22	USGS
40	16N20W-5aab	Newton	1970	150	1140	50	1090	25	100	AGC
41	16N20W-8bca	Newton	1970	210	770	25	745	15	32	AGC
42	16N20W-12aab1	Newton	-	24	1365	17	1348	-	-	USGS
43	16N20W-12abc1	Newton	-	193	1330	50	1280	-	-	USGS
44	16N20W-25aba	Newton	1971	270	1250	85	1165	12	18	AGC
45	16N20W-25bdb	Newton	1971	810	1160	442	718	12	19	AGC
46	16N20W-25cbb	Newton	1973	506	1160	375	785	2	17	AGC
47	16N20W-27bdd	Newton	1971	280	1100	160	940	15	92	AGC
48	16N19W-4cac	Newton	1973	385	980	245	735	12	42	AGC
49	16N19W-6bad1	Newton	1968	-	1430	49	1381	-	-	USGS
50	16N19W-9bbc	Newton	1971	340	1100	200	900	12	35	AGC
51	16N19W-19abd	Newton	1970	634	1290	480	810	5	46	AGC
52	16N19W-20bca1	Newton	1955	642	1250	180	1142	-	11	USGS
53	16N18W-2add	Searcy	1973	175	1150	80	1070	2	56	AGC
54	16N18W-4abb	Searcy	1972	304	1090	150	940	3	62	AGC
55	16N18W-5cbc1	Searcy	-	132	1225	94	1131	-	-	USGS
56	16N18W-5dcd1	Searcy	1964	310	1225	88	1137	-	-	USGS

Table 22. (continued)

Map Number Plate__	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
57	16N18W-12bbb	Searcy	1972	184	1270	160	1110	20	150	AGC
58	16N18W-22cba	Searcy	1964	100	1250	40	1210	-	-	USGS
59	16N17W-29bbd	Searcy	1973	640	1120	400	720	20	18	AGC
60	16N17W-7bab	Searcy	1959	580	1240	300	940	-	-	USGS
61	16N17W-16cab	Searcy	1974	125	790	21	769	0.9	40	AGC
62	16N17W-16bdd	Searcy	1974	85	793	15	778	18	45	AGC
63	16N17W-25bdd	Searcy	1972	535	650	150	500	100	72	AGC
64	16N14W-35bdb	Searcy	1970	730	1100	500	600	2.5	51	AGC
65	16N13W-30bac	Baxter	1972	2603	1280	640	640	60	209	AGC
66	15N22W-7abd	Newton	1970	100	2200	62	1380	3	24	AGC
67	15N22W-22caa	Newton	1971	205	2100	90	2010	7	98	ACG
68	15N21W-24cda	Newton	1971	435	2000	350	1650	1	25	AGC
69	15N18W-2baa	Searcy	-	50	685	37	648	-	-	USGS
70	15N17W-1bdc	Searcy	1973	400	870	250	620	16	43	AGC
71	15N17W-1cca	Searcy	1952	157	925	77	848	12	-	USGS
72	15N17W-23bac	Searcy	1972	330	950	125	825	2	29	AGC
73	15N17W-25dab	Searcy	1972	497	905	127	778	-	-	USGS
74	15N17W-26ccc	Searcy	1972	104	905	50	900	5	10	AGC
75	15N17W-31aac	Searcy	1971	350	875	90	785	12	55	AGC

Table 22. (continued)

Map Number Plate	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
76	15N17W-32bcc	Searcy	1972	145	800	70	730	30	44	AGC
77	15N16W-15acc	Searcy	1974	440	970	340	630	2	35	AGC
78	15N16W-14bac	Searcy	1972	450	970	340	630	5	32	AGC
79	15N16W-25dca	Searcy	1948	2415	1045	205	840	55	500	USGS
80	15N16W-23cbb	Searcy	1972	260	960	140	820	2	65	AGC
81	15N15W-5abd	Searcy	1974	260	1100	120	980	0.5	100	AGC
82	15N15W-18abd	Searcy	1972	400	1100	150	950	0.5	20	AGC
83	15N15W-19dbc	Searcy	1973	324	1000	214	786	60	22	AGC
84	15N15W-31bca	Searcy	1974	61	1050	18	1032	25	60	AGC
85	15N15W-33dbc	Searcy	1971	145	1530	70	1460	0.1	21	AGC
86	14N20W-36bdb	Newton	1970	240	1875	70	1805	1.5	21	AGC
87	14N19W-23cdd	Newton	1972	101	2000	10	1990	20	20	AGC
88	14N18W-30abb	Searcy	1936	116	2000	76	1924	-	-	AGC
89	14N16W-1ddd	Searcy	1970	205	1560	52	1508	0.5	0	AGC
90	14N16W-3cbd	Searcy	1972	254	860	100	760	1.5	20	AGC
91	14N16W-11dca	Searcy	1970	250	1500	60	1440	0.5	19	AGC
92	14N16W-14cdd	Searcy	1972	50	1500	25	1475	4	20	AGC
93	14N16W-21bbd	Searcy	1973	100	1500	40	1460	2	14	AGC
94	14N15W-6abd	Searcy	1973	-	1500	30	1470	1	15	AGC
95	14N14W-11abc	Searcy	1972	120	1200	50	1150	1.5	19	AGC

Table 22. (continued)

Map Number Plate	Location	County	Year Completed	Depth of Well	LSD	Water Level Below Surface	Water Level Relative to Sea Level	Approximate Yield (gpm)	Casing (ft)	Source
96	14N14W-18cad	Searcy	1971	80	1650	20	1630	6.6	30	AGC
97	14N14W-22aca	Searcy	1972	145	1500	40	1640	2	37	AGC
98	13N24W-14adc	Newton	1971	70	2300	20	2280	3.3	20	AGC
99	13N20W-34dad	Newton	1929	500	2000	35	1965	-	-	AGC
100	13N18W-11abc	Searcy	1972	154	1800	50	1750	8	20	AGC
101	13N18W-12bcc	Searcy	1972	154	1800	50	1750	5	11	AGC
102	13N18W-13baa	Searcy	1973	125	1940	50	1890	2	-	AGC
103	13N18W-13cbd	Searcy	1971	75	1870	25	1845	5	12	AGC
104	13N18W-14dab	Searcy	1972	150	1880	40	1840	2	20	AGC
105	13N18W023aba	Searcy	1971	100	1870	30	1840	3.3	10	AGC
106	13N17W-5bcd	Searcy	1971	115	1850	35	1815	2.6	20	AGC
107	13N17W-14caa	Searcy	1974	58	1850	12	1838	30	10	AGC
108	13N17W-27baa	Searcy	1971	75	1720	30	1690	5	25	AGC
109	13N17W-27bdb	Searcy	1971	75	1850	30	1820	5	10	AGC
110	13N17W-30aca	Searcy	1971	110	1900	60	1840	10	56	AGC
111	13N17W-32	Searcy	1971	63	1900	30	1870	10	10	AGC

logy as the information is not comprehensive. There are no additional sources of data. Pump tests have not been run on the wells. Consequently, information on sustained rates of production, specific capacities, and coefficients of storage and transmissivity is not available for analysis. There is no frequently monitored ground water well or spring in the Buffalo drainage area. A comprehensive program of ground water data collection must be initiated before a complete understanding of the hydrology of the area can be achieved.

Ground Water Recharge

The shallow aquifer system receives recharge from precipitation falling directly into the basin. The deeply incised valleys and steep slopes of the drainage divides surrounding the Buffalo River basin prevent ground water from adjacent areas from moving into the shallow aquifer system. Precipitation falling within the Buffalo River basin directly infiltrates aquifers that are present at the surface (see geologic map, Figure 40). Further downward infiltration of the ground water supplies shallow aquifers in the subsurface. Thus, it is the impinging meteoric water percolating downward to the main body of ground water that recharges the shallow aquifer system. According to Miller et al. (1974), the amount of recharge from precipitation depends on the physical character and general configuration of the land surface, the distribution and quantity of precipitation, the composition and moisture content of the soil and underlying rock, and the amount and type of vegetation.

It must be remembered that not all of the precipitation falling on the Buffalo River basin becomes ground water recharge. Surface runoff and evapotranspiration account for most of the water lost to ground water recharge. It is beyond the scope of this report to determine precisely the amount of water in the basin that is lost by the processes of evaporation and transpiration by plants; however, the amount is significant and is the single most important factor diminishing the amount available for recharge of ground water supplies. A rough approximation for transpiration and evaporation in the Buffalo drainage area, based on an average annual precipitation of 48.6 inches, is 66.1 percent. This figure is calculated from the average annual runoff (16.08 inches) for the 42-year period, 1928-1970, from the United States Geological Survey continuous record gaging station near Rush, Arkansas, on the Buffalo River.

Because it is precipitation falling within the Buffalo River basin that recharges the shallow aquifer system's ground water supplies, it should follow that water table levels rise in response to precipitation with no significant time lag. Unfortunately, within the Buffalo River basin no water well is monitored in sufficient detail to allow confirmation of this premise. Recharge of ground water from precipitation in the Buffalo area is ephemeral. Meinzer (1949) reports that maximum ground water recharge will take place during the winter months, when evaporation and transpiration rates are minimal. During the spring and summer, demand for water by plants and evaporation rates are at a maximum, thus recharge of ground water supplies is small. In the fall, amounts of precipitation are generally low, preventing maximum recharge.

The ground water in the deep aquifer system is artesian. It is possible that accretion from this artesian source supplies water to the shallow aquifer system. Three deep wells in the Buffalo

River basin penetrate the deep aquifer system, the Marble Falls water well (reference well 18), the Big Flat water well (reference well 65), and the Marshall water well (reference well 79). In all three deep wells the water rises under artesian pressure to elevations well within the shallow aquifer system. Thus, the elevation of the piezometric surface of the deep aquifer system overlaps that of the shallow aquifer system. It is plausible that fractures penetrating the deep and shallow aquifers permit the deep water under artesian pressure to rise into the shallow aquifer, thus recharging it. Sufficient data are not available to define clearly the relationship between these systems.

Ground Water Movement

The direction of ground water movement in the shallow aquifer system can be determined from the configuration of the piezometric surface on the potentiometric surface map, Figure 41. Ground water moves in a direction that is down the hydrodynamic gradient and at right angles to contours on the potentiometric surface map. Movement of ground water is from areas of high hydrostatic pressure to areas of low hydrostatic pressure. In the Buffalo River basin, ground water in the shallow aquifer system moves in the direction of lower elevations where it is discharged into the Buffalo River and its tributaries. The potentiometric surface map shows that regionally the ground water in the shallow aquifer system migrates in the direction of the Buffalo River. Thus, in the shallow aquifers north of the Buffalo River the ground water moves generally southward; south of the Buffalo River the ground water in the shallow aquifers migrates generally northward from the higher elevations in the Boston Mountains. Locally, ground water moves toward and into tributaries of the Buffalo River and on into the river itself.

Ground Water Discharge

The ground water in the shallow aquifer system moves down gradient in the direction of the slope of the potentiometric surface until it moves out of the basin or is discharged. Discharge may be by springs (see section on springs), seepage into streams, evaporation, plant transpiration, or pumpage from wells. Over long periods of time, recharge of the shallow aquifers balances the discharge and water levels are not affected drastically.

The Buffalo River and its major tributaries are effluent, that is, ground water is fed into them by natural seeps or springs from the shallow aquifers. Effluent streams are generated where the ground water table intersects the sloping surface of the land, producing a spring, or intersects the ground at stream level, as in the case of the Buffalo River and its larger tributaries. The ground water discharge supplies streams during periods of low flow when surface water from precipitation is absent. At higher elevations the streams may be influent; these perennial streams are above the water table, and hence water on the surface migrates into the subsurface.

As discussed heretofore, it is possible that the hydrostatic pressure of the artesian deep aquifer system causes discharge of ground water from the deep aquifers into the shallow aquifers through fractures. Undoubtedly, where head differences permit, some ground water is moving from the shallow aquifers into deeper ones through fractures or by downward infiltration. This downward movement of ground water is considered to be discharge because the water is lost to the shallow aquifers.

Shallow Aquifers

Most wells drilled into bedrock in the study area are left open below a certain casing depth. In many cases water entering the well is from more than one geologic unit. Individually, many of the rock units yield only small amounts of water. However, collectively, units may yield water in sufficient quantities for most users. For this reason, and to facilitate discussion of the shallow aquifer system, it is practical to treat large sequences of both water-bearing and non-water-bearing rocks as groups in the shallow water system. The shallow aquifer system is divided into four groups. As the demarcation between the deep and shallow aquifer systems, the boundaries of the groups are somewhat arbitrary; hydrologically the groups are interconnected and are not separate entities.

The groups of the shallow aquifer system are based primarily on similar lithologic characteristics and geographic distribution. Lithologic and stratigraphic descriptions of the individual rock units that comprise each group are given in the section of this report entitled, "Stratigraphy." By consulting the geologic map, Figure 40, and the stratigraphic section in the Buffalo drainage area, Table 21, one can determine which rock units are likely to be present in any given geographic area of the Buffalo River basin.

The older Ordovician rocks low in the stratigraphic section are at or near the surface in the northern part of the basin, and on the south these units are overlain by successively younger rocks. The younger rocks are generally present at relatively high elevations; an increase in elevation is accompanied by an addition of younger units to the stratigraphic section. Thus, that part of the stratigraphic section which is present and therefore available for ground water storage depends on geographic location within the Buffalo River basin.

Group 1 includes the Pennsylvanian-age rocks of the Atoka Formation. The Atoka Formation is present only in the higher elevations of the Boston Mountains in the extreme southern and western parts of the Buffalo River basin, where it is exposed at the surface (see geologic map). Underlying the group 1 Atokan rocks is the Bloyd Formation which is dominantly shale. The shale probably acts as an aquiclude in the study area.

The Atoka Formation consists of alternate beds of sandstone and shale. The interspersed shale units may act as confining layers, or aquicludes, within the formation. Such an arrangement is conducive to perched water tables, where saturated rock is above the general water table. Perched water tables are uncommon and are present only on mountaintops and ridges. They are confined in areal extent. The alternate arrangement of sandstone and shale units also causes ground water to be under artesian pressure, especially where anomalous dips are present.

The Atoka sandstone beds are not reliable water producers. Porosity and permeability are variable because clay material deposited with the sand seals off the pore spaces in much of the rock. Atoka shale beds, though water saturated, are not permeable and therefore do not supply ground water to wells. Lamonds (1972) states that ground water from wells in the Atoka Formation is derived from fractured zones, bedding planes, and weathered zones.

Water wells in the Atoka Formation yield small quantities of water in the Buffalo River basin. Approximate yields of these wells range from 2 gallons per minute to a reported 30 gallons per minute from one well. Most wells yield approximately 1 to 5 gallons per minute. It is important to realize that pump tests have not been run on these wells, and thus the sustained yield rates for long periods of time and specific capacities are unknown. Lamonds (1972) reports that wells in the Atoka may yield up to 25 gallons per minute, but that most yield only 1 to 3 gallons per minute.

Group 2 includes all rock units below the Atoka Formation and above the Boone Formation (Table 21). The units of this sequence in ascending order are the Moorefield Formation, the Ruddle Shale, the Batesville Sandstone, the Fayetteville Shale, the Pitkin Limestone, the Hale Formation, and the Bloyd Shale. This sequence crops out along the northern face of the Boston Mountains and is present in the subsurface south of this band (see geologic map, Figure 40). Thus, group 2 aquifers are present in the western and southern parts of the Buffalo River basin. North of the Buffalo area these units have been removed by erosion.

Group 2 consists primarily of shale and beds of sandstone and limestone. The shale units, which are up to 400 feet thick in the Buffalo River basin, are interspersed throughout the sequence. They probably act as aquicludes, retarding or preventing the downward seepage of ground water. Because of the aquicludes, perched water tables may be locally present. However, perched water tables are uncommon and not widespread.

In general, the Moorefield-Bloyd group does not contain reliable water-producing rocks. It is composed dominantly of shale which is not conducive to the development of ground water supplies. The Batesville Sandstone, which is moderately thick, is thoroughly cemented with calcareous material (Cronies, 1930). Calcium carbonate introduced extensively, cements the sand grains together and reduces porosity and permeability. Near the surface, where the sandstone has been weathered and the carbonate removed, the Batesville is very porous. The Hale Formation is locally porous enough to supply wells. Limestone units in group 2 are not important water producers. Water that is available for production in the group 2 sequence generally is derived from wells which penetrate secondary openings such as fractures, bedding planes, and solution channels. Lamonds (1972) comments that local intensely fractured zones and bedding planes are responsible for the better producing ground water wells in the Moorefield-Bloyd interval. Wells may yield as much as 25 gallons per minute, but in most places yields can be expected to range from 2 to 5 gallons per minute.

Group 3 includes all of the rock units between the base of the Moorefield Formation and the base of the Brassfield Limestone. The units of this sequence in ascending order are the Brassfield Limestone, the St. Clair Limestone, the Lafferty Limestone, the Penters Chert, the Chattanooga Shale, and the Boone Formation. The ubiquitous lower Mississippian Boone Formation underlies and forms the surface of the Springfield Plateau. Southward it is present in the subsurface. The Chattanooga Shale is present in the Buffalo area only in western Newton County; the Penters Chert is present only in southern Newton and Searcy Counties. The Silurian rocks, Brassfield Limestone, St. Clair Limestone, and Lafferty Limestone, are distributed sporadically in the southern half of the Buffalo River basin.

In the Buffalo River basin group 3 is primarily limestone; as much as 450 feet may be present. The Chattanooga Shale and the Penters Chert, where present, may serve as aquicludes at the base of the Boone Formation. In the subsurface, downward infiltration of ground water into group 3 may be retarded by the overlying aquicludes of group 2, except where there are fracture zones.

In the study area most wells in the shallow aquifer system bottom in the Boone Formation because of its widespread distribution and thickness. The Boone consists of dense impermeable limestone with interbedded chert. Ground water in the Boone Formation is in secondary openings along fractures, joints, and solution channels. Water-containing secondary openings are common in carbonate terranes and have been documented by Parizek and Drew (1966), Hanson (1973), and Lamonds (1972), among others. Thus, the presence of sufficient ground water in the Boone Formation is fortuitous. Many springs are present in the Boone where fractures reach the surface (see section on springs, page 164). Because of the interconnected secondary openings, recharge to intersecting wells is rapid and water is vulnerable to pollution. A mantle of chert debris formed by the weathering of the Boone Formation covers much of the study area. It tends to retard and retain surface runoff. Wells obtain water directly from the mantle or from the fractures and solution channels which it supplies (Baker, 1955). The impermeable Silurian limestone units, Brassfield through Lafferty, are limited both on the outcrop and in the subsurface and are not considered to be ground water-producing aquifers.

There is a wide range in the yields of wells tapping the group 3 rocks. As indicated, the Boone Formation is the principal water-producing aquifer of this interval. Wells in the Boone which penetrate saturated fractures can produce sufficient quantities of ground water for domestic use. However, if no fractures are encountered by a well no water is produced. Lamonds (1972) reports that yields of 2 to 5 gallons per minute are common and wells tapping the more prolific solution channels may produce more than 25 gallons per minute.

Group 4 includes the Ordovician sequence from the base of the Cotter Dolomite up through the Cason Shale. In ascending order the units of this interval are the Cotter Dolomite, the Powell Dolomite, the Everton Formation, the St. Peter Sandstone, the Joachim Dolomite, the Plattin Limestone, the Fernvale Limestone, and the Cason Shale. These Ordovician rocks crop out along the Buffalo River and its tributaries, and underlie and form the surface of the Salem Plateau in the northeastern part of the Buffalo River basin. Elsewhere this interval, Cotter through Cason, is present in the subsurface as it extends southward from the area of surface exposure beneath younger rocks. Where elevation is great, as in the Boston Mountains, the group 4 rocks are buried relatively deeply.

The rocks of this Ordovician sequence are very thick and are primarily carbonate, limestone and dolomite, with minor amounts of shale and sandstone (see section on stratigraphy, page 111). In the limestone and dolomite water is present in fractures, joints, and solution channels and along bedding planes. Springs are common where these features intersect the surface (see section on springs). These ancient carbonate rocks are generally dense, fine-grained, and impervious to ground water. Wells must penetrate the secondary openings in order to tap ground water supplies; consequently, as in the Boone Formation, two wells only a few feet apart at the same depth may supply markedly different volumes of water.

The sandstone members of the Everton Formation and the St. Peter Sandstone are potential aquifers. However, locally the St. Peter Sandstone is well cemented with calcareous material (Giles, 1922); the Everton sandstone is cemented both siliciously and with carbonate material (Shum, 1974). Where well cemented, these aquifers are of limited porosity and permeability. Because they crop out in the walls of streams in many parts of the basin, the Everton sandstone beds and the St. Peter Sandstone would be available to water wells only at hilltop sites. Farther south in the subsurface they are a possible source of ground water.

Little is known about the potential yields of the group 4 sequence. Where water wells penetrate the solution channels, fractures, and productive bedding planes in the limestone and dolomite, yields commonly range from 5 to 10 gallons per minute. Porous or fractured zones of the St. Peter Sandstone and the Everton sandstone beds usually yield similar amounts. Anomalous wells in the shallow Ordovician rocks may produce more than 5 gallons per minute (Lamonds, 1972).

Water Quality

The chemical quality of ground water is affected measurably by the geologic character of the area in which it is found. The mineral content of ground water depends on the type and amount of soluble minerals in the rocks and the length of time in which the ground water is in contact with these rocks as it passes through them. Pollutants, commonly the result of human activities, also may modify ground water, although ground water is less susceptible to such hazards than surface water. However, once polluted the ground water generally requires much more time for purification than surface water. Ground water is more uniform in chemical quality and temperature, and contains less sediment and fewer bacteria than surface water. Ground water contains more dissolved material and may be considerably harder than surface water.

Information on the ground water quality in the Buffalo River basin is severely limited. It is not possible, at this time, to describe the quality of water in each aquifer or to recognize and delineate trends in ground water quality. The only information available for the Buffalo area was provided by the Arkansas State Department of Health and is summarized in Table 23. Ground water in the Buffalo River basin, with few exceptions, is of good quality and is used without treatment throughout the area.

In general, the ground water type in the Buffalo River basin depends on the rock present in the area. Most wells are not deeply cased; thus, below the point at which the casing is set all aquifers penetrated may contribute to the well so that the water is mixed. For this reason and because of lack of data, quality of ground water in the shallow aquifers is considered in this report by shallow aquifer group.

Steele, et al. (1975), in a study in Northwest Arkansas, found water from limestone aquifers to be of calcium bicarbonate type, that from dolomite aquifers to be of the calcium-magnesium bicar-

Table 23. CHEMICAL DATA FOR GROUNDWATER SAMPLES (PPM)

Date	City	Source	pH	Total Solids	Alka- linity	Carb. hard.	Non- carb.	Ca	Mg	Fe	Mn	Cl	SO_4	Na	K	F	NO_3	NO_2	As	Pb
7-71	Bass	Well 1	8.0	222	172	160	0	48	9.7	0.9	0	2.5	4	15	-	0.3	0.14	0	<0.01	0.04
8-71	Bass	Well 2	7.6	291	233	232	0	44.4	29.4	<0.05	<0.02	3	86	16.2	-	0.28	0.15	<0.01	<0.01	<0.01
7-69	Dogpatch USA	Well 1	6.9	270	238	218	0	58.8	17	T	0	3.5	16	25	-	0.75	-	-	-	-
4-70	Dogpatch USA	Well 2	7.8	247	174	140	0	30.4	15.5	0.1	0	27	16	-	-	0.9	-	-	-	-
8-65		Hughes Sp.	7.4	207	197	186	0	70.4	2.4	T	0	4	T	1.5	1.1	0.05	0.6	0.01	-	0
6-66	Jasper	Well	8.2	173	142	139	0	28	17	T	0	9.5	15	-	-	0.2	2.18	0	-	0
2-70	Jasper	Well	7.3	184	137	137	5.0	50.4	39	0.05	0	7	10.5	7.8	-	0.2	-	-	-	-
3-72	Marshall	Horton Sp.	8.2	193	172	152	0	58.4	1.5	0.2	0.1	6	4	1.9	-	0.04	1.5	<0.01	0.003	<0.01
3-72	Marshall	Scott Sp.	8.1	168	164	164	12	68	1.5	0.05	0.002	5.8	0	1.9	-	0.06	0.64	<0.01	0.003	<0.01
1-72	Marshall	Well	7.9	275	204	204	45.5	71.2	17.5	0.22	0.008	9.5	72	2.99	-	0.23	0.01	<0.01	<0.01	<0.01
5-68	Mt. Judea	Well	7.0	177	145	140	0	53	1.5	0.35	0	1.5	T	5.5	-	0.2	0.54	T	-	0
9-68	Mt. Judea	Well	7.9	184	148	148	20	60.8	4	0.05	0	4.5	5	3.4	-	0.15	-	-	-	-
8-65		Zack Sp.	7.3	203	192	184	0	69.6	2.4	T	0	3.5	T	1.5	1.1	0.05	0.72	0.01	-	0

Source: Arkansas State Department of Health.

bonate type, and that from shale to be of the sodium-calcium bicarbonate type. These general rock type-water type associations are applicable in the Buffalo River basin. Ground water from the shallow aquifer group 1 Atokan rocks is of the sodium-calcium bicarbonate type; dissolved solids range from 20 to 200 milligrams per liter (mg/l). The water is soft to moderately hard with a hardness range of 0 to 100 mg/l. Excessive amounts of iron may be present. Group 2 shallow aquifer rocks usually contain ground water of the calcium bicarbonate type; dissolved solids range from 200 to 1200 mg/l. The water is moderately hard to very hard and has a hardness range of 100 to 200 mg/l. Excessive amounts of iron, sulfate, and sulfide are present locally in the ground water from shale and sandstone. Shallow aquifer group 3, a dominantly limestone sequence, characteristically contains calcium bicarbonate water with a dissolved solid range of 100 to 400 mg/l. It is moderately hard to very hard with a hardness range of 80-400 mg/l. Shallow aquifer group 4, dominantly dolomite, contains ground water of the calcium-magnesium bicarbonate type. The water is moderately hard to very hard with a hardness range of 100 to 500 mg/l and a dissolved solid range of 100 to 650 mg/l (Lamonds, 1972).

Deep Aquifer System

The deep aquifer system in the Buffalo River basin consists of those strata below the base of the Cotter Formation and above the Precambrian basement rocks. The interval includes, in ascending order, the Upper Cambrian Lamotte Sandstone, Bonneterre Dolomite, and Eminence Dolomite; and the Ordovician-age Gasconade Formation, Roubidoux Formation, and Jefferson City Dolomite (Table 21). The deep aquifer system sequence of Cambrian and Ordovician rocks is dominantly dolomite with some sandstone units (see section on stratigraphy, page 111). The deep aquifers are present in the subsurface and do not crop out in the Buffalo area. They crop out across large areas of southern Missouri. This Cambrian-Ordovician sequence lies on the broad structural platform that dips southward from the Ozark dome in Missouri to the Arkhoma Basin in the Arkansas River Valley. These rocks and the overlying strata dip less than one-half degree beneath successively younger strata. At the margin of the Arkhoma Basin in central Newton and Searcy Counties the dip steepens to approximately one degree or slightly more (Chinn and Konig, 1973).

Little information is available on the ground water potential of the Cambrian rocks in Arkansas. The prohibitive cost of drilling deep wells has curtailed development of the deeper aquifers and relatively few wells in northern Arkansas have penetrated to such depths. There are no water wells in the Cambrian sequence beneath the Buffalo River basin. The Cambrian rock units are considered to be prolific water producers in southern Missouri where they are nearer the surface and are closer to their area of outcrop and recharge. Substantial ground water supplies may be present in the Cambrian rock beneath the Buffalo drainage area. However, the quantity of water undoubtedly is smaller than that in Missouri because of the greater depth of burial and greater distance from the area of recharge. At depth, the weight of the overlying rocks causes sandstone to be more compacted and better cemented;

thus, porosity and permeability are reduced. Also, secondary openings in carbonate rocks generally decrease in number and size with depth (Lamonds, 1972). Saline ground water may be present in the lower part of the Cambrian section, jeopardizing water quality. As the development of deeper aquifers proceeds, the quantity and availability of the ground water of the Cambrian section beneath the Buffalo River basin should become known.

Above the Cambrian strata are the Ordovician units of the deep aquifer system. Among these the Roubidoux Formation and the basal Gunter Sandstone Member of the Gasconade Formation are important ground water producers in southern Missouri and counties adjacent to the Missouri border in northern Arkansas. These units are potentially important ground water aquifers for the Buffalo River basin. The chert-bearing dolomite of the Gasconade Formation above the Gunter Sandstone Member and below the Roubidoux has not been evaluated as to ground water potential. Numerous wells in northern Arkansas which penetrate the Roubidoux are completed in this Gasconade interval, which averages 400 feet in thickness. Significant increases in water production have not occurred in these Gasconade wells. The Jefferson City Dolomite, above the Roubidoux Formation and below the Cotter Formation, is the uppermost unit of the deep aquifer system. The dense dolomite of the Jefferson City is thought to be relatively impermeable and the unit is not used as an aquifer in northern Arkansas.

Large quantities of good quality ground water sufficient for municipal, industrial, or agricultural uses have been produced from deep wells in the Roubidoux Formation and Gunter Sandstone

Member of the Gasconade Formation. These units are developed extensively for water in southern Missouri and northern Arkansas by users needing larger quantities than are generally available from the shallower aquifers. At this time, extensive development of these aquifers in northern Arkansas has been limited by the prohibitive cost of drilling deep wells, and by the fact that large quantities of ground water generally are not required in this dominantly rural and sparsely populated region. Domestic supplies are obtained from wells tapping the shallower aquifers well above the Roubidoux Formation. According to Melton (1975), the future development of large quantities of good quality ground water in northern Arkansas depends primarily on the water-bearing properties of the Roubidoux and Gunter units. Because large supplies of ground water are scarce in northern Arkansas, the economic development of the area depends in large part on the ultimate potential of these aquifers.

Information on the Roubidoux Formation and the Gunter Member in Arkansas has been published by Caplan (1960), Lamonds and Stephens (1969), and Lamonds (1972). However, in these studies the Roubidoux and Gunter are discussed in a cursory manner and the information is limited. The most comprehensive and enlightening report on these deep aquifers is by Melton (1975). The information herein relating the Roubidoux and Gunter to the Buffalo River basin was taken in part from this source. Additional work on the lithologic parameters of these units was done by Synder (1975).

Three producing water wells in the Buffalo River basin have penetrated the deep aquifer system. The water well at Marble

Falls (reference well 18) was drilled through the Roubidoux Formation and the Gunter Sandstone Member and was completed 43 feet into the Eminence. The well at Marshall (reference well 79) was drilled through the Roubidoux 75 feet into the Gasconade; the Big Flat water well (reference well 65) bottoms in the Roubidoux 243 feet below its top. Ground water from these wells is undifferentiated as to aquifer source because of the lack of casing.

The Gunter Sandstone Member of the Gasconade Formation is an interval of sandstone and sandy dolomite at the base of the Gasconade Formation. It is bound, above and below, by the chert-bearing dolomite of the Gasconade Formation and the Eminence Dolomite, respectively. Extensive outcrops of the Gunter Member are known in central Missouri. From there it extends southward in the subsurface and is present beneath the Buffalo River basin.

In Missouri, the Gunter Member averages 25 to 30 feet in thickness. Regionally, the Gunter thickens to the south and southeast. Thicknesses of 20 to 40 feet are common throughout the northernmost counties in Arkansas. Thickness beneath the northern part of the Buffalo River basin is approximately 40 to 50 feet; approximately 90 feet of Gunter may be present beneath the southern part of the basin. The isopachous map (Figure 42) shows the generalized thickness of the Gunter Member in the Buffalo River basin. Locally the Gunter varies in thickness from place to place because the sand of the Gunter Member accumulated on the irregular erosional surface of the underlying Eminence Dolomite (Knight, 1954).

Depth to the top of the Gunter beneath the Buffalo River basin depends on its location in relation to the structural platform in

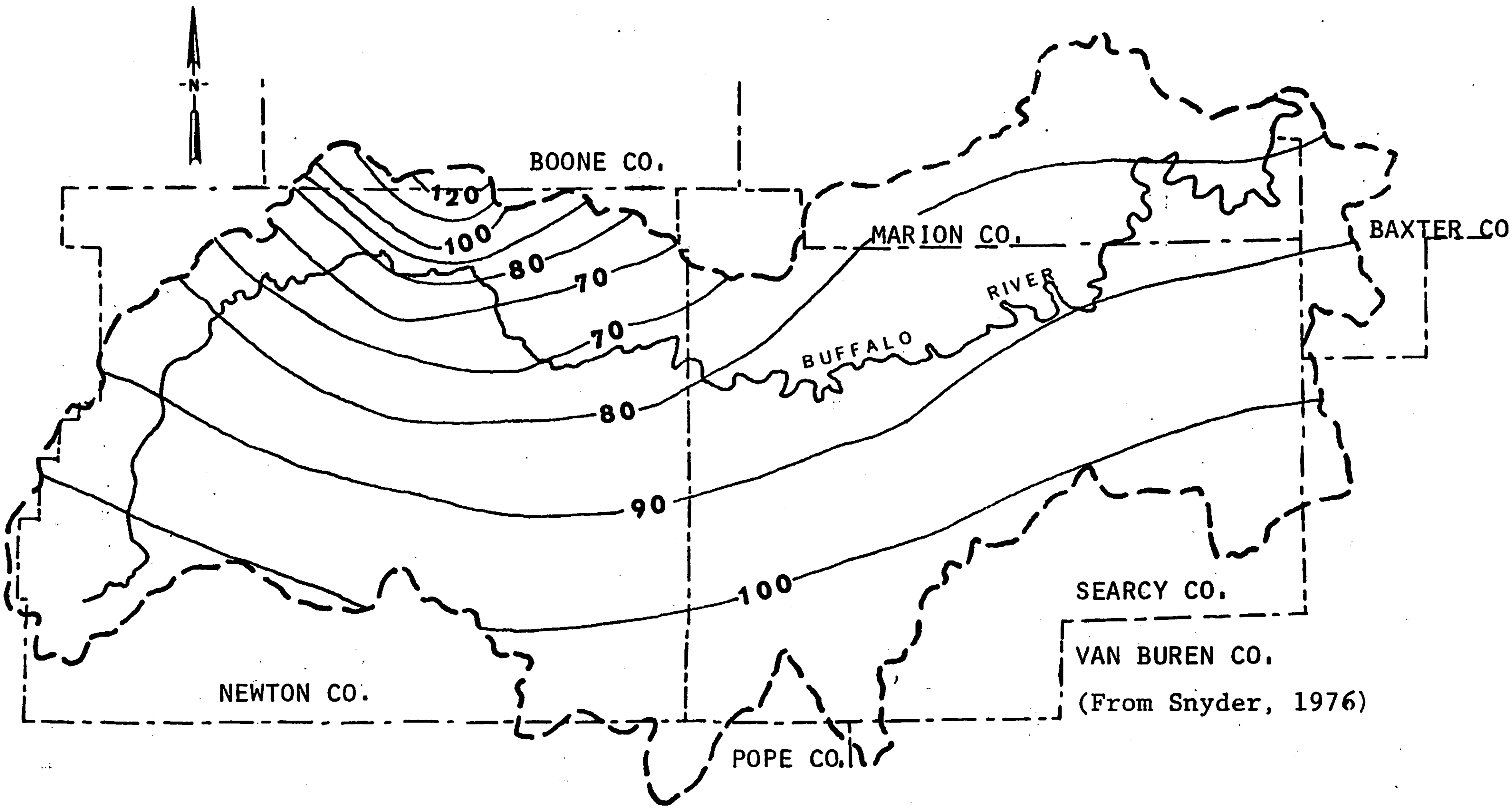


FIGURE 42. ISOPACHOUS MAP OF THE GUNTER MEMBER

0 2 4 6 8 10
Miles

Contour Interval 10 Feet

the area. Altitude of the top of the Gunter ranges from 800 feet below mean sea level to approximately 1600 feet below mean sea level from the northern part of the Buffalo River basin to the hinge line of the structural platform in central Newton and Searcy Counties. In the Marble Falls water well, the base of the Gunter is 1265 feet below mean sea level. South of the hinge line the depth increases greatly. Immediately south of the Buffalo River basin in southern Newton County the top of the Gunter is 2868 feet below mean sea level.

The Roubidoux Formation unconformably overlies the Gasconade Formation. It crops out over a large area of southeastern Missouri and is present in the subsurface south of this area. The Roubidoux consists of sandstone and sandy chert-bearing dolomite. The chert-bearing dolomite beds of the Jefferson City Dolomite overlie the Roubidoux Formation. Like the Gunter, the Roubidoux in Missouri is varied regionally in lithology. The lithic variations, which affect the hydrologic properties of the Roubidoux, undoubtedly are present in the subsurface of northern Arkansas.

The Roubidoux Formation ranges in thickness from 105 to 250 feet in Missouri. Thickness increases regionally to the southeast. In the Arkansas counties adjacent to the Missouri border the Roubidoux is as much as 260 feet thick. The isopachous map (Figure 43) shows the generalized thickness of the Roubidoux beneath the Buffalo River basin. The thickness increases southeastward from approximately 180 feet in the northwestern part of the basin to approximately 260 feet in the southeast. In the Marble Falls water well (reference well 18), 180 feet of Roubidoux was found; 235 feet of Roubidoux is

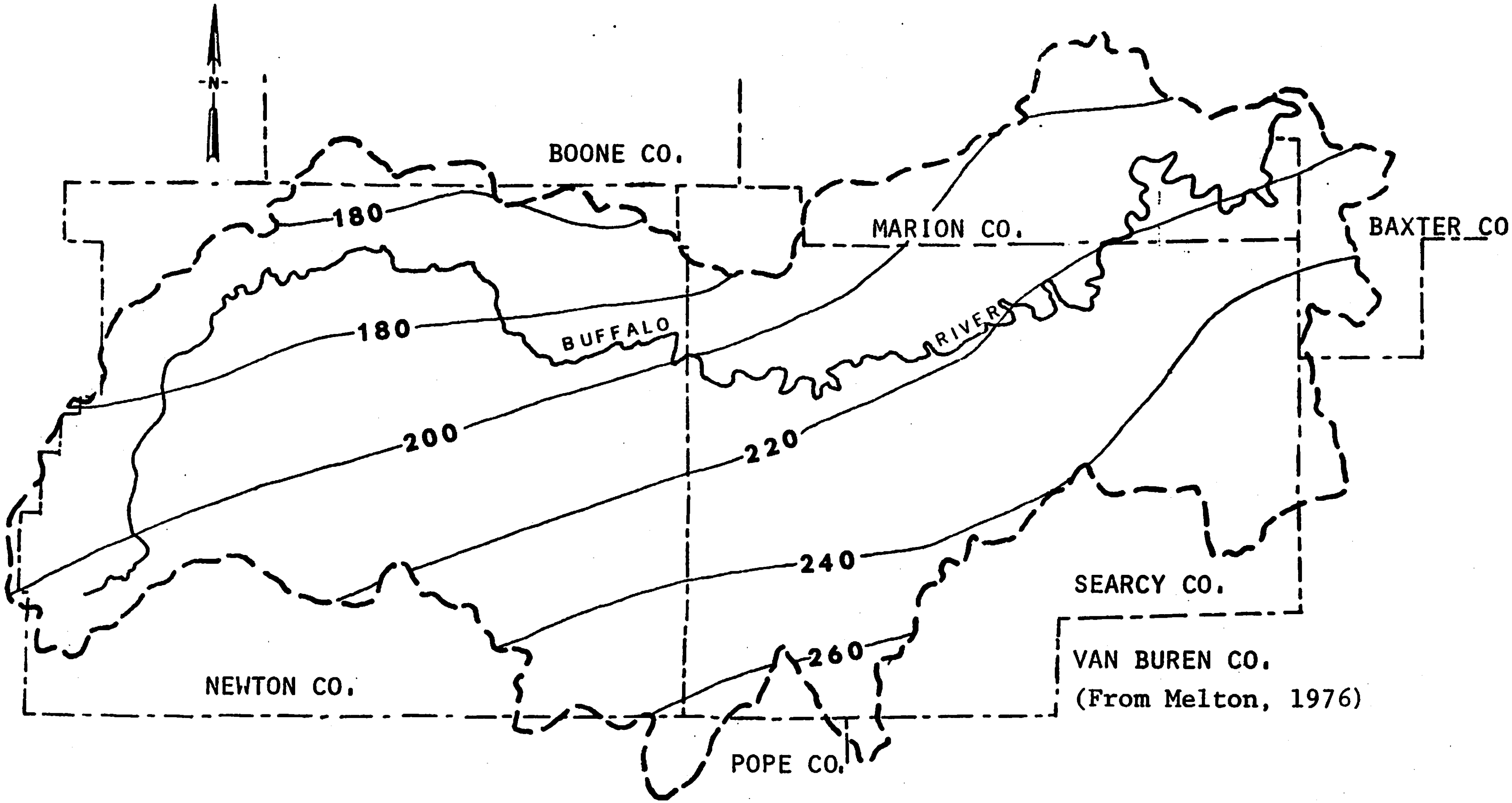


FIGURE 43. ISOPACHOUS MAP OF THE ROUBIDOUX FORMATION

Contour Interval 10 Feet

present in the Marshall water well (reference well 79).

Depth of the Roubidoux Formation beneath the Buffalo River basin reflects its position in relation to the structural platform. Beneath the northern part of the basin the top of the Roubidoux is approximately 200 feet below mean sea level. The depth of the top of the Roubidoux increases southward. At the southern margin of the structural platform in central Searcy and Newton Counties, the Roubidoux is approximately 1000 feet below mean sea level. In the Marshall well, the base of the Roubidoux Formation is 1265 feet below sea level, whereas in the Marble Falls well the base of the Roubidoux is only 376 feet below sea level.

Hydrologic Characteristics

The Ordovician strata of the deep aquifer system include the Gunter Member and the Roubidoux Formation which crop out across a large area of southern Missouri. The Ordovician rocks in the outcrop area are extensively fractured and permeable. In addition, karstlike conditions are common. Precipitation falling on southern Missouri tends to infiltrate the subsurface rather than run off on the surface. Thus, these rocks receive a significant amount of recharge in the outcrop (State of Missouri, 1967).

A secondary source of recharge to the deep aquifers is the water moving vertically through the overlying shallow rocks. However, such recharge is probably not great in comparison with the amount of recharge from the outcrop area. Water-level measurements at the deep aquifer wells at Marble Falls, Big Flat, and Marshall (reference wells 18, 65, and 79) indicate that the piezometric surface of the deep aquifers coincides with that of the shallow aquifers. This relationship does not favor the downward seepage of ground water into the deep aquifers, although it does not preclude it. In addition, where the deep and shallow aquifers are separated by the Jefferson City Dolomite or other impermeable rock, these strata act as aquicludes and permit little shallow aquifer water to pass through into the deep aquifers. Undoubtedly, where faults and fractures connect the deep and shallow aquifers and the hydrologic head permits, downward movement of ground water occurs and with it recharge to the deeper aquifers.

The principal areas of recharge of the deep aquifers are outside the Buffalo River basin. Supply is relatively constant within the basin, as local variations in precipitation do not directly affect the quantity of ground water present. Only major long-term changes in the climate of the area of recharge, aided by overproduction by water wells, could affect the supply available from the deep aquifers in the Buffalo River basin.

Regionally, movement of ground water in the deep aquifer system is down the hydrodynamic gradient in the direction of dip, which is south. In the carbonate aquifers, the ground water moves along secondary openings such as fractures, faults, joints, solution channels, and bedding planes as the original rock is relatively impermeable. Thus, the ground water movement in the dense, deep dolomite aquifers depends upon the number and size of interconnected secondary openings. Most carbonate rocks have at least some fracture porosity and permeability. Hanson (1973), in a study of carbonate aquifers in northwestern Arkansas, confirms the correlation between high yield wells and springs and their proximity to linear zones of rock fracture. Where these linear fracture zones extend into the deep aquifers, rapid movement of ground water occurs. In clastic rocks, such as sandstone, the intergranular spaces provide porosity and permeability and the movement of ground water is more uniform and not localized as in carbonate rocks.

The rate of ground water movement in the deep aquifers is probably not rapid, except along linear fracture zones. Without exception specific capacities of wells in the deep aquifers are low. Specific capacity is the rate of discharge of a water well per unit of drawdown. It is not only the measure of the performance of a well, but is also an indication of the performance of the aquifer. Generally, high specific capacity indicates an aquifer with great transmissivity and rapid movement of ground water. For the Big Flat Roubidoux well (reference well 65) specific capacity is 0.23 gallons per minute per foot of drawdown and for the Marble Falls well (reference well 18), which is drilled into the Eminence, specific capacity is 1.8 gallons per minute per foot of drawdown. Specific capacity data for the Marshall well are not available. The figures indicate that the ground water in the deep aquifers is primarily in storage and that little horizontal movement takes place.

Discharge of ground water from the deep aquifers takes place by underflow generally to the south, pumpage, and upward vertical movement into the shallow aquifers. As was stated, the piezometric surface of the deep aquifers coincides with that of the shallow aquifers. The deep water is under enough hydrostatic head to allow movement upward and into the shallower strata through connecting fractures. Of course, the hydrostatic pressure of the water in the shallow aquifers must be less than that of the water in the deep aquifers for this movement to occur. The quantity lost by the deep aquifers and gained by the shallow aquifers as a result of this transfer is probably not great.

The ground water in the deep aquifer system is artesian. Above the Gunter Sandstone Member is the chert-bearing dolomite of the Gasconade Formation. However, the upper 50 to 75 feet of the Gasconade is dense, finely crystalline dolomite with very little chert. The Jefferson City above the Roubidoux is also dense dolomite. These relatively dense impermeable units serve as aquicludes which produce artesian pressure. In the Marble Falls well, the water rises to within 355 feet of the surface, whereas in the Big Flat water well it rises to within 656 feet of the surface. At Marshall, the water from the lower aquifers rises to within 206 feet of the surface. The piezometric surface created by the hydrostatic pressure of the deep aquifer system coincides with the piezometric surface of the shallow aquifer system. The hydrodynamic gradient of the deep aquifers is regionally to the southeast and locally to the south in the Buffalo area.

Yields from wells drilled into the Roubidoux in Arkansas range from 30 to 600 gallons per minute, although most yields are between 50 and 100 gallons per minute. Generally, higher yields can be expected in the counties adjacent to the Missouri border and lower yields are obtained on the south. The occasional higher yields may be associated with fracture patterns. Apparently most of the water from the Roubidoux Formation is from the sandstone units. In the Buffalo River basin, the Big Flat well (reference well 65) which is completed in the Roubidoux produces 54 gallons per minute with a drawdown of 237 feet. The water well at Marshall (reference well 79) in the Gasconade Formation produces 55 gallons per minute. Because these wells are not cased to the Roubidoux Formation they contain water from the overlying rocks as well as water from the Roubidoux.

The most productive aquifer in north Arkansas is the Gunter Sandstone Member. Yields of wells drilled into the Gunter range from 26 to 581 gallons per minute. Most commonly, yields between 185 and 300 gallons per minute can be expected. In the Buffalo River basin, the Marble Falls well (reference well 18) which was drilled through the Gunter into the Eminence Dolomite yields 250 gallons per minute with a drawdown of 140 feet. As in the Roubidoux wells, yields from the Gunter include water from the overlying strata because of the lack of deep casing.

The general practice in north Arkansas well drilling is to case off only the shallowest strata and to leave the rest of the hole open. This allows mixing of water from all the rocks penetrated by the well and makes it difficult to determine the yield and other hydrologic properties of the aquifer. In general, and especially for the deep wells, the more strata penetrated the greater the water supply. However, the maximum supply of water available from even the deepest wells is variable. If wells drilled through the Roubidoux into the Gasconade fail to produce sufficient quantities of water, one should expect to drill to the

Gunter Sandstone Member at the base of the Gasconade.

Water Quality

Because wells in the deep aquifer system are left open, it is not feasible to sample water from individual aquifers. The water quality of the deep aquifers therefore is considered by group and not by individual aquifer.

The ground water of the deep aquifer system in north Arkansas is generally of very good quality. The chemical quality is relatively uniform. The deep aquifer ground water is of the calcium-magnesium bicarbonate type, reflecting the predominantly dolomitic character of the rocks. Thus, calcium, magnesium, and bicarbonate are the dominant constituents dissolved in the water. Dissolved solids range in content from 87 to 535 milligrams per liter (mg/l) in the deep aquifers of north Arkansas. In the Buffalo River basin, the dissolved solid content is 239 mg/l at Marble Falls and 180 mg/l at Big Flat. Other constituents are generally present, but only in small amounts. The water from the deep aquifers is hard to very hard. It is potable and can be used for human consumption with little or no treatment.

Springs

Springs in the Buffalo area are of little direct economic importance. Only minor quantities of spring discharge are used for municipal and domestic water supplies, medicinal purposes, or commercial fisheries. Springs contribute to the area by sustaining the flow of streams and by enhancing aesthetic qualities. Little is known of the origin and geologic characteristics of springs in the Buffalo area, and they are not monitored in sufficient detail to provide information necessary for a complete understanding of them.

In the Buffalo River basin, springs range in size from small seeps on hillsides and cliffs to strong flows issuing from valley floors. However, most are small and probably variable (e.g., respond quickly to precipitation and have little or no flow during dry weather). Data on several of the larger springs in the Buffalo River basin are summarized in Table 24.

Most springs in the study area are on the Springfield and Salem Plateaus. In these areas, rocks near the surface are dominantly limestone and in places dolomite. Springs occur in these carbonate rocks where fractures, joints, and bedding planes, commonly enlarged by solution, intersect the surface. These rocks correspond to shallow aquifer groups 3 and 4. On the Springfield Plateau, where the Boone Formation forms much of the surface rock, the Boone Limestone is extensively fractured and pervious to water; thus, much precipitation infiltrates the subsurface. Water percolating downward through the Boone encounters impervious strata at its base. Consequently, a great many of the springs in the Buffalo area and throughout northern Arkansas are where these strata are exposed. The spring at Marble Falls issuing from the base of the St. Joe member of the Boone Formation is an example. In some cases, the impervious limestone below and in the more permeable sections of the St. Peter Sandstone and the Everton sandstone results in springs from these rocks (Giles, 1922). As the result of spring activity on the Springfield and Salem

Table 24. DISCHARGE OF SELECTED SPRINGS

Spring Number	Location	Name	Number of Measurements	Maximum Discharge (cfs)	Date	Minimum Discharge (cfs)	Date	Average Discharge (cfs)
1	15N16W3bc	Hughes Sp.	9	7.89	5-12-66	0.59	9-09-65	2.55
2	15N16W10acd	Zack Sp.	2	1.11	8-29-68	0.70	8-17-65	0.90
3	16N16W13bba	Unknown	1	2.2	4-12-61	2.2	4-12-61	-
4	16N20W6dcd	Unknown	1	1.27	5-02-68	1.27	5-02-68	-
5	16N20W29abd	Big Bear Cave Sp.	1	0.17	5-03-68	0.17	5-03-68	-
6	16N20W29abd	Unknown	1	0.54	5-03-68	0.54	5-03-68	-
7	16N21W13ccd	Unknown	1	0.62	5-02-68	0.62	5-02-68	-
8	17N20W20cad	Marble Falls Sp.	1	8.42	5-02-68	8.42	5-02-68	-
9	17N21W25aad	Unknown	1	2.61	5-02-68	2.61	5-02-68	-

Source: Lamonds and Stephens (1969).

Plateaus, ground water runoff (low flow) is relatively great and streams are sustained. In the Boston Mountains, the rocks near the surface correspond to shallow aquifer groups 1 and 2. Ground water runoff is reduced and surface runoff is great. Springs are not prevalent.

Only three springs within the Buffalo River basin have been evaluated for water quality: the spring(s) at Marshall, Hughes Spring, and Zack Spring (Table 23). In general, these springs contain less dissolved material than wells in the same area. This finding is plausible because the rate of flow is greater in springs than in wells, and thus the length of time the ground water is in contact with rocks and is able to dissolve material is shorter for springs than for wells. Where springs are in direct contact with surface runoff via fractures, contamination from effluents is a constant pollution hazard.

Surface Water

Runoff from the land surface is, in a sense, the residual water of the hydrologic cycle. It consists of water which flows directly over the surface of the land and water which has been released from ground water reservoirs into streams. It does not include water which has been lost to evapotranspiration (transpiration by plants and evaporation) or water which infiltrates the surface of the ground and is held in storage. The quantity of surface water available is not predictable with precision and reliability because its distribution in time is never certain. Further, the mineral characteristics of the surface water vary with the passage of time and differ from place to place depending on the geologic formations and soils on which it flows. Thus, the runnoff cycle designates a description of water and land and their interaction in the drainage area associated with a stream.

The quantity and quality of streamflow in the Buffalo River basin varies areally, seasonally and annually. In order to provide information concerning the interaction of water and land within the basin, the surface water is defined in terms of variability, average, duration, flood and low flows, and water quality.

The data used for the quantitative analysis of the surface water consists of measurements of daily discharge from two United States Geological Survey (U.S.G.S.) continuous record gaging stations located near St. Joe and Rush, Arkansas on the Buffalo River. The St. Joe gaging station is 58.3 miles upstream from the mouth of the river. Its drainage area is 825 square miles representing 62 percent of the Buffalo River basin. The period of record available was October 1939 to September 1973. Although the Rush gage has been discontinued, its record encompasses the period from October 1928 to September 1970. The drainage area for the Rush recording station was 1,091 square miles, representing 81 percent of the Buffalo River basin. The Rush gaging station is 24.3 miles from the mouth of the river. In addition to these two continuous record gaging stations data for the analysis of low-flows was available from U.S.G.S. low-flow partial-record gaging stations on the Buffalo River at Pruitt, the Little Buffalo River at Jasper, Bear Creek near Marshall and Big Creek near Big Flat, Arkansas. Low-flows are the water in streams during periods of no precipitation.

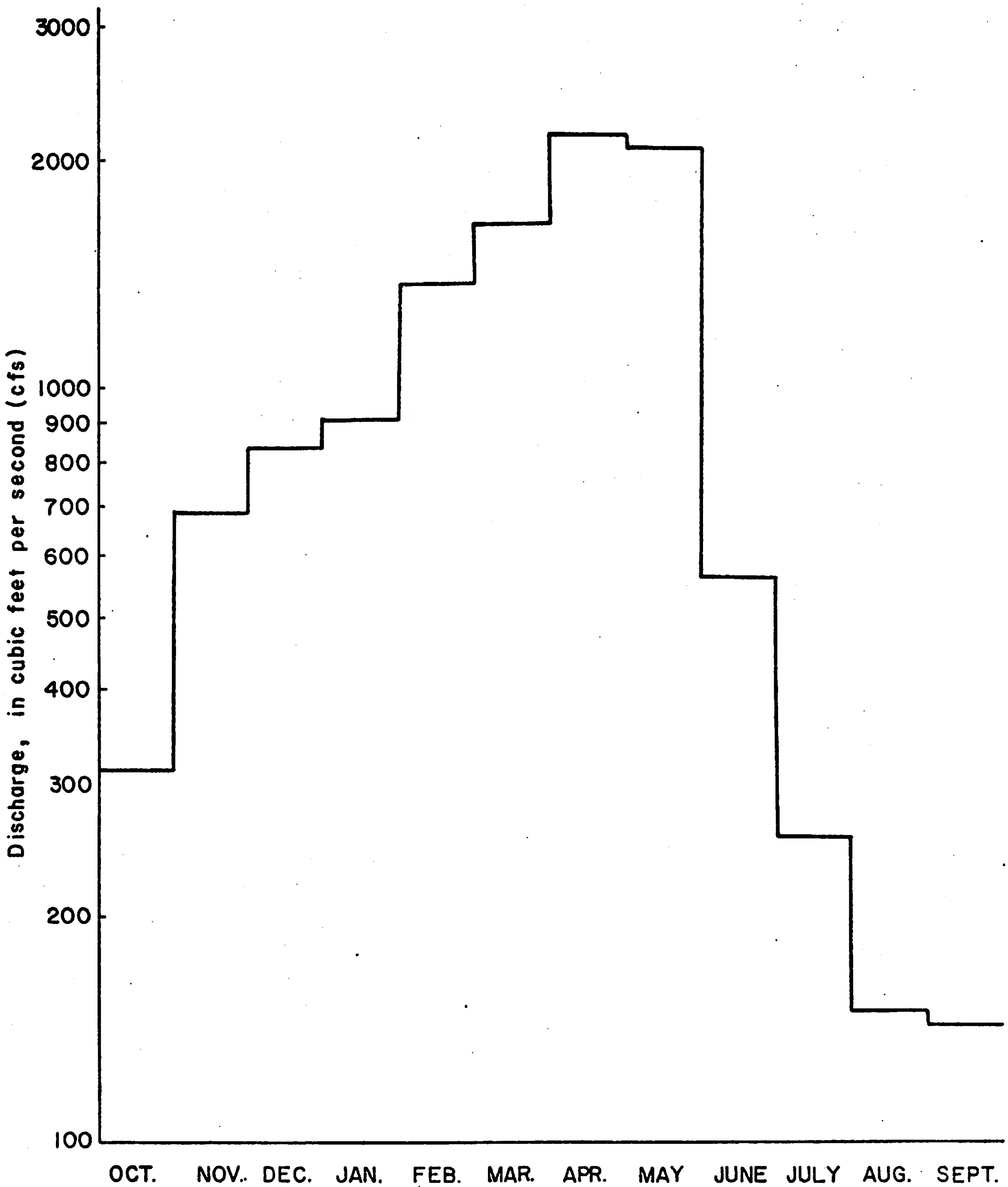
Variability of Flow

The Buffalo River and its tributaries do not discharge water at their average rate at all times. There are seasonal and daily variations in runoff that combine to produce considerable contrasts in total runoff from year to year. These variations are due in the main to the distribution of precipitation in the form of rainfall and the interaction of temperature and evapotranspiration rates upon that precipitation. The variability in average monthly runoff for the 20 year period of 1954 through 1973 is indicated by the record of the St. Joe gaging station (Figure 44). The variability of mean yearly runoff is indicated by the long-time record of the Buffalo River at Rush (Figure 45).

Minimum streamflows in the area usually occur during the fall or late summer when precipitation rates are low and evapotranspiration rates are high. Statistical analysis of the gaging station records for the 44 year period from 1929 to 1973 shows that 76.5 percent of the minimum flows occur equally during September and October. Of the remainder, 14.5 percent occurs during August and the rest during July and November. The lowest streamflows reported on the Buffalo River were discharges of 12 cubic feet per second (cfs) on September 17, 18 and 20, 1954 at Rush and 6.6 cfs on September 16, 17 and 20, 1954 at St. Joe.

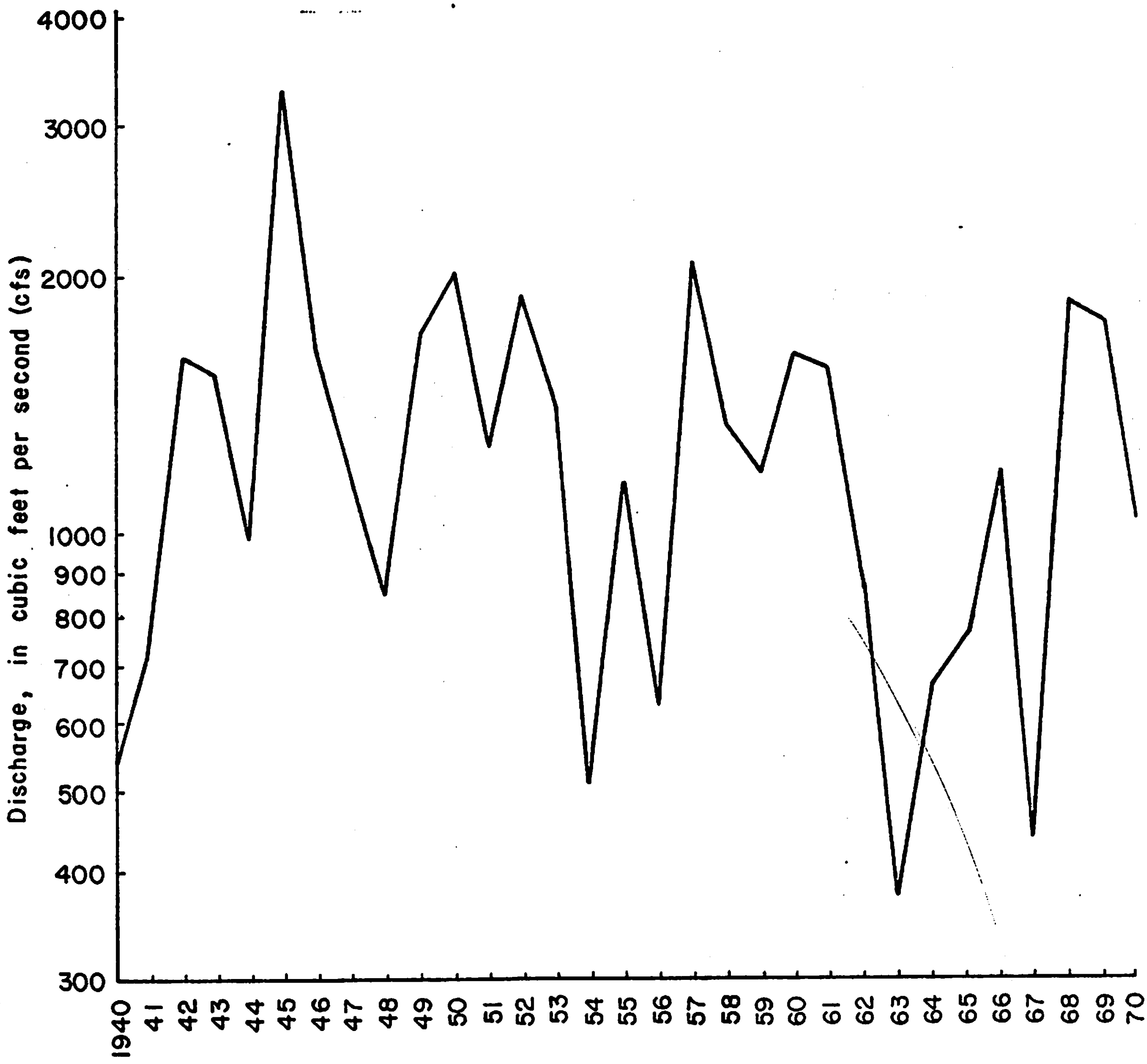
Maximum streamflows on the Buffalo River occur most often in the winter and spring. The stream gaging records over the 44 year period from 1929 to 1973 show that 88.3 percent of the maximum flows occur from January through May. Of this 88.3 percent 66.0 percent occur equally during March through May. The remainder of

Figure 44. Hydrograph of Mean Monthly Flows, 1954-1973, Buffalo River near St. Joe, Arkansas showing variability in streamflow.



Data source: U.S.G.S.

Figure 45. Hydrograph of Annual Mean Flow, 1940-1970, Buffalo River near Rush, Arkansas showing variability of streamflow.



Data Source: U.S.G.S.

the maximum streamflows (11.7 percent) were found to be confined to October and December. Flooding, often the result of maximum streamflow, resulting from heavy rains may occur during any month but occurs most frequently during the spring months. The greatest known floods in the Buffalo area occurred at St. Joe on December 10, 1971 with a discharge of 102,000 cfs and at Rush on April 15, 1945 with a discharge of 121,000 cfs.

Average Flow

According to Chandler, Lines and Scott (1972) the long-term (20 years or more) average flow of a stream represents the water yield of the drainage basin and can be used to evaluate the availability of surface water. Average flow data for the Buffalo River basin were derived from the U.S.G.S. recording stations at St. Joe and Rush. The base period used for computation of average flow in this report is 1929 through 1970 for the Rush station and 1940 through 1973 for the St. Joe station. These periods contain a balance of wet and dry years. The average discharge for the St. Joe and Rush gaging stations is 1040 cubic feet per second (cfs) and 1292 cfs, respectively. These values may be converted to millions of gallons per day (mgd) by the conversion factor 1 cfs = 0.646 mgd. Thus, the average flow of the Buffalo River is 671.84 million gallons per day at the St. Joe station and 834.63 million gallons per day at the Rush gage.

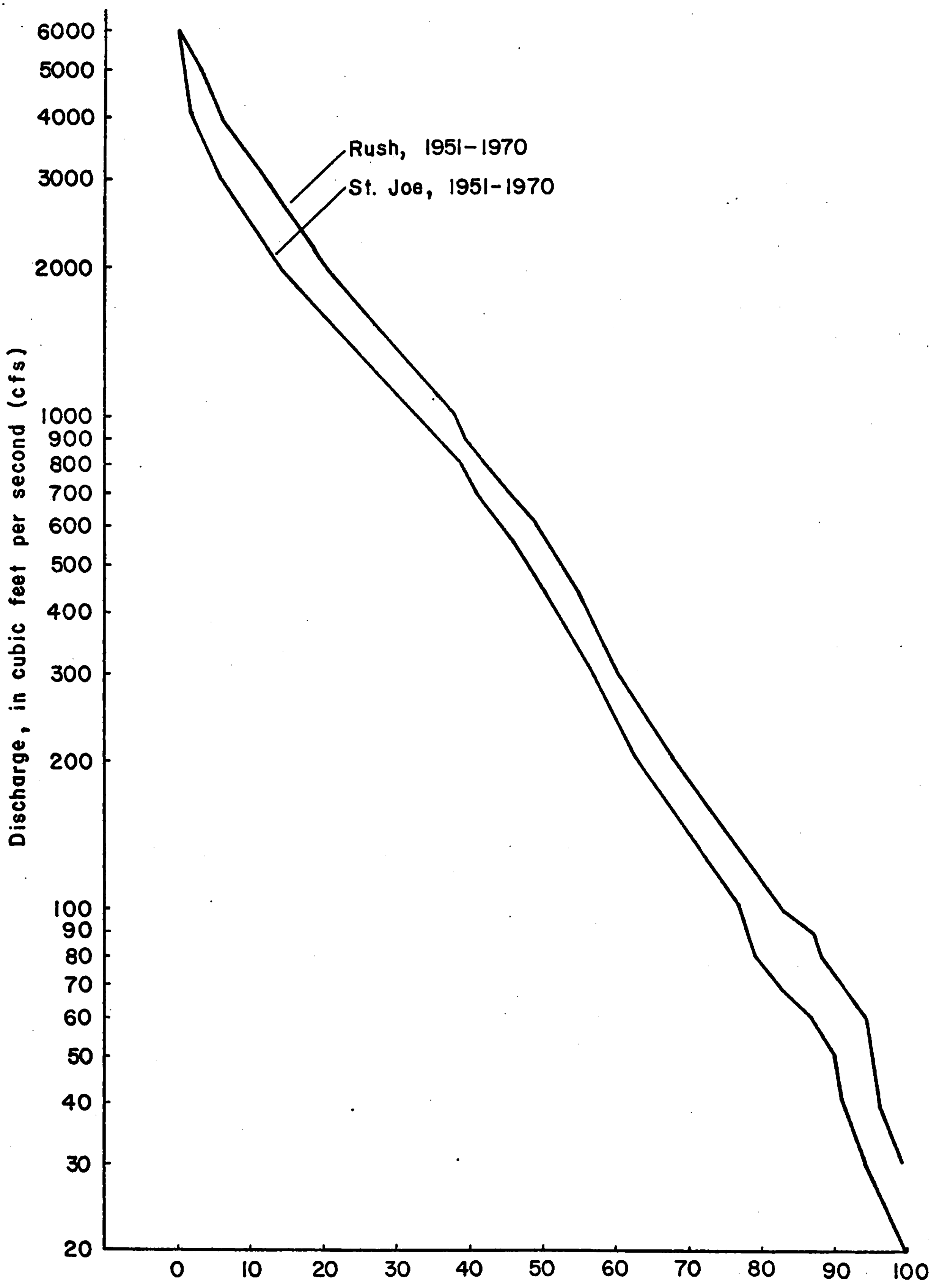
Infiltration rates in the basin are low to moderate when compared to nearby basins. Average annual runoff for the Buffalo River basin ranges from less than 1.0 cubic feet per second per square mile (cfs/mi^2) to more than 1.6 cfs/mi^2 (Lamonds, 1972). Runoff for the entire basin averages about 1.2 cfs/mi^2. This runoff is the actual water yield per square mile and may be defined as the average discharge rate (cfs) divided by the area from which it is derived (St. Joe, 829 square miles; and Rush, 1091 square miles). According to Lamonds, highest runoff occurs in the Boston Mountains as the result of steep gradients and heavy precipitation. On the Springfield and Salem Plateaus where the average annual precipitation and gradients are lower the runoff is less.

Duration of Flow

The flow duration curve (Figure 46) provides an excellent comparison of the flow characteristics of streams because the slope and shape of the curve indicates the variability of streamflow and the hydrologic characteristics of a drainage basin (Miller et al. 1974). More explicitly, the flow duration curve indicates the percentage of time for the period of record during which the mean daily flow indicated was equaled or exceeded. The flow duration curve provides information concerning the relative baseflow and flood characteristics of a stream. In general, a curve with a steep slope denotes a basin in which the streamflow is mostly from direct runoff. A curve with a flat slope denotes a basin with a large groundwater storage capacity.

Kazmann (1965) states that flow duration curves can be used to anticipate future streamflow conditions within the limits of probability; that is, the curve is representative of the percentage of time that various mean daily flows may be expected to be equaled or exceeded in the future. It should be noted that the flow duration curve gives no information on the chronological sequence,

Figure 46. Flow Duration Curve



Percentage of time that mean daily flow indicated was equaled or exceeded.

Data Source: U. S. G. S.

duration or frequency of streamflows.

Flow duration curves of the Buffalo River at the St. Joe and Rush gaging stations (Figure 46) graphically illustrate stream flow characteristics in the river basin. To construct the curves, the magnitude in cubic feet per second is plotted as ordinates while the corresponding percents of time are plotted as abscissas. Both curves are for the 20 year period of 1951 through 1970 and represent the mean daily flow at each station.

The St. Joe and Rush curves are essentially similar in slope and shape, differing only in magnitude of flow. Thus, it may be concluded that the basin characteristics for the Buffalo River at these two points are similar. The steep slope of each curve indicates that the Buffalo River is a highly variable stream deriving much of its flow from direct overland runoff. It can further be inferred that the natural groundwater storage of the Buffalo River basin is small because the steepness of the curve precludes large groundwater bodies with high specific yield draining slowly into the river.

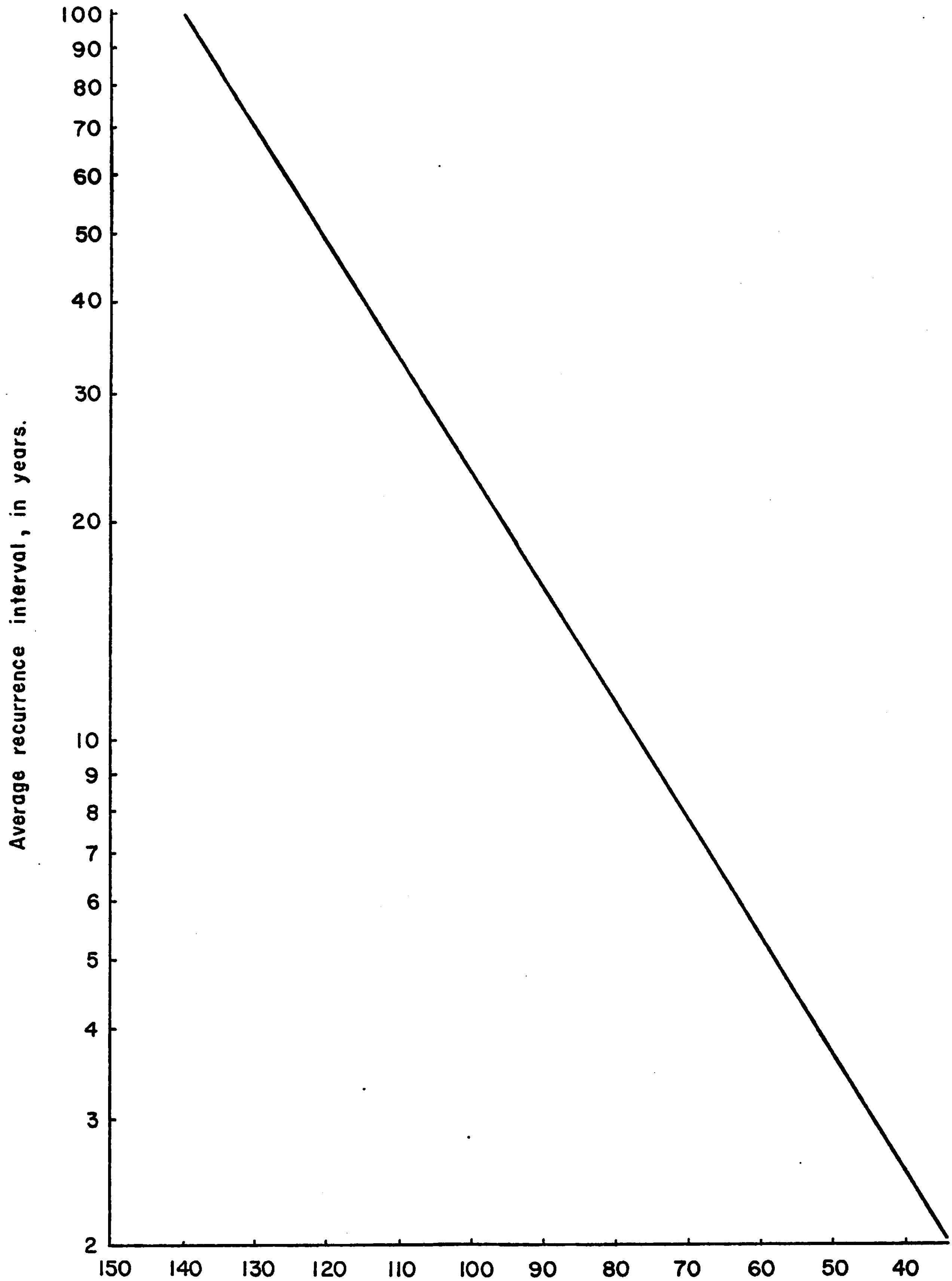
That portion of the flow duration curves exceeding 90 percent duration represents groundwater discharge into the Buffalo River (Feder et al., 1969). The curves for the Buffalo River at St. Joe and Rush are not well sustained in this lower region, implying that the capacity of the geologic formations to store and yield water is small. The shape of the extreme upper left part of the curves reflects the amount of runoff from periods of excessive precipitation. The steepness of the curve here indicated large amounts of runoff with little water infiltrating the ground. Johnstone and Cross (1949) state that inferences such as the above can be drawn with confidence from duration curves of daily flow.

Floods

Floods occur frequently in the Buffalo River basin along the Buffalo River and its tributaries because the mountainous terrain enhances both high precipitation and rapid runoff. There is no general relationship between the annual water yield of an area and flood flow. Flood flow results from periods of intense precipitation. In the Buffalo drainage area, floods may occur at any time, but occur most frequently from January to May as the result of intense local storms. On the Buffalo River, channel capacities are estimated to be about 25,000 cfs in the St. Joe area, approximately 35,000 cfs from St. Joe to Rush and about 45,000 cfs from Rush to the White River. Damage as the result of flood flow in the basin is limited due to the relatively large channel capacities and the small amount of human activity along the river. However, areas where floodplains exist are vulnerable to flooding. A knowledge of the magnitude and frequency of floods is necessary in order to minimize property loss and to insure proper design of bridges and other structures.

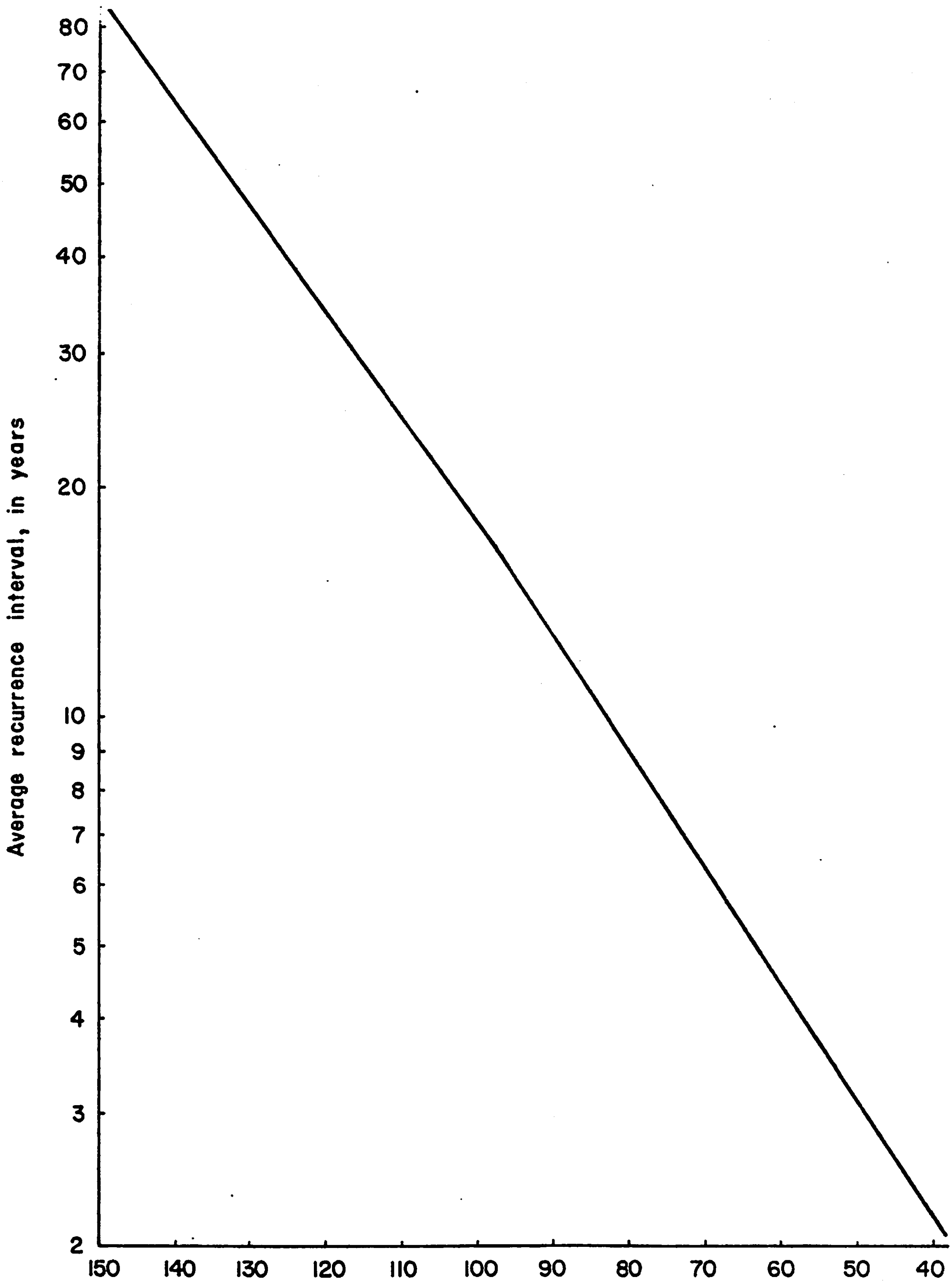
The magnitude and frequency of floods on the Buffalo River at the St. Joe and Rush gaging stations are described by the flood frequency curves (Figures 47 and 48). These graphs were obtained from the United States Army Corps of Engineers (1964). Observed data for the period of record was used to construct the curves. These graphical curves employ the annual-flood series method in

Figure 47. Flood Frequency Curve, Buffalo River near St. Joe, Arkansas.



Peak discharge, in 1000 cubic feet per second.
Data source: U.S.G.S.

Figure 48. Flood Frequency Curve, Buffalo River near Rush, Arkansas.



Peak discharges, in 1000 cubic feet per second.

Data source: U.S.G.S.

which only the maximum peak discharge for each year is used to analyze the frequency and magnitude of floods.

Analysis of peak flow data at each gaging station defines the relation between the magnitude of peak flow and its recurrence interval or probability of occurrence. For example, at St. Joe (Figure 47) a flood equal to or greater than 95,000 cubic feet per second will occur once in an average 20 year interval. At Rush (Figure 48) for an average 20 year interval a flood equal to or greater than 105,000 cubic feet per second will occur. Thus, in the annual-flood series a flood discharge that has a recurrence interval of 20 years may be expected to be exceeded as an annual maximum on the average of once in 20 years. Likewise, a discharge that has a recurrence interval of 10 years is expected to be exceeded as the annual maximum on the average of once in 10 years. The probability of exceedence is the reciprocal of the recurrence interval; thus, a flood having a recurrence interval of 20 years has a 5 percent chance of occuring during any year. Kazmann (1965) warns that in spite of a statistical approach to magnitude and frequency of floods, it is actually impossible to calculate exactly what flood conditions nature will create at any given time.

Low Flows

The ability of a drainage basin to supply ground water runoff to streams is measured by the magnitude, frequency and duration of low streamflow. Thus, low-flows are the natural ability of streams to supply water, of course excluding overland surface runoff. Low-flows determine to some extent the development or utilization of a stream since they illustrate the minimum amount of water to be expected.

The runoff within the Buffalo River basin varies to a greater degree than is indicated by the nearly uniform rainfall pattern (Table 20). Characteristically, low-flows occur most frequently in the late summer and fall and are most pronounced during drought years. These reduced flows often fall below one percent of the mean annual flow.

Low-flow data for the continuous record gaging stations at St. Joe and Rush and for low-flow partial-record gaging stations within the basin are given in Table 25, which summarized low-flow characteristics. These data, provided by Lamonds (1972), are for a standard reference period, 1929 through 1957. Table 25 includes the minimum average 7-day and 30-day low flows that may be expected to recur at average intervals of 2 and 10 years and the magnitude of flows that were exceeded 90 and 95 percent of the time.

Low-flow frequency data relate recurrence interval to lowest average discharge for periods of various length during each climatic year. For example, using the data from the table for the St. Joe gaging station the average low-flow of the Buffalo River will be less than 36 cubic feet per second for a 7-day period at intervals averaging 2 years in length; and for a period averaging 10 years it would be less than 14 cubic feet per second. The 30-day period of low-flows at St. Joe would be less than 41 cubic feet per second for the interval averaging 2 years and less than 17 cubic feet per second for the interval averaging 10 years in length. The flow at St. Joe will equal or exceed 48 cubic

Table 25. LOW-FLOW CHARACTERISTICS

Station Number	Location	Drainage area in square miles	Annual low-flow, cfs, for indicated recurrence interval				Flow, cfs, which was equaled or exceeded for indicated % of time	
			7-day		30-day			
			2-year	10-year	2-year	10-year	90%	95%
556.8	Buffalo River at Pruitt, AR	190	3.3	-	4.6	-	5.0	3.2
557	Little Buffalo River at Jasper, AR	124	1.6	0.3	2.1	0.4	2.8	1.3
560	Buffalo River Near St. Joe, AR	825	36	14	41	17	48	32
565.1	Bear Creek Near Marshall, AR	78.3	3.4	1.3	3.9	1.6	4.5	3.0
570	Buffalo River Near Rush, AR	1,091	46	22	64	30	71	51
571	Big Creek Near Big Flat, AR	90.3	1.0	0	1.5	0.1	2.3	0.5

Source: Lamonds (1972).

feet per second 90 percent of the time (320 days a year) and will equal or exceed 32 cubic feet per second 95 percent of the time (338 days a year). Similar interpretations can be made for the other low-flow stations using Table 25.

Low-flows along the Buffalo River and its tributaries are maintained by water from springs (see section on springs, page 164). The northern portion of the Buffalo River basin, which approximates the area underlain by the Boone Formation (Mississippian Age) and older strata (see geologic map, Figure 40), has a relatively high ground water runoff when compared to the southern portion of the basin. Here, the Upper Mississippian and Pennsylvanian sandstones and shales have low permeability, causing an extremely high rate of runoff and relatively little infiltration and ground water storage (Lamonds, 1972). The area to the north which is underlain predominately by limestones and dolomites allows greater infiltration and storage of ground water because it is extensively fractured and pervious to water. Consequently, this area provides a higher, better sustained ground water discharge to streams to maintain low flows.

Water Quality

Water is never found in its pure state in nature. Substances derived from the natural environment and/or from the waste products of man's activities ultimately modify water. These substances which modify water are the basic criteria in the determination of water quality. Thus, the quality of water is the combined physical, chemical and biological characteristics which are present.

In the Buffalo River basin, the quality of the surface water is controlled mainly by natural processes; that is, it is not influenced significantly by human activities. According to Chow (1964) climate and geology affect the quality of water in a river basin more than any other factor. The Buffalo River basin is no exception. The chemical quality of the water in the streams of the Buffalo area reflects the presence of the type of geologic formations; especially during low-flows when base flow is made up primarily of ground water discharge from springs and seeps, which are similar in character to ground water in the basin. The surface water in the basin is of the calcium bicarbonate chemical type. Ground water is generally of this same chemical type (Lamonds, 1972). The ground water (see section on ground water quality, page 148) is more highly mineralized and more uniform in chemical quality and temperature than the surface water, which varies daily and areally.

It is during periods of high runoff following heavy rainfall that the streams exhibit their most favorable chemical water-quality characteristics. The rapid runoff in the Buffalo River basin prevents significant amounts of solution of surface materials. Therefore, in the streams minimum concentrations of dissolved minerals occur following periods of heavy rainfall while maximum concentrations coincide with low-flows. The surface water of course will contain maximum concentrations of suspended matter during periods of high runoff.

The most recent and thorough investigation of the surface water quality of the Buffalo River and its tributaries was under the auspices of the National Park Service and conducted by the University of Arkansas Water Resource Research Center (1975).

The purpose of this study was to establish a baseline for the present surface water quality of the Buffalo River system, so that changes in the water quality that may take place as the result of the expected increased recreational use might be evaluated. Parker and Nix, in two separate studies, were the principal investigators of the physical and chemical characteristics of the above investigation. Steele was the principal investigator of the trace element geochemistry. A summary of these characteristics follows:

Physical and Chemical Properties

1. The surface water chemistry of the Buffalo River appears to be dominated by the rock strata through which it flows. Significant increases in calcium, magnesium, sulfate and alkalinity (and thus hardness) were recognized in a downstream direction. This trend would reflect the change from the predominantly sandstone-shale terrain upstream to the limestone-dolomite downstream. It also illustrates that the river continues to dissolve material from sediment as it flows.

2. Nitrate and orthophosphate levels are relatively low yet increase in concentration downstream, possibly as the result of an increase in agricultural runoff and domestic waste discharge into the river in those areas.

3. Concentrations of calcium, magnesium and sulfate and values for specific conductance and alkalinity are higher for tributaries when compared to the mainstream of the Buffalo River. This is plausible because the tributaries contain a greater percentage of ground water than the Buffalo River. Water in the Buffalo River is more diluted with surface runoff.

4. Dissolved oxygen values for the Buffalo River (about 7.2 mg/l.) are above saturation values. Total organic content is low. Thus, oxygen depletion is minimal, and organic loading is not currently a problem but may become one during extended periods of low-flow.

5. High concentrations of coliform organisms at various locations in the river indicate the possibility of fecal contamination. Thus, the Buffalo River water should not be used as a source of untreated drinking water and discharges of fecal waste should be closelv regulated in the watershed.

6. The pH varies from 7.0 to 7.9. Temperature is essentially Constant.

Geochemical Properties

1. Sodium, potassium, iron and manganese sediment concentrations decrease downstream while calcium and magnesium sediments increase in concentration downstream. These trends are related to the change from a sandstone-shale environment to a limestone-dolomite environment.

2. Anomalously high concentrations of zinc and cadmium exist in the river sediment below Rush.

3. There is a correlation between sediment composition and water chemistry.

Environmental Hazards

Environmental strains inevitably become more numerous as human activity increases and as land use practices intensify and become more diverse. These strains are the result of society's increasing demand on a relatively finite resource base. The environment of the Buffalo River basin is such a resource. Potential for environmental damage exists in the Buffalo River basin because of the increase in use caused by the creation of the Buffalo National River. Primary sources of ground and surface water pollution in the Buffalo River basin are septic tanks, sewage, oxidation ponds, landfills, animal waste, agricultural waste and recreational use of the Buffalo National River.

The natural features that are inherent to the Buffalo River basin make the ground and surface water particularly susceptible to environmental hazards. Carbonate terrane exists in approximately the northeastern one-half of the Buffalo River drainage area, which corresponds to that area encompassed by the Springfield and Salem Plateaus (Figure39). Ground water pollution and physical damage often result from a variety of land uses in carbonate terranes particularly where residual soils are thin to discontinuous and carbonate rocks are exposed at the land surface (Parizek et al., 1971). Thus, environmental strains unique to carbonate terrane occur over large areas of the Buffalo River basin.

The shallow aquifer system in the Buffalo area is readily susceptible to pollution, particularly in those areas dominated by carbonate strata and where fractures exist or where there is poor soil filtration. The deep aquifer system, while not as vulnerable, is susceptible where fractures allow the direct input of pollutant material. In the shallow carbonate aquifers the ground water is able to travel rapidly along solution channels and fracture zones. Therefore, the shallow wells and springs in the area are susceptible to the rapid input and distribution of pollutants. Because of the ease with which water can move from the surface into the subsurface throughout many portions of the Buffalo River basin, surface disposal of liquid and solid waste, both human and animal, must be carefully considered.

In the southwestern half of the Buffalo River basin, the shallow aquifer system is dominated by sandstone and shale of Atokan age. Ground water from these non-carbonate rocks is not as vulnerable to pollution as carbonate rocks because the water can be filtered as it travels through the intergranular pore spaces of the rock; however, pollution is still possible. It might also be noted that because of the steep slopes found in this area, soils are thin or often absent; thus, contaminants are not likely to be filtered as water infiltrates into the subsurface.

In the carbonate areas of the Buffalo River basin, the limestone and dolomite at or near the surface is much more soluble than other rock types common to the Buffalo area, such as sandstone and shale. Precipitation falling on the area becomes weakly acidic (carbonic acid) and slowly dissolves the carbonate rocks at the surface and along bedding planes, joints and fractures. As a result, enlarged solution channels, caverns, sinks and residuum are common features. Because the residual soils are thin, porous and transmit water freely in carbonate terranes, the water at the surface is able to infiltrate rapidly without filtering into the subsurface. Once in the subsurface, ground water moves rapidly along solution channels and other permeable zones without natural filtering. Thus, the pollution susceptibility of carbonate terranes is great as contaminants are often not filtered out by natural processes.

One of the most pertinent problems to be dealt with in rural land use planning is the contamination of ground water aquifers. Coughlin (1975), in a study of the geologic and environmental factors affecting ground water in the Boone Limestone in rural northwest Arkansas found that 80 per cent of the wells investigated were polluted as the result of human activities. Coughlin and other workers have also found high incidences of polluted ground water associated with wells or springs located on linear fracture zones. The Boone Limestone which crops out in Northwest Arkansas is also extensive in the Buffalo River basin.

The steep slopes common to most areas of the Buffalo River basin also present environmental problems. Steep slopes often transmit pollutant material into the surface water system before it can be absorbed and filtered by the soil. Pollution of streams from over-land sources is a constant hazard in the Buffalo River area. Locally, defoliatants such as 2-4D and 2-45T are used in efforts to clear relatively steep slopes for pastures. Erosion of what soil is present and sedimentation of streams often are the result of such activities. In places, on steep slopes which have been cleared, shale beds may become unstable and result in landslides or other processes of mass wasting. Disposal of liquid waste is a particular hazard where slopes are too steep for the construction of sewage lagoons, or where through negligence they have not been built.

The steep slopes and rapid runoff in the Buffalo River basin lead to periodical flooding of the river and its tributaries. Flooding can occur in any valley regardless of whether the valley has a flowing stream, an intermittent stream, or no stream at all. Sewage lagoons or landfill sites constructed in flood prone areas are likely to be inundated by flood waters.

Although the Buffalo River is, in most palces, unpolluted, its increased use will inevitably result in water quality problems. The Buffalo River near Mill Creek and the Little Buffalo River at Jasper are already contaminated by fecal material. The river will be particularly susceptible to pollution during periods of low-flow because only minimal amounts of water will be in the river during these times. Low-flows on the Buffalo occur commonly during the late summer and early fall. Particular care should be taken to avoid possible pollution of the river during low flows.

Generalizations must be made when discussing potential environment hazards because so many variables are involved. However, within the Buffalo River basin, many geologic conditions are conducive to environmental problems, particularly ground and surface water pollution. Land use planning and management studies which emphasize the geologic environment are necessary to protect the Buffalo area from physical damage and water pollution.

VEGETATIONS ON SELECTED SITES

General information about the vegetation of the Buffalo River area has been known for many years, but few ecological studies have been made. Read (1952) correlates the occurrence of tree species with soils and underlying rocks in the Koen Experimental Forest in Newton County, Dale (1973) describes general habitat conditions and vegetation communities of eight sites along the river, and Thompson (1975) presents an annotated checklist of vascular plants of Lost Valley and correlates the occurrence of principal forest community types with soils. However, some of the areas of interest to the present study have not been fully investigated, and quantitative field data on distribution, numbers, and sizes of principal species have not been used consistently as a basis for plant community descriptions. Also, very little information is given concerning the ecological relations of saplings and high and low understory species present in the principal forest types.

The primary objectives of this study were to identify and locate the principal vegetation types present, determine relationships between these vegetation types and environmental conditions, and investigate successional trends as influenced by environmental conditions near the river. Secondary objectives were to correlate soil and other environmental conditions with principal vegetation types and to inventory vascular plants present in selected study sites.

Methods

A field reconnaissance of areas selected for study was made in June, 1975 for orientation purposes and to plan the work. Vegetation sampling was started in July and continued at varying intervals during July and August.

Trees over 3.5 inches in diameter breast high (d.b.h.) were sampled by means of the augmented variable radius method as described by Rice and Penfound (1955). Saplings between 1 inch and 3.5 inches d.b.h. and high understory between 5 feet tall and 1 inch d.b.h. were sampled by one one-hundredth acre arm-length rectangles (Penfound and Rice, 1957). Low understory (forest floor) vegetation less than five feet tall was determined by a modification of the crosswire sighting tube method described by Winkworth and Goodall (1962).

All sampling points were determined randomly.

Field data for trees were converted to importance values (Curtis and McIntosh, 1951), high and low understories to density per acre (numbers of individuals, by species) and low understory (forest floor) vegetation to percent cover. Briefly, the importance value is a figure representing the combined values of relative frequency (a measure of distribution), relative density (number of individuals) and relative basal area (a measure of size). It represents an overall summation figure useful for determining relative importance of a given tree species within a forest community or for comparison of tree species of one community with another.

The various vegetation community types present were determined from a study of the compiled data and arbitrarily designated by principal species present. The locations and boundaries of these communities were determined and indicated on maps on the basis of ground observations supplemented by studies of black and white vertical photographs and low-angle Kodachrome and Ektachrome infrared transparencies taken from an altitude of about 1000 feet in October, 1975.

Soil samples were taken in July and August from all sites sampled and sent for analysis to the University of Arkansas Soils Laboratory, Department of Agronomy.

Duplicate voucher specimens of vascular plants were collected at various times during the investigation, pressed, dried, labeled, and mounted. One set of these collections is on file in the University of Arkansas Herbarium and the other set was sent to the Superintendent, Buffalo National River.

Designation of Dominance and Important Secondary Species

A plant which characterizes and exerts control over a plant community is termed a dominant (Clements, 1916; Oosting, 1956). According to Rice and Penfound (1959), trees with an importance percentage of 25 or more are considered dominant species and those with I.P.s between 5 and 25 are considered as important secondary species. Since the importance percentage is equivalent to the importance value divided by 3, importance values of 75 or more are dominants and those between 15 and 75 are important secondary species. These values are in general agreement with results of studies by Hite (1960), Bullington (1962), Fullerton (1964) and Youree (1969) in northwest Arkansas and Sullins (1969) in north central Arkansas.

It is generally recognized that in order for a species to dominate a forest community, it must be in the overstory. Other species, however, may show dominance within their own stratum. Saplings and high understories are considered as dominants if their density values are 100 or more per acre and as important secondary species with densities between 60 and less than 100 per acre. Plants in the low understory are dominant with cover percentages of 10 or more, and important secondary species with percentages between 5 and 10.

Results and Discussion

There are nine major forest types present in the three sites where vegetation was sampled. These types arranged along an increasing moisture gradient are the cedar glade (Juniperus virginiana) type, post oak (Quercus stellata) type, pine-oak (Pinus echinata, Quercus spp.) type, black oak (Quercus velutina) type, white oak (Quercus alba) type, mixed hardwood type, beech (Fagus grandifolia) type, elm-oak-maple (Ulmus americana, Fraxinus pennsylvanica, Acer saccharinum) floodplain type, and the willow (Salix caroliniana, Salix interior) or gravel-bar type.

The cedar glade at Buffalo Point, Site 8 (Map 1), is typical of many other glades of this and nearby areas (Kucera and Martin, 1957; Hite, 1960; Sullins, 1969; and others). These glades are almost always associated with limestone or dolomite and occur frequently on the tops and sides of limestone bluffs along the Buffalo and other major rivers in the Ozarks.

The soils are typically thin and dry, with high calcium content and pH values near neutral (Table 26).

The only dominant tree species present at Site 8 is red cedar (Juniperus virginiana), with chinquapin oak (Quercus prinoides), white oak (Quercus alba), post oak (Quercus stellata), Shumard oak (Quercus shumardii) and mockernut hickory (Carya tomentosa) occurring as important secondary species. Mockernut hickory and white ash (Fraxinus pennsylvanica) are dominant in both sapling and high understory layers, and winged elm (Ulmus alata) dominates in the high understory only (Table 27).

Open areas at most glade sites frequently support stands of prairie grasses and forbs, but this was not the case at Site 8. The presence of poison ivy (Rhus radicans) as a dominant and almost total lack of prairie species suggests that overgrazing or other disturbance occurred in the past or that grasses have been suppressed by a dense overstory canopy (Table 28) . Also, the large number of oaks in the tree overstory and other hardwood species in understories indicate that an oak forest type is rapidly developing at this site.

Post oak forests usually occur on hilltops and south- or west-facing slopes with thin, dry soils where drainage is excessive. The typical open canopy admits large amounts of light, which in turn, raises soil temperatures and increases moisture loss.

A representative post oak forest located at Buffalo Point, Site 1, is characterized by the occurrence of post oak as the only dominant with black hickory (Carya texana), black oak, mockernut hickory and short-leaf pine as important secondary species. Blackjack oak (Quercus marilandica) frequently occurs as a co-dominant in many dry upland forests of this type, but none was present at this site.

Dominance was lacking in the sapling-sized trees, but post oak, black hickory, wild plum (Prunus americana), sumac (Rhus copallina) and winged elm dominated in the high understory (Table 29).

The extensive ground cover of the low understory at this site (77%) and the large number of different species present indicate extensive past disturbance (Table 30).

Pine-oak forests occur in more or less isolated areas in sites similar to those supporting post oak or post oak-blackjack oak-black oak forests (Turner, 1935).

Soils of the pine-oak forests are generally somewhat sandy and dry with pH values usually between 4.5 and 5.5.

Short-leaf pine (Pinus echinata) is the only dominant overstory tree in the pine-oak forest at Buffalo Point, Site 5, and white oak and black oak are the only important secondary species. Pine and flowering dogwood (Cornus florida) are dominant saplings and high understory species, and black gum (Nyssa sylvatica) and winged elm dominate the high understory only.

No species occur as a dominant in the low understory, but Johnson grass (Sorghum halepense) and poison ivy (Rhus radicans) are present as important secondary species.

Pine forests at Buffalo Point, Site 6 and Site 9, are essentially similar except that oaks are co-dominants with the pine. Also, species such as white oak, cedar (Juniperus virginiana), chinquapin oak (Quercus prinoides), northern red oak (Quercus borealis), blackjack oak, black hickory and sassafras (Sassafras albidum) occur as important secondary species in the overstory or as dominant saplings or high understory species.

Low understory dominants in these other sites include broomsedge (Andropogon virginicus), poison ivy (Rhus radicans) and dryland blueberry (Vaccinium vacillans).

Black oak forests are found principally on upper slopes and ridges intermediate in moisture conditions between post oak and white oak (Quercus alba) types on east- or west-facing slopes and ridges, and less commonly on north- or south-facing slopes (Turner, 1955). Black hickory is usually associated with white oak, mockernut or black hickory, post oak or pine. Also, black oak or black oak-hickory forests are the most common forest types of the Ozarks.

The four black oak forests examined in this study are located at Buffalo Point, Sites 3 and 4, Lost Valley, Site 5, and Leatherwood Creek, Site 1 (Maps 1, 2, and 3).

The forest at Buffalo Point, Site 4, is typical. Black oak occurs as the only dominant and white oak, short-leaf pine, mockernut hickory and post oak are important secondary species. Mockernut hickory is a dominant sapling and high understory species, and black oak and sassafras (Sassafras albidum) dominate the high understory (Table 33).

No species is a dominant in the low understory, but wild grape (Vitis sp.) and sassafras are important secondary species (Table 34).

White oak forests are the most mesic of the common upland forest types that occur throughout the Ozarks. It is usually found on north-facing, gentle slopes or on upper slopes of protected ravines. Also, it occurs in the bottoms of valleys of small mountain streams (Turner, 1935).

The soils are usually deep and well drained, fairly high in organic matter and with a pH generally between 5.2 and 5.5.

The white oak forest at Lost Valley, Site 3, is typical. The overstory is dominated by white oak, although black oak occurs as a weak (I.V. 75.2) co-dominant. Mockernut hickory and white ash are important secondary species at Site 3 (Table 35), and northern red oak (Quercus borealis), black oak, and post oak are in this category in the white oak forest at Buffalo Point, Site 7. White oak and mockernut hickory are dominant saplings and mockernut hickory and winged elm are dominant in the high understory. Flowering dogwood (Cornus florida) occurs frequently as a dominant sapling or high understory species in white oak forests elsewhere in the Ozarks (Youree, 1969; Sullins, 1969), but not in the stands sampled at Lost Valley or Buffalo Point.

Percent cover is relatively low in most well-developed forests of this type, primarily because of the characteristically dense overstory canopy. Hickory and dogwood are dominants and white oak is the only important secondary species of the low understory at Lost Valley, Site 3 (Table 36).

Mixed hardwood forest types of the Buffalo River area and elsewhere in the Ozarks are restricted primarily to sides of upland ravines and transition zones between upland and floodplain types of forest. Habitats are moist most of the year, and soils and vegetation are highly variable. These areas usually support large number of different species typical of both uplands and lowlands, and overstory tree species rarely occur as dominants. One exception was noted at Buffalo Point, Site 2, where white oak is present as a dominant with an importance value of 95.0.

The mixed hardwood forest at Lost Valley, Site 2, supports more different species than any other forest type. Black oak, southern red oak, white oak, and flowering dogwood occur as important secondary species in the overstory and dogwood is the only dominant sapling. Black hickory, winged elm, hazel brush (Corylus americana) and tree huckleberry (Vaccinium arboreum) are dominants in the high understory, and hog peanut (Amphicarpa bracteata) is the only dominant of the low understory (Tables 37 and 38).

It should be noted that important secondary species in overstories at other sites include sweetgum (Liquidambar stryaciflua), mockernut hickory, black gum (Nyssa sylvatica), dogwood, beech (Fagus grandifolia) and northern red oak. Also, dominant and important secondary species of sapling and high understory strata at other sites, in addition to those listed as present at Lost Valley, Site 2, are black gum, witchhazel (*Hamamelis virginiana*), paw-paw (*Asimina triloba*), blue beech (*Carpinus caroliniana*), post oak, and black oak.

Beech forests, particularly those in relatively undisturbed condition, are rare in the Ozark region and are generally regarded as outliers of mesophytic forests of the southern Appalachians. They are usually small, seldom covering more than a few acres and are restricted to moist, sheltered upland habitats on north- or northeast-facing slopes or along the sides of ravines near floodplains.

The beech forest at Leatherwood Creek, Site 1, is the only forest of this type examined, although the frequent occurrence of beech was noted in mixed hardwood forests at Lost Valley.

The only dominant tree at Leatherwood Creek, Site 1, is beech, but ironwood (*Ostyra virginiana*), black hickory, and shagbark hickory (*Carya ovata*) are present as important secondary species. It should be noted also that the cucumber tree (*Magnolia acuminata*) which is relatively uncommon in most of the Ozarks is almost an important secondary species with an importance value of 22.1.

Dominant saplings are sugar maple (*Acer saccharum*) and dogwood, and dominant high understory species are beech, ironwood, sugar maple, dogwood, and witchhazel.

No species occur as a dominant in the low understory althcugh poison ivy, ironwood and virginia creeper (*Parthenocissus quinquefolia*) are present as important secondary species.

Elm-ash-maple floodplain forests are common along most of the larger streams in the Ozarks although most of them have been destroyed or extensively altered. These areas are subject to flooding at least once or twice every year and their deep, rich soil make them particularly well suited for agricultural uses.

Species composition of the elm-ash-maple forest examined at Buffalo Point, Site 10, is essentially the same as floodplain forests described by Dale and Fullerton (1964) along the White River or by Youree (1969) along the Illinois in northwest Arkansas. However, the low basal area of trees (44.1 square feet per acre) and presence of large numbers of weeds such as bouncing bet (Saponaria officinalis), meadow fescue (Festuca elatior) and tall ragweed (Ambrosia trifida) reflect the extensive disturbance of this forest in years past.

Green ash and American elm occur as dominants and silver leaf maple (Acer saccharinum) as an important secondary species of the overstory. No saplings occur as dominants, but green ash and cane (Arundinaria gigantea) dominate the high understory (Table 42).

The only dominant in the low understory is Virgina wild rye (Elymus virginicus) which is the most common native low understory species in forests of this type (Table 42).

The willow forest type is present adjacent to floodplain forests on gravel bars in most rivers of the Ozarks and Ouachitas.

Ward willow (Salix caroliniana) and sandbar willow (Salix interior) are the most common species at Buffalo Point, Site 11. These two species collectively comprise roughly 85 percent of the vegetation on the basis of density and much more than that on the basis of biomass (Table 43). This is true also at nearly all other places where this type occurs.

The low understory at Site 11 is comprised mostly of weeds, with poor jo (Diodia teres) and crabgrass (Digitaria adscendens) occurring as the only dominants (Table 44).

Weed populations of such areas vary considerably at different locations and at different times of the year, depending on the nature of seed sources and degree and time of flooding and deposition of seeds along banks and on gravel bars.

The foregoing description of results of this study will be supplemented later by a Master's Thesis by Stephen Bailey, Graduate Assistant.

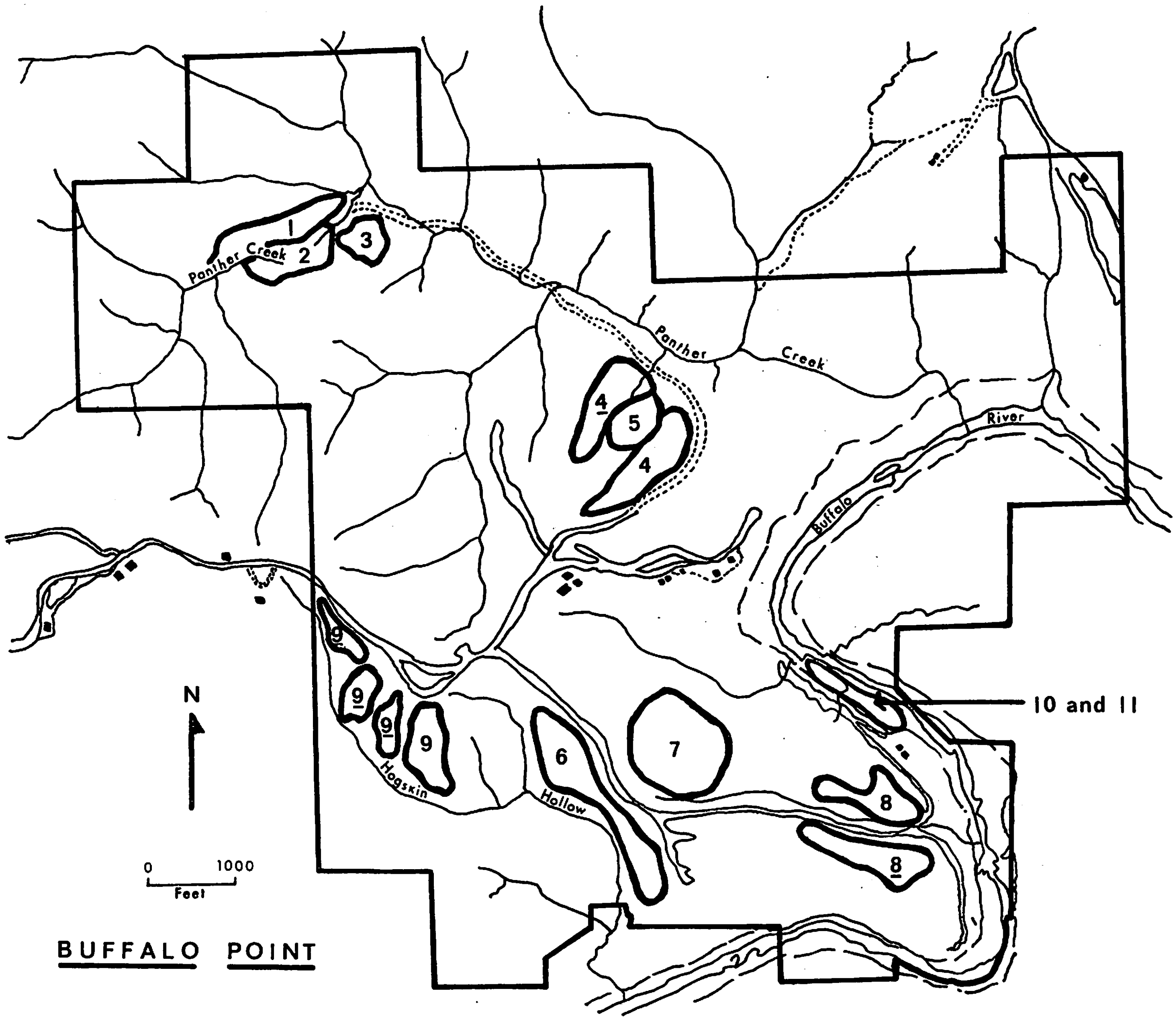
MAPS

Map 1. Buffalo Point. Sampling sites are indicated by numbers surrounded by heavy lines. Numbers not underlined indicate sites where quantitative vegetation sampling was accomplished. Underlined numbers show sites not sampled, but where field observations indicated that the forest type present was essentially the same as in a quantitatively sampled site with the same number. The kinds of forest types present are listed below:

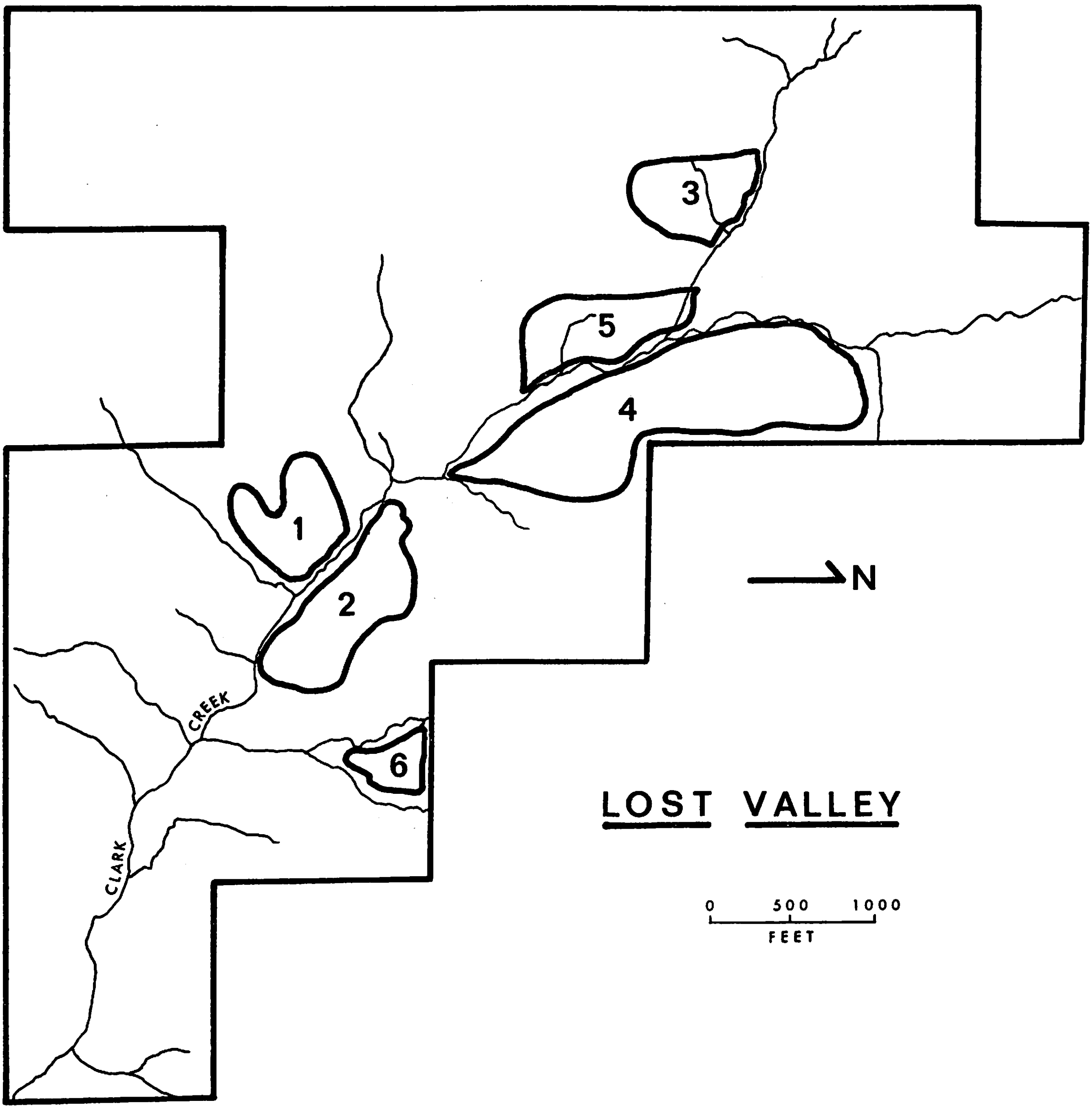
Site 1 - Post oak
2 - Mixed hardwood
3 - Black oak
4 - Black oak
5 - Pine-Oak
6 - Pine-Oak
7 - White oak
8 - Cedar Glade
9 - Pine-Oak
10 - Elm-Ash-Maple
11 - Willow

Map 2. Lost Valley. Sampling sites are indicated by numbers surrounded by heavy lines. The kinds of forest types present are listed below:

Site 1 - Mixed hardwood
2 - Mixed hardwood
3 - White oak
4 - Mixed hardwood
5 - Black oak
6 - Post oak



BUFFALO POINT


1
2
3
4
5
6
CREEK
CLARK
N
LOST VALLEY
0 500 1000
FEET

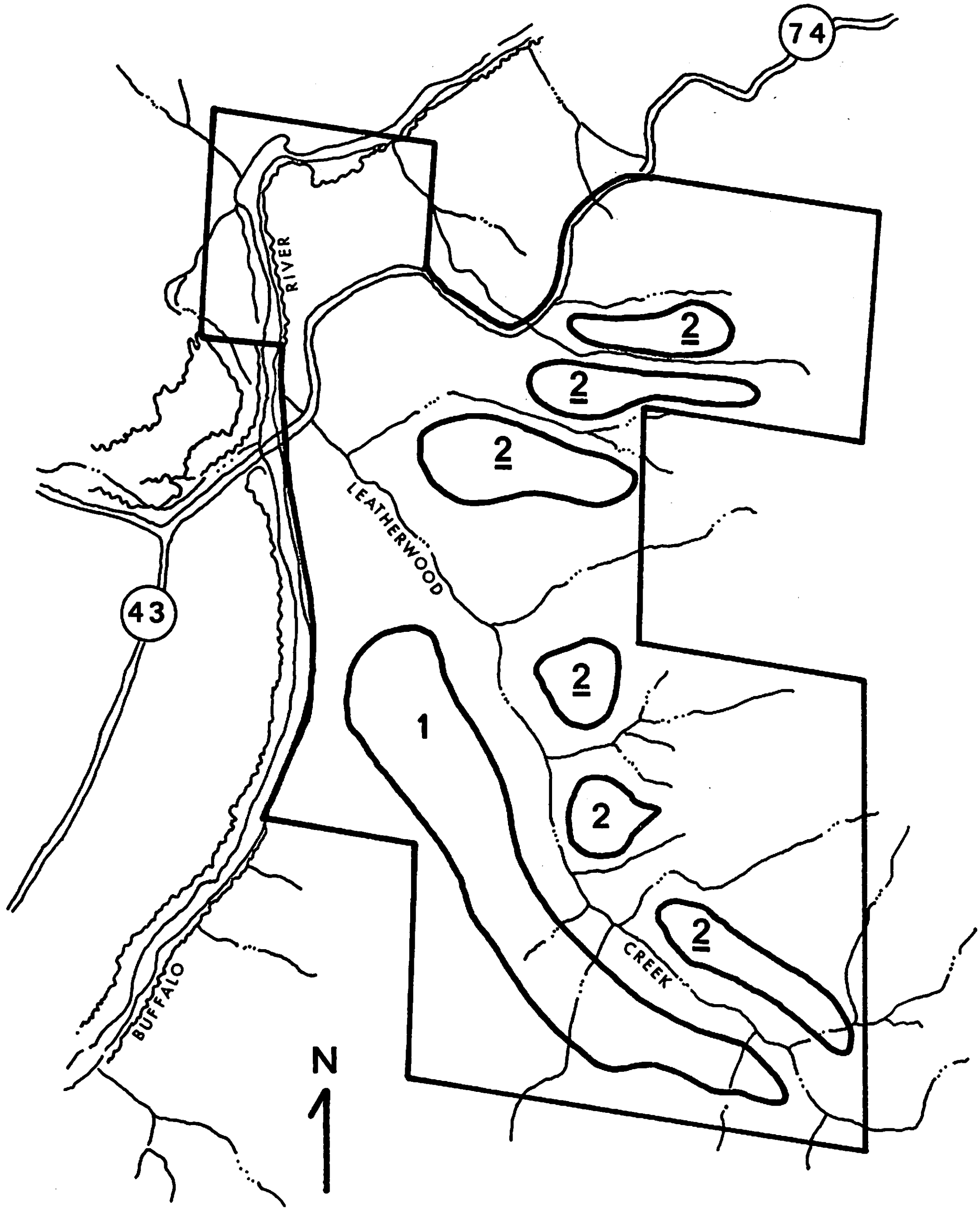
Map 3. Leatherwood Creek. Sampling sites are indicated by numbers surrounded by heavy lines. Numbers not underlined indicate sites where quantitative vegetation sampling was accomplished. Underlined numbers show sites not sampled, but where observations indicated that the forest type present was essentially the same as in a quantitatively sampled site with the same number. The kinds of forests present in each site are listed below:

Site 1 - Beech

Site 2 - Black oak

Table 26. Soil factors of different forest types at selected locations, Buffalo National River. BP refers to Buffalo Point, LV to Lost Valley and LC to Leatherwood Creek. Locations of all sites are indicated on Maps 1, 2 and 3. Soil samples were taken in July, 1975.

Forest Type	Site	pH	% OM	lbs/A P	lbs/A K	lbs/A Ca	lbs/A Na	lbs/A Mg
Post Oak	BP-1	6.1	3.80	27	195	3500	115	120
Mixed Hardwood	BP-2	6.3	3.32	34	130	2700	145	175
Black Oak	BP-3	6.4	3.80	47	245	5000	160	205
Black Oak	BP-4	5.2	3.80	23	135	1650	145	240
Pine-Oak	BP-5	5.6	3.38	28	210	1950	140	240
Pine-Oak	BP-6	5.2	3.80	16	145	2200	150	235
White Oak	BP-7	5.4	3.85	40	165	1450	110	275
Cedar Glade	BP-8	6.5	3.91	60	400	5000	135	290
Pine-Oak	BP-9	4.6	3.60	20	100	2100	110	140
Elm-Ash-Maple	BP-10	8.2	2.40	28	130	3650	140	160
Willow	BP-11	8.6	2.28	24	65	3500	140	145
Mixed Hardwood	LV-1	6.0	3.80	45	155	3250	135	240
Mixed Hardwood	LV-2	5.2	3.50	15	125	1350	130	135
White Oak	LV-3	5.3	3.32	13	145	950	140	250
Mixed Hardwood	LV-4	5.2	3.80	17	160	2300	150	240
Black Oak	LV-5	5.9	3.38	15	170	2200	140	250
Cedar Glade	LV-6	6.5	3.60	7	225	9800	115	195
Beech	LC-1	5.7	3.42	9	245	6400	145	230
Black Oak	LC-2	4.5	3.38	10	135	450	145	105



LEATHERWOOD CREEK

Table 27. Species present, importance values of trees, and density per acre of saplings and high understory of a cedar glade at Buffalo Point, Site 8. Basal area of trees is 118 square feet and density is 520 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Juniperus virginiana	123.5	60	60
Quercus prinoides	38.4	60	60
Quercus alba	36.7	-	20
Quercus stellata	31.6	20	-
Quercus shumardii	31.6	40	20
Carya tomentosa	15.5	100	120
Fraxinus americana	13.8	120	160
Quercus velutina	5.1	-	-
Carya texana	1.7	-	40
Diospyros virginiana	1.7	20	20
Rhamnus caroliniana	-	-	80
Cercis canadensis	-	-	40
Ulmus alata	-	20	240
Prunus serotina	-	-	20
Prunus mexicana	-	-	40
Ulmus rubra	-	-	80
Viburnum rufidulum	-	-	60
Pinus echinata	-	20	-
Morus rubra	-	-	60
Celtis reticulata	-	-	20
Ostrya virginiana	-	20	-
	Totals . . .	480	1140

Table 28. Species present and percent cover of low understory vegetation of a cedar glade at Buffalo Point, Site 8.

Species	Percent Cover
Rhus radicans	20
Parthenocissus quinquefolia	7
Ostrya virginiana	6
Fraxinus americana	2
Helianthus divaricatus	2
Prunus mexicana	1
Verbesina sp.	1
Amphicarpa bracteata	1
Juniperus virginiana	1
Galium sp.	1
Smilax bona-nox	1
Carex sp.	1
Monarda bradburiana	1
Vitis sp.	1
Misc. forbs	4
Misc. grasses	8
Total . . .	58%

Table 29. Species present, importance value of trees, and density per acre of saplings and high understory of a post oak forest at Buffalo Point, Site 1. Basal area of trees is 56 square feet and density is 140 per acre. Dash (–) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Quercus stellata	136.0	80	140
Carya texana	35.5	20	100
Quercus velutina	35.5	–	–
Pinus echinata	35.5	40	80
Carya tomentosa	35.5	40	40
Quercus prinoides	10.7	20	–
Juniperus virginiana	3.6	–	–
Fraxinus americana	3.6	–	–
Quercus shumardii	3.6	–	–
Prunus americana		60	220
Rhus copallina	–	–	240
Ulmus alata	–	–	200
Sassafras albidum	–		80
Cercis canadensis	–	20	40
Vaccinium arboreum	–	–	40
Celtis laevigata	–	20	–
Diospyros virginiana	–	–	20
Rhus aromatica	–	–	20
Misc. saplings	–	–	40
Totals . . .		300	1260

Table 30. Species present and percent cover of low understory vegetation of a post oak forest at Buffalo Point, Site 1.

Species Present	Percent Cover
Vitis aestivalis	7
Desmodium sp.	6
Helianthus divaricatus	5
Sorghum halepense	5
Berchemia scandens	5
Smilax bona-nox	4
Prunus americana	4
Vaccinium arboreum	4
Rhus radicans	3
Rhus copallina	3
Scleria sp.	1
Silphium terebinthinaceum	1
Celtis laevigata	1
Monarda sp.	1
Dioscorea villosa	1
Antennaria plantaginifolia	1
Heuchera sp.	1
Ulmus alata	1
Quercus stellata	1
Zizia aurea	1
Taraxicum sp.	1
Sassafras albidum	1

Table 30.

(cont'd.)

Species Present	Percent Cover
Carya cordiformis	1
Misc. forbs	7
Misc. grasses	11
Total . . .	77%

Table 31. Species present, importance values of trees, and density per acre of saplings and high understory of a pine-oak forest at Buffalo Point, Site 5. Basal area of trees is 130 square feet and density is 560 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Pinus echinata	191.2	280	120
Quercus alba	30.1	-	20
Quercus velutina	25.6	-	20
Cornus florida	22.9	100	120
Nyssa sylvatica	21.0	80	200
Quercus falcata	4.6	-	-
Ulmus alata	3.1	20	240
Acer saccharum	1.5	-	-
Amelanchier arborea	-	-	60
Ostrya virginiana	-	-	60
Carya tomentosa	-	120	80
Prunus americana	-	20	40
Diospyros virginiana	-	-	20
Quercus stellata	-	-	20
Rhus copallina	-	-	20
Juniperus virginiana	-	-	20
Liquidambar styraciflua	-	-	20
	Totals . .	620	1060

Table 32. Species present and percent cover of low understory vegetation of a pine-oak forest at Buffalo Point, Site 5.

Species	Percent Cover
Sorghum halapense	9
Rhus radicans	7
Vaccinium vacillans	4
Andropogon virginicus	4
Amphicarpa bracteata	4
Cornus florida	3
Panicum sp.	3
Vitis vulpina	3
Vaccinium arboreum	2
Quercus alba	2
Helianthus divaricatus	2
Nyssa sylvatica	2
Aster anomalis	1
Antennaria plantaginifolia	1
Prunus serotina	1
Smilax bona-nox	1
Rubus sp.	1
Zizia aurea	1
Quercus marilandica	1
Carya tomentosa	1
Taraxicum officinale	1
Misc. forbs	8
Total . . .	62%

Table 33 . Species present, importance values of trees, and density per acre of saplings and high understory of a black oak forest at Buffalo Point, Site. 4. Basal area of trees is 128 square feet and density is 480 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Quercus velutina	139.1	80	160
Quercus alba	70.3	80	60
Pinus echinata	37.4	-	-
Carya tomentosa	22.9	200	220
Quercus stellata	22.4	60	20
Quercus falcata	4.7	-	-
Nyssa sylvatica	3.1	60	60
Quercus marilandica	-	-	40
Ulmus alata	-	20	20
Cornus florida	-	40	20
Prunus americana	-	-	60
Amelanchier arborea	-	-	20
Acer rubrum	-	-	20
Diospyros virginiana	-	40	40
Carya cordiformis	-	20	20
Sassafras albidum	-	-	260
	Totals . . .	600	1020

Table 34. Species present and percent cover of low understory vegetation of a black oak forest at Buffalo Point, Site 4.

Species Present	Percent Cover
Vitis sp.	6
Sassafras albidum	5
Vaccinium vacillans	4
Amphicarpa bracteata	4
Diospyros virginiana	3
Rhus radicans	3
Zizia aurea	2
Ceanothus americanus	2
Panicum sp.	2
Carya tomentosa	2
Helianthus divaricatus	2
Cornus florida	1
Quercus alba	1
Smilax bona-nox	1
Coreopsis palmata	1
Desmodium paniculatum	1
Rubus sp.	1
Parthenocissus quinquefolia	1
Prunus serotina	1
Misc. forbs	2
Total . . .	45%

Table 35. Species present, importance value of trees, and density per acre of saplings and high understory of a white oak forest at Lost Valley, Site 3. Basal area of trees is 78 square feet and density is 242 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Quercus alba	150.7	114	14
Quercus velutina	75.2	43	29
Carya tomentosa	18.9	157	114
Fraxinus americana	18.1	-	43
Sassafras albidum	14.8	-	29
Acer rubrum	14.6	-	-
Cornus florida	3.8	72	43
Ulmus alata	2.6	57	215
Juglans nigra	1.3	-	-
Rhamnus caroliniana	-	29	43
Amelanchier arborea	-	-	57
Juniperus virginiana	-	-	14
Carya ovata	-	29	29
Ulmus rubra	-	-	14
Totals . . .		501	644

Table 36. Species present and percent cover of low understory vegetation of a white oak forest at Lost Valley, Site 3.

Species	Percent Cover
Carya sp.	12
Cornus florida	12
Quercus alba	6
Parthenocissus quinquefolia	4
Vaccinium vacillans	4
Fraxinus americana	4
Sassafras albidum	2
Vitis sp.	2
Andropogon virginicus	2
Total . . .	48%

Table 37 . Species present, importance value of trees, and density per acre of saplings and high understory of a mixed hardwood forest at Lost Valley, Site 2. Basal area of trees is 100 square feet and density is 310 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Quercus velutina	56.6	50	30
Quercus falcata	50.1	-	20
Quercus alba	48.6	80	20
Cornus florida	28.6	120	90
Fagus grandifolia	23.9	10	90
Liquidambar stryaciflua	23.7	30	10
Carya texana	15.7	50	110
Quercus stellata	8.7	-	10
Ulmus alata	7.7	10	110
Corylus americana	7.7	-	120
Diospyrus virginiana	7.7	10	20
Carya tomentosa	7.0	-	-
Nyssa sylvatica	4.0	40	50
Juglans nigra	3.0	-	-
Quercus prinoides	2.0	-	-
Acer rubrum	1.0	20	20
Quercus marilandica	1.0	-	-
Fraxinus pennsylvanica	1.0	-	
Juniperus virginiana	1.0	-	20

Table 37
(cont'd.)

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Vaccinium arboreum	-	30	110
Ulmus rubra	-	-	20
Rhododendron roseum	-	-	40
Amalanchier arborea	-	-	30
Viburnum prunifolium	-	-	20
Carya cordiformis	-	-	20
Celtis laevigata	-	-	20
Bumelia lanuginosa	-	-	20
Cercis canadensis	-	-	20
Tilia americana	-	-	10
Fraxinus americana	-	-	10
Hamamelis vernalis	-	-	10
Symphorocarpos orbiculatus	-	-	10
Acer negundo	-	-	10
Rhamnus caroliniana	-	-	10
Acer saccharum	-	-	10
	Totals . . .	450	1090

Table 38 . Species present and percent cover of low understory vegetation of a mixed hardwood forest at Lost Valley, Site 2.

Species	Percent Cover
Amphicarpa bracteata	11.0
Rhus radicans	9.5
Vaccinium vacillans	7.5
Andropogon virginicus	4.5
Acer rubrum	3.5
Panicum sp.	2.5
Cornus florida	2.0
Ulmus rubra	2.0
Antennaria plantaginifolia	1.5
Quercus alba	1.5
Vitis sp.	1.5
Parthenocissus quinquefolia	1.5
Juniperus virginiana	1.5
Carya tomentosa	1.5
Fagus grandifolia	1.0
Cassia nictitans	1.0
Passiflora lutea	1.0
Aster sp.	1.0
Carya tomentosa	1.5
Carex sp.	1.0
Rudbeckia hirta	1.0
Vaccinium arboreum	1.0

Table 38
(cont'd.)

Species	Percent Cover
Sassafras albidum	1.0
Cynoglossum virginianum	.5
Zizia aurea	.5
Cimicifuga racemosa	.5
Smilax sp.	.5
Agrimonia rostellata	.5
Hydrastis canadensis	.5
Misc. forbs	2.5
Total . . .	66.5

Table 39 . Species present, importance value of trees, and density per acre of saplings and high understory of a beech forest at Leatherwood Creek, Site 1. Basal area of trees is 94 square feet and density is 380 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Fagus grandifolia	108.6	-	360
Ostyra virginiana	43.9	40	100
Carya texana	29.4	-	-
Carya ovata	25.2	-	-
Magnolia acuminata	22.1	-	-
Robinia pseudo-acacia	21.1	-	-
Quercus borealis	13.7	-	-
Juglans nigra	11.5	-	-
Acer saccharum	9.6	160	320
Ulmus americana	4.3	60	60
Cornus florida	4.3	120	210
Quercus shumardii	2.1	-	-
Carya tomentosa	2.1	-	-
Nyssa sylvatica	2.1	-	-
Cercis canadensis	-	-	20
Hamamelis sp.	-	-	180
Lindera benzoin	-	-	40
Fraxinus pennsylvanica	-	-	80
Carpinus caroliniana	-	20	60
Quercus alba	-	20	-
Tilia americana	-	-	20
Asimina triloba	-	-	60
	Totals . . .	420	1510

Table 40. Species present and percent cover of understory vegetation of a beech forest at Leatherwood Creek, Site 1.

Species	Percent Cover
Rhus radicans	7.3
Ostyra virginiana	5.3
Parthenocissus quinquefolia	5.3
Hydrangea arborescens	4.0
Polystichum acrostichoides	3.3
Galium sp.	2.7
Amphicarpa bracteata	2.0
Fagus grandifolia	2.0
Acer sacchrum	2.0
Fraxinus americana	2.0
Adiantum pedatum	2.0
Ulmus americana	1.3
Dioscorea villosa	1.3
Hamamelis sp.	1.3
Carya sp.	.7
Panicum sp.	.7
Cercis canadensis	.7
Misc. forbs	5.3
Total . . .	49.2%

Table 41 . Species present, importance value of trees and density per acre of saplings and high understory of an elm-ash-maple flood-plain forest at Buffalo Point, Site 10. Basal area of trees is 44.1 square feet and density is 480 per acre. Dash (-) indicates that the species was not present.

Species	Importance Value	Saplings Density per Acre	High Understory Density per Acre
Fraxinus pennsylvanica	96.6	30	190
Ulmus americana	95.7	70	20
Acer saccharinum	46.1	40	50
Liquidambar stryaciflua	18.0	30	10
Platanus occidentalis	14.5	10	30
Salix nigra	10.2	-	-
Gleditsia triacanthos	9.5	-	-
Celtis laevigata	9.5	-	10
Acer negundo	-	20	40
Arundinaria gigantea	-	-	160
Ambrosia trifida	-	-	90
Rudbeckia laciniata	-	-	40
Sambucus canadensis	-	-	20
Catalpa speciosa	-	-	10
Juglans nigra	-	10	-
Quercus prinoides	-	10	-
	Totals . . .	220	670

Table 42. Species present and percent cover of low understory vegetation of an elm-ash-maple flood-plain forest at Buffalo Point, Site 10.

Species	Percent Cover
Elymus virginicus	16
Saponaria officinalis	6
Festuca elatior	4
Polygonum virginianum	4
Ambrosia trifida	4
Mikania scandens	4
Commelina virginica	4
Panicum Boscii	4
Chasmanthium latifolium	3
Solidago sp.	3
Vitis sp.	2
Silphium perfoliatum	2
Sassafras albidum	2
Helianthus divaricatus	1
Desmodium paniculatum	1
Rudbeckia laciniata	1
Liquidambar stryaciflua	1
Smilax sp.	1
Misc. forbs	5
Total . . .	68%

Table 43 . Density per acre of trees, saplings, and high understory of a willow (gravel bar) forest at Buffalo Point, Site 11. Dash (-) indicates that the species was not present.

Species	Trees Density per Acre	Saplings Density per Acre	High Understory Density per Acre
Salix caroliniana	28	26	9
Salix interior	2	9	1
Platanus occidentalis	1	1	1
Betula nigra	1	-	-
Acer saccharinum	1	-	-
Ulmus americana	-	2	-
Fraxinus pennsylvanica	-	1	1
Totals . . .	33	39	12

Table 44. Species present and percent cover of a willow (gravel bar) forest at Buffalo Point, Site 11.

Species	Percent Cover
Diodia teres	23
Digitaria adscendens	22
Ambrosia artemisiifolia	6
Bidens sp.	3
Euphorbia maculata	3
Oenothera biennis	2
Chenopodium album	2
Amaranthus spinosus	2
Ambrosia trifida	1
Cassia fasciculata	1
Erigeron canadensis	1
Saponaria officinalis	1
Lespedeza cuneata	1
Gaura biennis	1
Xanthium strumarium	1
Polygonum hydropiper	1
Carex sp.	1
Acalypha rhomboidea	1
Total . . .	73%

LIST OF PLANT COLLECTIONS

Plants collected at Buffalo Point, Leatherwood Creek and Lost Valley are listed in alphabetical order by family on the pages that follow. Both the scientific names and most commonly used colloquial names are given.

A total of 93 plants indicated by asterisk (*) are new county records.

The following plants in the list are considered as rare:

BUFFALO POINT
Gravel bar and floodplain No. 1

Coreopsis pubescens Ell. var. *pubscens* X *C. grandiflora* Hogg

LOST VALLEY
Cedar Glade

Cotinus obovatus Raf.

Phlox bifida Beck

LEATHERWOOD CREEK

Paronychia canadensis (L.) Wood

Veronica serpyllifolia L.

BUFFALO POINT

AQUIFOLIACEAE	Holly Family	
Ilex ambigua (Michx.) Torr.		Winterberry
ASCEPIADACEAE	Milkweed Family	
Asclepias sp.		Milkweed
CELASTRACEAE	Staff-tree Family	
Euonymus atropurpureus Jacq.		Wahoo
COMPOSITAE	Sunflower Family	
Aster patens Ait.		Spreading Aster
Lactuca sp.		Wild Lettuce
Silphium laciniatum L.		Compass Plant
Solidago arguta Ait. var. arguta		Goldenrod
*Solidago nemoralis Ait.		Old-field Goldenrod
CONVOLVULACEAE	Morning Glory Family	
Ipomoea sp.		Morning Glory
CORNACEAE	Dogwood Family	
Cornus drummondi Meyer		Rough-leaved Dogwood
CYPERACEAE	Sedge Family	
Carex muhlenbergii Schk.		Sedge
EBENACEAE	Ebony Family	
Diospyros virginiana L.		Persimmon

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*Indicates a new county record.

Buffalo Point (cont.)

EUPHORBIACEAE	Spurge Family	
*<u>Euphorbia</u> <u>heterophylla</u> L.		Painted Leaf
FAGACEAE	Beech Family	
<u>Quercus</u> <u>shumardii</u> Buckl.		Shumard Oak
GRAMINEAE	Grass Family	
*<u>Chasmanthium</u> <u>latifolium</u> (Michx.) Yates		Inland Sea Oats
LABIATAE	Mint Family	
<u>Monarda</u> sp.		Horsemint
LEGUMINOSAE	Pea Family	
<u>Baptisia</u> <u>leucophaea</u> Nutt.		Long-bracted Wild Indigo
<u>Desmanthus</u> <u>illinoensis</u> (Michx.) MacM.		Prairie Mimosa
<u>Lespedeza</u> <u>repens</u> (L.) Bart.		Bush Clover
<u>Stylosanthes</u> <u>biflora</u> (L.) BSP.		Pencil Flower
<u>Tephrosia</u> <u>virginiana</u> (L.) Pers.		Goat's Rue
POLEMONIACEAE	Phlox Family	
<u>Phlox</u> <u>bifida</u> Beck		Sand Phlox
POLYPODIACEAE	Fern Family	
<u>Pteridium</u> <u>aquilinum</u> (L.) Kuhn		Bracken
RHAMNACEAE	Buckthorn Family	
*<u>Rhamnus</u> <u>caroliniana</u> Walt.		Carolina Buckthorn
ROSACEAE	Rose Family	
*<u>Amelanchier</u> <u>arborea</u> (Michx. f.) Fern.		Shadbush
<u>Prunus</u> <u>mexicana</u> S. Wats.		Big Tree Plum

Buffalo Point (cont.)

RUBIACEAE	Madder Family	
Galium circaezans Michx.		Wild Licorice
Galium pilosum Ait.		Hairy Bedstraw
*_Hedyotis nigricans_ (Lam.) Fosberg		Bluets
SAPOTACEAE	Sapodilla Family	
Bumelia lanuginosa (Michx.) Pers. var. _albicans_ Sarg.		Chittim-wood
SCROPHULARIACEAE	Figwort Family	
Gerardia flava L.		Gerardia
ULMACEAE	Elm Family	
*_Celtis tenuifolia_ Nutt.		Dwarf Hackberry
VITACEAE	Grape Family	
*_Vitis vulpina_ L.		Winter Grape

BUFFALO POINT
Gravel bar and floodplain No. 1

ACERACEAE	Maple Family	
Acer negundo L.		Box Elder
AMARANTHACEAE	Amaranth Family	
Amaranthus palmeri S. Wats.		
Amaranthus spinosus L.		Thorny Amaranth
Froelichia gracilis (Hook.) Moq.		Cottonweed
Iresine rhizomatosa Standl.		Bloodleaf
ANACARDIACEAE	Cashew Family	
Rhus glabra L.		Smooth Sumac
ASCLEPIADACEAE	Milkweed Family	
Matelea gonocarpa (Walt.) Shinners		Climbing Milkweed
BIGNONIACEAE	Trumpet Creeper Family	
Campsis radicans (L.) Seem.		Trumpet Creeper
Catalpa sp.		Catalpa
CAMPANULACEAE	Bellflower Family	
Campanula americana L.		Tall Bellflower
CAPPARIDACEAE	Caper Family	
Polanisia dodecandra (L.) DC. subsp. dodecandra		Clammy-weed
CARYOPHYLLACEAE	Pink Family	
Saponaria officinalis L.		Bouncing Bet

CHENOPODIACEAE	Goosefoot Family	
Chenopodium album L.		Pigweed
Chenopodium ambrosioides L.		Mexican Tea
Cycloloma atriplicifolium (Spreng.) Coult.		Winged Pigweed
COMMELINACEAE	Spiderwort Family	
Commelina erecta L.		Dayflower
COMPOSITAE	Sunflower Family	
Ambrosia artermisiifolia L.		Common Ragweed
Artemisia annua L.		Sweet Wormwood
Aster sp.		Aster
Astranthium integrifolium (Michx.) Nutt.		Western Daisy
Bidens bipinnata L.		Spanish Needles
Bidens sp.		Beggar Ticks
Chrysanthemum leucanthemum L.		Ox-eye Daisy
Coreopsis pubescens Ell. var. *pubescens*		Star Tickseed
Coreopsis pubescens Ell. var. *pubescens* X *Coreopsis grandiflora* Hogg		(natural hybrid!)
Elephantopus carolinianus Raeusch.		Elephant's-foot
Erigeron canadensis L.		Horseweed
Eupatorium coelestinum L.		Mist-flower
Grindelia lanceolata Nutt.		Gum Plant
Helenium amarum (Raf.) H. Rock		Bitterweed
Heterotheca latifolia Buckley		Golden Aster
Heterotheca pilosa (Nutt.) Shinners		Golden Aster
Lactuca canadensis L.		Wild Lettuce
Lactuca serriola L.		Prickly Lettuce

Gravel bar and floodplain No. 1 (cont.)

Rudbeckia laciniata L.	Wild Goldenglow
Rudbeckia triloba L.	Brown-eyed Susan
Silphium perfoliatum L.	Cup Plant
Solidago arguta Ait. var. arguta	Goldenrod
Solidago gigantea Ait.	Late Goldenrod
Verbesina virginica L.	White Crown-beard
Vernonia arkansana DC.	Arkansas Ironweed
Xanthium strumarium L.	Cocklebur

CONVOLVULACEAE Morning Glory Family

Cuscuta sp.	Dodder

CUCURBITACEAE Gourd Family

Melothria pendula L.	Creeping Cucumber
Sicyos angulatus L.	Bur Cucumber

CYPERACEAE Sedge Family

Cyperus uniflorus T. & H.	Umbrella Sedge

EUPHORBIACEAE Spurge Family

Croton glandulosis L. var. septentrionalis Muell. Arg.	Croton
Croton monanthogynus Michx.	Croton
Euphorbia heterophylla L. var. heterophylla	Painted Leaf
Euphorbia maculata L.	Nodding Spurge

FAGACEAE Beech Family

Quercus prinoides Willd. var. acuminata (Michx.) Gl.	Chestnut Oak

Gravel bar and floodplain No. 1 (cont.)

GRAMINEAE	Grass Family	
Arundinaria gigantea (Walt.) Chapm.		Cane
Chasmanthium latifolium (Michx.) Yates		Inland Sea Oats
Cynodon dactylon (L.) Pers.		Bermuda Grass
Digitaria adscendens (H.B.K.) Henr.		Southern Crab Grass
Elymus virginicus L.		Wild Rye
Panicum clandestinum L.		Panic Grass
Setaria viridis (L.) Beauv.		Green Foxtail
Sorghum halapense (L.) Pers.		Johnson Grass
HAMAMELIDACEAE	Witch Hazel Family	
Liquidambar stryraciflua L.		Sweet Gum
LABIATAE	Mint Family	
Isanthus brachiatus (L.) BSP.		False Pennyroyal
Perilla frutescens (L.) Britt.		Beef-steak Plant
Teucrium canadense L.		Wood Sage
LAURACEAE	Laurel Family	
Lindera benzoin (L.) Blume		Spicebush
LEGUMINOSAE	Pea Family	
Cassia fasciculata Michx.		Partridge Pea
Cassia marilandica L.		Wild Senna
Desmodium paniculatum (L.) DC.		Tick Trefoil
Lespedeza cuneata (Dumont) G. Don		Sericea Lespedeza
Melilotus albus Desr.		White Sweet Clover
Strophostyles helvola (L.) Ell.		Wild Bean
LILIACEAE	Lily Family	
Smilax bona-nox L.		Catbrier

Gravel bar and floodplain No. 1 (cont.)

MENISPERMACEAE	Moonseed Family	
Cocculus carolinus (L.) DC.		Carolina Moonseed
NYCTAGINACEAE	Four o-clock Family	
Mirabilis nyctaginea (Michx.) Mac M.		Wild Four-o'clock
OLEACEAE	Olive Family	
Fraxinus pennsylvanica Marsh.		Green Ash
ONAGRACEAE	Evening Primrose Family	
Gaura biennis L.		Biennial Gaura
Oenothera biennis L.		Evening Primrose
OXALIDACEAE	Wood Sorrel Family	
Oxalis stricta L.		Yellow Wood Sorrel
PASSIFLORACEAE	Passion-flower Family	
Passiflora incarnata L.		Maypops
PLATANACEAE	Plane Tree Family	
Platanus occidentalis L.		Sycamore
POLYGONACEAE	Buckwheat Family	
Polygonum pensylvanicum L. var. *eglandulosum* J. C. Myers		Pinkweed
Polygonum virginianum L.		Virginia Knotweed
Polygonum sp.		Smartweed
Rumex crispus L.		Sour Dock
ROSACEAE	Rose Family	
Geum canadense Jacq.		White Avens
Rubus trivialis Michx.		Southern Dewberry

Gravel bar and floodplain No. 1 (cont.)

RUBIACEAE	Madder Family	
Diodia teres Walt.		Rough Buttonweed
SALICACEAE	Willow Family	
Salix caroliniana Michx.		Ward's Willow
Salix interior Rowlee		Sandbar Willow
SCROPHULARIACEAE	Figwort Family	
Conobea multifida (Michx.) Benth.		
Kickxia elatine (L.) Dumort.		Cancer Root
Verbascum thapsus L.		Mullein
SOLANACEAE	Nightshade Family	
Physalis heterophylla Nees		Ground Cherry
Solanum rostratum Dunal		Buffalo Bur
ULMACEAE	Elm Family	
Ulmus americana L.		American Elm
UMBELLIFERAE	Parsley Family	
Daucus carota L.		Wild Carrot
URTICACEAE	Nettle Family	
Boehmeria cylindrica (L.) Sw.		False Nettle
VERBENACEAE	Vervain Family	
Verbena urticifolia L.		White Vervain
VITACEAE	Grape Family	
Ampelopsis cordata Michx.		Raccoon Grape
Vitis cinerea Engelm.		Grayback Grape
Vitis vulpina L.		Winter Grape

ALSO SAW, BUT DID NOT COLLECT:

ANACARDIACEAE Cashew Family

Rhus radicans L. Poison Ivy

BUFFALO POINT
Gravel bar and floodplain No. 2

ACANTHACEAE	Acanthus Family	
Justicia americana (L.) Vahl		Water Willow
ACERACEAE	Maple Family	
* *Acer negundo* L.		Box Elder
Acer saccharinum L.		Silver Maple
AIZOACEAE	Carpet-weed Family	
Mollugo verticillata L.		Carpet-weed
ALISMACEAE	Water Plaintain Family	
Alisma plantago-aquatica L.		Water Plantain
AMARANTHACEAE	Amaranth Family	
Amaranthus spinosus L.		Thorny Amaranth
Iresine rhizomatosa Standl.		Bloodleaf
BIGNONIACEAE	Trumpet Creeper Family	
* *Campsis radicans* (L.) Seem.		Trumpet Creeper
Catalpa sp.		Catalpa
CAPPARIDACEAE	Caper Family	
* *Polanisia dodecandra* (L.) DC. subsp. *dodecandra*		Clammy-weed
CAPRIFOLIACEAE	Honeysuckle Family	
Sambucus canadensis L.		Common Elderberry

Gravel bar and floodplain No. 2 (cont.)

CHENOPODIACEAE Goosefoot Family

*Chenopodium album L. — Pigweed

Chenopodium botrys L. — Jerusalem Oak

*Cycloloma atriplicifolium (Spreng.) Coult. — Winged Pigweed

COMPOSITAE Sunflower Family

*Ambrosia artemisiifolia L. — Common Ragweed

Ambrosia trifida L. — Horse Weed

*Artemisia annua L. — Sweet Wormwood

Aster pilosus Willd. — White Heath Aster

Bidens sp. — Beggar Ticks

Eupatorium serotinum Michx. — Late Boneset

Helenium autumnale L. — Sneezeweed

*Rudbeckia laciniata L. — Wild Goldenglow

*Xanthium strumarium L. — Cocklebur

CONVOLUVULACEAE Morning Glory Family

Cuscuta indecora Choisy — Pretty Dodder

CRUCIFERAE Mustard Family

Lepidium virginicum L. — Pepper Grass

CUCURBITACEAE Gourd Family

*Sicyos angulatus L. — Bur Cucumber

CYPERACEAE Sedge Family

Cyperus acuminatus Torr. & Hook. — Umbrella Sedge

Cyperus aristatus Rottb. — Umbrella Sedge

Cyperus odoratus L. — Umbrella Sedge

*Cyperus uniflorus T. & H.	Umbrella Sedge
Fimbristylis autumnalis (L.) R. & S.	
EUPHORBIACEAE Spurge Family	
Acalypha rhomboidea Raf.	Three-seeded Mercury
Euphorbia dentata Michx.	Spurge
*Euphorbia maculata L.	Nodding Spurge
GRAMINEAE Grass Family	
*Arundinaria gigantea (Walt.) Chapm.	Cane
*Digitaria adscendens (H.B.K.) Henr.	Southern Crab Grass
Echinochloa crusgalli (L.) Beauv.	Barnyard Grass
Eleusine indica (L.) Gaertn.	Goose Grass
Eragrostis pectinacea (Michx.) Nees	Love Grass
LABIATAE Mint Family	
*Perilla frutescens (L.) Britt.	Beef-steak Plant
LYTHRACEAE Loosestrife Family	
Ammannia coccinea Rothb.	Tooth-cup
Rotala ramosior (L.) Koehne var. interior Fern. & Grisc.	Tooth-cup
OLEACEAE Olive Family	
Fraxinus pennsylvanica Marsh.	Green Ash
ONAGRACEAE Evening Primrose Family	
Ludwigia decurrens Walt.	Primrose Willow
Oenothera laciniata Hill	Evening Primrose
OXALIDACEAE Wood Sorrel Family	
Oxalis stricta L.	Yellow Wood Sorrel

PHYTOLACCACEAE	Pokeweed Family	
Phytolacca americana L.		Pokeweed
PLANTAGINACEAE	Plantain Family	
Plantago rugelii Dcne.		Rugel Plantain
PLATANACEAE	Plane Tree Family	
*Platanus occidentalis L.		Sycamore
POLYGONACEAE	Buckwheat Family	
Polygonum persicaria L.		Lady's Thumb
*Polygonum virginianum L.		Virginia Knotweed
Polygonum sp.		Knotweed
PONTEDERIACEAE	Pickerel-weed Family	
Heteranthera dubia (Jacq.) MacM.		Water Star-grass
ROSACEAE	Rose Family	
Rubus trivialis Michx.		Southern Dewberry
RUBIACEAE	Madder Family	
Cephalanthus occidentalis L.		Buttonbush
*Diodia teres Walt.		Rough Buttonweed
SALICACEAE	Willow Family	
Salix nigra Marsh.		Black Willow
SAXIFRAGACEAE	Saxifrage Family	
*Penthorum sedoides L.		Ditch Stonecrop

SCROPHULARIACEAE Figwort Family	
*Conobea multifida (Michx.) Benth.	
Lindernia anagallidea (Michx.) Pennell	False Pimpernel
*Mimulus alatus Ait.	Monkey Flower
SOLANACEAE Nightshade Family	
Physalis pubescens L. var. integrifolia (Dunal) Waterfall	Ground Cherry
Solanum americanum Mill.	Black Nightshade
Solanum carolinense L.	Horse Nettle
*Solanum rostratum Dunal	Buffalo Bur
URTICACEAE Nettle Family	
*Boehmeria cylindrica (L.) Sw.	False Nettle
VERBENACEAE Vervain Family	
Lippia lanceolata Michx.	Fog Fruit
VITACEAE Grape Family	
*Ampelopsis cordata Michx.	Raccoon Grape
Parthenocissus quinquefolia (L.) Planch.	Virginia Creeper

ALSO SAW, BUT DID NOT COLLECT:

ANACARDIACEAE Cashew Family	
Rhus radicans L.	Poison Ivy
SOLANACEAE Nightshade Family	
Datura stramonium L.	Jimson Weed

BUFFALO POINT
Small depression or valley behind Pavilion No. 2

ACERACEAE	Maple Family	
Acer rubrum L.		Red Maple
*Acer saccharum Marsh.		Sugar Maple
ANNONACEAE	Custard Apple Family	
Asimina triloba (L.) Dunal		Pawpaw
BETULACEAE	Birch Family	
Carpinus caroliniana Walt.		Blue Beech
CAPRIFOLIACEAE	Honeysuckle Family	
Viburnum prunifolium L.		Black Haw
CELASTRACEAE	Staff-tree Family	
Euonymus americanus L.		Strawberry Bush
CORNACEAE	Dogwood Family	
Cornus florida L.		Flowering Dogwood
DIOSCOREACEAE	Yam Family	
Dioscorea quaternata (Walt.) G. F. Gmel.		Yam
LEGUMINOSAE	Pea Family	
Desmodium nudiflorum (L.) DC.		Tick Trefoil
Phaseolus polystachios (L.) BSP.		Wild Bean
LILIACEAE	Lily Family	
Smilax herbacea L. var. lasioneura (Hook.) A. DC.		Carrion Flower

Valley behind Building No. 2 (cont.)

Uvularia grandiflora Sm.		Bellwort
MORACEAE	Mulberry Family	
Morus rubra L.		Red Mulberry
OLEACEAE	Olive Family	
Fraxinus pennsylvanica Marsh.		Green Ash
PASSIFLORACEAE	Passion-flower Family	
Passiflora lutea L.		Passion-flower
PHRYMACEAE	Lopseed Family	
* *Phryma leptostachya* L.		Lopseed
POLYPODIACEAE	Fern Family	
Adiantum pedatum L.		Maidenhair Fern
Polystichum acrostichoides (Michx.) Schott f. *acrostichoides*		Christmas Fern
RANUNCULACEAE	Crowfoot Family	
* *Aneomone virginiana* L.		Thimbleweed
Clematis virginiana L.		Virgin's Bower
RHAMNACEAE	Buckthorn Family	
Rhamnus caroliniana Walt.		Carolina Buckthorn
ROSACEAE	Rose Family	
Aruncus dioicus (Walt.) Fern. var. *pubescens* (Rydb.) Fern.		Goat's Beard
SAXIFRAGACEAE	Saxifrage Family	
Hydrangea arborescens L.		Wild Hydrangea

Valley behind Building No. 2 (cont.)

STAPHYLEACEAE	Bladder-nut Family	
Staphylea trifolia L.		American Bladder-nut
TILIACEAE	Linden Family	
Tilia americana L.		Basswood
UMBELLIFERAE	Parsley Family	
Sanicula gregaria Bicknell		Black Snakeroot

BUFFALO POINT
Glade Site (August 6, 1975)

ACANTHACEAE	Acanthus Family	
Ruellia humilis Nutt.		Wild Petunia
ANACARDIACEAE	Cashew Family	
Rhus aromatica Ait.		Fragrant Sumac
CAPRIFOLIACEAE	Honeysuckle Family	
Symphoricarpos orbiculatus Moench		Coral Berry
COMPOSITAE	Sunflower Family	
Antennaria plantaginifolia (L.) Hook.		Pussy's Toes
Aster patens Ait.		Spreading Aster
Coreopsis grandiflora Hogg var. *harveyana* (Gray) Sherff —contaiminated with var. *saxicola* (Alex.) E. B. Smith		Tickseed
**Grindelia lanceolata* Nutt.		Gum Plant
Liatris cylindracea Michx.		Blazing Star
Palafoxia callosa (Nutt.) T. & G. var. *callosa*		
Rudbeckia missouriensis Engelm.		Coneflower
Solidago arguta Ait. var. *strigosa* (Small) Steyerm.		Goldenrod
Solidago nemoralis Ait.		Old-field Goldenrod
CRASSULACEAE	Stonecrop Family	
Sedum pulchellum Michx.		Widow's Cross

Glade Site (cont.)

ERICACEAE	Heath Family	
Vaccinium arboreum Marsh.		Farkleberry
EUPHORBIACEAE	Spurge Family	
Crotonopsis elliptica Willd.		Rushfoil
Euphorbia corollata L.		Flowering Spurge
FAGACEAE	Beech Family	
Quercus stellata Wang.		Post Oak
GRAMINEAE	Grass Family	
Andropogon gerardi Vitman		Big Bluestem
Elymus virginicus L.		Wild Rye
Tridens flavus (L.) Hitchc.		Purpletop
HYPERICACEAE	St. John's-wort Family	
Hypericum drummondii (Grev. & Hook.) T. & G.		Nits-and-lice
LABIATAE	Mint Family	
Pycnanthemum tenuifolium Schrad.		Slender Mountain Mint
LEGUMINOSAE	Pea Family	
Galactia volubilis (L.) Britt. var. *mississippiensis* Vail		Milk Pea
Lespedeza cuneata (Dumont) G. Don		Sericea Lespedeza
Petalostemon candidum (Willd.) Michx.		White Prairie Clover
Schrankia uncinata Willd.		Sensitive Brier
Stophostyles helveola (L.) Ell.		Wild Bean
Tephrosia virginiana (L.) Pers.		Goat's Rue

Glade Site (cont.)

LINACEAE	Flax Family	
Linum medium (Planch.) Britt. var. texanum (Planch.) Fern.		Flax
OLEACEAE	Olive Family	
Fraxinus pennsylvanica Marsh.		Green Ash
POLYGONACEAE	Buckwheat Family	
Eriogonum longifolium Nutt.		Umbrella Plant
POLYPODIACEAE	Fern Family	
Cheilanthes lanosa (Michx.) D.C. Eaton		Hairy Lip-fern
PORTULACACEAE	Purslane Family	
Talinum calycinum Engelm.		Fame Flower
ROSACEAE	Rose Family	
Amelanchier arborea (Michx. f.) Fern.		Shadbush
*Crataegus crus-galli L.		Cockspur Thorn
*Prunus americana Marsh.		Wild Plum
RUBIACEAE	Madder Family	
Hedyotis nigricans (Lam.) Fosberg		Bluets
SCROFHULARIACEAE	Figwort Family	
Gerardia sp.		Gerardia
ULMACEAE	Elm Family	
Celtis tenuifolia Nutt.		Dwarf Hackberry
*Ulmus alata Michx.		Winged Elm
Ulmus ruba Muhl.		Slippery Elm

COLLECTION FROM BUFFALO POINT (7/8&9/1975);
1 specimen from Lost Valley (7/1/1975)

Lost Valley Specimen:

CORNACEAE	Dogwood Family	
*Nyssa sylvatica Marsh.		Black Gum

Specimens from Buffalo Point:

APOCYNACEAE	Dogbane Family	
Apocynum sp.		Indian Hemp
BETULACEAE	Birch Family	
*Carpinus caroliniana Walt.		Blue Beech
COMPOSITAE	Sunflower Family	
*Aster patens Ait.		Spreading Aster
Aster sp.		Aster
Coreopsis palmata Nutt.		Tickseed
Helianthus divaricatus L.		Sunflower
*Lactuca canadensis L.		Wild Lettuce
Liatris squarrosa (L.) Michx.		Blazing Star
*Rudbeckia missouriensis Engelm.		Coneflower
Silphium terebinthinaceum Jacq.		Prairie Dock
*Solidago arguta Ait. var. strigosa (Small) Steyerm.		Goldenrod
CYPERACEAE	Sedge Family	
Scleria sp.		Nut Rush

DIOSCOREACEAE	Yam Family	
Dioscorea quaternata (Walt.) Gmel.		Yam
EUPHORBIACEAE	Spurge Family	
*Euphorbia corollata L.		Flowering Spurge
FAGACEAE	Beech Family	
Castanea pumila (L.) Mill. var. ozarkensis (Ashe) G. Tucker		Ozark Chinquapin
GRAMINEAE	Grass Family	
Bouteloua curtipendula (Michx.) Torr.		Sideoats Grama
*Elymus virginicus L.		Wild Rye
HAMAMELIDACEAE	Witch Hazel Family	
*Hamamelis virginiana L.		Eastern Witch Hazel
LABIATAE	Mint Family	
Monarda sp.		Horsemint
*Scutellaria elliptica Muhl.		Skullcap
LEGUMINOSAE	Pea Family	
Desmodium paniculatum (L.) DC.		Tick Trefoil
Desmodium sp.		Tick Trefoil
*Petalostemon candidum (Willd.) Michx.		White Prairie Clover
*Tephrosia virginiana (L.) Pers.		Goat's Rue
Vicia sp.		Vetch
LILIACEAE	Lily Family	
*Smilacina racemosa (L.) Desf.		False Solomon's Seal

OLEACEAE	Olive Family	
*<u>Fraxinus</u> <u>pennsylvanica</u> Marsh.		Green Ash
POLYPODIACEAE	Fern Family	
<u>Thelypteris</u> <u>hexagonoptera</u> (Michx.) Weath.		Broad Beech Fern
RANUNCULACEAE	Crowfoot Family	
<u>Hepatica</u> <u>nobilis</u> Schreb. var. <u>obtusa</u> (Pursh) Steyerm.		Round-lobed Liverleaf
RHAMNACEAE	Buckthorn Family	
<u>Berchemia</u> <u>scandens</u> (Hill) K. Koch		Supple-jack
<u>Ceanothus</u> <u>americanus</u> L.		New Jersey Tea
SAPOTACEAE	Sapodilla Family	
*<u>Bumelia</u> <u>lanuginosa</u> (Michx.) Pers. var. <u>albicans</u> Sarg.		Chittim-wood
SAXIFRAGACEAE	Saxifrage Family	
<u>Heuchera</u> sp.		Alum Root
STAPHYLEACEAE	Bladder-nut Family	
<u>Staphylea</u> <u>trifolia</u> L.		American Bladder-nut
TILIACEAE	Linden Family	
<u>Tilia</u> <u>americana</u> L.		Basswood
UMBELLIFERAE	Parsley Family	
<u>Zizia</u> <u>aurea</u> (L.) Koch.		Golden Alexanders
VITACEAE	Grape Family	
<u>Vitis</u> <u>aestivalis</u> Michx.		Summer Grape

LOST VALLEY
First Collection

ACERACEAE	Maple Family	
Acer rubrum L.		Red Maple
*Acer saccharum Marsh.		Sugar Maple
ANACARDIACEAE	Cashew Family	
Rhus copallina L.		Dwarf Sumac
ARACEAE	Arum Family	
Arisaema atrorubens (Ait.) Blume		Jack-in-the-pulpit
BORAGINACEAE	Borage Family	
Cynoglossum virginianum L.		Wild Comfrey
CAPRIFOLIACEAE	Honeysuckle Family	
Viburnum prunifolium L.		Black Haw
COMPOSITAE	Sunflower Family	
Aster sp.		Aster
Helianthus hirsutus Raf.		Sunflower
Silphium asperrimum Hook.		Starry Rosin-weed
Solidago caesia L.		Blue-stem Goldenrod
Solidago sp.		Goldenrod
CORNACEAE	Dogwood Family	
Nyssa sylvatica Marsh.		Black Gum

Lost Valley (cont.)
1st Collection

ERICACEAE	Heath Family	
Rhododendron roseum (Loisel.) Rehd.		Mountain Azalea
Vaccinium stamineum L.		Deerberry
Vaccinium vacillans Torr.		Lowbush Blueberry
EUPHORBIACEAE	Spurge Family	
**Euphorbia corollata* L.		Flowering Spurge
FAGACEAE	Beech Family	
**Quercus prinoides* Willd. var. *acuminata* (Michx.) Gl.		Chestnut Oak
GRAMINEAE	Grass Family	
Danthonia spicata (L.) Beauv.		Poverty Grass
Panicum lanuginosum Ell.		Panic Grass
HAMAMELIDACEAE	Witch Hazel Family	
Hamamelis virginiana L.		Eastern Witch Hazel
IRDACEAE	Iris Family	
Iris cristata Ait.		Crested Iris
Sisyrinchium campestre Bickn.		Prairie Blue-eyed Grass
LABIATAE	Mint Family	
Cunila origanoides (L.) Britt.		Dittany
Scutellaria elliptica Muhl.		Skullcap
LEGUMINOSAE	Pea Family	
Desmodium nudiflorum (L.) DC.		Tick Trefoil
Desmodium sp.		Tick Trefoil

Lost Valley (cont.)
1st Collection

Lespedeza sp.		Bush Clover
Rhynchosia latifolia Nutt.		
*Robinia pseudo-acacia L.		Black Locust
LILIACEAE	Lily Family	
Smilacina racemosa (L.) Desf.		False Solomon's Seal
Smilax hispida Muhl.		Bristly Greenbrier
OLEACEAE	Olive Family	
Fraxinus americana L.		White Ash
Fraxinus quadrangulata Michx.		Blue Ash
POLYGALACEAE	Milkwort Family	
Polygala senega L.		Seneca Snakeroot
RANUNCULACEAE	Crowfoot Family	
Cimicifuga racemosa (L.) Nutt.		Black Cohosh
RHAMNACEAE	Buckthorn Family	
*Rhamnus caroliniana Walt.		Carolina Buckthorn
ROSACEAE	Rose Family	
Prunus americana Marsh.		Wild Plum
RUBIACEAE	Madder Family	
*Galium arkansanum Gray		Arkansas Bedstraw
SAXIFRAGACEAE	Saxifrage Family	
Hydrangea arborescens L.		Wild Hydrangea
VITACEAE	Grape Family	
*Vitis vulpina L.		Winter Grape

LOST VALLEY
Cedar Glade

ANACARDIACEAE	Cashew Family	
Cotinus obovatus Raf.		American Smoke Tree
AQUIFOLIACEAE	Holly Family	
Ilex decidua Walt.		Possum Haw
ASCLEPIADACEAE	Milkweed Family	
Asclepias verticillata L.		Whorled Milkweed
BETULACEAE	Birch Family	
Corylus americana Walt.		Hazelnut
BORAGINACEAE	Borage Family	
Onosmodium subsetosum Mackenz. & Bush		False Gromwell
CAMPANULACEAE	Bellflower Family	
Lobelia spicata Lam.		Lobelia
COMPOSITAE	Sunflower Family	
* *Aster patens* Ait.		Spreading Aster
Aster sp.		Aster
Liatris squarrosa (L.) Michx.		Blazing Star
Rudbeckia missouriensis Engelm.		
Solidago sp.		Goldenrod
CUPRESSACEAE	Cypress Family	
Juniperus virginiana L.		Red Cedar

CYPERACEAE	Sedge Family	
Scleria oligantha Michx.		Nut Rush
EUPHORBIACEAE	Spurge Family	
Euphorbia corollata L.		Flowering Spurge
FAGACEAE	Beech Family	
Quercus michauxii Nutt.		Basket Oak
Quercus rubra L.		Red Oak
GRAMINEAE	Grass Family	
**Elymus virginicus* L.		Wild Rye
Panicum linearifolium Scribn.		Panic Grass
HYPERICACEAE	St. John's-wort Family	
Ascyrum hypericoides L.		St. Andrew's Cross
LEGUMINOSAE	Pea Family	
Desmodium canadense (L.) DC.		Tick Trefoil
Desmodium sp.		Tick Trefoil
Petalostemon purpureum (Vent.) Rydb.		Purple Prairie Clover
Rhynchosia difformis (Ell.) DC.		
Robinia pseudo-acacia L.		Black Locust
**Tephrosia virginiana* (L.) Pers.		Goat's Rue
OLEACEAE	Olive Family	
**Fraxinus pennsylvanica* Marsh.		Green Ash
POLEMONIACEAE	Phlox Family	
**Phlox bifida* Beck		Sand Phlox

Lost Valley (cont.)

RANUNCULACEAE	Crowfoot Family	
*Anemone virginiana L.		Thimbleweed
RHAMNACEAE	Buckthorn Family	
Rhamnus caroliniana Walt.		Carolina Buckthorn
ROSACEAE	Rose Family	
Amelanchier arborea (Michx. f.) Fern.		Shadbush
Crataegus crus-galli L.		Cockspur Thorn
Prunus mexicana S. Wats.		Big Tree Plum
RUBIACEAE	Madder Family	
Galium arkansanum Gray		Arkansas Bedstraw
*Hedyotis nigricans (Lam.) Fosberg		
SAPOTACEAE	Sapodilla Family	
*Bumelia lanuginosa (Michx.) Pers. var. albicans Sarg.		Chittim-wood
SAXIFRAGACEAE	Saxifrage Family	
Philadelphus hirsutus Nutt.		Mock Orange
ULMACEAE	Elm Family	
*Ulmus alata Michx.		Winged Elm
VERBENACEAE	Vervain Family	
Verbena canadensis (L.) Britt.		Rose Verbena

LOST VALLEY
3rd Collection

ANACARDIACEAE	Cashew Family	
*_Rhus aromatica_ Ait.		Fragrant Sumac
ASCLEPIADACEAE	Milkweed Family	
Asclepias verticillata L.		Whorled Milkweed
BETULACEAE	Birch Family	
*_Corylus americana_ Walt.		Hazelnut
BORAGINACEAE	Borage Family	
*_Cynoglossum virginianum_ L.		Wild Comfrey
CAMPANULACEAE	Bellflower Family	
*_Lobelia spicata_ Lam.		Lobelia
CARYOPHYLLACEAE	Pink Family	
Silene stellata (L.) Ait. f.		Starry Campion
COMPOSITAE	Sunflower Family	
Aster anomalus Engelm.		Aster
Echinacea purpurea (L.) Moench		Purple Coneflower
Prenanthes altissima L. var. _cinnamomea_ Fern.		Rattlesnake Root
Solidago caesia L.		Blue-stem Goldenrod
CYPERACEAE	Sedge Family	
Carex sp.		Sedge

Lost Valley (cont.)
3rd Collection

ERICACEAE	Heath Family	
*Rhododendron roseum (Loisel.) Rehd.		Mountain Azalea
*Vaccinium arboreum Marsh.		Farkleberry
*Vaccinium vacillans Torr.		Lowbush Blueberry
GRAMINEAE	Grass Family	
Panicum linearifolium Scribn.		Panic Grass
LABIATAE	Mint Family	
Monarda bradburiana Beck		Horsemint
Pycnanthemum albescens T. & G.		Mountain Mint
*Pycnanthemum tenuifolium Schrad.		Slender Mountain Mint
LEGUMINOSAE	Pea Family	
Cassia nictitans L.		Sensitive Pea
Desmodium glutinosum (Muhl.) Wood		Tick Trefoil
Desmodium laevigatum (Nutt.) DC.		Tick Trefoil
*Desmodium nudiflorum (L.) DC.		Tick Trefoil
Desmodium rotundifolium DC.		Tick Trefoil
Lespedeza intermedia (S. Wats.) Britt.		Bush Clover
*Schrankia uncinata Willd.		Sensitive Brier
RANUNCULACEAE	Crowfoot Family	
*Cimicifuga racemosa (L.) Nutt.		Black Cohosh
Hydrastis canadensis L.		Golden Seal
Ranunculus hispidus Michx.		Hispid Buttercup
ROSACEAE	Rose Family	
*Agrimonia rostellata Wallr.		Agrimony
*Amelanchier arborea (Michx. f.) Fern		Shadbush

Lost Valley (cont.)
3rd Collection

Crataegus sp.		Hawthorn
**Prunus mexicana* S. Wats.		Big Tree Plum
SAPOTACEAE	Sapodilla Family	
Bumelia lanuginosa (Michx.) Pers. var. *albicans* Sarg.		Chittim-wood
SCHROPHULARIACEAE	Figwort Family	
**Gerardia flava* L.		Gerardia
**Pedicularis canadensis* L.		Wood Betony
UMBELLIFERAE	Parsley Family	
**Zizia aurea* (L.) Koch		Golden Alexanders

LEATHERWOOD CREEK
Newton Co.

ARACEAE	Arum Family	
*Arisaema atrorubens (Ait.) Blume		Jack-in-the-pulpit
BALSAMINACEAE	Touch-me-not Family	
Impatiens capensis Meerb.		Spotted Touch-me-not
BETULACEAE	Birch Family	
Carpinus caroliniana Walt.		Blue Beech
BORAGINACEAE	Borage Family	
Cynoglossum virginianum L.		Wild Comfrey
Hackelia virginiana (L.) I. M. Johnston		Beggar's Lice
CAMPANULACEAE	Bellflower Family	
*Campanula americana L.		Tall Bellflower
Lobelia inflata L.		Indian Tobacco
CARYOPHYLLACEAE	Pink Family	
Paronychia canadensis (L.) Wood		Forked Chickweed
COMPOSITAE	Sunflower Family	
Polymnia canadensis L.		Leaf Cup
Rudbeckia hirta L.		Black-eyed Susan
*Rudbeckia laciniata L.		Wild Goldenglow
HAMAMELIDACEAE	Witch Hazel Family	
Hamamelis sp.		Witch Hazel

LABIATAE	Mint Family	
*Perilla frutescens (L.) Britt.		Beef-steak Plant
Prunella vulgaris L.		Self-heal
Salvia lyrata L.		Cancer Weed
LEGUMINOSAE	Pea Family	
Amphicarpa bracteata (L.) Fern. var. bracteata		Hog Peanut
Cercis canadensis L.		Red Bud
Desmodium pauciflorum (Nutt.) DC.		Tick Trefoil
MAGNOLIACEAE	Magnolia Family	
Magnolia acuminata L.		Cucumber Tree
OXALIDACEAE	Wood Sorrel Family	
*Oxalis stricta L.		Yellow Wood Sorrel
PHRYMACEAE	Lopseed Family	
Phryma leptostachya L.		Lopseed
PLANTAGINACEAE	Plantain Family	
Plantago rugelii Dcne.		Rugel Plantain
POLYGONACEAE	Buckwheat Family	
Polygonum hydropiper L.		Water Pepper
Polygonum virginianum L.		Virginia Knotweed
POLYPODIACEAE	Fern Family	
Adiantum pedatum L.		Maidenhair Fern
PRIMULACEAE	Primrose Family	
Samolus parviflorus Raf.		Water Pimpernel

RANUNCULACEAE	Crowfoot Family	
Anemone virginiana L.		Thimbleweed
Ranunculus recurvatus Poir. var. recurvatus		Hooked Crowfoot
RHAMNACEAE	Buckthorn Family	
Rhammus caroliniana Walt.		Carolina Buckthorn
ROSACEAE	Rose Family	
Agrimonia rostellata Wallr.		Agrimony
*Geum canadense Jacq.		White Avens
RUBIACEAE	Madder Family	
Galium arkansanum Gray		Arkansas Bedstraw
Galium triflorum Michx.		Sweet-scented Bedstraw
SAPOTACEAE	Sapodilla Family	
Bumelia lanuginosa (Michx.) Pers. var. albicans Sarg.		Chittim-wood
SAXIFRAGACEAE	Saxifrage Family	
*Hydrangea arborescens L.		Wild Hydrangea
Penthorum sedoides L.		Ditch Stonecrop
SCROPHULARIACEAE	Figwort Family	
Mimulus alatus Ait.		Monkey Flower
Pedicularis canadensis L.		Wood Betony
Scrophularia marilandica L.		Figwort
Veronica serpyllifolia L.		Thyme-leaved Speedwell

UMBELLIFERAE Parsley Family

Cryptotaenia canadensis (L.) DC. Honewort

URTICACEAE Nettle Family

Boehmeria cylindrica (L.) Sw. False Nettle

RESOURCE CAPACITY

The literature continues to reflect a wide variety of studies being conducted that deal with the concept of resource management and resource capacity. One such report clearly defines the concept of resource capacity (Pfister and Frenkel, 1975). These authors point out that resource capacity is goal-oriented and that a goal must be accompanied by criteria standards that identify limiting factors. These limiting factors are then expressed in terms of thresholds that provide management with the information necessary to accomplish the original goal.

The master plan for the Buffalo National River (National Park Service, 1975) establishes the goal of the river to be:

> "To provide three general visitor experiences - - a point of interest for the tourist, a swimming and fishing area for local users, and a destination area for the avid canoeist . . . its lands are to be in a state of the simplest possible development."

The key to accomplishing this goal as stated above is to develop criteria standards that identify limiting factors in the assessment of the river quality. River quality may be defined as the physical, chemical, and biological character of a river with regard to its suitability for a specified purpose (Hines, et al, 1975). River quality is not only concerned with observed quality in a river, but also involves the analysis of environmental factors on land, water, and in the air that are responsible for the observed quality. All of this is interpreted to mean that the Buffalo National River is to be managed so that tourism, fishing, swimming, and canoeing can be experienced without permanently reducing river quality below its natural environment.

The first step in assessing river quality is to develop a conceptual model, which presumably with time and subsequent data generation can progress to an applied model. In the applied state, a basic understanding of the particular river system is needed to formulate the conceptual model and to quantify its parameters and limiting factors (Hines, et al, 1975). The concept is to fit the model to the river rather than the river to the model.

It is particularly important in the case of the Buffalo National River to recognize that a model need not simulate the river in question through all seasonal changes in water quality. Also, care must be taken to make sure the type of model being used is applicable to the season during which the model is being applied. For example, modeling the dissolved oxygen (DO) during the winter months would be useless since critically low DO conditions have historically occurred during the low-flow, high temperature summer months.

River Quality Models

River hydrology exercises a dominant control over river quality. Hydrologic characteristics determine the physical dynamics of rivers, which in turn, control the pattern and extent of chemical and biological processes. Because of this, analysis of river hydrology is a prerequisite to selecting a model or identifying the data needed to assess the river quality of the Buffalo National River (Rickert and Hines, 1975). A cursory look at the hydrology of the Buffalo National River supports the above statement. Figure 49 is a bar graph depicting the average percent runoff as a function of months for the Buffalo River near St. Joe, Arkansas during the period 1963-1972. This chart was prepared under the assumption that groundwater recharge and groundwater enflux were equal. The resulting curve drastically points out the influence of evapotranspiration during the heavy foliage summer months of June, July, August, September, and October. In fact, a detailed analysis of the monthly percent runoff for the individual months (Figure 50), when compared with the monthly rainfall, reveals that a relatively wet month in the summer has very little effect on the monthly river flow. It is obvious that this type of analysis would serve as an indicator of land use within the river watershed, particularly as to the influence of human use on the deciduous forest ecosystem.

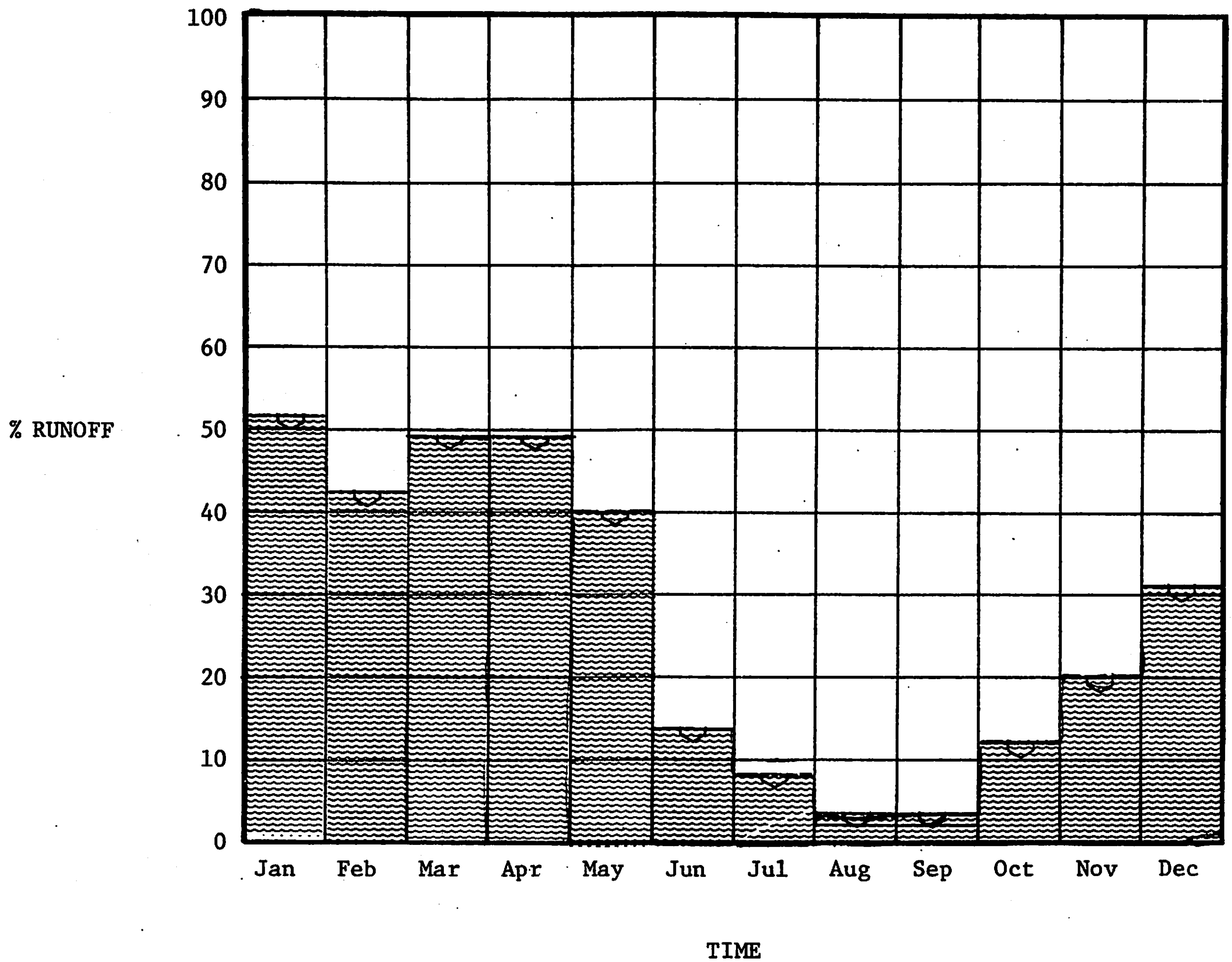
Once the river hydrology is documented and understood (groundwater recharge and enflux included) there are at least three models that should be developed for the river. They are:

1. DO: Temperature: Dissolved Solids
2. Algal Growth: Nutrient Transport
3. Coliform Transport: Bacteria Indicator: Sediment Transport

All of these models would provide vital information relative to limiting factors and thresholds on the river, but the hydrology of the river must be documented first.

A time-lapse movie camera was stationed on a bluff overlooking a gravel bar between Buffalo Point and Rush Creek. This camera took a picture of the river and gravel bar every 100 seconds for the period of 11:00 a.m. Friday, August 29 to 4:00 p.m. Monday, September 1, 1975 (Labor Day Weekend). Figure 51 shows the number of canoes as a function of time for the first day (Friday). This technique has proven to be effective for providing data input into the models that will eventually be chosen for the management of the river.

Figure 49.
AVERAGE PERCENT RUNOFF AS A FUNCTION OF MONTHS FOR THE PERIOD 1963-1972



Monthly Percent Runoff vs. Time

Buffalo National River

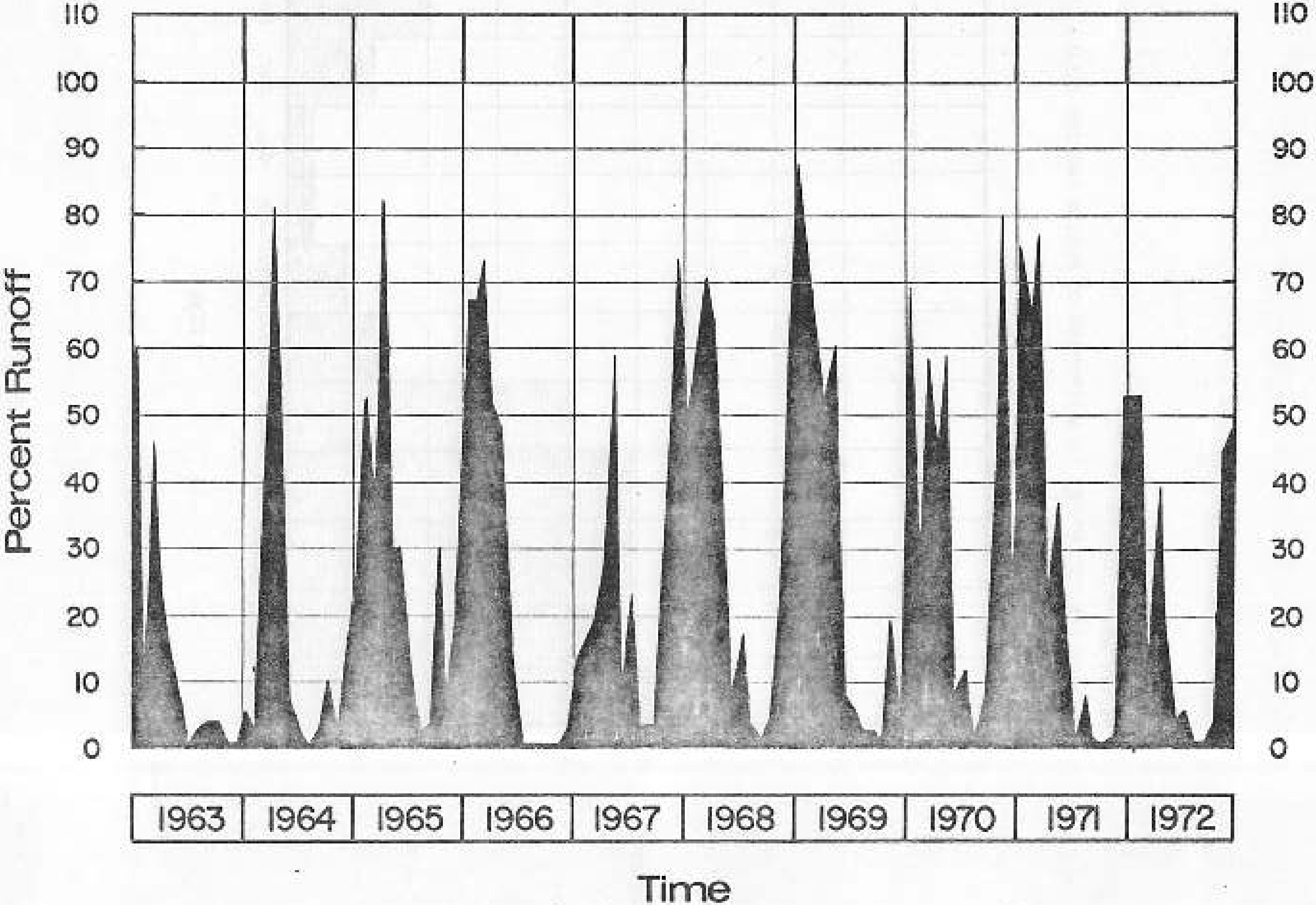
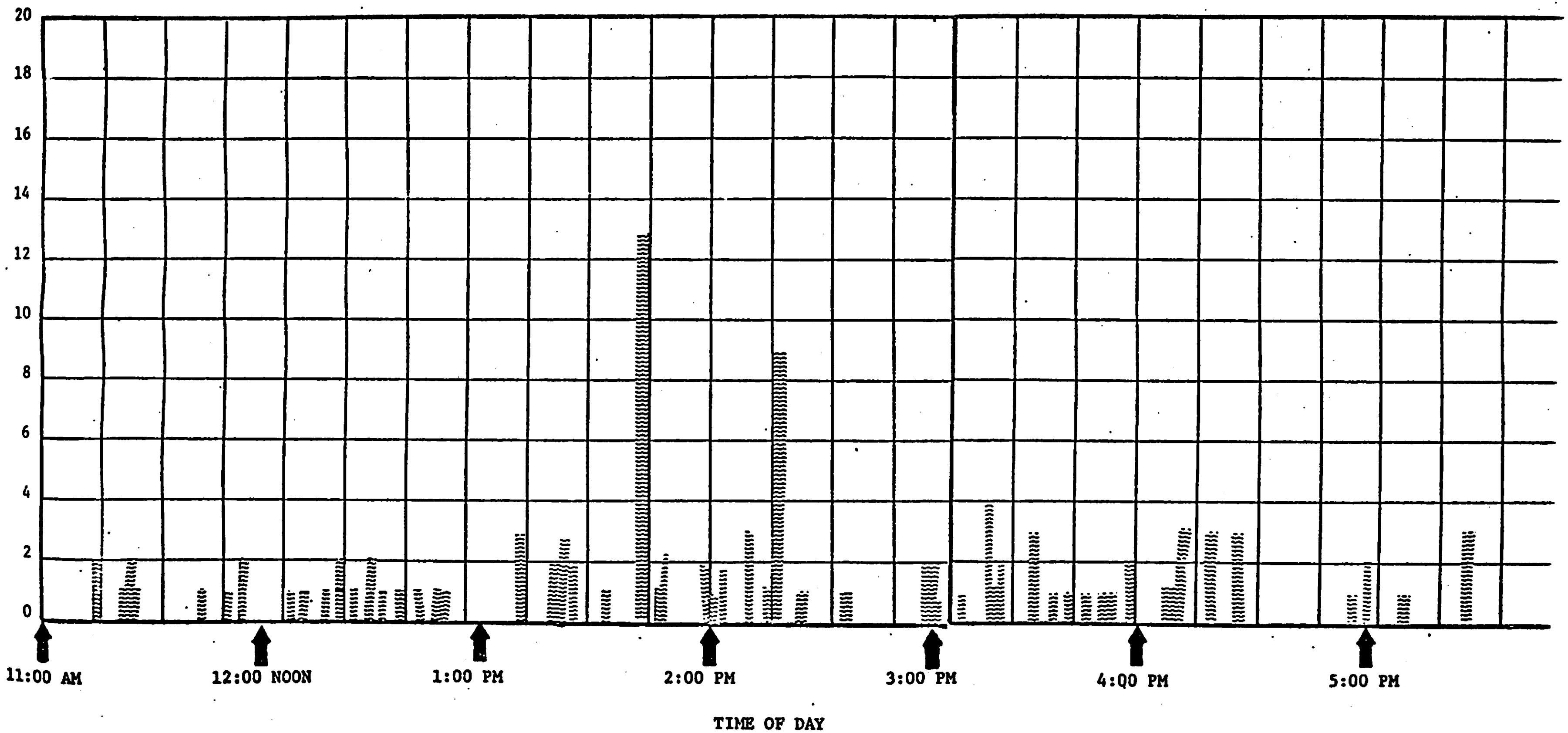


Figure 51. Number of Canoes vs. Time for Friday, August 29, 1975 (Labor Day Weekend).
Section of the River: Buffalo Point to Rush, 113 Canoes Total from 11:00 a.m. to 6:00 p.m.



SUMMARY AND CONCLUSIONS

Analysis of the results of the water quality sampling and monitoring programs indicates that the water quality of the Buffalo National River remains good. It is concluded that the river hydrology exercises dominant control over the quality and therefore should be studied extensively in the future. This conclusion was also reached in a previous study (Babcock and MacDonald, and contributing authors, 1975, p. 48) in which it was concluded that:

> "In general, the chemistry of the Buffalo River seems to be responsive to the geologic environment and lateral inflow during periods of runoff. This study has demonstrated that concentration gradients exist throughout the length of the river and that the river responds to the particular geologic formation through which it flows. This study has also presented data that suggest that during periods of runoff, the river may become heterogeneous with constituents such as sodium and potassium and that these constituents may originate in the watershed immediately adjacent to the stream."

This conclusion makes the geohydrology of the area very important with regard to ground water being able to contribute to the flow of the river and with regard to the pollution of the river by this same process.

Rocks underlying the Buffalo River basin range in age from Precambrian to early Pennsylvanian. The sedimentary section is approximately 5,000 feet thick and is composed mainly of limestone, dolomite, sandstone and shale. The strata are essentially horizontal and structural deformation is minimal.

For the purpose of this investigation, the aquifers have been considered in two parts: the shallow and the deep aquifer system, however, both are under artesian pressure and the piezometric surfaces of each coincide. The shallow aquifers are recharged by precipitation falling directly within the basin and the ground water moves from the higher elevation down the hydrodynamic gradient where it is discharged into the effluent streams. In contrast to the shallow aquifers, the deep aquifers receive most of their recharge outside of the Buffalo basin where they crop out in southern Missouri. Water moves south down the hydrodynamic gradient into northern Arkansas.

Ground water quantities in the shallow aquifers are relatively low in yield, but are sufficient for domestic use. Because carbonate rocks make up much of the sedimentary section, the occurrence of ground water is largely dependent on secondary openings such as interconnected fractures and solution channels. Wells encountering secondary openings are generally fortuitous. The deep aquifers, the Roubidoux Formation and the Gunter Member of the Gasconade Formation are the most reliable aquifers in the basin, yielding 55 and 250 gallons per minute, respectively.

The amount of surface water in the Buffalo River and its tributaries varies daily, seasonally and annually in response to precipitation and evapotranspiration. Minimum streamflows occur during the late summer or fall. Maximum streamflows occur most often in the winter and spring. The Buffalo River near St. Joe averages 1040 cubic feet per second and near Rush 1292 cubic feet per second.

Most of the water in the Buffalo River basin which is not lost to the processes of evapotranspiration results in overland runoff discharged into streams. It may be concluded then, that the Buffalo River derives most of its high-flow from direct overland runoff rather than from ground water discharge, and streams respond quickly to rainfall.

The absence of precipitation for extended periods results in low-flow conditions on the Buffalo River and its tributaries. During these periods streams are supplied by ground water discharge; thus, low-flows are a measure of the ability of the aquifer to supply water. They illustrate the minimum amount of water to be expected. Characteristically, low-flows occur most frequently in the late summer and fall and are most pronounced during drought years.

The quality of the surface water is generally good with the exception of possible fecal contamination in certain areas. The Buffalo River Ecosystem is most readily susceptible to stress during periods of low-flow although pollution in terms of bacteria, chemicals, and minerals is higher during storm event runoffs.

Although pollution is not at present a problem in the Buffalo River basin, natural features make both the ground and surface water particularly susceptible to environmental hazards. Carbonate terranes, which underlie the Buffalo River basin, are especially susceptible. Fractures and solution channels in carbonate rocks allow the direct input and rapid distribution without natural filtering of pollutant materials. The shallow aquifer system is particularly vulnerable to pollution, because it is composed dominantly of limestone and dolomite. Steep slopes transmit pollutants into the surface water system before they can be absorbed and filtered by the soil. Disposal of liquid and solid waste should be carefully considered as the result of these factors.

Because the geohydrology of the river plays such a dominant role in the river quality it is recommended that the hydrology and geohydrology be studied to the extent that a water budget for the watershed can be constructed accounting for ground water recharge, ground water enflux to the river, river runoff, and evapotranspiration. This water budget is necessary if the physical, chemical, and biological water quality monitoring is to significantly contribute to the management of the river.

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