Benthic Biodiversity and Physico-Chemical Parameters of Acid Mine Drainage, Acid Impacted and Nonimpacted Streams

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ABSTRACT

South Fork of Sand Lick Creek, Logan County, West Virginia, drains an abandoned coal strip mine which had exploited Pottsville series coalbeds (Pennsylvania strata). These strata outcrop throughout southwestern West Virginia. North Fork watershed is relatively unchanged, save a small roadcut throughout. South Fork benthic community had not recovered although mining activity had ceased about 20 years earlier. Benthic communities were analyzed with detrended correspondence analysis (DCA). Family Chironomidae predominated South Fork benthic community throughout the study. North Fork's benthic community had as major contributors acid resistant caddisfly family Hydropsychidae, mayfly family Baetidae, and stonefly families Perlodidae and Nemouridae. Family Chironomidae exploited spate events and episodically become a major community component. Sand Lick Creek's benthic community was a subset of North Fork's community with similar indices but many fewer organisms. Spates were found to be the greatest contributing factor to community variation. North Fork pH was above 6.5 (high 7.66), falling to 5.23 only during a spate event. South Fork pH ranged from 3.36 to 4.82. Sand Lick Creek pH broadly ranged from 3.88 to 6.04. Spates changed North Fork water chemistry by decreasing pH and increasing cations and sulfate in solution. Flushing of perched aquifers within fractured coalbeds was indicated as the cause of this drainage chemistry change. Paradoxically lower iron concentrations in South Fork than the other streams is best explained by lack of photoreactivity recycling. A well developed canopy covered this stream reducing sunlight energy input. Aluminum remained solubilized in South Fork until confluence with North Fork since pH never rose above 5.2. Aluminum hydroxide precipitate formed a remarkable white streambed covering throughout the confluence mixing zone. This precipitate is hypothesized to be responsible for reduced organism numbers collected at Sand Lick station.

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CHAPTER I

INTRODUCTION

Acidification of natural waters by abandoned mines has received much study and popular reportage. Benthic communities are strong indicators of increased acidity, and, more importantly, they are the major biotic faction of headwater stream ecosystems. Thus, understanding benthic community changes caused by increased acidity is important when determining stream ecology impact. The primary objective of this study is to compare benthic communities of an acid impacted stream, a (relatively) nonimpacted stream, and mixing zone (zone of recovery). A secondary objective is to compare chemistries of each of these streams and determine the impacts on their respective benthic communities. These streams must necessarily have the same external inputs and the same initial watershed chemistries, with mining activity as the only variable.

Stream acidification leads to decreased species diversity, increased representation of community dominants, and decreased food web complexity (Hall et al., 1980; Hendrey, 1978; Hendrey et al., 1976; Mulholland et al., 1992). Acidification effects occur at many trophic levels and have interlocking results. Bacterial activity is reduced which leads to decreased leaf breakdown causing reduced shredder activity. This is seen as increased coarse particulate matter accumulation, often whole leaves. Collectors, or filter feeders, have less coarse particulate matter upon which to feed. Fewer scrapers lead to noticeable periphyton increase. Fewer predators allow increased prey species numbers and reduced nutrient cycling. There is retention and temporary storage of organic matter and nutrients. Generally, there are major shifts in functional groups, shredders, collectors, scrapers, decreased leaf (riparian vegetation) breakdown and an increase of periphyton.

Numerous studies have been performed upon acidic drainage and acid impacted streams. These studies generally compare upstream reaches to downstream reaches with acidic inputs as the divisions. This, however, inherently compares a stream of smaller order to one of greater order (Allen, 1995) with possible varying inputs and differing watershed nature between the two study reaches. Few, if no, studies have been able to compare essentially identical streams for a reasonable control and experimental comparison.

Mixing zones have received little attention (Havas & Rosseland, 1995). Refugia or alkaline waters (to neutralize reduced pH) can have aluminum hydroxide precipitant at boundaries (Hall et al., 1987; Havas & Rosseland, 1996). White precipitate covering the streambed of Sand Lick Creek was identified by Hamrick and Ghosh (1996) as aluminum hydroxide [$Al(OH)_3$]. Precipitation starts immediately at the confluence of the North and South Forks of Sand Lick Creek and often continued the length of the creek to its confluence with the Guyandotte River, 3.1 km away. This is an uncommon occurrence and is not often noted even in the well studied field of acidification and acidic mine drainage. Another unusual circumstance lead to choosing this study site, as well.

There are two forks of Sand Lick, the North Fork and the South Fork. They drain geological strata which are the same and have the same allochthonous inputs. The only difference between the two watersheds is that South Fork watershed was strip mined for coal. Coal was last extracted from this site in the late 1970s. This watershed has thus had almost twenty years to recover. North Fork watershed is relatively undisturbed except for a small dirt road cut on the north side of the creek. This site allows for a side by side comparison of acidic drainage and nonacidic drainage. Sand Lick, with its mixing of both waters, has an ecosystem that lies between the two forks. Thus, this provides for an excellent opportunity to study the water chemistries, zone of recovery, and related benthic communities of three lotic systems that vary only by their chemistries.

CHAPTER II

WATERSHED GEOLOGY AND CHEMISTRY

Geology produces lotic ecosystem chemistry which, in turn, leads to the biotic community inhabiting that system. Exposed strata of the Appalachian Mountains in southeastern West Virginia creates the watershed drainage chemistry of concern. These strata are of the Pennsylvanian and Mississippian periods (Janssen, 1964). Permian sequence strata (which overlies the Pennsylvanian sequence) are not found in Logan County, so geology of the highest elevations are from the Pennsylvanian period (Colton, 1970). Coal beds of West Virginia were formed during the Pennsylvanian period (also known as the Great Coal Age) from vast swampland forests (Janssen, 1964). Vast outcrops of Pennsylvanian strata in West Virginia have resulted in the most strippable coal in Appalachia. Logan County is one of the top ten Appalachian counties with these strippable reserves (Hutchins, 1978). The chemical nature and physical activity of these strata lead to naturally occurring acidity in lotic waters and acidic mine site drainage throughout southern West Virginia.

Logan Plateau Physical Aspects

The Logan Plateau is typified by dendritic watershed systems and is highly dissected with narrow valleys, steep slopes, narrow crested ridges, and landslides (Janssen, 1964; Outerbridge, 1987). Dendritic drainages are created in areas of relative geological uniformity (Gordon et al., 1992). These flat lying beds are Pennsylvanian shales and sandstones which form horizontal rock layers west of the Allegheny Front (Outerbridge, 1987). Logan Plateau valleys have steep reliefs with slope means of about 26° or 50 percent grade. Heads of valleys are bowl shaped and bottoms lie at sharp angles to the walls. Flood plains are narrow with valley bottoms clear of colluvium except at valley walls. Streams are undercutting, flowing over bedrock streambeds directed by the geology (Outerbridge, 1987; Gordon et al., 1992). Sediment comes from creep, debris flows, and landslides (Outerbridge, 1987). Locally, strip mine debris adds to sediment. Valley fill is alluvium of three meters and less.

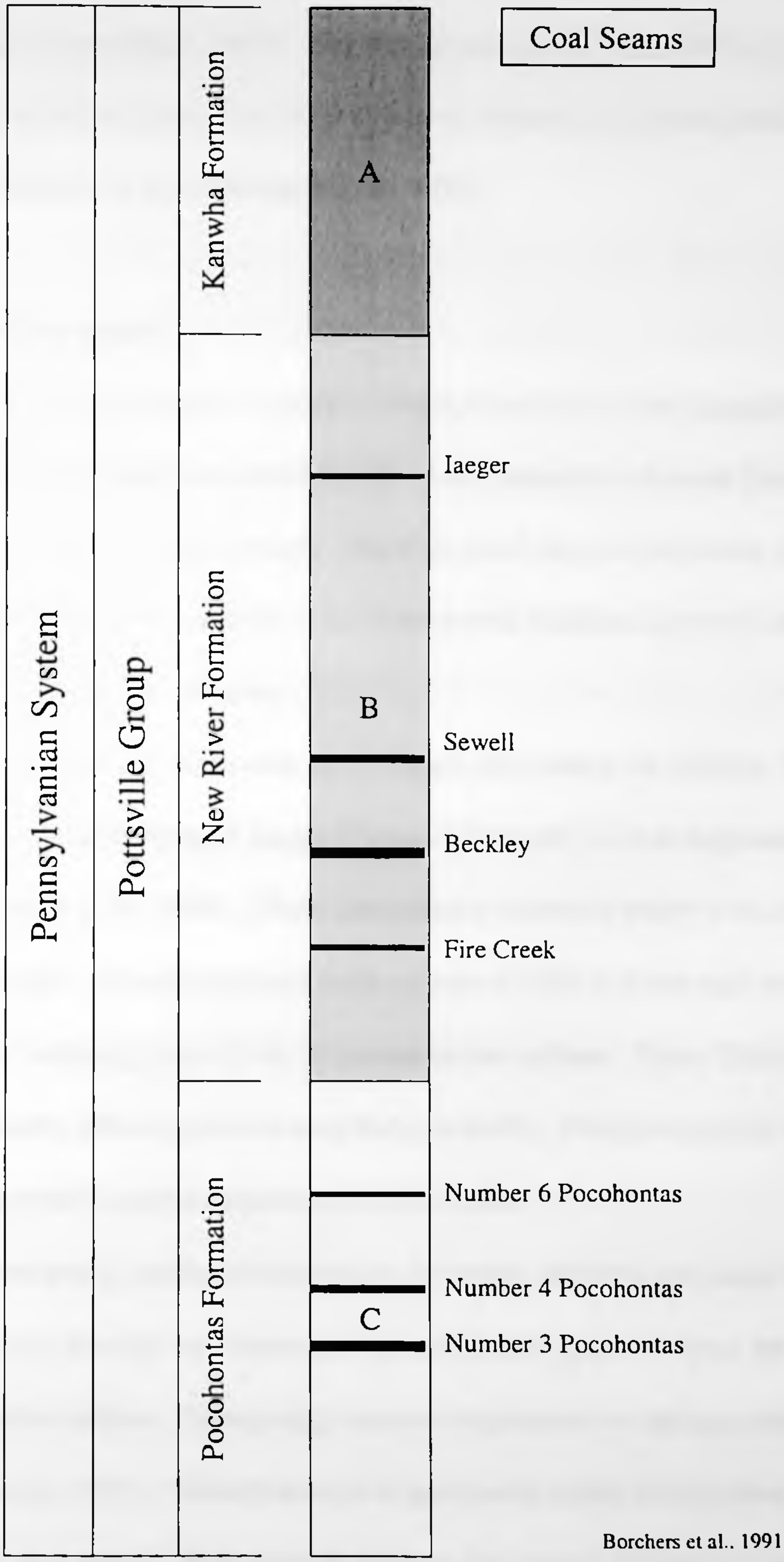
Sandstone and Sedimentary Stone

Appalachian Paleozoic strata are predominantly sedimentary rocks with 23 percent sandstone making up the Appalachian basin (Colton, 1970). Sandstone strata with the coarsest grain are found in the Mississippian sequence, which lies beneath the Pennsylvanian sequence. Oil and gas are found in the Murraysville ("gas") sand within the Mississippian sequence. Pennsylvanian and Mississippian sequences are strata of sandstone, siltstone, and red beds (reddish-brown, and grayish-red sandstone, shale, mudstone, and a relatively small amount of red limestone). General composition is 30 percent sandstone (and conglomerate), 60 percent shale (and claystone), and 10 percent limestone and coal. Red beds typify the Juniata, Catskill, and Mauch Chunk series while conglomerate dominates the Tuscarora, Pocono, and Pottsville series (Meckel, 1970). Guyandotte River watershed geological stratas are resistant sandstone, siltstone shale of New River formation, and is heavily mined for coal (Outerbridge, 1987).

Coal Strata

Kanawha and New River groups (in Pottsville series) are commercially important coal and can be easily strip mined (Menendez, 1978). Figure 1 shows these strata and named commercially important coal seams mined in the Logan Plateau (Borchers et al., 1991).

Figure 1. Outcropping geological strata of Logan Plateau with named commercially important coal seams (Borchers et al., 1991).



Borchers et al.. 1991

Pottsville series coal strata cause natural acidity because they are found near hill tops and ridges, outcropping on slopes (Outerbridge, 1987). The Pocahontas group has commercially important coal, as well, but is the lowest strata of the Pennsylvanian series and is more difficult to exploit, having been shaft mined in the past (Borchers et al., 1991).

Physical conditions of the strata

Primary permeability of rock is negligible throughout much of the Appalachian Plateau (Borchers et al., 1991). Secondary permeability, however, caused by physical flaws and features, allows a great deal of water through. These physical features are joints, faults, coal elements, fractures associated with anticlines and lineaments, solution openings, and subsidence fractures (e.g. underground mine collapses).

Synclines are local strata minimums, or U shapes, and used to be valleys. Weathering and physical degradation have changed Logan Plateau topography so that ridge and hilltops have syncline stratas (Borchers et al., 1991). These are resistant bedrocks which were streambeds of past valleys and drainages. Tensile fractures form on tops of hills in these rigid strata and run vertically, stopping at bedding planes 10 to 30 meters below surface. These fractures lead to crumbling along hillsides, allowing rain to seep through easily. Perched aquifers are also created in fractured coal beds which overlie impermeable clay layers.

Anticlines, conversely, are local maximums, or arches, in strata and used to be mountain peaks and ridges. Again, through weathering and physical changes, anticlines are the strata formations now found in valleys. Topography causes compression in valleys creating arching fractures (Borchers et al., 1991). These fractures in permanent strata of claystone, shale, coal are filled with sand, clay, and rubble. Wet weather streams are created if carrying capacity is greatly exceeded by precipitation. This causes these valleys to be local aquifers and their streams' basins are thus gaining basins.

Sources of Acidity

Pyrite and marcasite (both ferrous sulfide, FeS_2) are associated with coal seams, pyrite being the most abundant sulfate mineral in Earth's crust (Schrenk et al., 1998). Coal also has sulfur throughout due to its biogenic origin. Sulfides are formed in reducing environments devoid of oxygen. Weathering causes sulfides to become sulfates through the following general reaction:

$$FeS_2 + 14Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$$ (Rose and Ghazi, 1997).

Notice that hydrogen ion is a significant product. Weathering causes the acid drainage from the coal seam. Recall, also, that coal seams are important strata creating perched aquifers in this area (Borchers et al., 1991). This allows a significant residence time for water to be in contact with the coal, associated pyrites and underlying clay layer.

Sandstone in these strata also lend to acid drainage (Menendez, 1978). Pyrites are disseminated throughout the lower Pennsylvanian strata which has commercially important coal seams (Rose and Ghazi, 1997). Benches are cut into slopes exposing these pyritic strata as well as coal. So, a large section containing pyrite is exposed to weathering and creating acidic drainage.

Lack of Buffering Capacity

Alleghany Plateau geology has poor buffering capacity. Upper bedrock sandstone and shale are not soluble to any extent and most of these have low alkalinity in solution (Arnold et al., 1981; Winger, 1978). Water in these systems is soft, with little soluble limestone in the strata, and sensitive to acidity because of poor buffering (Winger, 1978).

Chemistry Creates Ecosystem Environment

Oxidation of pyrite occurs in a series of steps, each having an impact on the ecosystem. The first step is weathering, represented by this equation:

$$2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$$ (Schrenk et al., 1998).

Iron oxidation:

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

occurs next and is the rate limiting step (Rose and Ghazi, 1997; Schrenk et al 1998). Oxidation is represented by this equation:

$$4\ Fe^{2+} + O_2 + 4\ H^+ \rightarrow 4\ Fe^{3+} + 2\ H_2O$$ (Schrenk et al., 1998).

It is bacterially mediated by *Thiobacillus ferrooxidans* in the watershed environment (i.e. relatively cool coal bed and pH greater than 1.3) (Schrenk et al., 1998). However, *Leptospirillum ferrooxidans* is found on the pyrite surface and may initiate weathering. *L. ferrooxidans* is generally responsible for oxidation at higher temperatures and lower pH (0.3<pH<0.7). The final step in the reaction is precipitation of iron and formation of hydrogen ion:

$$Fe^{3+} + 3\ H_2O \rightarrow Fe(OH)_3 + 3\ H^+$$ (Schrenk et al 1998).

These steps taken together are summarized in the general equation presented previously in the section on sources of acidity.

Photoreactivity plays an important role once iron has precipitated in its ochreous (oxy hydroxy sulfate) or ferric hydroxide (Kimball et al., 1994). Kimball et al. (1994) found that iron in solution was reactive throughout the studied 1500 m reach. The cycle of redissolution and reprecipitation was discovered to have this mechanism. By day, photoreduction puts ferrous iron back into solution, having gained electrons from organic ligands. This also puts adsorbed cations (copper, lead, zinc, and cadmium in this study) back into solution (Webster et al., 1998). Three reactions take place by night. First, oxidation of ferrous iron results in reprecipitation of fresh iron (ferric) hydroxides. Second, precipitation of iron oxides and hydroxides coprecipitates fulvic acid. Finally, coprecipitation and sorption of cations by ocher [ferric oxy hydroxy sulfate, $FeO(OH)SO_4$], goethite (FeOOH) and jarosite [$KFe^{3+}{}_3(SO4)_2(OH)_6$] (Hem, 1985; Webster et al., 1998). Geothite and ocher are more poorly ordered than jarosite (Hem, 1985), causing them to play a greater role in photoreactive reactions. The more amorphous the precipitate, the more active in cation adsorption. Photoreactivity decreases downstream due to precipitate age (Webster et al., 1998). Older precipitates are more crystallized and therefore less reactive (Hrncir and McKnight, 1998).

Sources of Cations in Logan Plateau Watersheds

Iron has been, and continues to be, one of the major cations studied and measured when investigating acidified aquatic systems. Pyrite (FeS_2) is the iron source and is the major mineral of concern when studying naturally acidified waters and acidic mine drainage.

Aluminum comes from clays, such as kaolinite [$Al_2Si_2O_5(OH)_4$] (Hem, 1985), and their weathering products, such as gibbsite [$Al(OH)_3$] (Ridley et al., 1997). Aluminum leaves the water column through precipitation with little of it leaving through adsorption to floc (Kimball et al., 1994).

Calcium comes almost entirely from sedimentary carbonate rocks weathering (Allen, 1995). Sandstone is the primary source of calcium in this watershed. Little limestone is found in Pennsylvanian and Mississippian geological strata (Colton, 1970). Limestone that is found in these strata is resistant to weathering, contributing even less calcium than might be expected.

Magnesium silicate minerals and dolomite [Mg or Ca + $(CO_3)_2$] are the usual magnesium sources (Janssen, 1964; Allen, 1995). Sandstones are the primary source of magnesium which is conserved in the watershed through ion exchange within clays (Allen, 1995). Manganese substitutes for iron, aluminum, and calcium in minerals and resultantly found in many different strata and rocks (Hem, 1985). It accumulates in tree leaves, such as chestnut oak, and released into solution when detritus decomposes.

Potassium is found in interstitial spaces adsorbed in clays and sedimentary rocks (Hem, 1985). It tends to remain in sedimentary rocks, though more abundant than sodium. About 90 percent of potassium comes from weathering of silicates, especially potassium feldspar ($KAlSi_3O_8$) (Hem, 1985) and mica (Allen, 1995). These minerals are found in sandstone.

Silica's source is clay, along with aluminum, and some arises from weathering of sandstone mica [$H_2KAl_3(SiO_4)_3$] (Janssen, 1964). Silicate (SiO_4) is biotically important molecule necessary for diatom utilization (Allen, 1995).

Watershed Sulfate Activity

Sulfide minerals (pyrite) and biogenic deposits (coal) formed under reducing conditions are the primary source of sulfate (Hem, 1985). Sulfate is generally a major anion in aquatic systems and is of utmost importance in acidic aquatic systems (Shaver and Galloway, 1982). Sulfate concentration is inversely proportional to bicarbonate in solution (Allen, 1995). Most carbonate will be atmospheric since there is little sedimentary rock in the watershed. Sulfate in the precipitate reduces adsorption of cations (Webster et al., 1998). As pH increases, aqueous sulfate increases; at pH 7, 35 to 50 percent of the absorbed sulfate is desorbed into the water (Rose and Ghazi, 1997).

Acid Drainage

Parsons (1968) listed a set of effects acidic drainage has on an affected lotic system. There is precipitation of normal silt load, destruction of bicarbonate buffering system, increase of titratable acidity and hydrogen ion concentration, introduction of various cations into solution, and reduction of dissolved oxygen in downstream stations. Shaver and Galloway (1982) stated that sulfate adsorption and reduction of bicarbonate which leads to a loss of buffering capacity allows more cations to solublize, thus being lost to the watershed. Ionic stability in the lotic system is achieved at the cost of long term soil system degradation. This cationic stability leads to net export of potassium, magnesium, bicarbonate, and silicate out of the watershed. There is a net accumulation of hydrogen ion, ammonium, nitrate, sulfate, and calcium. Gray (1996) stated that the four categories of acidic pollution are salinization, metal toxicity, acidity, and sedimentation with turbidity. Sediments are aluminum hydroxides, iron hydroxides, and poorly crystallized ochreous precipitations [oxy hydroxy sulfates of Fe(III)] (Webster et al. 1998).

CHAPTER III

ACIDIC DRAINAGE AFFECTS ON BIOTA

Increased acidity leads to reduced epilithic bacteria and reduced bacteria on decomposing leaves (Mulholland et al., 1992). Leaf decomposition rate is decreased and results in lowered generic richness of scraped/grazer macroinvertebrates. A pH reduction of only 1.4 to 1.7 causes reduction in bacterial microdecomposer activity (Hendrey et al., 1976). Detrital conditioning is attenuated and microbial biomass reduction decreases available nutrients for shredders (Hendrey, 1978). Hendrey (1978) noticed abnormal accumulations of CPOM in West Virginia streams which indicates decreased recycling of organic material, leaf litter in particular.

Acidity alone can cause direct tissue damage through hydrolysis of proteins (Lechleitner et al., 1985). Parsons (1952) suggested this when he discusses coagulation of albumin in fish gill cells as causing reduced cell permeability. Direct increase of blood hydrogen ion concentration (acidosis) can also be found (Havas and Rosseland, 1995).

Aluminum and hydrogen ions both affect chloride cells (Havas and Rosseland, 1995). Their effects are also species and stage specific. Benthos, especially Ephemeroptera, is often more susceptible during emergence (Fiance, 1978). It is also well known that macrobenthos taxa are variable in their response. This is the basis of bioassessments and application of pollution indices.

Well studied fish gill failure is equivalent to chloride cell or anal papillae failure in macrobenthos and sodium reduction in benthos is understood through fish mechanism studies (Havas, 1981; Havas and Rosseland, 1995). Loss of calcium leads to reduced ionoregulation which leads to reduced sodium and chloride exchange (Havas and Rosseland, 1995).

Morphological changes in benthos can result in distension of cuticular disk (osmoregulatory cells) and increased numbers of vesicles in gill tissue (Lechleitner et al., 1985).

Solubilized aluminum harms aquatic biota physiologically in four general ways. These are iono/osmoregulatory failure, acid-base regulatory failure, respiratory failure, and circulatory failure. Increase in metals concentration causes organism damage indirectly (physiology), especially through damage to the sodium – potassium ion pump (Havas, 1981). Aluminum causes harm directly through binding to the carapace and reducing ability to molt (Havas and Rosseland, 1995).

Aluminum in solution with a pH range of 4.5 to 5.5 favors binding to oxygen based functional groups such as phosphate, carboxylates, carboxyls, and hydroxyls (Havas and Rosseland, 1995). This reduces membrane fluidity, diffusion of molecular oxygen, diffusion of carbon dioxide, excretion of ammonium, and other nitrogenous wastes. Aluminum also possibly replaces calcium in intercellular cement.

Zones of stream recovery also cause benthic stress but of a different type than acidity. Organism respiration is debilitated when aluminum precipitation clogs active filtering appendages (Havas and Rosseland, 1995). This may ultimately kill the organism or so hamper its survival that it is not able to thrive to reproduce. Organisms also practice behavioral avoidance. There will be an increase in drift (emigration) specifically from the affected area or avoidance of the area by drifting through or avoiding oviposition (e.g. mayflies) causing a lack of recruitment.

Mixing of waters causes precipitation of low molecular weight aluminum out of solution in the form of high molecular weight complexes which decreases the concentration of metals in the water column (Ridley et al., 1997). Mixing zones with pH greater than 4.3 causes iron hydroxides [$Fe(OH)_3$] and iron hydroxy sulfates [$Fe(OH)SO_4$] to precipitate (Gray, 1996). Aluminum comes out of solution at pH greater than 5.2 which leads to aluminum hydroxide [$Al(OH)_3$] and aluminum hydroxy sulfate [$Al(OH)SO_4$] precipitation (Gray, 1996). Rose and Ghazi (1997) found that as pH rises, sulfate is desorbed, thus neutralizing acidic waters with crushed limestone results in the unwanted effect of increasing sulfate concentration and concomitant cation increase.

CHAPTER IV

LITERATURE REVIEW

Acidic mine drainage has been a long standing concern for ecologists and other field scientists. Lackey (1938) noticed absence of fish and other aquatic life in seeps and drainage from mine sites near Fairmont, West Virginia. Macroinvertebrates reported by Lackey (1938, 1939) in these acidic waters (pH 3.2 – 1.8) were *Gammarus* spp. (amphipods), *Corethra* (= *Chaoborus*) spp. (phantom midges), *Chironomus* spp. (blood worms), mosquito larvae, caddisfly larvae and beetles. However, no sponges, hydras, platyhelminthes, nor molluscs were observed (Lackey 1938, 1939). Mosses were the only aquatic macrophytes he found (Lackey 1938). No bacteria were found and fungi were rare with protozoans being the dominant microbial biota (Lackey, 1938, 1939). Flagellated algae made up the epiphyton Lackey (1939) found covering substrate with *Euglena* species being the most abundant. Physicochemically, Lackey (1938, 1939) noted that sulfuric acid caused the acidity and that fast flowing streams are often deceivingly clear because floc precipitates over a much greater distance that in slower waters. Ultimately, Lackey (1938) called upon federal and state governments to created agencies to create acid reduction operations.

Gaufin's work of the 1950's is the basis of biomonitoring performed today. Gaufin and Tarzwell (1952) worked to develop, or devise, field test procedures and equipment for biological surveys and investigations of polluted streams. Increased biochemical oxygen demand and wastewater outfalls were the types of pollution primarily studied. They noted that mayflies (Ephemeroptera), caddisflies (Trichoptera), stoneflies (Plecoptera), and hellgrammites (Megaloptera) were essentially limited to clean water. Taxa found in great numbers in polluted water may be found in limited numbers in clean water. Taxa found in low numbers discourage their individual use for indicator species. They pointed out that erosion, floods, size of stream, type of stream, flight range of adults, and stretch of stream studied limit distribution of certain species are frequently create the resultant benthic community rather than pollution. Moderate abundance of a single species found in polluted waters should not be used as indication of pollution. Absence or reduction of formerly present clean water species may be as important as numbers of pollution resistant species. However, absence of clean water species alone cannot be taken as evidence of pollution, but pollution is indicated by large numbers of few pollution evident taxa. Necessity of understanding and applying knowledge of organism life cycle is stressed. Generally, Gaufin and Tarzwell (1952) generalized that physical and chemical effects lead to qualitative and quantitative aquatic populations which in turn affects physical and chemical components of aquatic systems.

Parsons (1952) studied acid impacted aquatic systems. He noticed that wildlife will absent an area where they cannot drink the water. Parsons, more importantly, made observations which focused research on acid spates over twenty years after being made. Parsons noticed that streams more acid polluted in winter had greater acidity than increases occurring during normal stream flow. However that streams more acid polluted in summer have acid flow that is more constant.

In the later 1950's, Gaufin et al. (1956) recommended that a combination of dredge, kick net, and Surber sampler be utilized for biomonitoring. Organism observations were further extended. It was pointed out that an Ephemeropteran, Plecopteran, or a Trichopteran may be found in a stretch which is not septic for a period and survive until a pollution outfall kills it (Gaufin, 1958). Air breathing organisms can survive low dissolved oxygen water but gill breathers are more susceptible to pollution. Benthic populations dominated by gill breathing taxa are largely restricted to clean water. Size of organisms also limits the ability to determine presence and numbers (Gaufin et al., 1956), causing a lower size limit to organisms sampled. Also, organism distribution will affect its ability to be sampled. Benthos with patchy distribution are more difficult to sample whereas widely distributed benthos are more easily collected. These are important considerations and guidelines still affect present biomonitoring studies and applications.

Parsons (1968) studied lotic systems within Missouri's central coal fields. He found that benthic communities established during spate acidification remain after acidic input cessation. Thus, acid tolerant taxa persist long after the perturbations which allowed replacement of original benthic communities. Parsons also remarked on noticing whitish flocculent precipitate but did not identify it as aluminum hydroxide nor make any comment of its difference from iron precipitate.

Warnick and Bell (1969) realized that studies had little metals toxicity information and recommended that dissolved oxygen, pH, alkalinity, acidity, and hardness be included in studies. They hypothesized that heavy metals were the most important parameter influencing benthic mortality. Metals tested were arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, silver, and zinc. They determined that copper is the most toxic of all the metals.

Bell studied acidity effects on aquatic insects in the late 1960's and the early 1970's. His research was laboratory study on a variety of insect orders that became the pollution bellwethers. These orders are Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). Bell also studied odonates, another important aquatic insect order. He created the basis of what is presently known about acid's effect on aquatic insect communities (Bell and Nebeker, 1969).

Ephemeropterans tend to be the least tolerant of low pH. Few can tolerate less than pH 4.0 and some are intolerant of pH less than 5.5 (Bell, 1971). Trichopterans tend to be fairly acid tolerant, many genera tolerant to pH ranges of 2-3 (Bell and Nebeker, 1969). Plecopteran tolerance is more dependent on the genus or species. Some Plecopterans are incompatible with pHs close to 4.0. Several are tolerant to pHs as low as 3.0. Bell (1970, 1971) also noted that emergence is the stage which aquatic insects are most sensitive to low pHs. So even if larvae can thrive in very acidic waters, they may be vulnerable to morbidity or mortality during emergence.

Hoehn and Sizemore (1977) found that most detrimental effects of iron hydroxide floc is physical, having tested the drainage for calcium, magnesium, iron, manganese, copper, and zinc. Menendez (1978), however, determined that reclaimed mines do not change water quality (i.e. decrease acidity). He did find that benthos numbers stayed reduced downstream until the stream ran through a limestone system (Menendez, 1978). This caused pH increase and addition of buffering to the water allowing the benthic community to recover taxa and numbers.

Hendrey (1978) noted much the same biotic community as Lackey in the late 1930s. He extended these observations into hypotheses about why acidic waters have this type of biotic community. A paucity of microbial activity leads to two observable outcomes. One is that there is little decomposition of coarse particulate organic matter (CPOM), thus leading to allochthonous inputs remaining largely intact. The other outcome being no food for small community members upon which to feed, leading to a reduced number of organisms in these communities.

Hubbard Brook Experimental Forest in New Hampshire was created by the USDA Forest Service in 1955 (1999). In 1963, the National Science Foundation created the Hubbard Brook Ecosystem Study and stream ecosystem studies began in the late 1960's. The quantitative effects of such acidification on biogeochemistry and biological function in natural stream have received little attention (Hall and Likens, 1981). A large scale acidification study was carried out in 1978. A stream in the Hubbard Brook drainage was acidified to pH 4.0 for a period of months and observations of the resultant macroinvertebrate community reaction and water quality changes were studied. Hall et al. (1980) noted concentrations of cations in solution changed and pointed to the necessity for in depth macroinvertebrate physiological and behavioral studies. Aluminum, calcium, magnesium and potassium concentrations all increased with aluminum and calcium having the greatest increases. Aluminum was the most significant inorganic compound affected (Hall and Likens, 1981). It was hypothesized that manganese, iron and cadmium concentrations would also increase. Fiance (1978) observed that order Ephemeroptera was the most sensitive to this acidification. Ephemeropteran recovery was observed, however, downstream from the acid input as stream order increased, as distance increased downstream, and pH rose back to neutral. Acidification had no effect on the emergence of ephemerotperan adults. He noted, however, a direct decrease in growth and recruitment is nearly eliminated. *Ephemerella funeralis* (two year cycle) was eliminated through lack of recruitment in permanently acidified streams.

Arnold et al. (1981) studied benthic communities of acid waters within Pennsylvania's Allegheny Plateau . They found that with increased acidity there was reduced benthic recruitment. Their study indicated that reduced benthic biomass in acidic waters was primarily due to reductions in algavores. Arnold et al. (1981) determined that a reduction of algae available in acidic waters resulted in reduced algavore numbers.

Havas (1981) determined that the great cause of harm to benthos by acidic waters was through sodium regulation interferences. He noted that the focus had been on fish and their reaction to acidified waters. Havas (1981) reasoned that benthos reacted in the same manner.

Research showed that a reduction of benthic sodium had a concomitant occurrence of mortality. Havas reasoned since aluminum caused sodium reduction in fish that a similar mechanism must occur in macroinvertebrates.

Voshell (1980) worked on a method of determining benthic community health for determination of polluted systems. He determined that the indicator species concept was too rigid, some indicator species can be found in pristine waters. Diversity indices can be misleading if used alone and may ignore information about an important species involved (Voshell, 1980). Some pristine waters (such as small, cold streams and desert streams) have naturally low diversity. Voshell (1980) determined that methods which correlate relative abundance and aspects of constituent organisms' ecologies (role of physical habitat on benthos distribution) have the greatest potential for accurate pollution determination.

Havas and Rosseland (1995) show that solubilized aluminum is the primary toxicant to fauna in acidified aquatic ecosystems. Its effects can be mitigated by water with high calcium concentration (hard water) and by humic acids, which act as ligands by chelating aluminum ions from solution. Acute aluminum toxicity caused by episodic or seasonal events cause greater harm than chronic exposure. They determined that osmoregulation in fish is similar to that in insects. The inability to osmoregulate, which leads to failure of fish gill function, is equivalent to failure of aquatic insect chloride cells and anal papillae. They determined that aluminum and hydrogen ion in solution have both synergistic effects and antagonistic effects, thus causing difficulty in finding the mechanism of toxicity. Havas and Rosseland (1995) also suggested that aluminum might replace calcium in the intercellular cement. Ridley et al. (1997) showed that aluminum concentration increases with decreased ambient temperature. Concentration of aluminum increases as elevation or latitude increase which leads to an increase in aluminum residence time.

Australia has been the focus of recent acid mine drainage studies. Gray (1996, 1998) has developed a visual staging technique for the level of impact on a lotic ecosystem. This acid mine drainage index (AMDI) an five stages based on the levels of discoloration and thickness of substrate cover by iron hydroxide floc. This same system could also describe the aluminum hydroxide floc found at this study site. Gray (1998) found that only water in the zone of recovery in an LC_{50} study toxic to the macroinvertebrates tested (*Gammarus dueberi, Ephemerella ignita, Baetis rhodani*). Recovery zone community was 78 percent Diptera and 11 percent uncased Trichoptera.

CHAPTER V

STUDY SITE

Sand Lick Creek is a Guyandotte River tributary which has its confluence at Bruno, West Virginia in southern Logan County. North Fork of Sand Lick and South Fork of Sand Lick (both stream order 1) join to form Sand Lick Creek (stream order 2) (Cole, 1988). North Fork of Sand Lick and South Fork of Sand Lick are both about one meter in breadth. Sand Lick Creek itself is 2 – 2.5 m across. Bed load for these streams is generally equal to or less than sand in size (Gordon et al., 1992). Gravel, cobbles, and boulders are found throughout these streams but are too massive to be transported under usual flow circumstances. Spate flows, however, transport much streambed material. These streams are considered widening (indicated by trees falling in) and cause degradation (downcutting of stream into bed materials).

These are typical headwater streams flowing through V shaped valleys with steep slopes (Janssen, 1964; Gordon et al., 1992). Streambeds are bedrock throughout most of their courses with sediment coming primarily from creep and landslides (Outerbridge 1987). Overlying substrate in the streams is similar and typified as sand, gravel, and rubble (Gordon et al., 1992; Allen, 1995). Water in these streams is clear except in times of runoff after storms when they are very turbid until spate subsidence. Scouring and riparian shading minimize aquatic macrophytes and algae in both North Fork and Sand Lick Creek (Gordon et al., 1992), although South Fork does have sphagnum moss growing on its rocky substrate. Confluence is in alluvial deposit and subject to morphological changes during spates.

North Fork starts at an elevation of 488 m (1600 ft) above mean sea level and runs 1750 meters almost due east to its confluence. South Fork begins at an elevation of 402 m (1320 ft) above mean sea level and travels 1260 meters northeast to its confluence. Elevation at the confluence of these streams and the beginning of Sand Lick Creek is 305 m (1000 ft) above mean sea level. Sand Lick Creek continues east northeast 3100 meters to its confluence with the Guyandotte River. The mountain dividing the watersheds of the North and South Forks is 670 m (2200 ft) above mean sea level at its peak. The confluence is at 37°40'20'' longitude and 81°53'27" latitude. The study area is within the Man quadrangle of the 7.5 minute U.S.G.S. topographic series of West Virginia.

South Fork drains a watershed that has been strip mined for coal and is, therefore, acid mine drainage (Hamrick and Ghosh, 1996). The bench is cut into the ridge which is its watershed's southern boundary. Acidic groundwater seepage occurs about 400 m upstream from the confluence and has a $pH < 3.0$. North Fork has a moderately disturbed watershed with a road along its north ridge. Aluminum hydroxide precipitant covers the forks' confluence streambed between spate event scourings. Using Gray's (1996) acid mine drainage index (AMDI), precipitate covering would be a B (scale is A – E, A being most covered, E being least covered) which is typified by large stones having a thick crust on top and discolored floc between loose stones.

Both forks have gas pipelines running through their watersheds with concomitant maintenance roads. Both watersheds are within a natural gas field which taps the Murraysville ("gas") sand of the Mississippian sequence (Colton, 1970). Sand Creek continues about 2000 meters through the gas field until it reaches the southern most edge of Bruno, West Virginia. Sand Lick Creek continues its northeasterly course through the village to the Guyandotte River.

Central hardwood forests are the defining climax vegetation in the plateau and are found as cove hardwoods or mixed mesophytic forests (mesic) (Strausbaugh and Core, 1977). These trees form a canopy over the streams. Riparian vegetation for the study site comes from the upland forest which fills the watershed. Logan County forest is 88 percent oak/hickory forest (Table 1) and 12 percent northern hardwoods (Table 2) (DiGiovanni, 1990).

Table 1. Trees found in an oak/hickory dominant forest as described by the USDA Forest Service (DiGiovanni, 1990).

Upland Oaks and Associates	
Post Oak	*Quercus stellata*
Black Oak	*Q. velutina*
Bear Oak	*Q. ilicifolia*
Chestnut Oak	*Q. primus*
White Oak	*Q. alba*
Scarlet Oak	*Q. coccinea*
Black Locust	*Robinia pseudoacacia*
Sassafras	*Sassafras albidum*
Persimmon	*Diospyros virginia*
Red Maple	*Acer rubrum*
Hawthorn	*Crataegus* spp.
Hard Pines	*Pinus* spp.
Hemlock	*Tsuga canadensis*
Maple	*Acer* spp.
Birch	*Betula* spp.
Hickory	*Carya* spp.
Yellow Poplar	*Liriodendron tulipifera*

Table 2. Trees found in northern hardwood forest as described by the USDA Forest Service (DiGiovanni, 1990)

Sugar Maple	*Acer saccharum*
Beech	*Fagus grandiflora*
Yellow Birch	*Betula alleghaniensis*
Red Maple	*Acer rubrum*
Pin Cherry	*Prunus pennsylvanica*
Black Cherry	*P. serotina*
Hard Pines	*Pinus* spp.
Hemlock	*Tsuga canadensis*
Ash	*Fraxinus* spp
Yellow Poplar	*Liriodendron tulipifera*
Hickory	*Carya.* spp.

CHAPTER VI

METHODS AND MATERIALS

Field Measured Parameters, Precipitation, and River Staging

Stream temperature (°C) and pH were measured with a Hanna™ combination meter until 12/15/96 sampling date. Oakton™ hand held meters for temperature and pH were used after that date. The Hanna™ pH meter was calibrated with buffers in the field. The Oakton™ pH meter was calibrated in the laboratory prior to the field trip. Alkalinity (mg $CaCO_3$/L) and free acidity (mg $CaCO_3$/L) of each station were measured in the field using Hach™ water chemistry kits (Model AL-35B). Rainfall and Guyandotte River staging records for Man, West Virginia were obtained from the National Climatic Data Center in Asheville, North Carolina (1998). Dissolved oxygen was not measured because was assumed that saturation in small, turbulent streams is near one hundred per cent at a given temperature (Allen, 1995).

Laboratory Measured Parameters

Water samples for sulfate (SO_4^{-2}) determination were caught in clean polypropylene sample bottles and immediately placed on ice (APHA, 1995). Samples were taken back to Marshall University where sulfate was tested immediately upon arrival. Sulfate concentration was determined by turbidimetric method with a Hach DR 2000 spectrophotometer.

Water samples for cations were captured in acid washed polypropylene sampling bottles and acidified with concentrated nitric acid to pH less than 2 in the field as per Standard Methods (1995) to break down colloids and keep metals from adsorbing to the container wall (Hem, 1985). Cation samples were stored at 18 °C until the complete set was collected and ready to be tested. They were then filtered through cellulose acetate filters with 0.45μm openings to remove solids from the dissolved phase (Hem, 1985; APHA, 1995). Aluminum, calcium, iron, magnesium, manganese, potassium, and silicon in solution were measured using inductively coupled plasma atomic emission spectrometry (ICP-AES) (APHA, 1995). A Liberty 110 ICP Emission Spectrometer (Varian Co.) was used for these measurements. The ICP is driven by a microcomputer using proprietary software to control the machine, create a linear transmission correlation for predetermined standards, and measure ionic concentrations in the samples.

The computer algorithm determines a best fit linear regression line based on a series of concentration standards and resultant intensities for a particular cation (Analytical Methods, 1991). Distance from line for intensities of each standard concentration is measured and reported as the error. Percent error is also calculated. Cation concentrations are determined by intensity of a particular light wavelength and resultant intersection with the calculated regression line developed from the series of concentration standards for the cations. This is important because the ICP software gave out error messages and did not run the algorithm for several cations. Thus, a contingent algorithm was developed.

Values calculated by the Varian software were used if cation concentration values were valid (e.g. not a negative number). If the Varian software y – intercept was greater than zero, a linear regression calculated with Excel ™ was used to determine concentration. The values for this linear regression came from the Varian program record. If the Varian program y-intercept was less than 0, an Excel linear regression was created with Varian program values and with the y-intercept set at zero. In this way, ICP measurements were still utilized to determine cations in solution.

Cation concentrations measured using only results from the Varian program were aluminum, magnesium, potassium, silicon, and sodium. Calcium was the only cation measured with an Excel linear regression line based only on Varian program values. Iron and manganese used Excel linear regressions based on Varian program values and setting the y-intercept at zero.

Statistical Analysis for Chemical Parameters

The physical data were all analyzed utilizing KwikStat (TexasSoft, 1993) and Statlets (Version 1.1B). A standard parametric ANOVA was applied to hydrogen ion, aluminum, calcium, iron, magnesium, manganese, potassium, silicon, sodium, and sulfate concentrations to determine water chemistry differences of the stations. Stations were grouped using Newman – Keuls multiple comparisons statistic and Duncan multiple range test. Hydrogen ion concentration was compared to each of the other chemical parameters utilizing linear regression analysis and correlations determined with Pearson's r statistic, which runs from negative one to positive one. Values for the spate flow sampled on January 28, 1997 have been omitted from statistical analysis data.

Benthic Sampling

Benthic samples were preserved in 70 percent ethanol in the field and identified in the laboratory. Benthic populations were sampled utilizing EPA Rapid Bioassessment Protocol III (Plafkin, 1989). Kick samples covering one square meter and taking 5 minutes each were taken from a riffle and a pool. Collection of leaf packets for CPOM (coarse particulate organic matter) were taken for shredder determination. Sampling sites were moved serially upstream for North Fork of Sand Lick and South Fork of Sand Lick while serially downstream in Sand Lick Creek.

This was done to prevent measuring benthic rehabitation rather than gathering a typical benthic sample for that site. Benthos were identified to the lowest practical taxon according to Merritt and Cummins (1996), Peckarsky (1990), Wiggins (1996), and Tarter (1976).

Benthos Statistical Analysis

The Shannon measure of diversity (Shannon-Wiener diversity index, Shannon-Weaver index) was applied as the initial analysis of benthic data (Zar, 1996). The following equivalent equation:

$$H' = (3.3219)\frac{n \log n - \sum_{i=1}^{k} p_i \log p_i}{n}$$

is a mathematical manipulation of Shannon's original equation which was utilized. This expresses the index as a log 2 number which is commonly found in the literature. An Excel™ spreadsheet was used to calculate the index. The equation for taxa evenness developed by Pielou:

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

was used for this analysis, as well, to ameliorate the bias inherent in the Shannon measure of diversity.

The Kruskal – Wallis test, an ANOVA of ranks for more than two sets of data, was used as a second step in the benthic data. This test was run on Kwikstat™ to compare Shannon's measure and Pielou's evenness calculated on the benthos collected from North Fork, Sand Lick, and South Fork. Huffman (1989) stated that the null hypothesis as follows:

$$H_o = P(x_i > y_i) = (x_i < y_i).$$

This test is not a rigorous test and any difference found is an actual difference, thus reducing the probability of false positive analyses (Huffman, 1989). Duncan multiple range test was performed, as well, again utilizing the Statlets program.

A detrended correspondence analysis (DCA) was performed on the benthic data to determine community changes. DCA analysis indicates how benthic communities change temporally and in relation to one another. This analysis also determines species which are most important in numbers.

CHAPTER VII

RESULTS

SECTION A: FIELD MEASURED PARAMETERS, RIVER STAGING, AND PRECIPITATION

Stream temperatures were essentially the same with small variation between stations (Fig. 2, Table 3). Hydrogen ion concentration measured as pH varied greatly between stations as shown in Figure 3 and Table 3. The lowest pH values for all stations are from a spate flow sampled during the study. These spate pH values are 5.23 for North Fork, 3.88 for Sand Lick, and 3.35 for South Fork (Appendix A, Table 1). In contrast, lowest normal flow pH values are 6.62 for North Fork, 4.51 for Sand Lick, and 3.69 for South Fork. This indicates that spate flows change drainage chemical nature in this watershed. The complete data set is in Appendix A.

Table 3: Field measured parameters' means and standard deviations.

Parameter	North Fork	Sand Lick	South Fork
Temperature (°C)	11.5 (SD = 4.7)	11.3 (SD = 4.7)	11.2 (SD = 4.5)
pH	7.06 (SD = 0.56)	5.20 (SD = 0.53)	4.06 (SD = 0.34)
Acidity (mg $CaCO_3$/L)	∅	7.18 (SD = 7.78)	43.14 (SD = 17.02)
Alkalinity (mg $CaCO_3$/L)	24.99 (SD = 6.16)	5.52 (SD = 7.32)	∅

North Fork showed no measured acidity while South Fork consistently had measurable acidity (Fig. 4). Sand Lick oscillated between acidity and alkalinity as shown in Figures 4 and 5. This oscillation produces a statistically difficult situation. For a sample number of 13, there were six acidities of zero and seven alkalinities of zero. This results in standard deviations being larger than their means in both cases. South Fork showed no measured alkalinity during the study. Titration to phenolphthalein endpoint was not performed so only free acidity was

Figure 2. Temperature (°C) of streams at North Fork, Sand Lick, and South Fork stations.

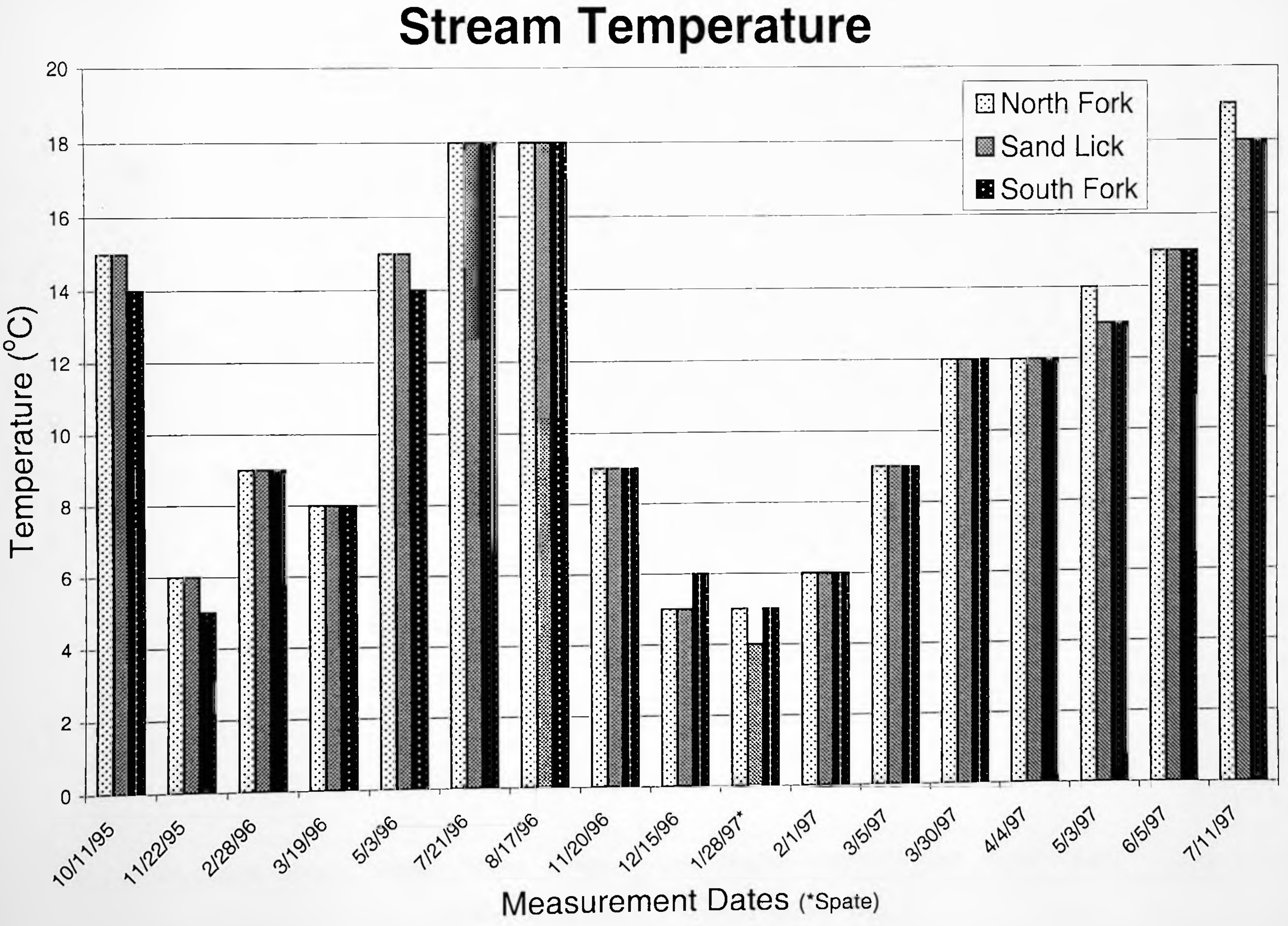

Stream Temperature
North Fork
Sand Lick
South Fork
Temperature (°C)
20
18
16
14
12
10
8
6
4
2
0
10/11/95
11/22/95
2/28/96
3/19/96
5/3/96
7/21/96
8/17/96
11/20/96
12/15/96
1/28/97*
2/1/97
3/5/97
3/30/97
4/4/97
5/3/97
6/5/97
7/11/97
Measurement Dates (*Spate)

Figure 3. Stream pHs measured at North Fork, Sand Lick, and South Fork stations.

Stream pH

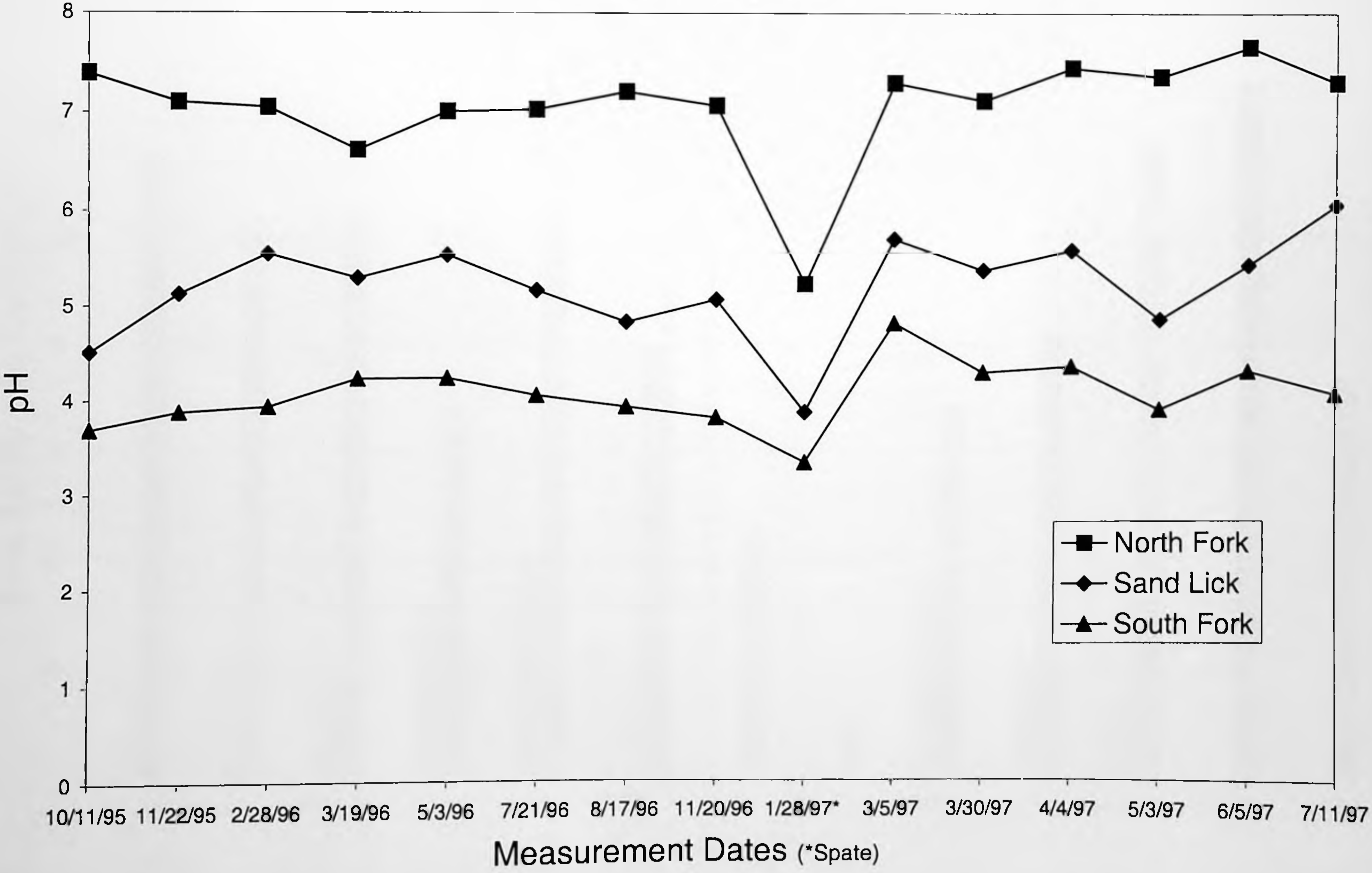

pH
8
7
6
5
4
3
2
1
0
10/11/95
11/22/95
2/28/96
3/19/96
5/3/96
7/21/96
8/17/96
11/20/96
1/28/97*
3/5/97
3/30/97
4/4/97
5/3/97
6/5/97
7/11/97
Measurement Dates (*Spate)
North Fork
Sand Lick
South Fork

Figure 4. Free acidity (mg $CaCO_3$/L) of streams at North Fork, Sand Lick, and South Fork stations. North Fork had no measurable free acidity during the study.

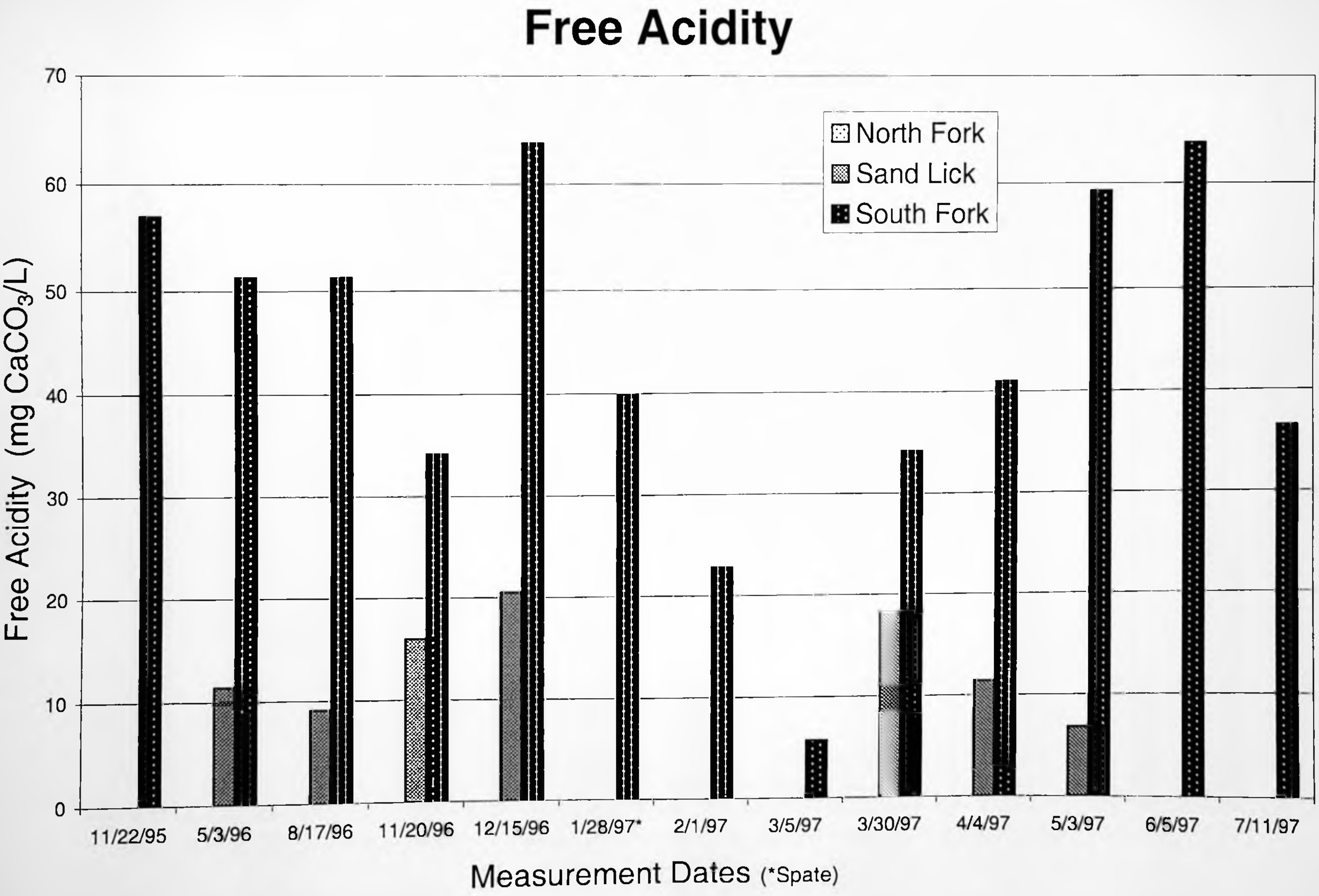
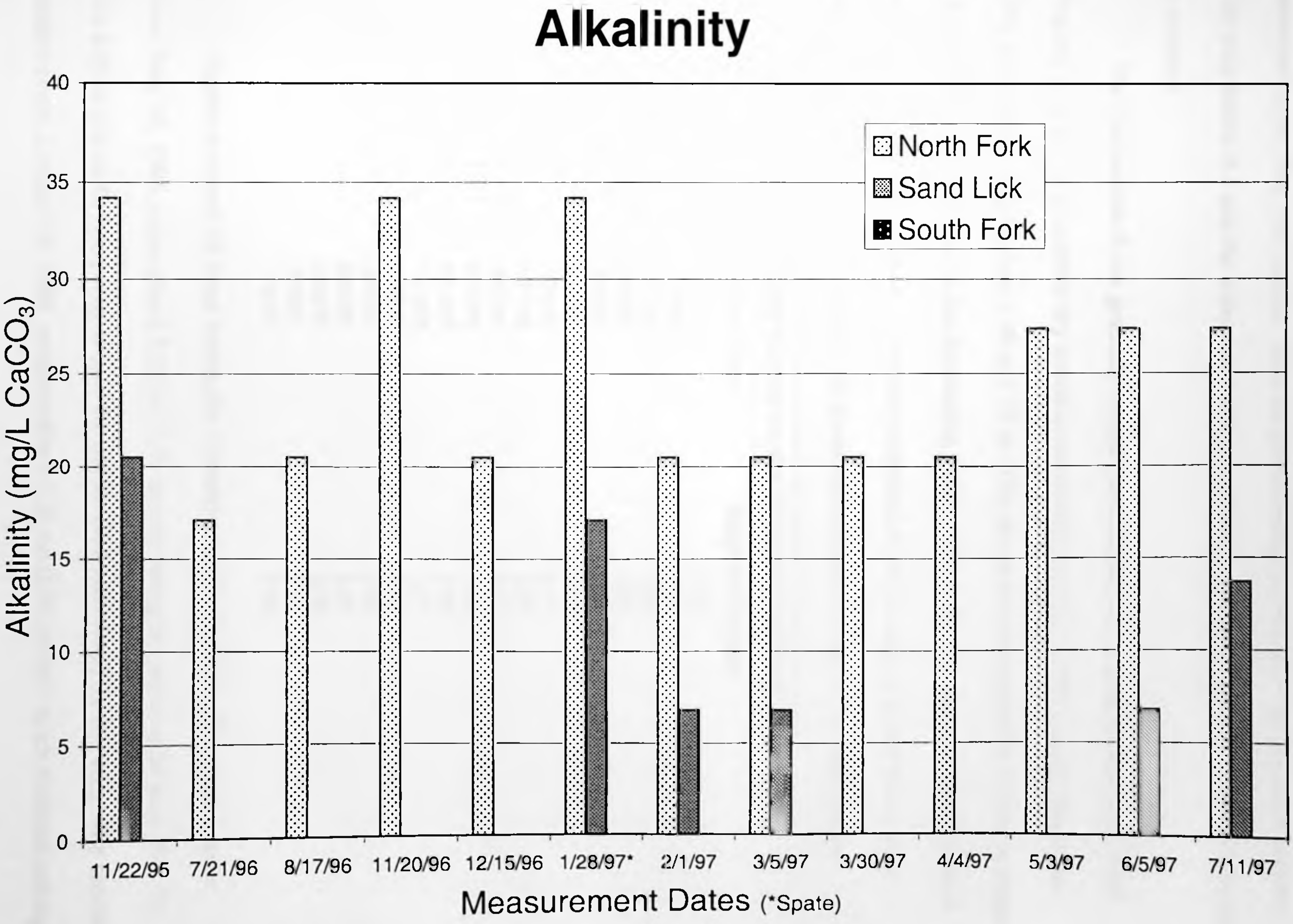

Free Acidity
North Fork
Sand Lick
South Fork
Free Acidity (mg $CaCO_3$/L)
70
60
50
40
30
20
10
0
11/22/95
5/3/96
8/17/96
11/20/96
12/15/96
1/28/97*
2/1/97
3/5/97
3/30/97
4/4/97
5/3/97
6/5/97
7/11/97
Measurement Dates (*Spate)

Figure 5. Alkalinity (mg $CaCO_3$/L) of streams at North Fork, Sand Lick, and South Fork stations. South Fork had no measurable free acidity during the study.


Alkalinity
North Fork
Sand Lick
South Fork
Alkalinity (mg/L CaCO3)
0
5
10
15
20
25
30
35
40
11/22/95
7/21/96
8/17/96
11/20/96
12/15/96
1/28/97*
2/1/97
3/5/97
3/30/97
4/4/97
5/3/97
6/5/97
7/11/97
Measurement Dates (*Spate)

measured rather than total acidity. Also, no phenolphthalein alkalinity was measured because pHs were below 8.3 and the watershed had little buffering capacity. This leads to little carbonate in solution.

The Guyandotte River generally ranged from 1.25 to 1.50 m in depth near Man, West Virginia (Fig. 6). A noticeable dry period occurred from mid June, 1996 to early November, 1996 with depths ranging from 1.00 to 1.25 m. This period was interrupted by a spate on August 13, 1996 and a lesser event in mid-September, 1996 (Table 4, Fig. 6). Spate events in Table 4 are defined as any event which caused the Guyandotte River to stage at greater than 2.10 m which is one standard deviation (0.47 m) above mean stage (1.62 m) for the study period.

Table 4: Spate events on the Guyandotte River.

Date of Event Peak	Stage (m) at Peak
1/4/96	2.31
1/19/96	4.13
1/25/96	2.86
2/9/96	3.03
3/8/96	2.41
3/21/96	2.26
3/30/96	2.11
4/17/96	2.37
5/7/96	2.77
5/16/96	4.36
8/13/96	2.40
12/3/96	2.71
1/30/97	2.52
3/7/97	2.65
3/20/97	2.26
5/26/96	2.19
6/3/97	2.16
7/4/97	3.09

Spates occurred 18 times during the 17 month period of records. The greatest spate event, May 16, 1996, came after a 8.23 cm (3.24 in) rain during the previous 24 hour (Fig. 7). This 4.36 m (14.32 ft) flood stage is now the one hundred years flood for this area. The second greatest event, January 19, 1996, occurred after a 3.30 cm (1.30 in) rain which finished melting

Figure 6. Guyandotte River stage throughout study period graphed in meters. Reported in feet by the National Climatic Data Center (1998).

Guyandotte River Stage at Man, West Virginia

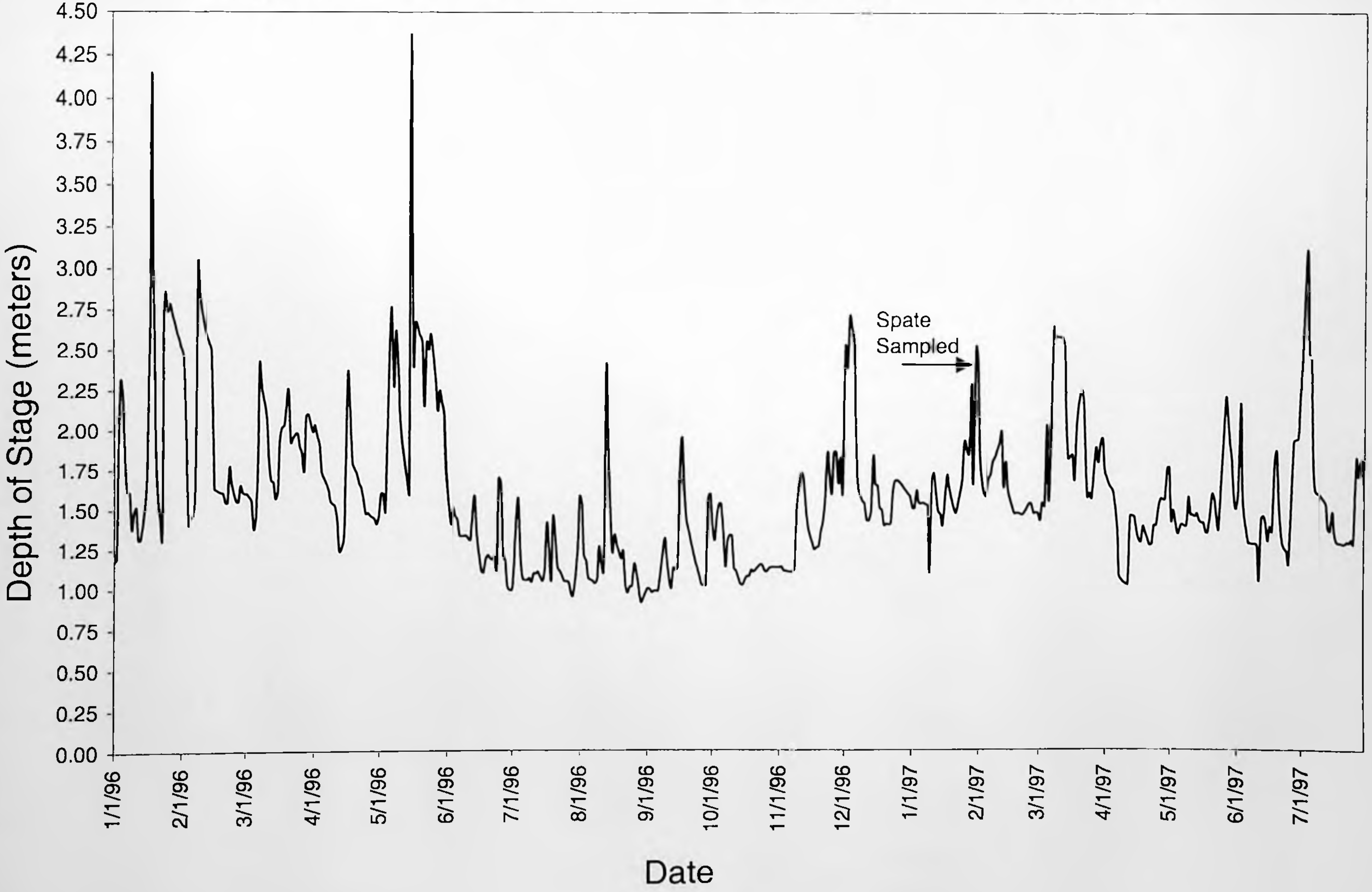
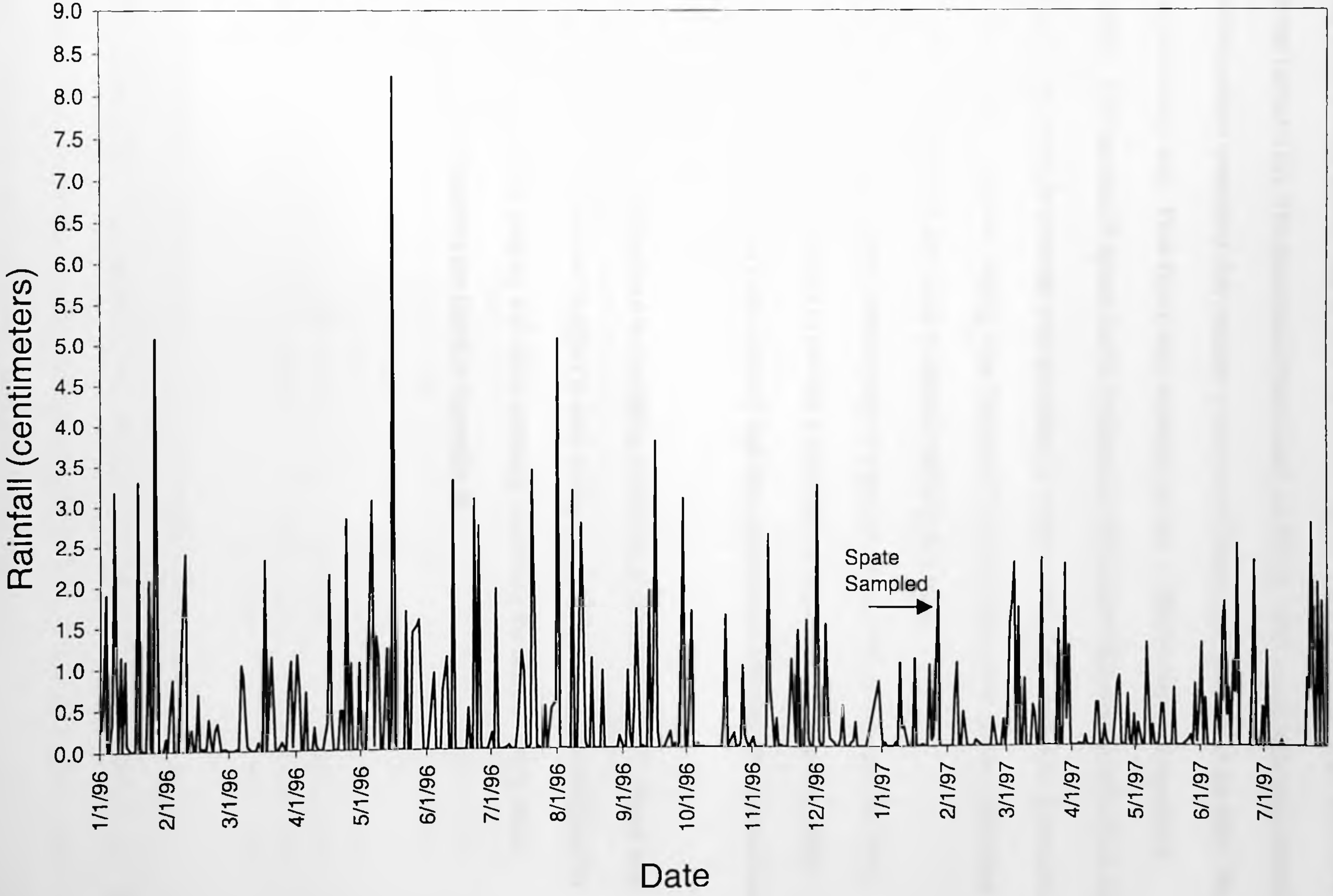


Figure 7. Precipitation for Man, West Virginia graphed in centimeters. Reported in inches by the National Climatic Data Center (1998).

Rainfall Record from Man, West Virginia



snow cover from several snows, one of 25.4 cm (10 in), one of 15.24 cm (6 in), with several of about five cm (about 2 in). The third major flood event, on July 4, 1997, came after rain events in the upper Guyandotte watershed that resulted in less than 1.20 cm rain recorded at the Man, West Virginia measurement site. Peak flows were recorded on July 2, 1997 at two sites upstream (USGS, 1999). The balance of spates can be compared to Guyandotte River stage (Fig. 6) or rain events (Fig. 7) and found to coincide with precipitation events in the area. Appendix II provides complete precipitation and river staging data (National Climatic Data Center, 1998). Individual spate and precipitation events are easier to delimit utilizing this table.

The January 28, 1997 spate (leading edge of a greater spate event on January 30, 1997) was sampled at the study site stations to provide a rough determination of drainage chemistry change during these events. Study data indicate that these spates have different chemistries from what is usually found.

Daily rain amounts throughout the sampling period are graphed in Figure 7. Snow was not included in this record because its effect is seen during melts. Snow melts are indicated by increased Guyandotte River staging with field sampling measuring the effects. Daily snow accumulations and rain amounts are listed in Appendix B.

SECTION B: CATIONS AND SULFATE

Normal ranges for cation concentration are listed in Table 5 so that they can be compared with measured values for the study site. Table 6 shows ranges for dissolved cation and sulfate measured concentration. Cation and sulfate concentration data can be found in Appendix C, Table 1. Statistical analyses for ion concentrations and correlations are also in Appendix C.

Table 5: Normal cation ranges in natural waters. (Hem, 1985)

Cation:	Range (mg/L):	Notes:
Aluminum	n/10 or n/100	Rarely in greater concentrations
Calcium	20 – 25	Usually predominant cation
Iron	50 @ pH 6-8	Reducing environment
	15 @ pH < 3	Acid mine drainage
Manganese	> 1	Acid mine drainage
Silicon	< 10	
Potassium and Sodium	Na < 10 → K > Na	Comparatively proportional
	10 < Na < 20 → K ≡ Na	
	Na >> 10 → K $^{1}/_{10}$ or ½ Na	

Table 6: Ranges of cation concentrations (mg/L) in solution by station.

	North Fork	Sand Lick	South Fork
Aluminum	0.12 - 2.34	1.28 – 15.44	3.17 – 24.31
Calcium	14.27 - 47.34	20.63 – 68.05	27.00 – 93.03
Iron	0.17 - 3.82	0.11 – 2.57	0.13 - 1.86
Magnesium	8.14 - 24.68	11.85 – 43.62	17.93 – 68.01
Manganese	0.02 - 0.22	0.39 – 2.38	0.91 - 5.41
Potassium	1.13 - 2.69	1.16 – 2.89	1.24 - 3.39
Silicon	3.26 - 6.19	4.07 – 6.55	5.35 – 10.68
Sodium	3.16 - 12.93	3.61 – 13.15	4.12 – 14.04
Sulfate	45 – 200	105 – 240	125 – 456

Calcium (Fig. 8), magnesium (Fig. 9), potassium (Fig. 10), and sodium (Fig. 11) had significant concentration peaks for North Fork, Sand Lick, and South Fork at the September 15, 1996 sampling. Notice that this sampling occurred during a low flow period (Fig. 6). Also, the January 28, 1997 spate resulted in the least concentration for these ions

Figure 8. Calcium (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Calcium in Solution

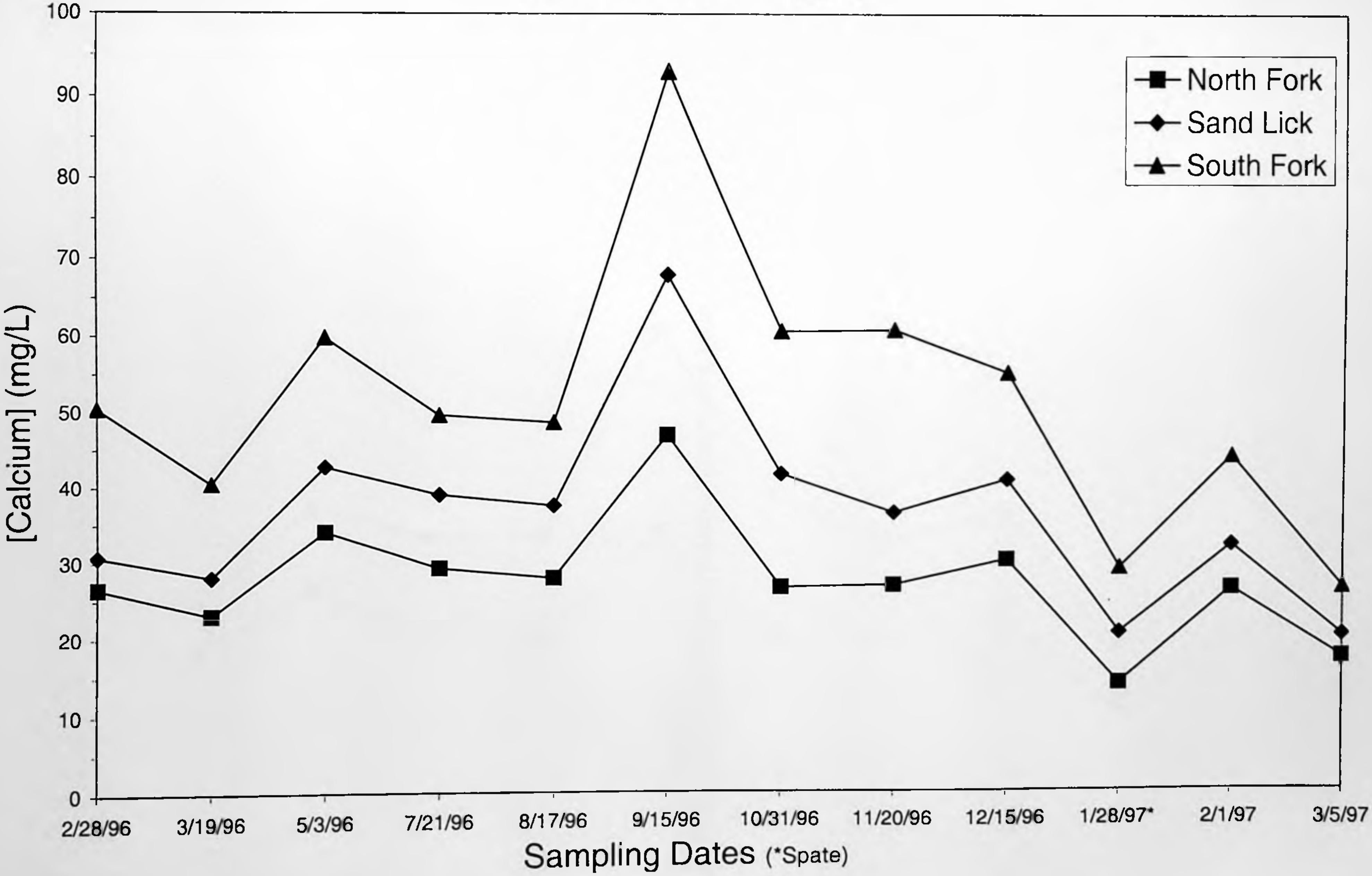


Figure 9. Magnesium (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Magnesium in Solution

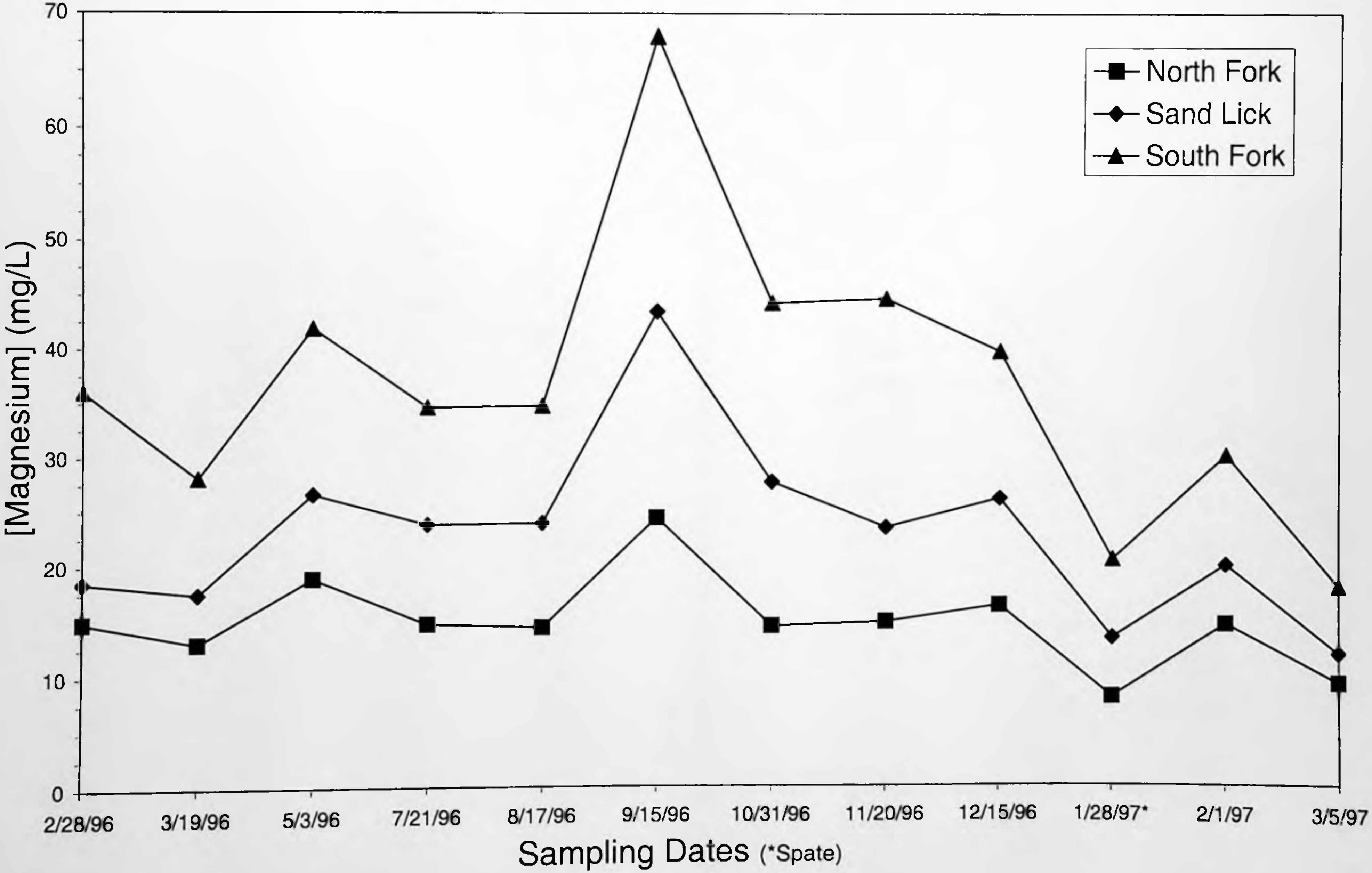


Figure 10. Potassium (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Potassium in Solution

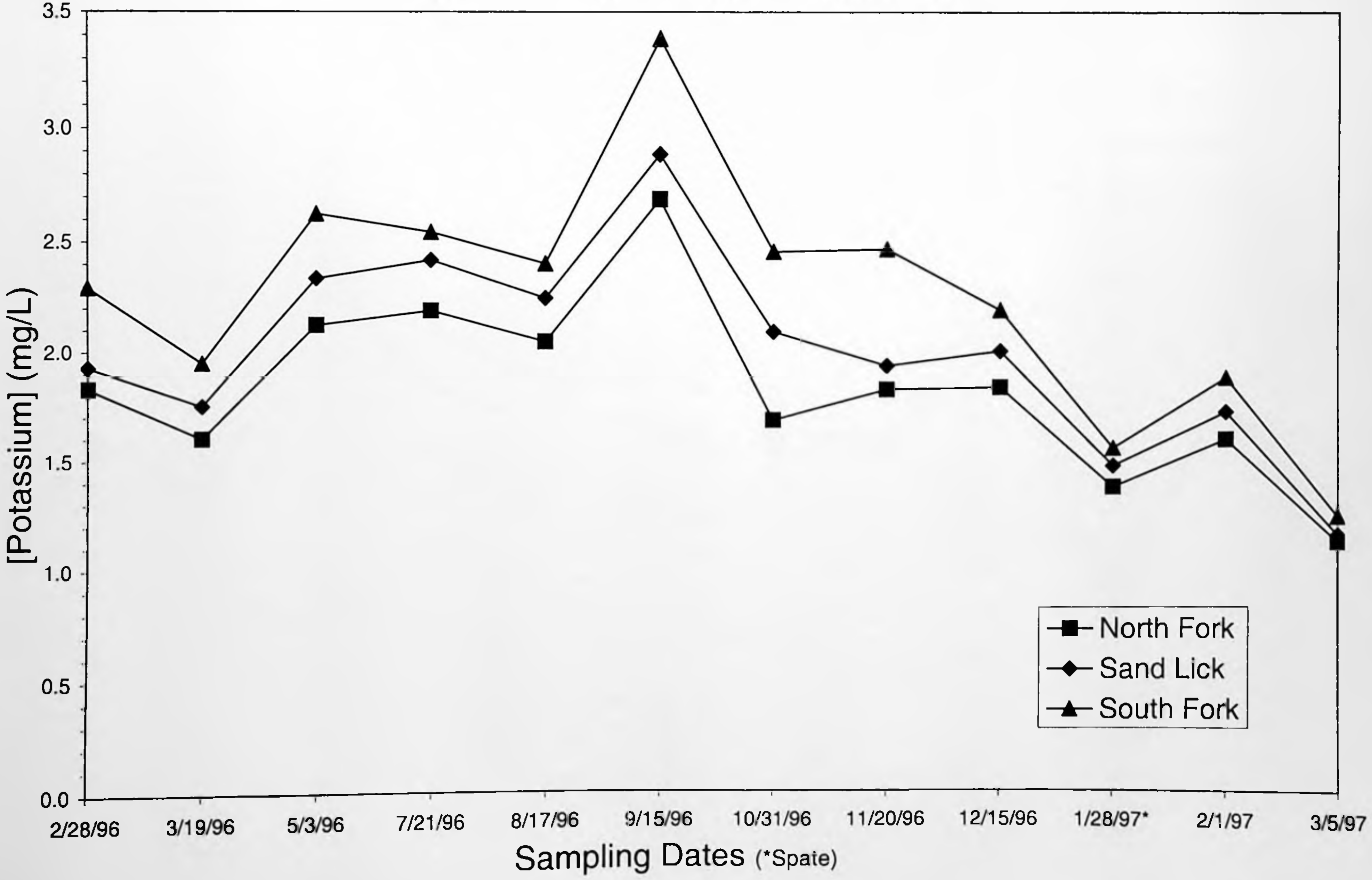
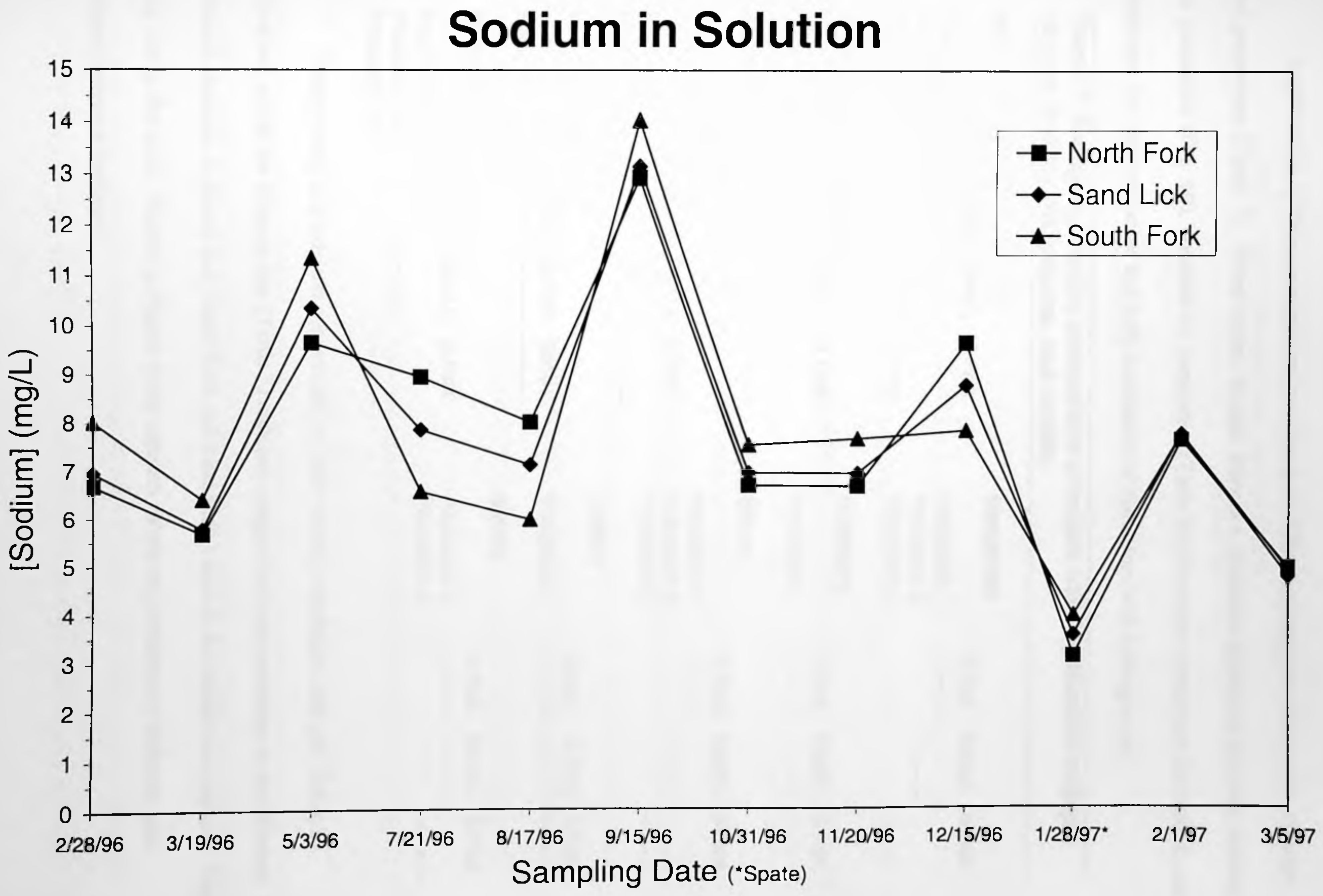


Figure 11. Sodium (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.


Sodium in Solution
North Fork
Sand Lick
South Fork
[Sodium] (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
2/28/96
3/19/96
5/3/96
7/21/96
8/17/96
9/15/96
10/31/96
11/20/96
12/15/96
1/28/97*
2/1/97
3/5/97
Sampling Date (*Spate)

Application of Duncan statistical test found no difference between stations for sodium and potassium (Table 7). There seems, though, there is a consistent difference between stations for potassium (Fig. 10). Pearson's r correlation (Table 8) showed no correlation for sodium and hydrogen ion concentration and little association of potassium with hydrogen ion.

Table 7: Sampling station comparison of means utilizing Duncan multiple ranges test for pH, cations, and sulfate.

PH

	N Fork	Sand L	S Fork
Population 1	-----------		
Population 2		-----------	
Population 3			-----------

Aluminum

	N Fork	Sand L	S Fork
Population 1	-----------		
Population 2		-----------	
Population 3			-----------

Calcium

	N Fork	Sand L	S Fork
Population 1	-----------	-----------	
Population 2			-----------

Iron

	N Fork	S Fork	Sand L
Population 1	-----------	-----------	-----------

Magnesium

	N Fork	Sand L	S Fork
Population 1	-----------		
Population 2		-----------	
Population 3			-----------

Manganese

	N Fork	Sand L	S Fork
Population 1	-----------		
Population 2		-----------	
Population 3			-----------

Potassium

	N Fork	Sand L	S Fork
Population 1	-----------	-----------	-----------

Silicon

	N Fork	Sand L	S Fork
Population 1	-----------		
Population 2		-----------	
Population 3			-----------

Sodium

	Sand L	N Fork	S Fork
Population 1	-----------	-----------	-----------

Sulfate

	N Fork	Sand L	S Fork
Population 1	-----------	-----------	
Population 2			-----------

Magnesium and calcium concentrations show strong correlation with pH (Table 6). However, while the Duncan test (Table 7) indicates magnesium concentrations to be different between stations, it shows that North Fork and Sand Lick values to be similar for calcium. This may not be the case. Notice in Figure 8 that calcium values are consistently different and ordered between stations.

Table 8: Pearson's r correlation of cations and sulfate with hydrogen ion concentration.

	Pearson's r
Aluminum	0.8357
Calcium	0.8150
Iron	-0.1409
Magnesium	0.8674
Manganese	0.8347
Potassium	0.5307
Silicon	0.8474
Sodium	0.0768
Sulfate	0.8065

Aluminum (Fig. 12), manganese (Fig. 13), and silicon (Fig. 14) show peaks for September 9, 1996 similar to those for calcium, magnesium, potassium, and sodium with an important difference. North Fork values remain consistent for these ions through the study while it is South Fork and Sand Lick values that peak. Notice, also, North Fork has a peak value for the January 28, 1997 spate for these cations. Sand Lick and south Fork have concentration depressions for aluminum and manganese during the spate. Silicon, though, shows an increase in Sand Lick during the spate while South Fork has a decreased value. Duncan testing (Table 7) shows that aluminum, manganese, and silicon all have significantly different values between each station. Pearson's r correlation (Table 8) shows these ions have strong correlations with hydrogen ion concentration.

Iron (Fig. 15) shows a very different concentration profile than the other cations. There is normally no significant difference between stations (Table 7). During the January 28, 1997 spate, there was a great increase. Like silicon, North Fork had the greatest concentration during this event. Both South Fork and Sand Lick showed spate increases but values are considerably less than North Fork's.

Iron samples also produced enigmatic findings for March 19, 1996, May 3, 1996, and July 21, 1996 samplings. Sand Lick has greater concentrations than either South or North Forks'

Figure 12. Aluminum (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Aluminum in Solution

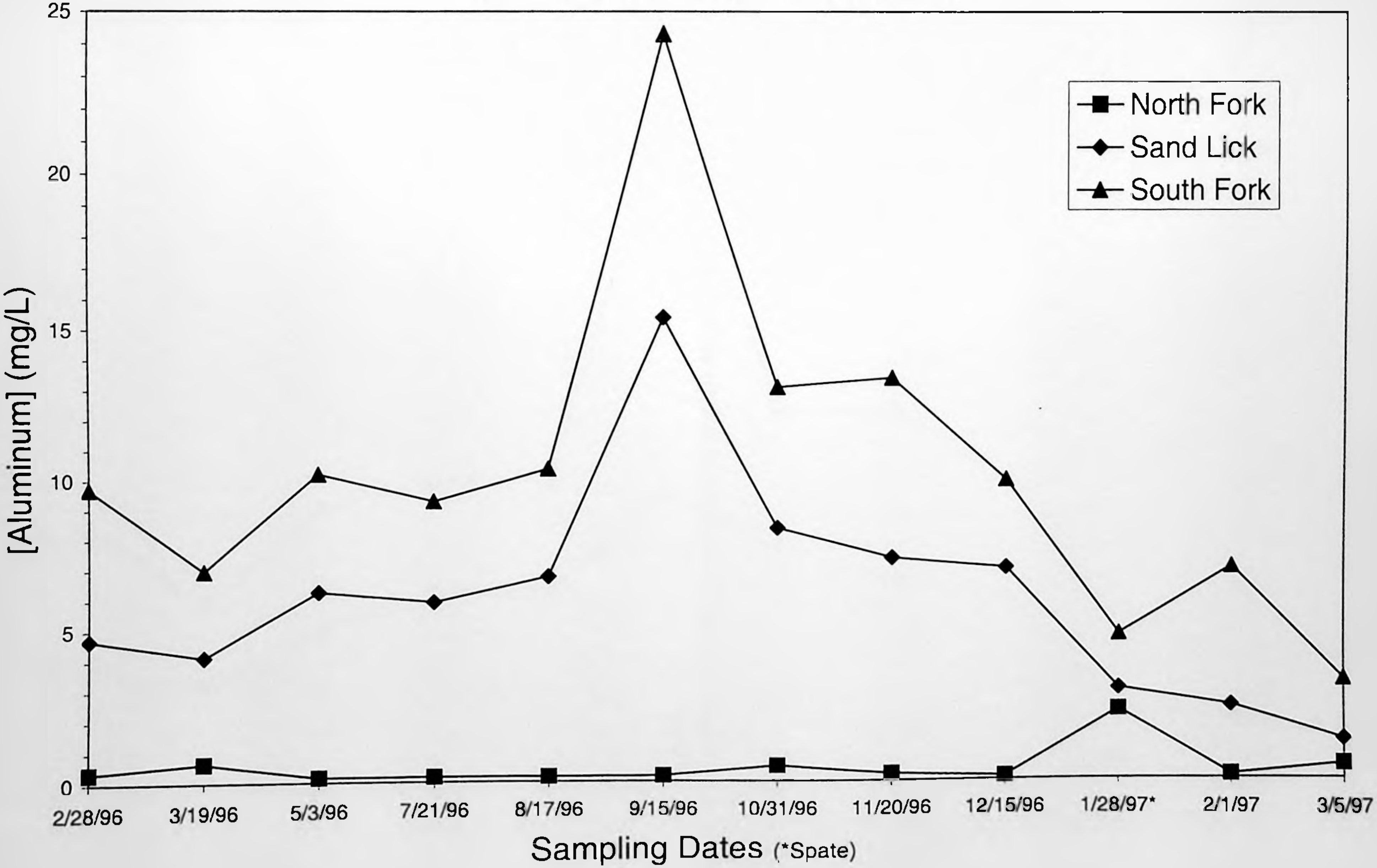


Figure 13. Manganese (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Manganese in Solution

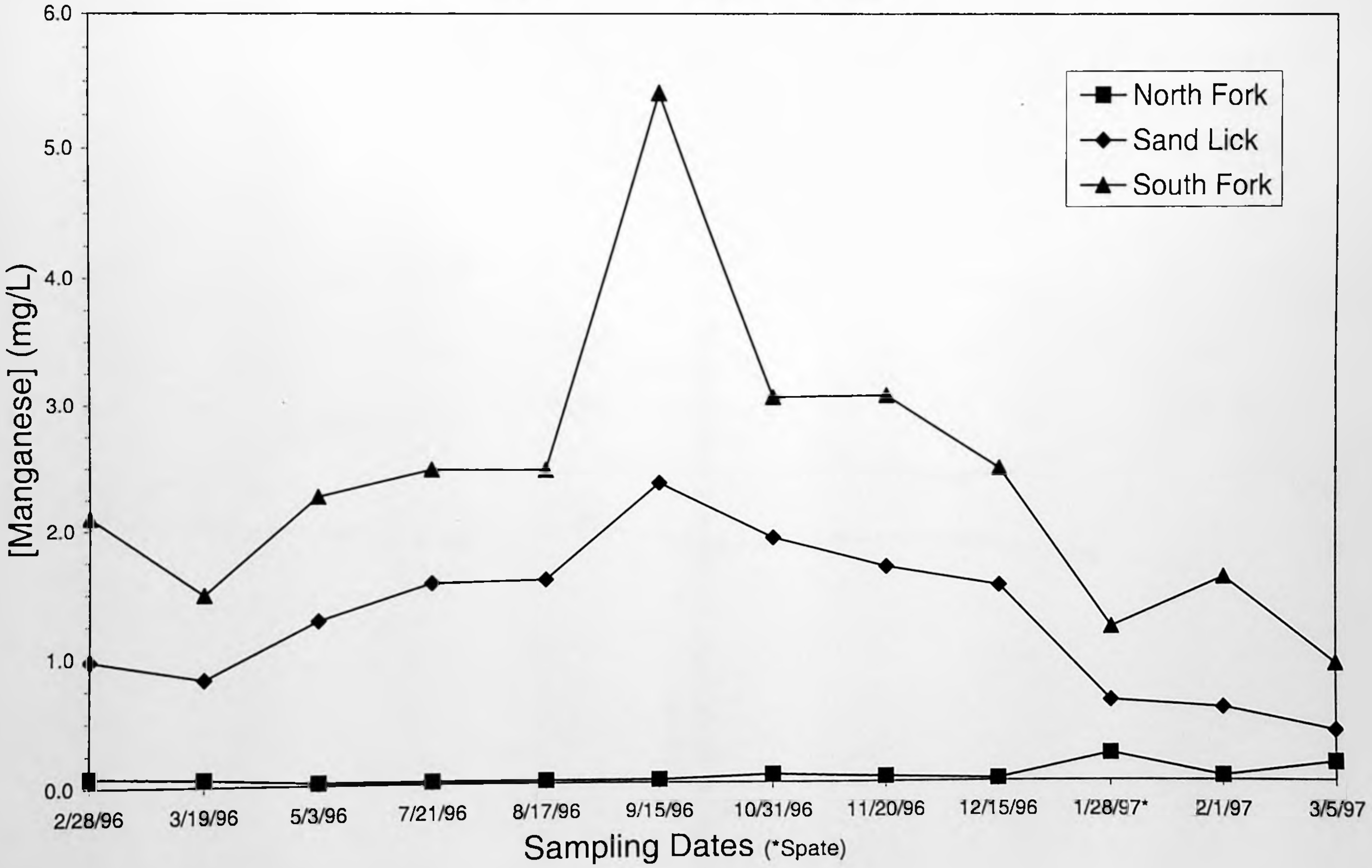


Figure 14. Silicon (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

Silicon in Solution

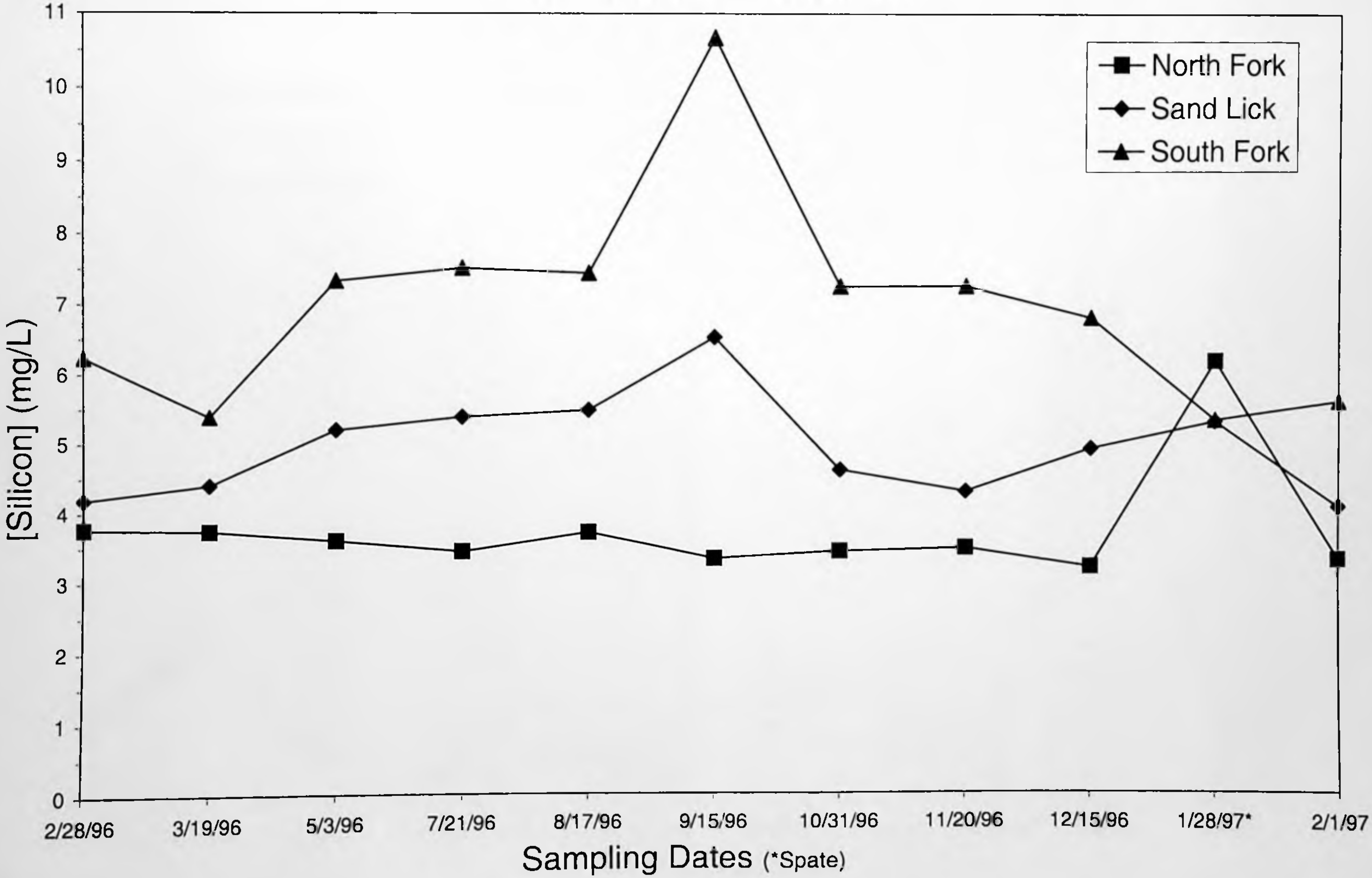
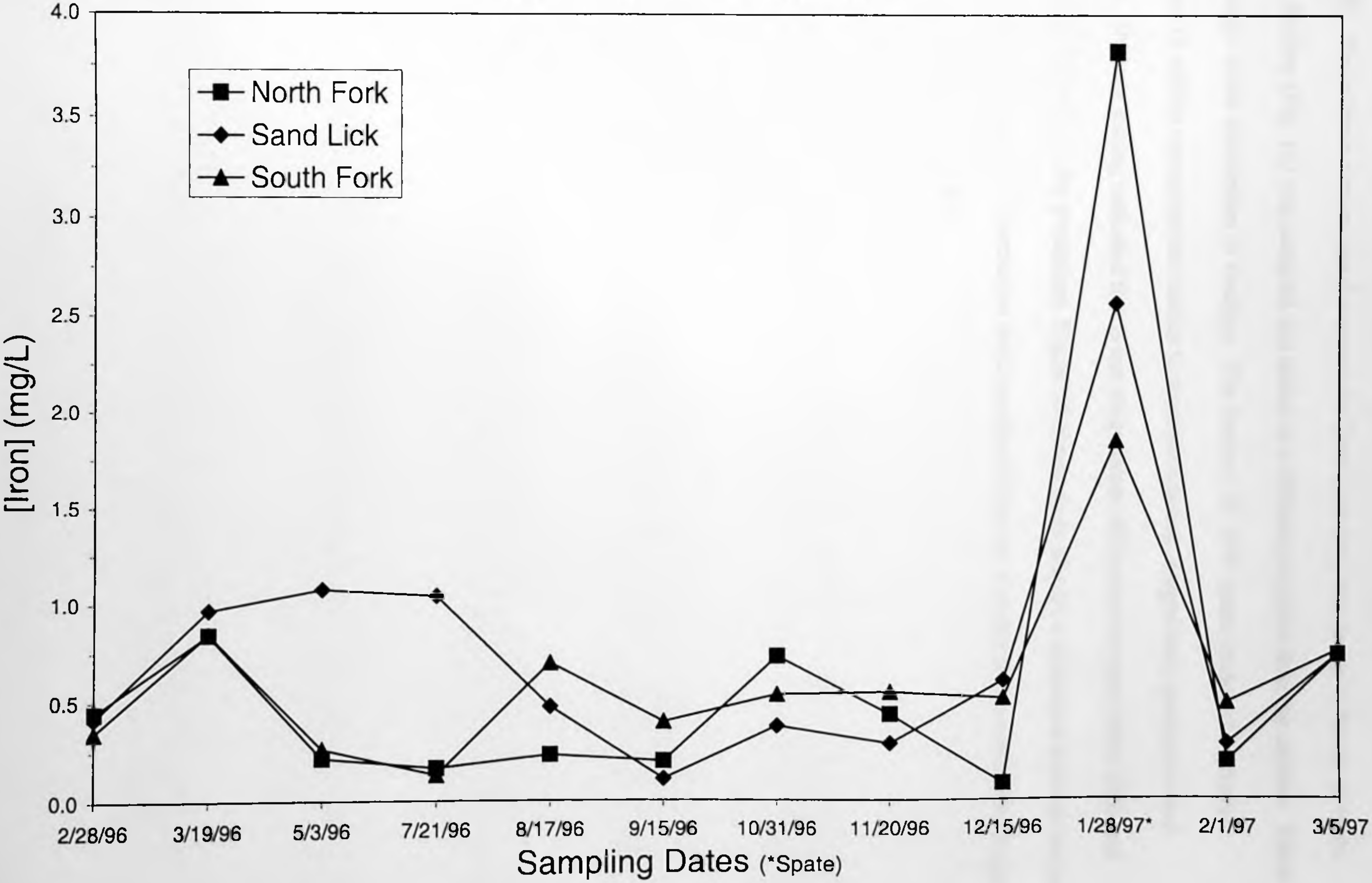


Figure 15. Iron (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.

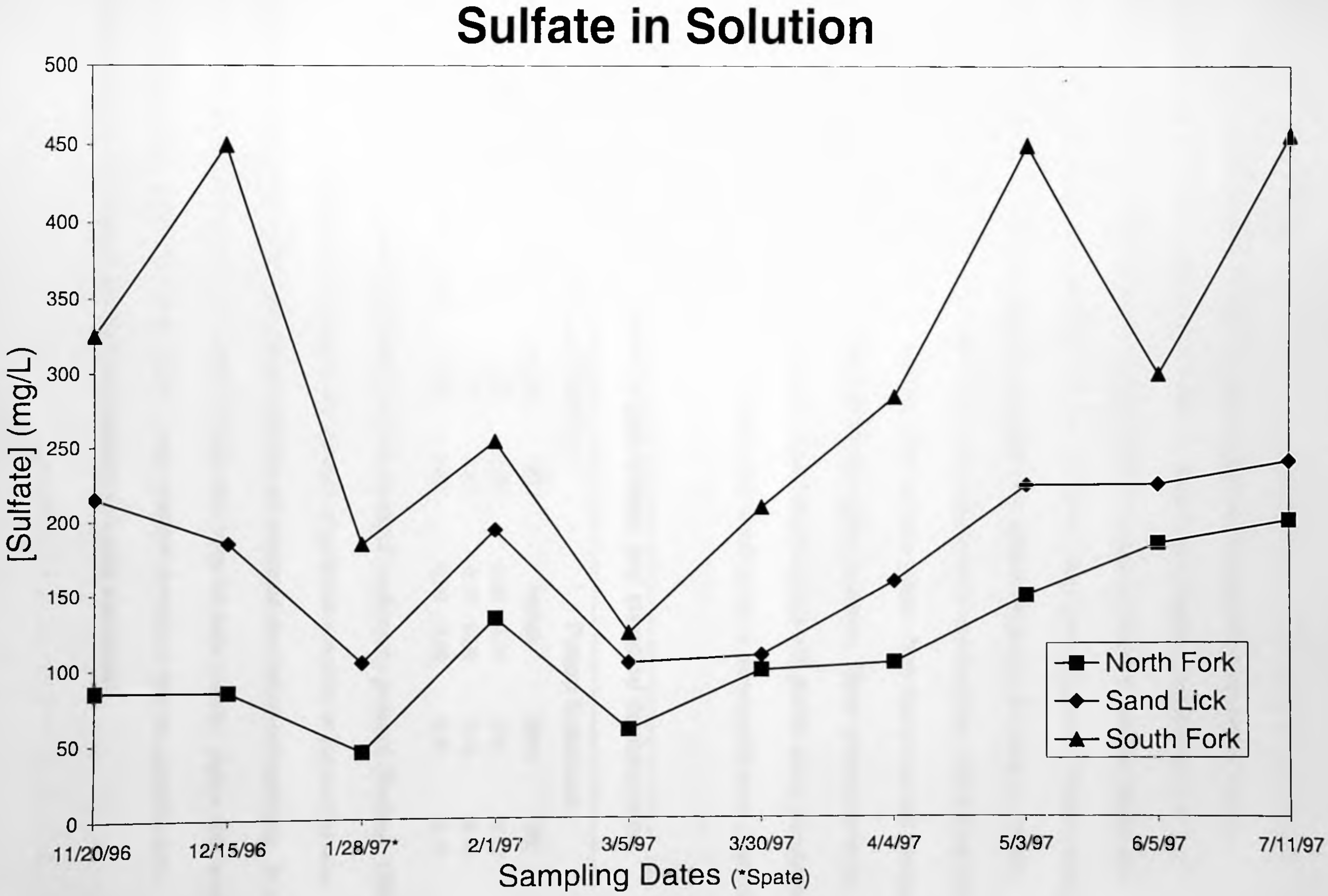
Iron in Solution



(Fig. 15). Since these streams are the source for Sand Lick iron, this seems to be out of order.

Sulfate (Fig. 16) was sampled and tested on a different schedule than the cations. There are, though, some similarities in findings. The January 28, 1997 spate produced a general reduction in sulfate concentration similar to those for calcium, magnesium, potassium, and sodium. Duncan testing indicated that is not a significant difference between North Fork and Sand Lick (Table 7). Like potassium, Figure 16 shows there may be a difference between station sulfate values. Pearson's r correlation indicates that sulfate has a strong relationship to hydrogen ion concentration (Table 8).

Figure 16. Sulfate (mg/L) in solution of streams at North Fork, Sand Lick, and South Fork stations.



Sulfate in Solution

SECTION C: BENTHOS

North Fork benthic samples yielded the greatest Shannon diversity index with the broadest range (Table 9; Appendix D, Table 1). Sand Lick's benthic samples had Shannon indices which were similar to those of North Fork's benthos and Duncan multiple ranges test supports this assertion (Appendix D, Table 1). South Lick had generally greater Pielou evenness indices and, again, a Duncan multiple ranges test was applied (Appendix D, Table 1). South Fork was consistently lower than these stations in both diversity and evenness. South Fork had no benthos in the March 19, 1996 collection, thus the zero values. Note that means and standard deviations are presented in Table 9 for general descriptive purposes. These samples cannot be pooled for statistical analysis because, as the multivariate analysis will plainly show, populations for each station change through time. To ignore this would result in pseudoreplication (Hurlbert, 1984).

Table 9: Biodiversity indices ranges, means, and standard deviations for benthos.

	Shannon Diversity			Pielou Evenness		
	Range	Mean	SD	Range	Mean	SD
North Fork	1.10 – 3.28	2.62	0.58	0.39 – 0.81	0.66	0.12
Sand Lick	1.25 – 3.11	2.43	0.52	0.47 - 0.90	0.76	0.10
South Fork	0.00 – 1.88	0.92	0.58	0.00 – 0.59	0.31	0.19

Several indices are suggested by the EPA for rapid biodiversity protocol (Barbour, 1999). They are generally descriptive counts or percentages of pollution sensitive or insensitive taxa (Table 10.) Again, means and standard deviations are presented descriptive comparisons. In no way is it implicit that samples are similar through time from the same station. Again, this would lead to pseudoreplication (Hurlbert, 1984). Large standard deviations indicate possible zero values for data. Percentages are also poor numbers to handle statistically.

Table 10: EPA suggested metrics for benthic samples, means, and standard deviations.

	North Fork	Sand Lick	South Fork
Richness:			
Number of taxa	16.8 (SD = 5.61)	9.8 (SD = 3.29)	7.9 (SD = 3.66)
Number of Ephemeroptera	67.5 (SD = 81.67)	2.1 (SD = 3.38)	0.1 (SD = 0.28)
Number of Plecoptera	69.6 (SD = 117.38)	5.8 (SD = 7.20)	2.1 (SD = 2.56)
Number of Trichoptera	50.6 (SD = 34.43)	11.2 (SD = 10.83)	6.6 (SD = 7.33)
Composition:			
Percent EPT*	66.2% (SD = 26.44%)	54.6% (SD = 15.57%)	6.5% (SD = 7.20%)
Percent Ephemeroptera	21.7% (SD = 17.65%)	5.8% (SD = 7.55%)	0.2% (SD = 0.79%)
Percent Chironomidae	26.3% (SD = 23.71%)	29.3% (SD = 22.31%)	74.5% (SD = 27.58%)
Trophic – Habitat:			
Number of Clingers	191.4 (SD = 170.72)	20.8 (SD = 14.64)	13.3 (SD = 11.20)
Percent Clingers	68.3% (SD = 25.88%	60.3% (SD = 25.47%	9.8% (SD = 9.49%)
Percent Filterers	21.5% (SD = 11.69%)	34.0% (SD = 23.28%)	4.9% (SD = 5.73%)
Percent Scrapers	22.8% (SD = 16.56%)	6.7% (SD = 7.89%)	0.6% (SD = 0.95%)

*EPT – Ephemeroptera, Plecoptera, and Trichoptera

A full data set for each sample is presented in Appendix D, Table 2. An example of different communities can be understood by the number of Plecoptera, 433, in North Fork for May 3, 1996. The previous sample, March 3, 1996, only had 49 Plecoptera and the following sample, July 21, 1996 had only one. This indicates that these communities have different structures with different numbers of different organisms.

General trends can be seen in Table 10 and verified in Appendix D, Table 2. North Fork has significantly greater numbers of taxa than Sand Lick or South Fork. Richness indicators show that North Fork is significantly less impacted than either South Fork or Sand Lick. Composition also shows that North Fork is a more pristine system with greater percentages of sensitive organisms and lower percentages of Chironomidae. There was a sampling, August 17, 1996, for North Fork that indicated benthos was 81.8% Chironomidae, a percentage closer to that of South Fork than North Fork. Trophic levels and habitats can be used as well. Percent clingers is a bit greater than percent EPT because it includes different groups outside these families, an important inclusion being family Simuliidae in order Diptera family. Simuliidae is found in clean waters and indicates nonpolluted waters by its presence, even though it is a fly.

Detrended correspondence analysis (DCA) is a type of multivariate analysis and was applied to the benthic samples. This statistic compares communities based upon taxa and their numbers. The seven greatest contributors were plotted and are shown in Figure 17. Undetermined Chironomidae (midge) taxa represent the point furthest to the right. A perlodid, *Isoperla spp.*, is represented by the upper left point. A nemurid stonefly, *Amphinemura spp.*, is represented by the lower left point. These taxa represent the furthest excursions of benthic community constituancy for the three stations.

General changes in each benthic community are shown in Figure 18. Notice that South Fork has by far the least excursion, thus the most consistent benthic community. The other two sites, North Fork and Sand Lick, changed a great deal during the study, indicated by relatively large excursion vectors.

North Fork had the greatest changes in benthic communities, well seen in Figure 19. Notice that its benthic community changes move through the triangle defined by the major species (Fig. 17). Early in the study, the stonefly taxa previously noted, are very important to its community, but that it has a major chironomid component as shown by the august 17, 1996 sampling date (data point 4 on the graph). Also, it starts to trend roughly along a line from family Chironomidae (close to data point 4) and family Perlodidae (data point 10). There are oscillations along this axis as well.

Sand Lick follows a trend similar to that of North Fork (Fig. 20). An exception is that on the initial sampling date (data point 1), it beginning location is near that of family Chironomidae location. However, notice its lowest point (data point 2) is the same as North Fork's and that

Figure 17. Taxa which are the major contributors to benthic community structure and their relative positions determined by DCA analysis.

Major Contributors to Benthic Community Structure

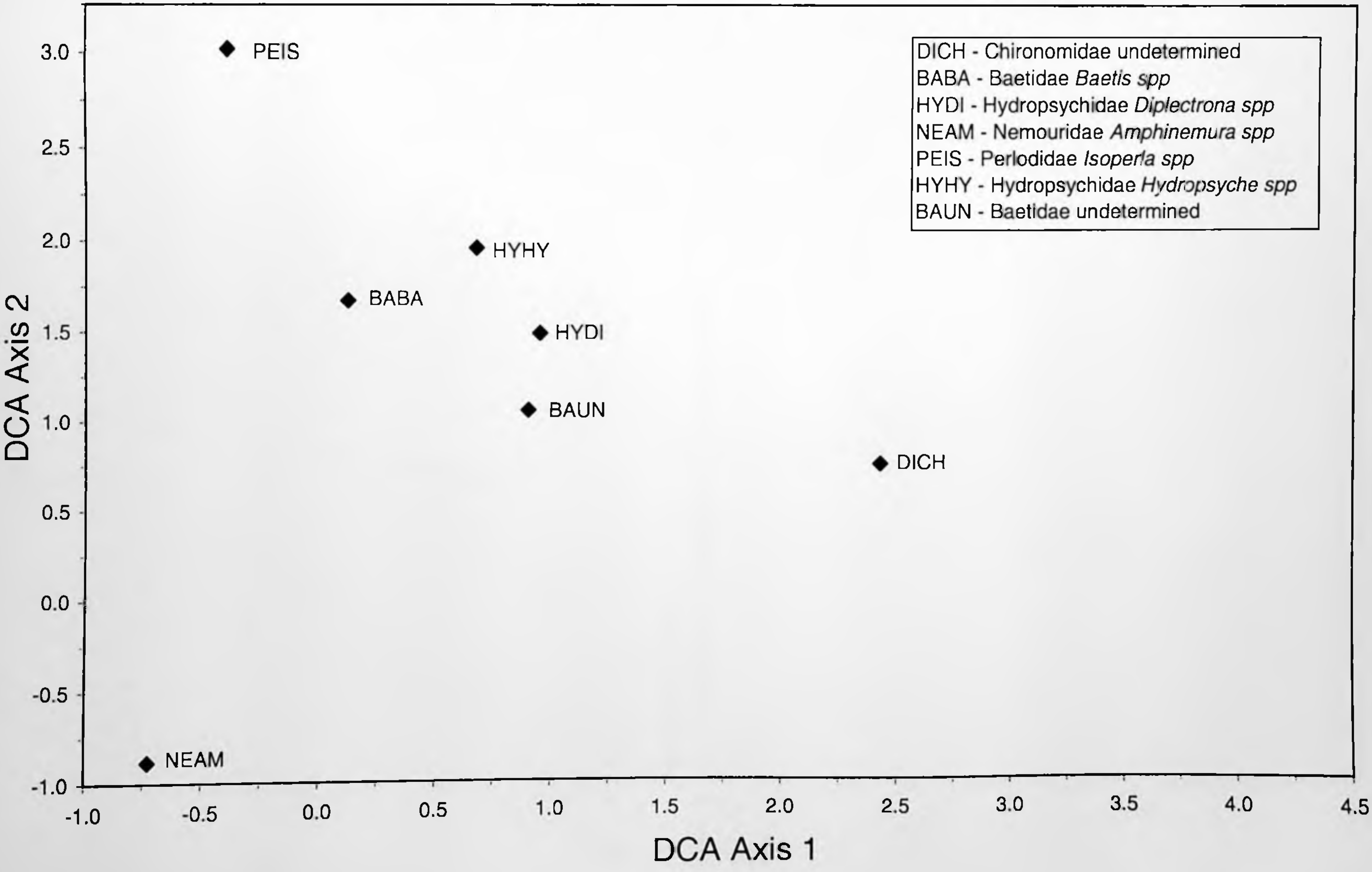
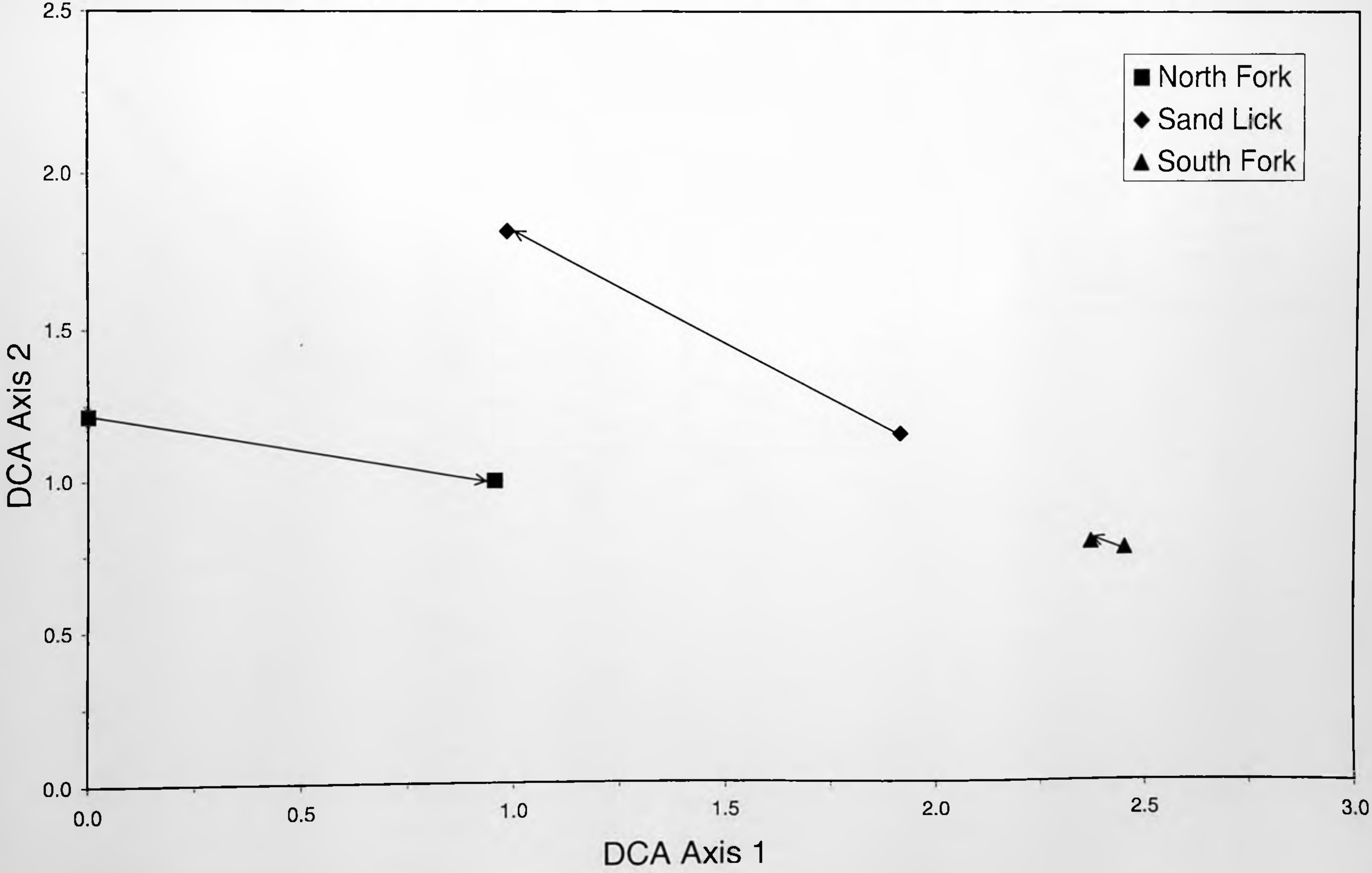


Figure 18. DCA analysis of general benthic community shifts during the study. Initial and final positions plotted.



DCA Analysis of Benthic Community Shifts During Study

Figure 19. DCA analysis of North Fork benthic community changes.

DCA Analysis of North Fork Benthic Community Changes

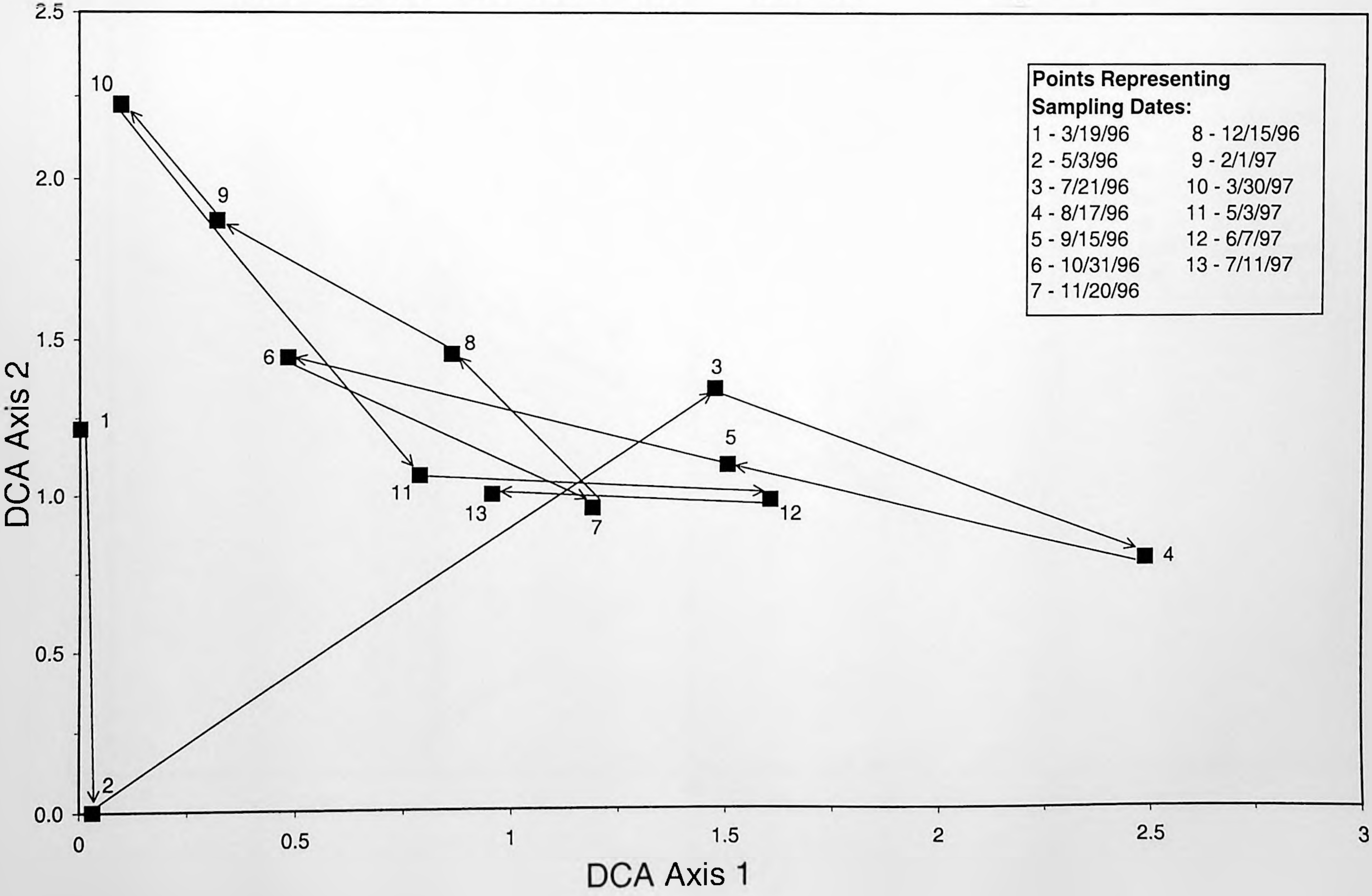
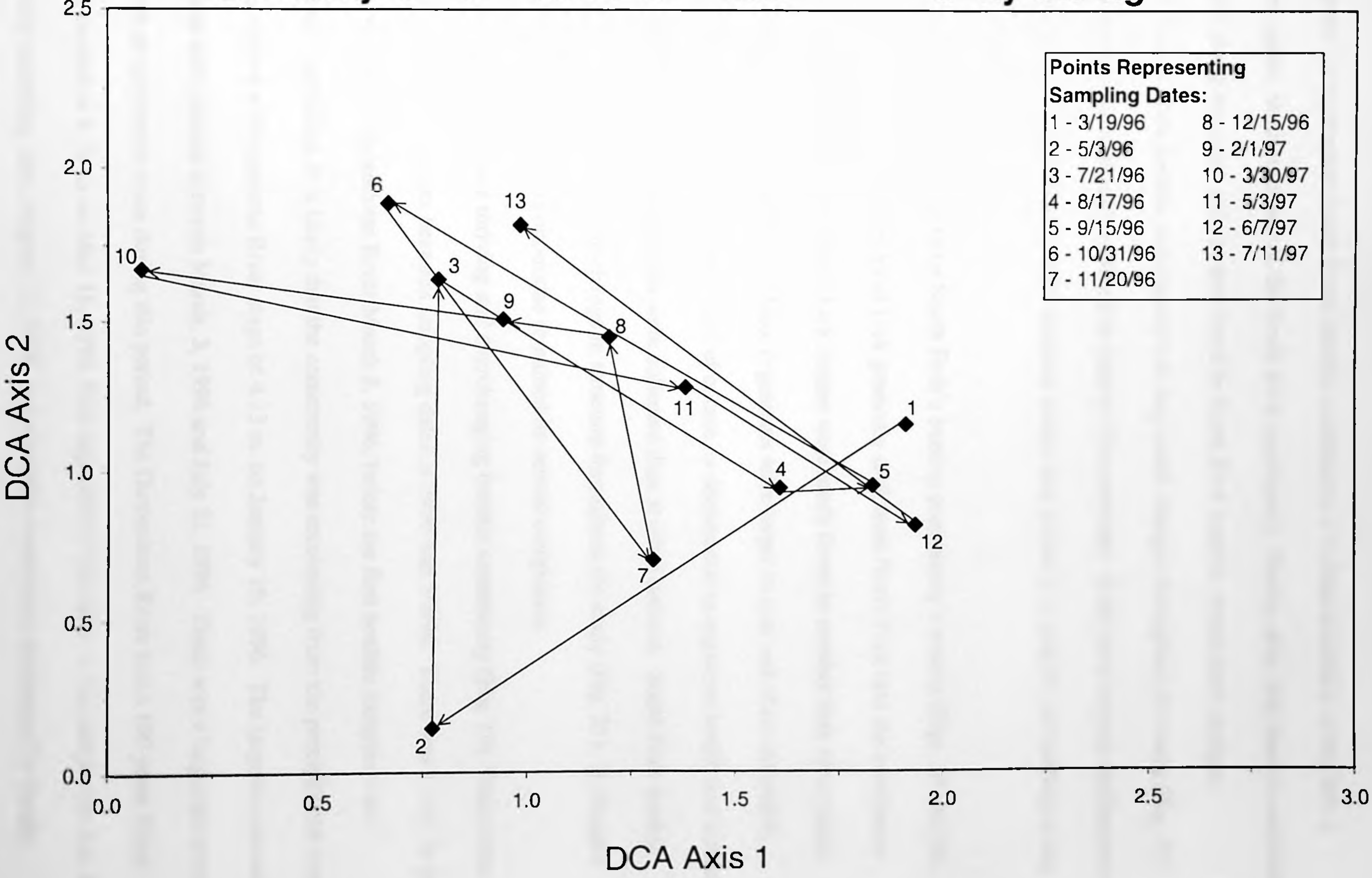


Figure 20. DCA analysis of Sand Lick benthic community changes.



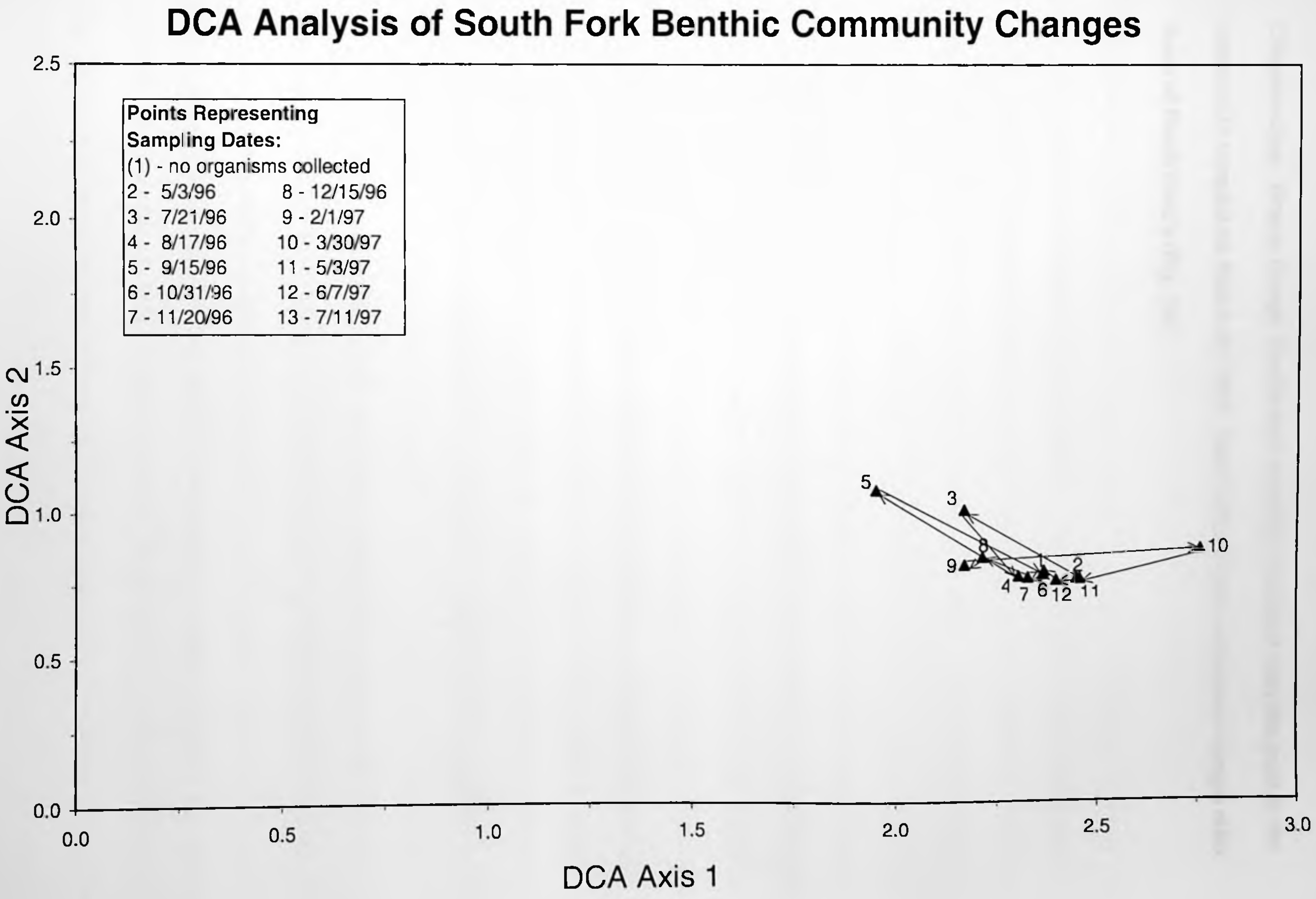
DCA Analysis of Sand Lick Benthic Community Changes data point 10 represents South Forks benthic community's furthest excursion to the left; a pattern, again, similar to that of the North Fork community. Notice, also, that there is oscillation roughly along the same axis as that found in North Fork benthic community changes.

South Fork benthic community had very small changes throughout the study (Fig. 21). Its community was strongly defined by family Chironomidae. It did have several oscillations in its community type, like both other stations; notice data points 3, 5, and 10, but nothing to any great degree.

North Fork appears to be South Fork's benthic community's source (Figs. 19 and 20). This indicates that benthos in Sand Lick generally drift from North Fork into the confluence mixing zone. Benthos from Sand Lick station were much fewer in number than either other stations (Appendix IV, Table 2). Also, organisms were larger in size and often covered in aluminum hydroxide precipitate. This, of course, is detrimental to organism health and indicates why consistently fewer organisms were collected than at other stations. South Fork benthic community showed very little change in structure throughout the study (Fig. 21). It changed somewhat but family Chironomidae remained its central component.

North Fork had a thriving and everchanging benthic community (Fig. 19). There were large community changes between sampling dates 3/19/96 and 5/3/96. There was a 2.41 m spate (Table 4) on the Guyandotte River March 8, 1996, before the first benthic samples were collected. However, it is likely that the community was recovering from the precipitation event which caused a Guyandotte River stage of 4.13 m. on January 19, 1996. The largest community structure shift occurs between March, 3, 1996 and July 21, 1996. There was a large rain event causing an enormous spate during this period. The Guyandotte River had a 100 years flood which peaked at 4.36 m on May 16, 1996. Few organisms were taken in the sample for that date. The next sampling date, August 17, 1996, had a benthic community dominated by family

Figure 21. DCA analysis of South Fork benthic community changes.



DCA Analysis of South Fork Benthic Community Changes

Chironomidae. Notice, though, that the next samplings oscillated from this point to the community sampled on March 30, 1997. Sand Lick's benthic community changes echo those of North Fork's (Fig. 20).

CHAPTER VIII

DISCUSSION

CHEMISTRY

Acidity is the driving force which defines this ecosystem. This is shown by the ions which have a strong Pearson's r correlation to hydrogen ion concentration (Table 4). These ions are aluminum, calcium, magnesium, manganese, silicon, and sulfate. Absent from this list are potassium, sodium, and, notably, iron.

Iron hydroxide precipitates the 400m from the acidic seep to the confluence. Hamrick and Ghosh (1996) found that iron precipitates for only 300m. Dissolved iron in south Fork was generally similar to North Fork in concentration (Fig. 15). A concentration peak during the January 8, 1997 spate is the most prominent feature for soluble iron. This peak also shows how aquifers perched within fractured coalbeds in North Fork's watershed are flushed during high precipitation. Thus, there is an enormous increase in dissolved iron at the North Fork station. This peak also indicates that iron precipitates much further upstream in South Fork. it is only during high flow that water with greater iron concentration is washed downstream to the sampling site.

There is a more remarkable feature of Figure 15. Iron concentrations in Sand Lick for march 19, 1996, May 3, 1996, and July 21, 1996 are higher than those for the other stations. Iron coming out and remaining out of solution upstream in South Fork helps create the unusual situation found at Sand Lick. Photoreactivity causes iron to resolubilize during the day (Kimball et al., 1994). South Fork, the acidic drainage, is surrounded by forest canopy throughout its reach. Thus, once iron precipitates, there is not enough sunlight to break up precipitate lattices and reintroduce iron into solution. Also, critical pH for ferric solubility is 4.3 (Gray, 1996). South Fork pH is quite often at, or above, 4.3 (Appendix I, Table 1), so iron will not resolubilize by simply dissolving. Therefore, iron has precipitated out of solution and remains out of solution until acidic drainage reaches the South Fork sampling station. this also suggests why iron data does not show a correlation with acidity (Table 6).

Aluminum hydroxide can precipitate over 200m to the Guyandotte River which creates a very large recovery zone throughout Sand Lick. Hamrick and Ghosh (1996) determined that aluminum hydroxide precipitates for 800m downstream from the confluence. Aluminum has been determined to be the most significant inorganic compound affected by acidity (Hall and Likens, 1981). Aluminum does not come out of solution in the iron complex flocs in South Fork (Kimball et al., 1994). It causes a remarkable aluminum hydroxide precipitate at the confluence of South Fork and North Fork. Aluminum hydroxide floc precipitates immediately upon pH increasing above 5.2 (Gray, 1996). This the case for the confluence where pH hovered at just above 5.2 throughout the study (Appendix I, Table 1).

Hamrick and Ghosh (1996) found that manganese and silicon mimic iron. Manganese and silicon are not photoreactive so their activity actually more closely mimics aluminum than iron. Most importantly, flushing during the January 8, 1997 spate has concentration increases of manganese (Fig. 13) and silicon (Fig. 14) as well as iron and aluminum. This indicates spate flushing of the watershed.

Sulfate activity is what is expected. Its solubility is strongly correlated to hydrogen ion concentration (Table 6). Spate concentration reverses this correlation, however. Sulfates' concentration is high during low flow and low during high flow. This indicates a conservative, rather than reactive, concentration based on flow volume. This indicates that sulfate leaves the watershed fairly consistently based on solubility at the solutions' pH.

Calcium, magnesium, potassium, and sodium concentrations are based on flow volume (Figs. 8, 9, 10, 11). Calcium and magnesium solubilities are strongly correlated to hydrogen ion concentration (Table 6). Potassium solubility is marginally correlated to hydrogen ion concentration. Sodium solubility is not correlated with hydrogen ion concentration.

Foam was a notable feature of the Sand Lick station. There was a persistent foam found around varying objects in the stream at varied amounts. This is probably a result of decreased surface tension caused complex reactions between aluminum and DOC at low pH (Hall et al., 1987). This effect was seen by Hall et al. upon addition of $AlCl_3$ and HCl to a stream during a study.

BENTHOS

Benthic indices and analyses show the complex nature of studying and interpreting a lotic benthic community. Lancaster et al. (1996) pointed out the weakness in most studies is a short study period, usually less than one year and recommends 10 to 100 year studies. This study did not last 10 years but it does show the drastic benthic community changes which occur in relatively short (less than one month) periods. Nelson and Roline (1996) state that classical inferential statistics cannot be used to demonstrate recovery caused by decreased metal concentration because of inherent problems with pseudoreplication, inability to randomly select samples from sites and lack of independence between sites in the same river. These problems are addressed by using multivariate analysis, in this case DCA

DCA

Detrended correspondence analysis (DCA) analyzes species composition by comparing dimensionless scores (Gilliam et al., 1995). DCA measures actual species changes with respect to environment (Lancaster et al., 1996). Multivariate analysis makes no assumptions about species' tolerance or mechanisms of change and subtle or unexpected changes in species abundance are not masked by a need to describe a site as a single value. DCA ensures that similar ecological differences will be expressed as similar distances in ordination space. Actual species changes with respect to time will be detected and expressed.

Multivariate analysis application and many samples over a long period will give the best indication of benthic community composition and changes which typify a particular system. The greatest changes in benthic community are indicated by greatest distances between data points. The greatest excursions between data points, thus the greatest variations in community structure, come after spate events. Multivariate analysis gives an analysis that is descriptive while not falling into the trap of pseudoreplication. It presents changes in benthic communities from the same sample stations and makes it possible to compare one set of changes for a station to those of another.

It is easily seen that North Fork's benthic community is based primarily upon the families Baetidae (BABA, BAUN) and Hydropsychidae (HYDI, HYHY) (Figs. 17, 19). Baetidae is a mayfly family with a genus, *Baetis*, which is tolerant to increased metal concentrations in solution (Roline, 1988). Hydropsychidae is a caddisfly family which tolerant of acidity (Arnold et al., 1981; Letterman and Mitsch, 1978: Roline, 1988; Winger, 1978). Chironomidae is a diptera family that is an important community member. The other two major taxa are stoneflies, *Isoperla* and *Amphinemura*. *Isoperla* is moderately acid tolerant and metals tolerant (Arnold, et al., 1981; Roline, 1988). *Amphinemura* is in a family, Nemouridae, which has acid tolerant genera (Arnold et al., 1981). Spates change benthic community composition. The greatest change of North Fork community is after a one hundred year record flood on the Guyandotte River. This community was solidly based upon family Chironomidae, in great numbers. However, the aforementioned Ephemeroptera, Plecoptera, and Trichoptera orders provided the resilient headwater taxa that generally provided structure for this everchanging community.

DCA analysis shows that Sand Lick mimics North Fork community's composition and variations but with changes which are never as great (Figure 20). This implies that Sand Lick benthic community is supplied by drift organisms from North Fork. Sand Lick is the mixing zone of acidic South Fork and neutral North Fork waters. The organisms that reside here, however, do not thrive here. They do not ever occur in numbers (Appendix D, Table 6) and tend to be large enough to survive the beginnings of aluminum hydroxide precipitant covering them. It is not know if they are able to drift enough to escape the precipitant threat.

South Fork has a very narrow, acid driven benthic community based on family Chironomidae (Figure 21). this community is very stable and can have great numbers of organisms (Appendix D, Table 6). At times, it can have Trichoptera or Plecoptera taxa present (Appendix D, Table 2). They do not occur in numbers and are from acid tolerant families Hydropsychidae (mayfly) or Perlodidae (stonefly).

EPA INDICES

Chessman and McEvoy (1998) concluded that individual taxa vary widely on sensitivity depending on the disturbance. They suggest a suite of indices targeted for a specific impact such as dams, municipal wastewater, or metals from mine drainage. As long ago as 1952, Parsons recommended that each stream be treated individually. Barbour et al. (1999) also suggest multiple indices which can be adapted and attenuated for the particular system and area of concern. Winner et al. (1980) suggest that Chironomidae percentage would be a good indicator of heavy metals. This has been incorporated by the EPA (Barbour et al., 1999)

Voshell (1980, 1981) stated that an indicator species method was too rigid to apply to bioassessment. He proposed a correlation of relative abundance and aspects of organisms' ecologies as having greatest potential for accuracy. Vaughn et al. (1978) represents researchers who made general benthic community determinations. They found that undisturbed streams had communities of about 70 percent Ephemeroptera whereas disturbed sites only had about 40 percent and did not recover. Acidity eliminated herbivorous Plecoptera, *Psephenus* Coleoptera, and eliminated periphyton grazers. However, filter feeders and Trichoptera were unaffected. Poulton et al. (1995) found that best indicators of relative impact were taxa richness, EPT richness, chironomid richness, percent dominant taxon density. These are concepts that the EPA has utilized in its rapid bioassessment protocol (Barbour et al., 1999). There are numerous studies that have provided benthic information that lead to EPA analyses.

Order Ephemeroptera is usuallyconsidered to be universally sensitive to acidity (Arnold et al., 1981; Fiance, 1977; Nichols and Bulow, 1973; Tomkiewics and Dunson, 1977; Winner et al., 1980). Bell (1971) found that some taxa were somewhat acid tolerant but generally sensitive to acidity during emergence. Metals sensitivity is shown by *Ephemerella subvaria* (Warnick and Bell, 1969) and *Rhithrigens hageni* (Nelson and Roline, 1996). However, *Stenonema* showed acid tolerance (Winger, 1978) and *Baetis* showed metals tolerance(Roline, 1988). *Ephemerella cornuta* tolerated some acidity (Arnold et al., 1981).

Order Plecoptera has a broad range of varying acidity tolerance (Bell and Nebecker, 1969). *Isogenus* (Letterman and Mitsch, 1978), *Nemoura* (Tomkiewicz and Dunson, 1977), *Nemoura* (Weed and Rutschky, 1972), *Ptilostomos* (Warner, 1971), Perlodidae, and Peltoperlidae (Arnold et al., 1981) were found to be tolerant of moderate acidity. *Alloperla* and *Isoperla* were found to be metal tolerant as well (Roline, 1988). Generally sensitive to acidity is shown by *Allonarcys* (Vaughn et al., 1978; Weed and Rutschky, 1972), *Peltoperla* (Vaughn et al., 1978), and *Acroneuria* (Weed and Rutschky, 1972). Winger (1978) found Plecoptera to be generally acid intolerant whereas Vaughn et al. (1978) found that it was the herbivorous Plecoptera that were acid sensitive.

The order Trichoptera is found through a broad range of pHs (Bell, 1971). Ecnomidae (Chessman and McEvoy, 1998) and *Rhycophila* were found to be metals sensitive (Letterman and Mitsch, 1978; Roline, 1988). Acid tolerant taxa are *Cheumatopsyche* (Parsons, 1968; Winger, 1978), Hydropsychedae (Arnold et al., 1981; Letterman and Mitsch, 1978; Roline, 1988; Winger 1978), *Ptilostomais* (Nichols and Bulow, 1973; Tomkiewicz and Dunson, 1977). Several researchers found trichopterans to be acid tolerant (Arnold et al., 1981; Bell and Nebecker, 1967; Weed and Rutschky, 1972) or tolerant to minimal or moderate acidity (Winner et al, 1980). Other researchers found trichopterans to be acid sensitive (Nichols and Bulow, 1973; Tomkiewicz and Dunson, 1977).

Coleoptera had a marked difference in acid tolerance of two families. Psphenidae (*Psphenus*) is acid sensitive (Tomkiewicz and Dunson, 1977; Vaughn et al., 1978). Dytiscidae, conversely, is found in acidic waters (Nichols and Bulow, 1973; Warner, 1971; Weed and Rutschky, 1972). Winger (1978) noted that Coleoptera were sporadically collected in his study.

Megaloptera are generally considered acid tolerant (Winger, 1978). Specifically, *Chaoloides* (fishfly) (Nichols and Bulow, 1973). Corydalidae being metal tolerant (Chessman and McEvoy, 1998). *Sialis* (alderfly) being most sited as acid tolerant (Arnold et al., 1981; Hendry, 1978; Parsons, 1968; Roback and Richardson, 1969; Tarter and Woodrum, 1972; Warner, 1971).

Hemiptera are more difficult to categorize. Notonectidae, Corixidae (Hendry, 1978) and Gerridae (Arnold et al., 1981 and Hendry, 1978) are all acid tolerant. Chessman and McEvoy (1998) found Hydrometridae and Notonectidae to be tolerant of high metals concentration as well. However, they found that Veliidae were not metal tolerant. Winger (1978) noted that Hemiptera were found sporadically in his study.

Chironomidae (midges) typify polluted, repopulated disturbed, stressed and unrecovered stream reaches (Gray, 1998; Hall et al., 1980, Hendry, 1978; Lackey, 1938, 1939; Letterman and Mitsch, 1978; Nichols and Bulow, 1973;Tomkiewicz and Dunson, 1977; Warner, 1971; Winner et al.; 1980). Diptera (true flies) are generally found to be tolerant of pollution (Nichols and Bulow, 1972; Parsons, 1968; Weed and Rutschky, 1972). Hall et al. (1980) notes specifically Tipulidae, Ceratopogonidae and Chironomidae as acid tolerant. Notably, however, Simuliidae (black flies) are sensitive to acidity and metals (Chessman and McEvoy, 1998).

EPA suggested indices (Barbour et al., 1999) echoes DCA analyses. An advantage is to see actual counts of taxa and the EPT taxa presented as a number (Appendix D, Table 2). A concrete representation of generally sensitive taxa can be reported. This, however, can be overcome by simply reporting counts with multivariate analysis data (DCA) or presenting the data set, as in this study (Appendix D, Table 6). Percentages, however, obscure the picture somewhat as does the Shannon diversity and Pielou evenness indices. Notice that Sand Lick has reasonably god percentages for sensitive taxa. This is misleading which is obvious when compared to actual counts.

SHANNON AND PIELOU INDICES

The Shannon index is interpreted generally as indicating clean water for values greater than three (Dills and Rogers, 1974; Weed and Rutschky, 1972). Moderate pollution results in values between one and three. Values less than one indicate severely polluted waters. Shannon diversity increases as stream order increases (Dills and Rogers, 1974). Shannon diversity can paradoxically produce a fairly high species diversity index even under polluted conditions in a stable environment (Moon and Lucostic, 1979).

North Fork had a mean Shannon index of about 2.6 (Table 6). Four determined indices were greater than three. Sand Lick had two Shannon indices greater than three with a mean of 2.4. South Fork had a mean of 0.92 with eight values less than one and five greater than one. Shannon indices indicate that North Fork is somewhat polluted, Sand Lick is moderately polluted, and South Fork severely polluted. It is important to recall that means were used for description, not for analyses. These values changed drastically between samplings. Different benthic communities were sampled indicated by DCA analysis.

Sand Lick had a greater overall Pielou evenness index than North Fork, suggesting that Sand Lick had a more stable community and greater diversity than North Fork. Duncan multiple ranges test indicates no difference between Sand Lick and North Fork benthic communities. This indicates that Sand Lick and North Fork have the same level of impact.

There are problems with the Shannon and Pielou indices. A reason there has been so much research looking for relevant, descriptive biotic indices. In this study, a great difference in numbers of organisms and Sand Lick is a mixing zone where aluminum hydroxide precipitates and harms benthos. The Shannon index will often indicate low diversity in some pristine waters (Voshell, 1980). Importantly, the Shannon index never gives an unbiased approximation of diversity because it is based only on the number of taxa collected (Dills and Rogers, 1974).

SPATES

Water percolates through fractured stratigraphy and comes to reside in Pottsville series coal strata which overlie impermeable clays (Borchers et al., 1991; Outerbridge, 1987). These structures allow water to become acidic and bring about increased metals concentrations (Chessman and McEvoy, 1998). Precipitation events cause spates which are definitive of small order headwater streams. Resident water is flushed from these coal seams during precipitation events, creating a different chemical profile for spate flows than that which typifies normal flow. Aluminum is the most significant inorganic compound effected by increased acidity (Hall and Likens, 1981). Aluminum magnifies negative pH affects. In most streams, pH and aluminum covary. The predominant form of aluminum can differ due to speciation and complexation with other solutes, especially dissolved organic carbon (DOC) (Mulholland et al., 1992). Higher monomeric aluminum leads to greater toxicity. Aluminum concentration is the best predictor of spate associated fish mortality (Baker et al., 1996) which indicates that it may also be the best indicator for macrobenthos mortality (Havas and Rosseland, 1996). Natural organic acids (ligands), or humic acids, neutralize aluminum toxicity (Havas, 1981; Havas and Rosseland, 1995). Water hardness (calcium and magnesium in solution) also decreases acidity and aluminum toxicity effects. Aluminum toxicity also increases with elevation or decreased temperature (Ridley, 1997). Thus, level of acidification, temperature, dissolved calcium, dissolved aluminum, and presence of natural organic acids determine acute toxicity during a spate.

Aluminum, iron, manganese, and silicon all had concentration increases during spate flow in North Fork. There was also a precipitous drop in pH. South Fork and Sand Lick both have higher than normal calcium and it is the dominant cation (Appendix C, Table 1; Table 3). There was no noticeable organic acids, all stations having unstained water and unprocessed leaves found in South Fork and Sand Lick. Aluminum concentration was very high, ten times natural waters in Sand Lick and twenty times natural waters in South Fork (Hem, 1985). Importantly, when aluminum concentration rose in North Fork during the spate, there was no increase in calcium. Calcium actually was diluted to below normal concentrations. (Table 3; Fig. 8). Some aspect of spates caused benthic community changes detected by DCA. Spates are difficult to detect unless the watershed is constantly monitored. The July 4, 1997 spate makes this point. Little officially measured rainfall in the area, however, resulted in a modest change measured by DCA. Recall, also, that the studied watershed had no stream gauge. Spates were inferred from nearby Guyandotte River gauge data compared with the precipitation record.

Sporadic disturbances themselves bring about benthic community changes (Chessman and McEvoy, 1998). It is thought that episodic acidity decreases population quality and have severe consequences for benthos (Baker et al., 1996; Hall et al., 1987). However, North Fork benthic community was varied and generally populated by taxa which indicate a healthy lotic system. These taxa also were generally represented in good numbers with good diversity and richness indices. Plecoptera, Ephemeroptera, and Trichoptera represented in North Fork are older taxa adapted for the diverse conditions found in headwaters (Hall et al., 1987).

Chironomidae is a newer terrestrial invader which has kept its cuticle and is resistant to toxic stream conditions.

Episodic events or seasonal aluminum increases lead to acute toxicity and are more dangerous than chronic exposure (Havas, 1981; Havas and Rosseland, 1995). Increase in aluminum is the toxicity problem with concomitant decreased buffering capacity (Allen, 1995) as seen in the January 28, 1997 spate. Bioassays may underestimate the importance of episodic acidification effects if they are cumulative (and sublethal) though time (Baker et al., 1996). Macrobenthos survivability dependent upon available microhabitat refugia (Baker et al., 1996; Havas and Rosseland, 1996).

Mixing zones have received little attention and they are important to understand because they are kill zones for benthic migration generally inhabited by tolerant taxa (Havas and Rosseland, 1996; Gray, 1998). The effects of increasing pH is confounded by increase in metals concentration and precipitation of iron hydroxide (Hall et al., 1980) and in this study precipitation of aluminum hydroxide. Refugia can actually bring harm to organisms during or after an acidic episode (Havas and Rosseland, 1996). Aluminum and reduced pH flow into higher pH areas and aluminum hydroxide precipitates onto organisms in mixing zones (Havas and Rosseland, 1995). Aluminum hydroxide precipitate determines if the zone of recovery is good or bad for benthos. This is the case found in Sand Lick. Organisms drift downstream from North Fork into the mixing zone at the confluence and confronted by being covered with aluminum hydroxide precipitant.

CHAPTER IX

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APPENDIX A

Field measured parameters

Appendix A, Table 1: Field Measured Parameters

Sampling	Temperature (°C)		
Dates	N Fork	Sand Lick	S Fork
10/11/95	15	15	14
11/22/95	6	6	5
2/28/96	9	9	9
3/19/96	8	8	8
5/3/96	15	15	14
7/21/96	18	18	18
8/17/96	18	18	18
11/20/96	9	9	9
12/15/96	5	5	6
1/28/97*	5	4	5
2/1/97	6	6	6
3/5/97	9	9	9
3/30/97	12	12	12
4/4/97	12	12	12
5/3/97	14	13	13
6/5/97	15	15	15
7/11/97	19	18	18

Sampling	pH		
Dates	N Fork	Sand Lick	S Fork
10/11/95	7.39	4.51	3.69
11/22/95	7.10	5.13	3.88
2/28/96	7.05	5.55	3.94
3/19/96	6.62	5.30	4.24
5/3/96	7.01	5.54	4.25
7/21/96	7.03	5.17	4.07
8/17/96	7.21	4.84	3.95
11/20/96	7.07	5.07	3.83
1/28/97*	5.23	3.88	3.35
3/5/97	7.30	5.70	4.82
3/30/97	7.12	5.37	4.30
4/4/97	7.45	5.58	4.36
5/3/97	7.36	4.85	3.90
6/5/97	7.66	5.42	4.30
7/11/97	7.30	6.04	4.05

Sampling	Acidity (mg $CaCO_3$/L)		
Dates	N Fork	Sand Lick	S Fork
11/22/95	-	0.0	57.0
5/3/96	-	11.4	51.3
8/17/96	-	9.1	51.3
11/20/96	-	16.0	34.2
12/15/96	-	20.5	63.8
1/28/97*	-	0.0	39.9
2/1/97	-	0.0	22.8
3/5/97	-	0.0	5.7
3/30/97	-	18.2	34.2
4/4/97	-	11.4	41.0
5/3/97	-	6.8	59.3
6/5/97	-	0.0	63.8
7/11/97	-	0.0	36.5

Sampling	Alkalinity (mg $CaCO_3$/ L)		
Dates	N Fork	Sand Lick	S Fork
11/22/95	34.2	20.5	-
7/21/96	17.1	0.0	-
8/17/96	20.5	0.0	-
11/20/96	34.2	0.0	-
12/15/96	20.5	0.0	-
1/28/97*	34.2	17.1	-
2/1/97	20.5	6.8	-
3/5/97	20.5	6.8	-
3/30/97	20.5	0.0	-
4/4/97	20.5	0.0	-
5/3/97	27.4	0.0	-
6/5/97	27.4	6.8	-
7/11/97	27.4	13.7	-

*Indicates spate flow event.

APPENDIX B

Guyandotte River stage and precipitation record for Man, West Virginia from January 1, 1996 to July 31, 1997

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
1/1/96	3.87	1.18	0.11	0.28	0.00	0.00
1/2/96	3.93	1.20	0.25	0.64	0.00	0.00
1/3/96	6.19	1.89	0.75	1.91	0.00	0.00
1/4/96	7.59	2.31	0.01	0.03	0.01	0.03
1/5/96	7.33	2.23	0.01	0.03	0.01	0.03
1/6/96	5.87	1.79	0.13	0.33	2.00	5.08
1/7/96	5.29	1.61	1.25	3.18	10.00	25.40
1/8/96	5.29	1.61	0.38	0.97	2.00	5.08
1/9/96	4.53	1.38	0.01	0.03	0.01	0.03
1/10/96	4.87	1.48	0.45	1.14	1.00	2.54
1/11/96	4.97	1.51	0.00	0.00	2.00	5.08
1/12/96	4.32	1.32	0.43	1.09	6.00	15.24
1/13/96	4.32	1.32	0.03	0.08	2.00	5.08
1/14/96	---	---	0.00	0.00	0.00	0.00
1/15/96	4.97	1.51	0.00	0.00	0.00	0.00
1/16/96	5.55	1.69	0.00	0.00	0.00	0.00
1/17/96	7.52	2.29	0.01	0.03	0.00	0.00
1/18/96	9.28	2.83	1.30	3.30	0.01	0.03
1/19/96	13.56	4.13	0.01	0.03	0.01	0.03
1/20/96	6.30	1.92	0.01	0.03	0.01	0.03
1/21/96	5.24	1.60	0.00	0.00	0.00	0.00
1/22/96	4.75	1.45	0.00	0.00	0.00	0.00
1/23/96	4.33	1.32	0.82	2.08	0.00	0.00
1/24/96	8.71	2.65	0.02	0.05	0.01	0.03
1/25/96	9.39	2.86	0.00	0.00	0.00	0.00
1/26/96	9.00	2.74	2.00	5.08	0.00	0.00
1/27/96	9.15	2.79	0.55	1.40	0.00	0.00
1/28/96	8.96	2.73	0.00	0.00	0.00	0.00
1/29/96	8.78	2.68	0.00	0.00	0.00	0.00
1/30/96	8.60	2.62	0.00	0.00	0.00	0.00
1/31/96	8.45	2.58	0.06	0.15	0.01	0.03
2/1/96	8.28	2.52	0.00	0.00	0.00	0.00
2/2/96	8.13	2.48	0.21	0.53	2.00	5.08
2/3/96	6.75	2.06	0.34	0.86	4.00	10.16
2/4/96	4.63	1.41	0.00	0.00	0.00	0.00
2/5/96	4.78	1.46	0.00	0.00	0.00	0.00
2/6/96	4.80	1.46	0.00	0.00	0.00	0.00
2/7/96	5.16	1.57	0.45	1.14	0.00	0.00
2/8/96	---	---	---	---	---	---
2/9/96	9.95	3.03	0.95	2.41	0.00	0.00
2/10/96	9.31	2.84	0.00	0.00	0.00	0.00
2/11/96	---	---	---	---	---	---
2/12/96	8.70	2.65	0.10	0.25	1.00	2.54
2/13/96	8.50	2.59	0.01	0.03	0.01	0.03
2/14/96	8.35	2.55	0.00	0.00	0.00	0.00
2/15/96	8.20	2.50	0.27	0.69	0.00	0.00

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
2/16/96	5.38	1.64	0.01	0.03	0.01	0.03
2/17/96	5.34	1.63	0.01	0.03	0.01	0.03
2/18/96	---	---	---	---	---	---
2/19/96	5.29	1.61	0.01	0.03	0.01	0.03
2/20/96	5.28	1.61	0.15	0.38	0.00	0.00
2/21/96	5.09	1.55	0.05	0.13	0.00	0.00
2/22/96	5.09	1.55	0.00	0.00	0.00	0.00
2/23/96	5.82	1.77	0.10	0.25	0.00	0.00
2/24/96	5.48	1.67	0.13	0.33	0.00	0.00
2/25/96	---	---	---	---	---	---
2/26/96	5.12	1.56	0.00	0.00	0.00	0.00
2/27/96	5.11	1.56	0.01	0.03	0.00	0.00
2/28/96	5.44	1.66	0.01	0.03	0.01	0.03
2/29/96	5.30	1.62	0.00	0.00	0.00	0.00
3/1/96	5.27	1.61	0.00	0.00	0.00	0.00
3/2/96	5.27	1.61	0.00	0.00	0.00	0.00
3/3/96	5.20	1.58	0.00	0.00	0.00	0.00
3/4/96	5.13	1.56	0.01	0.03	0.01	0.03
3/5/96	4.54	1.38	0.00	0.00	0.00	0.00
3/6/96	4.74	1.44	0.41	1.04	0.00	0.00
3/7/96	5.94	1.81	0.36	0.91	0.00	0.00
3/8/96	7.92	2.41	0.16	0.41	0.01	0.03
3/9/96	7.43	2.26	0.02	0.05	0.01	0.03
3/10/96	---	---	---	---	---	---
3/11/96	6.90	2.10	0.00	0.00	0.00	0.00
3/12/96	5.95	1.81	0.00	0.00	0.00	0.00
3/13/96	5.55	1.69	0.00	0.00	0.00	0.00
3/14/96	5.51	1.68	0.04	0.10	0.00	0.00
3/15/96	5.17	1.58	0.02	0.05	0.00	0.00
3/16/96	5.31	1.62	0.01	0.03	0.00	0.00
3/17/96	6.35	1.94	0.92	2.34	0.00	0.00
3/18/96	6.64	2.02	0.00	0.00	0.00	0.00
3/19/96	6.68	2.04	0.25	0.64	0.00	0.00
3/20/96	7.06	2.15	0.45	1.14	1.00	2.54
3/21/96	7.40	2.26	0.24	0.61	1.00	2.54
3/22/96	6.33	1.93	0.01	0.03	0.01	0.03
3/23/96	6.43	1.96	0.00	0.00	0.00	0.00
3/24/96	---	---	---	---	---	---
3/25/96	6.52	1.99	0.04	0.10	0.00	0.00
3/26/96	6.25	1.91	0.02	0.05	0.00	0.00
3/27/96	6.12	1.87	0.00	0.00	0.00	0.00
3/28/96	5.75	1.75	0.30	0.76	0.00	0.00
3/29/96	6.87	2.09	0.43	1.09	0.00	0.00
3/30/96	6.91	2.11	0.02	0.05	0.00	0.00
3/31/96	---	---	0.00	0.00	0.00	0.00
4/1/96	6.55	2.00	0.46	1.17	0.00	0.00

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
4/2/96	6.69	2.04	0.30	0.76	0.00	0.00
4/3/96	6.47	1.97	0.00	0.00	0.00	0.00
4/4/96	6.28	1.91	0.00	0.00	0.00	0.00
4/5/96	5.73	1.75	0.28	0.71	0.00	0.00
4/6/96	5.60	1.71	0.00	0.00	0.00	0.00
4/7/96	---	---	---	---	---	---
4/8/96	5.37	1.64	0.00	0.00	0.00	0.00
4/9/96	5.13	1.56	0.11	0.28	0.00	0.00
4/10/96	5.07	1.55	0.02	0.05	0.01	0.03
4/11/96	5.03	1.53	0.00	0.00	---	---
4/12/96	4.73	1.44	0.00	0.00	---	---
4/13/96	4.09	1.25	0.00	0.00	---	---
4/14/96	---	---	---	---	---	---
4/15/96	4.37	1.33	0.13	0.33	---	---
4/16/96	5.92	1.80	0.85	2.16	---	---
4/17/96	7.76	2.37	0.15	0.38	---	---
4/18/96	7.04	2.15	0.00	0.00	---	---
4/19/96	5.93	1.81	0.00	0.00	---	---
4/20/96	5.80	1.77	0.00	0.00	---	---
4/21/96	5.70	1.74	0.19	0.48	---	---
4/22/96	5.50	1.68	0.19	0.48	---	---
4/23/96	5.41	1.65	0.00	0.00	---	---
4/24/96	5.15	1.57	1.12	2.84	---	---
4/25/96	4.87	1.48	0.00	0.00	---	---
4/26/96	4.89	1.49	0.42	1.07	---	---
4/27/96	4.84	1.48	0.00	0.00	---	---
4/28/96	4.80	1.46	0.00	0.00	---	---
4/29/96	4.76	1.45	0.00	0.00	---	---
4/30/96	4.66	1.42	0.42	1.07	---	---
5/1/96	4.85	1.48	0.03	0.08	---	---
5/2/96	5.29	1.61	0.00	0.00	---	---
5/3/96	5.28	1.61	0.00	0.00	---	---
5/4/96	4.93	1.50	0.39	0.99	---	---
5/5/96	---	---	0.00	0.00	---	---
5/6/96	8.06	2.46	1.21	3.07	---	---
5/7/96	9.08	2.77	0.02	0.05	---	---
5/8/96	7.48	2.28	0.55	1.40	---	---
5/9/96	8.61	2.62	0.45	1.14	---	---
5/10/96	7.91	2.41	0.00	0.00	---	---
5/11/96	6.76	2.06	0.00	0.00	---	---
5/12/96	---	---	---	---	---	---
5/13/96	5.93	1.81	0.49	1.24	---	---
5/14/96	5.57	1.70	0.00	0.00	---	---
5/15/96	5.29	1.61	0.15	0.38	---	---
5/16/96	14.32	4.36	3.24	8.23	---	---
5/17/96	7.96	2.43	0.03	0.08	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
5/18/96	8.77	2.67	0.00	0.00	---	---
5/19/96	---	---	---	---	---	---
5/20/96	8.52	2.60	0.00	0.00	---	---
5/21/96	8.40	2.56	0.00	0.00	---	---
5/22/96	7.08	2.16	0.67	1.70	---	---
5/23/96	8.38	2.55	0.00	0.00	---	---
5/24/96	8.23	2.51	0.00	0.00	---	---
5/25/96	8.53	2.60	0.57	1.45	---	---
5/26/96	---	---	---	---	---	---
5/27/96	7.68	2.34	0.60	1.52	---	---
5/28/96	6.99	2.13	0.63	1.60	---	---
5/29/96	7.40	2.26	0.32	0.81	---	---
5/30/96	7.15	2.18	0.00	0.00	---	---
5/31/96	6.95	2.12	0.00	0.00	---	---
6/1/96	5.71	1.74	0.00	0.00	---	---
6/2/96	---	---	---	---	---	---
6/3/96	4.68	1.43	0.26	0.66	---	---
6/4/96	5.00	1.52	0.37	0.94	---	---
6/5/96	4.84	1.48	0.00	0.00	---	---
6/6/96	4.76	1.45	0.00	0.00	---	---
6/7/96	4.44	1.35	0.00	0.00	---	---
6/8/96	4.42	1.35	0.29	0.74	---	---
6/9/96	---	---	---	---	---	---
6/10/96	4.43	1.35	0.45	1.14	---	---
6/11/96	4.37	1.33	0.00	0.00	---	---
6/12/96	4.34	1.32	0.00	0.00	---	---
6/13/96	4.94	1.51	1.31	3.33	---	---
6/14/96	5.24	1.60	0.00	0.00	---	---
6/15/96	4.41	1.34	0.00	0.00	---	---
6/16/96	---	---	---	---	---	---
6/17/96	3.71	1.13	0.00	0.00	---	---
6/18/96	3.67	1.12	0.00	0.00	---	---
6/19/96	3.95	1.20	0.00	0.00	---	---
6/20/96	4.03	1.23	0.20	0.51	---	---
6/21/96	3.97	1.21	0.00	0.00	---	---
6/22/96	3.94	1.20	0.00	0.00	---	---
6/23/96	4.00	1.22	1.22	3.10	---	---
6/24/96	3.73	1.14	0.00	0.00	---	---
6/25/96	5.61	1.71	1.09	2.77	---	---
6/26/96	5.53	1.69	0.00	0.00	---	---
6/27/96	4.00	1.22	0.00	0.00	---	---
6/28/96	3.93	1.20	0.00	0.00	---	---
6/29/96	3.37	1.03	0.00	0.00	---	---
6/30/96	---	---	---	---	---	---
7/1/96	3.32	1.01	0.08	0.20	---	---
7/2/96	3.81	1.16	0.00	0.00	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
7/3/96	4.81	1.47	0.78	1.98	---	---
7/4/96	5.19	1.58	0.00	0.00	---	---
7/5/96	4.00	1.22	0.00	0.00	---	---
7/6/96	3.55	1.08	0.00	0.00	---	---
7/7/96	---	---	---	---	---	---
7/8/96	3.52	1.07	0.01	0.03	---	---
7/9/96	3.56	1.09	0.02	0.05	---	---
7/10/96	3.48	1.06	0.00	0.00	---	---
7/11/96	3.65	1.11	0.00	0.00	---	---
7/12/96	3.65	1.11	0.00	0.00	---	---
7/13/96	3.69	1.12	0.11	0.28	---	---
7/14/96	---	---	---	---	---	---
7/15/96	3.50	1.07	0.48	1.22	---	---
7/16/96	3.70	1.13	0.38	0.97	---	---
7/17/96	4.70	1.43	0.01	0.03	---	---
7/18/96	4.20	1.28	0.00	0.00	---	---
7/19/96	3.51	1.07	0.02	0.05	---	---
7/20/96	4.86	1.48	1.36	3.45	---	---
7/21/96	---	---	---	---	---	---
7/22/96	3.77	1.15	0.00	0.00	---	---
7/23/96	3.71	1.13	0.01	0.03	---	---
7/24/96	3.60	1.10	0.00	0.00	---	---
7/25/96	3.50	1.07	0.00	0.00	---	---
7/26/96	3.50	1.07	0.21	0.53	---	---
7/27/96	3.48	1.06	0.00	0.00	---	---
7/28/96	---	---	---	---	---	---
7/29/96	3.20	0.98	0.20	0.51	---	---
7/30/96	---	---	0.11	0.28	---	---
7/31/96	4.10	1.25	0.23	0.58	---	---
8/1/96	5.25	1.60	2.00	5.08	---	---
8/2/96	5.11	1.56	0.00	0.00	---	---
8/3/96	4.03	1.23	0.00	0.00	---	---
8/4/96	3.93	1.20	0.00	0.00	---	---
8/5/96	3.57	1.09	0.00	0.00	---	---
8/6/96	3.53	1.08	0.00	0.00	---	---
8/7/96	3.51	1.07	0.00	0.00	---	---
8/8/96	3.45	1.05	1.26	3.20	---	---
8/9/96	3.54	1.08	0.00	0.00	---	---
8/10/96	4.21	1.28	0.00	0.00	---	---
8/11/96	---	---	---	---	---	---
8/12/96	3.71	1.13	1.10	2.79	---	---
8/13/96	7.87	2.40	0.62	1.57	---	---
8/14/96	6.54	1.99	0.03	0.08	---	---
8/15/96	5.00	1.52	0.00	0.00	---	---
8/16/96	4.09	1.25	0.00	0.00	---	---
8/17/96	4.46	1.36	0.44	1.12	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
8/18/96	4.25	1.30	0.00	0.00	---	---
8/19/96	4.11	1.25	0.00	0.00	---	---
8/20/96	3.96	1.21	0.00	0.00	---	---
8/21/96	4.12	1.26	0.00	0.00	---	---
8/22/96	3.40	1.04	0.38	0.97	---	---
8/23/96	3.26	0.99	0.00	0.00	---	---
8/24/96	3.39	1.03	0.00	0.00	---	---
8/25/96	3.39	1.03	0.00	0.00	---	---
8/26/96	3.85	1.17	0.00	0.00	---	---
8/27/96	3.68	1.12	0.00	0.00	---	---
8/28/96	3.40	1.04	0.00	0.00	---	---
8/29/96	3.07	0.94	0.00	0.00	---	---
8/30/96	3.13	0.95	0.06	0.15	---	---
8/31/96	---	---	---	---	---	---
9/1/96	3.34	1.02	0.00	0.00	---	---
9/2/96	3.34	1.02	0.00	0.00	---	---
9/3/96	3.27	1.00	0.38	0.97	---	---
9/4/96	3.30	1.01	0.06	0.15	---	---
9/5/96	3.30	1.01	0.00	0.00	---	---
9/6/96	3.30	1.01	0.20	0.51	---	---
9/7/96	3.66	1.12	0.68	1.73	---	---
9/8/96	---	---	0.00	0.00	---	---
9/9/96	4.38	1.34	0.00	0.00	---	---
9/10/96	3.99	1.22	0.01	0.03	---	---
9/11/96	3.56	1.09	0.00	0.00	---	---
9/12/96	3.35	1.02	0.00	0.00	---	---
9/13/96	3.77	1.15	0.77	1.96	---	---
9/14/96	3.72	1.13	0.00	0.00	---	---
9/15/96	3.78	1.15	0.36	0.91	---	---
9/16/96	5.79	1.76	1.50	3.81	---	---
9/17/96	6.46	1.97	0.08	0.20	---	---
9/18/96	5.43	1.66	0.00	0.00	---	---
9/19/96	4.78	1.46	0.00	0.00	---	---
9/20/96	4.55	1.39	0.00	0.00	---	---
9/21/96	---	---	0.00	0.00	---	---
9/22/96	---	---	---	---	---	---
9/23/96	3.92	1.19	0.08	0.20	---	---
9/24/96	3.78	1.15	0.00	0.00	---	---
9/25/96	3.60	1.10	0.02	0.05	---	---
9/26/96	3.43	1.05	0.00	0.00	---	---
9/27/96	3.41	1.04	0.02	0.05	---	---
9/28/96	3.41	1.04	0.49	1.24	---	---
9/29/96	5.22	1.59	1.22	3.10	---	---
9/30/96	5.30	1.62	0.00	0.00	---	---
10/1/96	4.66	1.42	0.00	0.00	---	---
10/2/96	4.34	1.32	0.30	0.76	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
10/3/96	4.80	1.46	0.67	1.70	---	---
10/4/96	5.09	1.55	0.00	0.00	---	---
10/5/96	5.09	1.55	0.00	0.00	---	---
10/6/96	4.51	1.37	0.02	0.05	---	---
10/7/96	3.79	1.16	0.00	0.00	---	---
10/8/96	4.32	1.32	0.01	0.03	---	---
10/9/96	4.45	1.36	0.00	0.00	---	---
10/10/96	4.43	1.35	0.00	0.00	---	---
10/11/96	3.76	1.15	0.00	0.00	---	---
10/12/96	3.71	1.13	0.00	0.00	---	---
10/13/96	---	---	---	---	---	---
10/14/96	3.44	1.05	0.00	0.00	---	---
10/15/96	3.42	1.04	0.00	0.00	---	---
10/16/96	3.53	1.08	0.00	0.00	---	---
10/17/96	3.60	1.10	0.00	0.00	---	---
10/18/96	3.60	1.10	0.15	0.38	---	---
10/19/96	3.73	1.14	0.65	1.65	---	---
10/20/96	3.69	1.12	0.01	0.03	---	---
10/21/96	---	---	---	---	---	---
10/22/96	---	---	---	---	---	---
10/23/96	3.83	1.17	0.07	0.18	---	---
10/24/96	3.83	1.17	0.00	0.00	---	---
10/25/96	3.72	1.13	0.00	0.00	---	---
10/26/96	3.69	1.12	0.02	0.05	---	---
10/27/96	3.75	1.14	0.40	1.02	---	---
10/28/96	3.78	1.15	0.06	0.15	---	---
10/29/96	3.78	1.15	0.02	0.05	---	---
10/30/96	3.78	1.15	0.00	0.00	---	---
10/31/96	---	---	---	---	---	---
11/1/96	3.78	1.15	0.05	0.13	---	---
11/2/96	3.79	1.16	0.00	0.00	---	---
11/3/96	3.71	1.13	0.00	0.00	---	---
11/4/96	3.71	1.13	0.00	0.00	---	---
11/5/96	3.69	1.12	0.00	0.00	---	---
11/6/96	3.69	1.12	0.00	0.00	---	---
11/7/96	3.69	1.12	0.01	0.03	---	---
11/8/96	3.75	1.14	1.04	2.64	---	---
11/9/96	5.05	1.54	0.29	0.74	---	---
11/10/96	---	---	---	---	---	---
11/11/96	5.71	1.74	0.00	0.00	---	---
11/12/96	5.61	1.71	0.14	0.36	---	---
11/13/96	5.08	1.55	0.00	0.00	---	---
11/14/96	4.63	1.41	0.01	0.03	0.01	0.03
11/15/96	4.45	1.36	0.00	0.00	0.00	0.00
11/16/96	4.30	1.31	0.00	0.00	0.00	0.00
11/17/96	4.15	1.26	0.00	0.00	0.00	0.00

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
11/18/96	4.19	1.28	0.20	0.51	0.00	0.00
11/19/96	4.21	1.28	0.43	1.09	0.00	0.00
11/20/96	4.50	1.37	0.20	0.51	0.00	0.00
11/21/96	4.74	1.44	0.02	0.05	0.00	0.00
11/22/96	5.20	1.58	0.57	1.45	0.01	0.03
11/23/96	6.14	1.87	0.01	0.03	0.01	0.03
11/24/96	5.69	1.73	---	---	---	---
11/25/96	5.29	1.61	0.01	0.03	0.00	0.00
11/26/96	6.14	1.87	0.62	1.57	0.00	0.00
11/27/96	6.14	1.87	0.04	0.10	0.00	0.00
11/28/96	5.50	1.68	0.00	0.00	0.00	0.00
11/29/96	6.03	1.84	0.00	0.00	0.00	0.00
11/30/96	5.33	1.62	0.30	0.76	0.00	0.00
12/1/96	8.29	2.53	1.28	3.25	0.00	0.00
12/2/96	7.86	2.40	0.03	0.08	0.00	0.00
12/3/96	8.90	2.71	0.00	0.00	0.00	0.00
12/4/96	8.67	2.64	0.02	0.05	0.00	0.00
12/5/96	8.39	2.56	0.60	1.52	0.00	0.00
12/6/96	6.61	2.01	0.20	0.51	0.00	0.00
12/7/96	5.47	1.67	0.04	0.10	0.00	0.00
12/8/96	---	---	---	---	---	---
12/9/96	5.14	1.57	0.02	0.05	0.00	0.00
12/10/96	5.10	1.55	0.00	0.00	0.00	0.00
12/11/96	4.75	1.45	0.00	0.00	0.00	0.00
12/12/96	4.74	1.44	0.04	0.10	0.00	0.00
12/13/96	4.91	1.50	0.20	0.51	0.00	0.00
12/14/96	6.07	1.85	0.01	0.03	0.00	0.00
12/15/96	5.49	1.67	0.00	0.00	0.00	0.00
12/16/96	5.46	1.66	0.00	0.00	0.00	0.00
12/17/96	5.01	1.53	0.02	0.05	0.00	0.00
12/18/96	4.96	1.51	0.03	0.08	0.00	0.00
12/19/96	4.65	1.42	0.12	0.30	1.00	2.54
12/20/96	4.68	1.43	0.00	0.00	0.00	0.00
12/21/96	---	---	0.00	0.00	0.00	0.00
12/22/96	4.68	1.43	---	---	---	---
12/23/96	---	---	0.19	0.48	0.00	0.00
12/24/96	5.55	1.69	---	---	---	---
12/25/96	---	---	0.00	0.00	0.00	0.00
12/26/96	---	---	---	---	---	---
12/27/96	---	---	---	---	---	---
12/28/96	---	---	---	---	---	---
12/29/96	---	---	---	---	---	---
12/30/96	5.30	1.62	0.32	0.81	0.00	0.00
12/31/96	5.23	1.59	0.12	0.30	0.00	0.00
1/1/97	5.00	1.52	0.00	0.00	0.00	0.00
1/2/97	5.00	1.52	0.02	0.05	0.00	0.00

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
1/3/97	5.36	1.63	0.00	0.00	0.00	0.00
1/4/97	5.11	1.56	0.00	0.00	0.00	0.00
1/5/97	---	---	---	---	---	---
1/6/97	5.11	1.56	0.00	0.00	0.00	0.00
1/7/97	5.08	1.55	0.02	0.05	0.00	0.00
1/8/97	5.05	1.54	0.00	0.00	0.00	0.00
1/9/97	3.68	1.12	0.41	1.04	0.00	0.00
1/10/97	5.55	1.69	0.09	0.23	1.00	2.54
1/11/97	5.71	1.74	0.10	0.25	1.00	2.54
1/12/97	---	---	---	---	---	---
1/13/97	4.94	1.51	0.00	0.00	1.00	2.54
1/14/97	4.88	1.49	0.00	0.00	1.00	2.54
1/15/97	4.64	1.41	0.00	0.00	0.00	0.00
1/16/97	5.13	1.56	0.43	1.09	0.00	0.00
1/17/97	5.67	1.73	0.00	0.00	0.00	0.00
1/18/97	5.42	1.65	0.00	0.00	0.00	0.00
1/19/97	---	---	---	---	---	---
1/20/97	5.02	1.53	0.01	0.03	0.01	0.03
1/21/97	4.90	1.49	0.00	0.00	0.00	0.00
1/22/97	5.06	1.54	0.00	0.00	0.00	0.00
1/23/97	5.31	1.62	0.40	1.02	0.00	0.00
1/24/97	5.55	1.69	0.03	0.08	0.00	0.00
1/25/97	6.37	1.94	0.05	0.13	0.00	0.00
1/26/97	---	---	---	---	---	---
1/27/97	6.11	1.86	0.76	1.93	0.00	0.00
1/28/97	7.53	2.30	0.00	0.00	0.00	0.00
1/29/97	5.49	1.67	0.00	0.00	0.00	0.00
1/30/97	8.28	2.52	0.00	0.00	0.00	0.00
1/31/97	8.05	2.45	0.00	0.00	0.00	0.00
2/1/97	6.11	1.86	0.00	0.00	0.00	0.00
2/2/97	5.61	1.71	0.00	0.00	0.00	0.00
2/3/97	5.30	1.62	0.00	0.00	0.00	0.00
2/4/97	5.25	1.60	0.27	0.69	0.00	0.00
2/5/97	5.59	1.70	0.41	1.04	0.00	0.00
2/6/97	5.69	1.73	0.00	0.00	0.00	0.00
2/7/97	5.95	1.81	0.00	0.00	0.00	0.00
2/8/97	6.05	1.84	0.17	0.43	0.00	0.00
2/9/97	---	---	---	---	---	---
2/10/97	6.33	1.93	0.00	0.00	0.00	0.00
2/11/97	6.56	2.00	0.00	0.00	0.00	0.00
2/12/97	5.43	1.66	0.00	0.00	0.00	0.00
2/13/97	5.95	1.81	0.00	0.00	0.00	0.00
2/14/97	5.41	1.65	0.03	0.08	0.00	0.00
2/15/97	5.19	1.58	0.02	0.05	0.00	0.00
2/16/97	---	---	---	---	---	---
2/17/97	4.90	1.49	0.00	0.00	0.00	0.00

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
2/18/97	4.90	1.49	0.00	0.00	0.00	0.00
2/19/97	4.90	1.49	0.00	0.00	0.00	0.00
2/20/97	4.88	1.49	0.00	0.00	0.00	0.00
2/21/97	4.87	1.48	0.00	0.00	0.00	0.00
2/22/97	4.94	1.51	0.14	0.36	0.00	0.00
2/23/97	---	---	---	---	---	---
2/24/97	5.10	1.55	0.00	0.00	0.00	0.00
2/25/97	5.09	1.55	0.00	0.00	0.00	0.00
2/26/97	4.90	1.49	0.00	0.00	0.00	0.00
2/27/97	4.91	1.50	0.13	0.33	0.00	0.00
2/28/97	4.90	1.49	0.00	0.00	0.00	0.00
3/1/97	4.75	1.45	0.15	0.38	0.00	0.00
3/2/97	5.11	1.56	0.60	1.52	0.00	0.00
3/3/97	5.04	1.54	0.72	1.83	0.00	0.00
3/4/97	6.70	2.04	0.90	2.29	0.00	0.00
3/5/97	5.14	1.57	0.00	0.00	0.00	0.00
3/6/97	6.52	1.99	0.68	1.73	0.01	0.03
3/7/97	---	---	0.01	0.03	0.01	0.03
3/8/97	8.68	2.65	0.00	0.00	0.00	0.00
3/9/97	8.49	2.59	0.00	0.00	0.00	0.00
3/10/97	8.49	2.59	0.33	0.84	0.00	0.00
3/11/97	8.48	2.58	0.00	0.00	0.00	0.00
3/12/97	8.48	2.58	0.00	0.00	0.00	0.00
3/13/97	8.34	2.54	0.00	0.00	0.00	0.00
3/14/97	6.99	2.13	0.20	0.51	0.00	0.00
3/15/97	6.00	1.83	0.16	0.41	0.01	0.03
3/16/97	6.04	1.84	0.00	0.00	---	---
3/17/97	6.08	1.85	0.01	0.03	---	---
3/18/97	5.56	1.69	0.92	2.34	---	---
3/19/97	6.72	2.05	0.00	0.00	---	---
3/20/97	---	---	---	---	---	---
3/21/97	7.40	2.26	0.00	0.00	---	---
3/22/97	7.24	2.21	0.00	0.00	---	---
3/23/97	6.23	1.90	---	---	---	---
3/24/97	5.21	1.59	0.00	0.00	---	---
3/25/97	5.30	1.62	0.00	0.00	---	---
3/26/97	5.19	1.58	0.57	1.45	---	---
3/27/97	5.77	1.76	0.00	0.00	---	---
3/28/97	6.23	1.90	0.00	0.00	---	---
3/29/97	5.92	1.80	0.89	2.26	---	---
3/30/97	6.30	1.92	0.13	0.33	---	---
3/31/97	6.40	1.95	0.49	1.24	---	---
4/1/97	5.79	1.76	0.00	0.00	---	---
4/2/97	5.61	1.71	0.00	0.00	---	---
4/3/97	5.49	1.67	0.00	0.00	---	---
4/4/97	5.40	1.65	0.00	0.00	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
4/5/97	5.32	1.62	0.01	0.03	---	---
4/6/97	---	---	0.00	0.00	---	---
4/7/97	4.58	1.40	0.00	0.00	---	---
4/8/97	3.60	1.10	0.05	0.13	---	---
4/9/97	3.52	1.07	0.00	0.00	---	---
4/10/97	3.47	1.06	0.00	0.00	---	---
4/11/97	3.43	1.05	0.00	0.00	---	---
4/12/97	3.42	1.04	0.00	0.00	---	---
4/13/97	4.82	1.47	0.21	0.53	---	---
4/14/97	4.82	1.47	0.21	0.53	---	---
4/15/97	4.80	1.46	0.00	0.00	---	---
4/16/97	4.50	1.37	0.00	0.00	---	---
4/17/97	4.34	1.32	0.10	0.25	---	---
4/18/97	4.29	1.31	0.03	0.08	---	---
4/19/97	4.60	1.40	0.00	0.00	---	---
4/20/97	4.48	1.37	0.00	0.00	---	---
4/21/97	4.35	1.33	0.00	0.00	---	---
4/22/97	4.22	1.29	0.14	0.36	---	---
4/23/97	4.24	1.29	0.31	0.79	---	---
4/24/97	4.62	1.41	0.34	0.86	---	---
4/25/97	4.62	1.41	0.01	0.03	---	---
4/26/97	4.95	1.51	0.00	0.00	---	---
4/27/97	5.16	1.57	0.00	0.00	---	---
4/28/97	5.16	1.57	0.25	0.64	---	---
4/29/97	5.15	1.57	0.02	0.05	---	---
4/30/97	5.79	1.76	0.00	0.00	---	---
5/1/97	5.80	1.77	0.15	0.38	---	---
5/2/97	4.71	1.44	0.00	0.00	---	---
5/3/97	4.93	1.50	0.11	0.28	---	---
5/4/97	---	---	---	---	---	---
5/5/97	4.46	1.36	0.00	0.00	---	---
5/6/97	4.55	1.39	0.00	0.00	---	---
5/7/97	4.64	1.41	0.50	1.27	---	---
5/8/97	---	---	---	---	---	---
5/9/97	4.61	1.41	0.00	0.00	---	---
5/10/97	5.19	1.58	0.10	0.25	---	---
5/11/97	4.84	1.48	0.00	0.00	---	---
5/12/97	4.83	1.47	0.00	0.00	---	---
5/13/97	4.80	1.46	0.02	0.05	---	---
5/14/97	4.86	1.48	0.20	0.51	---	---
5/15/97	4.71	1.44	0.20	0.51	---	---
5/16/97	4.67	1.42	0.00	0.00	---	---
5/17/97	4.67	1.42	0.00	0.00	---	---
5/18/97	4.47	1.36	0.00	0.00	---	---
5/19/97	4.47	1.36	0.00	0.00	---	---
5/20/97	4.83	1.47	0.28	0.71	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
5/21/97	5.25	1.60	0.00	0.00	---	---
5/22/97	5.15	1.57	0.00	0.00	---	---
5/23/97	4.79	1.46	0.00	0.00	---	---
5/24/97	4.53	1.38	0.00	0.00	---	---
5/25/97	---	---	---	---	---	---
5/26/97	---	---	---	---	---	---
5/27/97	7.20	2.19	0.03	0.08	---	---
5/28/97	6.88	2.10	0.05	0.13	---	---
5/29/97	6.30	1.92	0.00	0.00	---	---
5/30/97	5.96	1.82	0.30	0.76	---	---
5/31/97	5.22	1.59	0.02	0.05	---	---
6/1/97	4.94	1.51	0.17	0.43	---	---
6/2/97	5.21	1.59	0.50	1.27	---	---
6/3/97	7.10	2.16	0.00	0.00	---	---
6/4/97	5.38	1.64	0.23	0.58	---	---
6/5/97	4.75	1.45	0.00	0.00	---	---
6/6/97	4.51	1.37	0.00	0.00	---	---
6/7/97	4.24	1.29	0.00	0.00	---	---
6/8/97	4.23	1.29	0.00	0.00	---	---
6/9/97	4.22	1.29	0.25	0.64	---	---
6/10/97	---	---	---	---	---	---
6/11/97	4.19	1.28	0.01	0.03	---	---
6/12/97	3.47	1.06	0.60	1.52	---	---
6/13/97	4.75	1.45	0.70	1.78	---	---
6/14/97	4.79	1.46	0.15	0.38	---	---
6/15/97	4.64	1.41	0.28	0.71	---	---
6/16/97	4.28	1.30	0.00	0.00	---	---
6/17/97	4.57	1.39	0.41	1.04	---	---
6/18/97	4.47	1.36	0.26	0.66	---	---
6/19/97	5.93	1.81	0.98	2.49	---	---
6/20/97	6.12	1.87	0.00	0.00	---	---
6/21/97	5.14	1.57	0.00	0.00	---	---
6/22/97	4.57	1.39	0.00	0.00	---	---
6/23/97	4.20	1.28	0.00	0.00	---	---
6/24/97	4.11	1.25	0.00	0.00	---	---
6/25/97	4.05	1.23	0.00	0.00	---	---
6/26/97	3.80	1.16	0.35	0.89	---	---
6/27/97	5.12	1.56	0.90	2.29	---	---
6/28/97	6.31	1.92	0.00	0.00	---	---
6/29/97	---	---	0.00	0.00	---	---
6/30/97	6.37	1.94	0.00	0.00	---	---
7/1/97	7.19	2.19	0.19	0.48	---	---
7/2/97	8.23	2.51	0.00	0.00	---	---
7/3/97	9.52	2.90	0.46	1.17	---	---
7/4/97	10.15	3.09	0.00	0.00	---	---
7/5/97	8.13	2.48	0.00	0.00	---	---

Appendix B, Table 1: Guyandotte River Stage and Precipitation Record for Man, West Virginia. (National Climatic Data Center, 1998)

Date	River Stage Depth		Rain		Snow	
	Feet	Meters	Inches	Centimeters	Inches	Centimeters
7/6/97	7.98	2.43	0.00	0.00	---	---
7/7/97	5.89	1.80	0.00	0.00	---	---
7/8/97	5.32	1.62	0.00	0.00	---	---
7/9/97	5.24	1.60	0.00	0.00	---	---
7/10/97	5.24	1.60	0.03	0.08	---	---
7/11/97	5.16	1.57	0.00	0.00	---	---
7/12/97	5.11	1.56	0.00	0.00	---	---
7/13/97	5.01	1.53	0.00	0.00	---	---
7/14/97	4.52	1.38	0.00	0.00	---	---
7/15/97	4.47	1.36	0.00	0.00	---	---
7/16/97	4.86	1.48	0.00	0.00	---	---
7/17/97	4.44	1.35	0.00	0.00	---	---
7/18/97	4.24	1.29	0.00	0.00	---	---
7/19/97	4.21	1.28	0.00	0.00	---	---
7/20/97	4.21	1.28	0.00	0.00	---	---
7/21/97	4.19	1.28	0.00	0.00	---	---
7/22/97	4.19	1.28	0.33	0.84	---	---
7/23/97	4.23	1.29	0.28	0.71	---	---
7/24/97	4.21	1.28	1.08	2.74	---	---
7/25/97	4.28	1.30	0.27	0.69	---	---
7/26/97	4.19	1.28	0.00	0.00	---	---
7/27/97	5.94	1.81	0.79	2.01	---	---
7/28/97	5.58	1.70	0.00	0.00	---	---
7/29/97	5.89	1.80	0.70	1.78	---	---
7/30/97	5.91	1.80	0.00	0.00	---	---
7/31/97	5.11	1.56	0.00	0.00	---	---

APPENDIX C

Cations and sulfate in solution data and analyses

Appendix C, Table 1: Cations and sulfate found in solution (mg/L).

Sampling	ALUMINUM			CALCIUM			IRON		
Dates	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork
2/28/96	0.34	4.68	9.70	26.51	30.68	50.41	0.44	0.42	0.34
3/19/96	0.63	4.13	6.99	23.06	28.10	40.56	0.85	0.97	0.85
5/3/96	0.16	6.32	10.27	34.28	42.92	59.92	0.22	1.08	0.26
7/21/96	0.17	6.02	9.39	29.56	39.34	49.85	0.17	1.06	0.13
8/17/96	0.17	6.89	10.47	28.35	37.98	48.98	0.24	0.49	0.71
9/15/96	0.19	15.44	24.31	47.34	68.05	93.03	0.21	0.11	0.41
10/31/96	0.52	8.48	13.15	27.18	42.17	60.85	0.75	0.39	0.55
11/20/96	0.24	7.50	13.45	27.33	36.99	61.02	0.45	0.30	0.56
12/15/96	0.12	7.18	10.12	30.73	41.38	55.45	0.09	0.63	0.53
1/28/97*	2.34	3.06	4.90	14.27	21.05	29.68	3.82	2.57	1.86
2/1/97	0.12	2.44	7.10	27.02	32.79	44.51	0.19	0.28	0.50
3/5/97	0.48	1.28	3.27	17.68	20.63	27.00	0.74	0.74	0.76

Sampling	MAGNESIUM			MANGANESE			POTASSIUM		
Dates	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork
2/28/96	14.89	18.50	36.05	0.08	0.98	2.10	1.83	1.93	2.29
3/19/96	13.03	17.49	28.15	0.06	0.83	1.50	1.61	1.75	1.95
5/3/96	18.98	26.71	41.99	0.02	1.29	2.28	2.13	2.34	2.63
7/21/96	14.87	24.02	34.79	0.02	1.59	2.49	2.19	2.42	2.55
8/17/96	14.62	24.19	34.97	0.02	1.62	2.49	2.05	2.25	2.41
9/15/96	24.68	43.62	68.01	0.02	2.38	5.41	2.69	2.89	3.39
10/31/96	14.75	27.96	44.37	0.06	1.94	3.06	1.69	2.10	2.46
11/20/96	15.11	23.77	44.77	0.04	1.71	3.07	1.83	1.94	2.47
12/15/96	16.61	26.44	39.96	0.02	1.56	2.50	1.84	2.01	2.19
1/28/97*	8.14	13.57	20.75	0.22	0.64	1.22	1.39	1.48	1.56
2/1/97	14.68	20.10	30.20	0.04	0.57	1.61	1.60	1.72	1.88
3/5/97	9.22	11.85	17.93	0.14	0.39	0.91	1.13	1.16	1.24

Sampling	SILICON			SODIUM			SULFATE		
Dates	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork	N Fork	Sand L	S Fork
2/28/96	3.76	4.19	6.24	6.68	6.96	8.02	85	215	325
3/19/96	3.75	4.41	5.39	5.69	5.79	6.41	85	185	450
5/3/96	3.63	5.22	7.35	9.66	10.36	11.36	45	105	185
7/21/96	3.49	5.42	7.53	8.97	7.89	6.60	135	195	255
8/17/96	3.77	5.52	7.46	8.05	7.17	6.04	60	105	125
9/15/96	3.39	6.55	10.68	12.93	13.15	14.04	100	110	210
10/31/96	3.49	4.65	7.26	6.72	6.99	7.56	105	160	285
11/20/96	3.54	4.35	7.27	6.70	6.97	7.69	150	225	450
12/15/96	3.26	4.96	6.82	9.66	8.79	7.86	185	225	300
1/28/97*	6.19	5.32	5.35	3.16	3.61	4.02	200	240	456
2/1/97	3.31	4.07	5.59	7.64	7.76	7.77			
3/5/97	---	---	---	4.94	4.76	4.89			

* Indicates spate flow event.

Aluminum Linear Regression

```
KWIKSTAT                                                            09-21-1999
------------------------------------------------------------------------------
Simple Linear Regression and Correlation                          PHYSHCON.dbf
------------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):ALUMINUM

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =     4.883    S.D. Y =     4.233    CORR YSS =       358.41
     REGRESSION MS=       250.318           RESIDUAL MS=            5.69

Pearson's r (Correlation Coefficient)=   0.8357        R-Square= 0.6984

The linear regression equation is:
     ALUMINUM =  2.585198  +  7.634899E-04 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    6.63   with    19 degrees of freedom    p = 0.000

     Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                          09-21-1999
----------------------------------------------------------------------------
Simple Linear Regression and Correlation                        PHYSHCON.dbf
----------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):CALCIUM

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =    36.245    S.D. Y =    12.306    CORR YSS =      3028.79
     REGRESSION MS=      2011.583            RESIDUAL MS=          53.54

Pearson's r (Correlation Coefficient)=   0.8150        R-Square= 0.6642

The linear regression equation is:
     CALCIUM =  29.73047  +  2.164345E-03 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    6.13   with    19 degrees of freedom    p = 0.000

     Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                            09-21-1999
------------------------------------------------------------------------------
Simple Linear Regression and Correlation                          PHYSHCON.dbf
------------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):IRON

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =     0.561    S.D. Y =     0.300    CORR YSS =          1.80
     REGRESSION MS=         0.036            RESIDUAL MS=            0.09

Pearson's r (Correlation Coefficient)=  -0.1409        R-Square= 0.0199

The linear regression equation is:
     IRON =  .5883886  + -9.114902E-06 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    0.62   with    19 degrees of freedom    p = 0.542
```

```
KWIKSTAT                                                        09-21-1999
-----------------------------------------------------------------------------
Simple Linear Regression and Correlation                       PHYSHCON.dbf
-----------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):MAGNESIUM

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =    23.138    S.D. Y =    10.248    CORR YSS =      2100.51
     REGRESSION MS=      1580.283             RESIDUAL MS=        27.38

Pearson's r (Correlation Coefficient)=   0.8674        R-Square= 0.7523

The linear regression equation is:
     MAGNESIUM =  17.36382  +  1.918337E-03 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    7.60   with    19 degrees of freedom    p = 0.000

     Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                             09-21-1999
-------------------------------------------------------------------------------
Simple Linear Regression and Correlation                          PHYSHCON.dbf
-------------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):MANGANESE

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =     1.125    S.D. Y =     0.987    CORR YSS =        19.50
     REGRESSION MS=        13.583             RESIDUAL MS=          0.31

Pearson's r (Correlation Coefficient)=   0.8347        R-Square= 0.6967

The linear regression equation is:
     MANGANESE =  .5899063  +  1.778487E-04 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    6.61   with    19 degrees of freedom    p = 0.000

     Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                         09-21-1999
----------------------------------------------------------------------------
Simple Linear Regression and Correlation                        PHYSHCON.dbf
----------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):POTASSIUM

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =     2.005    S.D. Y =     0.442    CORR YSS =          3.91
     REGRESSION MS=          1.100            RESIDUAL MS=           0.15

Pearson's r (Correlation Coefficient)=   0.5307        R-Square= 0.2816

The linear regression equation is:
     POTASSIUM =  1.852424  +  5.060992E-05 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    2.73   with    19 degrees of freedom    p = 0.013

     Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                        09-21-1999
--------------------------------------------------------------------------
Simple Linear Regression and Correlation                      PHYSHCON.dbf
--------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):SODIUM

 21  data points used in the calculation.

     MEAN X =  3010.041    S.D. X =  4633.696    CORR XSS =429422720.00
     MEAN Y =     7.219    S.D. Y =     1.764    CORR YSS =        62.21
     REGRESSION MS=         0.367             RESIDUAL MS=          3.25

Pearson's r (Correlation Coefficient)=   0.0768        R-Square= 0.0059

The linear regression equation is:
     SODIUM =  7.131049   +  2.923512E-05 * H+

Test of hypothesis to determine significance of relationship:
     H(null): Slope = 0   or  H(null): r = 0    (two-tailed test)
     t =    0.34   with    19 degrees of freedom    p = 0.741
```

```
KWIKSTAT                                                        09-21-1999
---------------------------------------------------------------------------
Simple Linear Regression and Correlation                      PHYSHCON.dbf
---------------------------------------------------------------------------
Simple Linear Regression Procedure

Independent Variable (X):H+
Dependent Variable   (Y):SULFATE

 21  data points used in the calculation.

    MEAN X =  2659.797    S.D. X =  4375.386    CORR XSS =382880064.00
    MEAN Y =   205.524    S.D. Y =   110.078    CORR YSS =   242345.23
    REGRESSION MS=    157617.160             RESIDUAL MS=       4459.37

Pearson's r (Correlation Coefficient)=   0.8065         R-Square= 0.6504

The linear regression equation is:
    SULFATE =  151.558   +  2.028945E-02 * H+

Test of hypothesis to determine significance of relationship:
    H(null): Slope = 0    or  H(null): r = 0    (two-tailed test)
    t =     5.95   with    19 degrees of freedom    p = 0.000

    Note: A low p-value implies that the slope does not = 0.
```

```
KWIKSTAT                                                          09-21-1999
-----------------------------------------------------------------------------
Independent Group Analysis Summary                              GROUPIII.dbf
-----------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is PH

Group Means and Standard Deviations   Missing cases removed= 12

NORTHFORK: mean= 7.190714        s.d.= .2499123           n= 14
SANDLICK: mean= 5.290714         s.d.= .3981787           n= 14
SOUTHFORK: mean= 4.112857        s.d.= .2891213           n= 14

Analysis of Variance Table

Source                S.S.        DF          MS         F         Appx P
-------------------------------------------------------------------------
Total                   71.49     41
  Treatment             67.53      2          33.76   332.55     <.001
  Error                  3.96     39           0.10

                                                              Critical q
Newman-Keuls Multiple Comparisons               P    Q          (.05)
----------------------------------------------------------------------
    Mean(NORTHFORK) -Mean(SOUTHFORK) =
                                       3.0779   3   36.142       3.446
    Mean(NORTHFORK) -Mean(SANDLICK) =
                                       1.9000   2   22.311       2.861
    Mean(SANDLICK) -Mean(SOUTHFORK) =
                                       1.1779   2   13.831       2.861

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

               Gp Gp Gp
                3  2  1
Population  1  ---
Population  2     ---
Population  3        ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                          09-21-1999
-----------------------------------------------------------------------------
Independent Group Analysis Summary                                GROUPIV.dbf
-----------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is H+

Group Means and Standard Deviations   Missing cases removed= 12

NORTHFORK: mean= 46.35           s.d.= 150.1617          n= 15
SANDLICK: mean= 1588.756         s.d.= 3296.548          n= 15
SOUTHFORK: mean= 11536.97        s.d.= 10394.25          n= 15

Analysis of Variance Table

Source              S.S.         DF          MS             F          Appx P
-------------------------------------------------------------------------
Total         2831924224.00     44
  Treatment   1166901248.00      2   583450624.00      14.72       <.001
  Error       1665022976.00     42    39643404.00

                                                             Critical q
Newman-Keuls Multiple Comparisons                   P     Q         (.05)
----------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                      11490.6182   3    7.068       3.438
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                       9948.2119   2    6.119       2.855
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                       1542.4058   2    0.949       2.855

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

              Gp Gp Gp
               1  2  3
Population  1  ------
Population  2        ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                          09-21-1999
----------------------------------------------------------------------------
Independent Group Analysis Summary                               GROUPIII.dbf
----------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is ALUMINUM

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= .2854545          s.d.= .1796866           n= 11
SANDLICK: mean= 6.396364           s.d.= 3.718393           n= 11
SOUTHFORK: mean= 10.74727          s.d.= 5.329088           n= 11

Analysis of Variance Table

Source               S.S.        DF          MS          F         Appx P
-------------------------------------------------------------------------
Total              1030.23       32
  Treatment         607.65        2        303.83      21.57      <.001
  Error             422.58       30         14.09

                                                               Critical q
Newman-Keuls Multiple Comparisons                P      Q         (.05)
----------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                       10.4618   3    9.245       3.486
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                        4.3509   2    3.845       2.888
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                        6.1109   2    5.400       2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

              Gp Gp Gp
               1  2  3
Population  1 ---
Population  2    ---
Population  3       ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                     09-21-1999
-----------------------------------------------------------------------
Independent Group Analysis Summary                           GROUPI.dbf
-----------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is CALCIUM

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= 29.00363       s.d.= 7.400073         n= 11
SANDLICK: mean= 38.27546        s.d.= 11.99356         n= 11
SOUTHFORK: mean= 53.78          s.d.= 16.4656          n= 11

Analysis of Variance Table

Source               S.S.       DF         MS        F         Appx P
---------------------------------------------------------------------
Total                8144.72    32
  Treatment          3447.50     2      1723.75    11.01      <.001
  Error              4697.23    30       156.57

                                                           Critical q
Newman-Keuls Multiple Comparisons                 P    Q       (.05)
------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                       24.7764   3    6.567       3.486
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                       15.5045   2    4.110       2.888
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                        9.2718   2    2.458       2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

               Gp Gp Gp
                1  2  3
Population  1  ------
Population  2        ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                         09-21-1999
---------------------------------------------------------------------------
Independent Group Analysis Summary                               GROUPI.dbf
---------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is IRON

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= .3954546          s.d.= .2704945          n= 11
SANDLICK: mean= .5881819           s.d.= .3345091          n= 11
SOUTHFORK: mean= .509091           s.d.= .2164464          n= 11

Analysis of Variance Table

Source                 S.S.         DF           MS          F          Appx P
------------------------------------------------------------------------
Total                    2.53      32
  Treatment              0.21       2             0.10        1.34      0.278
  Error                  2.32      30             0.08

                                                                Critical q
Newman-Keuls Multiple Comparisons                 P      Q         (.05)
----------------------------------------------------------------------
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                          0.1927   3    2.299         3.486
    Mean(SANDLICK) -Mean(SOUTHFORK) =
                                          0.0791   2    0.943         2.888
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                          0.1136   2    1.356         2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

              Gp Gp Gp
               1  3  2
Population  1  ---------

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                            09-21-1999
------------------------------------------------------------------------------
Independent Group Analysis Summary                                  GROUPI.dbf
------------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is MAGNESIUM

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= 15.58545        s.d.= 3.82105          n= 11
SANDLICK: mean= 24.05909         s.d.= 8.058769         n= 11
SOUTHFORK: mean= 38.29           s.d.= 12.60874         n= 11

Analysis of Variance Table

Source                   S.S.        DF          MS          F         Appx P
-----------------------------------------------------------------------------
Total                    5281.24     32
  Treatment              2896.00      2        1448.00      18.21     <.001
  Error                  2385.24     30          79.51

                                                                 Critical q
Newman-Keuls Multiple Comparisons                    P      Q        (.05)
--------------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                         22.7045    3     8.445       3.486
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                         14.2309    2     5.293       2.888
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                          8.4736    2     3.152       2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

                  Gp Gp Gp
                   1  2  3
Population  1     ---
Population  2        ---
Population  3           ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                            09-21-1999
------------------------------------------------------------------------------
Independent Group Analysis Summary                                  GROUPI.dbf
------------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is MANGANESE

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= 4.727273E-02     s.d.= 3.717282E-02      n= 11
SANDLICK: mean= 1.350909          s.d.= .6044908          n= 11
SOUTHFORK: mean= 2.492727         s.d.= 1.167683          n= 11

Analysis of Variance Table

Source                S.S.        DF          MS         F         Appx P
---------------------------------------------------------------------------
Total                  50.24      32
  Treatment            32.94       2           16.47     28.56      <.001
  Error                17.30      30            0.58

                                                                Critical q
Newman-Keuls Multiple Comparisons                     P     Q       (.05)
------------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                              2.4455   3   10.680      3.486
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                              1.1418   2    4.987      2.888
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                              1.3036   2    5.693      2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

               Gp Gp Gp
                1  2  3
Population  1  ---
Population  2     ---
Population  3        ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                            09-21-1999
------------------------------------------------------------------------------
Independent Group Analysis Summary                                  GROUPI.dbf
------------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is POTASSIUM

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= 1.871818        s.d.= .3999211          n= 11
SANDLICK: mean= 2.046364         s.d.= .4458769          n= 11
SOUTHFORK: mean= 2.314545        s.d.= .5346476          n= 11

Analysis of Variance Table

Source                  S.S.        DF           MS          F         Appx P
-------------------------------------------------------------------------
Total                      7.54      32
  Treatment                1.09       2             0.55       2.55     0.095
  Error                    6.45      30             0.21

                                                                 Critical q
Newman-Keuls Multiple Comparisons                    P      Q         (.05)
-----------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                            0.4427   3    3.168        3.486
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                            0.2682   2    1.919        2.888
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                            0.1745   2    1.249        2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

              Gp Gp Gp
               1  2  3
Population  1 ---------

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                        09-21-1999
--------------------------------------------------------------------------
Independent Group Analysis Summary                              GROUPI.dbf
--------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is SILICON

Group Means and Standard Deviations   Missing cases removed= 24

NORTHFORK: mean= 3.539          s.d.= .1862762           n= 10
SANDLICK: mean= 4.934           s.d.= .765205            n= 10
SOUTHFORK: mean= 7.158999       s.d.= 1.461937           n= 10

Analysis of Variance Table

Source                   S.S.        DF          MS         F        Appx P
-----------------------------------------------------------------------
Total                   91.49       29
  Treatment             66.67        2        33.34      36.27      <.001
  Error                 24.82       27         0.92

                                                              Critical q
Newman-Keuls Multiple Comparisons                   P     Q      (.05)
-------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                           3.6200   3   11.940      3.509
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                           2.2250   2    7.339      2.904
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                           1.3950   2    4.601      2.904

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

               Gp Gp Gp
                1  2  3
Population  1  ---
Population  2     ---
Population  3        ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                           09-21-1999
-----------------------------------------------------------------------------
Independent Group Analysis Summary                                 GROUPI.dbf
-----------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is SODIUM

Group Means and Standard Deviations   Missing cases removed= 21

NORTHFORK: mean= 7.967273         s.d.= 2.250507          n= 11
SANDLICK: mean= 7.871819          s.d.= 2.276801          n= 11
SOUTHFORK: mean= 8.021818         s.d.= 2.571584          n= 11

Analysis of Variance Table

Source                  S.S.       DF          MS         F        Appx P
--------------------------------------------------------------------------
Total                  168.74     32
  Treatment              0.13      2           0.06      0.01     0.989
  Error                168.62     30           5.62

                                                                Critical q
Newman-Keuls Multiple Comparisons                   P     Q        (.05)
----------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                         0.1500     3     0.210        3.486
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                         0.0545     2     0.076        2.888
    Mean(NORTHFORK) -Mean(SANDLICK) =
                                         0.0955     2     0.134        2.888

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

                   Gp Gp Gp
                    2  1  3
Population  1    ---------

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
KWIKSTAT                                                           09-21-1999
------------------------------------------------------------------------------
Independent Group Analysis Summary                                 GROUPI.dbf
------------------------------------------------------------------------------
Grouping variable is STATION
Analysis variable is SULFATE

Group Means and Standard Deviations   Missing cases removed= 27

NORTHFORK: mean= 122.7778        s.d.= 47.90036          n= 9
SANDLICK: mean= 184.4444         s.d.= 49.84002          n= 9
SOUTHFORK: mean= 317.2222        s.d.= 116.1656          n= 9

Analysis of Variance Table

Source                S.S.          DF          MS          F         Appx P
---------------------------------------------------------------------------
Total               323907.31       26
  Treatment         177724.00        2       88862.00      14.59      <.001
  Error             146183.33       24        6090.97

                                                                  Critical q
Newman-Keuls Multiple Comparisons                        P    Q        (.05)
------------------------------------------------------------------------
    Mean(SOUTHFORK) -Mean(NORTHFORK) =
                                         194.4445     3    7.474     3.532
    Mean(SOUTHFORK) -Mean(SANDLICK) =
                                         132.7778     2    5.104     2.919
    Mean(SANDLICK) -Mean(NORTHFORK) =
                                          61.6667     2    2.370     2.919

Homogeneous Populations, groups ranked

Gp  1  refers to STATION=NORTHFORK
Gp  2  refers to STATION=SANDLICK
Gp  3  refers to STATION=SOUTHFORK

                 Gp Gp Gp
                  1  2  3
Population  1   ------
Population  2          ---

This is a graphical representation of the Newman-Keuls multiple comparisons
test. At the 0.05 significance level, the Means of any two groups underscored
by the same line are not significantly different.
```

```
Multiple Range Tests
Response variable: pH
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean          Homogeneous Groups
--------------------------------------------------------------
South Fork     14     4.11286        X
Sand Lick      14     5.29071         X
North Fork     14     7.19071          X
--------------------------------------------------------------
Contrast                            Difference
--------------------------------------------------------------
North Fork - Sand Lick             *1.9000000000000004
North Fork - South Fork            *3.077857142857143
Sand Lick - South Fork             *1.1778571428571425
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 3 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: H
----------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean          Homogeneous Groups
----------------------------------------------------------------
North Fork     14     7.60143E-8    X
Sand Lick      14     7.60729E-6    X
South Fork     14     9.17071E-5     X
----------------------------------------------------------------
Contrast                            Difference
----------------------------------------------------------------
North Fork - Sand Lick              -7.531271428571432E-6
North Fork - South Fork            *-9.163112857142859E-5
Sand Lick - South Fork             *-8.409985714285715E-5
----------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 2 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Aluminum
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station          Count  Mean          Homogeneous Groups
--------------------------------------------------------------
North Fork       11     0.285455      X
Sand Lick        11     6.39636        X
South Fork       11     10.7473         X
--------------------------------------------------------------
Contrast                              Difference
--------------------------------------------------------------
North Fork - Sand Lick              *-6.1109090909090895
North Fork - South Fork             *-10.461818181818181
Sand Lick - South Fork              *-4.350909090909091
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 3 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Calcium
----------------------------------------------------------------
Method: 95.0 percent Duncan
Station          Count  Mean           Homogeneous Groups
----------------------------------------------------------------
North Fork       11     29.0036        X
Sand Lick        11     38.2755        X
South Fork       11     53.78           X
----------------------------------------------------------------
Contrast                               Difference
----------------------------------------------------------------
North Fork - Sand Lick                  -9.271818181818183
North Fork - South Fork                *-24.77636363636364
Sand Lick - South Fork                 *-15.504545454545458
----------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 2 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Iron
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean         Homogeneous Groups
--------------------------------------------------------------
North Fork     11     0.395455     X
South Fork     11     0.509091     X
Sand Lick      11     0.588182     X
--------------------------------------------------------------
Contrast                           Difference
--------------------------------------------------------------
North Fork - Sand Lick             -0.1927272727272727
North Fork - South Fork            -0.1136363636363637
Sand Lick - South Fork             0.07909090909090899
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. There are no statistically significant differences between any
pair of means at the 95.0% confidence level. At the top of the page,
homogenous groups are identified using columns of X's. Within each
column, the levels containing X's form a group of means within which
there are no statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Magnesium
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean          Homogeneous Groups
--------------------------------------------------------------
North Fork     11     15.5855       X
Sand Lick      11     24.0591        X
South Fork     11     38.29           X
--------------------------------------------------------------
Contrast                            Difference
--------------------------------------------------------------
North Fork - Sand Lick             *-8.473636363636368
North Fork - South Fork            *-22.70454545454546
Sand Lick - South Fork             *-14.23090909090909
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 3 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Manganese
-------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean          Homogeneous Groups
-------------------------------------------------------------
North Fork     11     0.0472727     X
Sand Lick      11     1.35091        X
South Fork     11     2.49273         X
-------------------------------------------------------------
Contrast                            Difference
-------------------------------------------------------------
North Fork - Sand Lick             *-1.3036363636363635
North Fork - South Fork            *-2.445454545454546
Sand Lick - South Fork             *-1.1418181818181825
-------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 3 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Potassium
-------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean          Homogeneous Groups
-------------------------------------------------------------
North Fork     11     1.87182       X
Sand Lick      11     2.04636       XX
South Fork     11     2.31455        X
-------------------------------------------------------------
Contrast                            Difference
-------------------------------------------------------------
North Fork - Sand Lick               -0.17454545454545456
North Fork - South Fork             *-0.44272727272727264
Sand Lick - South Fork               -0.2681818181818181
-------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 1 pair, indicating that
this pair shows a statistically significant difference at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Silicon
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean         Homogeneous Groups
--------------------------------------------------------------
North Fork     10     3.539        X
Sand Lick      10     4.934         X
South Fork     10     7.159          X
--------------------------------------------------------------
Contrast                           Difference
--------------------------------------------------------------
North Fork - Sand Lick            *-1.3949999999999987
North Fork - South Fork           *-3.619999999999999
Sand Lick - South Fork            *-2.2250000000000005
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 3 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Sodium
--------------------------------------------------------------------------------
Method: 95.0 percent Duncan
Station         Count   Mean            Homogeneous Groups
--------------------------------------------------------------------------------
Sand Lick       11      7.87182         X
North Fork      11      7.96727         X
South Fork      11      8.02182         X
--------------------------------------------------------------------------------
Contrast                                Difference
--------------------------------------------------------------------------------
North Fork - Sand Lick                  0.09545454545454568
North Fork - South Fork                 -0.054545454545454675
Sand Lick - South Fork                  -0.15000000000000036
--------------------------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. There are no statistically significant differences between any
pair of means at the 95.0% confidence level. At the top of the page,
homogenous groups are identified using columns of X's. Within each
column, the levels containing X's form a group of means within which
there are no statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

```
Multiple Range Tests
Response variable: Sulfate
--------------------------------------------------------------
Method: 95.0 percent Duncan
Station          Count  Mean          Homogeneous Groups
--------------------------------------------------------------
North Fork       9      122.778       X
Sand Lick        9      184.444       X
South Fork       9      317.222        X
--------------------------------------------------------------
Contrast                              Difference
--------------------------------------------------------------
North Fork - Sand Lick                 -61.6666666666667
North Fork - South Fork               *-194.444444444434
Sand Lick - South Fork                *-132.777777777777
--------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which
means are significantly different from which others. The bottom half
of the output shows the estimated difference between each pair of
means. An asterisk has been placed next to 2 pairs, indicating that
these pairs show statistically significant differences at the 95.0%
confidence level. At the top of the page, homogenous groups are
identified using columns of X's. Within each column, the levels
containing X's form a group of means within which there are no
statistically significant differences.

The method currently being used to discriminate among the means is
Duncan's multiple comparison procedure. With this method, there is no
more than a 5.0% risk of calling each pair of means significantly
different when the actual difference equals 0.
```

APPENDIX D

Benthic data and analyses

Appendix D, Table 1: Biodiversity indices for study site stations.

	Shannon Diversity			Pielou Evenness		
	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork
3/19/96	3.21	2.22	0.00	0.76	0.74	0.00
5/3/96	2.70	2.46	0.58	0.59	0.74	0.16
7/21/96	2.05	2.21	1.88	0.79	0.79	0.59
8/17/96	1.10	2.68	0.97	0.39	0.84	0.32
9/15/96	2.53	2.26	1.81	0.58	0.81	0.52
10/31/96	2.44	1.25	0.34	0.63	0.79	0.22
11/20/96	3.28	3.11	0.77	0.77	0.90	0.28
12/15/96	3.06	3.08	1.08	0.71	0.75	0.36
2/1/97	2.40	2.64	1.20	0.56	0.76	0.36
3/30/97	2.71	2.77	1.62	0.66	0.80	0.63
5/3/97	3.09	2.79	0.45	0.75	0.81	0.15
6/7/97	2.57	1.70	0.56	0.56	0.47	0.20
7/11/97	2.90	2.37	0.68	0.81	0.69	0.18
Mean	2.62	2.43	0.92	0.66	0.76	0.31
SD	0.58	0.52	0.58	0.12	0.10	0.19

```
Multiple Range Tests
Response variable: Shannon Diversity
--------------------------------------------------------------------------
Method: 95.0 percent Duncan
Station          Count  Mean          Homogeneous Groups
--------------------------------------------------------------------------
South Fork       13     0.918462      X
Sand Lick        13     2.42615        X
North Fork       13     2.61846        X
--------------------------------------------------------------------------
Contrast                              Difference
--------------------------------------------------------------------------
North Fork - Sand Lick                 0.19230769230769207
North Fork - South Fork               *1.7
Sand Lick - South Fork                *1.5076923076923079
--------------------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine which means
are significantly different from which others. The bottom half of the output
shows the estimated difference between each pair of means. An asterisk has
been placed next to 2 pairs, indicating that these pairs show statistically
significant differences at the 95.0% confidence level. At the top of the
page, homogenous groups are identified using columns of X's. Within each
column, the levels containing X's form a group of means within which there
are no statistically significant differences.

The method currently being used to discriminate among the means is Duncan's
multiple comparison procedure. With this method, there is no more than a 5.0%
risk of calling each pair of means significantly different when the actual
difference equals 0.
```

```
Multiple Range Tests
Response variable: Pielou
------------------------------------------------------------
Method: 95.0 percent Duncan
Station        Count  Mean             Homogeneous Groups
------------------------------------------------------------
South Fork     13     0.305385          X
North Fork     13     0.658462            X
Sand Lick      13     0.760769            X
------------------------------------------------------------
Contrast                                Difference
------------------------------------------------------------
North Fork - Sand Lick                   -0.10230769230769232
North Fork - South Fork                 *0.35307692307692307
Sand Lick - South Fork                  *0.4553846153846154
------------------------------------------------------------
* denotes a statistically significant difference.


Statistical Interpreter
-----------------------
This table applies a multiple comparison procedure to determine
which means are significantly different from which others. The
bottom half of the output shows the estimated difference between
each pair of means. An asterisk has been placed next to 2 pairs,
indicating that these pairs show statistically significant
differences at the 95.0% confidence level. At the top of the
page, homogenous groups are identified using columns of X's.
Within each column, the levels containing X's form a group of
means within which there are no statistically significant
differences.

The method currently being used to discriminate among the means
is Duncan's multiple comparison procedure. With this method,
there is no more than a 5.0% risk of calling each pair of means
significantly different when the actual difference equals 0.
```

Appendix D, Table 2: EPA suggested metrics for stream benthic macroinvertebrates. (Barbour et al., 1999)

SAMPLING DATE	3/19/96			5/3/96			7/21/96		
SAMPLING STATION	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork
RICHNESS									
Number of Taxa	19	8	0	24	10	12	6	7	9
Number of Ephemeroptera	8	1	0	37	0	0	0	0	0
Number of Plecoptera	49	1	0	433	23	4	1	4	0
Number of Trichoptera	14	4	0	63	8	2	6	12	4
COMPOSITION									
Per Cent EPT*	86.6%	30.0%	0.0%	77.2%	58.5%	0.9%	43.8%	88.9%	9.3%
Per Cent Ephemeroptera	9.8%	5.0%	0.0%	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Per Cent Chironomidae	4.9%	55.0%	0.0%	13.5%	30.2%	92.5%	43.8%	0.0%	65.1%
TROPHIC - HABITAT									
Number of Clingers	73	6	0	543	35	13	8	18	9
Per Cent Clingers	89.0%	30.0%	0.0%	78.7%	66.0%	2.0%	50.0%	100.0%	20.9%
Per Cent Filterers	14.6%	15.0%	0.0%	8.7%	15.1%	0.3%	37.5%	66.7%	9.3%
Per Cent Scrapers	14.6%	0.0%	0.0%	5.8%	1.9%	0.3%	6.3%	0.0%	2.3%

SAMPLING DATE	8/17/96			9/15/96			10/31/96		
SAMPLING STATION	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork
RICHNESS									
Number of Taxa	7	9	8	20	7	11	15	3	3
Number of Ephemeroptera	2	0	0	63	0	0	168	1	0
Number of Plecoptera	0	0	2	14	1	7	15	0	0
Number of Trichoptera	0	7	7	92	4	26	104	5	15
COMPOSITION									
Per Cent EPT*	2.0%	33.3%	10.2%	44.6%	35.7%	25.8%	90.3%	100.0%	5.0%
Per Cent Ephemeroptera	2.0%	0.0%	0.0%	16.6%	0.0%	0.0%	52.8%	16.7%	0.0%
Per Cent Chironomidae	81.8%	38.1%	85.2%	47.5%	50.0%	61.7%	7.2%	0.0%	94.4%
TROPHIC - HABITAT									
Number of Clingers	4	10	10	174	7	44	288	6	15
Per Cent Clingers	4.0%	47.6%	11.4%	45.9%	50.0%	34.4%	90.6%	100.0%	5.0%
Per Cent Filterers	0.0%	33.3%	6.8%	24.8%	35.7%	20.3%	32.4%	83.3%	5.0%
Per Cent Scrapers	4.0%	9.5%	0.0%	17.2%	0.0%	0.8%	52.8%	16.7%	0.0%

SAMPLING DATE	11/20/96			12/15/96			2/1/97		
SAMPLING STATION	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork
RICHNESS									
Number of Taxa	19	11	7	20	17	8	19	11	10
Number of Ephemeroptera	12	2	0	116	3	0	286	12	0
Number of Plecoptera	32	0	5	32	5	0	146	12	6
Number of Trichoptera	64	4	7	86	35	3	78	6	12
COMPOSITION									
Per Cent EPT*	68.4%	30.0%	5.7%	77.2%	63.2%	4.5%	88.7%	60.0%	14.4%
Per Cent Ephemeroptera	7.6%	10.0%	0.0%	38.3%	4.4%	0.0%	49.7%	24.0%	0.0%
Per Cent Chironomidae	18.4%	30.0%	88.6%	20.8%	20.6%	83.6%	7.8%	32.0%	80.0%
TROPHIC - HABITAT									
Number of Clingers	119	7	21	235	46	4	511	32	21
Per Cent Clingers	75.3%	35.0%	10.0%	77.6%	67.6%	6.0%	88.9%	64.0%	16.8%
Per Cent Filterers	40.5%	15.0%	3.3%	28.1%	51.5%	4.5%	13.2%	12.0%	9.6%
Per Cent Scrapers	8.9%	10.0%	0.9%	38.3%	5.9%	0.0%	49.9%	26.0%	0.0%

*EPT: Ephemeroptera, Plecoptera, and Trichoptera

Appendix D, Table 2: EPA suggested metrics for stream benthic macroinvertebrates. (Barbour et al., 1999)

SAMPLING DATE	3/30/97			5/3/97			6/7/97		
SAMPLING STATION	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork	N Fork	Sand Lick	S Fork
RICHNESS									
Number of Taxa	17	11	6	17	11	8	24	12	7
Number of Ephemeroptera	42	3	1	43	0	0	78	5	0
Number of Plecoptera	111	17	0	44	4	0	15	3	1
Number of Trichoptera	41	8	1	37	9	5	56	8	0
COMPOSITION									
Per Cent EPT*	89.4%	87.5%	5.7%	66.3%	40.6%	1.1%	40.7%	20.8%	0.6%
Per Cent Ephemeroptera	19.4%	9.4%	2.9%	23.0%	0.0%	0.0%	21.3%	6.5%	0.0%
Per Cent Chironomidae	3.2%	0.0%	40.0%	30.5%	37.5%	94.0%	52.2%	72.7%	92.4%
TROPHIC - HABITAT									
Number of Clingers	195	29	3	124	14	8	160	17	10
Per Cent Clingers	89.9%	90.6%	8.6%	66.3%	43.8%	1.8%	43.7%	22.1%	5.9%
Per Cent Filterers	18.9%	21.9%	2.9%	17.6%	28.1%	0.4%	14.8%	10.4%	0.0%
Per Cent Scrapers	17.5%	9.4%	2.9%	21.9%	0.0%	0.0%	23.8%	7.8%	0.0%

SAMPLING DATE	7/11/97		
SAMPLING STATION	N Fork	Sand Lick	S Fork
RICHNESS			
Number of Taxa	12	11	14
Number of Ephemeroptera	22	0	0
Number of Plecoptera	13	5	2
Number of Trichoptera	17	35	4
COMPOSITION			
Per Cent EPT*	85.2%	61.5%	1.9%
Per Cent Ephemeroptera	36.1%	0.0%	0.0%
Per Cent Chironomidae	9.8%	15.4%	91.6%
TROPHIC - HABITAT			
Number of Clingers	54	44	15
Per Cent Clingers	88.5%	67.7%	4.8%
Per Cent Filterers	27.9%	53.8%	1.0%
Per Cent Scrapers	36.1%	0.0%	0.3%

*EPT: Ephemeroptera, Plecoptera, and Trichoptera

Appendix D, Table 3: Trophic relationships and habits of aquatic insects collected. (Merritt and Cummins, 1996)

	TROPHIC RELATIONSHIPS	HABITS
EPHEMEROPTERA		
BAETIDAE		
Undetermined	collectors - gatherers, scrapers	swimmers, clingers
Baetis spp.	collectors - gatherers, scrapers	swimmers, climbers, clingers
Acentrella spp.	collectors - gatherers	swimmers, clingers
EPHEMERELLIDAE		
Undetermined	collectors - gatherers, scrapers	clingers, sprawlers, swimmers
Ephemerella spp.	collectors - gatherers, scrapers	clingers, swimmers
Eurylophella spp.	collectors - gatherers	clingers, sprawlers
HEPTAGENIIDAE		
Undetermined	scrapers, collectors - gatherers	generally clingers
Epeorus spp.	collectors - gatherers, scrapers	clingers
Stenonema spp.	scrapers, collectors - gatherers	clingers
SIPHLONURIDAE		
Amaletus spp.	collectors - gatherers	clingers
PLECOPTERA		
CAPNIIDAE		
Undetermined	shredders - detritivores	sprawlers - clingers
Allocapnia spp.	shredders - detritivores	clingers
Capnia spp.	shredders - detritivores	sprawlers - clingers
CHLOROPERLIDAE		
Haploperla spp.	predators	clingers
LEUCTIDAE		
Leuctra spp.	shredders - detritivores	sprawlers - clingers
NEMOURIDAE		
Amphinemura spp.	shredders - detritivores	sprawlers - clingers
Ostraceca spp.	shredders - detritivores	sprawlers - clingers
PELTOPERLIDAE		
Peltoperla arcuata	shredders - detritivores	clingers - sprawlers
PERLIDAE		
Acroneuria spp.	predators	clingers
Eccoptera spp.	predators	clingers
PERLOLIDAE		
Undetermined	predators	clingers
Isoperla spp.	predators	clingers, sprawlers
PTERONARCYIDAE		
Pteronarcys spp.	shredders - detritivores, herbivores	clingers - sprawlers
TRICHOPTERA		
UNDETERMINED		clingers, climbers, sprawlers
GLOSSOSOMATIDAE		
Glossoma spp.	scrapers	clingers
HYDROPSYCHIDAE		
Undetermined	collectors - filterers	clingers
Cheumatopsyche spp.	collectors - filterers	clingers
Diplectrona spp.	collectors - filterers	clingers
Hydropsyche spp.	collectors - filterers	clingers
LIMNEPHILIDAE		
Chyranda spp.	shredders - detritivores	sprawlers
Ironoquia spp.	shredders	sprawlers
RHYCOPHILIDAE		
Rhyacophila spp.	predators	clingers
PHILIPOTAMIDAE		
Undetermined	collectors - filterers	clingers
Dolophilodes spp.	collectors - filterers	clingers
POLYCENTROPODIDAE		
Cyrnellus spp.	collectors - filterers	clingers
Neureclipsis spp.	collectors - filterers, shredders - herbivores, predators	clingers
Polycentropus spp.	predators, collectors - filterers, shredder - herbivores	clingers
UENOIDAE		
Neophylax spp.	scrapers	clingers

Appendix D, Table 3: Trophic relationships and habits of aquatic insects collected. (Merritt and Cummins, 1996)

	TROPHIC RELATIONSHIPS	HABITS
COLEOPTERA		
UNDETERMINED		
DRYOPIDAE		
Helichus spp.	shredders - herbivores	clingers
ELMIDAE		
Undetermined	collectors, gatherers, scrapers	clingers
HYDROPHILIDAE		
Undetermined	collectors - gatherers, piercers - herbivores, predators	divers, swimmers, burrowers, climbers
PSEPHENIDAE		
Ectopria spp.	scrapers	clingers
Psephenus spp.	scrapers	clingers
DIPTERA		
UNDETERMINED		
CERATOPOGONIDAE		
Undetermined	predators, collectors - gatherers	sprawlers, burrowers
CHIRONOMIDAE		
Undetermined	collectors - gatherers, filterers	sprawlers, burrowers
DIXIDAE		
Undetermined	collectors - gatherers	swimmers - climbers
DOLICHOPODIDAE		
Undetermined	predators	sprawlers - burrowers
EMPIDIDAE		
Undetermined	predators	sprawlers - burrowers, clingers
MUSCIDAE		
Undetermined	predators	sprawlers, burrowers
SIMULIIDAE		
Undetermined	collectors - filterers	clingers
TIPULIDAE		
Dicranota spp.	predators	spawlers - burrowers
Erioptera spp.	collectors - gatherers	burrowers
Hexatoma spp.	predators	burrowers - sprawlers, clingers
Tipula spp.	shredders - detritivores and herbivores	burrowers
HEMIPTERA		
CORIXIDAE		
Undetermined	piercers: herbivores and some predators	swimmers
GERRIDAE		
Undetermined	predators	skaters
MACROVELIIDAE		
Undetermined	predators	climbers - sprawlers
NOTONECTIDAE		
Notonecta spp.	predators	swimmers
SALDIDAE		
Undetermined	predators	climbers
VELIIDAE		
Microvillia spp.	predators	skaters
LEPIDOPTERA		
PYRALIDAE		
Undetermined	shredders-herbivores	climbers
MEGALOPTERA		
CORYDALIDAE		
Chauloides spp.	predators	clingers - climbers - burrowers
Nigronia fasciatus	predators	clingers - climbers - burrowers
SIALIDAE		
Scialis spp.	predators	burrowers - climbers - clingers

Appendix D, Table 4: Taxa contributions to DCA analyses.

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DCA Canonical axes: 0 Covariables: 0 Scaling: -1
DETR-SEGME Rescaling: 4 Segments: 26 Threshold: 0
No transformation
Spec: Species scores

	N	NAME	AX1	AX2	AX3	AX4	WEIGHT	N2
		EIG	0.6142	0.237	0.1126	0.0767		
EPHEMEROPTERA								
BAETIDAE								
Undetermined	1	SPEC 1	0.9055	1.065	-0.9756	1.2958	123	4.69
Baetis spp	2	SPEC 2	0.1277	1.6725	0.3788	-0.1381	697	4.45
Acentrella spp	3	SPEC 3	0.588	1.9259	-0.5833	1.0758	6	1
EPHEMERELLIDAE								
Undetermined	4	SPEC 4	0.855	-0.0992	-0.5155	0.6091	2	2
Ephemerella spp	5	SPEC 5	-0.5098	1.8393	1.6573	0.0375	51	3.11
Eurylophella spp	6	SPEC 6	-0.9505	-1.0468	1.2539	0.2095	3	1
HEPTAGENIIDAE								
Undetermined	7	SPEC 7	0.8313	1.8176	-0.4605	0.6395	5	1.47
Epeorus spp	8	SPEC 8	0.1924	2.2477	-0.0393	-0.4015	2	2
Stenonema spp	9	SPEC 9	0.0885	-0.3717	2.3447	0.9943	5	1.47
SIPHLONURIDAE								
Ameletus spp	10	SPEC 10	-0.2779	2.8845	1.3918	-0.1492	11	3.9
PLECOPTERA								
CAPNIIDAE								
Undetermined	11	SPEC 11	3.6446	0.9463	1.2351	7.0561	4	1
Allocapnia spp	12	SPEC 12	0.8232	-0.192	-1.1953	1.0294	47	2.78
Capnia spp	13	SPEC 13	-0.9505	-1.0468	1.2539	0.2095	5	1
CHLOROPERLIDAE								
Haploperla spp	14	SPEC 14	-0.2391	0.1293	1.5764	0.0227	45	4.26
LEUCTIDAE								
Leuctra spp	15	SPEC 15	0.3996	2.6786	2.3561	-0.6519	3	3
NEMOURIDAE								
Amphinemura spp	16	SPEC 16	-0.7271	-0.8841	1.0799	0.2022	436	1.47
Ostracerca spp	17	SPEC 17	1.9429	0.5643	4.288	4.3533	1	1
PELTOPERLIDAE								
Peltoperla arcuata	18	SPEC 18	1.0208	-0.1984	-0.1843	0.275	49	6.51
PERLIDAE								
Acroneuria spp	19	SPEC 19	0.9122	1.5376	0.5188	0.8407	5	5
Eccoptera spp	20	SPEC 20	0.4678	-0.2635	-0.5605	1.0193	2	2
PERLOLIDAE								
Undetermined	21	SPEC 21	1.5445	1.1615	1.713	-0.7024	2	1
Isoperla spp	22	SPEC 22	-0.3881	3.0186	0.3229	0.148	407	4.93
PTERONARCYIDAE								
Pteronarcys spp	23	SPEC 23	0.6041	-0.2967	-3.2647	1.2895	1	1

Appendix D, Table 4: Taxa contributions to DCA analyses.

TRICHOPTERA									
UNDETERMINED	24	SPEC	24	1.2111	0.1319	1.8642	0.7644	9	3.52
GLOSSOSOMATIDAE									
Glossoma spp	25	SPEC	25	1.5445	1.1615	1.713	-0.7024	1	1
HYDROPSYCHIDAE									
Undetermined	26	SPEC	26	2.2431	0.8686	-0.1774	2.5456	2	2
Cheumatopsyche spp	27	SPEC	27	0.6498	-0.085	0.4867	-0.1687	51	6.39
Diplectrona spp	28	SPEC	28	0.9554	1.4917	0.4807	0.33	473	16
Hydropsychidae spp	29	SPEC	29	0.6819	1.9607	2.3564	-0.1505	288	10.9
LIMNEPHILIDAE									
Chyranda spp	30	SPEC	30	3.5905	1.0211	0.7623	6.4369	3	1.8
Ironoquia spp	31	SPEC	31	3.668	0.9837	0.8517	8.1665	1	1
RHYCOPHILIDAE									
Rhyacophila spp	32	SPEC	32	0.4435	0.8217	-0.112	0.3786	7	5.44
PHILIPOTAMIDAE									
Undetermined	33	SPEC	33	0.7425	2.7669	6.1372	-0.7529	1	1
Dolophilodes spp	34	SPEC	34	0.289	0.171	-0.2625	0.832	38	3.65
POLYCENTROPODIDAE									
Cyrnellus spp	35	SPEC	35	1.0776	2.1694	3.7234	-0.9455	1	1
Neureclipsis spp	36	SPEC	36	0.0625	3.6942	-0.9549	-0.2167	3	3
Polycentropus spp	37	SPEC	37	2.8706	1.047	0.3239	4.3664	6	4.5
UENOIDAE									
Neophylax spp	38	SPEC	38	-0.8997	2.0537	-0.2907	0.2782	5	2.78
COLEOPTERA									
UNDETERMINED	39	SPEC	39	1.2633	-0.3385	-0.2602	1.8179	7	5.44
DRYOPIDAE									
Helichus spp	40	SPEC	40	1.4354	-0.313	-0.715	0.1536	6	4.5
ELMIDAE									
Undetermined	41	SPEC	41	1.7538	0.4374	0.4038	-1.3855	24	6.55
HYDROPHILIDAE									
Undetermined	42	SPEC	42	1.8158	0.2872	0.142	-0.784	2	2
PSEPHENIDAE									
Ectopria spp	43	SPEC	43	1.9332	2.0971	1.1755	4.8086	4	2.67
Psephenus spp	44	SPEC	44	-0.6233	-0.7636	0.4715	0.5184	10	1.52

Appendix D, Table 4: Taxa contributions to DCA analyses.

DIPTERA									
UNDETERMINED	45	SPEC	45	2.2102	1.221	2.5797	3.0979	19	3.65
CERATOPOGONIDAE									
Undetermined	46	SPEC	46	3.365	0.8435	0.7513	-0.9361	69	4.93
CHIRONOMIDAE									
Undetermined	47	SPEC	47	2.4288	0.7576	0.77	0.7577	3237	11.72
DIXIDAE									
Undetermined	48	SPEC	48	1.3624	2.3046	2.7331	2.4289	1	1
DOLICHOPODIDAE									
Undetermined	49	SPEC	49	3.6167	1.0389	-0.3725	-5.2403	7	1
EMPIDIDAE									
Undetermined	50	SPEC	50	1.4893	0.9772	0.1754	-1.1535	47	7.44
MUSCIDAE									
Undetermined	51	SPEC	51	1.5445	1.1615	1.713	-0.7024	1	1
SIMULIDAE									
Undetermined	52	SPEC	52	1.5009	1.195	2.2368	0.9205	6	3
TIPULIDAE									
Dicranota spp	53	SPEC	53	0.5933	0.7254	1.8678	1.1625	3	3
Erioptera spp	54	SPEC	54	0.8175	3.167	3.4751	-0.0174	21	5.73
Hexatoma spp	55	SPEC	55	1.7796	1.1406	-0.1974	2.4054	5	3.57
Tipula spp	56	SPEC	56	0.8569	1.4229	1.3813	0.7896	79	11.98
HEMIPTERA									
CORIXIDAE									
Undetermined	57	SPEC	57	3.6167	1.0389	-0.3725	-5.2403	1	1
GERRIDAE									
Undetermined	58	SPEC	58	0.6969	-1.6209	-0.0904	-0.1516	2	1
MACROVELIIDAE									
Undetermined	59	SPEC	59	2.4457	0.6983	2.2937	-1.1279	3	1.8
NOTONECTIDAE									
Notonecta spp	60	SPEC	60	2.763	1.5385	2.4061	4.4167	1	1
SALDIDAE									
Undetermined	61	SPEC	61	2.763	1.5385	2.4061	4.4167	1	1
VELIIDAE									
Microvillia spp	62	SPEC	62	2.3829	1.4786	0.8452	2.6616	5	3.57
LEPIDOPTERA									
PYRALIDAE									
Undetermined	63	SPEC	63	2.681	1.399	1.824	1.7041	3	3
MEGALOPTERA									
CORYDALIDAE									
Chauloides spp	64	SPEC	64	3.4915	0.9307	0.9662	3.357	4	1.6
Nigronia fasciatus	65	SPEC	65	1.9412	1.4755	2.09	2.0153	71	13.16
SIALIDAE									
Sialis spp	66	SPEC	66	2.4258	-0.0909	2.3043	4.2033	3	3
DECAPODA									
CAMBARIDAE									
Cambarus spp	67	SPEC	67	0.5786	0.098	-0.1125	1.0122	21	6.04
ISOPODA									
ASELLIDAE									
Caecidotea spp	68	SPEC	68	-0.9505	-1.0468	1.2539	0.2095	1	1

Appendix D, Table 5: DCA analyses by sites and collection dates

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DCA Canonical axes: 0 Covariables: 0 Scaling: -1

DETR-SEGME Rescaling: 4 Segments: 26 Threshold: 0

No transformation

amp: Sample scores

Sampling Dates:	Sampling Sites:	N	NAME	AX1	AX2	AX3	AX4	WEIGHT	N2
			EIG	0.6142	0.237	0.1126	0.0767		
3/19/96	N Fork	1	SAMP 1	0	1.2141	0.7281	0.2881	82	5.85
5/3/96	N Fork	2	SAMP 2	0.0312	0	0.9566	0.2767	690	3.35
7/21/96	N Fork	3	SAMP 3	1.4743	1.3423	1.235	0.2771	16	3.28
8/17/96	N Fork	4	SAMP 4	2.4835	0.8002	0.6496	0.1046	99	1.48
9/15/96	N Fork	5	SAMP 5	1.5046	1.0995	0.8256	0.3555	379	3.6
10/31/96	N Fork	6	SAMP 6	0.4832	1.4424	0.7069	0.0656	318	3.29
11/20/96	N Fork	7	SAMP 7	1.1889	0.9614	0.3853	0.6344	158	7.14
12/15/96	N Fork	8	SAMP 8	0.8619	1.4525	0.5208	0.3297	303	6.16
2/1/97	N Fork	9	SAMP 9	0.3193	1.8716	0.4922	0.1215	575	3.52
3/30/97	N Fork	10	SAMP 10	0.0964	2.2238	0.7171	0.1425	217	3.83
5/3/97	N Fork	11	SAMP 11	0.7874	1.0651	0.9198	0.337	187	6.25
6/7/97	N Fork	12	SAMP 12	1.6043	0.9875	0.5513	0.5536	366	3.26
7/11/97	N Fork	13	SAMP 13	0.9558	1.0053	0	0.7184	61	5.29
3/19/96	Sand L	14	SAMP 14	1.91	1.1584	0.7869	0.5006	20	2.99
5/3/96	Sand L	15	SAMP 15	0.7733	0.1463	0.8638	0.4098	53	4.09
7/21/96	Sand L	16	SAMP 16	0.7884	1.6422	1.6146	0.2751	18	3.31
8/17/96	Sand L	17	SAMP 17	1.607	0.9485	1.0484	0.2709	21	4.74
9/15/96	Sand L	18	SAMP 18	1.8307	0.9569	1.2721	0.9239	14	3.38
10/31/96	Sand L	19	SAMP 19	0.6687	1.8889	0.2244	0.1608	6	2
11/20/96	Sand L	20	SAMP 20	1.304	0.7085	1.4863	0.9321	20	6.67
12/15/96	Sand L	21	SAMP 21	1.1972	1.4539	1.0827	0.3822	68	5.43
2/1/97	Sand L	22	SAMP 22	0.9428	1.5121	0.5863	0.2286	50	4.77
3/30/97	Sand L	23	SAMP 23	0.0799	1.6712	0.7647	0.2516	32	4.74
5/3/97	Sand L	24	SAMP 24	1.3799	1.2861	1.0089	0.5912	32	4.79
6/7/97	Sand L	25	SAMP 25	1.9328	0.8232	0.7413	0.5556	77	1.85
7/11/97	Sand L	26	SAMP 26	0.9842	1.8199	2.0639	0.225	65	3.3
3/19/96	S Fork	-	(There were no organisms in this sample.)						
5/3/96	S Fork	27	SAMP 28	2.4464	0.78	0.8079	0.8098	656	1.17
7/21/96	S Fork	28	SAMP 29	2.1681	1.0149	0.9818	1.1611	43	2.24
8/17/96	S Fork	29	SAMP 30	2.302	0.7878	0.8008	0.7457	88	1.37
9/15/96	S Fork	30	SAMP 31	1.952	1.0802	0.7678	0.7169	128	2.34
10/31/96	S Fork	31	SAMP 32	2.3616	0.7947	0.7554	0.7252	301	1.12
11/20/96	S Fork	32	SAMP 33	2.3254	0.784	0.7808	0.7376	211	1.27
12/15/96	S Fork	33	SAMP 34	2.213	0.8529	0.8654	0.7114	67	1.42
2/1/97	S Fork	34	SAMP 35	2.169	0.8255	0.7281	0.6921	125	1.54
3/30/97	S Fork	35	SAMP 36	2.7555	0.8802	0.8309	0	35	2.51
5/3/97	S Fork	36	SAMP 37	2.4543	0.7796	0.7925	0.7779	450	1.13
6/7/97	S Fork	37	SAMP 38	2.3956	0.7751	0.8177	0.8599	170	1.17
7/11/97	S Fork	38	SAMP 39	2.3657	0.8008	0.7783	0.7751	311	1.19

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	3/19/96			*5/3/96*			*7/21/96*			*8/17/96*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
EPHEMEROPTERA												
BAETIDAE												
Undetermined	1	-	-	-	-	-	-	-	-	-	-	-
Baetis spp.	5	-	-	9	-	-	-	-	-	2	-	-
Acentrella spp.	-	-	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella spp.	2	-	-	22	-	-	-	-	-	-	-	-
Eurylophella spp.	-	-	-	3	-	-	-	-	-	-	-	-
HEPTAGENIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus spp.	-	-	-	-	-	-	-	-	-	-	-	-
Stenonema spp.	-	-	-	-	-	-	-	-	-	-	-	-
SIPHLONURIDAE												
Ameletus spp.	-	1	-	3	-	-	-	-	-	-	-	-
PLECOPTERA												
CAPNIIDAE												
Undetermined	-	-	-	-	-	4	-	-	-	-	-	-
Allocapnia spp.	1	-	-	3	1	-	-	-	-	-	-	-
Capnia spp.	-	-	-	5	-	-	-	-	-	-	-	-
CHLOROPERLIDAE												
Haploperla spp.	1	-	-	19	3	-	-	1	-	-	-	-
LEUCTRIDAE												
Leuctra spp.	1	-	-	-	-	-	-	-	-	-	-	-
NEMOURIDAE												
Amphinemura spp.	21	-	-	357	19	-	-	-	-	-	-	-
Ostracerca spp.	-	-	-	-	-	-	-	-	-	-	-	-
PELTOPERLIDAE												
Peltoperla arcuata	1	-	-	16	-	-	-	1	-	-	-	2
PERLIDAE												
Acroneuria spp.	-	-	-	-	-	-	-	1	-	-	-	-
Eccoptera spp.	-	-	-	-	-	-	-	-	-	-	-	-
PERLODIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla spp.	24	1	-	33	-	-	1	1	-	-	-	-
PTERONARCYIDAE												
Pteronarcys spp.	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA												
UNDETERMINED	-	-	-	-	-	-	-	-	-	-	-	1
GLOSSOSOMATIDAE												
Glossoma spp.	-	-	-	-	-	-	-	-	-	-	-	-
HYDROPSYCHIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Cheumatopsyche spp.	1	-	-	7	-	-	-	-	-	-	1	-
Diplectrona spp.	7	2	-	51	7	1	1	3	4	-	4	5
Hydropsyche spp.	3	1	-	2	1	-	5	9	-	-	2	-
LIMNEPHILIDAE												
Chyranda spp.	-	-	-	-	-	-	-	-	-	-	-	-
Ironoquia spp.	-	-	-	-	-	-	-	-	-	-	-	-
RHYCOPHILIDAE												
Rhyacophila spp.	-	1	-	2	-	-	-	-	-	-	-	-
PHILOPOTAMIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Dolophilodes spp.	1	-	-	-	-	-	-	-	-	-	-	-
POLYCENTROPODIDAE												
Cymellus spp.	-	-	-	-	-	-	-	-	-	-	-	-
Neureclipsis spp.	-	-	-	-	-	-	-	-	-	-	-	-
Polycentropus spp.	-	-	-	-	-	1	-	-	-	-	-	1
UENOIDAE												
Neophylax spp.	2	-	-	1	-	-	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	9/15/96			*10/31/96*			*11/20/96*			*12/15/96*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
EPHEMEROPTERA												
BAETIDAE												
Undetermined	-	-	-	-	-	-	11	-	-	23	1	-
Baetis spp.	62	-	-	164	1	-	-	1	-	83	2	-
Acentrella spp.	-	-	-	-	-	-	-	-	-	6	-	-
EPHEMERELLIDAE												
Undetermined	-	-	-	-	-	-	1	-	-	-	-	-
Ephemerella spp.	-	-	-	-	-	-	-	-	-	-	-	-
Eurylophella spp.	-	-	-	-	-	-	-	-	-	-	-	-
HEPTAGENIIDAE												
Undetermined	1	-	-	-	-	-	-	-	-	4	-	-
Epeorus spp.	-	-	-	-	-	-	-	-	-	-	-	-
Stenonema spp.	-	-	-	4	-	-	-	1	-	-	-	-
SIPHLONURIDAE												
Ameletus spp.	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA												
CAPNIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Allocapnia spp.	-	-	-	-	-	-	27	-	-	3	-	-
Capnia spp.	-	-	-	-	-	-	-	-	-	-	-	-
CHLOROPERLIDAE												
Haploperla spp.	6	-	-	5	-	-	-	-	-	-	-	-
LEUCTRIDAE												
Leuctra spp.	-	-	-	-	-	-	-	-	-	-	1	-
NEMOURIDAE												
Amphinemura spp.	-	-	-	-	-	-	-	-	-	-	-	-
Ostracerca spp.	-	1	-	-	-	-	-	-	-	-	-	-
PELTOPERLIDAE												
Peltoperla arcuata	5	-	-	-	-	-	1	-	5	2	-	-
PERLIDAE												
Acroneuria spp.	-	-	-	-	-	-	1	-	-	1	-	-
Eccoptera spp.	-	-	-	1	-	-	1	-	-	-	-	-
PERLODIDAE												
Undetermined	2	-	-	-	-	-	-	-	-	-	-	-
Isoperla spp.	1	-	7	9	-	-	2	-	-	26	4	-
PTERONARCYIDAE												
Pteronarcys spp.	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA												
UNDETERMINED	-	-	-	-	-	-	-	1	-	1	-	-
GLOSSOSOMATIDAE												
Glossoma spp.	1	-	-	-	-	-	-	-	-	-	-	-
HYDROPSYCHIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Cheumatopsyche spp.	11	1	-	13	-	-	4	-	-	5	2	-
Diplectrona spp.	45	2	25	30	4	15	37	2	7	43	23	3
Hydropsyche spp.	35	1	-	43	-	-	16	1	-	29	9	-
LIMNEPHILIDAE												
Chyranda spp.	-	-	-	-	-	-	-	-	-	-	-	-
Ironoquia spp.	-	-	-	-	-	-	-	-	-	-	-	-
RHYCOPHILIDAE												
Rhyacophila spp.	-	-	-	1	-	-	-	-	-	1	-	-
PHILOPOTAMIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Dolophilodes spp.	-	-	-	17	-	-	6	-	-	7	-	-
POLYCENTROPODIDAE												
Cyrnellus spp.	-	-	-	-	-	-	-	-	-	-	1	-
Neureclipsis spp.	-	-	-	-	1	-	1	-	-	-	-	-
Polycentropus spp.	-	-	1	-	-	-	-	-	-	-	-	-
UENOIDAE												
Neophylax spp.	-	-	-	-	-	-	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	2/1/97			3/30/97			5/3/97			6/7/97		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
EPHEMEROPTERA												
BAETIDAE												
Undetermined	22	-	-	-	1	-	2	-	-	40	-	-
Baetis spp.	262	11	-	27	1	1	23	-	-	38	5	-
Acentrella spp.	-	-	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE												
Undetermined	-	-	-	-	-	-	1	-	-	-	-	-
Ephemerella spp.	-	-	-	11	1	-	15	-	-	-	-	-
Eurylophella spp.	-	-	-	-	-	-	-	-	-	-	-	-
HEPTAGENIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus spp.	1	1	-	-	-	-	-	-	-	-	-	-
Stenonema spp.	-	-	-	-	-	-	-	-	-	-	-	-
SIPHLONURIDAE												
Ameletus spp.	1	-	-	4	-	-	2	-	-	-	-	-
PLECOPTERA												
CAPNIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Allocapnia spp.	4	-	-	-	-	-	-	-	-	1	2	-
Capnia spp.	-	-	-	-	-	-	-	-	-	-	-	-
CHLOROPERLIDAE												
Haploperla spp.	-	-	-	6	2	-	1	1	-	-	-	-
LEUCTRIDAE												
Leuctra spp.	-	1	-	-	-	-	-	-	-	-	-	-
NEMOURIDAE												
Amphinemura spp.	-	-	-	1	3	-	28	-	-	6	1	-
Ostracerca spp.	-	-	-	-	-	-	-	-	-	-	-	-
PELTOPERLIDAE												
Peltoperla arcuata	-	-	5	2	-	-	-	1	-	2	-	1
PERLIDAE												
Acroneuria spp.	-	-	-	-	-	-	1	-	-	1	-	-
Eccoptera spp.	-	-	-	-	-	-	-	-	-	-	-	-
PERLODIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla spp.	142	11	1	102	12	-	14	2	-	5	-	-
PTERONARCYIDAE												
Pteronarcys spp.	-	-	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA												
UNDETERMINED	-	-	-	-	-	-	4	-	-	2	-	-
GLOSSOSOMATIDAE												
Glossoma spp.	-	-	-	-	-	-	-	-	-	-	-	-
HYDROPSYCHIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	1	-	-
Cheumatopsyche spp.	-	4	-	-	-	-	-	-	-	-	-	-
Diplectrona spp.	35	2	12	26	7	1	20	7	-	32	3	-
Hydropsyche spp.	37	-	-	14	-	-	13	2	-	17	4	-
LIMNEPHILIDAE												
Chyranda spp.	-	-	-	-	-	-	-	-	2	-	-	-
Ironoquia spp.	-	-	-	-	-	-	-	-	1	-	-	-
RHYCOPHILIDAE												
Rhyacophila spp.	-	-	-	-	1	-	-	-	-	1	-	-
PHILOPOTAMIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
Dolophilodes spp.	4	-	-	-	-	-	-	-	-	2	1	-
POLYCENTROPODIDAE												
Cyrnellus spp.	-	-	-	-	-	-	-	-	-	-	-	-
Neureclipsis spp.	-	-	-	1	-	-	-	-	-	-	-	-
Polycentropus spp.	-	-	-	-	-	-	-	-	2	1	-	-
UENOIDAE												
Neophylax spp.	2	-	-	-	-	-	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	7/11/97		
	NFSL	SL	SFSL
EPHEMEROPTERA			
BAETIDAE			
Undetermined	22	-	-
Baetis spp.	-	-	-
Acentrella spp.	-	-	-
EPHEMERELLIDAE			
Undetermined	-	-	-
Ephemerella spp.	-	-	-
Eurylophella spp.	-	-	-
HEPTAGENIIDAE			
Undetermined	-	-	-
Epeorus spp.	-	-	-
Stenonema spp.	-	-	-
SIPHLONURIDAE			
Ameletus spp.	-	-	-
PLECOPTERA			
CAPNIIDAE			
Undetermined	-	-	-
Allocapnia spp.	5	-	-
Capnia spp.	-	-	-
CHLOROPERLIDAE			
Haploperla spp.	-	-	-
LEUCTRIDAE			
Leuctra spp.	-	-	-
NEMOURIDAE			
Amphinemura spp.	-	-	-
Ostracerca spp.	-	-	-
PELTOPERLIDAE			
Peltoperla arcuata	4	1	-
PERLIDAE			
Acroneuria spp.	-	-	-
Eccoptera spp.	-	-	-
PERLODIDAE			
Undetermined	-	-	-
Isoperla spp.	3	4	2
PTERONARCYIDAE			
Pteronarcys spp.	1	-	-
TRICHOPTERA			
UNDETERMINED	-	-	-
GLOSSOSOMATIDAE			
Glossoma spp.	-	-	-
HYDROPSYCHIDAE			
Undetermined	-	-	1
Cheumatopsyche spp.	2	-	-
Diplectrona spp.	5	1	1
Hydropsyche spp.	10	33	1
LIMNEPHILIDAE			
Chyranda spp.	-	-	1
Ironoquia spp.	-	-	-
RHYCOPHILIDAE			
Rhyacophila spp.	-	-	-
PHILOPOTAMIDAE			
Undetermined	-	1	-
Dolophilodes spp.	-	-	-
POLYCENTROPODIDAE			
Cymellus spp.	-	-	-
Neureclipsis spp.	-	-	-
Polycentropus spp.	-	-	-
UENOIDAE			
Neophylax spp.	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	3/19/96			5/3/96			7/21/96			8/17/96		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
COLEOPTERA												
UNDETERMINED	-	-	-	2	-	1	-	-	-	-	-	-
DRYOPIDAE												
Helichus spp.	-	-	-	-	1	-	-	-	-	-	-	-
ELMIDAE												
Undetermined	-	-	-	-	1	-	1	-	-	2	2	-
HYDROPHILIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
PSEPHENIDAE												
Ectopria spp.	1	-	-	-	-	2	-	-	1	-	-	-
Psephenus spp.	1	-	-	8	-	-	-	-	-	-	-	-
DIPTERA												
UNDETERMINED	-	-	-	-	-	9	-	-	-	-	-	-
CERATOPOGONIDAE												
Undetermined	-	2	-	2	-	21	-	-	-	4	-	-
CHIRONOMIDAE												
Undetermined	4	11	-	93	16	607	7	-	28	81	8	75
DIXIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
DOLICHOPODIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	7	-	-
EMPIDIDAE												
Undetermined	-	-	-	3	-	-	-	-	-	2	-	-
MUSCIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
TIPULIDAE												
Dicranota spp.	-	-	-	-	-	-	-	-	-	-	-	-
Erioptera spp.	-	-	-	-	-	-	-	-	-	-	-	-
Hexatoma spp.	-	-	-	-	-	-	-	-	1	-	-	-
Tipula spp.	4	-	-	15	-	4	1	-	2	-	1	-
HEMIPTERA												
CORIXIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	1	-	-
GERRIDAE												
Undetermined	-	-	-	-	2	-	-	-	-	-	-	-
MACROVELIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	1	2
NOTONECTIDAE												
Notonecta spp.	-	-	-	-	-	-	-	-	1	-	-	-
SALDIDAE												
Undetermined	-	-	-	-	-	-	-	-	1	-	-	-
VELIIDAE												
Microvillia spp.	-	1	-	-	-	2	-	-	-	-	-	-
LEPIDOPTERA												
PYRALIDAE												
Undetermined	-	-	-	-	-	-	-	-	1	-	-	1
MEGALOPTERA												
CORYDALIDAE												
Chauloides spp.	-	-	-	-	-	-	-	-	-	-	-	-
Nigronia fasciatus	-	-	-	-	2	3	-	2	4	-	1	1
SIALIDAE												
Sialis spp.	-	-	-	-	-	1	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	9/15/96			10/31/96			11/20/96			12/15/96		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
COLEOPTERA												
UNDETERMINED	-	-	-	-	-	-	-	-	-	-	1	-
DRYOPIDAE												
Helichus spp.	-	-	1	-	-	-	-	-	-	-	-	-
ELMIDAE												
Undetermined	1	-	1	-	-	-	2	-	2	-	1	-
HYDROPHILIDAE												
Undetermined	1	-	-	-	-	-	-	-	-	-	-	-
PSEPHENIDAE												
Ectopria spp.	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus spp.	-	-	-	-	-	-	-	-	-	-	-	-
DIPTERA												
UNDETERMINED	1	-	-	-	-	-	-	2	-	-	3	1
CERATOPOGONIDAE												
Undetermined	-	-	2	-	-	2	-	-	2	-	-	-
CHIRONOMIDAE												
Undetermined	180	7	79	23	-	284	29	6	187	63	14	56
DIXIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
DOLICHOPODIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
EMPIDIDAE												
Undetermined	13	-	1	2	-	-	3	-	-	2	1	2
MUSCIDAE												
Undetermined	1	-	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE												
Undetermined	3	1	-	-	-	-	-	-	-	1	-	-
TIPULIDAE												
Dicranota spp.	-	-	-	-	-	-	-	1	-	1	-	-
Erioptera spp.	-	-	-	-	-	-	-	-	-	1	1	1
Hexatoma spp.	-	-	-	-	-	-	1	-	-	-	-	-
Tipula spp.	8	-	-	4	-	-	5	1	1	1	1	2
HEMIPTERA												
CORIXIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
GERRIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
MACROVELIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
NOTONECTIDAE												
Notonecta spp.	-	-	-	-	-	-	-	-	-	-	-	-
SALDIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
VELIIDAE												
Microvillia spp.	1	-	1	-	-	-	-	-	-	-	-	-
LEPIDOPTERA												
PYRALIDAE												
Undetermined	-	-	1	-	-	-	-	-	-	-	-	-
MEGALOPTERA												
CORYDALIDAE												
Chauloides spp.	-	-	-	-	-	-	-	-	-	-	-	-
Nigronia fasclatus	1	1	9	1	-	-	9	-	7	-	1	1
SIALIDAE												
Sialis spp.	-	-	-	-	-	-	-	1	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	2/1/97			*3/30/97*			*5/3/97*			*6/7/97*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
COLEOPTERA												
UNDETERMINED	-	-	-	-	-	-	-	-	-	1	-	-
DRYOPIDAE												
Helichus spp.	1	-	2	-	-	-	-	-	-	-	-	-
ELMIDAE												
Undetermined	-	1	-	-	-	-	-	-	-	8	1	-
HYDROPHILIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	1	-
PSEPHENIDAE												
Ectopria spp.	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus spp.	-	-	-	-	-	-	-	-	-	1	-	-
DIPTERA												
UNDETERMINED	-	-	1	-	-	1	-	-	-	-	-	-
CERATOPOGONIDAE												
Undetermined	-	-	1	-	-	17	-	-	14	1	-	-
CHIRONOMIDAE												
Undetermined	45	16	100	7	-	14	57	12	423	191	56	157
DIXIDAE												
Undetermined	-	-	-	-	-	-	-	1	-	-	-	-
DOLICHOPODIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
EMPIDIDAE												
Undetermined	2	1	-	1	-	-	-	-	-	7	1	-
MUSCIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	1	-	-
TIPULIDAE												
Dicranota spp.	1	-	-	-	-	-	-	-	-	-	-	-
Erioptera spp.	1	-	1	4	1	-	1	2	1	-	-	-
Hexatoma spp.	1	-	-	-	-	-	-	-	-	-	-	-
Tipula spp.	9	1	1	6	-	-	3	1	1	3	-	2
HEMIPTERA												
CORIXIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
GERRIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
MACROVELIIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
NOTONECTIDAE												
Notonecta spp.	-	-	-	-	-	-	-	-	-	-	-	-
SALDIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
VELIIDAE												
Microvillia spp.	-	-	-	-	-	-	-	-	-	-	-	-
LEPIDOPTERA												
PYRALIDAE												
Undetermined	-	-	-	-	-	-	-	-	-	-	-	-
MEGALOPTERA												
CORYDALIDAE												
Chauloides spp.	-	-	-	-	-	-	-	-	-	-	-	3
Nigronia fasciatus	-	1	1	1	1	1	-	1	6	-	-	5
SIALIDAE												
Sialis spp.	-	-	-	-	-	-	-	-	-	-	-	1

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	7/11/97		
	NFSL	SL	SFSL
COLEOPTERA			
UNDETERMINED	1	-	1
DRYOPIDAE			
Helichus spp.	1	-	-
ELMIDAE			
Undetermined	-	-	1
HYDROPHILIDAE			
Undetermined	-	-	-
PSEPHENIDAE			
Ectopria spp.	-	-	-
Psephenus spp.	-	-	-
DIPTERA			
UNDETERMINED	-	1	-
CERATOPOGONIDAE			
Undetermined	-	-	1
CHIRONOMIDAE			
Undetermined	6	10	285
DIXIDAE			
Undetermined	-	-	-
DOLICHOPODIDAE			
Undetermined	-	-	-
EMPIDIDAE			
Undetermined	-	-	6
MUSCIDAE			
Undetermined	-	-	-
SIMULIIDAE			
Undetermined	-	-	-
TIPULIDAE			
Dicranota spp.	-	-	-
Erioptera spp.	-	7	-
Hexatoma spp.	-	-	2
Tipula spp.	-	1	1
HEMIPTERA			
CORIXIDAE			
Undetermined	-	-	-
GERRIDAE			
Undetermined	-	-	-
MACROVELIIDAE			
Undetermined	-	-	-
NOTONECTIDAE			
Notonecta spp.	-	-	-
SALDIDAE			
Undetermined	-	-	-
VELIIDAE			
Microvillia spp.	-	-	-
LEPIDOPTERA			
PYRALIDAE			
Undetermined	-	-	-
MEGALOPTERA			
CORYDALIDAE			
Chauloides spp.	-	-	1
Nigronia fasciatus	-	4	7
SIALIDAE			
Sialis spp.	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	3/19/96			*5/3/96*			*7/21/96*			*8/17/96*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
DECAPODA												
CAMBARIDAE												
Cambarus spp.	-	-	-	7	-	-	-	-	-	-	-	-
ISOPODA												
ASELLIDAE												
Caecidotea spp.	-	-	-	1	-	-	-	-	-	-	-	-
LUMBRICULIDA												
LUMBRICULIDAE												
Undetermined	1	-	-	26	-	-	-	-	-	-	1	-
MOLLUSCA												
PLANORBIDAE												
Helosoma spp.	-	-	-	-	-	-	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	9/15/96			*10/31/96*			*11/20/96*			*12/15/96*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
DECAPODA												
CAMBARIDAE												
Cambarus spp.	-	-	-	1	-	-	1	-	-	-	-	-
ISOPODA												
ASELLIDAE												
Caecidotea spp.	-	-	-	-	-	-	-	-	-	-	-	-
LUMBRICULIDA												
LUMBRICULIDAE												
Undetermined	-	-	-	-	-	-	-	3	-	-	-	1
MOLLUSCA												
PLANORBIDAE												
Helosoma spp.	-	-	-	-	-	-	-	-	-	-	2	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	2/1/97			*3/30/97*			*5/3/97*			*6/7/97*		
	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL	NFSL	SL	SFSL
DECAPODA												
CAMBARIDAE												
Cambarus spp.	1	-	-	2	-	-	1	2	-	3	1	1
ISOPODA												
ASELLIDAE												
Caecidotea spp.	-	-	-	-	-	-	-	-	-	-	-	-
LUMBRICULIDA												
LUMBRICULIDAE												
Undetermined	4	-	-	2	2	-	1	-	-	1	1	-
MOLLUSCA												
PLANORBIDAE												
Helosoma spp.	-	-	-	-	-	-	-	-	-	-	-	-

Appendix D, Table 6: Sample benthos taxa collected and enumerated.

	7/11/97		
	NFSL	SL	SFSL
DECAPODA			
CAMBARIDAE			
Cambarus spp.	1	-	-
ISOPODA			
ASELLIDAE			
Caecidotea spp.	-	-	-
LUMBRICULIDA			
LUMBRICULIDAE			
Undetermined	-	2	-
MOLLUSCA			
PLANORBIDAE			
Helosoma spp.	-	-	-