ATTACHMENT 6

"AN ECOLOGICAL INVESTIGATION OF THE LOWER NORTH ANNA
AND UPPER PAMUNKEY RIVER SYSTEM,"
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Prepared for

Mr. J. D. Ristroph, Executive Director
Environmental Control
Virginia Electric and Power Company

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This study was supported by the Virginia Electric and Power Company.

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AN ECOLOGICAL INVESTIGATION OF THE LOWER NORTH ANNA AND UPPER PAMUNKEY RIVER SYSTEM

Introduction

The North Anna River originates in the upper Piedmont Region of Virginia in Albemarle and Orange Counties, approximately 20 miles east of the Blue Ridge Mountains (Figure 1).

The drainage basin is located in the north-central part of the Piedmont Physiographic Province of Virginia. This province is bordered on the east by the Coastal Plain Province and on the West by the Blue Ridge Province. The river flows eastward and eventually contributes to the formation of the York River which drains into the Chesapeake Bay. The drainage basin consists of gently rolling terrain with broad, flat-topped hills and narrow, eastward sloping valleys. The surface of the Piedmont Province exhibits a slight south-eastward slope from an altitude of approximately 1000 feet at the western margin to about 200 feet at the eastern margin.

The Piedmont Province contains a greater variety of mineral resources than either of the other two provinces. Many of these minerals are of commercial importance. Pyrite, associated with gold, silver, lead, and zinc is probably more abundant than any of the other minerals and occurs in many places throughout the gold-pyrite belt in the province. The portion of the belt through Louisa and Spotsylvania Counties has been extensively mapped (Cline, et al, 1921).

One of the main tributaries of the North Anna River is Contrary Creek (Figure 1). The land adjacent to the head waters of this stream was the site of extensive mining operations during the period 1882-1920. Although many minerals were mined, the primary elements sought were iron and sulfur in the form of iron pyrite - FeS_2. During this time (commercial operation: 1885 - 1920), three different mines were in operation and produced nearly 6,883,000 tons of pyrite which constituted approximately 13.2 percent of the national output. A comprehensive history of the ownership of the properties has been discussed in detail by Katz (1961), Painter (1905a, 1905b), and Watson (1907).

The ore was mined, milled, and washed at the mine sites, and the tailings were deposited along the stream bank (Painter 1905a, 1905b). It has been shown that sulfuric acid is produced when the sulfide is exposed to air and water (Parsons, 1968). As a result, sulfuric acid has been introduced into Contrary Creek, not only from the washings of the mining heyday, but also from subsequent drainage of the tailings along the stream bank. In summary, Contrary Creek and the area in the North Anna River below the entrance of the Contrary Creek has suffered from acid drainage for nearly 100 years. Figure 2 is an aerial photograph of a portion of the Contrary Creek basin approximately three miles below the mine sites in Louisa County. State Route 652 and the bridge across Contrary Creek are in the foreground. Figures 3 and 4 taken from the bridge seen in the Figure 2, show the erosion which occurred on the soils on which the vegetation had been destroyed by the acid mine drainage.

Statement of the Problem

Previous studies have shown that there is a 65 percent reduction in the fish species composition in the North Anna River below the entrance of Contrary Creek and a 40 to 60 percent over-all standing crop reduction of macrobenthic fauna (Simmons and Reed, in press; Simmons, in press). The Phylum Mollusca, which constitutes approximately 30 percent of this faunal segment above the entrance of Contrary Creek, have not become re-established below the entrance of Contrary Creek within the preimpoundment basin even though species of this phylum occur in tributaries below the entrance of Contrary Creek (Thomas and Simmons, 1970). Obviously, these species are constantly being re-introduced, but are failing to become re-established. The persistence of acid drainage has depleted much of the vegetation in the river bottom and extensive erosion and sedimentation has resulted. The biological recovery area of the North Anna River had not been determined before this study was conducted.

The impoundment on the North Anna River should ameliorate the effects of acid mine drainage and silt loads in the river, and there should be a significant improvement in water quality in the downstream area. Over an extended period of time, the recovery zone should progress up the river toward the dam site.

Project Proposal

An ecological study of the North Anna River below the impoundment was initiated during the summer of 1971 in order to locate and delineate the complete recovery zone of the biological community. This study will provide detailed pre-operational information on water quality in the lower North Anna and upper Pamunkey Rivers. This information will be used during post-impoundment and post-operational studies to evaluate the downstream effects of the impoundment.

Methods

Bi-weekly chemical and physical samples were collected from five stations on the lower North Anna River and five stations on the upper Pamunkey River (Figure 5, Table 1).

At the respective stations, the following water quality evaluations were made:

Physical

Temperature was collected by means of a calibrated long stem thermometer.

Total solids were collected with a non-metallic Kemmerer water bottle. One liter of water was evaporated in a pre-weighed crucible over a steam bath. Dry weight of the total solids was obtained by subtracting the difference between the tared crucible and crucible plus the residue. The crucibles were subsequently ashed at 500°C for 30 - 45 minutes to evaluate the organic and inorganic content of the total solids.

Turbidity values were estimated by means of a Bausch and Lomb Spectronic 20 and expressed in Jackson Turbidity Units.

Flow rate data was obtained on a daily basis from a calibrated discharge station at Doswell, Virginia. The station is maintained by the Virginia Department of Conservation and Economic Development, Division of Water Resources.

Chemical

Oxygen samples were collected with a non-metallic Kemmerer water bottle and analyzed by the Alsterberg (Azide) Modification of the Winkler Method (American Public Health Association, et al, 1971).

Salinity samples in the diurnal studies at West Point, Virginia were measured with a calibrated hydrometer.

The hydrogen ion concentrations were determined in the field with a Porto-matic Model 175 pH meter. Conductivity was collected by a Lab-Line portable conductivity meter (Model No. 11000).

Nutrient samples (nitrates and phosphate) and metals (iron, magnesium, zinc, and sulfates) were analyzed with a Bausch and Lomb Spectronic 20 and Hach chemical reagents.

Biological

Macrobenthos

The nature of the river bottom substrate does not lend itself to sampling with the conventional Súrber Square Foot sampling device. Therefore, shallow areas of the river were sampled with D-frame aquatic dip nets (Figures 6A, 6B) with an equal amount of effort being expended at each different habitat at the collection site. Samples were analyzed quantitatively for a diversity index utilizing the technique of Cairns, et al (1968, 1971) and Wilhem and Dorris (1968). SCUBA was also used to collect mussels in the deeper portions of the river to supplement the collections with the dip nets (Figure 7). SCUBA was also used to survey potential mussel habitats in otherwise uncolonized areas of the river below Contrary Creek and above the confluence of the South Anna River.

A ponar dredge was used at the White House Station due to the depth of the water. The data obtained were used to express density, diversity, and composition of the macrobenthic community.

Fishes

Several methods were employed to collect fishes. Shallow areas were sampled with a straight seine, 10 feet in length and 4 feet deep with 1/4 inch mesh. In deeper areas where access by wading was impossible, fishes were collected using either hoop nets (3 foot mouth) or an experimental monofilament gill net (1/2, 1, 1 1/2, 2, 2 1/2 inch square mesh) (Figures 8A, 8B). These latter nets necessitated the use of a boat and were only used at the Pamunkey River Stations.

In addition sampling was done by electrofishing using a 3 KW portable alternator which provided 230 volts of alternating current. This proved to be a very effective tool especially in deeper areas where seining was difficult or in and around log jams which could not have been sampled by other means.

The fishes collected were preserved in 10 percent formalin and stored in 40 percent isopropyl alcohol. The collections were analyzed for life history stages, condition of the fishes, diversity, and density parameters.

DESCRIPTION OF COLLECTION STATIONS

(c.f., Table 1, Figure 12)

Hanover - Spotsylvania Counties

Station 1 - State Route 658.

This station served as the most downstream collecting site in the pre-impoundment study of the North Anna Reservoir (Table 1). It is located approximately 2.0 river miles below the dam site and was selected as the most upstream collecting site for the present study.

The North Anna River at this site is divided into several channels by the presence of the bridge. High water in the past has piled logs and other debris around the bridge pilings and this in turn has provided a barrier for the build-up of small islands of sand. Beneath the bridge, there are many large rocks left from the bridge construction. These provide a deep riffle habitat with a series of shallow channels leading into them and several deep pools immediately downstream.

At a distance of 100 meters upstream or downstream from the bridge, the river is essentially a straight channel with a shifting sand bottom.

The number of habitats at this and many other sites in the study is greatly affected by water level. During times of high water, many shoreline areas are inundated and often provide good habitats for macrobenthos and fishes. These are usually temporary, however, and at times of low flow the number of habitats is greatly reduced.

Hanover - Caroline Counties

Station 2 - State Route 738

For purposes of water quality and other physical data, collections were made from the highway bridge at this site. However, the bridge has only recently been built and the river at this point was greatly modified by bridge construction, being widened and channeled.

Biological collections were made approximately one-half mile upstream at the site of an old mill.

This was an atypical situation for the North Anna River since the old mill dam was essentially intact except for a break at the north end. Above the dam was a large pond area and the water skirting the broken end of the dam had dug another pool area downstream. The bottom of the pond area above the dam was silt and sand, while the bottom of the pools below the dam were largely sand. The series of rapids resulting from the break in the mill dam had rocks and other debris from the dam as the substrate.

Station 3 - State Route 601

The area from this site downstream to the next station at U. S. Route 1 represents the fall line dividing the Piedmont and Coastal Plain geologic provinces. The habitat at Station 3 is varied, consisting of huge boulders of bedrock interspersed among the typical sandy river bottom. Areas of fast water exist where rocks are in close proximity to each other and between these rapids are small pool areas. Water willow (Justicia americana) and grasses grow in shallow shoreline regions where soil has been deposited.

There are several areas of slow, sluggish water that represent temporary river channels created by flood waters.

Fall Line - Area Between State Route 601 and U. S. Route 1

An area of approximately ten river miles separates stations 3 and 4. The greatest part of this stretch consists of a series of rapids and shelf areas with boulders and flat bedrock as the substrate. Between the sections of rapids lie areas of flat water with sand and silt substrates. This area terminates at the North Anna Falls, a series of abrupt drops in the river approximately two river miles above U. S. Route 1.

Below the North Anna Falls, the river returns to a flat, winding configuration with the characteristic sandy bottom interspersed with occasional patches of rubble or gravel.

Station 4 - U. S. Route 1

This station is like several others described in that the area of the river immediately above and below the bridge has been affected by bridge construction. The channel has been widened and the substrate immediately beneath the bridge consists of rocks and pieces of asphalt left from bridge construction and repair. These create a small riffle area which leads to several pools downstream from the bridge.

There is a Richmond, Fredricksburg and Potomac Railroad bridge approximately 300 meters downstream from U. S. Route 1 and this too has affected the North Anna River in much the same way as other bridges, i. e., by providing an abnormal substrate in the form of rocks and other debris.

There is an effluent discharge from the Evans Company, a synthetic fiber plant, which enters the river fifty meters upstream from the R. F. and P. Railroad bridge. The effluent was sampled and its effect is discussed herein.

Other collections at Station 4 were made between the U. S. Route 1 bridge and R. F. and P. bridge.

Station 5 - State Route 602

An extensive area of farmland borders Station 5 near the 602 bridge. The North Anna River at this site is slow and shallow, with occasional deep pools near the banks or around the bridge pilings. The substrate is almost entirely sand with areas of logs and debris present at wide intervals. These logs and debris and the holes near the banks provide the only suitable habitats at this station.

Confluence of North and South Anna Rivers

The confluence of the North and South Anna Rivers is not spectacular from a visual standpoint. Both rivers are small enough that an unknowing person might call one a tributary of the other. The confluence itself is characterized by a sandy bottom, with deep channels along the banks or in areas of log jams. Approximately 100 meters downstream the river bends and an area of gravel is exposed on the bottom. A similar gravel bed is located near the next bend downstream.

The river below the confluence (now the Pamunkey) is generally deeper than either the North Anna and South Anna above the confluence, although not significantly wider.

Station 6 - U. S. Route 301

Station 6 is the most upstream regular site on the Pamunkey River and is approximately 6.6 river miles below the confluence of the North and South Anna Rivers. The river here is typically deeper, but not much wider than the North Anna. Again the area immediately above and below the highway bridge is somewhat atypical in that shallow areas of gravel and rubble exist there. There are also several temporary channels which at times of high flow become flooded. During the early summer months, these are sluggish and represent backwater habitats, while late in the late summer they are generally dry.

The river proper has a substrate of sand, silt and debris in the channel and gravel or rubble on the outside of bends where the current tends to sweep the bottom.

Hanover - King William Counties

Station 7 - State Route 614

The aquatic habitat at Station 7 is quite limited. There is a new highway bridge at the site, but the rocks and rubble associated with bridge construction at other stations were lacking or so covered with silt as to be ineffective for biological substrates. The Pamunkey River is deep near the bridge and collecting by wading was difficult. The river bottom is typically sand or silt which makes this area a rather poor habitat. As in other cases, the best collecting was done near log jams.

Station 8 - State Route 615

The Pamunkey River at Station 8 is straight with high wooded banks. The river bottom is almost exclusively sand which is piled into a series of bars downstream from the 615 bridge. Other areas are too deep to collect in without a boat. There are several deep holes along the north bank of the river. As in other bridge areas, there are several temporary channels resulting from high flows around the bridge pilings. These channels are filled with sticks and debris, but offer suitable substrate for many forms. There are no rocks in the area of the collecting site.

Station 9 - U. S. Route 360

This site has a new bridge providing no easy access to the river. Physical and chemical water samples were taken from the bridge, but biological collections were made about three river miles upstream at State Route 602 which provided excellent access to the river.

The Pamunkey is deep in the main channel, but where a bend occurs 100 meters downstream from the access point, there is a gravel bar and a shallow channel area which allowed collecting by wading.

The river banks are high and wooded and the bottom is mud or clay in the channel, with gravel or rubble in some areas, especially at the wide bends in the river. There are also many fallen trees and log jams which provide additional habitats for macrobenthos and fishes.

Some collecting of fishes was done by boat at this station.

New Kent - King William Counties

Station 10 - White House, Virginia

This station represents the most downstream site sampled regularly during the study. Many different habitats exist at Station 10, since this is tidal water that occasionally becomes brackish during very low fresh water inflow. The shore is marsh and woodland. The channel of the Pamunkey has mud, gravel and clay as a substrate while the shallow areas bordering the channel are typically tidal mud flats. Collections were made in all of these areas, often with the aid of a boat.

RESULTS

Temperature

The temperature of the river rose from a mean of 22.9 C on June 10 to a mean of 25.9 C on July 8. After July 8, the temperature of the river began to drop and the final mean value was 23.6 C on August 19. The highest recorded values were 28.0 C at White House (Station 10), and 27.0 C at State Route 658 (Station 1) and U. S. 301 (Station 6). The temperature of the river varied as much as 3 C between different stations on the same collecting date. The highest temperatures observed on an individual collecting trip were at White House (Station 10), even though these values were collected in the morning at the beginning of each collecting trip.

Total Solids

Observations on total solids (T. S.) in the river system during the summer show that the river carries approximately 113.7 mg/l T. S. during the Summer, although there is considerable variation between individual stations. In general, the stations above State Route 602 (Station 5) carried slightly more total solids and were more characteristic of an erosional habitat than did the lower stations which were characteristic of a depositional habitat (135.4 mg/l and 110.8 mg/l T. S., respectively). This is to be expected since the fall line delineating the Piedmont and Coastal Plain Provinces occurs between State Route 601 (Station 3) and U. S. 1 (Station 4). The maximum amount of total solids observed at any one time in the river was 509.50 mg/l at State Route 738 (Station 2) on August 5. The lowest level of total solids carried by the river at any one time was 52.9 mg/l at State Route 601 (Station 3) on June 10. The mean maximum load carried by the river on an individual collecting date was 168.1 mg/l T. S. on June 24, and the minimum was 88.0 mg/l on July 22.

Since the majority of solids collected at any one time were usually retained after ashing, it would appear that the major portion of solids carried by the river are inorganic in nature.

Turbidity

The turbidity units were closely correlated with the total solids. Although no attempts were made to filter through .45u Millipore filters, the majority of solids collected upon evaporation would fall into the non-filterable category. Also, as observed with the total solids, the stations above and immediately below the fall line showed a higher mean turbidity than the lower stations (84.7 and 65.9, respectively). The highest turbidity, 395 JTU, occurred on August 5 at State Route 738 (Station 2) and the lowest 16 JTU, occurred at State Route 602 (Station 5) and U. S. 301 (Station 6) on August 19.

Oxygen

The concentration of oxygen also showed variation at the respective stations throughout the summer study. The highest values were usually found at the upper stations while the lowest values were always at White House (Station 10). Station 9 (U. S. 360) also showed lower than normal values, in comparison with the other stations, except on July 22. The mean value for the river changed from 7.1 mg/l on June 10 to a high of 7.3 mg/l on July 22. The highest recorded value was 8.1 mg/l at State Route 602 (Station 5) on June 10, 1971. The lowest recorded value was 3.8 mg/l at White House (Station 10) on June 10. This is not an unusual value for tidal streams receiving marsh drainage.

The mean values in the river for the respective months were 6.8 mg/l for June, 7.3 mg/l for July, and 6.5 mg/l for August. Observation of oxygen values reinforce Minckley's summation (1963) that rivers in every case cannot be regarded as horizontal profiles as limnologists have historically regarded vertical profiles in lakes. For the most part, the stations, under natural conditions, tend to be independent and may show considerable variation.

pH

As stated in an earlier paper (Simmons and Reed, in press), the pH and alkalinity values quickly return to normal below the confluence of Contrary Creek and the North Anna River. The pH values collected during the summer support this observation. The pH of the stations studied ranged between 6.5 to 9.2, but with 62 percent of the observations occurring between 7.0 to 7.5. There was no difference in pH values between the stations above and below the confluence with the South Anna River.

Conductivity

Approximately 68 percent of the samples collected ranged between 80 to 100 micromhos. The highest conductivity observation corresponded with the highest pH value (June 24 at State Route 615). Moreover, the stations above and immediately below the fall line tended to have higher values.

Nutrients

Reid (1961) points out that the nutrient level of streams varies considerably with discharge rate. Usually the concentrations increase as the flow rate increases and diminish as flows decrease. Phosphates, particularly, are not depleted in streams as in lakes, although there may be considerable longitudinal variation. Ammonia compounds in unpolluted streams are generally less than 1 mg/l.

The current water quality standards in Virginia (Annon., 1970) require that iron should not exceed 0.3 mg/l, nitrates 10 mg/l, and sulfates 250 mg/l. The National Technical Advisory Committee (1968) recommended that the concentration of total phosphorus should not exceed 0.100 mg/l in flowing streams or 0.05 mg/l where streams enter reservoirs.

The analyses of our water samples show that nitrate nitrogen levels ranged between 0.5 and <0.01 mg/l. The highest values occurred on August 19. The mean nitrate level for the study period was 0.300 mg/l (60 observations). Nitrite nitrogen levels were very low, usually 0.05 mg/l or less. Thirty-four samples (more than 50 percent of those collected) contained less than 0.005 mg/l. Ammonium nitrogen showed several high peaks. On June 24, values exceeded 1.0 mg/l and similar trends were noted on August 19. By far, however, the majority of samples consisted of less than 1.0 mg/l. The mean level for the period of study was 0.839 mg/l (60 observations).

Sulfate concentrations were quite variable and ranged from >100 mg/l to <1.0 mg/l. The highest values occurred during the early summer when the river discharge was greater. The mean value for the period of study was 33.265 mg/l (52 observations). Eight samples contained over 100 mg/l.

Using our techniques of water analyses, we believe that the majority of phosphate occurred in the particulate organic form. Using the Hach methods, the majority of phosphates showed up in the organic fraction. However, since it is known that phosphate ions absorb to soil particles (Taylor, 1967; Wadleigh, 1970), they can easily be stripped with dilute acid. The levels we encountered would not react until the samples had been treated with heat and acid. The concentrations of phosphate were surprisingly high. Since acid-washed glassware was used and standard curves were established on known phosphate values, the data are considered reliable. The majority of phosphate values greatly exceeded 1 mg/l. The highest values encountered (10.5 - 21.0 mg/l) occurred on June 24, 1970, one day after an increased river discharge. The values then dropped on July 8, to less than 1.0 mg/l only to climb again on July 22 to 2.5 - 16.0 mg/l. On July 22, samples were collected after a rain and during peak discharge. The values declined again in general, by August 5. During July and August, the phosphate level also varied more along the water course than was observed in June.

The only known major industrial discharge occurred from the Evans plant immediately below U. S. 1 (Station 4). On July 22, our measurements showed an orthophosphate level of 23 mg/l and total phosphate level of 40 mg/l. A dense growth of algae also occurred at the discharge point even though the effluent was quite turbid (Figures 8A, 8B). The overall effects of this discharge upon the general water quality was not investigated and is not known. However, judging from the biological collections at the next downstream station, the discharge has a negligible effect. The mean orthophosphate level (inorganic, soluble, and reactive) for the period of study was 0.315 mg/l (50 observations: 10 observations were less than 0.01 mg/l). The total phosphate level for the period of study was 5.798 mg/l (60 observations).

It was not unusual for the concentrations of iron to exceed 0.3 mg/l. The highest concentrations were found on June 24 and the lowest values on July 22. Values ranged between 0.15 - 1.37 mg/l with a mean of 0.704 mg/l for the study period (60 observations). Magnesium also showed considerable variation throughout the study period. The values ranged from 2.2 - <0.05 mg/l. The mean value was 0.97 mg/l for the period of study (49 observations: 11 observations showed less than 0.05 mg/l). Zinc was also measured and showed higher concentrations during June than July and August. However, the highest single value (2.3 mg/l) occurred at Station 1 on August 5. The concentrations of this metal ranged between 2.3 - 0.22 mg/l with a mean of 0.705 mg/l for the study period (60 observations).

Macrobenthos

Fourteen different collections were made of macrobenthic communities in an effort to determine the recovery zone of the river. In addition to the stations at the regular sites (bridges,), supplemental stations were established immediately above and below the confluence of the North Anna and South Anna Rivers and at two points on the North Anna between State Route 601 and U. S. 1. The latter collecting stations were located at the North Anna Falls (Figures 10A, 10B) and in an area approximately one mile further upstream in a region known among canoeists as the "shelf area" (Figures 11A, 11B).

The biological communities varied considerably through the segment of river under study. This variation was due more to the changes in physical habitats which in turn was due to changes in slope of the river bed (Figure 11). As indicated in an earlier report (Simmons, 1970), the insect community re-established itself quickly after the confluence of the North Anna River and Contrary Creek. This is expected since aquatic insects have an aerial stage in their life cycle and tend to move upstream before laying eggs (Hultin, et al, 1969), and because the aquatic stages exhibit drift (Waters, 1961a, 1961b, 1968; Cushing, 1964, Hynes, 1970). Without a doubt, the North Anna River is a trichopteran habitat and this order is one which contains species that are regarded as being very sensitive to different forms of pollutants (Gaufin and Tarzwell, 1952; Gaufin, 1958; Keup, et al, 1966; Mackenthun, 1966). The four dominant genera of Trichoptera encountered were Brachycentrus, Cheumatopsyche, Hydropsyche, and Macronenum. The relationship of abundance depended upon current and bottom characteristics. Populations of the Plecoptera and Ephemeroptera, although present in the North Anna River, were sporadic and appeared to vary according to the physical habitats available. Since the aquatic insects recovered quickly from the acid drainage and dominated the benthic communities, it is not surprising that the diversity indices of community structure in previously studied areas did not show a recovery zone.

Above the confluence of the North Anna River and Contrary Creek, approximately seven species of Mollusca could be found before basin clearing (Figures 13A, 13B) (3 gastropoda and 4 pelecypods). Since the molluscan segment of the benthic community did not re-establish itself below the entrance of Contrary Creek within the pre-impoundment basin, these organisms represented a more sensitive segment of the macrobenthos than did certain insect orders and were used to mark the area of full biological recovery.

Figure 14 shows the distribution of certain biotic categories which occupied 15 percent or more of the benthic community in at least one station. Note that the Mollusca do not become re-established until the confluence of the North Anna and South Anna Rivers. The first major mussel population occurred less than 100 meters downstream from the confluence of the two rivers (Figure 15). Based upon the re-establishment of the mussel genera, the North Anna River recovers biologically at the confluence with the South Anna River, i.e., at the beginning of the Pamunkey River.

After the first stable mussel bed was found, a search was made in similar habitats further down the Pamunkey River. The characteristic habitat of mussels was found to be the outside bottom in a river bend or immediately downstream where the current constantly sweeps the bottom and exposes a bed of gravel and cobble-stone size rocks (Figures 16A, 16B). Few mussels were found in the sandy bottom areas of the Pamunkey River. However, major beds of *Elliptio complanata* were found in mud bottoms at White House, (Figure 17). The quantity of mussels varied at each Pamunkey River Station, but the representation was uniform. Station 9 (U. S. 360) particularly was a good habitat for mussels (Figures 18A, 18B).

Once we were able to distinguish potential mussel habitats in the Pamunkey River, an upstream excursion was made on the North Anna from the confluence to State Route 602 (Figure 19). Although several potential habitats were discernable, no mussels were found. Within the last three years of study, an occasional gastropod or specimen of *Sphaerium striatum* has been found at one or more stations between the confluence of the

North Anna River and Contrary Creek, and the North Anna and South Anna Rivers, but to date only one specimen of *E. complanata* has been found in the degraded zone. This specimen was collected approximately 25 meters below the river bend above the bridge at State Route 602 (Figure 70). The lack of a mussel fauna in the degraded zone is probably due to the effects of siltation on mussels and associated fish populations. The lack of a suitable host fish species for the mussel glochidia would prevent completion of the life cycle. Similar relationships have been studied in the Tennessee River system (Ellis, 1931, 1936; Scruggs, 1960). It would be germane at this point to determine the host fish for the glochidia of the mussels in the Pamunkey River and correlate the recovery of the river in relation to re-establishment of the host fish and mussel populations.

The South Anna and Pamunkey Rivers harbor two large mussel species, *E. complanata* and *Lampsilis ovata cohongoronta* (Figures 21A, 21B), but of these two, the North Anna River harbors only the former. A limited population of the smaller *E. productus* was also found at State Route 208. The reason for the discrepancy between the distribution of these two large species merits further investigation. The other species of molluscs found at State Route 208 (Figures 13A, 13B) were not found in comparable quantities in the Pamunkey River. The lack of recolonization by these species is due more to a change in habitat than effects from Contrary Creek. The gastropods, in particular, were found to be very abundant in the beds of *Podostemum* at State Route 208. These beds of vegetation did not occur in the Pamunkey River.

Table 2 lists the diversity indices of the macrobenthic communities and Figure 23 graphically illustrates the data. As Figure 23 shows, there was a close correlation between the two methods of evaluating diversity indices ($r^2 = 0.8586$; $F = 78.97$ [1/13 0.05] = 4.7). The date shows that there was an initial high index at Station 1 and then a general decline to Station 4 where there was another peak. At Station 6 and the area above the confluence, the indices declined further. The lowest diversity index (0.27, 1.18) was found immediately above the confluence of the North Anna and South Anna Rivers. The low diversity at this station reflects the condition of the physical habitat rather than prevailing water quality. At this site, there was no rubble bottom or riffle area. The entire area consisted of a sandy bottom and banks. The dominant organism collected was Brachycentrus numerosus (Figures 24A, 24B) and the redundancy value of the Information Theory Diversity Index indicates the preponderance of a single species. Below the confluence, the diversity indices returned to the higher values observed in the upstream stations. There was another general decline until Station 10, when, oddly enough, the diversity indices returned to the values observed at Station 1 and immediately below the confluence of the North Anna and South Anna Rivers. The increase in chironomid species at Station 10 compensated for the other invertebrate forms found at the upper stations. It is indeed ironic that one of the locations of highest community diversity occurred in an area of slack water, high temperature, and low oxygen. However, if one considers that the increase in diversity is related to the increase in dipteran species, perhaps the discrepancy is not unusual.

Figure 23 shows that there were, in general, three peaks of maximum community diversity. One peak was found at the first collecting station, a second peak in the vicinity of U. S. 1 and the area below the confluence of the two rivers (dotted line) and a third peak at the last collecting station (White House). Since there was no distinct difference between community diversity indices at the confluence of the North Anna and South

Anna Rivers and some of the other stations, it is questionable whether or not the diversity indices revealed the biological recovery zone of the North Anna River. In our opinion they do not. The best index of full recovery is the presence of the extensive mussel bed immediately below the confluence of the North Anna and South Anna Rivers.

Recent studies on other benthic communities in Giles County, Virginia have shown Information Theory Diversity Indices of 4.14 - 4.33 on White Rock Branch, 3.60 - 4.12 on Spruce Run, and 0.71 - 4.61 on Little Stony Creek (Mathis, 1968). Diversity Indices based on the Sequential Comparison Index showed a range of 0.52 - 0.75 on the Appomattox River between Farmville and Petersburg, Virginia (Johnson and Rhodes, unpublished data) and 0.80 - 0.90 in the Blue Ridge pre-impoundment area on the New River (Rhodes, unpublished data). In comparison with these other studies, the community structure in the North Anna River reveals a healthy stream even without the mussel component of the benthos. The only variations in diversity indices were in those areas with a poor physical habitat.

State Route 208 (Figure 25) was visited again to ascertain what effect the basin clearing had on the benthic community. Even after basin clearing, the index of community diversity still remained high. In previous years, the mean diversity index was 0.92, and the 1971 Summer collection (0.88) indicated that the diversity had not changed significantly. In fact, the highest community diversity of all the stations investigated occurred at State Route 208. Aggus and Warren (1965) found that the dipteran element "appeared to increase" in an Arkansas reservoir basin cleared for impoundment. In contrast, we found the Coleoptera to increase in relation to previous observations.

Fishes

Thirty-two collections were made at fourteen different stations in the lower North Anna and upper Pamunkey Rivers. A total of 17 families and 51 species of fish were collected.

The greatest number of species (12) was from the minnow family, Cyprinidae. Several of these species were restricted to the upper stations of the North Anna because they prefer smaller and cooler waters (Table 3). Notropis analostranus, the satinfin shiner, and N. amoenus, the attractive shiner, were present throughout the study area. In fact, N. analostanus appeared to be the dominant fish in abundance wherever it was captured. In the 32 collections made, it occurred 22 times with a total of 305 individuals collected (Table 3).

Another common minnow, the golden shiner (Notemigonus crysoleucas), was present more often at the upper stations than in the deeper waters of the Pamunkey. A fish that preferred the deeper habitats of the lower stations was the spottail shiner Notropis hudsonium (Table 3).

Two other families are of particular interest when discussing fish populations in the North Anna - Pamunkey system. These are the sunfishes, Family Centrarchidae, and the eel, Family Anguillidae.

The Sunfish family was the second most common group of fishes collected, secondonly to the minnows. This is of interest because many species in this family are considered gamefish and are eagerly sought after by sportsmen. Two species were extremely common, the redbreast sunfish, Lepomis auritus and the bluegill, Lepomis macrochirus. Both grow to a good size and provide excellent sportfishing.

The redbreast sunfish, L. auritus, occurred in 19 of the 32 collections while the bluegill, L. macrochirus, was present in 22 collections. These fish, like other species of this family prefer slow, deep water, such as is usually found near banks or around log jams in the river. These habitats are somewhat limited, particularly in the North Anna, and as a result one could be assured of almost certain success when looking for these species where the habitat was suitable.

Several stages in the life history of the redbreast sunfish and bluegill were captured giving evidence that reproduction is occuring successfully.

Another gamefish of interest in this family, the largemouth bass, Micropterus salmoides, occurred in 11 of the 32 collections. It was most common in the Pamunkey River which is deeper and has more pools and areas of vegetation than the lower North Anna. Most of the largemouth bass collected were young of the year captured by seining in shallow, weedy areas. This indicated that reproduction is occurring successfully. Large bass are notoriously wary of nets and only one adult was captured in this manner. Electrofishing was often successful, but again the largemouth bass is a wary species and the noise and disturbance created by the portable alternator or the boat probably scared the larger fish away. Several large bass were sighted by Dr. Simmons and the assistants while using SCUBA gear to collect bottom fauna. The Pamunkey River is an ideal habitat for this species and is popular among sportsmen for bass fishing. This should be a gamefish of prime importance in the reservoir.

One other member of the sunfish family present, the black crappie, Pomoxis nigromaculatus is of interest since this species will also probably be an important gamefish in the new reservoir. This species is not basically a river fish, but is found in large pools and holes, typically at old mill sites or around log jams. The crappie is an uncommon fish in the North Anna being found only in those habitats just described. The Pamunkey is a better habitat for this species, although only one fish was captured at Station 10 (White House). This is possibly due to the lack of sampling in preferred crappie habitats, near brush or fallen trees.

Other sunfish occurred sporadically. One, the pumpkinseed, Lepomis gibbosus was present in 11 of 32 collections and rather generally widespread in the study area. This species is also an excellent pan fish for sport and food value.

The Family Anguillidae was the third most common family encountered during the study (Table 3). This group is composed of a single species, Anguilla rostrata, the American eel. Eels were captured at nearly every collecting station and occurred in 18 of 32 collections. Several sizes were collected except the large spawning adults which migrate downstream to the Atlantic Ocean to reproduce. Eels were especially susceptible to electrofishing and most of the samples taken were obtained by this method. This fish is extremely quick and perhaps as many as 30 percent of those encountered were not captured. The eel is very tolerant to adverse habitat conditions and in this study was collected many times where few other species were found.

Other fish distributions generally reflected habitat preferences, with such species as channel catfish Ictalurus punctatus, being more common in the Pamunkey than the North Anna. The young of the anadromous fishes, genus Alosa, were found in the upper and middle Pamunkey (Stations 9 and 10 downstream from where the adults had migrated to spawn in the spring).

The johnny darter, Etheostoma nigrum is a widespread species being found in 13 of the 32 collections and present at 11 different sites (Table 3). This is a small, bottom-dwelling member of the Family Percidae. It prefers the quiet, sandy habitat so prevalent in the North Anna and upper Pamunkey Rivers. Its value is probably as a forage fish and it could occur in the reservoir if the bottom there remains sandy.

One other gamefish, the chain pickerel, Esox niger, is present in the North Anna - Pamunkey system but this fish was uncommon in the collections of this study. It occurred only once, at Station 6. It is, however, probably quite common in the Pamunkey River where more vegetation is present. Another smaller specie of this genus, the redfin pickerel, Esox americanus, was much more common in the collections. It occurred in 10 of 32 collections and was taken throughout the study area (Table 3). Both of these pickerels should be present in the reservoir with the larger chain pickerel, being more important as a gamefish.

Two collections were made at State Route 208 in Louisa County. This station had been the control in the pre-impoundment study completed in 1970. We again used this site as an upstream control since it is located just upstream from the confluence of Contrary Creek and the North Anna River.

It was also of interest to evaluate the effects of clear cutting the impoundment basin on the fishes at this station. In the pre-impoundment survey this site was wooded on both sides of the river. The river bottom consisted of sand and gravel with many pools and some riffles.

Seventeen species and 170 individuals were captured by seining only. In the present study the diversity at State Route 208 was still good, with 19 species captured and a total of 98 individuals (Tables 3 and 4). However, it was obvious that the lack of cover and possible effects of siltation had reduced the populations of fishes at this site. While the data are comparable between the two collections from a diversity standpoint, it should be noted that twice as much effort was spent at this station in the present study and that electrofishing gear as well as a seine was used.

In three months of sampling the lower North Anna and upper Pamunkey Rivers, 17 families and 51 species of fish were collected. The most common families were the eel family, Anguillidae; minnow family, Cyprinidae; and the sunfish family, Centrarchidae. These typical for a Piedmont-Coastal Plain river system of the type studied. Some species within these families were ubiquitous, i.e. the eel, the satinfin shinner, the redbreast sunfish and the bluegill. These fishes showed up consistently and in the greatest numbers in the study collections, indicating their overall tolerance or preference for the conditions encountered in the rivers studied (Table 3). Other species were locally abundant depending upon habitat availability or in some cases, collection methods.

The diversity of the fish fauna in the North Anna is rather constant although Stations 1 and 3 immediately downstream from Contrary Creek exhibit depressed populations (Table 4). Station 2, State Route 738, is atypical in that it is an old mill site and the effects of erosion and sedimentation from Contrary Creek which are common elsewhere in this stretch of river have been ameliorated by the mill dam. These upper stations are probably under the influence of the sedimentation and occasional heavy metal runoff from the Contrary Creek which enters the North Anna River approximately 22 river miles upstream from Station 3 (State Route 601).

The stations below the fall line (Stations 4 through 10) appear to be less influenced by Contrary Creek. The diversity of fishes was greater and populations were larger as indicated by numbers of individuals taken per collection and per station (Table 4). The increase in river size below the confluence of the North and South Anna Rivers increases the number of potential habitats for fishes and as in the case of largemouth bass and and chain pickerel, the increase in vegetation along the banks and tributaries actually provides new and more desirable habitats for these species.

Thus, it becomes difficult to define a recovery area from the effects of Contrary Creek based solely on fishes. The increase in diversity and numbers of individuals in the Pamunkey River is probably due to the fact that a larger river with more diverse habitats will support more fish.

It is only in the North Anna River at Stations 1 and 3 where the habitats are numerous and diverse, yet where the fish populations are low, that one can see the effects of Contrary Creek on the fishes in the lower North Anna - upper Pamunkey system. Otherwise, the stations under natural conditions tend to be independent and may show considerable variation. The fishes reflect the diversity and abundance of macrobenthos and the results of the study show that molluscs, rather than aquatic insects or fishes are the best biological indicators of the recovery area of the North Anna River.

Salinity Studies

The Pamunkey River is tidal and thus subject to intrusions of brackish water for varying distances upstream depending on season of the year and river flow.

The river discharge is extremely variable, but generally low flows are experienced during the late Summer and early Autumn months. These low flows may allow brackish water from the York River to move up the Pamunkey for more than 50 miles. Such salt water intrusion is of biological significance because the marsh lands bordering the Pamunkey River are nursery grounds for many anadromous and estuarine fish and the effects of increased salinity on the larval and juvenile stages are not well known.

Because the discharge patterns of the North Anna - Pamunkey River system may be altered by the presence of the reservoir and dam located on the North Anna River, it is of interest to determine what the present patterns of tidal action in the system are in order to better assess the effects of the dam and reservoir on salinity intrusions in the future.

The Division of Water Resources of the Virginia Department of Conservation and Economic Development operates two stream gauges on the North Anna - Pamunkey River system, one on the North Anna River near Doswell, Virginia and a second on the Pamunkey River near Hanover, Virginia (Appendices 5,6).

From data compiled by Hyer, et al (1971), the brackish water of the York River has, on occasion, moved up the Pamunkey more than 50 miles.

In our study, the salinity of the lower Pamunkey River was checked on three different occasions. During the months of June and July, 24-hour studies were conducted to determine the extent of the tidal escursion in the upper York and lower Pamunkey, while in August the salinity was measured just prior to, and at a day-time, high tide.

The Pamunkey discharge during the June diurnal study dropped from 4030 cfs on June 17, the day prior to the study, to 2880 cfs on June 18, the day of the study. The flow continued to drop to 1610 cfs on June 19 (Table 6).

These flows reflect a rather heavy period of rainfall from June 15 to June 17. As a result of the large discharge of fresh water in the Pamunkey River at this time, surface salinities of 0.5 ppt or higher did not occur above the confluence of the Pamunkey and Mattaponi Rivers at West Point, Virginia.

In the July study, the discharge of the Pamunkey River was much less than during the June study. The flow on July 11, the day prior, was

273 cfs, while on July 12, the day of the study, it was 595 cfs. The discharge increased to 708 cfs on July 13 (Table 6). At periods of high tide, surface salinities of 0.5 ppt were measured approximately six miles upstream from West Point, Virginia.

During August, the discharge of the Pamunkey was quite low. The salinity was measured on August 23, just prior to and at a daytime high tide. The flow on this date was 192 cfs (Appendix 6). A surface value of 0.5 ppt was recorded approximately eight miles upstream from West Point, Virginia.

The location of the transition zone between fresh and salt water is directly related to freshwater inflows and the duration of a flow regime. The Summer of 1971 was one of moderate rainfall, thus extreme saltwater intrusions were prevented by fresh water discharges from the river system. It was obvious that in this study abnormal drought conditions were not encountered; and therefore, little can be said with respect to the upstream intrusion of brackish water in the Pamunkey River except under the specific conditions described.

Both the Division of Water Resources and VIMS have constructed computer models depicting the physical dynamics of the Upper York system. Our data generally agree with the controlled flow-maximum salinity model of the Division of Water Resources (Figure 26), except for the August values which show the salinity to be much farther downstream in the Pamunkey than predicted by the model for the particular flow rate (Figure 26).

The VIMS study showed that observed salinities in the Pamunkey approximated those calculated from their computer model. Because the results of these several studies indicate a highly variable and complex situation in the lower Pamunkey and upper York Rivers, we would agree with the recommendations of the VIMS report, namely that "a continuing program of measurements needs to be maintained to enable updating of the parameter used in the equations. Thus the effects of changes in river flow, or climate or state of health of the wetlands, may be detected and included in the model" (Hyer, P. V., _et al_, 1971).

Summary

A three month study has been made on the lower North Anna and upper Pamunkey River system to locate the recovery zone of the North Anna River from the acid drainage on Contrary Creek. The study included the collection of physical, chemical and biological information. Ten stations were sampled bi-weekly for physical and chemical data and fourteen stations were sampled for macrobenthos and fishes.

Physical and chemical information did not reveal any difference between water quality in the North Anna and Pamunkey Rivers. The temperature ranged between 22°C and 28°C for the Summer and the majority of oxygen samples showed 75 - 95 percent saturation. The lowest oxygen concentrations (3.8 mg/l) were found at White House (Station 10).

Nutrient analyses indicate that there is a potential for eutrophication which appears to be due to farming and livestock practices since few industries and municipalities discharge into the North Anna River. The pH of the river did not reveal the presence of acid drainage.

On the basis of the macrobenthos, the river recovered at the confluence of the North Anna and South Anna River, i.e., at the beginning of the Pamunkey River. Recovery is based upon the re-establishment of mussel populations. Diversity indices, because of the dominance of insect species, did not reveal the recovery zone. Potential habitats were located upstream on the North Anna, but did not harbor mussels. Mussels were found, however, throughout the Pamunkey. The fishes reflected the diversity and abundance of macrobenthos in the North Anna and Pamunkey Rivers. A specific recovery area could not be defined solely on the basis of fishes. Several important game and forage species are present in this river system and these should carry over to the new reservoir.

Now that the recovery zone has been located, another parameter is available to evaluate the effects of the North Anna dam and the North Anna Nuclear Power Station. If land reclamation can be accomplished at the old mine sites, the reservoir is expected to ameliorate the effects of Contrary Creek and, due to the design of the reservoir, the heated water discharge should not have any deleterious effects upon the receiving river biota. Further observations, within the context of our planned reservoir studies, will provide the opportunity to substantiate or reject these predictions.

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Table 1

Collection Site No.	
	HANOVER - SPOTSYLVANIA COUNTIES
1	State Route 658
	HANOVER - CAROLINE COUNTIES
2	State Route 738
3	State Route 601
Extra biological station	Fall Line and Shelf Areas
4	U.S. Route 1
5	State Route 602
Extra biological station	Confluence of North Anna and South Anna Rivers
6	U.S. Route 301 - State Route 2
	HANOVER - KING WILLIAM COUNTIES
7	State Route 614
8	State Route 615
9	U.S. Route 360
	NEW KENT - KING WILLIAM COUNTIES
10	Near White House, Virginia

Table 2

Sample size, species numbers, and diversity indices of macrobenthic communities in study area

Station	# of organisms	# of species	Diversity Index S.C.I.	Information Theory	Max.	Min.	R.
208	1913	55	.88	4.14	5.67	0.31	0.29
658	243	31	.84	3.74	4.62	0.97	0.24
758	1212	30	.73	2.80	4.81	0.24	0.44
601	1015	23	.69	2.56	4.44	0.21	0.44
Shelf	1368	34	.70	2.46	4.99	0.25	0.53
Falls	541	20	.73	2.6	4.20	0.32	0.41
U.S. 1	1388	25	.83	3.06	4.57	0.18	0.35
602	325	24	.69	2.88	4.37	0.59	0.39
Above Confl.	431	16	.27	1.18	3.88	0.30	.76
Below Confl.	434	25	.82	3.34	4.46	0.48	0.28
U.S. 301	292	21	.75	3.00	4.18	0.56	0.32
614	786	29	.74	2.78	4.73	0.34	0.44
615	609	21	.68	2.40	4.27	0.30	.47
360	1871	31	.72	2.70	4.89	0.17	.46
White House	529	18	.86	3.37	4.05	0.29	.18

Diversity Indices:
Coefficient of Determination : $r^2 = 0.85863$
Correlation Coefficient : $r = 0.9266$
: $F = 78.96987$; [1/13 0.05] = 4.7

Table 3

COLLECTING STATIONS

	Control 70	Control 71	1	2	3	Fall Line	4	5	Confluence	6	7	8	9	10	Occ. / 32 Coll.	Total Fish / 32 Coll.
Petromyzontidae																
Lampetra aepyptera									1		9				2	10
Lepisosteidae																
Lepisosteus osseus														41	2	41
Amiidae																
Amia calva													1	1	2	2
Anguillidae																
Anguilla rostrata	19	22	1		12	1	12	3	7	9	4	2	5	2	18	80
Clupeidae																
Alosa aestivalis														24	1	24
A. pseudoharengus													32		1	32
A. sapidissima														5	1	5
Dorosoma cepedianum														6	2	6
Umbridae																
Umbra pygmaea			2												1	2
Esocidae																
Esox americanus			1		1		5	2	2	8				4	10	23
E. niger										1					1	1
Cyprinidae																
Clinostomus funduloides			1													
Cyprinus carpio														1	1	1
Hybognathus nuchalis														1	1	1
					6	40				56		20	13			
Nocomis leptocephalus	73	1	1												8	135
N. micropogon															2	2
							1									
Notemigonus crysoleucas	3	11	19	54	6	4	7		3						1	1
Notropis amoenus				11	2	1	2	3	7	1	4	5		2	9	106
N. analostanus		22	1	9		5	20	17	52	27	46	50	27	29	11	36
															22	305

Collecting Stations
Table 3 Continued

	Control 70	Control 71	1	2	3	Fall Line	4	5	Confluence	6	7	8	9	10	Occ./ 32 Coll	Total Fish/ 32 Coll.
N. cornutus	5	1					46								2	47
N. hudsonius		1						4	4	7	9	1	10	33	10	69
N. procne	4	7				5	2			2	1				7	17
Semotilus corporalis	7	2					1	2	2						4	7
Catostomidae																
Catostomus commersoni	5	2													2	2
Erimyzon oblongus		4	4				1			1					5	6
Hypentelium nigricans	2															
Moxostoma macrolepidotum	5	2												17	3	19
Ictaluridae																
Ictalurus catus													9	2	2	8
I. natalis	1	1					1								2	1
I. nebulosus														11	3	11
I. punctatus													2	13	3	15
Noturus insignis	33	3					3			1	1		1		5	9
Aphredoderidae																
Aphredoderus sayanus			1					1	1		1			2	5	6
Cyprinodontidae																
Fundulus diaphanus														1	1	1
F. majalis														9	3	9
Poeciliidae																
Gambusia affinis						3	6		2	12	4	3			7	30
Atherinidae																
Menidia beryllina														10	3	10
Percichthyidae																
Morone americana										1		3		66	7	70
M. saxatilis												1			1	1

Collecting Stations
Table 3 continued

	Control 70	Control 71	1	2	3	Fall Line	4	5	Confluence	6	7	8	9	10	Occ./ 32 Coll.	Total Fish/ 32 Coll.
Centrarchidae																
Acantharchus pomotis				1							1	1			3	3
Enneacanthus gloriosus							1							8	3	9
Lepomis auritus	7	11	2	2			6	1	5	14	3	7	4	12	19	67
L. gibbosus	1	2		3		1	16			4	1	1		9	13	37
L. gulosus							1								1	1
L. macrochirus	4	5		5	2	1	22	4	21	25	7	1	2	11	22	106
Micropterus salmoides		1							1	6	3	1	3	1	11	15
Pomoxis nigromaculatus							2			1				1	4	4
Percidae																
Etheostoma nigrum	3	1			1	1	1		1	1	2	5	5	5	13	23
E. vitreum	13															
Perca flavescens							1		1					15	6	17
Percina notogramma	15	1					1								2	2

COLLECTING STATIONS

Table 4

	Control 70	Control 71	1	2	3	Fall Line	4	5	Confluence	6	7	8	9	10
Number of Collections	1	2	3	1	3	1	4	2	2	3	2	2	2	5
Number of Families	6	6	7	4	5	5	8	5	8	9	8	5	8	14
Number of Species	17	19	10	7	7	10	22	9	15	18	15	12	15	28
Total Number of Fish per Station	170	98	33	85	30	62	158	37	110	178	96	97	115	341

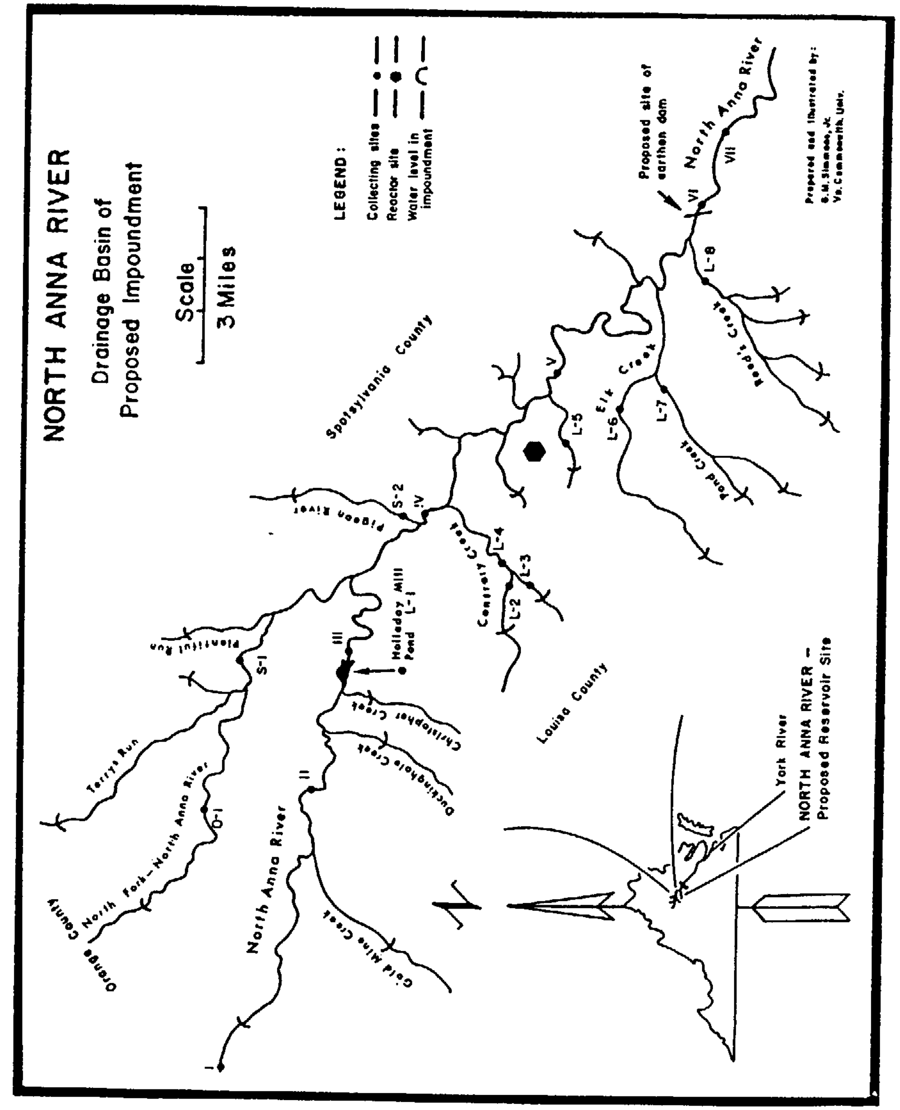


Figure 1. River basin map of the pre-impoundment area showing the location of Contrary Creek in relation to the reactor site and lagoon areas.

Figure 2. Aerial photograph of upper portion of Contrary Creek. Most of the eroded area in this photograph will be inundated by the reservoir.

Figure 3. Contrary Creek bed as seen from the bridge in foreground in Figure 2. Note the extent of erosion. Left upstream view.

Figure 4. Contrary Creek bed as seen from the bridge in foreground in Figure 2. Note the extent of erosion. Right upstream view.

Figure 5. Area of study during the 1971 summer with station sites on the North Anna and Pamunkey River system.

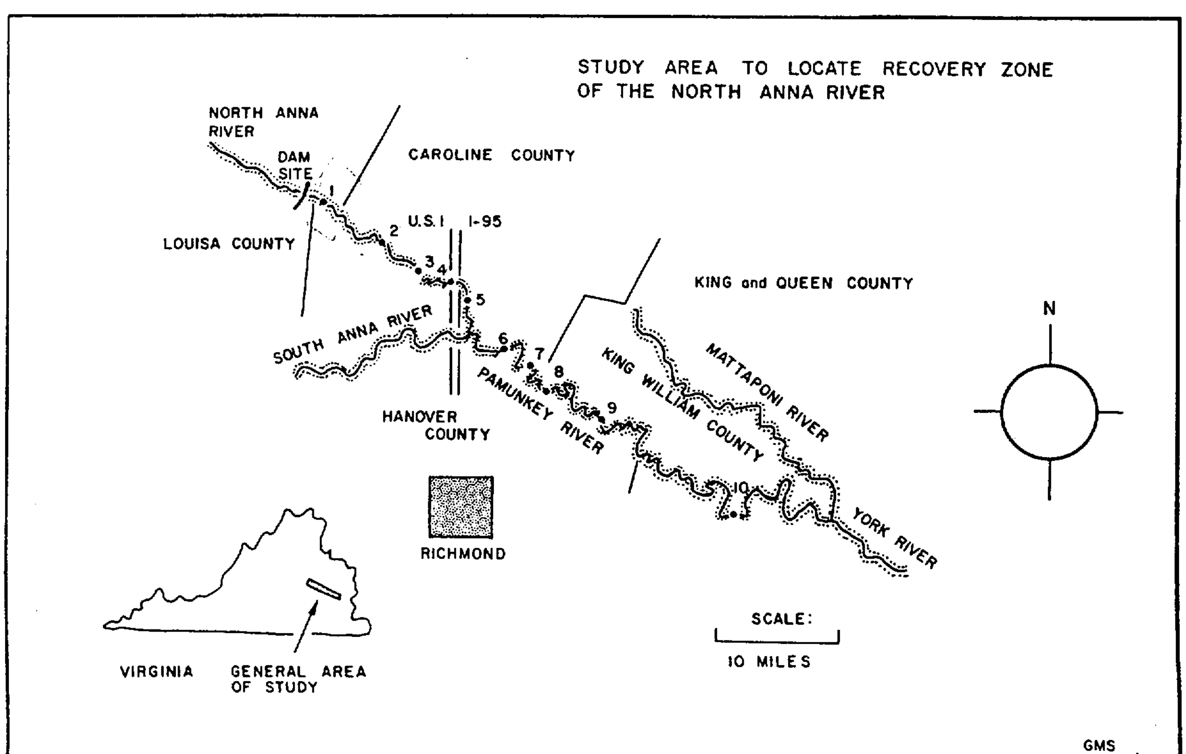


Figure 6A. Manner in which the aquatic D-Frame dip net is used to collect macrobenthos.

Figure 6B. Use of the aquatic D-Frame dip net in the collection of macrobenthos.

Figure 7. Use of SCUBA in the collection of mussels in the 1971 summer study.

Figure 8A. The use of hoop nets to collect fish species. Note the large gar.

Figure 8B. The use of hoop nets to collect fish species. Note the large carp.

Figure 9A. Discharge from the Evans Plant on the North Anna River below U. S. 1. Note the turbidity and algal growth.

Figure 9B. Close up of effluent.

Figure 10A. Upper portion of the North Anna falls.

Figure 10B. Lower portion of the North Anna falls.

Figure 11A. The "Shelf Area" on the North Anna River above the falls. Note the extensive growth of *Justicia americana* (water willow) which provides a habitat for many species of aquatic insects.

Figure 11B. The "Shelf Area" on the North Anna River above the falls. Note the extensive growth of *Justicia americana* (water willow) which provides a habitat for many species of aquatic insects.

Figure 12. River profile through the pre-impoundment basin on the North Anna River and continuing to the tidal area at White House.

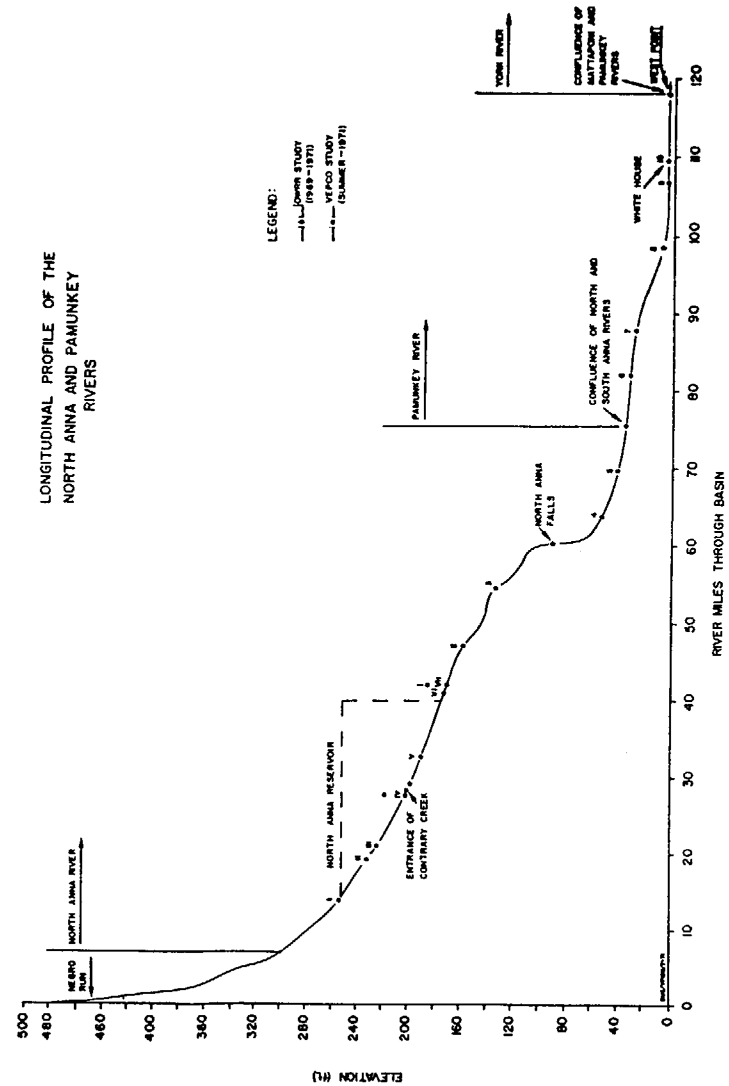


Figure 13A. The dominant mussel (number and size) collected above the confluence of the North Anna River and Contrary Creek. Elliptio complanata

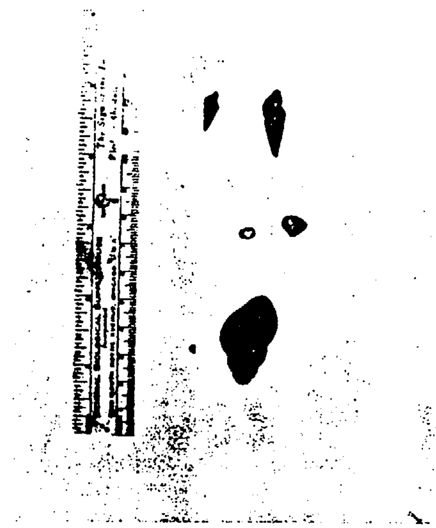
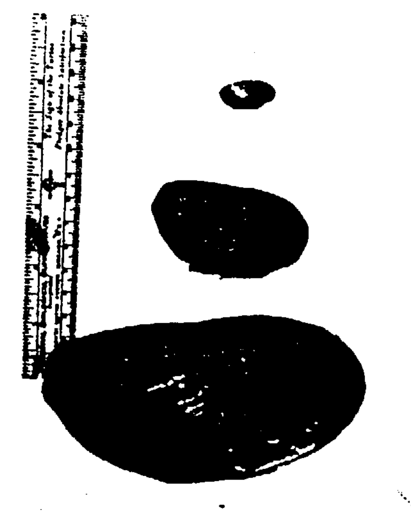


Figure 13B. Dominant mollusca collected above the confluence of the North Anna River and Contrary Creek.

1. Campeloma sp.
2. Sphaerium striatum
3. Goniobasis virginica



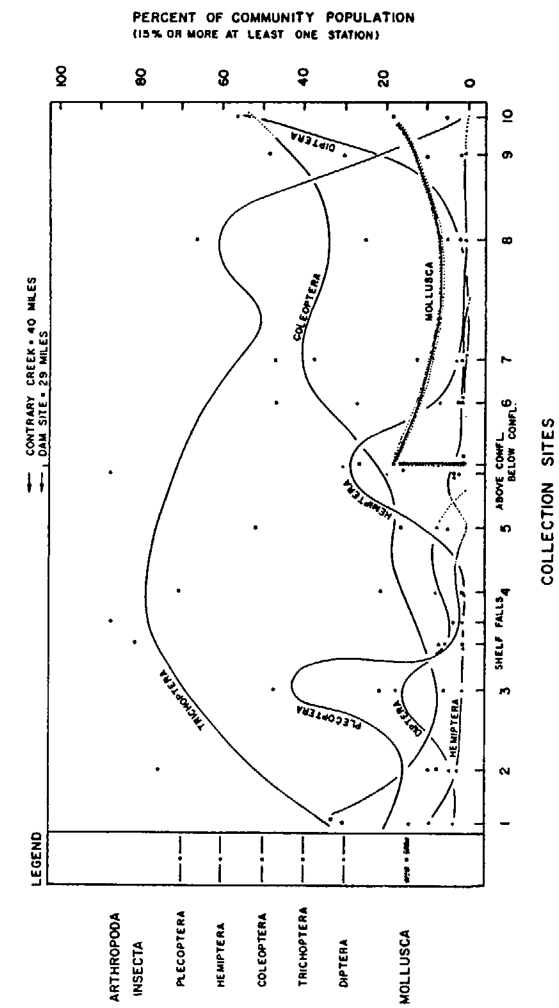


Figure 14. The distribution of major occurring macrobenthic forms in the summer study area. Note the sudden appearance of the mollusca (mostly mussels) at the confluence of the North Anna and South Anna rivers.

Figure 1.

...graph of the converging North Anna and South Anna ...s. This picture was made directly opposite the first ... mussel bed on the Pamunkey River.

Figure 16A. Underwater photograph of mussels showing the type of physical habitat where such organisms were characteristically found.

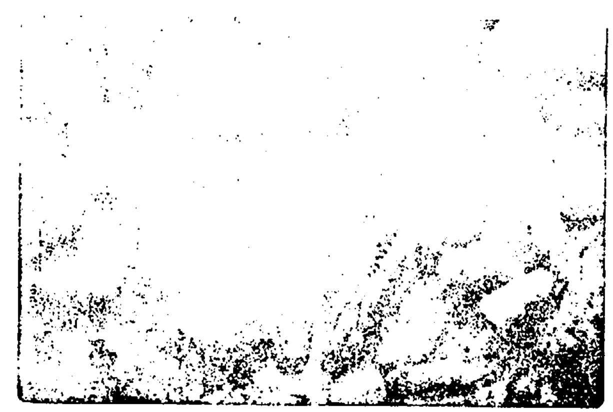


Figure 16B. Underwater photograph of mussels showing the type of physical habitat where such organisms were characteristically found.

Figure 17. Collecting mussels for community representation and back-ground radiation samples in mud shallows at White House.

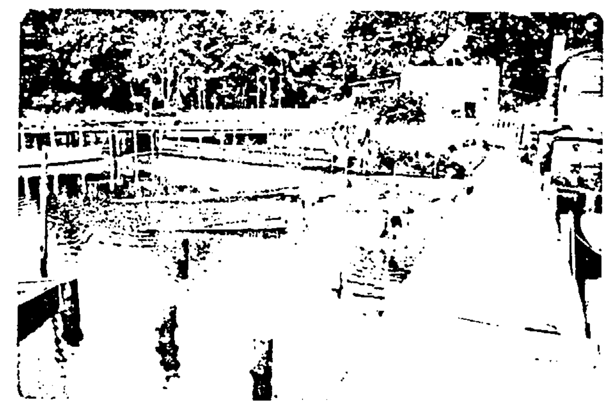
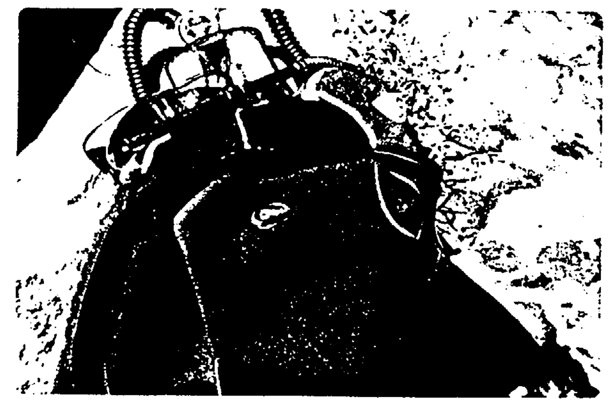


Figure 18A. Looking down on river bend at Station 9 where mussels were very abundant.

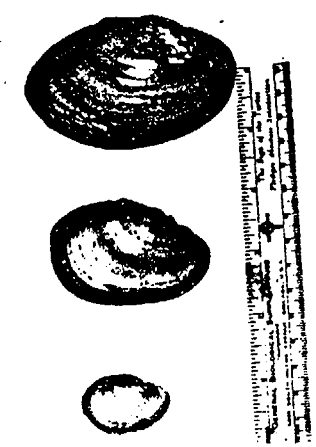
Figure 18B. Riffle area below river bend at Station 9.

Figure 19. Typical habitat on the lower North Anna. Note the densely wooded, steep-sided, mud banks.

Figure 20. The one and only specimen of *E. complanata* found in three years of study on the North Anna River between the confluence with Contrary Creek and the confluence with the South Anna River.



igure 21A. Elliptio complanata. Found on the North Anna, South Anna, and Pamunkey rivers.



'igure 21B. Lampsilis ovata cohongoronta. Found on the South Anna and Pamunkey rivers.

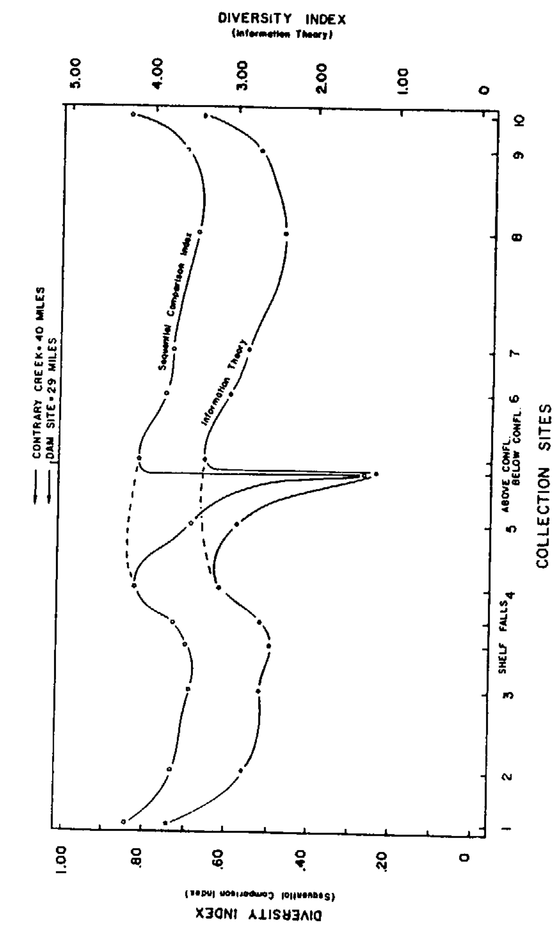


Figure 22. Profiles of diversity indices of community structure at the respective stations investigated during the summer. Note that neither technique clearly shows the recovery zone.

Figure 23A. The manner of occurrence of one of the more dominant caddisflies (Brachycentrus) found on the North Anna and Pamunkey Rivers.

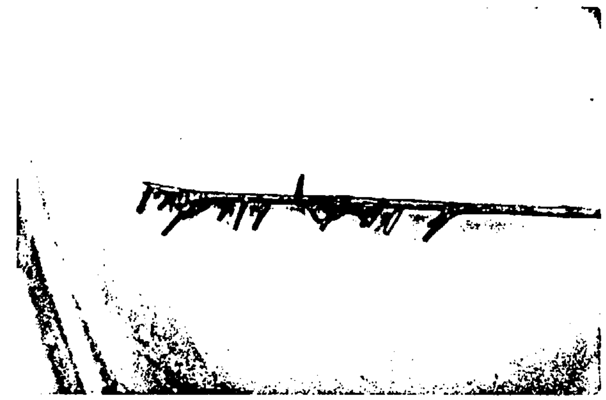


Figure 23B. Close-up of the genus. Note the outstretched legs which are used to collect detritus suspended in the water.

Figure 24. Collections from the old control station above Contrary Creek (State Route 208).

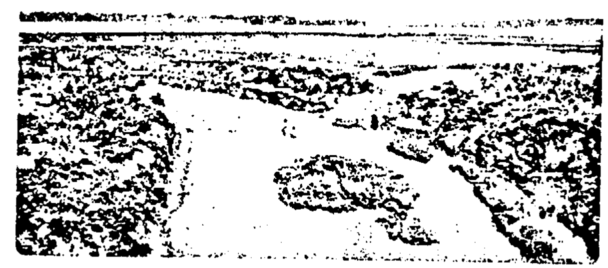


Figure 25. Flow rate versus salinity profile in Pamunkey River.

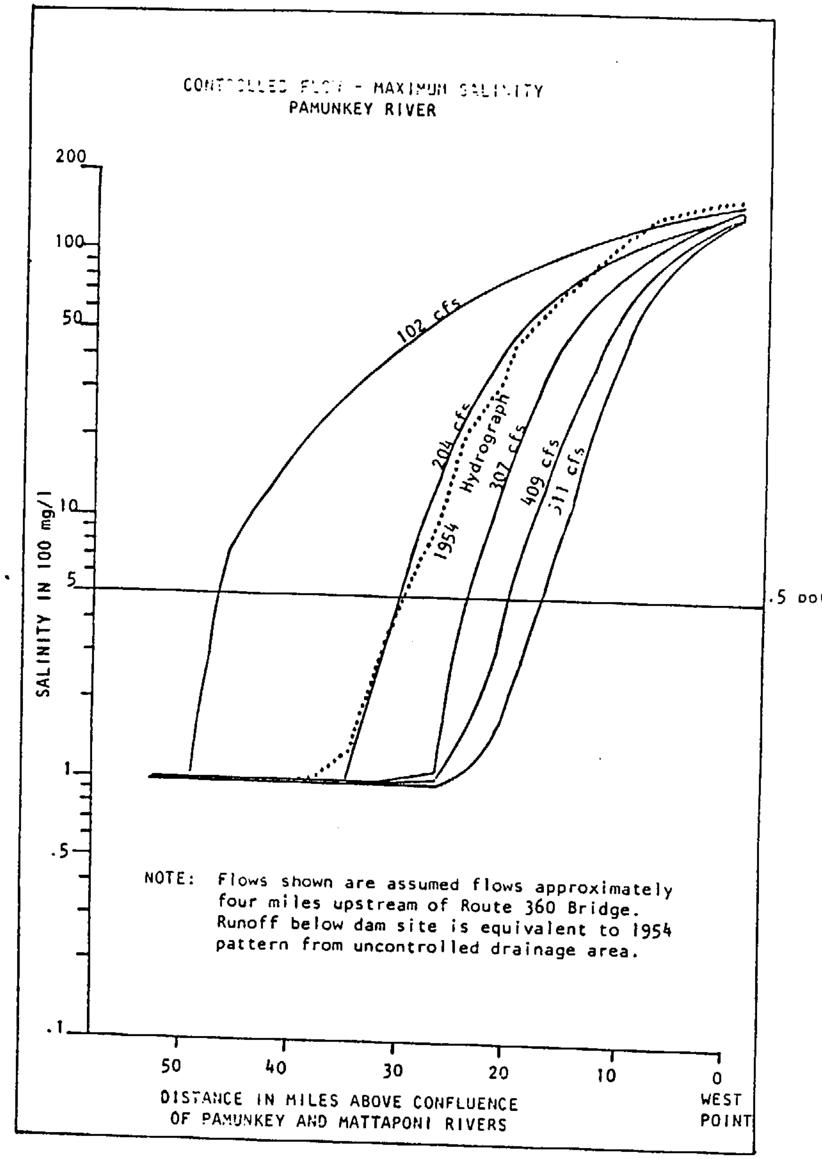


Figure 25.

Figure 26. Habitats of collection sites:

A. North Anna above State Route 715 (Station 2).

B. Under bridge at U. S. 1 (Station 4).

Figure 26 (Cont'd.)

C. Upper North Anna Falls
(Extra Biological Station)

Appendix 1

Temperature °C

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House	
Date											
June 10	23.0°	25.0°	22.5°	23.0°	22.0°	22.0°	23.0°	22.0°	23.0°	23.0°	Tide out 22.9°
June 24	25.0°	25.0°	24.0°	24.0°	24.0°	24.0°	24.0°	23.5°	23.0°	23.5°	Ebb tide 24.0°
July 8	27.0°	26.0°	26.0°	25.0°	25.0°	27.0°	25.0°	25.0°	25.0°	28.0°	Low 25.9°
July 22	27.0°	25.0°	25.0°	25.0°	24.0°	24.0°	24.0°	24.0°	24.0°	26.0°	Tide out 24.8°
Aug. 5	24.0°	26.5°	25.0°	24.5°	24.0°	24.0°	24.0°	24.0°	24.0°	26.0°	T. going out 24.6°
Aug. 19	24.0°	24.0°	23.0°	23.0°	23.0°	23.0°	23.0°	23.0°	24.0°	25.0°	23.6°

Appendix 2

Total Solids: mg/l dry weight

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	87.7	Lost	52.9	100.8	111.4	80.6	130.7	89.5	92.5	89.8
June 24	66.62	167.60	174.86	211.16	207.14	146.26	255.44	187.30	148.12	116.92
July 8	107.29	101.37	105.02	88.32	181.06	87.84	78.98	81.30	85.86	101.22
July 22	78.44	92.08	93.60	84.66	92.54	75.90	76.12	87.38	103.24	104.06
Aug. 5	386.8	509.50	Lost	107.6	Lost	149.8	94.0	80.0	176.80	94.0
Aug. 19	81.0	103.2	100.6	83.8	79.4	78.4	Lost	88.2	97.4	135.4

Appendix 3

Total Solids: per cent loss on ignition

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	48.4%	Lost	45.5%	25.4%	20.3%	62.1%	20.2%	22.6%	24.9%	24.3%
June 24	17.7%	37.2%	23.7%	25.1%	18.3%	15.2%	34.2%	15.7%	24.0%	26.5%
July 8	23.1%	25.2%	24.0%	28.9%	27.0%	27.8%	26.4%	12.4%	31.3%	35.1%
July 22	26.2%	30.6%	32.4%	25.3%	38.1%	13.4%	17.9%	70.8%	73.6%	71.5%
Aug. 5	14.4%	49.9%	Lost	20.5%	Lost	15.3%	19.7%	33.0%	15.5%	23.5%
Aug. 19	30.4%	44.7%	30.6%	30.6%	49.0%	32.6%	Lost	29.0%	31.1%	37.1%

Appendix 4

Turbidity: Jackson Turbidity Units

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	128	---	125	88	104	150	134	125	65	71
June 24	47	71	106	160	175	56	84	59	104	84
July 8	77	71	75	44	56	39	22	32	42	51
July 22	36	32	26	22	20	20	16	20	36	49
Aug. 5	193	395	56	68	144	114	61	101	184	59
Aug. 19	22	36	36	22	16	16	---	26	36	54

Appendix 5

Discharge of North Anna River at
Doswell, Virginia for period of study

Date	Flow Rate	Date	Flow Rate	Date	Flow Rate
6-01	7100	6-21	481	7-11	135
6-02	1690	6-22	449	7-12	169
6-03	986	6-23	583	7-13	281
6-04	666	6-24	459	7-14	251
6-05	713	6-25	381	7-15	176
6-06	620	6-26	327	7-16	137
6-07	507	6-27	287	7-17	123
6-08	555	6-28	264	7-18	116
6-09	630	6-29	236	7-19	111
6-10	531	6-30	217	7-20	108
6-11	450	7-01	218	7-21	130
6-12	397	7-02	226	7-22	143
6-13	360	7-03	286	7-23	123
6-14	543	7-04	319	7-24	106
6-15	1350	7-05	245	7-25	98
6-16	1400	7-06	197	7-26	93
6-17	1180	7-07	181	7-27	90
6-18	942	7-08	181	7-28	89
6-19	673	7-09	178	7-29	84
6-20	543	7-10	151		

Appendix 5
Continued

Date	Flow Rate	Date	Flow Rate	Date	Flow Rate
8-03	163	8-13	76	8-23	85
8-04	175	8-14	76	8-24	73
8-05	294	8-15	69	8-25	65
8-06	672	8-16	63	8-26	58
8-07	331	8-17	61	8-27	721
8-08	178	8-18	65	8-28	738
8-09	127	8-19	71	8-29	667
8-10	103	8-20	87	8-30	273
8-11	91	8-21	106	8-31	128
8-12	124	8-22	109		

Appendix 6

Discharge of Pamunkey River at
Hanover, Virginia for period of study

Date	Discharge	Date	Discharge	Date	Discharge
6-01	8520.00S	6-21	930.00	7-11	273.00
6-02	9920.00S	6-22	1350.00	7-12	595.00
6-03	8430.00S	6-23	1440.00	7-13	708.00
6-04	6360.00S	6-24	1010.00	7-14	550.00
6-05	3950.00S	6-25	830.00	7-15	423.00
6-06	1980.00S	6-26	700.00	7-16	300.00
6-07	1440.00	6-27	610.00	7-17	275.00
6-08	1310.00	6-28	538.00	7-18	236.00
6-09	1430.00	6-29	645.00	7-19	218.00
6-10	1190.00	6-30	590.00	7-20	196.00
6-11	930.00	7-01	470.00	7-21	183.00
6-12	775.00	7-02	448.00	7-22	167.00
6-13	695.00	7-03	460.00	7-23	156.00
6-14	890.00	7-04	523.00	7-24	162.00
6-15	1560.00S	7-05	455.00	7-25	176.00
6-16	3540.00S	7-06	380.00	7-26	158.00
6-17	4030.00S	7-07	346.00	7-27	152.00
6-18	2880.00S	7-08	339.00	7-28	134.00
6-19	1610.00S	7-09	304.00	7-29	123.00
6-20	1200.00	7-10	291.00	7-30	269.00
				7-31	453.00

Appendix 6
Continued

Date	Discharge	Date	Discharge	Date	Discharge
8-01	555.00	8-11	209.00	8-21	229.00
8-02	570.00	8-12	189.00	8-22	220.00
8-03	515.00	8-13	174.00	8-23	192.00
8-04	395.00	8-14	163.00	8-24	158.00
8-05	450.00	8-15	156.00	8-25	137.00
8-06	498.00	8-16	152.00	8-26	140.00
8-07	450.00	8-17	144.00	8-27	755.00S
8-08	368.00	8-18	144.00	8-28	3520.00S
8-09	324.00	8-19	198.00	8-29	2680.00S
8-10	251.00	8-20	258.00	8-30	1370.00S
				8-31	760.00

Appendix 7

Oxygen: mg/1
(100% saturation)

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	7.7 (8.4)	7.5 (8.1)	7.4 (8.5)	7.9 (8.4)	8.1 (8.5)	7.3 (8.5)	7.1 (8.4)	7.1 (8.5)	6.6 (8.4)	4.7 (8.4)
June 24	7.2 (8.1)	6.7 (8.1)	7.0 (8.3)	7.5 (8.3)	7.2 (8.3)	6.8 (8.3)	6.7 (8.3)	6.5 (8.3)	6.0 (8.4)	3.8 (8.3)
July 8	7.6 (7.9)	7.8 (8.0)	7.9 (8.0)	7.7 (8.1)	7.1 (8.1)	7.1 (7.9)	6.9 (8.1)	6.9 (8.1)	6.5 (8.1)	6.2 (7.8)
July 22	8.0 (7.9)	6.2 (8.1)	8.0 (8.1)	7.6 (8.1)	7.6 (8.3)	7.3 (8.3)	7.0 (8.3)	7.3 (8.3)	7.5 (8.3)	6.0 (8.0)
Aug. 5	6.2 (8.3)	6.5 (7.9)	7.4 (8.1)	7.1 (8.2)	6.4 (8.3)	5.8 (8.3)	6.0 (8.3)	5.8 (8.3)	5.4 (8.3)	5.3 (8.0)
Aug. 19	7.5 (8.3)	8.0 (8.3)	7.6 (8.3)	7.8 (8.4)	618 (8.4)	6.5 (8.4)	6.6 (8.4)	6.2 (8.4)	5.1 (8.3)	5.0 (8.1)

Appendix 8

Oxygen: per cent saturation

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	91.6%	92.5%	87.0%	94.0%	95.3%	85.9%	84.5%	83.5%	78.6%	56.0%
June 24	88.8%	82.7%	84.3%	90.3%	86.7%	81.9%	80.7%	78.3%	71.4%	45.7%
July 8	96.2%	97.5%	98.8%	95.1%	87.7%	89.9%	85.2%	85.2%	80.2%	79.5%
July 22	101.3%	76.5%	98.8%	93.8%	91.6%	88.0%	84.3%	88.0%	90.4%	75.0%
Aug. 5	74.7%	82.3%	91.4%	86.6%	77.1%	69.9%	72.3%	69.9%	65.1%	66.3%
Aug. 19	90.4%	96.4%	91.6%	92.9%	81.0%	77.4%	78.6%	73.8%	61.4%	61.7%

Appendix 9

pH

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10			Instruments		not		in			
June 24	7.0	9.2	7.1	9.0	7.0	7.1	6.9	9.7	6.9	6.5
July 8	7.5	7.4	6.7	7.4	7.4	7.5	7.2	7.3	7.5	7.0
July 22	7.2	7.3	7.5	7.4	7.4	7.4	7.4	7.3	7.2	7.1
Aug. 5	7.4	7.4	7.7	7.5	7.3	7.3	7.7	7.6	7.6	7.5
Aug. 19	7.2	7.9	8.0	8.0	8.2	8.5	8.3	8.5	8.5	8.5

Appendix 10

Conductivity

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10				Instruments not in						
June 24	95	160	104	128	94	83	83	255	71	110
July 8	102	87.5	100.5	90.5	99	94.5	84	85	87	85
July 22	102.5	94.0	110.0	93.0	90.0	89.0	95	89	103	102
Aug. 5	120.0	89.0	100.2	90.0	76.0	84.0	92	85	84	100.2
Aug. 19				Conductivity Instrument Broken						

Appendix 11

Nitrate Nitrogen

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.450	.400	.470	.515	.539	.392	.475	.495	.435	.365
June 24	.385	.41	.56	.64	.69	.59	.49	.33	.49	.37
July 8	.200	.200	.200	.100	.150	.120	.140	.280	.410	.140
July 22	.19	.26	.24	.05	.03	.08	.15	.24	.25	.03
Aug. 5	.69	.70	.29	.28	.34	.40	.37	.41	.56	.14
Aug. 19	.06	.04	.02	<.01	.01	.08	.18	.24	.25	<.01

Appendix 12

Nitrite Nitrogen

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.038	.025	.042	.060	.070	.018	.033	.018	.005	.005
June 24	.018	.035	.115	.115	.120	.090	.042	<.005	.035	<.005
July 8	<.005	<.005	<.005	<.005	.005	<.005	<.005	<.005	<.005	<.005
July 22	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Aug. 5	.115	.090	<.005	.025	.100	.085	.040	.060	.090	<.005
Aug. 19	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005

Appendix 13

Ammonia Nitrogen

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.40	.40	.62	.68	.82	.57	.56	.40	.80	.70
June 24	1.0	1.0	1.90	1.7	1.3	1.6	1.3	1.1	1.6	1.1
July 8	1.2	1.4	0.80	0.60	2.40	0.60	0.40	0.50	0.50	0.60
July 22	1.2	.50	.60	1.40	.50	.40	.50	.50	.50	.70
Aug. 5	1.1	1.0	0.5	0.5	0.9	0.6	0.2	0.6	1.2	0.2
Aug. 19	.55	.40	.50	.55	.80	1.05	1.10	1.20	0.65	1.40

Appendix 14

Sulfates

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	31.5	38.8	53.0	58.0	71.0	71.0	71.0	23.0	19.0	21.5
June 24	34.0	37.0	61.0	67.0	65	53	37	22	35	36
July 8	20	19	16	3	17	3	<1	2	1	12
July 22	18	22	61	18	2	<1	<1	<1	<1	1
Aug. 5	110	104	25	33	51	40	14	27	49	<1
Aug. 19	20	18	12	8	8	<1	1	3	<1	1

Appendix 15

Ortho Phosphate

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.102	.066	.62	.68	.82	.57	.56	.40	.80	.70
June 24	.76	.036	.90	.10	.20	.084	1.75	5.8	.039	.050
July 8	.013	.014	.017	.013	.015	.013	.017	.013	.036	.028
July 22	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
August 5	.050	.060	.125	.020	.042	.025	.012	.015	.036	.010
Aug. 19	.017	.012	.036	.012	.011	.015	.013	.017	.014	.013

Appendix 16

Total Phosphate

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date (1970)										
June 10	.150	.140	.160	.173	.200	1.78	.220	.160	.150	.130
June 24	18.75	16.0	17.5	14.0	17.5	18.5	19.0	21.0	10.5	19.0
July 8	.76	.92	.03	.078	.028	.90	.036	.90	.092	.180
July 22	16.0	4.5	5.0	8.8	2.5	.078	8.8	.025	16.0	14.0
Aug. 5	2.40	.072	12.5	.060	6.80	10.5	.042	.078	9160	.056
Aug. 19	12.0	.031	3.50	.056	.029	8.4	12.0	15.0	.062	.066

Appendix 17

Zinc

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.450	.800	1.240	.925	1.025	.650	.750	.740	.800	.500
June 24	.406	.878	1.025	1.100	1.125	.800	.700	2.075	.95	.875
July 8	.420	.420	.420	.350	.620	.220	.420	.350	.500	.500
July 22	.73	.65	.65	.43	.50	.45	.50	.53	.37	.80
Aug. 5	2.325	.875	.500	.575	.875	.875	.575	.700	.900	.550
Aug. 19	.675	.625	.450	.550	.625	.550	.550	.650	.550	.675

Appendix 18

Iron

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	.430	.925	.670	.935	.875	.540	.580	.520	.520	.460
June 24	.75	1.0	1.20	1.37	1.24	1.13	.78	.65	.84	.650
July 8	.39	.50	.49	.31	.46	.25	.25	.28	.31	.46
July 22	.52	.43	.37	.27	.15	.15	.15	.15	.18	.21
Aug. 5	.91	.78	.31	.40	.75	.72	.40	.55	.87	.15
Aug. 19	.78	.53	.43	.37	.33	.33	.31	.33	.25	.32

Appendix 19

Magnesium

Station	Rt. 658	Rt. 738	Rt. 601	Rt. U.S. 1	Rt. 602	Rt. 301	Rt. 614	Rt. 615	Rt. 360	White House
Date										
June 10	1.03	1.45	1.70	2.10	3.25	.82	1.00	0.90	0.85	0.79
June 24	.70	1.30	2.20	2.05	2.10	1.50	.85	.20	1.10	.70
July 8	.70	.78	.80	.20	1.10	.35	.35	.35	.35	.35
July 22	.65	.65	.55	.20	<.05	<.05	.10	<.05	.65	1.60
Aug. 5	3.15	1.50	1.10	.60	1.30	1.00	0.30	0.60	1.30	<.05
Aug. 19	.30	<.05	<.05	<.05	<.05	<.05	<.05	.20	<.05	.10

Appendix 20

LIST OF FISHES COLLECTED FROM LOWER NORTH ANNA

AND UPPER PAMUNKEY RIVERS

Family	Genus	Species	Common Name
Petromyzontidae	Lampetra	aepyptera	Least brook lamprey
Lepisosteidae	Lepisosteus	osseus	Longnose gar
Amiidae	Amia	clava	Bowfin
Anguillidae	Anguilla	rostrata	American eel
Clupeidae	Alosa	aestivalis	Blueback herring
	Alosa	pseudoharengus	Alewife
	Alosa	sapidissima	American shad
	Dorosoma	cepedianum	Gizzard shad
Umbridae	Umbra	pygmaea	Eastern mudminnow
Esocidae	Esox	americanus americanus	Redfin pickerel
	Esox	niger	Chain pickerel
Cyprinidae	Clinostomus	funduloides	Rosyside dace
	Cyprinus	carpio	Carp
	Hybognathus	nuchalis	Silvery minnow
	Nocomis	leptocephalus	Bluehead chub
	Nocomis	micropogon	River chub
	Notemigonus	crysoleucas	Golden shiner
	Notropis	amoenus	Comely shiner
	Notropis	analostanus	Satinfin shiner
	Notropis	cornutus	Common shiner
	Notropis	hudsonius	Spottail shiner

Family	Genus	Species	Common Name
Cyprinidae (cont.)	Notropis	procne	Swallowtail shiner
	Semotilus	corporalis	Fallfish
Catostomidae	Catostomus	commersoni	White sucker
	Erimyzon	oblongus	Creek chubsucker
	Hypentelium	nigricans	Northern hog sucker
	Moxostoma	macrolepidotum	Shorthead redhorse
Ictaluridae	Ictalurus	catus	White catfish
	Ictalurus	nebulosus	Brown bullhead
	Ictalurus	punctatus	Channel catfish
	Noturus	insignis	Margined madtom
Aphredoderidae	Aphredoderus	sayanus	Pirate perch
Cyprinodontidae	Fundulus	diaphanus	Banded Killifish
	Fundulus	majalis	Striped killifish
Poeciliidae	Gambusia	affinis	Mosquitofish
Atherinidae	Menidia	beryllina	Tidewater silverside
Percichthyidae	Morone	americanus	White perch
	Morone	saxatilis	Striped bass
Centrarchidae	Acantharchus	pomotis	Mud sunfish
	Enneacanthus	gloriosus	Bluespotted sunfish
	Lepomis	auritus	Redbreast sunfish
	Lepomis	gibbosus	Pumpkinseed
	Lepomis	gulosus	Warmouth
	Lepomis	macrochirus	Bluegill
	Micropterus	salmoides	Largemouth bass
	Pomoxis	nigromaculatus	Black crappie

Family	Genus	Species	Common Name
Percidae	Etheostoma	nigrum	Johnny darter
	Etheostoma	vitreum	Glassy darter
	Perca	flavescens	Yellow perch
	Percina	notogramma	Stripeback darter

Family	Genus	Species	Common Name
Percidae	Etheostoma	nigrum	Johnny darter
	Etheostoma	vitreum	Glassy darter
	Perca	flavescens	Yellow perch
	Percina	notogramma	Stripeback darter