Pamunkey River slack water data report: temperature, salinity, dissolved oxygen, 1970 - 1980

T. J. Brooks

Virginia Institute of Marine Science

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PAMUNKEY RIVER SLACK WATER DATA REPORT
TEMPERATURE, SALINITY, DISSOLVED OXYGEN
1970 - 1980

T. J. Brooks

Data Report #20

Virginia Institute of Marine Science
School of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

October 1983
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ACKNOWLEDGEMENTS

I express my appreciation to the following VIMS scientific personnel for their suggestions and contributions to the development of this monitoring program: Dr. C. S. Fang for his initiation of the program and for committing many of the department resources to the data collection; Dr. John M. Zeigler, Associate Dean, for his encouragement and leadership; Dr. Bruce Neilson and Dr. A. Y. Kuo for their periodic reviews of the program and design of the field work and the lab analysis; Drs. Evon Ruzecki, Paul Nyer, Christopher Welch, and Carl Cerco for their suggestions for improving the monitoring program.

Over the past ten years, many students and technicians in the Department of Physical Oceanography and Hydraulics have shared in the hard work and the frustrations that accompany bad weather conditions and the problems of boats and instruments. They also have suggested many improvements based on their accumulated field experience. I particularly thank the following persons for their long time contribution to the program by conducting the field work: Messrs. W. Matthews, S. Snyder, K. Worrell, J. Cumbee and S. Fenstermacher. I also thank Ms. Nancy Courtney for the data reduction and Mr. Hugh Brooks for the development of the interfacing program and the selection of the SURFACE II options.
The funding of this project is jointly provided by the Virginia State Water Control Board and the Virginia Institute of Marine Science through the Cooperative State Agencies program.
INTRODUCTION

The slack water survey program, which has been supported by the State Water Control Board and the Virginia Institute of Marine Science under the Cooperative State Agencies program, provides an extended series of temperature, salinity, dissolved oxygen and nutrient measurements along the Pamunkey River. These have been used to:

1) calibrate, verify, and update mathematical models;
2) provide a baseline against which effects of unusual events have been measured;

and could be used to:

3) establish annual and longer period "climatological" trends in response to changing natural phenomena and man-made modifications to the estuary;
4) provide a basis against which fluctuations in biota could be compared.

This report contains station locations, survey schedules, field procedures, sample handling procedures, and data reduction and storage procedures. In addition, 11 years of contoured temperature, salinity, and dissolved oxygen data is presented.

The primary purpose of this report is to provide the data in a format which will be useful to others. Analysis and interpretation of the data is underway and this will be the subject of a later report.
I. SLACK WATER SURVEY PROGRAM

A. Description of the Study Area

The Pamunkey River is located in Virginia as can be seen in Figure 1. The tidal portion of the Pamunkey River extends 90 kilometers from West Point in a generally north-west direction (Division of Water Resources, 1970). This portion of the river drains an area of 1,005 square kilometers and is meandering with extensive marshes. The 47 kilometers of river which are not tidal drain an additional 2,776 square kilometers (Seitz, 1971). The average discharge near Hanover is 28.74 cubic meters per second (cms) based on 39 years of record. The discharge has ranged from 0.34 to 1,140 cms (USGS, Water Resources Data for Virginia, 1981).

The water surface area of the tidal Pamunkey River is 29.28 square kilometers at mean low water. The mean low water volume is $1.098 \times 10^8$ cubic meters. Figure 2 is a plot of the mean tidal range which is 0.90 meters at West Point and 1.18 meters at a location 87 kilometers further upstream. Figure 3 shows the time difference for high and low water relative to Hampton Roads. The duration of tidal rise and the duration of tidal fall are presented in Figure 4 (Cronin, 1971).

The climate in the study area is classified as humid subtropical. The average annual air temperature in the
Figure 1. Map Locating the Pamunkey River Within Virginia
FIGURE 2. MEAN TIDAL RANGE

FIGURE 4. DURATION OF TIDAL RISE AND DURATION OF TIDAL FALL

FIGURE 3. TIME DIFFERENCE FOR HIGH AND LOW WATER RELATIVE TO HAMPTON ROADS

(Cronin, 1971)
Pamunkey River basin is 13.4°C. Average monthly air temperatures range from 0.9°C in February to 25.9°C in August. The average annual precipitation in the basin is 95.9 centimeters (NOAA, Climatological Data, 1980).

B. Slack Water Survey Criteria

A slack water survey is made by taking water samples at designated locations while following either the high or low water slack wave (slack water before ebb tide or slack water before flood tide respectively) as it progresses upstream from the estuary mouth. Most stations are located near the middle of the navigation channel. Water samples from at least two points in the water column, one near the surface and one near the bottom, are taken at each station. At stations of sufficient depth additional points in the water column may be sampled. (See section C, "Field Procedures", for more detailed information.) The locations of the most frequently sampled stations are shown in Figure 5, where the station designation refers to the distance from the river mouth in kilometers. Table 1 lists each station by its kilometer designation, latitude and longitude, and water depth.

A reasonable time table for collecting the samples is 15-20 minutes at the first station. This estimate includes the time spent getting the equipment organized and situated in the boat. Stations up river average 5 to 10 minutes each.
Figure 5. Map of the Pamunkey River Showing the Station Locations
Table 1. Pamunkey River Slack Water Survey Stations

<table>
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<tr>
<th>Distance (km)</th>
<th>Latitude (north)</th>
<th>Longitude (west)</th>
<th>Depth (m)</th>
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Every effort is made to complete a slack water survey once it has started. The decision to abort a survey may be made when weather conditions, and more importantly wave conditions, have reached such a point that the slack water timetable can not be met. In some cases a few of the stations near the river mouth can be skipped and the survey continued upstream. If half of the river is skipped in order to find more tranquil water conditions the lower portion is rescheduled for no later than the next day. When this is not possible the entire slack water survey is rescheduled.

Surveys usually are conducted monthly, except in the winter, by two-person crews in small outboard boats which are able to keep pace with the slack wave. Winter sampling is generally suspended due to the over-saturation of dissolved oxygen and the low temperatures. The months during which slack water surveys have been conducted are presented in Table 2.

The slack water surveys are scheduled so that the field crews spend the least possible amount of time working during darkness. Usually, the surveys start no earlier than one hour before daylight and are run no later than one hour after sunset. This policy is mainly a safety consideration in an effort to avoid running the boats at top speeds in a limited visibility situation. Since they are the longest, the Rappahannock and James rivers are given first priority as to scheduling dates.
Table 2. Months of Slack Water Surveys (High and Low) for 1970-1980

**Pamunkey River**

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X : Temperature, Salinity, D.O.  
H : High water slack; slack before ebb  
△: T, S, D.O., B.O.D., Chlorophyll and Nutrients  
L : Low water slack; slack before flood  
○: T, S, D.O., B.O.D.
Prior to 1978 when daily precipitation was greater than 0.3 of an inch the survey was postponed for a period of usually three days. This sometimes caused problems as far as scheduling the surveys, especially when the month was drawing to a close. Since 1978 the policy has been changed and the surveys are no longer postponed due to rain.

Figures 6a-k show daily fresh water discharge and the date of each slack water survey. The fresh water discharge is measured near Hanover (USGS, Water Resources Data for Virginia, Water Years 1970-1981) and represents approximately 73% of the drainage area of the Pamunkey River basin (Seitz, 1971). Figures 7a-k show average predicted tide heights and the date of each slack water survey. The tidal data is from Sewells Point and is presented as the average of the high tide heights for each day and the average of the low tide heights for each day (NOAA, Tide Tables 1970-1980).

C. Field Procedures

Several types of samples are collected during each survey. Temperature readings, salinity, and dissolved oxygen samples are taken during each slack water survey. Conductivity readings and biochemical oxygen demand samples are often taken. Since 1974, nutrient concentrations and chlorophyll 'a' have been measured at least a few times each year, as indicated in Table 2.
Figure 6a. Fresh Water Discharge and Slack Water Survey Dates, 1970
Figure 6b. Fresh Water Discharge and Slack Water Survey Dates, 1971
Figure 6c. Fresh Water Discharge and Slack Water Survey Dates, 1972
Figure 6d. Fresh Water Discharge and Slack Water Survey Dates, 1973
Figure 6e. Fresh Water Discharge and Slack Water Survey Dates, 1974
Figure 6f. Fresh Water Discharge and Slack Water Survey Dates, 1975
Figure 6g. Fresh Water Discharge and Slack Water Survey Dates, 1976
Figure 6h. Fresh Water Discharge and Slack Water Survey Dates, 1977
Figure 6i. Fresh Water Discharge and Slack Water Survey Dates, 1978
Figure 6j. Fresh Water Discharge and Slack Water Survey Dates, 1979
Figure 6k. Fresh Water Discharge and Slack Water Survey Dates, 1980
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Figure 7b. Average Predicted Tide and Slack Water Survey Dates, 1971
Figure 7c. Average Predicted Tide and Slack Water Survey Dates, 1972
Figure 7d. Average Predicted Tide and Slack Water Survey Dates, 1973
Figure 7e. Average Predicted Tide and Slack Water Survey Dates, 1974
Figure 7f. Average Predicted Tide and Slack Water Survey Dates, 1975
Figure 7g. Average Predicted Tide and Slack Water Survey Dates, 1976
Figure 7h. Average Predicted Tide and Slack Water Survey Dates, 1977
Figure 7. Average Predicted Tide and Slack Water Survey Dates, 1978
Figure 7j. Average Predicted Tide and Slack Water Survey Dates, 1979
Figure 7k. Average Predicted Tide and Slack Water Survey Dates, 1980
Sampling depths vary with the parameter being considered. Temperature, conductivity, and salinity are sampled every two meters between the surface and the bottom. Dissolved oxygen samples are collected at the surface, mid-depth, and bottom. Biochemical oxygen demand, nutrients, and chlorophyll 'a' samples are collected at the surface and bottom.

Temperature measurements are made with either an Interocean Model 513 CTD instrument or a Hydrolab Model ARA ET-100 thermistor. Conductivity measurements are made with a modified Interocean Model 513 CTD instrument. Water samples for the other analyses are collected by pumping water with a modified bilge pump from the desired sampling depth or with a weighted 5-liter PVC Frautschy bottle attached to a metered line. The bottle is lowered by the hand line to the desired sampling depth, then closed by a messenger and pulled to the surface. At the surface, the water is placed in appropriate containers for various laboratory analyses. While in the field, the instrument readings and sample bottle numbers are recorded on an Oceanography Form 1 as illustrated in Figure 8.

D. Sample Handling Procedures

Samples for salinity are placed in 125-ml sample-rinsed glass bottles. When brought back to the laboratory the samples are run on an Industrial Instrument Laboratory Salinometer Model RS7A. Salinity is sometimes calculated
Figure 8. Sample Oceanography Form 1
from temperature and conductivity readings taken from the Interoccean Model 513 CTD instrument.

Samples for dissolved oxygen analysis are placed in 125-ml sample-rinsed glass bottles. Reagents are added immediately in preparation for the azide modification of the Winkler procedure to be conducted later in the laboratory.

Biochemical oxygen demand (BOD) samples are collected in standard 300-ml glass stoppered BOD bottles. Nutrient samples are collected in 1-liter plastic "cubitainers". Chlorophyll samples are collected in opaque plastic containers. All three types of samples are placed on ice immediately after collection and until they can be processed in the laboratory. Nutrient and chlorophyll samples are filtered within 24 hours of collection. The details of the laboratory procedures and analytical methods can be found in other VIHS reports such as "Water Quality in the York River" (Sturm and Neilson, 1977).

E. Data Reduction and Storage

Central to the reduction of data collected by the Department of Physical Oceanography and Hydraulics is the Oceanography Form 1. The Form 1 serves the dual purpose of providing a sheet for field and laboratory use as well as a form from which oceanographic data may be entered to the computer-based storage system via either punched cards or magnetic tape.
The data are available on request. Printouts of work done by the Department of Physical Oceanography and Environmental Engineering are kept in the department library and in the VIMS library.
II. DISCUSSION

A. River Discharge

Pamunkey River discharge, measured near Hanover, during the 1970-1980 study period covered a wide range of values. The maximum daily average discharge was $2.50 \times 10^4$ cubic feet per second (cfs) ($7.5 \times 10^2$ cms). This occurred on 23 June 1972 due to the heavy rains of Tropical Storm Agnes. Minimum daily average discharge was 22 cfs (0.66 cms) and occurred on 16 September, 8 October and 9 October 1970. Mean daily freshwater flow near Hanover, during the study period, averaged 1269 cfs (38.07 cms). The greatest total discharge for a given year during the 11 year study was $6.77 \times 10^5$ cubic feet ($2.03 \times 10^4$ cubic meters) in 1979. The year with the least total discharge was 1977 with $2.14 \times 10^5$ cubic feet ($6.42 \times 10^3$ cubic meters).

B. Temperature

Water temperatures in the Pamunkey River showed a seasonal pattern following the air temperature pattern through the year. Minimum temperatures around $5.5^\circ$C were observed in February. The water temperatures increased through the spring reaching maximum temperatures around $27.5^\circ$C in August. Water temperatures declined in September and continued to decrease through the fall.
C. Salinity

Salinity in the Pamunkey River decreased from the mouth to the head of the estuary. The salt content of the water tended to increase with depth.

Salt regularly intruded from West Point to the region around kilometer 25. The 1970-1980 slack water data set showed a maximum intrusion of the 1 ppt isohaline beyond kilometer 42. The minimum intrusion of the 1 ppt isohaline was downstream of West Point. This report does not include data from the study of Tropical Storm Agnes. That study reported a minimum intrusion to the area around West Point (Andersen, Davis, Lynch, Schubel (ed.), 1973). In addition to longitudinal movements of the salinity intrusion, salinity has also undergone variable degrees of vertical stratification.

D. Dissolved Oxygen

The dissolved oxygen concentration in an estuary is dependent on several physical and biological factors. The solubility of oxygen is influenced by temperature and salinity. Turbulence affects atmospheric reaeration rates. Metabolism and the decomposition of organic material exert demands on the available oxygen.
The dissolved oxygen values in the Pamunkey River showed a seasonal pattern. The highest values, around 10.0 mg/l, were reported in the winter during the time of low temperatures and reduced oxygen demand. The level of dissolved oxygen decreased through the spring reaching average minimum values around 5.7 mg/l in the summer during the season of low fresh water discharge and increased temperatures and salinities.

The State Water Control Board has set the water quality standards for acceptable levels of dissolved oxygen (State Water Control Board, 1980). The minimum allowable oxygen concentration for estuarine waters is 4.0 mg/l. The daily average concentrations should exceed 5.0 mg/l. Although the dissolved oxygen values in the Pamunkey River were generally above these levels, values less than 4.0 mg/l have occurred between May and December. The minimum value recorded was 0.20 mg/l which occurred at both kilometer 0 and kilometer 5 on 17 November 1970.
REFERENCES


APPENDICES

A. Longitudinal Contours
B. Temperature (°C)
C. Salinity (ppt)
D. Dissolved Oxygen (mg/l)
A. LONGITUDINAL CONTOURS

Longitudinal contours of temperature, salinity and dissolved oxygen have been generated for each of the slack water surveys. A listing of these surveys is contained in Table 3. The bottom profile is based on the water depth at mean low water as taken from National Ocean Survey charts at the most frequently sampled slack water stations.

Temperature, salinity, and dissolved oxygen values are recorded at each depth sampled. When the sampling is taken at an angle to the vertical because of bottom currents or sampling is slightly off-station, the sampled bottom depth can be deeper than the bottom profile. In this case, the sampling depths for the entire cast at that station are scaled so the bottom depths correspond to each other. When the bottom depth sampled is shallower than the bottom of the profile, the sample depths are used as recorded.

SURFACE II is a computer software system developed by the Kansas Geological Survey for computer contouring and graphics display. The user is able to specify plotting options by selecting appropriate operation commands. The isotherms, isohalines, and lines of constant dissolved oxygen in this report have been drawn using a SURFACE II plotting package and Tectronix plotter. When a parameter has been measured by more than one method the most complete data set is used.
Table 3. Dates of Slack Water Surveys and Contours Generated Pamunkey River

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<td>OSP12</td>
<td>H</td>
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<td>S</td>
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</table>

H: HIGH WATER SLACK, SLACK BEFORE EBB
T: TEMPERATURE GENERATED
S: SALINITY GENERATED
L: LOW WATER SLACK, SLACK BEFORE FLOOD
D: DISSOLVED OXYGEN GENERATED
N: NO CONTOUR GENERATED (NO DATA AVAILABLE OR NOT ENOUGH TO CONTOUR)
B. Temperature (°C)
PAMUNKEY RIVER  18 OCTOBER 1971  TEMPERATURE  SLACK BEFORE FLOOD

KILOMETERS  DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER

22 OCTOBER 1971

TEMPERATURE

SLACK BEFORE FLOOD

KILOMETERS

DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER  01 MARCH 1972  TEMPERATURE  SLACK BEFORE EBB

DEPTHM  TEMPERATURE  SLACK BEFORE EBB

DISTANCE UPSTREAM FROM MOUTH

KILOMETERS  TEMPERATURE  SLACK BEFORE EBB
Parunkey River  31 May 1972
Temperature

Depth (m)

Kilometers
Distance upstream from mouth
PAMUNKEY RIVER
07 AUGUST 1974
TEMPERATURE
SLACK BEFORE FLOOD

DEPTH (M)

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER  14 APRIL 1975  TEMPERATURE  SLACK BEFORE FLOOD

DEPTI (M)

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER

08 MAY 1975

TEMPERATURE

SLACK BEFORE EBB

DEPTH (M)

DISTANCE UPSTREAM FROM MOUTH

KILOMETERS

-1.0 -0.8 -0.6 -0.4 -0.2 -0.0 0.2 0.4 0.6 0.8 1.0

-1.1 -1.0 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

-1.7 -1.6 -1.5 -1.4 -1.3 -1.2 -1.1 -1.0 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

-10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

-17.0 -16.0 -15.0 -14.0 -13.0 -12.0 -11.0 -10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0

-19.0 -18.0 -17.0 -16.0 -15.0 -14.0 -13.0 -12.0 -11.0 -10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0 30.0

-19.5 -19.0 -18.5 -18.0 -17.5 -17.0 -16.5 -16.0 -15.5 -15.0 -14.5 -14.0 -13.5 -13.0 -12.5 -12.0 -11.5 -11.0 -10.5 -10.0 -9.5 -9.0 -8.5 -8.0 -7.5 -7.0 -6.5 -6.0 -5.5 -5.0 -4.5 -4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 -0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0 19.5 20.0 20.5 21.0 21.5 22.0 22.5 23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5 27.0 27.5 28.0 28.5 29.0 29.5 30.0

-10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

-12.0 -11.0 -10.0 -9.0 -8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0 18.0 19.0 20.0 21.0 22.0 23.0 24.0 25.0 26.0 27.0 28.0 29.0 30.0
PAMUNKEY RIVER 23 SEPTEMBER 1976 TEMPERATURE SLACK BEFORE FLOOD

DEPTH (M)

KILOMETERS DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER 11 OCTOBER 1977 TEMPERATURE SLACK BEFORE EBB

DISTANCE UPSTREAM FROM MOUTH
Pamunkey River

21 June 1978

Temperature

Slack Before Flood

Depth (M)

Kilometers

Distance Upstream from Mouth
PAMUNKEY RIVER
25 SEPTEMBER 1978
TEMPERATURE
SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
C. Salinity (ppt)
PARUNKEY RIVER 23 SEPTEMBER 1971 SALINITY SLACK BEFORE EBB

DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER
08 SEPTEMBER 1972
SALINITY
SLACK BEFORE EBB

DEPTH (M)

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
EXPLANATION

- **Depth (m)**: Vertical axis indicating depth in meters.
- **Kilometers**: Horizontal axis representing distance upstream from the mouth.
- **Salinity**: Contour lines indicating salinity levels.
- **Slack Before Flood**: Depicts slack before flood conditions.

**Legend**
- Different symbols and colors represent various salinity levels and other conditions.

**Map Details**
- The map shows the distribution of salinity and depth in the Pamunkey River on July 6, 1973, before the slack before flood conditions.

**Note**
- The image contains specific data points and contour lines that are crucial for understanding the salinity and depth distribution in the river.
PANUNKEY RIVER

05 JULY 1977

SALINITY

SLACK BEFORE FLOOD

DISTANCE UPSTREAM FROM MOUTH

KILOMETERS

DEPTH (M)

KILOMETERS

DISTANCE UPSTREAM FROM MOUTH

DISTRIBUTION OF SALT
D. Dissolved Oxygen (mg/l)
PAMUNKEY RIVER
18 OCTOBER 1971
DISSOLVED OXYGEN
SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER

13 DECEMBER 1971

DISSOLVED OXYGEN SLACK BEFORE EBB

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER  01 MARCH 1972  DISSOLVED OXYGEN  SLACK BEFORE EBB

KILOMETERS  DISTANCE UPSTREAM FROM MOUTH
DISSOLVED OXYGEN
SLACK BEFORE EBB

PAMUNKEY RIVER
20 SEPTEMBER 1972

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

DEPTH (M)

X8.0
X8.1
X8.7
X8.8
X8.9
X8.1
X8.4
X0.0
X8.1
X8.7
X8.5
X8.6
X8.7
X8.1
X8.4
X0.0
X7.1

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PANUNKEY RIVER  10 OCTOBER 1972  DISSOLVED OXYGEN  SLACK BEFORE EBB

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
DISSOLVED OXYGEN
SLACK BEFORE FLOOD

PAWMUNKEY RIVER
26 OCTOBER 1972

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

DEPTH (M)
PAMUNKEY RIVER
21 MAY 1973
DISSOLVED OXYGEN
SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH

DEPT H (M)
PAMUNKEY RIVER 25 JUNE 1974 DISSOLVED OXYGEN SLACK BEFORE FLOOD

DEPTH (ft)

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMLUNKEY RIVER  07 AUGUST 1974  DISSOLVED OXYGEN  SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER
15 OCTOBER 1974
DISSOLVED OXYGEN
SLACK BEFORE EBD

DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER 13 NOVEMBER 1974 DISSOLVED OXYGEN SLACK BEFORE EBB

KILOMETERS DISTANCE UPSTREAM FROM MOUTH
16 OCTOBER 1975 DISSOLVED OXYGEN SLACK BEFORE EBB
PANUNKEY RIVER 15 DECEMBER 1976 DISSOLVED OXYGEN SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER 19 MAY 1977 DISSOLVED OXYGEN SLACK BEFORE FLOOD

KILOMETERS DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER 06 AUGUST 1977
DISSOLVED OXYGEN SLACK BEFORE FLOOD

KILOMETERS DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER

20 JULY 1978

DISSOLVED OXYGEN  SLACK BEFORE EBB

DISTANCE UPSTREAM FROM MOUTH
PAP11.JN(E'RIVER
25 SEPTEMBER 1978 DISSOLVED OXYGEN SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH
PAMUNKEY RIVER
16 OCTOBER 1980
DISSOLVED OXYGEN
SLACK BEFORE FLOOD

KILOMETERS
DISTANCE UPSTREAM FROM MOUTH