REPORT OF THE JOINT TASK FORCE

INSTREAM FLOW NEEDS ANALYSIS

FOR

NORTHERN NEW CASTLE COUNTY, DELAWARE

PHASE TWO: 7Q10 ASSESSMENT

Delaware Department of Natural Resources & Environmental Control,
Water Resources and Fish and Wildlife Divisions

Delaware Geological Survey

Pennsylvania Department of Environmental Protection

Water Resources Agency for New Castle County

City of Wilmington

City of Newark

Artesian Water Company

United Water Delaware

Technical Advisors
Delaware River Basin Commission
Delaware Nature Society

Prepared by David C. Yaeck, Consulting Services, West Chester, PA
in cooperation with the Delaware Department of Natural Resources
and Environmental Control and Water Resources Agency
for New Castle County, DE

January 31, 1997

TABLE OF CONTENTS

LIST OF FIGURES

Figure

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

The participation of the multi-disciplinary Insert Flow Needs Joint Task Force in the development of this study is gratefully acknowledged. Special thanks is extended to Roy Miller and Michael Sating of the Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control for the extensive field investigation and literature search which defined the target species utilized in this report. The Task Force is also indebted to Richard W. Greene, Environmental Engineer, Water Resources Division, Department of Natural Resources and Environmental Control, and Gerald J. Kauffman, P.E., Water Resources Engineer, Water Resources Agency for New Castle County, for the development of the wetted perimeter analyses vital to this effort. The Geographic Information Systems (GIS) mapping included in this report is the professional product of Vern Svatos and Nicole Minni of the Water Resources Agency for New Castle County whose work is especially acknowledged.

The diligence and dedication of the Study Coordinating Group contributed substantially to the successful conclusion of Phase I and Phase 11 of the Instream Flow Needs Study and that contribution is sincerely acknowledged. In addition to Greene and Kauffman, membership included Stewart Lovell, P.G., Water Resources Division, Department of Natural Resources and Environmental Control, and David C. Yaeck, consultant and Joint Task Force Chairman.

EXECUTIVE SUMMARY

The Scope of Work for the Instream Flow Needs Analysis for Northern New Castle County; Phase Two: 7Q10 Assessment was incorporated in the Phase One Final Report approved by the Joint Task Force on June 15, 1995 and refinements approved when the group reconvened April 26, 1996 University of Delaware's Clayton Hall. The second phase of the study was funded after the Fish & Wildlife Division of the Delaware Department of Natural Resources and Environmental Control expressed reservation concerning the development of a statewide policy regarding instream flow needs based on the general approach to target fish species used in the Phase One assessment. The Joint Task Force acknowledged this concern in its Phase One recommendations, pointing out additional information such as habitat suitability and water quality data within the study reaches should be generated through more detailed study before the 7Q10 Assessment can be considered complete. The Task Force noted the development of Phase Two of the 7Q10 Assessment would also provide needed data to develop a wetted perimeter analysis using habitat information obtained in the extended study. The wetted perimeter analysis will assist in evaluating the effect of a 7Q10 passby requirement on public water purveyors withdrawing for the streams in the study area while seeking to protect all instream flow needs.

Although nearly ten months elapsed between the conclusion of the Phase One study and initiation of Phase Two, Michael Stangl, fisheries biologist from the Division of Fish and Wildlife was able to proceed with stream habitat and fisheries investigations during the fall of 1995 under separate Federal funding. His field work also resulted in the development of additional stream cross sections for use in the Phase Two study. This activity occurred during the critical low flows in the White Clay and Brandywine creeks resulting from drought conditions experienced in September and October. In fact, the drought of 1995 provided unique hydrological and meteorological conditions during July through October enabling the Study Coordinating Group to develop a data base representing a "snapshot" of wet, dry and normal conditions which otherwise would have required a much longer time frame to develop.

Stangl reported on his findings in detail at the April 25, 1996 meeting, presenting study objectives, fisheries data tables, sampling locations and summaries for use by the Task Force in developing the wetted perimeter analyses. He said the objectives of the fisheries study were met with the exception of obtaining specific habitat data for all species, additional criteria for the target species identified in the Phase One study was available. However, the fisheries study revealed to better represent a balanced, indigenous fauna, the target species for the Phase Two assessment should be Longnose Dace, Satinfin Shiner and Tessellated Darter in the Brandywine and Longnose Dace, Blacknose Dace and Common Shiner in White Clay Creek. These target species are found in the sensitive riffle sections of the Brandywine Creek and White Clay Creek study areas. Habitat criteria for the optional target species was not available for the original presentation, but Stangl later obtained data from various jurisdictions and the literature which confirmed the best available information narrowed the target species for both the Brandywine and the White Clay to the Longnose Dace. It was also agreed the focus for the wetted perimeter analyses on both creeks would be the riffle cross sections which defined the target species habitat.

Richard W. Greene, Environmental Engineer, Water Resources Division, Department of Natural Resources and Environmental Control, and Gerald J. Kauffman, P.E., Water Resources Engineer, Water Resources Agency for New Castle County, collaborated with Stangl on wetted perimeter analyses which disclosed the habitat flow depth and velocity criteria in the riffle areas would be met under 7Q10 conditions. The analyses also indicated the flow objective in the Brandywine could be met under drought conditions by utilizing the wetted perimeter breakpoint on an interim basis if required by the City of Wilmington. Greene further developed the water quality section of the Phase Two assessment which concluded a 7Q10 passby requirement at United Water Delaware's Stanton intake would be necessary to meet the objectives of the state's Water Quality Standards and for salinity control, as well as protecting the aquatic habitat.

The Study Coordinating Group undertook a detailed review of the City of Newark and MBNA surface water withdrawals from the White Clay Creek, identifying inconsistencies between the state permits issued by the Department of Natural Resources and Environmental Control and the docket decisions of the Delaware River Basin Commission. Meetings were held with the United Water Delaware to review the proposed tidal retention structure designed to capture excess flows and with the City of Newark and City of Wilmington to discuss diversion operations in order to reduce transfer

of excess flows. Detailed recommendations pertaining to these issues appears in Section 2.5 of this report.

Based on the results of the Instream Flows Needs Analysis for Northern New Castle County, Phase One and Phase Two, the Joint Task Force concluded the imposition of a 7Q10 minimum flow standard for all withdrawals over 50,000 gallons per day will protect instream uses in the Christina River Basin in Northern New Castle County. The 7Q10 flow was found to protect multiple instream uses, including aquatic habitat, water quality and, in the tidal setting, salt front maintenance. Further studies would have to be conducted before a recommendation could be made regarding development of a statewide policy mandating a 7Q10 passby requirement. The imposition of such a passby requirement for the water supply intakes of the City of Newark and United Water Delaware can be met with supplemental water supply through interconnections with the City of Wilmington, Artesian Water Co. And the Chester Water Authority and releases from Wilmington-owned Hoopes Reservoir, except during a declared drought emergency. Substitution of the wetted perimeter lower breakpoint flow identified in this study for the 7Q10 passby requirement at the City of Wilmington's Brandywine intake during a drought emergency will enable the City to supply water through interconnections to other purveyors pending the development of a new source of supply for Northern New Castle County. The Churchman's Marsh Environmental Impact Statement process, now nearing completion, will determine the new supply source to be developed.

The implementation of the recommendations contained in this report will rely on coordinated activity to properly manage the water resources of the Christina River Basin in Northern New Castle County including the White Clay, Red Clay, and Brandywine Creek Watersheds. To accomplish this goal, a water resources management plan should be developed for the basin incorporating an operating plan for the public/private water supply systems serving the study area. The development of the operating plan was a priority recommendation of the Joint Task Force to be undertaken as soon as possible by the Department of Natural Resources and Environmental Control and the Water Resources Agency for New Castle County. When completed, the plan will be incorporated in this study as an appendix.

In order to avoid duplication of data and exhibits, the completed Instream Flow Needs Analysis is presented in two volumes referenced as Phase One and Phase Two. Final conclusions and

recommendations for the Joint Task Force contained in this volume will be forwarded to the Department of Natural Resources and Environmental Control for consideration in the development of water supply policy and water allocation permit regulations.

1. INTRODUCTION

The first phase of the Instream Flow Needs Analysis for Northern New Castle County was completed by the Joint Task Force on June 15, 1995. Although significant steps were taken to complete an assessment of 7Q10 as a minimum flow passby requirement for public water supply intakes in the study area, the Joint Task Force recommended additional information such as target fish species habitat suitability and water quality data within the study reaches identified in Phase I be generated through a more detailed Phase II study before the assessment could be considered complete. This conclusion was reached after the Fish and Wildlife Division, Delaware Department of Natural Resources and Environmental Control expressed reservation about the development of a statewide regulatory policy regarding instream flow needs based on the generalized approach to target fish species employed in the initial phase of the study. Although the selection was made on best available data at the commencement of the Phase I assessment, collection of more specific data within the study reaches was deemed desirable by the Joint Task Force before considering any recommendations regarding regulatory policy which would be advanced to the Department. The Joint Task Force also endorsed the concept of a wetted perimeter analysis using habitat information developed in the second phase effort as an additional data input to the evaluation of a 7Q10 passby requirement for public water purveyors in the study area while seeking at the same time to protect all instream flow needs.

1.1 BACKGROUND

The establishment of technically-based minimum instream (passby) flow requirements is an emerging need for water supply management in northern New Castle County, Delaware. Other states have or are currently establishing such standards for surface water supply as well as aquatic habitat, fishery, and recreation management purposes. Recognizing this need, the Delaware Department of Natural Resources and Environmental Control circulated a draft state water supply policy at a public workshop in April, 1993 suggesting the 7Q10 design flow as the minimum passby requirement for surface water withdrawal projects. In response to the workshop, the Department embarked on a formal instream flow analysis to verify the 7Q10 flow requirement or some other passby standard as appropriate for the unique water supply and aquatic habitat circumstances in northern New Castle County. A multi-disciplinary Joint Task Force was convened in September, 1994

to undertake the formal analysis resulting in the Phase I report of June, 1995. That document contributes detailed reference material to the Phase 11 study.

There are four major public water supply withdrawals and 21 others along Christina River Basin streams in northern New Castle County (Figure 1). Of these, only two public water purveyors have had a 7Q10 passby requirement imposed by the Delaware River Basin Commission - the City of Newark withdrawal on the White Clay Creek (1991) and United Water Delaware (formerly Wilmington Suburban) (1991) from the tidal White and Red Clay Creeks at Stanton (Figure 2). The City of Wilmington withdrawal on the Brandywine Creek and United Water Delaware's withdrawal from the Upper Christina River at Smalley's Pond are as yet unaffected. It is anticipated, however, the Commission will mandate passby requirements at these withdrawal points unless the State of Delaware moves ahead with a water supply policy incorporating minimum flow passby requirements.

1.2 STUDY OBJECTIVES

The objective of this Phase II study was to further refine the methodology utilized in the Phase I Instream Flow Needs Analysis of June, 1995 to assess the effectiveness of a 7Q10 minimum flow standard in the protection of all instream uses, including water supply, aquatic habitat and recreation. To accomplish this, the original study was expanded to include wetted perimeter breakpoint analyses of riffle areas within the previously-identified study reaches, modification of the target fish species and habitat data listed in Phase 1, and results of extensive field investigations conducted by the Division of Fish and Wildlife, Delaware Department of Natural Resources and Environmental Control during low flow and drought conditions in the fall of 1995. The study was conducted by the same multi-disciplinary Task Force responsible for the Phase I effort with David C. Yaeck, consultant, responsible for the overall direction of the study and coordination of the Joint Task Force activities as chairman.

1.3 SCOPE OF WORK

The Scope of Work for the Instream Flow Needs Analysis, Phase II, was developed as a recommendation resulting from the Phase I study, updated by the Joint Task Force and approved when the group reconvened on April 26, 1996. Meteorological events of 1995 provided an opportunity for a condensed

water-year approach and utilization of the current data base to more accurately identify hydrologic conditions associated with wet, dry and normal years. With the drought conditions existing in 1995, the study was able to focus on pre-drought (July 1995), drought (August, September 1995) and post-drought (October 1995) regimes. The fish abundance and habitat studies conducted by the Division of Fish and Wildlife, DNREC, during the same period, enabled the condensation of the study reaches utilized in the Phase I effort to the riffle areas within those reaches in Phase 11 identified by the Division as the critical habitat areas in need of protection.

PHASE II

SCOPE OF WORK

A. Revisit target fish species in Phase I Scope of Work and make revisions as necessary. Conduct fish abundance investigations in the four study reaches.

B. Revisit target fish species habitat criteria through literature search to:

1. Determine habitat criteria to include, depth, velocity, substrate type and temperature for various life stages.

2. Describe the effects of varying instream flows used wetted perimeter breakpoint analysis and relate to habitat types in the riffle areas of the study reaches.

3. Determine these criteria for critical flow period (July-October).

C. Conduct field reconnaissance to identify habitat types in Phase I study reaches.

D. Conduct a water quality analysis to evaluate the adequacy of 7Q 10 as a minimum flow standard in accordance with the State of Delaware Surface Water Quality Standards. Prepare temperature/discharge data for public water supply intakes in study reaches and dissolved oxygen and chloride in tidal portion.

E. Conduct wetted perimeter breakpoint analysis using habitat data generated in Phase II, incorporating depth, flow and velocity data generated in Phase I of the 7Q 10 assessment. The analysis will account for seasonal variations in flow for the **full** tidal cycle, including low, slack and high tide conditions, incorporating the operational plan of the inflatable dam proposed by United Water Delaware in the vicinity of the Stanton intake.

F. Prepare automated mapping, refining GIS products produced for Phase 1.

G. Evaluate the effect of a 7Q 10 passby requirement on public water supply intakes within the study reaches and the protection of all instream flow needs, including a review of the Delaware River Basin Commission and DNREC dockets and permits which apply within the study reaches.

H. Prepare a report to DNREC regarding suitability of a 7Q 10 passby requirement for public water supply and other withdrawals as a statewide regulatory policy.

2. ADVANCED METHODOLOGY

2.1 MODIFICATION OF STUDY REACHES

Although the overall study reaches defined and mapped in the Phase One Assessment remain unchanged, the focus of Phase Two was directed to the stream cross sections in the riffle areas of those reaches on the recommendation of the Division of Fish and Wildlife, Department of Natural Resources and Environmental Control. The recommendation was Forthcoming upon the completion of fish surveys and habitat evaluation conducted by Fisheries Biologist Michael Stangl during low flow conditions in the fall of 1995, as part of the effort to identify the final target fish species for the purposes of the Instream Flow Needs Analysis. The wetted perimeter analyses conducted for this study were based on this approach at cross sections 2.55, 2.65 and 2.94 on the Brandywine Creek at Wilmington (Figure 3) and 53115, 55713 and 56970 on the White Clay Creek at Newark (Figure 4) which were deemed the most critical to the goals of the Phase Two Assessment.

2.2 REVISION OF TARGET SPECIES

The selection of target fish species during the Phase One activity centered on native and non-native recreational sport fisheries considered worthy of minimum flow protection. The initial focus, resolved after considerable debate, was for Smallmouth and Rock Bass in the Brandywine and Catfish species and White Perch for the tidal portion of the Red Clay and White Clay creeks. For the freshwater portion of the White Clay, Brown and Rainbow Trout were selected, while Rainbow Trout and Redbreast Sunfish were chosen as the target species for the Upper Christina River above Smalley's Pond and Catfish species and White Perch for the portion below Smalley's Pond. A literature search conducted by the Division of Fish and Wildlife and other members of the Joint Task Force found insufficient data available regarding minimum flow depth, velocity and habitat criteria for these species and a more intensive literature search and field surveys of the waterways was recommended. The Joint Task Force included this approach in the Scope of Study for the Phase Two Assessment.

During the low stream flow period occurring in September and October, 1995, Michael Stangl, Fisheries Biologist, Division of Fish and Wildlife conducted field investigations in the study reaches, including fish surveys, habitat evaluation and establishment of additional stream cross sections under a separate Federal program and made the data available to the Joint Task Force. Table 1 summaries the study areas and habitat sections which were sampled. Additionally, Stangl conducted a detailed literature search resulting in the initial recommendation that the study focus on riffle areas and afford protection to the Longnose Dace, Satinfin Shiner and Tessellated Darter on the Brandywine and the Longnose Dace, Blacknose Dace and Common Shiner in the White Clay Creek at Newark. The study areas along the Tidal Christina River at Smalley's Pond (Figure 5) and the tidal White Clay Creek at Stanton (Figure 6) do not have riffle section's and therefore were not included in this analysis.

Further literature search and communication with other jurisdictions resulted in the final recommendation identifying the Longnose Dace as the target species requiring flow, velocity and habitat protection in the riffle areas of the "White Clay and Brandywine creeks. Wetted perimeter breakpoint analyses were conducted to establish the necessary parameters to achieve this goal. Stangl's completed study appears as Appendix A in this report.

2.3 WETTED PERIMETER ANALYSIS

Introduction

The Joint Task Force selected the wetted perimeter technique (Nelson, 1980) to verify minimum instream flow needs for the study reaches (Figure 7). Critical riffle sections were selected since these habitat are the most sensitive to fluctuations in flow. The HEC-2 model was used to plot discharge versus wetter perimeter for various flow scenarios. The "breakpoints" or "inflection points" in the wetted perimeter curve were chosen as surrogates for minimally acceptable habitat (Figures 8 and 9). The discharges at the inflection points are assumed to be the minimum flow needed for food production, fish passage, and spawning of the indicator fish species. The minimum flow selected for the sensitive riffle sections is also assumed to protect other habitat areas such as. natural pools and dam pools.

Methodology

The Joint Task Force performed wetted perimeter analysis according to the following methods:

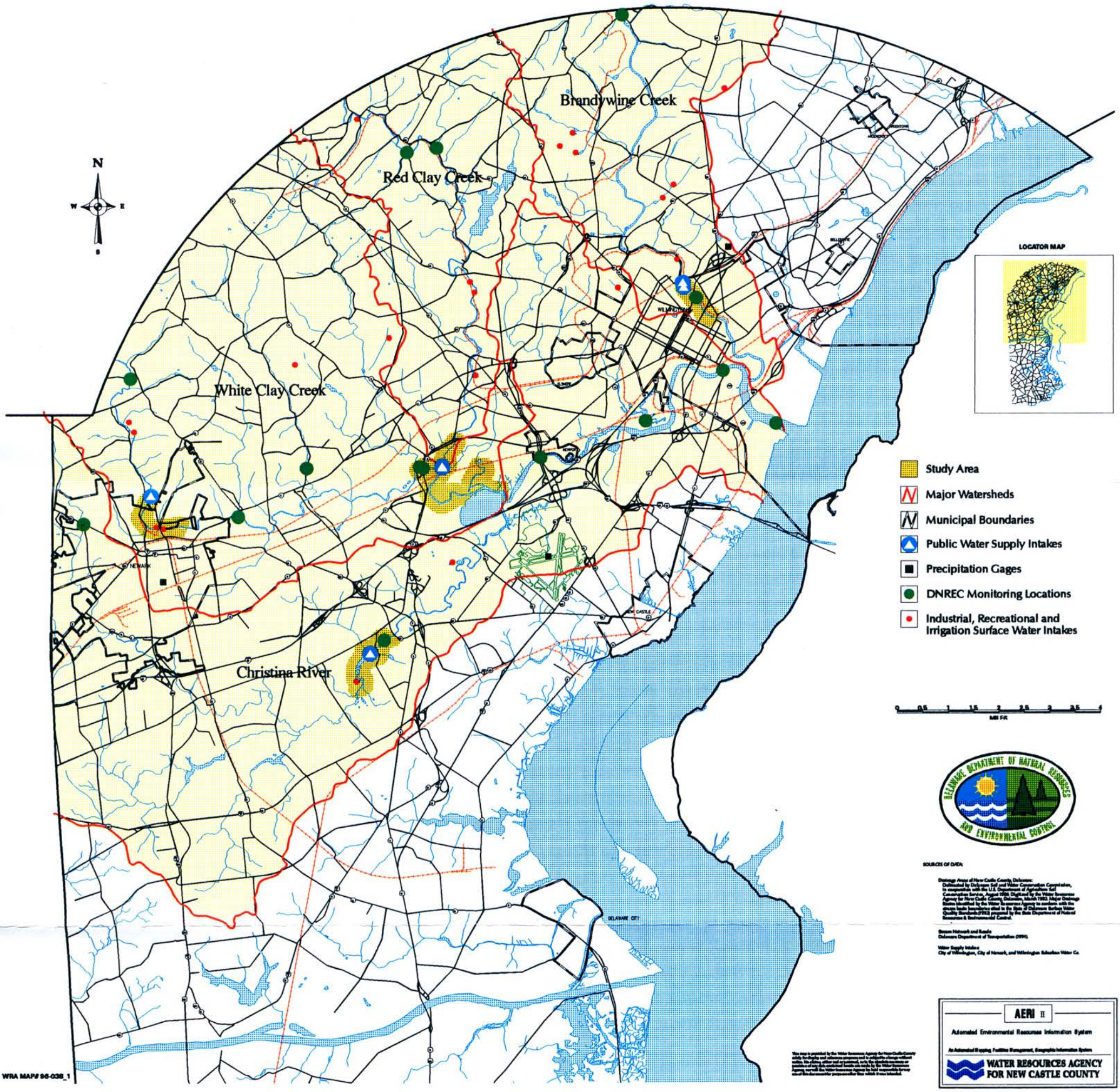
1. Select critical riffle sections based on fishery sampling stations monitored by the Delaware DNREC in the summer and fall of 1995. Three sections at each of the study areas were selected as representative of high velocity and shallow depth riffles. The Christina River at Smalley's Pond was not appropriate for the wetted perimeter technique since this reach exhibits tidal pools with no riffle sections. The following riffle sections were selected for the wetted perimeter analysis:

   - Brandywine Creek **at** Wilmington - 2.55
     - 2.65
     - 2.94
   - White Clay Creek at Newark - 53115
     - 53713
     - 57970
   - White Clay Creek at Stanton - 13843

INSTREAM FLOW NEEDS ANALYSIS - PHASE II

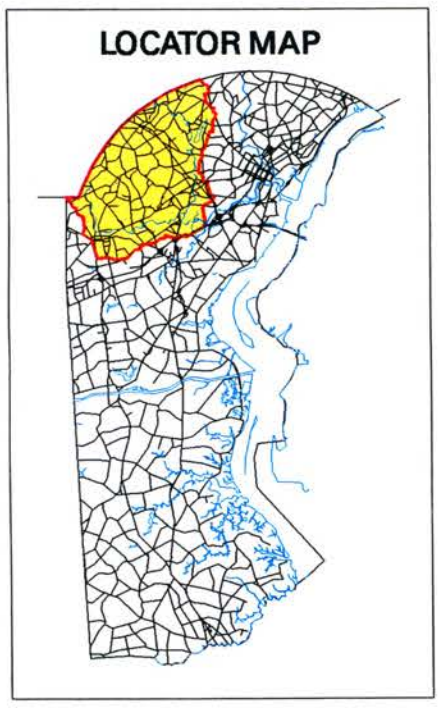
Figure 1. 7Q10 Study Area in the Christina River Basin

December 1996



EXISTING WATER SUPPLY WITHDRAWALS
IN THE
WHITE CLAY CREEK WATERSHED

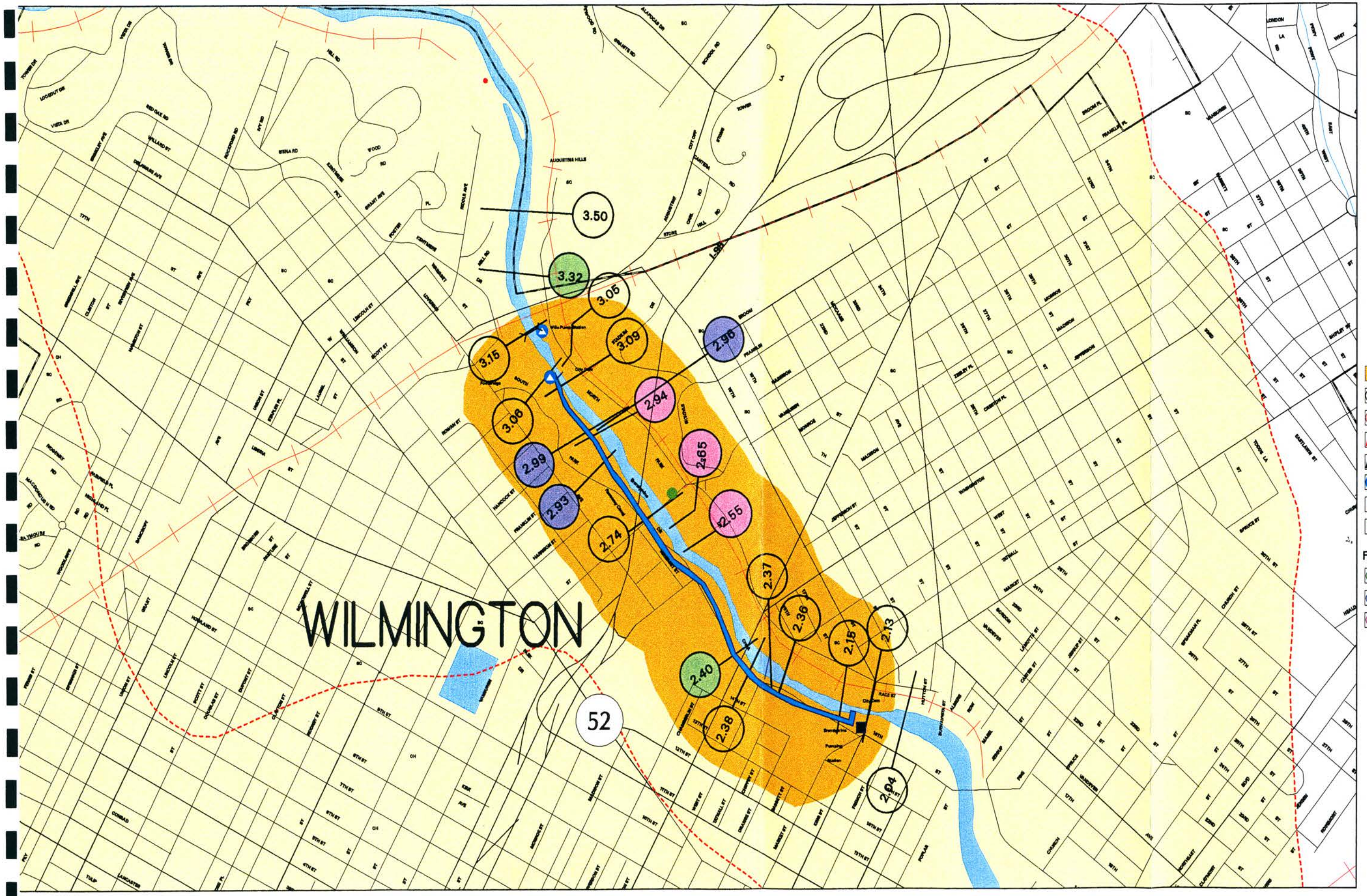
Figure 2
December 1996



INSTREAM FLOW NEEDS ANA
PHASE II
CHRISTINA RIVER BASIN

Figure3. Study Reach along the Brandywine Creek at Wilmington

December 1996



LOCATOR MAP

- Study Area
- HEC-2 Cross-Sections
- Field Survey Cross-Sections (April 1995)
- Major Watersheds
- Municipal Boundaries
- Public Water Supply Intakes
- DNREC Monitoring Locations
- Industrial, Recreational and Irrigation Surface Water Intakes

Fish Habitat Sampling Stations

- Dam Pool
- Pool
- Riffle

0 0.05 0.1 0.15 0.2 0.25
MILES
Approximate Scale 1 : 12000

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

AERI II
Automated Environmental Resources Information System
An Automated Mapping, Facilities Management, Geographic Information System
WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY

WRA MAP # 96-038:2

INSTREAM FLOW NEEDS ANAI
PHASE II
CHRISTINA RIVER BASIN

Figure 4. Study Reach along the White Clay Creek at I

December 1996

N

W E

S

LOCATOR MAP

- Study Area
- HEC-2 Cross-Sections
- Field Survey Cross-Sections (April 1995)
- Major Watersheds
- Municipal Boundaries
- Public Water Supply Intakes
- DNREC Monitoring Locations
- Industrial, Recreational and Irrigation Surface Water Intakes

Fish Habitat Sampling Stations

- Dam Pool
- Pool
- Riffle

0 0.05 0.1 0.15 0.2 0.25

MILES

Approximate Scale 1 : 12000

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

AERI II

Automated Environmental Resources Information System

An Automated Mapping, Facilities Management, Geographic Information System

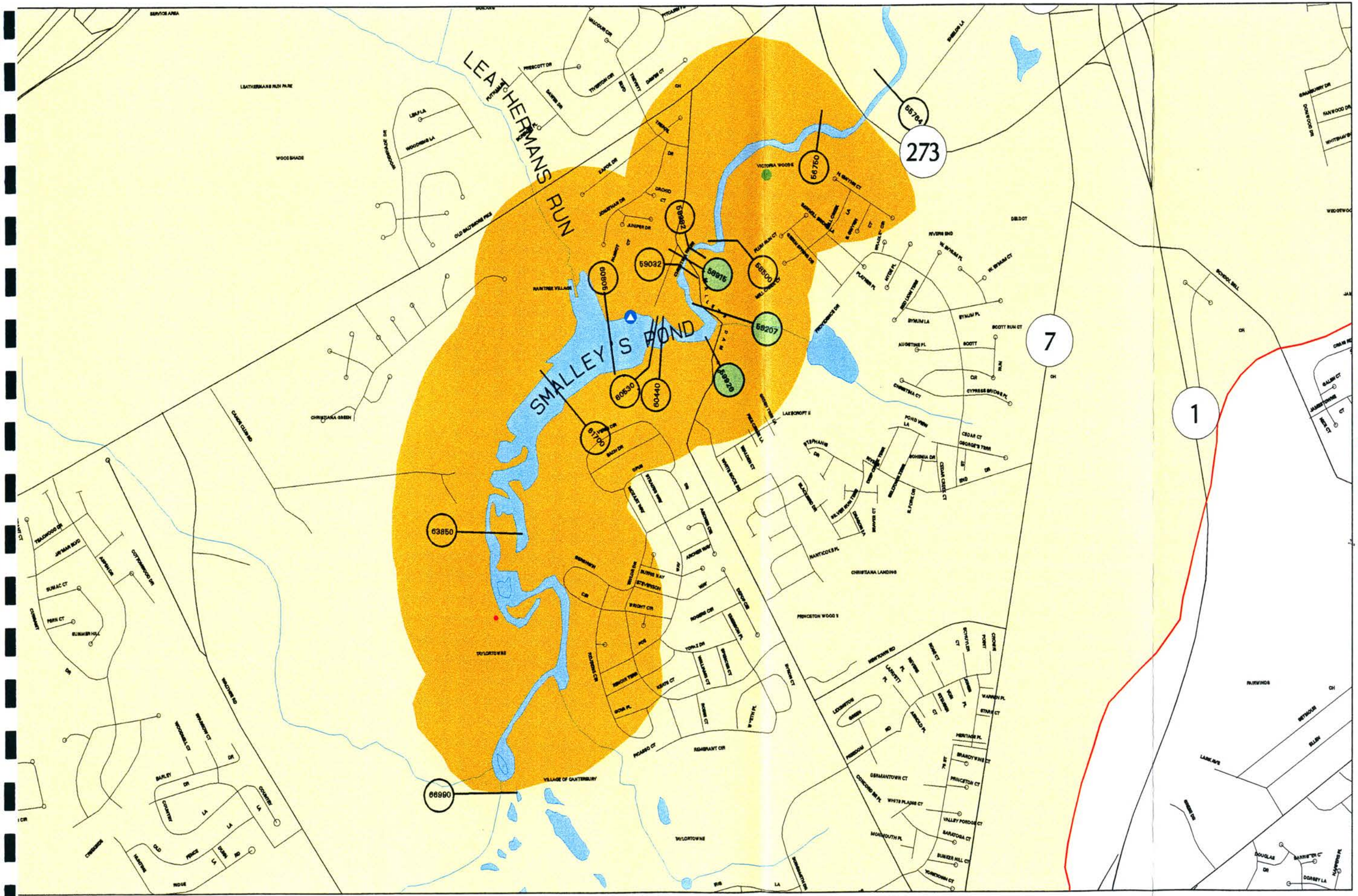
WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY

WRA MAP# 96-038:4

INSTREAM FLOW NEEDS ANALY
PHASE II
CHRISTINA RIVER BASIN

Figure 5. Study Reach along the Christina River at Smalleys Pond

December 1996



LOCATOR MAP

- Study Area
- HEC-2 Cross-Sections
- Field Survey Cross-Sections (April 1995)
- Major Watersheds
- Municipal Boundaries
- Public Water Supply Intakes
- DNREC Monitoring Locations
- Industrial, Recreational and Irrigation Surface Water Intakes

Fish Habitat Sampling Stations

- Tidal Pool

0 0.05 0.1 0.15 0.2 0.25
MILES
Approximate Scale 1 : 12000

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

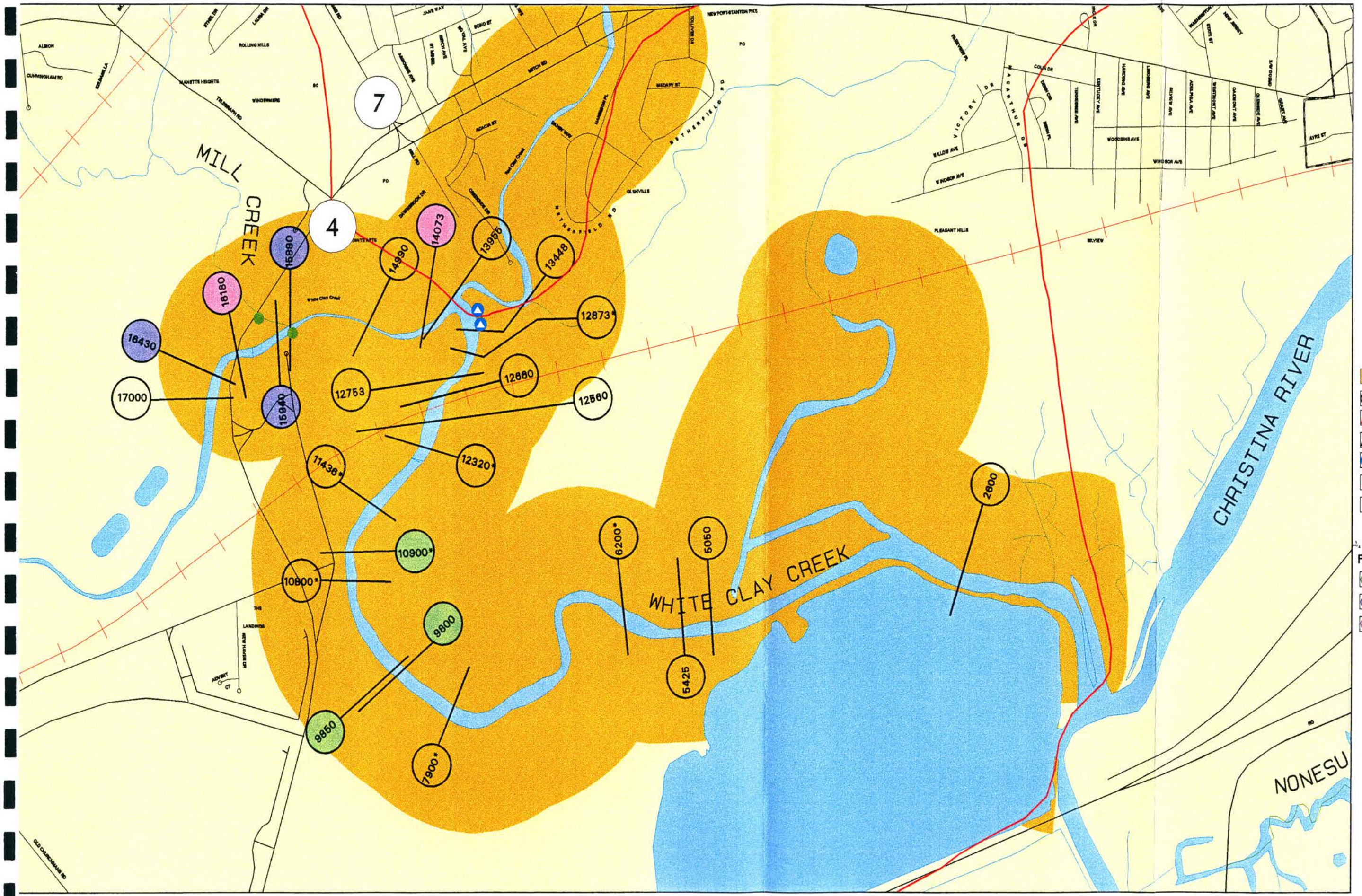
AERI II
Automated Environmental Awareness Information System
An Automated Mapping, Facilities Management, Geographic Information System
WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY

WRA MAP# 96-038.5

INSTREAM FLOW NEEDS ANALYS
PHASE II
CHRISTINA RIVER BASIN

Figure 6. Study Reach along the White Clay Creek at Star

December 1996



LOCATOR MAP

- Study Area
- HEC-2 Cross-Sections
- Major Watersheds
- Municipal Boundaries
- Public Water Supply Intakes
- DNREC Monitoring Locations
- Industrial, Recreational and Irrigation Surface Water Intakes

Fish Habitat Sampling Stations

- Dam Pool
- Pool
- Riffle

0 0.05 0.1 0.15 0.2 0.25
MILES
Approximate Scale 1:12000

DELAWARE DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

AERI II
Automated Environmental Resources Information System
An Automated Mapping, Facilities Management, Geographic Information System
WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY

VRA MAP# 96-038:6

Table1. Sample section locations by water and habitat type for the four study reaches. BW = Brandywine Creek, CC = Christina Creek, WCCN = White Clay Creek at Newark, and WCCS = White Clay Creek near Stanton.

Date Sampled	Water	Habitat Type	Section No.	Location Description*
08-15-95	WCCS	Riffle	14073	First riffle downstream from old Rt. 7 Bridge
08-15-95	WCCS	Pool	15890	First pool downstream from old Rt. 7 Bridge
08-16-95	WCCN	Riffle	53155	Riffle beginning at bridge on Papermill Rd.
08-23-95	WCCN	Pool	56000	Deep pool located at sharp curve on Tweeds Mill Rd.
08-24-95	BW	Riffle	2.55	First riffle upstream from Baynard Blvd.
08-28-95	CC	Tidal Pool	58915	Pool at Smalley's Dam Rd intersection
09-01-95	BW	Pool	2.99	Plunge pool below city dam
09-05-95	WCCN	Riffle	57970	Riffle at approximately 1300 feet downstream from dam at water intake. Marked on west trail - WCC1
09-06-95	WCCN	Pool	58305	Plunge pool below dam at water intake
09-07-95	BW	Riffle	2.94	Riffle at concrete box on east shoreline, below city dam
09-08-95	WCCN	Pool	56623	Located upstream from curve on Tweeds Mill Rd. begins where small tributary enters creek on east side. Marked on west trail - WCC3
09-11-95	WCCS	Tidal Pool	9800	Pool located directly below 1st ravine on the northside of the Artesian Water Company access road off Rd 336D
09-12-95	CC	Tidal Pool	59926	Pool located approximately 600 feet downstream from dam where Smalley's Dam Rd. (on S. side) of river meets the stream (marked on trail)
09-13-95	WCCS	Pool	16430	Pool located 250 feet upstream from RT 4 Bridge
09-14-95	WCCS	Tidal Pool	9750	Pool begins 50 feet downstream from section 9800 and continues downstream where channel narrows
09-20-95	WCCN	Dam Pool	53345	Dam pool located above dam at Paper Mill Rd.
09-28-95	BW	Dam Pool	3.32	Dam pool located 50 feet upstream from upstream end of the Augustine Cutoff Bridge Abutment
09-29-95	BW	Pool	2.93	Pool begins at tributary on east side, below city dam
10-2-95	WCCN	Riffle	55713	Riffle located where Tweeds Mill Rd. meets the creek 1st riffle below curve. Marked on road - WCC4
10-3-95	WCCN	Dam Pool	55360	Pool located 300 feet downstream from section 55713
10-4-95	WCCN	Dam Pool	58375	Pool sampled begins 100 feet upstream from dam at intake
10-10-95	WCCN	Pool	57000	Pool located between two riffles. Directly upstream from Section No. 57970.
10-11-95	WCCS	Pool	15940	Downstream end of section sampled is located 22 feet upstream from confluence with Mill Creek
10-12-95	WCCS	Tidal Pool	10900	Section sampled begins 100 feet upstream from upstream corner of the Hale Byrnes house.
10-13-95	CC	Tidal Pool	59207	Tidal pool located between Section Nos. 59926 and 58915. Marked on south side
10-19-95	BW	Riffle	2.67	1st riffle downstream from Van Buren St. Bridge.
10-20-95	WCCS	Riffle	16180	Riffle located directly under the Route 4 Bridge.
10-31-95	BW	Pool	2.96	Pool located 100 feet downstream from end of riffle at Section No. 2.95
11-01-95	BW	Dam Pool	2.4	Directly under the Baynard Blvd. bridge

* See text for description of the study reaches. Maps indicating the locations of the study reaches and the sampling sections are available in Yaeck, 1995.

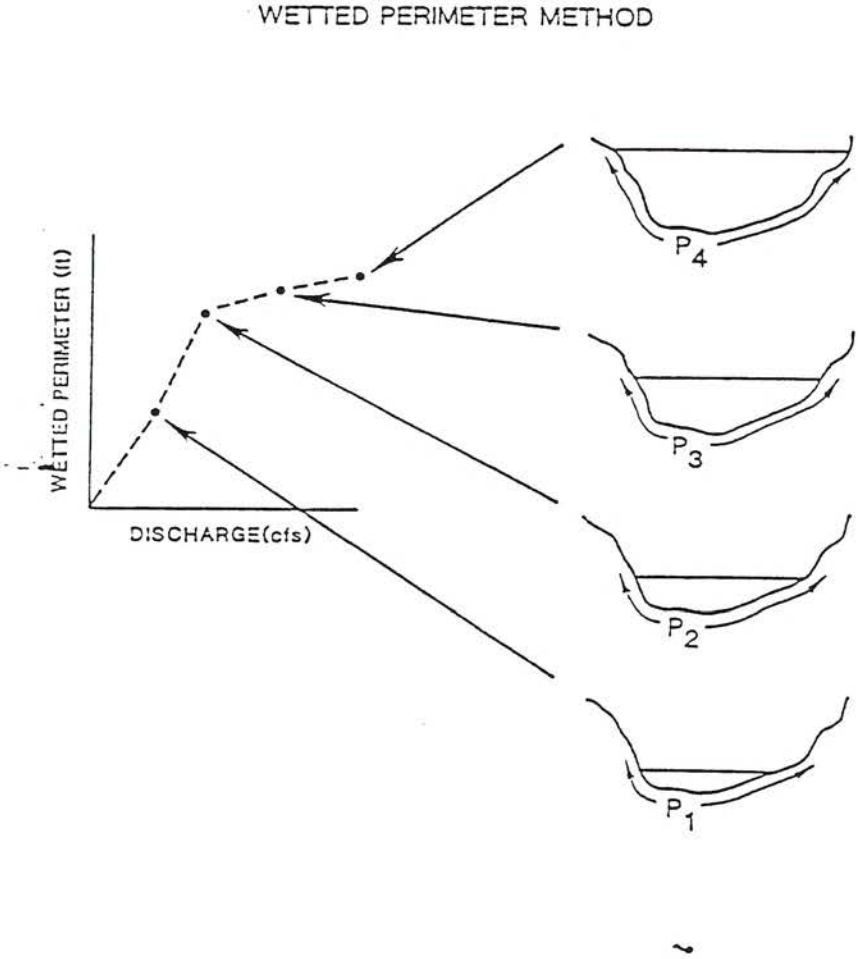


Figure 7. Use of the Wetted Perimeter Method to Estimate Instream Flows.

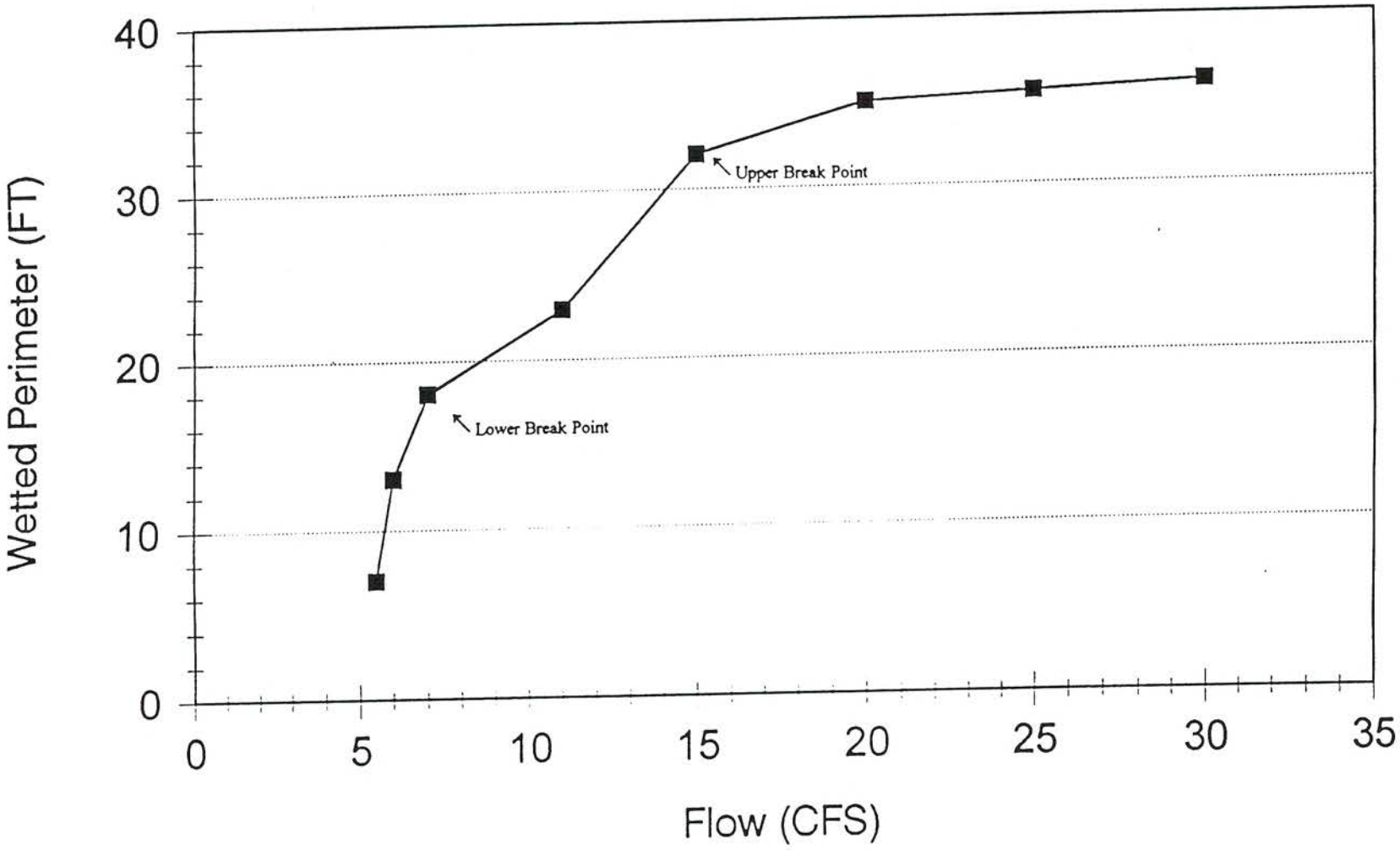


Figure 8 . A hypothetical example of a plot of wetted perimeter versus flow for a stream riffle cross-section showing the upper and lower wetted perimeter break points.

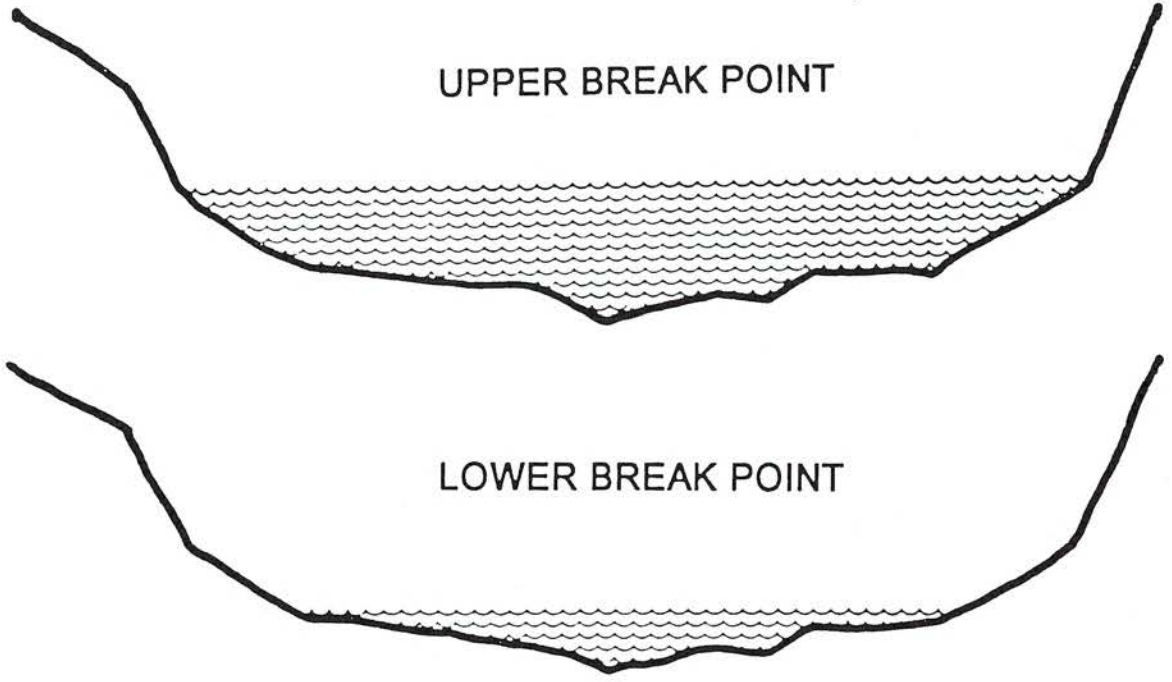


Figure 9. A diagrammatic representation of the flow at the upper and lower wetted perimeter break points obtained from Leathe and Nelson 1989.

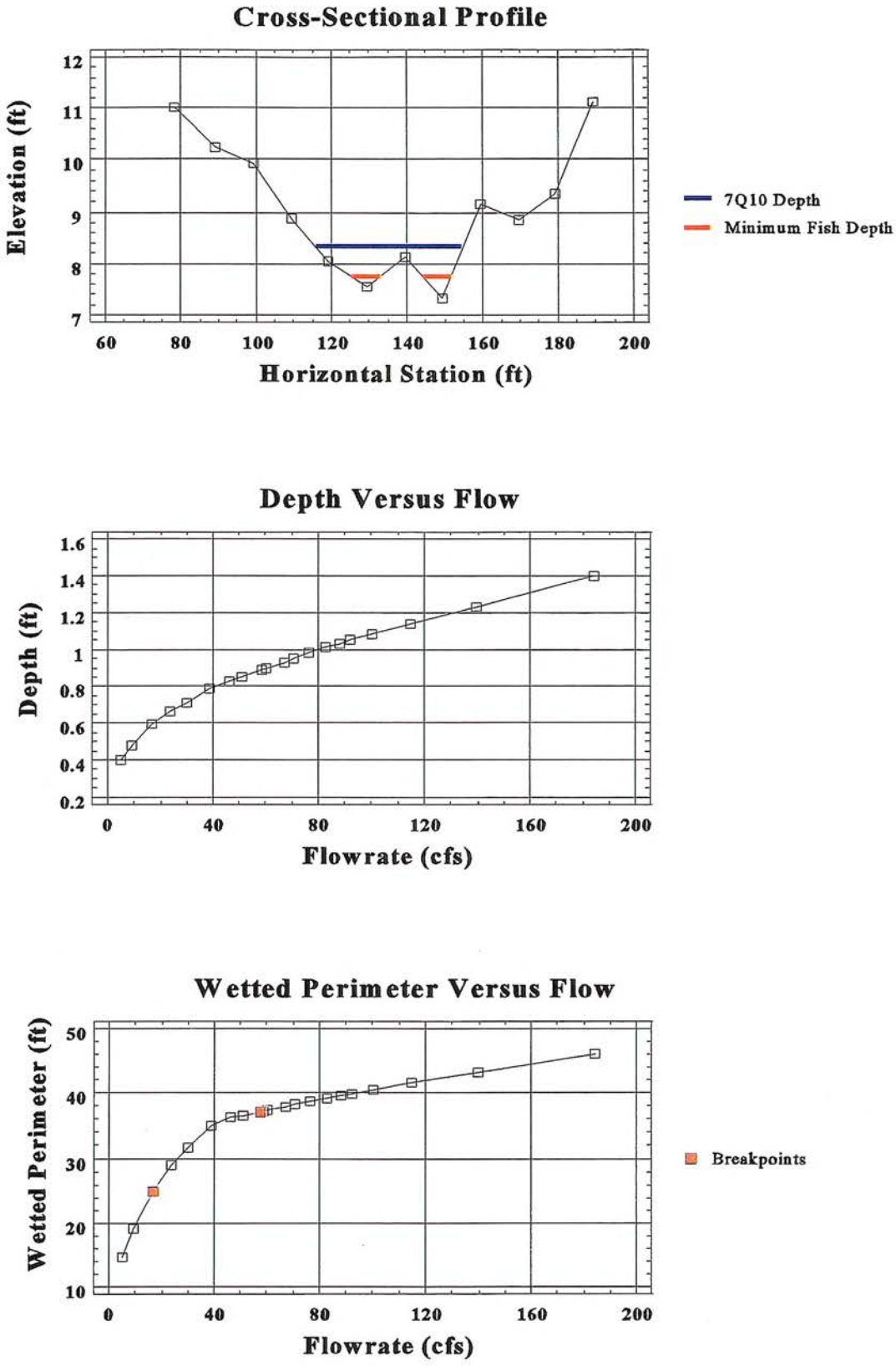


FIGURE 10. Hydraulic Characteristics for the Brandywine Creek at Section 2.55

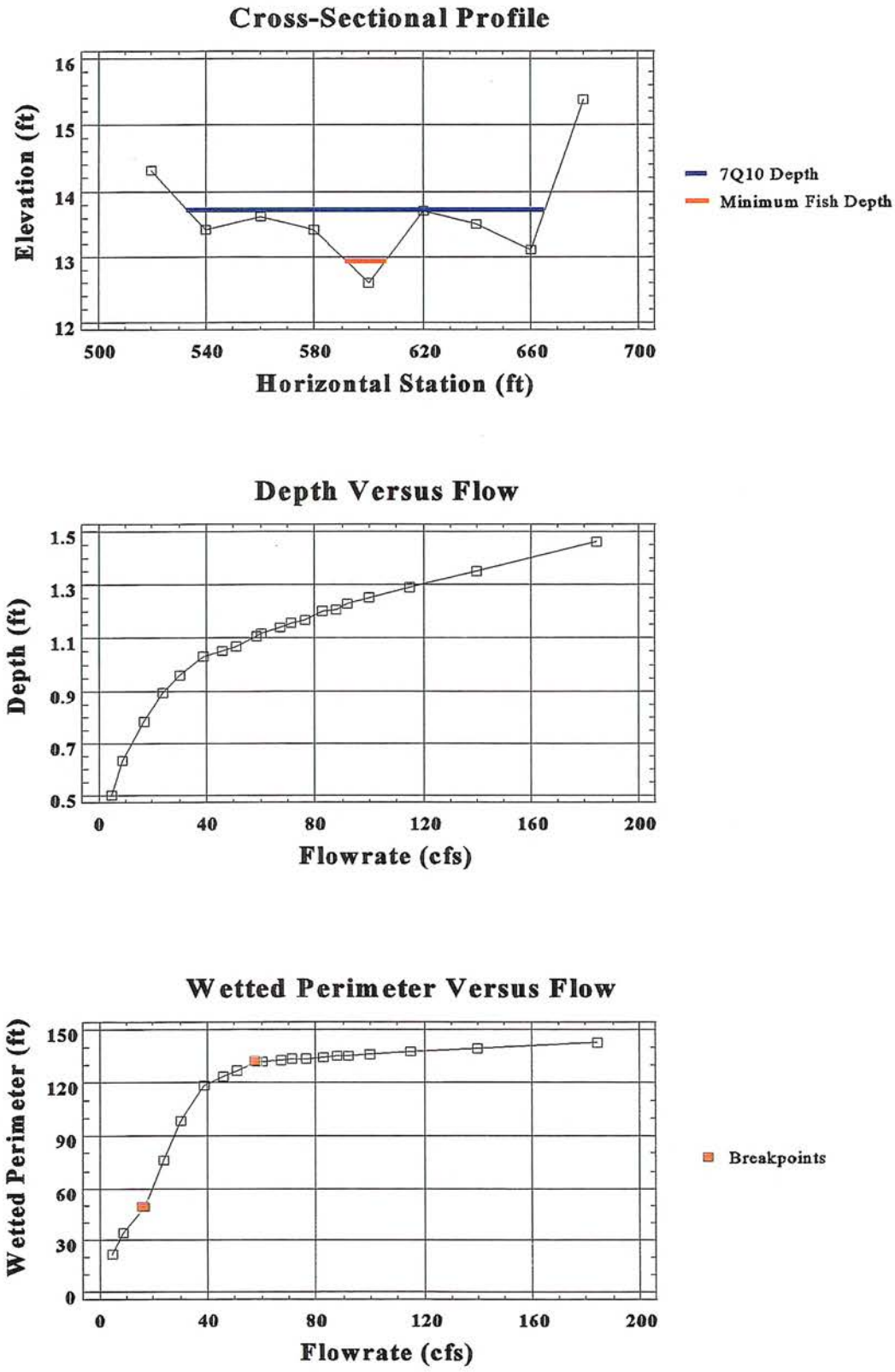


FIGURE 11. Hydraulic Characteristics for the Brandywine Creek at Section 2.65

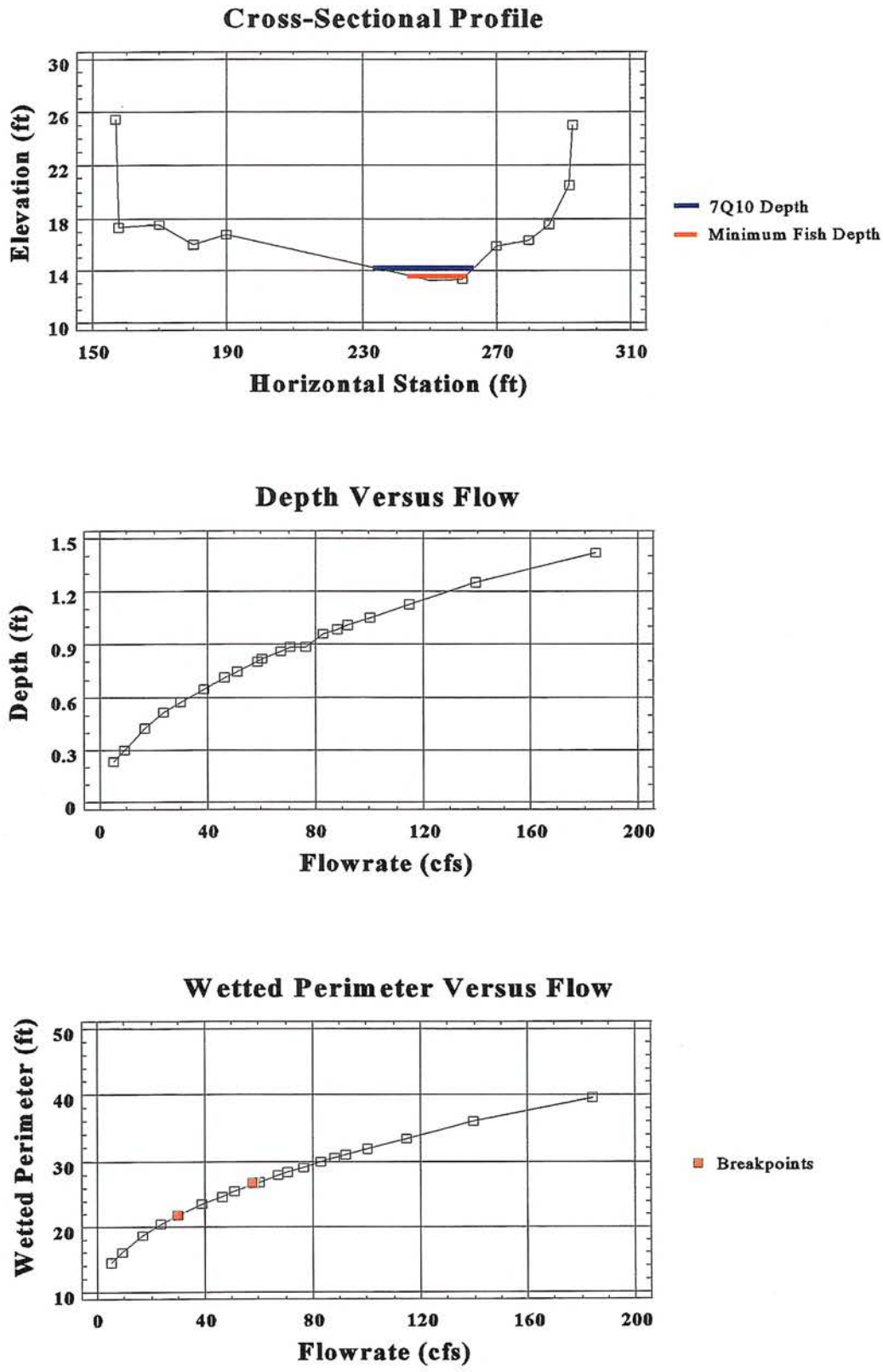


FIGURE 12. Hydraulic Characteristics for the Brandywine Creek at Section 2.94

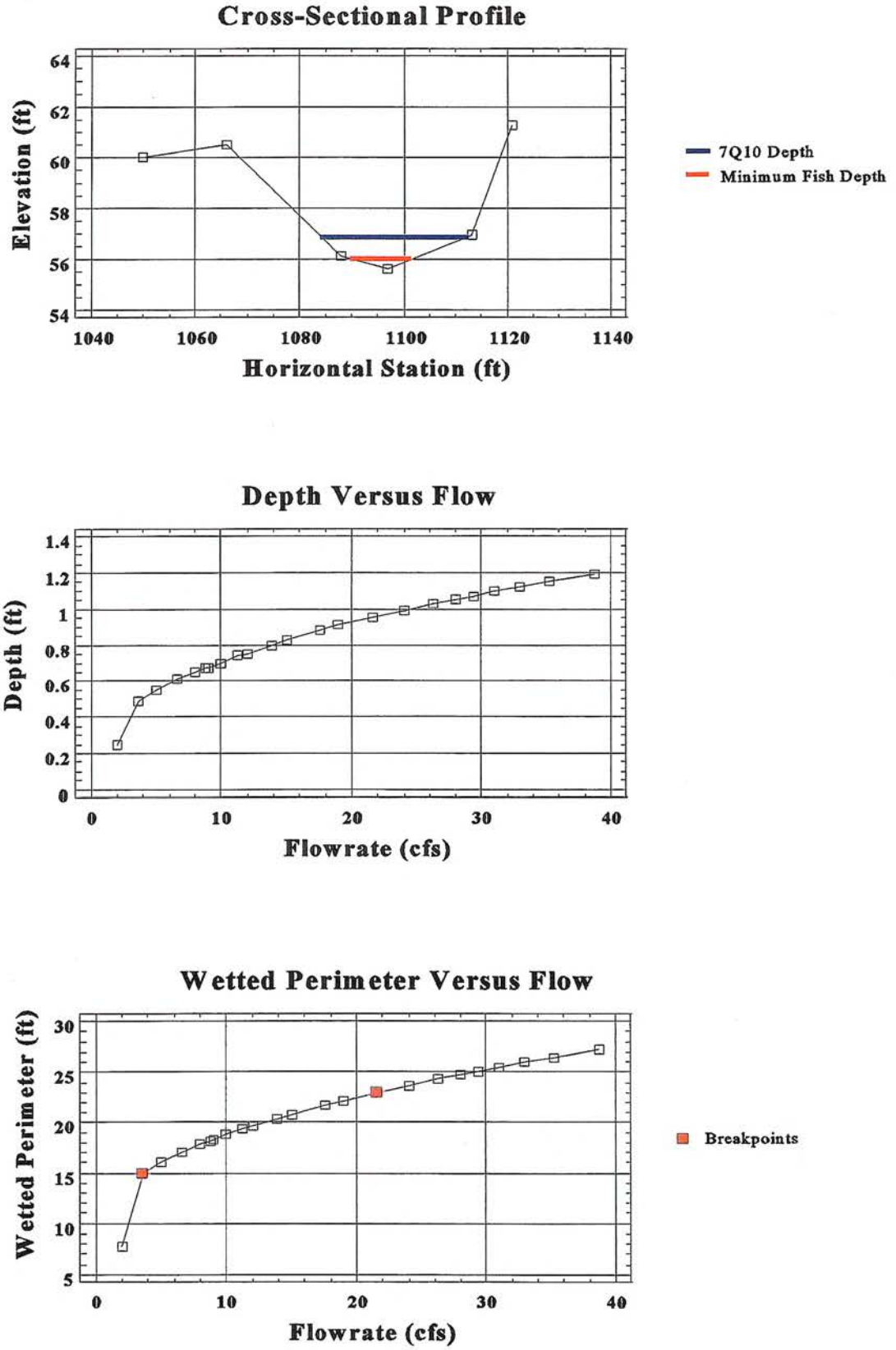


FIGURE 13. Hydraulic Characteristics for the White Clay Creek Newark at Section 53115

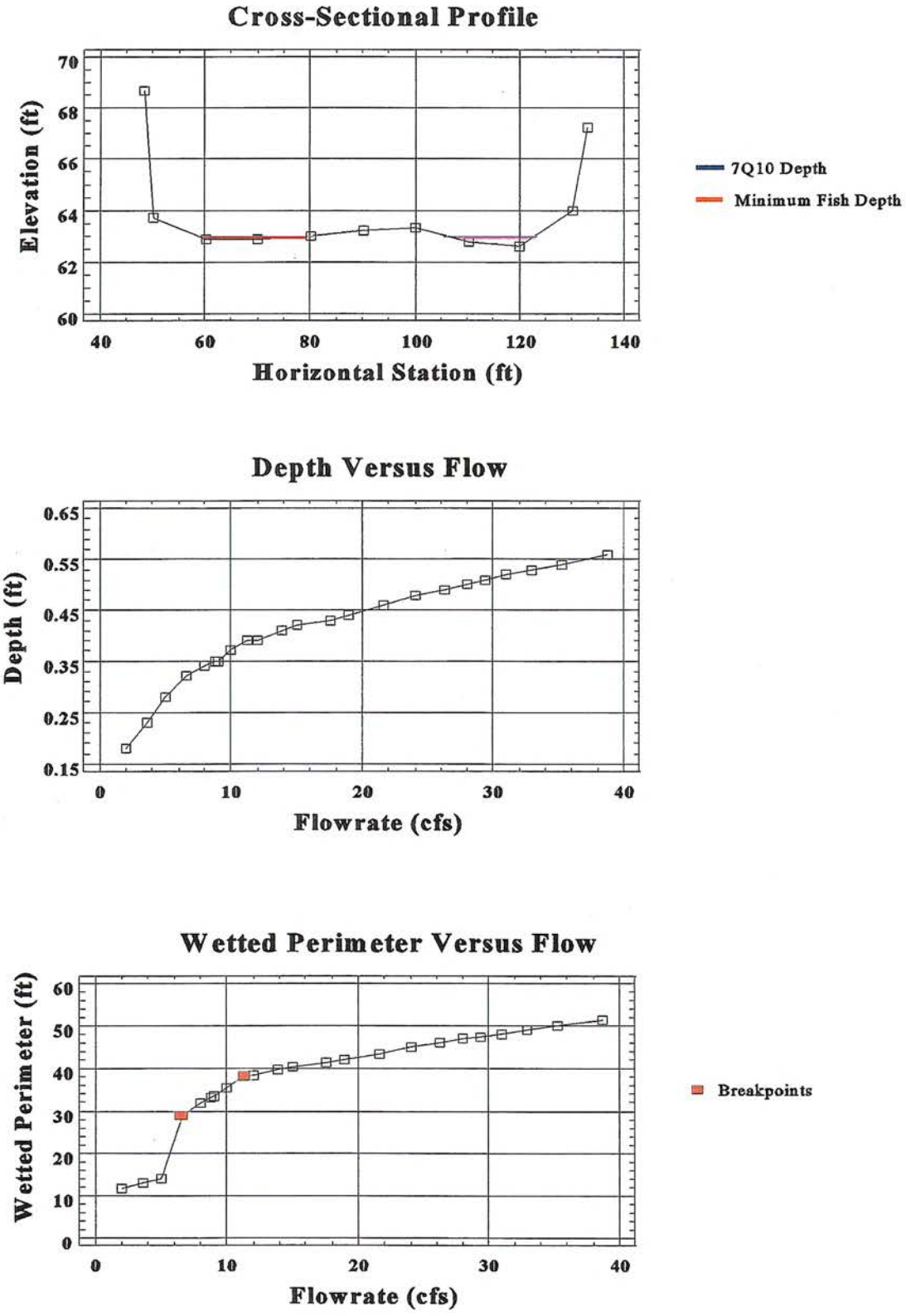


FIGURE 14. Hydraulic Characteristics for the White Clay Creek Newark at Section 55713

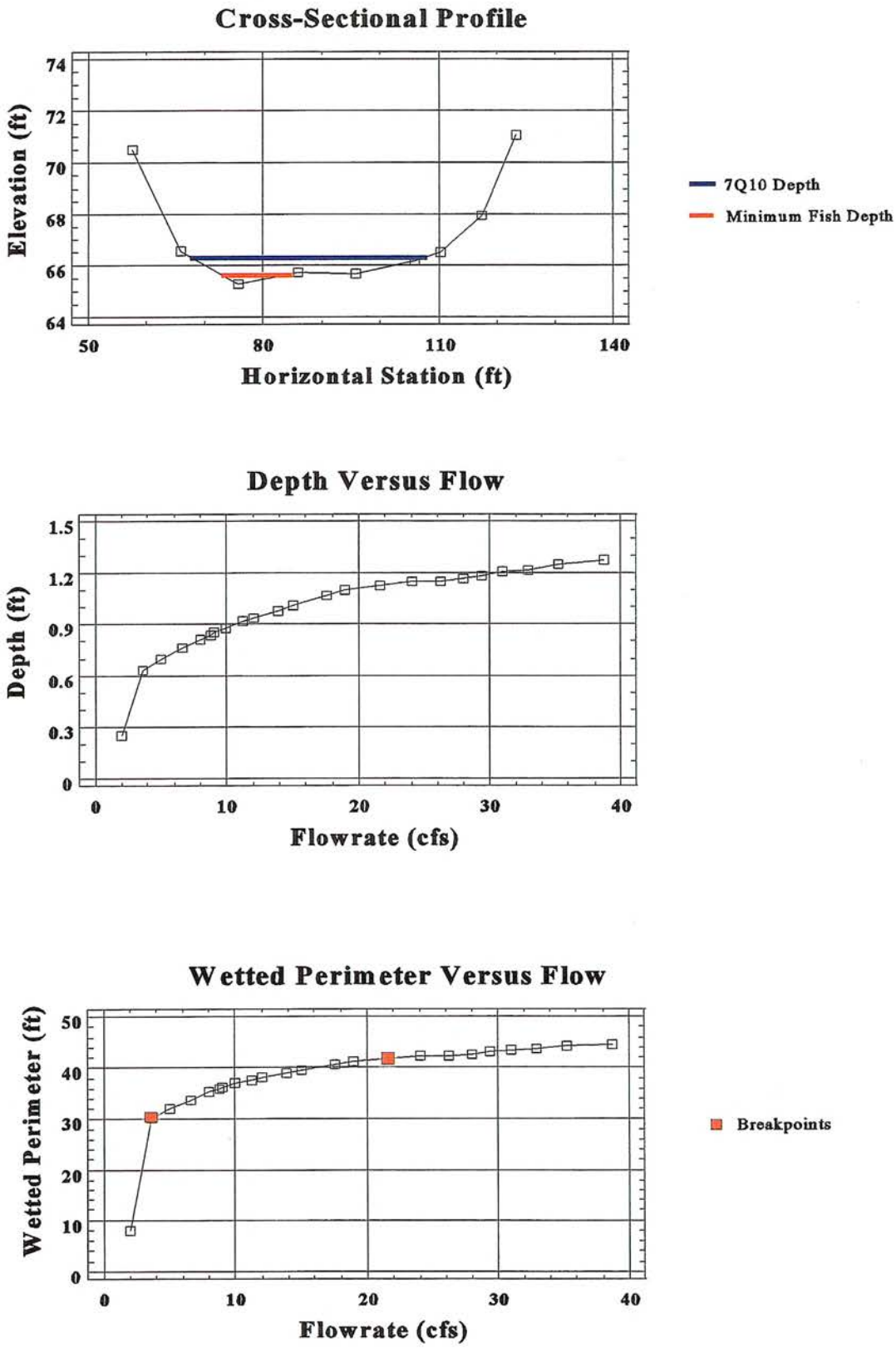


FIGURE 15. Hydraulic Characteristics for the White Clay Creek Newark at Section 57970

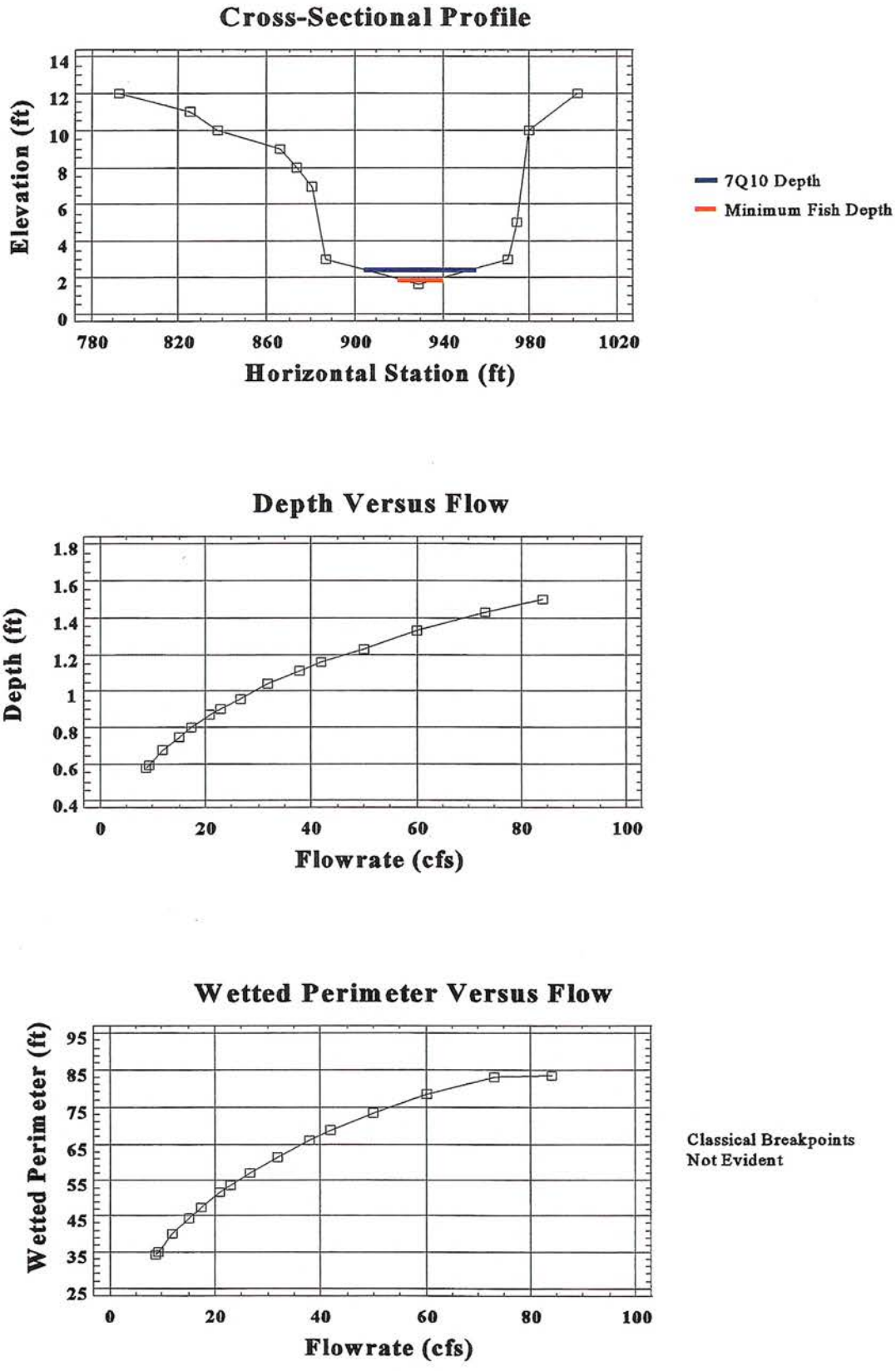


FIGURE 16. Hydraulic Characteristics for the White Clay Creek Stanton at Section 13843

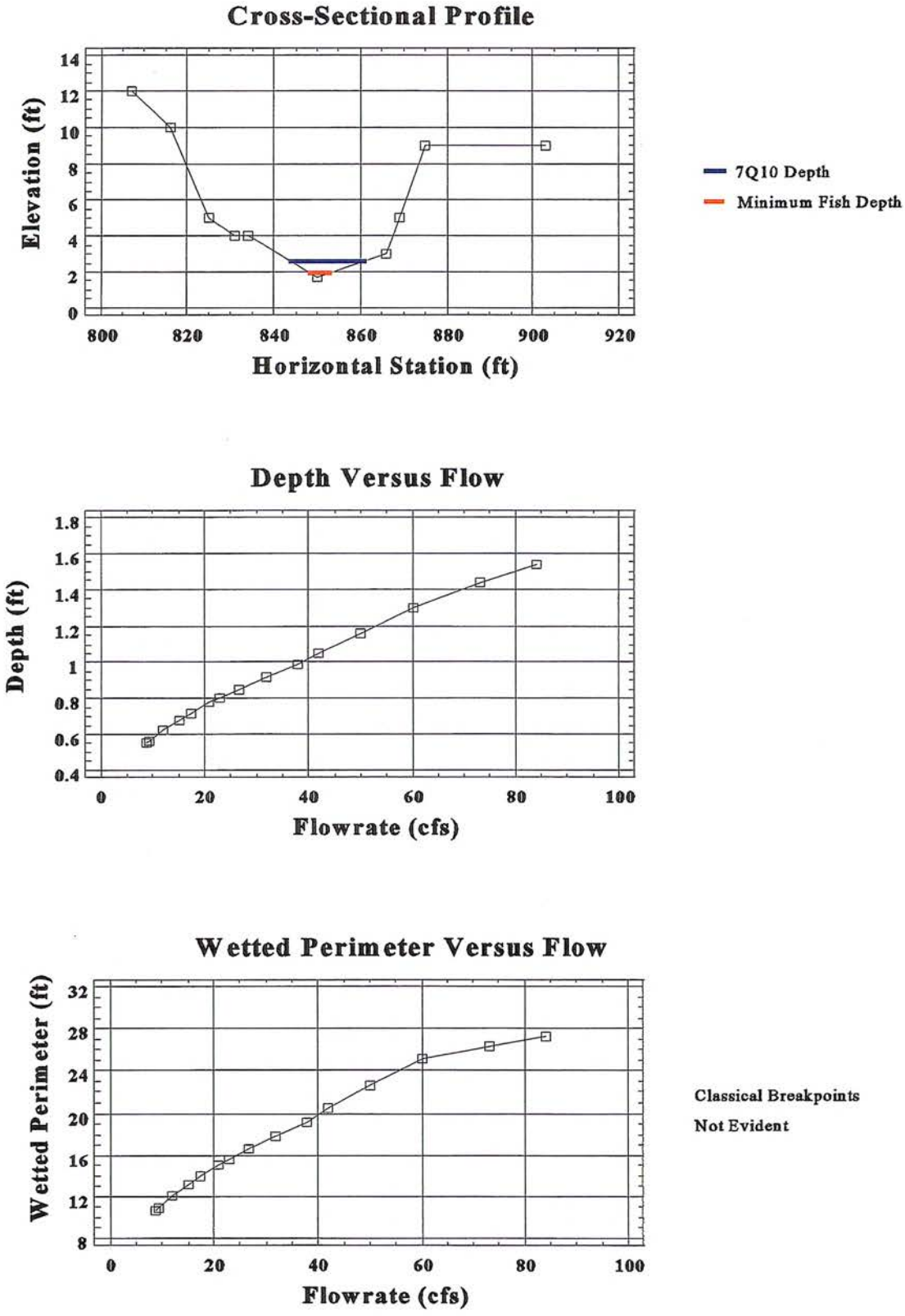


FIGURE 17. Hydraulic Characteristics for the White Clay Creek Stanton at Section 14073

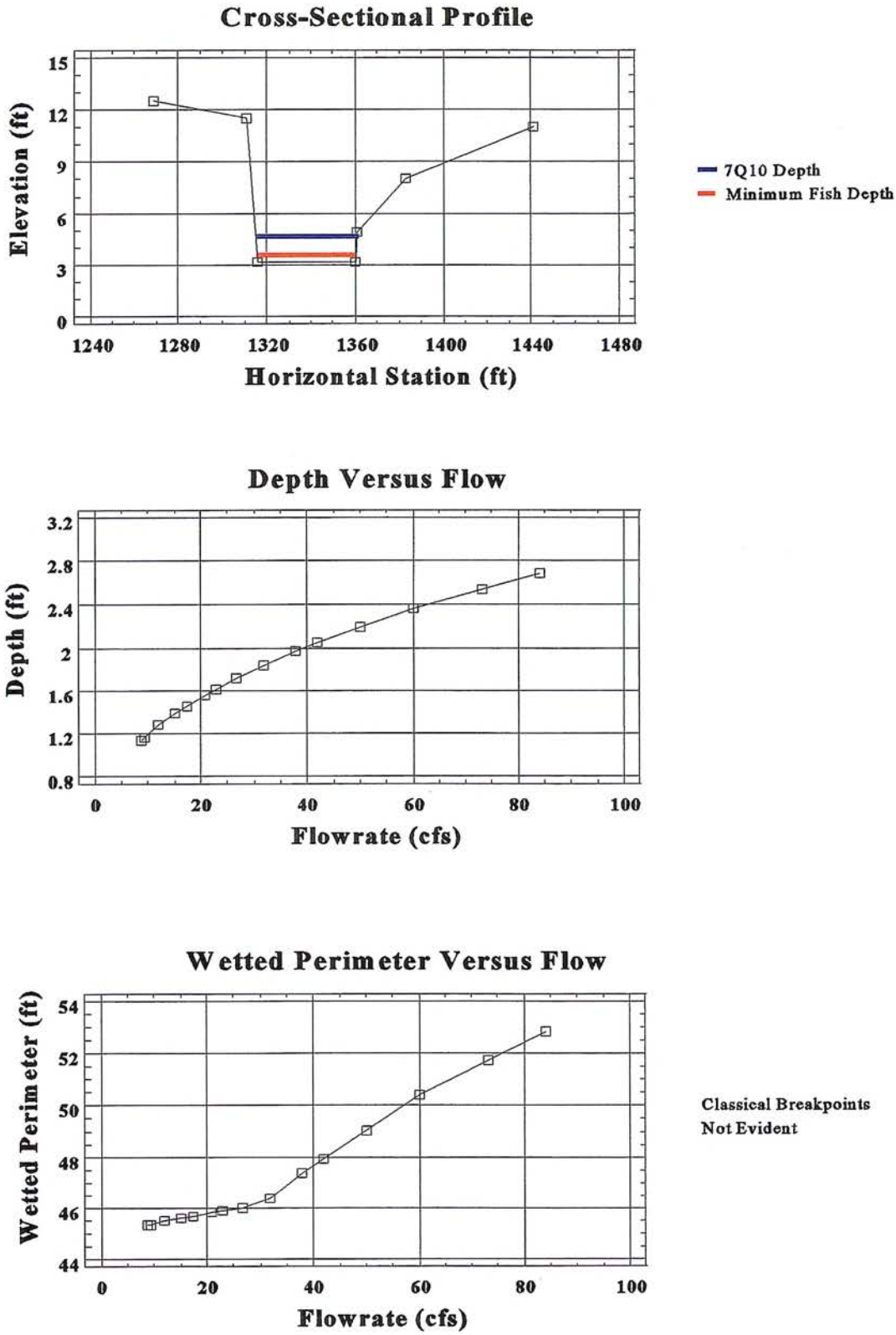


FIGURE 18. Hydraulic Characteristics for the White Clay Creek Stanton at Section 16180

- 14073
- 16280

- Christina River at Smalley's Pond
  - Not appropriate for wetted perimeter analysis

2. With the HEC-2 water surface profile model, compute discharge, velocity, and wetted perimeter values for a range of flow scenarios, including-.

   - 1948 drought
   - 1995 drought
   - 7Q50
   - 7Q20
   - 7Q10
   - 7Q5
   - 20% of mean annual flow
   - 7Q10 plus withdrawal
   - 40% of mean annual flow

3. Plot elevation versus horizontal station to delineate the stream cross section of each riffle area (Figures 10 through 18).

4. Plot the wetted perimeter versus discharge curve for each riffle section. Identify the visible lower and upper wetted perimeter "breakpoint" on the graph. Select the discharge associated with the lower and upper perimeter "breakpoint". Figures 10 through 18 provide the wetted perimeter discharge curve.

5. Plot depth and velocity versus discharge for each riffle section (Figures 10 through 18). Determine the flow depth and velocity associated with the lower and upper wetted perimeter "breakpoint" discharge.

6. Compare "breakpoint" discharge, velocity, and depth to 7Q10 and the minimum fish habitat criteria. Summarize the results in a table for comparison.

2.4 WATER QUALITY ANALYSES

Introduction

Surface water intake samples are routinely collected by the City of Newark, United Water Delaware, and the City of Wilmington in order to characterize the quality of their respective source

waters prior to treatment and distribution. Parameters measured typically include dissolved oxygen, pH, temperature, chlorides, conductivity, alkalinity, hardness, and bacteria. Depending on the parameter and the facility, the frequency of collection varies from daily, weekly, monthly to occasional.

Water quality data collected by the purveyors during the period July 1, 1995 through October 31, 1995 were provided to the Task Force for detailed evaluation. These data represent the quality of the raw water after withdrawal from the study reaches and just prior to treatment.

Methodology

1. Water quality data were first merged with USGS streamflow data. The merged data appear in their entirety in Appendix C of this report.

2. The water quality data were then plotted against time and streamflow to provide a visual picture of temporal trends and flow dependence. Any violations of applicable Delaware water quality criteria were noted.

3. Next, statistical analyses were performed on the data. Analyses included the preparation of summary statistics (e.g., number of measurements, average, median, minimum, maximum, etc.), correlation matrices, covariance matrices, and regression modelling for selected parameters. Special attention was given to the evaluation of any apparent relationships between water quality and streamflow.

4. Finally, the results were summarized.

2.5 WATER SUPPLY AND PERMIT APPLICATION REVIEW

A review of the docket decisions of the Delaware River Basin Commission and the Public Water Supply allocations granted by the Delaware Department of Natural Resources and Environmental Control regarding withdrawals in the Christina River Basin comprised of the Red and White Clay and Brandywine Watersheds in Northern New Castle County indicated inconsistencies in the various authorizations and supports the development of a water resources management plan for the to resolve these issues. Members of the Study Coordinating Group of the Joint Task Force have met with the permitees to discuss the details of the review and the recommendations included in this report.

MBNA golf course irrigation - DRBC Docket No. D-77-25 dated April 27, 1977 was transferred from the previous holder, duPont Co., when MBNA purchased the Louviers Building and the accompanying golf course. The docket provides for withdrawal of 225,000 gpd except when the White Clay flow falls below 7Q10 at USGS Gage 0 1 478500 when no water shall be withdrawn. That gage no longer exists and the docket should be changed to reflect correlation with the new USGS Gage 01478650 near the City of Newark filtration plant. The 7Q10 flow at the new gage has been established as II. 07 cfs (7.1 5 mgd) by extrapolation from the discontinued gage which had 23 years of record and an established 7Q10 of 10.97 cfs (6.92 mgd). Additionally, the DRBC docket should be revised and a DNREC allocation permit issued to incorporate the public water supply needs of both Newark and United Water Delaware downstream with the passby requirement increased accordingly. A recommendation for the construction of surface storage at the golf course for irrigation purposes should be included in the operating plan.

MBNA Recommendations: Both the DRBC docket and the DNREC permit need to be revised to incorporate the new USGS gage near the Newark filtration plant for calculation of the 7Q10 flow of 11.07 cfs (7.15 mgd) as extrapolated from the discontinued gage above Newark. The passby requirement in the dockets and permits should be increased to include provision for the public water supply requirements of Newark and United Water Delaware and surface water storage constructed on the MBNA golf course to provide supplemental irrigation.

City of Newark - The passby flow requirement established by the DRBC in the Newark Docket No. D-90-1 10 CP (S) dated May 22, 1991 sets the precedent for accommodating downstream public water supply withdrawals resulting in the prior recommendation to increase the MBNA passby. Newark's passby requirement, however, was based on a 16 mgd withdrawal by United Water Delaware (formerly Wilmington Suburban Water Corp.) and does not reflect the increased withdrawal to 30 mgd by United Water Delaware at the Stanton plant. Because the Newark application was approved (1991) before the United Water Delaware 1993 application, a case can be made for retaining the City's passby flow requirement at its current level of 14.0 mgd.

If the Newark docket is adjusted to accommodate the higher United Water Delaware withdrawal, the passby requirement would have to be increased to 19.92 mgd (7Q10 flow of 7.27 mgd plus a prorated flow of 12.65 mgd to meet United Water Delaware's downstream demands). On the other hand, such a requirement is already in place as determined by the Public Water Allocation Permit issued by the Department of Natural Resources and Environmental Control (88-018-A dated Dec. 20, 1990) Under the conditions set forth by DNREC, the 5.0 mgd withdrawal by Newark is regularly permitted whenever the simultaneous flow of the White and Red Clay Creeks is 30 mgd or greater. If the flow is less, withdrawal is permitted with the consent of Wilmington Suburban Water Corp. (now United Water Delaware). Upon the first sustained flow of 31.3 mgd for 24 hours after the last withdrawal curtailment, withdrawal by Newark may be increased in 1.0 mgd increments. However, when the flow is less than 31.3 mgd, withdrawal may be **increased** in 1.0 mgd increments. The Joint Task Force questioned the validity of this language which was drawn from the DNREC permit and needs to be reconciled. The inconsistency which exists between the DRBC docket and the DNREC permit also needs to be addressed.

The physical features for the Newark system described in the DRBC docket note the existence of interconnections with Artesian Water Co. and United Water Delaware providing a supplemental capability of 2.45 mgd and 4.8 mgd from the City's 14 wells. Both the Laird Tract and South well fields, however, have reported iron and manganese problems affecting water quality. Additionally, DRBC docket decision (D-90-110 CP) (G) cites a direct connection between the two newest wells (Ca45-98 and Cb4l-14) identified as wells 20 and 21 in DNREC Permit #88-0018-D approved on December 20, 1990 and the White Clay Creek influencing the reliability of any withdrawal. This

conclusion has been brought into question and the City of Newark has retained a consultant to review any degree of interconnection between each of the wells and the creek.

The City of Newark has shown a projected average water demand of 4.5 mgd and a peak of 6.3 mgd for 1995, and an average water demand of 3.91 mgd (with water conservation measures implemented) projected for the year 2040. Updated data reveals a 1995 average demand of 3.86 mgd with a peak of 5.9 mgd. The four-year average for the average daily demand is 3.83 mgd. This would substantiate an average water allocation of 5.0 mgd **from the** City's **combined** sources to ensure meeting the needs of its current water distribution system as well as providing flexibility for its future water supply system. It is important to note DRBC staff estimated the 1995 projected demand figure of 4.5 mgd could only be met 86 percent of the time with the 14 mgd passby requirement in place and the City of Newark should consider the surface water supply from White Clay Creek unreliable until supplemental storage can be provided. In granting the City of Newark temporary approval to withdraw 5.0 mgd from the White Clay Creek for public water supply purposes, the Commission required "the proposed project intake, and all existing wells and surface water intakes shall be metered with an automatic continuous recording device that measures to within 5 percent of actual flow."

Visual inspection of the intake indicates such a continuous recording device has not been installed as required by the Commission and the diversion from the "White Clay Creek to the Newark filtration plant is not controlled by a gated structure. Lacking such control, it is likely more water is being diverted from the stream than is required for public water supply purposes effectively reducing the flow available for the protection of instream uses below the point of diversion. The Public Water Allocation Permit issued DNREC also requires metering of the intake.

An operational inspection conducted by Stewart Lovell of DNREC with representatives of the City of Newark and Curtis Paper Co. and the study consultant in October disclosed the installation of a high technology meter in the filtration plant which records intake from the ponds supplied by the White Clay Creek. Although not calibrated at the time of the inspection, the meter location is protected from the elements and vandalism which could be experienced at the point of diversion at Newark's upstream dam where the raceway begins. Joseph Dombrowski, director of Newark's Water and Wastewater Department, also detailed the controls which could be utilized to prevent excess flows from being

diverted from the White Clay Creek during drought conditions through installation of membranes at the three overflow points associated with the ponds. According to Dombrowski, the system is in equilibrium except when pumpage occurs for public water supply by Newark or industrial use by Curtis Paper Co. Dombrowski advocated the membrane system in lieu of a more expensive gated structure at the head of the raceway. He later covered these points during a formal presentation to the Joint Task Force at the October 24 meeting.

City of Newark Recommendations: The installation of the required meter within the filtration plant is an acceptable alternative to the original requirement which would have placed the meter in an exposed location at the head of the raceway at the actual point of diversion from the "White Clay Creek. Because the system remains in equilibrium except when pumpage occurs, the filtration plant meter meets the intent of both the DNREC permit and the DRBC docket for the Newark system withdrawal. In lieu of the Task Force-recommended gated structure at the head of the raceway, excess flows during drought conditions shall be controlled through the placement of membranes at the three overflow points in the ponds system serving the Newark filtration plant and Curtis Paper Co. This alternative is considered an interim measure and will be replaced with a permanent gated structure at the head of the raceway if the membrane system fails to meet the requirements of the Department of Natural Resources and Environmental Control. The DRBC docket for the two new wells (Ca45-98) and Cb41-14) (DNREC Permit #88-0018-D) in the Laird Tract should be revised based on findings of the City of Newark's consultant to permit reliable withdrawal from this source. The City of Newark should direct ground water from these wells to the filtration plant to provide for removal of any iron and manganese found present in the new source.

The City should also explore the expanded operation of the South well field to regain full allocated capacity, particularly if upstream storage is not available.. The inconsistency between the DRBC docket and DNREC permit regarding surface water withdrawal needs to be reconciled with the docket adjusted to reflect a passby requirement of 19.92 mgd (7Q10 flow of 7.27 mgd plus 12.65 mgd reflecting United Water Delaware's demands at the Stanton intake. Also, the following constraint in DNREC Public Water Allocation Permit #88-0018-A Section 4.B should be deleted, "Further, upon first sustained flow of 31.3 mgd for 24 hours after the last withdrawal curtailment, withdrawal by Newark may be increased in 1.0 mgd increments. However, when the flow is less than 31.3 mgd,

withdrawal may be increased in 1.0 mgd increments. These recommendations are consistent with condition 13 of the DNREC permit issued December 20, 1990, which states, "This approval is contingent on practice of the permit holder to employ to the greatest practicable extent conjunctive use of its available ground and surface water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment."

United Water Delaware - The former Wilmington Suburban Water Co. held a DNREC Public Water Supply Allocation Permit (90-0013 dated July 16, 1993) to withdraw 30 mgd at the Stanton intakes at the confluence of the Red and White Clay creeks which was subsequently conveyed to United Water Delaware. A temporary allocation (Docket No. D-91-72-CP dated Aug. 4, 1993) for the same amount has been issued by the Delaware River Basin Commission which established a passby requirement of 17.2 mgd representing 7Q10. The Commission, however, cautioned the applicant the source should be considered unreliable because of inadequacy of flow to meet the withdrawal 100 percent of the time **until storage or a supplemental source can be provided.** Through the construction of an inflatable flow retarding structure to capture tidal flow, United Water Delaware is developing a supplemental source expected to be operational 1997. In the interim, the purveyor utilizes Hoopes Reservoir releases from Wilmington for make-up water during periods of low flow to maintain the passby requirement. Withdrawal was permitted for a limited period when the 17.2 passby requirement could not be met during the 1995 drought when mandatory restrictions were in place. Studies initiated by the Joint Task Force have concluded the passby requirement should continue in place for waste load allocation purposes and salinity control as determined by the Department of Natural Resources and Environmental Control.

United Water Delaware Recommendations: Temporary suspension of the the passby requirement at Stanton and other intakes along the White Clay Creek during **declared drought emergency** should be considered by the Christina River Basin Drought Management Committee as a revision to the Christina River Basin Drought Management Plan along with a water budget analysis supporting this approach. Flow conditions for such suspension should be clarified in the Plan and submitted as revisions for adoption by Delaware Department of Natural Resources and Environmental Control, the Pennsylvania Department of Environmental Protection and final approval by the Delaware River Basin

Commission. The current passby requirement imposed by Delaware River Basin Commission should be maintained for waste load allocation purposes, aquatic habitat protection and salinity control unless modified during **declared drought emergency.** Although the tidal control structure being developed by United Water Delaware at Stanton represents a supplemental source of water, the purveyor is still reliant on releases from Hoopes Reservoir by the City of Wilmington for supply during critical flow periods. To reduce this dependency, an additional source of supply needs to be developed in Northern New Castle County.

City of Wilmington - The City of Wilmington under a Certificate of Entitlement from the Delaware River Basin Commission withdraws water from the Brandywine Creek for public supply through a mile-long diversion raceway. Water not withdrawn from the raceway flows back into the Brandywine over a tailgate dam at the tail of the raceway. An additional withdrawal point is located upstream of the dam (the Wills Pump Station).

The City of Wilmington also has supplemental supply available from the Hoopes Reservoir pumped storage facility. Stream flow in the Red Clay Creek can be augmented by releases from Hoopes during low flow conditions. These releases serve as additional raw water supply for United Water Delaware, enabling it to meet the 7Q]O passby requirement imposed by the Delaware River Basin Commission to United Water Delaware's intake on the White Clay Creek. Finished water interconnections are also in place between the City's distribution system and those of United Water Delaware and Artesian Water Co. These interconnections are a potential source of supplemental supply during drought conditions. This potential source of water could also supply the City of Newark through purchase from either United Water Delaware or Artesian Water Co. when drought conditions warrant.

The Certificate of Entitlement for the City of Wilmington issued by the Delaware River Basin Commission does not mandate a passby requirement, but discussion between the Study Coordinating Group and the City indicates any future 7Q 10 passby requirement would render the system incapable of providing supplemental water through the interconnections to enable Newark and United Water Delaware to meet the 7Q 10 passby requirement on the White Clay Creek. The 7Q10 flow of the Brandywine at the Wilmington intake is 49.3 mgd (76.3 cfs) while current system demand is 39 mgd

average daily usage, which includes the 10 mgd raw water interconnection with United Water Delaware. During periods of critical low flow, augmentation from Hoopes Reservoir would be required to meet any 7Q10 passby mandate at the Wilmington intake with little or no excess available for exportation to the other purveyors.

The wetted perimeter analysis conducted as part of the Phase 11 instream flow needs analysis disclosed stream cross sections in the Brandywine study reach below the Wilmington intake meet depth and flow velocity criteria for the target fish species under 7Q10 flow conditions. The results of the wetted perimeter analysis conducted for the three stream cross sections identified within the Brandywine study research also established the fish habitat criteria for depth and velocity was met or exceeded for both the upper and lower breakpoints. Based on this data, the Study Coordinating Group agreed the requirements of the lower wetted perimeter breakpoint (60 cfs or 3 8.8 mgd) could be substituted for the 7Q10 flow (76.3 cfs or 49.3 mgd) at the City of Wilmington's diversion raceway intake as a passby requirement during a **declared drought emergency** to permit continuing releases from Hoopes Reservoir to service the interconnection system with other purveyors until such time as a new source of supply is developed for Northern New Castle County. Additionally, the diversion into the raceway to supply the Brandywine pump station should be adjusted to meet minimum flow standards and steps taken to establish and calibrate a staff gage at the diversion gate to provide flow control to meet these criteria. The diversion from the Brandywine to the Porter treatment facility should also be limited during a declared drought emergency to insure the passby flow requirement is met. The City of Wilmington has advised the Joint Task Force that the historic mile-long raceway is subject to leakage of an estimated 7 cfs (5 mgd) and will undertake a study to address this issue.

City of Wilmington Recommendations: The imposition of a 7Q10 passby flow requirement of 76.3 cfs at the City of Wilmington's raceway diversion will protect instream uses within the study reach identified by the Joint Task Force. However, exportation of water via service interconnections is required to assist other purveyors in the White Clay Creek Watershed in meeting a similar requirement at their intakes during critical low flow periods renders it impossible for the City to observe the 7Q10 passby requirement during such a low flow regime. The wetted perimeter analysis of the Brandywine study reach concluded temporary relief may be available during a **declared drought emergency** pending development of a new source of supply for Northern New Castle County.

Due to the complexity of this issue, the Joint Task Force has recommended development of an operating plan for the Christina River Basin in Northern New Castle County to address these matters.. The Study Coordinating Group will undertake this task in conjunction with the City of Wilmington and the Water Resources Agency for New Castle County in the immediate future and will issue the operating plan as an appendix to the Instream Flow Needs Study, Phase Two.

2.6 PUBLIC PARTICIPATION

During the development of Phase 11, Instream Flow Needs Study, two public briefings were held at the Blue and Gold Club, University of Delaware, for the benefit of interested citizens. Each was held in the afternoon following the morning Joint Task Force meeting and provided an opportunity for interchange between Task Force members and the public. The initial session was held on July 24, 1996, where copies of the Scope of Study were distributed for review and comment. A final briefing as conducted on December 17, 1996, where contents of the final draft report were made available. A detailed discussion of the report's conclusions and recommendations was conducted with members of the public actively participating.

SCHEDULE OF ACTIVITIES

April 26, 1996	- Initial meeting of Joint Task Force regarding Phase 11 Study
May 22, 1996	- Joint Task Force Meeting
July 24, 1996	- Joint Task Force Meeting - Public Briefing
October 24, 1996	- Joint Task Force Meeting
December 17, 1996	- Final Joint Task Force Meeting - Public Briefing
January 10, 1997	- Deadline for final review and comment on Phase 11 report

In addition, the Study Coordinating Group met in while or in part on 15 occasions during the study period to review evolving work products and assemble the final report.

3A. RESULTS (Wetted Perimeter)

Table 2 summarizes the results of the wetted perimeter analysis. The following decision matrix is used to determine the adequacy of the 7Q10 as a flow standard based on the wetted perimeter analysis:

Scenario	Decision
7Q10 discharge, depth and velocity exceeds upper WP "breakpoint" and the minimum target fish species criteria	7Q10 is the minimum flow standard based on DNREC Water Quality Standards
7Q10 discharge, depth and velocity is between upper and lower WP "breakpoint".	Minimum flow standard could range between 7Q10 and the upper WP "breakpoint".
7Q10 less than lower WP "breakpoint"	The lower WP "breakpoint" is the minimum flow standard

3A1. Brandywine Creek at Wilmington: The result of the wetted perimeter analysis indicate the depth and velocity of the 7Q10 lower WP and upper WP discharge all exceed suitable target fish species habitat criteria for all three riffle sections. The 7Q10 depth and velocity also exceeds the upper WP "breakpoint" depth and velocity. Therefore, the 7Q10 is suitable as a minimum flow standard along the Brandywine Creek. Table 3 presents stream riffle data for the critical sections in this study reach.

3A2. White Clay Creek at Newark: The results of the WP analysis indicate the depth and velocity of the 7Q10, lower WP and upper WP discharge exceed the minimum target fish species criteria at cross sections 53115 and 55713. The upper WP velocity at cross section 57970 does not exceed the minimum velocity for the fish criteria. Section 57970 is not a classic riffle section and was therefore deleted from consideration. The consensus of the Joint Task Force is the 7Q10 is suitable as a minimum flow standard since its depth and velocity exceeds the lower WP "breakpoint" and the suitable target fish species habitat criteria in all three riffle sections. Table 4 presents stream riffle data for the critical sections in this study reach.

Table 2 Instream flow needs analysis (Phase II) wetted perimeter results and fish habitat criteria for comparison to the 7Q10 levels, and the upper and lower wetted perimeter breakpoints.

Stream and Section	Discharge (m3/s)			Flow Depth (m)					Velocity (cm/s)					7Q10 suitable for fish?		Suitable Depth for fish?		Suitable Velocity for fish?	
	7Q10	Upper WP	Lower WP	7Q10	Upper WP	Lower WP	Avg. Fish Criteria	Range of Fish criteria	7Q10	Upper WP	Lower WP	Avg. Fish Criteria	Range of Fish criteria	Depth	Velocity	Upper WP Depth	Lower WP Depth	Upper WP Velocity	Lower WP Velocity
Brandywine Creek at Wilmington																			
2.55	2.2	1.7	0.5	0.3	0.3	0.2	0.1	0.03-1.03	121.6	114.6	86.6	36.6	17.1-182.0	Y	Y	Y	Y	Y	Y
2.65	2.2	1.7	1.7	0.4	0.3	0.3	0.1	0.03-1.03	43.0	39.0	39.0	36.6	17.1-182.0	Y	Y	Y	Y	Y	Y
2.94	2.2	1.7	0.9	0.3	0.2	0.2	0.1	0.03-1.03	41.1	126.8	108.8	36.6	17.1-182.0	Y	Y	Y	Y	Y	Y
White Clay Creek at Newark																			
53115	0.3	0.6	0.2	0.2	0.3	0.2	0.1	0.03-1.03	43.3	53.0	36.3	36.6	17.1-182.0	Y	Y	Y	Y	Y	N
55713	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.03-1.03	63.1	63.1	60.4	36.6	17.1-182.0	Y	Y	Y	Y	Y	Y
57970	0.3	0.6	0.3	0.3	0.3	0.3	0.1	0.03-1.03	18.6	24.4	17.1	36.6	17.1-182.0	Y	N	Y	Y	N	N

TABLE 3
BRANDYWINE CREEK AT WILMINGTON
STREAM RIFFLE DATA
INSTREAM FLOW NEEDS ANALYSIS, PHASE II
June, 1996
Revised December, 1996

Section	Scenario	Discharge (cfs)	Discharge (mgd)	Min. Channel Elevation (ft)	Water Surface Elevation (ft)	Depth (ft)	Velocity (fps)	Wetted Perimeter (ft)
2.55		5.00	3.2	7.34	7.74	0.40	2.26	14.69
		9.00	5.8	7.34	7.82	0.48	2.52	19.10
		17.00	11.0	7.34	7.93	0.59	2.84	25.09
		24.00	15.5	7.34	8.00	0.66	3.03	29.00
	1948 Drought	30.00	19.4	7.34	8.05	0.71	3.17	31.64
		39.00	25.2	7.34	8.13	0.79	3.30	34.94
	1995 Drought	46.10	29.8	7.34	8.17	0.83	3.40	36.21
		51.00	33.0	7.34	8.19	0.85	3.57	36.55
	7Q50	58.50	37.8	7.34	8.23	0.89	3.76	37.16
		60.30	39.0	7.34	8.24	0.90	3.79	37.32
	7Q20	67.25	43.5	7.34	8.27	0.93	3.89	37.96
		71.00	45.9	7.34	8.29	0.95	3.93	38.30
	7Q10	76.28	49.3	7.34	8.32	0.98	3.99	38.77
		83.00	53.7	7.34	8.35	1.01	4.13	39.21
		88.00	56.9	7.34	8.37	1.03	4.20	39.58
	20% of MAF	92.20	59.6	7.34	8.39	1.05	4.26	39.89
		100.00	64.7	7.34	8.42	1.08	4.35	40.47
	7Q2	115.00	74.4	7.34	8.48	1.14	4.50	41.55
	7Q10 plus Withdrawal	139.78	93.3	7.34	8.57	1.23	4.76	43.12
	40% of MAF	184.40	119.2	7.34	8.74	1.40	4.98	46.09
2.65		5.00	3.2	12.6	13.10	0.50	0.95	21.16
		9.00	5.8	12.6	13.23	0.63	1.01	34.09
		17.00	11.0	12.6	13.38	0.78	1.13	48.88
		24.00	15.5	12.6	13.49	0.89	1.10	76.58
	1948 Drought	30.00	19.4	12.6	13.56	0.96	1.09	98.48
		39.00	25.2	12.6	13.63	1.03	1.13	118.48
	1995 Drought	46.10	29.8	12.6	13.65	1.05	1.20	123.47
		51.00	33.0	12.6	13.67	1.07	1.22	127.23
	7Q50	58.50	37.8	12.6	13.71	1.11	1.27	131.95
		60.30	39.0	12.6	13.72	1.12	1.28	132.15
	7Q20	67.25	43.5	12.6	13.74	1.14	1.34	132.88
		71.00	45.9	12.6	13.76	1.16	1.37	133.26
	7Q10	76.28	49.3	12.6	13.77	1.17	1.41	133.78
		83.00	53.7	12.6	13.80	1.20	1.45	134.50
		88.00	56.9	12.6	13.81	1.21	1.49	134.98
	20% of MAF	92.20	59.6	12.6	13.83	1.23	1.51	135.38
		100.00	64.7	12.6	13.85	1.25	1.56	136.09
	7Q2	115.00	74.4	12.6	13.89	1.29	1.64	137.40
	7Q10 plus Withdrawal	139.78	93.3	12.6	13.95	1.35	1.76	139.47
	40% of MAF	184.40	119.2	12.6	14.06	1.46	1.97	142.59
2.94		5.00	3.2	13.20	13.43	0.23	2.25	14.36
		9.00	5.8	13.20	13.50	0.30	2.64	16.01
		17.00	11.0	13.20	13.62	0.42	3.11	18.54
		24.00	15.5	13.20	13.71	0.51	3.37	20.33
	1948 Drought	30.00	19.4	13.20	13.77	0.57	3.57	21.63
		39.00	25.2	13.20	13.85	0.65	3.79	23.40
	1995 Drought	46.10	29.8	13.20	13.91	0.71	3.94	24.63
		51.00	33.0	13.20	13.95	0.75	4.02	25.48
	7Q50	58.50	37.8	13.20	14.00	0.80	4.16	26.58
		60.30	39.0	13.20	14.02	0.82	4.19	26.85
	7Q20	67.25	43.5	13.20	14.06	0.86	4.30	27.83
		71.00	45.9	13.20	14.09	0.89	4.35	28.34
	7Q10	76.28	49.3	13.20	14.09	0.89	4.35	29.03
		83.00	53.7	13.20	14.16	0.96	4.48	29.92
		88.00	56.9	13.20	14.19	0.99	4.55	30.50
	20% of MAF	92.20	59.6	13.20	14.21	1.01	4.60	30.97
		100.00	64.7	13.20	14.25	1.05	4.69	31.85
	7Q2	115.00	74.4	13.20	14.33	1.13	4.80	33.54
	7Q10 plus Withdrawal	139.78	93.3	13.20	14.45	1.25	5.00	35.99
	40% of MAF	184.40	119.2	13.20	14.62	1.42	5.34	39.67

MAF = Mean Annual Flow

Rifldata.wk4

TABLE 4
WHITE CLAY CREEK AT NEWARK
STREAM RIFFLE DATA
INSTREAM FLOW NEEDS ANALYSIS, PHASE II
June, 1996
Revised August, 1996

Section	Scenario	Discharge (cfs)	Discharge (mgd)	Min. Channel Elevation (ft)	Water Surface Elevation (ft)	Depth (ft)	Velocity (fps)	Wetted Perimeter (ft)
53115	1995 Drought	2.00	1.3	55.60	55.85	0.25	2.05	7.69
	1966 Drought	3.60	2.3	55.60	56.09	0.49	0.98	14.95
		5.00	3.2	55.60	56.15	0.55	1.09	16.03
	7Q50	6.60	4.3	55.60	56.21	0.61	1.19	17.04
		8.00	5.2	55.60	56.25	0.65	1.27	17.79
	10% of MAF	8.80	5.7	55.60	56.27	0.67	1.31	18.18
	7Q20	9.00	5.8	55.60	56.27	0.67	1.32	18.28
		10.00	6.5	55.60	56.30	0.70	1.36	18.77
	7Q10	11.30	7.3	55.60	56.34	0.74	1.42	19.35
		12.00	7.8	55.60	56.35	0.75	1.44	19.66
		13.90	9.0	55.60	56.40	0.80	1.52	20.39
		15.00	9.7	55.60	56.43	0.83	1.56	20.79
	20% of MAF	17.60	11.4	55.60	56.48	0.88	1.63	21.72
		19.00	12.3	55.60	56.51	0.91	1.67	22.18
	DRBC Passby	21.60	14.0	55.60	56.55	0.95	1.74	22.98
		24.00	15.5	55.60	56.59	0.99	1.80	23.66
	Passby plus Max. Withdrawal	26.30	17.0	55.60	56.63	1.03	1.85	24.30
		28.00	18.1	55.60	56.65	1.05	1.89	24.75
		29.40	19.0	55.60	56.67	1.07	1.91	25.11
		31.00	20.0	55.60	56.70	1.10	1.95	25.49
		33.00	21.3	55.60	56.72	1.12	1.98	25.97
	40% of MAF	35.30	22.8	55.60	56.75	1.15	2.03	26.49
		38.70	25.0	55.60	56.79	1.19	2.08	27.25
55713	1995 Drought	2.00	1.3	62.58	62.76	0.18	1.78	11.60
	1966 Drought	3.60	2.3	62.58	62.81	0.23	2.09	12.85
		5.00	3.2	62.58	62.86	0.28	2.13	14.02
	7Q50	6.60	4.3	62.58	62.90	0.32	1.98	28.99
		8.00	5.2	62.58	62.92	0.34	2.04	31.85
	10% of MAF	8.80	5.7	62.58	62.93	0.35	2.08	33.29
	7Q20	9.00	5.8	62.58	62.93	0.35	2.08	33.64
		10.00	6.5	62.58	62.95	0.37	2.12	35.37
	7Q10	11.30	7.3	62.58	62.97	0.39	2.07	38.00
		12.00	7.8	62.58	62.97	0.39	2.10	38.48
		13.90	9.0	62.58	62.99	0.41	2.15	39.96
		15.00	9.7	62.58	63.00	0.42	2.24	40.41
	20% of MAF	17.60	11.4	62.58	63.01	0.43	2.43	41.42
		19.00	12.3	62.58	63.02	0.44	2.48	42.21
	DRBC Passby	21.60	14.0	62.58	63.04	0.46	2.56	43.62
		24.00	15.5	62.58	63.06	0.48	2.58	45.14
	Passby plus Max. Withdrawal	26.30	17.0	62.58	63.07	0.49	2.68	45.98
		28.00	18.1	62.58	63.08	0.50	2.68	47.06
		29.40	19.0	62.58	63.09	0.51	2.75	47.43
		31.00	20.0	62.58	63.10	0.52	2.78	48.13
		33.00	21.3	62.58	63.11	0.53	2.83	49.00
	40% of MAF	35.30	22.8	62.58	63.12	0.54	2.87	49.97
		38.70	25.0	62.58	63.14	0.56	2.93	51.35
57970	1995 Drought	2.00	1.3	65.26	65.51	0.25	2.03	7.88
	1966 Drought	3.60	2.3	65.26	65.89	0.63	0.42	30.02
		5.00	3.2	65.26	65.96	0.70	0.47	31.94
	7Q50	6.60	4.3	65.26	66.02	0.76	0.51	33.82
		8.00	5.2	65.26	66.07	0.81	0.55	35.29
	10% of MAF	8.80	5.7	65.26	66.10	0.84	0.56	36.06
	7Q20	9.00	5.8	65.26	66.11	0.85	0.57	36.23
		10.00	6.5	65.26	66.14	0.88	0.59	36.96
	7Q10	11.30	7.3	65.26	66.18	0.92	0.61	37.69
		12.00	7.8	65.26	66.20	0.94	0.63	38.06
		13.90	9.0	65.26	66.24	0.98	0.66	39.05
		15.00	9.7	65.26	66.27	1.01	0.68	39.55
	20% of MAF	17.60	11.4	65.26	66.33	1.07	0.72	40.66
		19.00	12.3	65.26	66.36	1.10	0.75	41.10
	DRBC Passby	21.60	14.0	65.26	66.39	1.13	0.80	41.84
		24.00	15.5	65.26	66.41	1.15	0.85	42.43
	Passby plus Max. Withdrawal	26.30	17.0	65.26	66.41	1.15	0.95	42.20
		28.00	18.1	65.26	66.43	1.17	0.98	42.69
		29.40	19.0	65.26	66.45	1.19	1.00	43.04
		31.00	20.0	65.26	66.47	1.21	1.02	43.45
		33.00	21.3	65.26	66.48	1.22	1.06	43.75
	40% of MAF	35.30	22.8	65.26	66.51	1.25	1.10	44.19
		38.70	25.0	65.26	66.54	1.28	1.15	44.57

MAF = Mean Annual Flow

Rifldata.wk4

TABLE 5
WHITE CLAY CREEK AT STANTON
STREAM RIFFLE DATA
INSTREAM FLOW NEEDS ANALYSIS, PHASE II
June, 1996
Revised August, 1996

Section	Scenario	Discharge (cfs)	Discharge (mgd)	Min. Channel Elevation (ft)	Water Surface Elevation (ft)	Depth (ft)	Velocity (fps)	Wetted Perimeter (ft)
13843	1966 Drought	8.80	5.7	1.60	2.18	0.58	0.90	34.13
		9.30	6.0	1.60	2.19	0.59	0.89	35.17
		12.00	7.8	1.60	2.28	0.68	0.88	40.12
	1995 Drought	15.00	9.7	1.60	2.35	0.75	0.90	44.45
	7Q50	17.30	11.2	1.60	2.40	0.80	0.91	47.58
	10% of MAF	21.00	13.6	1.60	2.47	0.87	0.94	51.55
	7Q20	22.80	14.7	1.60	2.50	0.90	0.95	53.47
	7Q10	26.60	17.2	1.60	2.56	0.96	0.97	57.01
		32.00	20.7	1.60	2.64	1.04	1.00	61.49
		38.00	24.6	1.60	2.71	1.11	1.04	65.94
	20% of MAF	42.10	27.2	1.60	2.76	1.16	1.06	68.56
		50.00	32.3	1.60	2.83	1.23	1.10	73.35
		60.00	38.8	1.60	2.93	1.33	1.15	78.59
	7Q10 plus Withdrawal	73.00	47.2	1.60	3.03	1.43	1.21	83.09
	40% of MAF	84.10	54.4	1.60	3.10	1.50	1.27	83.35
14073	1966 Drought	8.80	5.7	1.71	2.26	0.55	2.98	10.69
		9.30	6.0	1.71	2.27	0.56	3.01	10.94
		12.00	7.8	1.71	2.33	0.62	3.21	12.04
	1995 Drought	15.00	9.7	1.71	2.39	0.68	3.35	13.18
	7Q50	17.30	11.2	1.71	2.43	0.72	3.43	13.98
	10% of MAF	21.00	13.6	1.71	2.49	0.78	3.59	15.06
	7Q20	22.80	14.7	1.71	2.51	0.80	3.65	15.57
	7Q10	26.60	17.2	1.71	2.56	0.85	3.76	16.56
		32.00	20.7	1.71	2.63	0.92	3.90	17.83
		38.00	24.6	1.71	2.70	0.99	4.03	19.11
	20% of MAF	42.10	27.2	1.71	2.76	1.05	3.92	20.42
		50.00	32.3	1.71	2.87	1.16	3.82	22.54
		60.00	38.9	1.71	3.01	1.30	3.68	25.08
	7Q10 plus Withdrawal	73.00	47.2	1.71	3.15	1.44	3.61	26.36
	40% of MAF	84.10	54.4	1.71	3.25	1.54	3.68	27.20
16180	1966 Drought	8.80	5.7	3.10	4.23	1.13	0.18	45.29
		9.30	6.0	3.10	4.25	1.15	0.18	45.32
		12.00	7.8	3.10	4.37	1.27	1.21	45.46
	1995 Drought	15.00	9.7	3.10	4.48	1.38	0.24	45.58
	7Q50	17.30	11.2	3.10	4.55	1.45	0.27	45.67
	10% of MAF	21.00	13.6	3.10	4.66	1.56	0.30	45.80
	7Q20	22.80	14.7	3.10	4.71	1.61	0.31	45.85
	7Q10	26.60	17.2	3.10	4.81	1.71	0.35	45.97
		32.00	20.7	3.10	4.94	1.84	0.39	46.36
		38.00	24.6	3.10	5.07	1.97	0.43	47.36
	20% of MAF	42.10	27.2	3.10	5.14	2.04	0.46	47.91
		50.00	32.3	3.10	5.29	2.19	0.50	49.03
		60.00	38.9	3.10	5.47	2.37	0.55	50.44
	7Q10 plus Withdrawal	73.00	47.2	3.10	5.64	2.54	0.62	51.74
	40% of MAF	84.10	54.4	3.10	5.78	2.68	0.68	52.83

MAF = Mean Annual Flow

3A3. White Clay Creek at Stanton: Discernible wetted perimeter "breakpoint" were not evident at the selected riffle sections along the tidal reach at Stanton. The selected sections are normally pools during most of the tidal cycle except for low tide where they appear to be riffle sections. Examinations of the stream geomorphology along this tidal reach indicate the eroded rectangular shape and flat bottom of the channel are not true riffle sections. Therefore, the wetted perimeter analysis is not deemed to be appropriate as a minimum instream flow procedure along the tidal reach at Stanton. Table 5 presents stream riffle data for the critical sections in this study reach.

3B. RESULTS (Water Quality)

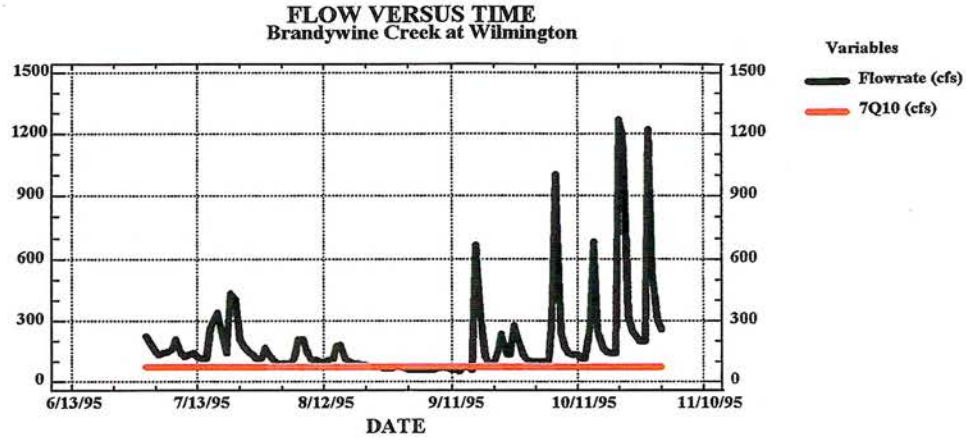
3B1. Brandywine Creek at Wilmington

Please refer to FIGURES 19, 20, and 21 which present plots of streamflow, dissolved oxygen, pH, water temperature, coliform bacteria, conductivity, and chlorides in the Brandywine Creek during the period July 1, 1995 through October 31, 1995. Summary statistics for these parameters appear in Appendix D along with correlation and covariance matrices. A brief explanation of how to read these matrices appears within the Appendix.

Considering the plots and statistical analyses, the following observations can be made for the Brandywine Creek during the targeted period:

- The streamflow in the Brandywine dropped below the 7Q10 from late August through mid September.

- Dissolved oxygen levels were generally lower during the period of sustained low flow, although this was not categorically true. Increasing DO levels at the end of the period were most likely the result of turbulence associated with an increasing number of storm events. No violations of Delaware's DO criteria during the period were noted, although concentrations on 8 and 29 August (6.5 and 6.4 mg/l, respectively), and again on 8 September (6.4 mg/l), began to approach Delaware's daily average DO criterion of 5.5 mg/l for freshwaters.



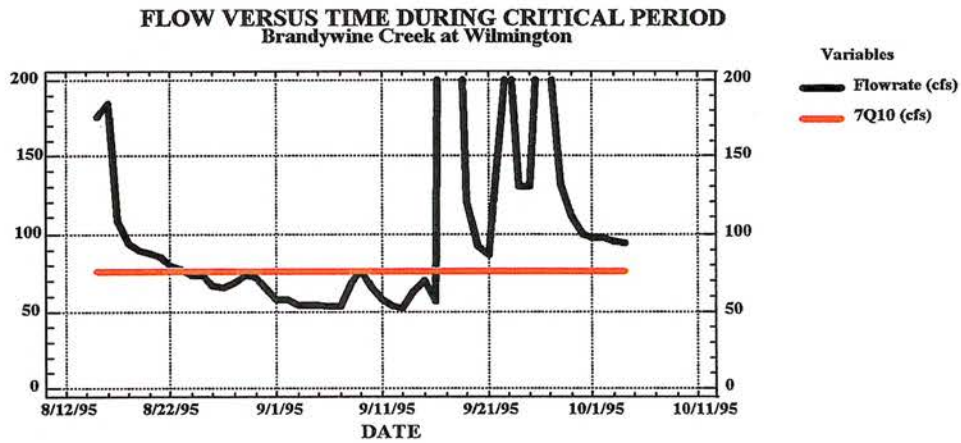
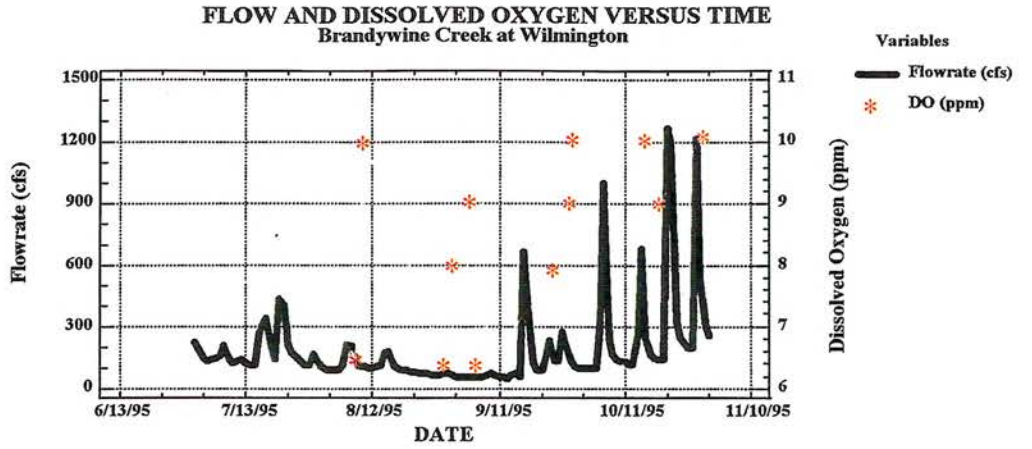
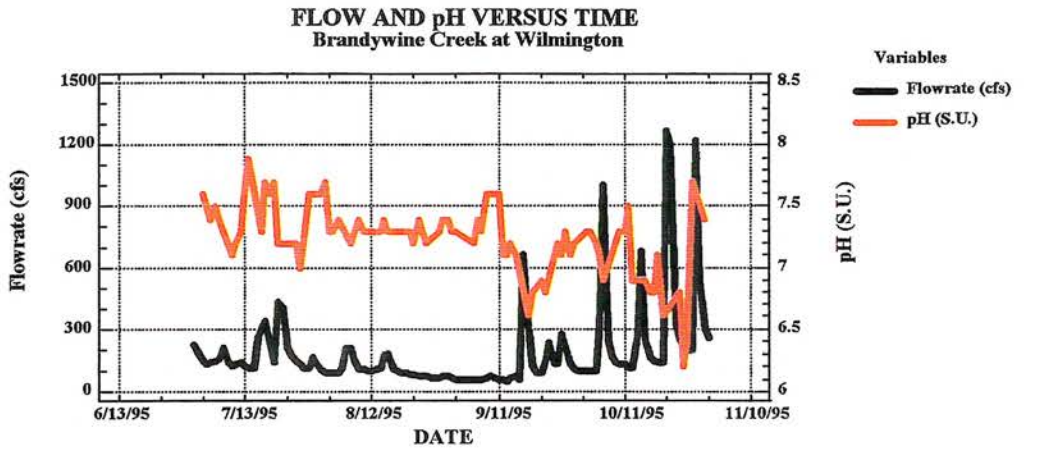


FIGURE 19. Streamflow During Drought of 1995, Brandywine Creek at Wilmington





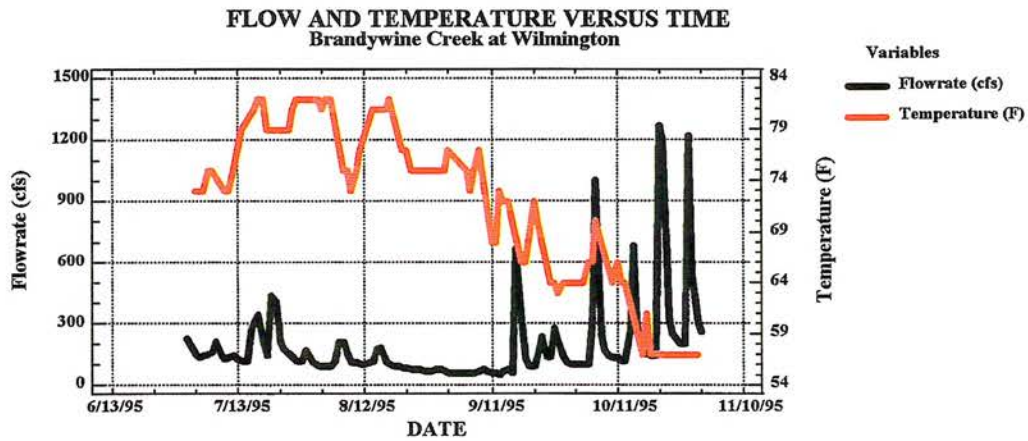
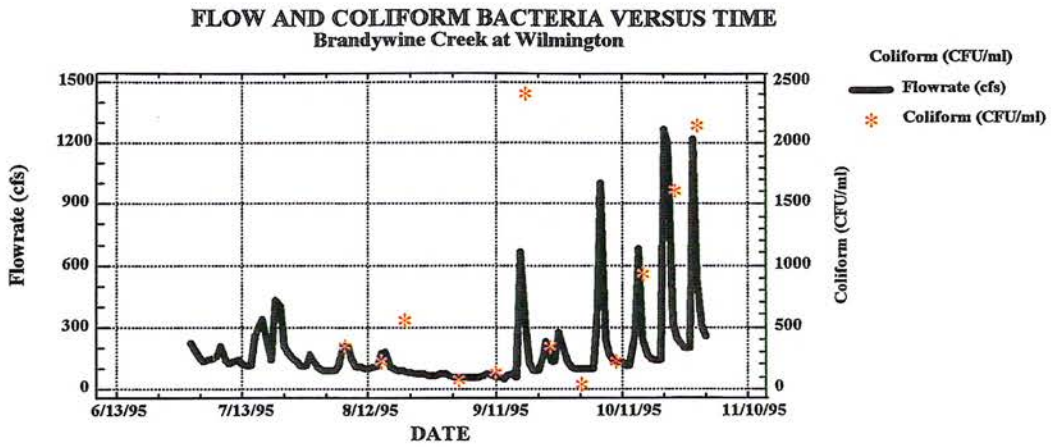
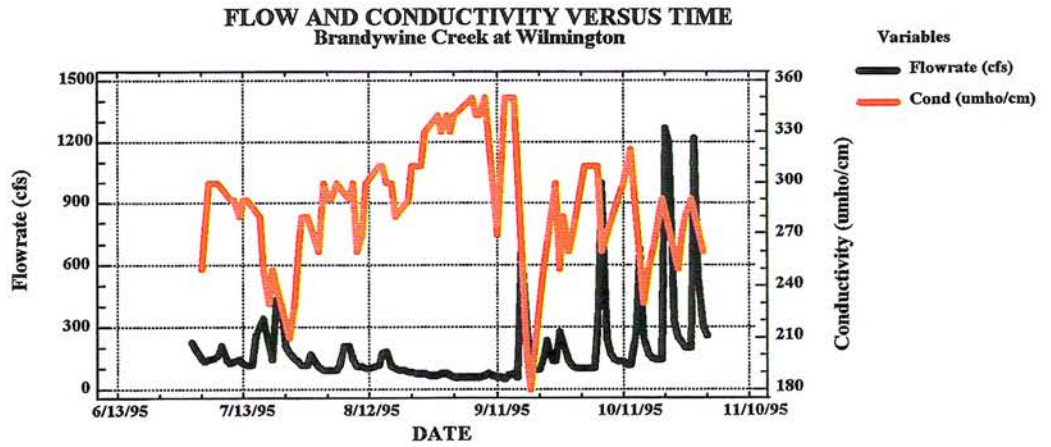


FIGURE 20. Flow, Dissolved Oxygen, pH, and Temperature During the Drought of 1995, Brandywine Creek at Wilmington





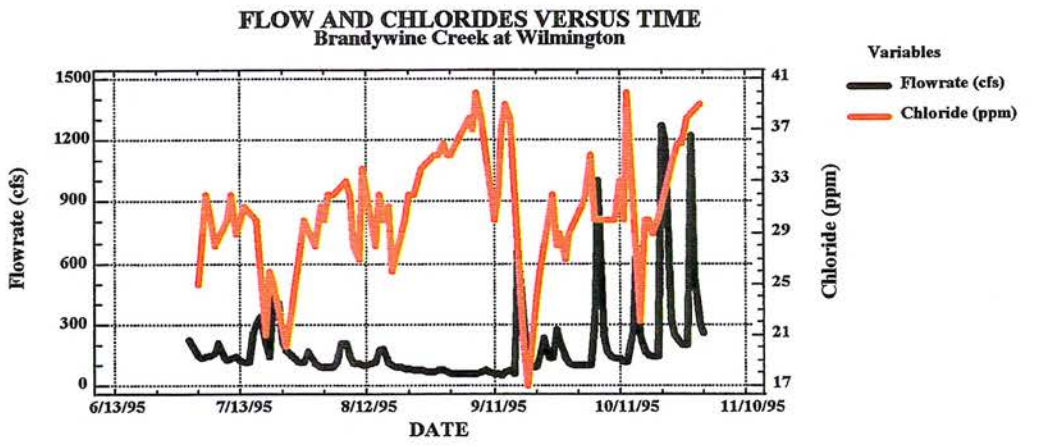


FIGURE 21. Flow, Coliform Bacteria, Conductivity, and Chlorides During Drought of 1995, Brandywine Creek at Wilmington

- pH levels remained steady during times of steady flowrate. However, significant drops in pH were evident in response to spike increases of streamflow. This phenomenon is explained due to acid rain in combination with low available base flow to dilute the spike acidity loading. The intake water pH on 25 and 26 October, 6.2 and 6.4, respectively, were both lower than Delaware's minimum pH criterion of 6.5. The pH on 27 October quickly recovered to a normal level.

- Water temperatures were generally higher during periods of sustained low flow, although there was a clear cooling trend that appeared to be independent of streamflow, most likely due to cooling air temperatures. The relationship between water temperature and air temperature is explored further in the discussion on White Clay Creek Newark that follows. Water temperatures on 1, 3, 4, and 18 August all reached 82 degrees Fahrenheit, which is Delaware's daily average temperature criterion. The maximum criterion of 86 degrees was not exceeded.

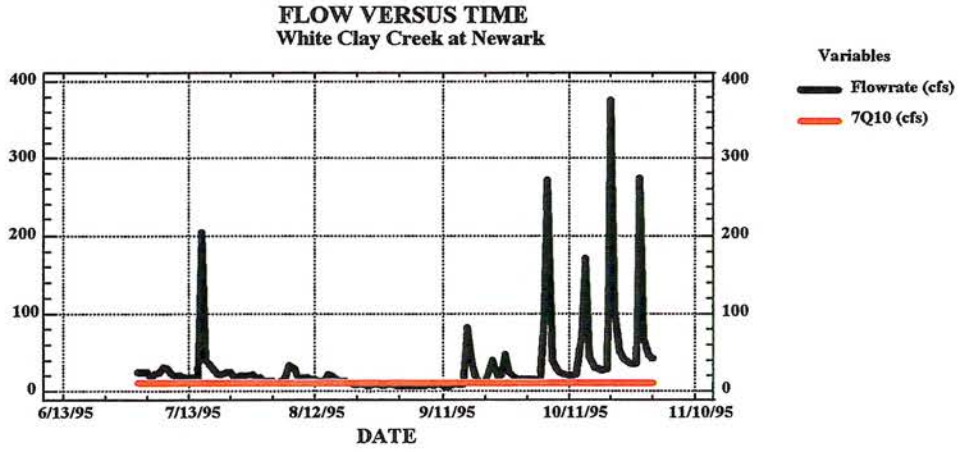
- Coliform bacteria levels increased markedly in response to increased streamflow. This was no doubt due to overland flow and discharge of stormwater runoff which contained coliform bacteria. Delaware's Surface Water Quality Standards do not contain a criterion for coliform bacteria.

- Conductivity readings steadily increased during periods of declining streamflow and fell rapidly in response to spike increases of streamflow. Chlorides displayed similar behavior. This observation no doubt reflects the higher dissolved mineral content of groundwater than rainwater. As the ratio of groundwater flux to surface runoff increases during drought, the dissolved mineral content in the stream will rise concomitantly.

3B2. White Clay Creek at Newark

Figures 22 and 23 present plots of streamflow, dissolved oxygen, pH, and conductivity versus time for the White Clay Creek at Newark. Summary statistics for these parameters plus temperature appear in Appendix C. along with correlation and covariance matrices.

The following observations can be made from the figures and statistical analyses just noted:



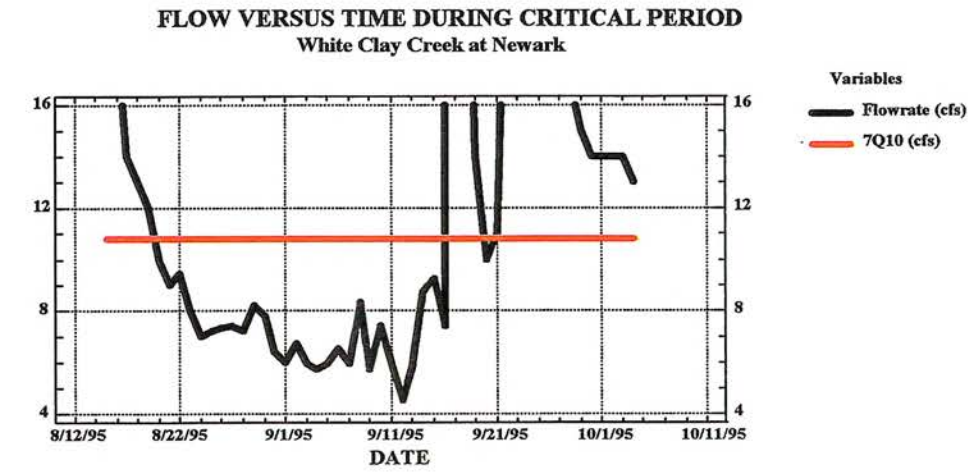


FIGURE 22. Streamflow During Drought of 1995, White Clay Creek at Newark

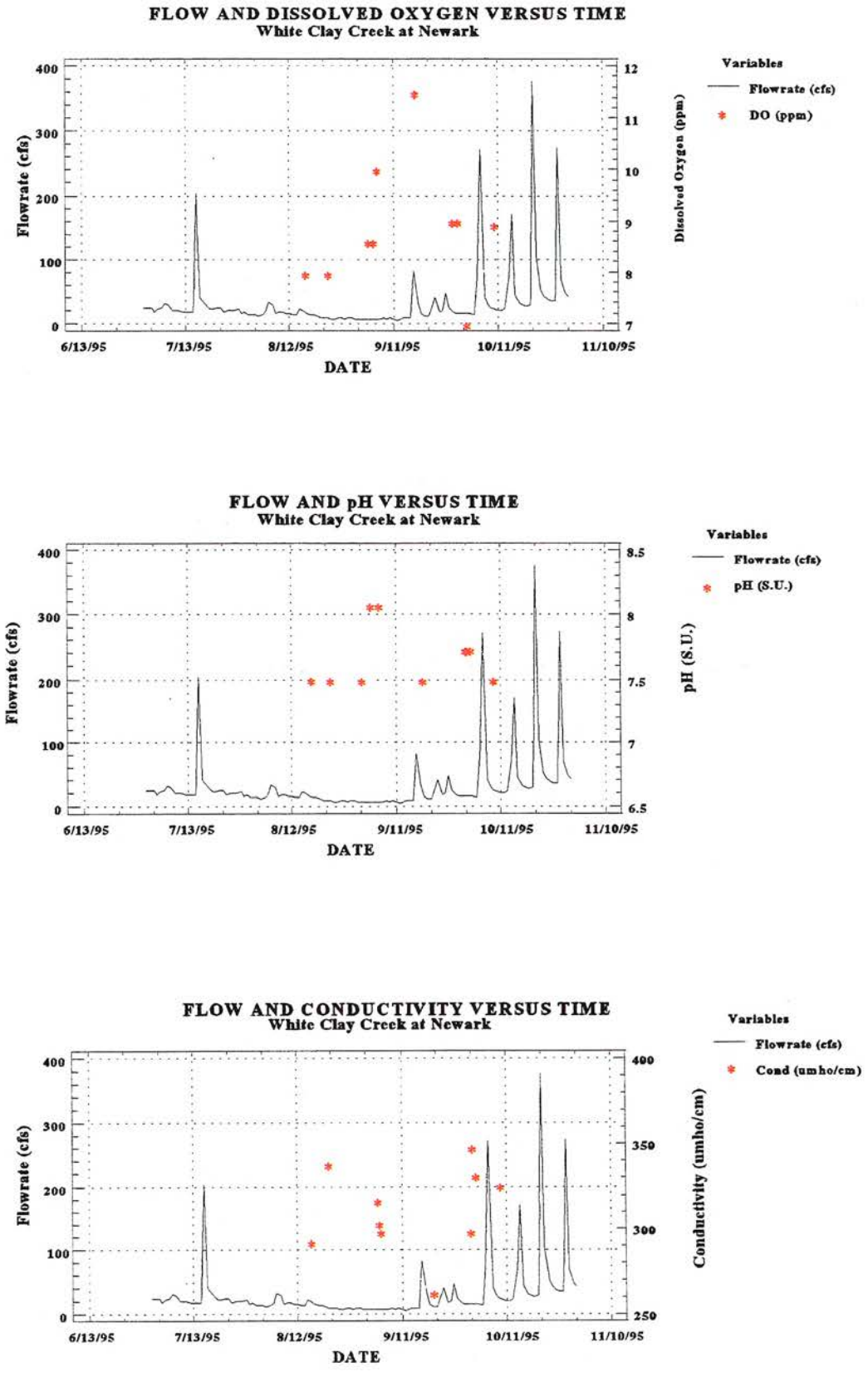


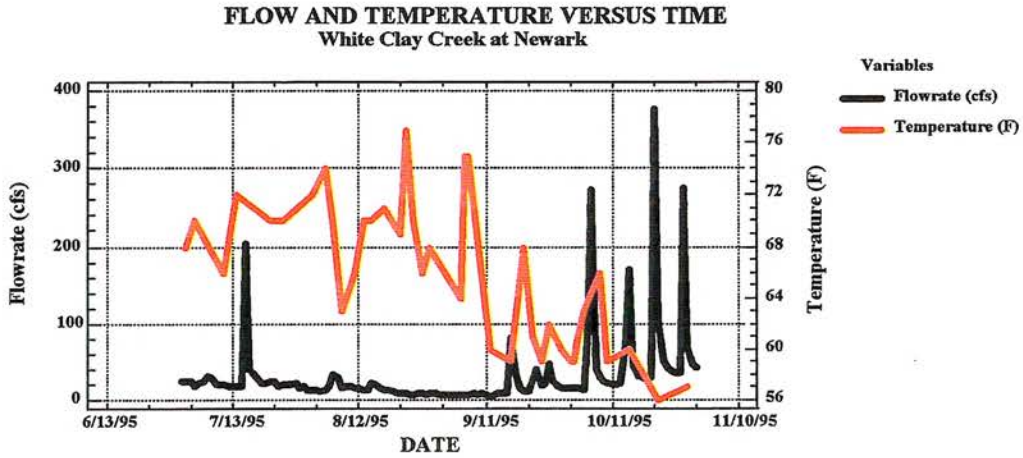
FIGURE 23. Flow, Dissolved Oxygen, pH, and Conductivity During Drought of 1995, White Clay Creek at Newark

- The streamflow in the White Clay Creek at Newark dropped below its 7Q10 from mid to late August through mid September.

- Despite the extended period of low flow, dissolved oxygen, pH, and conductivity levels were normal, although the dataset for these parameters was somewhat sparse. No violations of applicable water quality standards for DO and pH were noted.

Figure 23 depicts water temperature as a function of time and also shows temperature plotted against streamflow. No temperature readings exceeded the general temperature criteria for fresh waters (82 degree average, 86 degree max). There was a single reading of 77 degrees that occurred on 23 August that exceeded the more stringent criterion to protect the cold water fishery use of the White Clay (75 degrees). However, since that criterion only applies from March 15 through June 30, the timing of the reading does not constitute an exceedance.

The Task Force expressed an interest in exploring the reason(s) why water temperature in the White Clay exhibited a decline in late summer and early fall of 1995. Increasing streamflows and air temperature were postulated as possible explanations. In an effort to better understand the relationship between flow and water temperature, various alternative regression models were fit to the data. The best model that could be obtained for these two parameters was a reciprocal-Y relationship between temperature and $\log_{10}$ of flow. That model was judged to be unsatisfactory however based upon a low R-squared value (24.8%) and non-random residuals (see Figure 25). A much stronger regression was obtained between air temperature and water temperature. That relationship was also a reciprocal-Y equation, but this time the R-squared value was able to account for 73.4% of the variation in water temperature and the residuals plotted against predicted water temperature exhibited the desired randomness (see Figure 26).



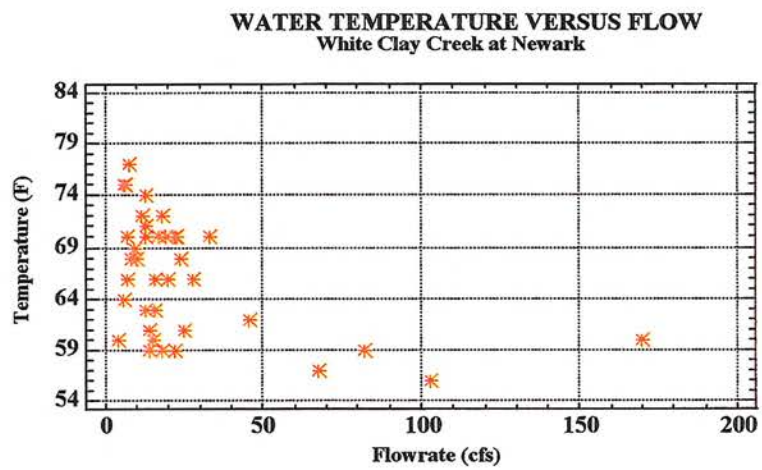
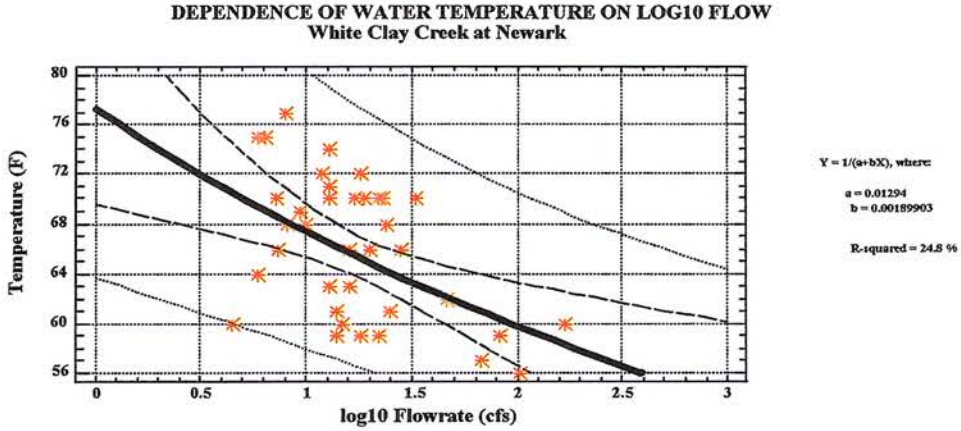


FIGURE 24. Flow and Temperature During Drought of 1995, White Clay Creek at Newark



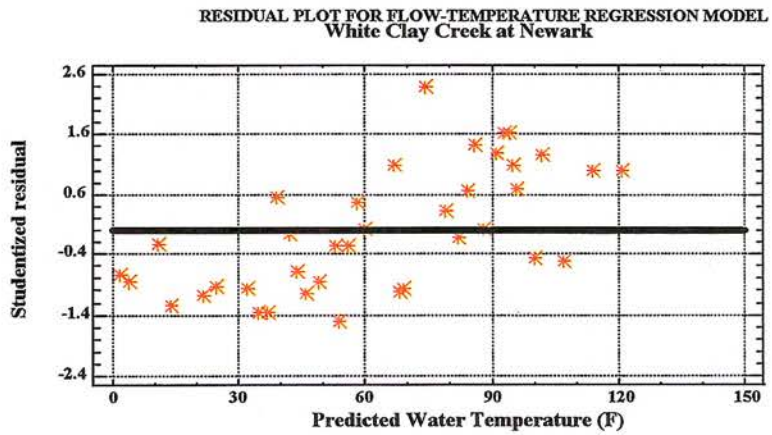


FIGURE 25. Streamflow-Temperature Regression Model, White Clay Creek at Newark

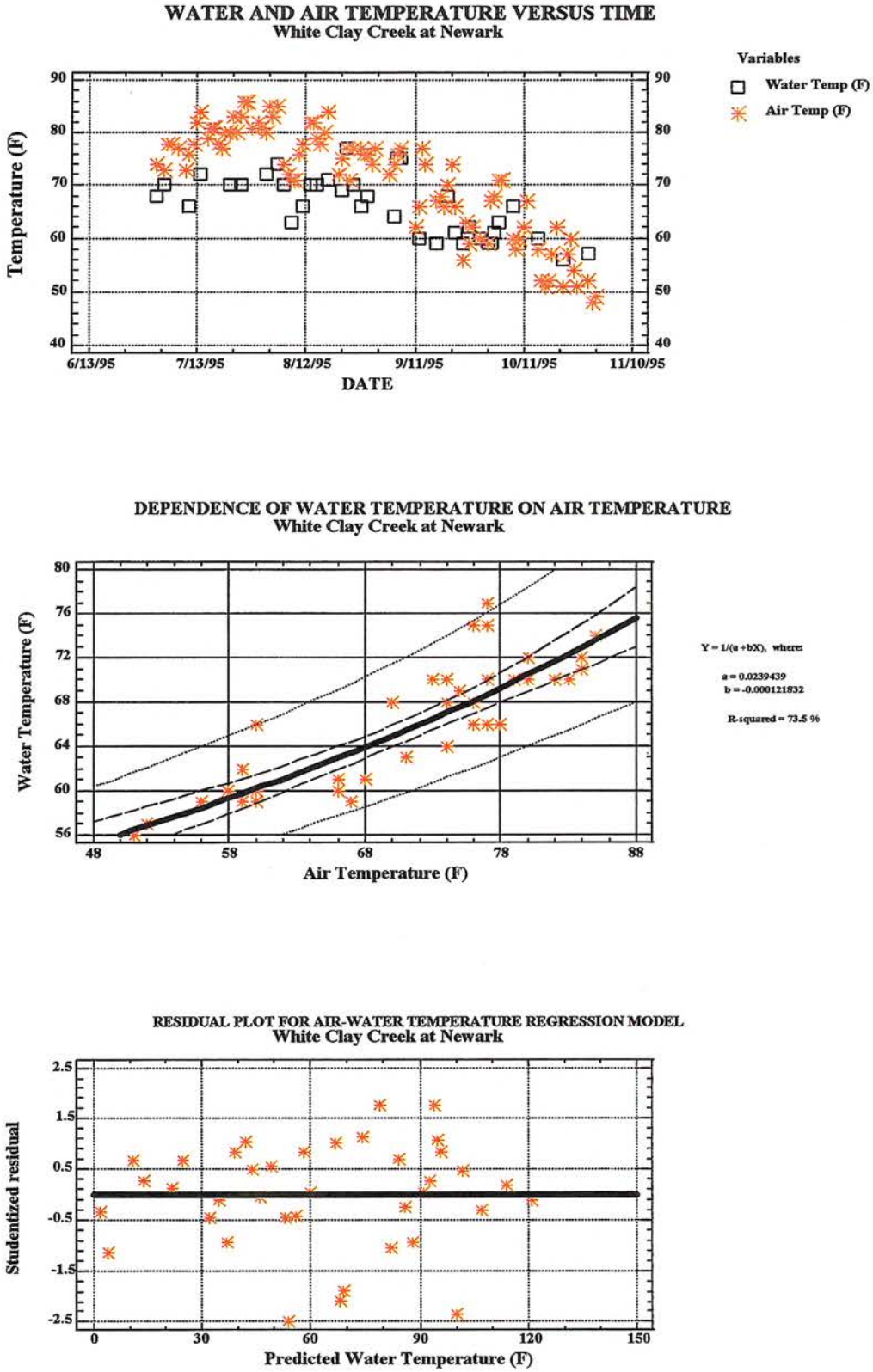
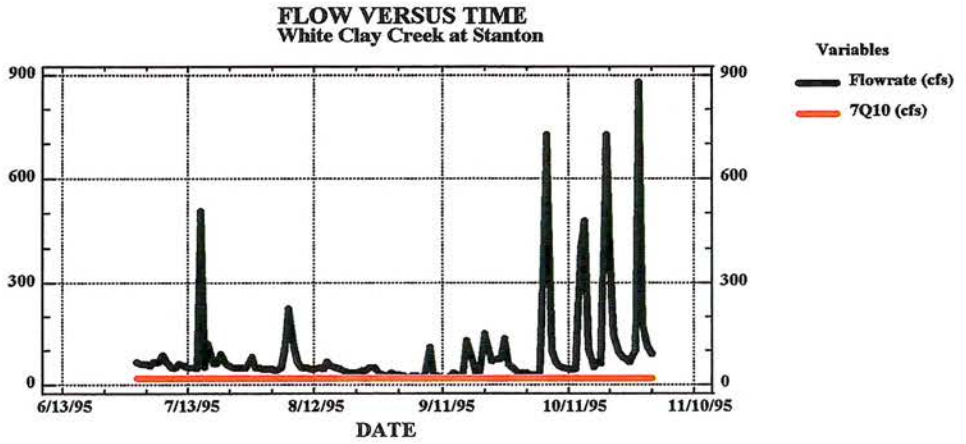


FIGURE 26. Water Temperature-Air Temperature Regression Model, White Clay Creek at Newark



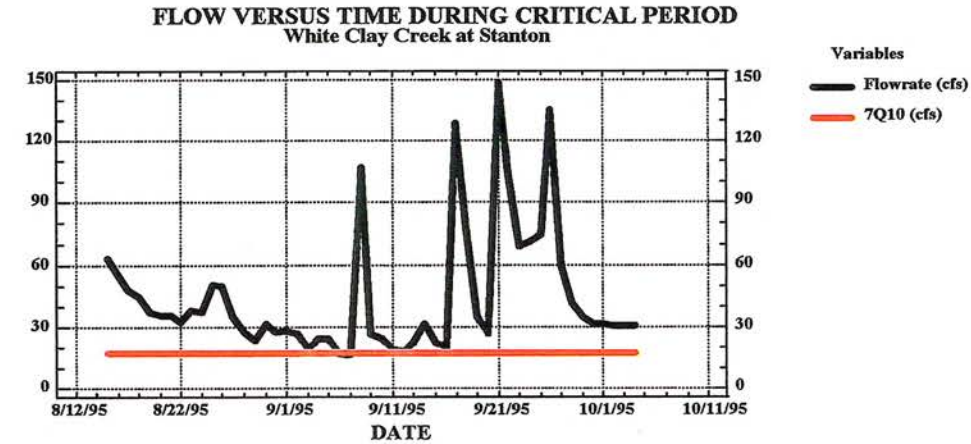


FIGURE 27. Streamflow During Drought of 1995, White Clay Creek at Stanton

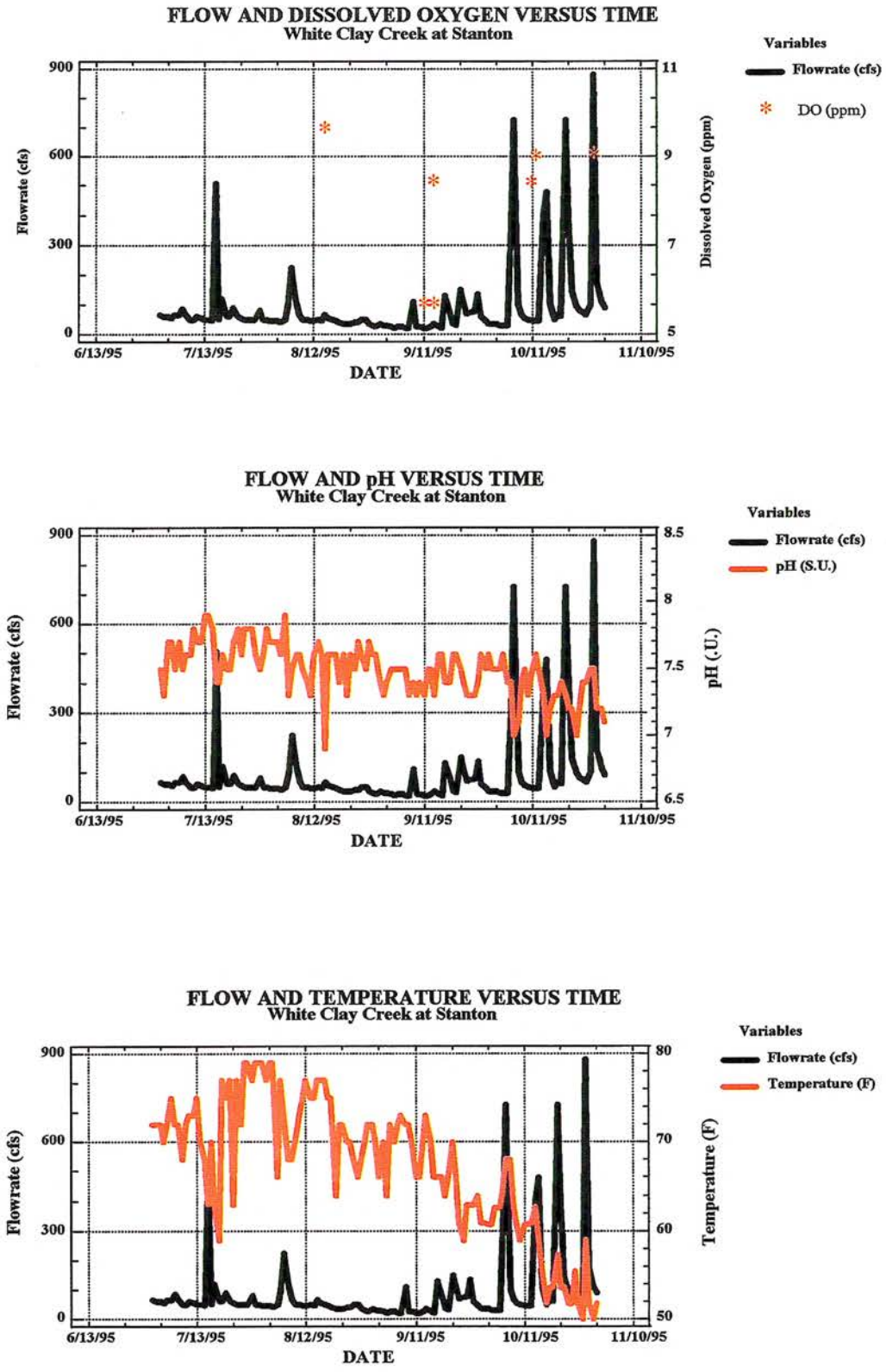
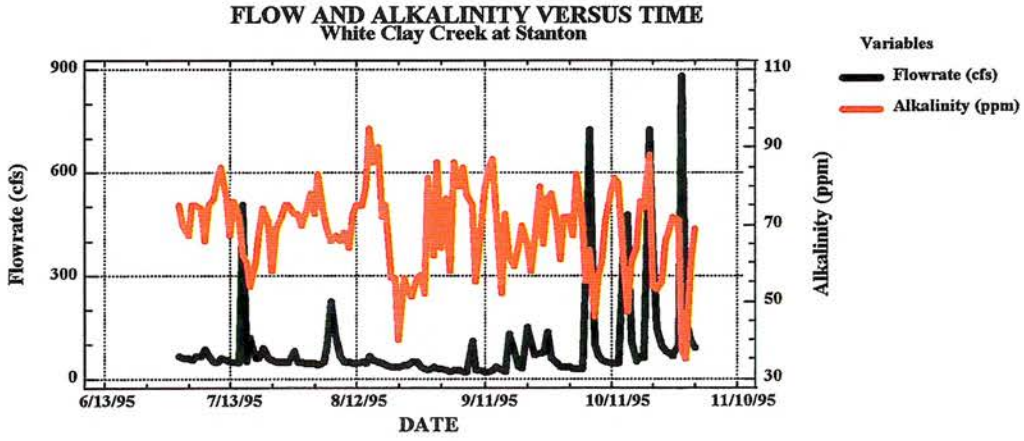


FIGURE 28. Flow, Dissolved Oxygen, pH, and Temperature During Drought of 1995, White Clay Creek at Stanton



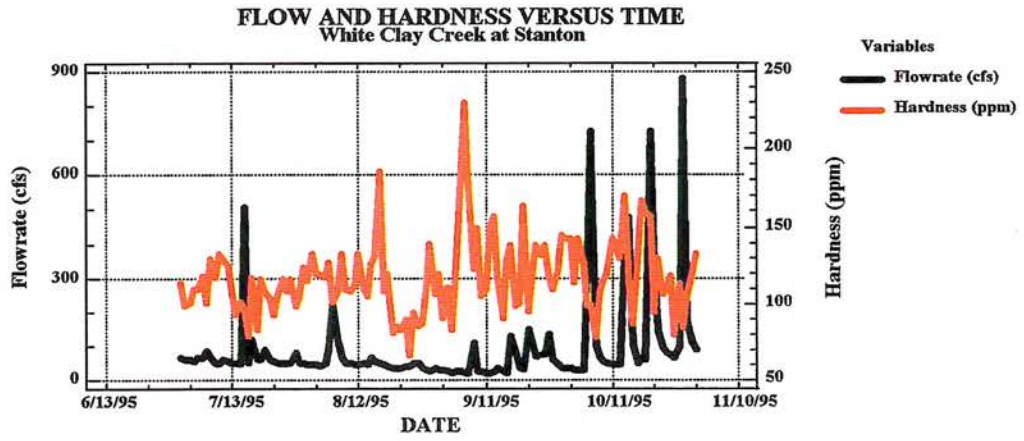


FIGURE 29. Flow, Alkalinity, and Hardness During Drought of 1995, White Clay Creek at Stanton

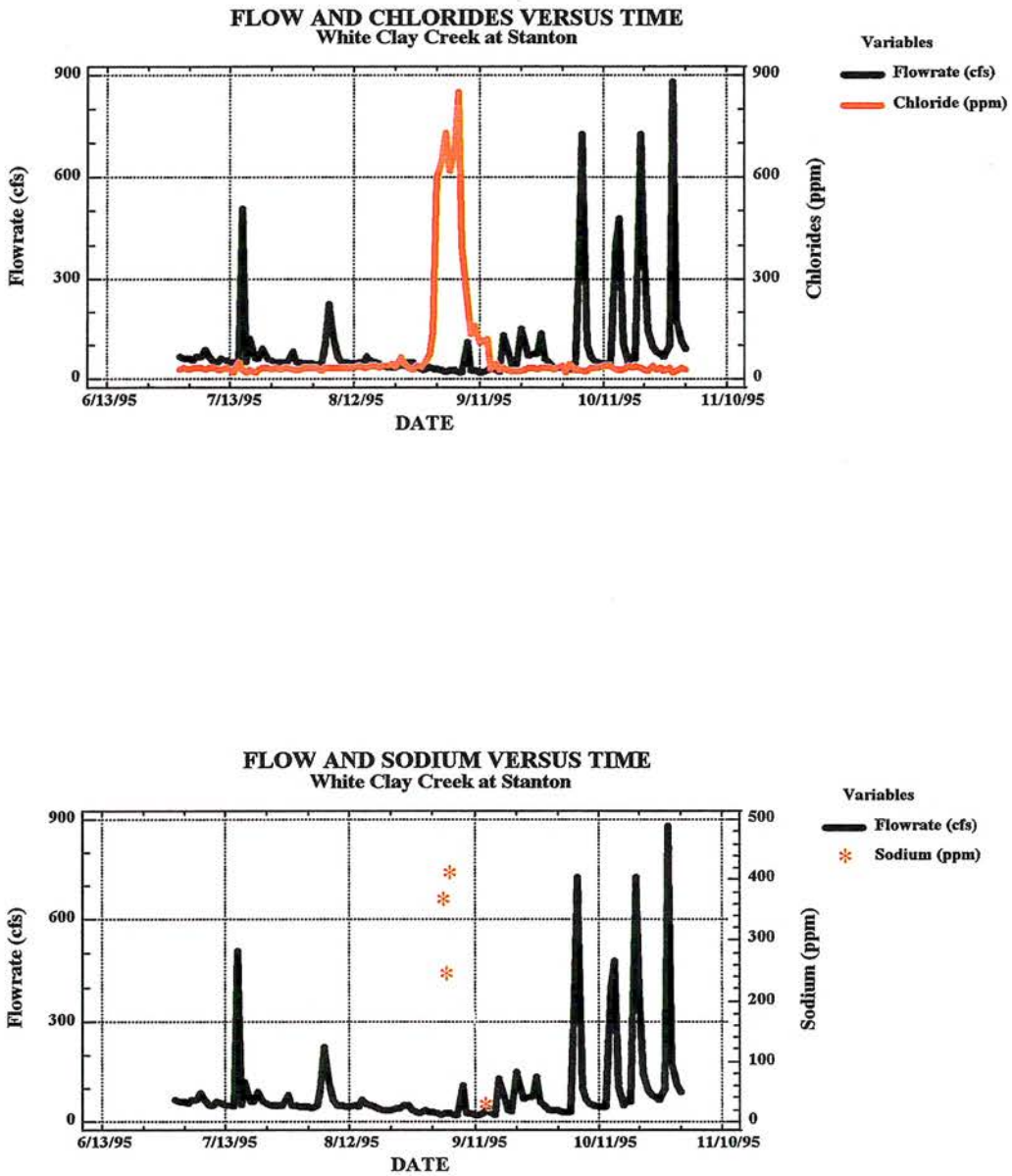


FIGURE 30. Flow, Chlorides, and Sodium During Drought of 1995, White Clay Creek at Stanton

At the request of the Task Force, a relationship was developed between streamflow and chloride levels in the White Clay Creek at Stanton. The purpose of developing such a relationship is to forecast a streamflow at which chloride levels reach 250 mg/l. A plot of the relationship, along with the residuals, is shown in FIGURE 31. The regression model relates chloride levels to the reciprocal squared power of streamflow through an exponential function. The regression model is as follows:

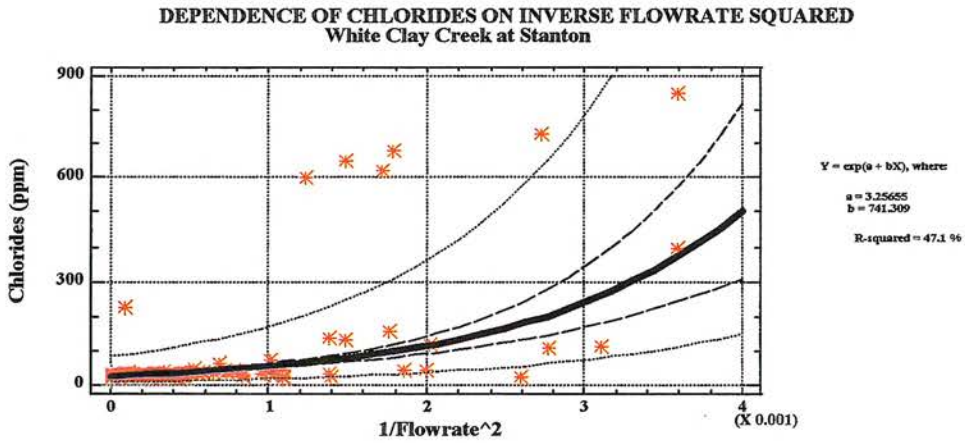
$$Chloride = \exp\left(3.25655 + \frac{741.309}{(flowrate)^2}\right)$$

Units in the above equation are parts per million (ppm) for chlorides and cubic feet per second (cfs) for flowrate. "Exp" means the natural (base "e") antilogarithm, which is equivalent to the value of "e" (2.71828) raised to the power of the value in the parentheses. Note that the model accounts for nearly 50% of the variability in chloride levels (R-squared = 47.1%). Despite this reasonable fit, the residuals appear non-random and the prediction limits of the model are rather wide. The model predicts that chloride levels will begin to exceed 250 mg/l when the flow in the White Clay Creek drops below 18.1 cfs.

3B4. Water Quality Summary

Few water quality criteria violations for the conventional parameters considered were noted during the period 1 July, 1995 through 31 October, 1995. However, water quality was generally worse during the critical drought period from late August through mid September. Dissolved oxygen levels tended to be lower and temperatures tended to be higher during this period. Furthermore, the streams were more vulnerable to acid rain impacts due to the diminished dilution capability during low flow.

Overall, water quality conditions would be expected to contribute some nominal added stress to aquatic life during drought conditions. This stress is more likely to involve subtle, sublethal effects,



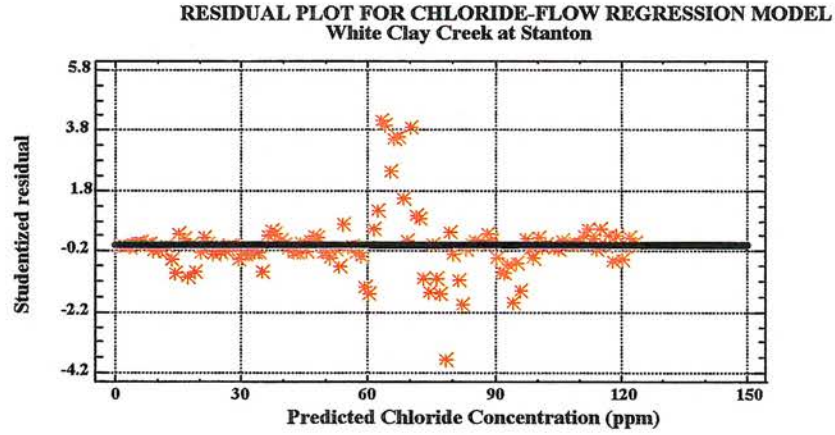


FIGURE 31. Streamflow-Chloride Regression Model, White Clay Creek at Stanton

rather than mortality. In other word, the animals may be uncomfortable and challenged by their surroundings, but they are not likely to be seriously threatened with death.

Although extreme adverse aquatic life impacts were not observed during the 1995 drought due to poor water quality, it is important to recognize that any stresses associated with water quality would be added to those associated with reduction of available habitat. As discussed in previous sections of this report, as streamflows fall, wetted perimeter, which serves as a proxy for aquatic habitat, also drops. The result is less and less available space and food supply for fish and other aquatic life. In this sense, loss of habitat during critical low flows can serve as a physical stressor on aquatic life. Marginal water quality during these same periods only acts to intensify the stress.

Finally, with respect to chloride levels in the White Clay Creek at Stanton, it was shown that streamflows less than 18.1 cfs are likely to result in chloride concentrations in excess of 250 ppm. Since this flow is nominally equivalent to the 7Q10 at Stanton, it will be important to maintain that flow in order to prevent salt front encrouchment at United Water's intakes.

3C. RESULTS SUMMARY

The charge of the Joint Task Force was to determine the adequacy of the 7Q10 as a minimum instream flow standard along the four streams used for surface water supply in the Christina River Basin. The 7Q10 assessment was conducted utilizing minimum fish habitat, wetted perimeter, and water quality analyses along the study reaches. The Joint Task Force determined, through best professional judgment and analysis of the data, that the 7Q10 is adequate as a minimum flow standard along the Brandywine Creek at Wilmington and White Clay Creek at Newark and Stanton. The following sections discuss the results of these analyses.

3C1. Brandywine Creek at Wilmington

The analyses concluded the 7Q10 is an adequate minimum flow standard along the Brandywine Creek. Through a fishery survey conducted during the drought of 1995 the Long Nose Dace,

Satinfin Shiner, and Tessellated Darter were identified as the critical, riffle-sensitive species along the Brandywine Creek. Suitable discharge, velocity, and flow depth criteria were developed for these fish species. The wetted perimeter analyses concluded that the 7Q10 exceeds the suitable fish habitat criteria and the upper WP breakpoint discharge at three critical riffle-sections. The water quality analyses indicate water quality was generally worse during the drought of August and September 1995 when stream flows declined below the 7Q10. The Delaware Surface Water Quality Standards identify the 7Q10 as the minimum flow needed for wastewater assimilation of point source discharges. Based on the information, the Joint Task Force concluded the 7Q10 is adequate as a minimum flow standard along the Brandywine Creek.

3C2. White Clay Creek at Newark

The analyses concluded the 7Q10 is adequate as a minimum instream flow standard along the White Clay Creek at Newark. The Longnose Dace, Blacknose Dace, and Common Shiner were selected as the critical riffle-sensitive species along this reach. The wetter perimeter analyses indicated the 7Q10, lower WP, and upper WP discharge, velocity, and depth exceeded the minimum fish criteria at Sections 53115 and 55713. Section 57970 exhibited the characteristics of a pool section and was deleted from consideration since it does not exhibit the classic "riffle" geomorphology needed for the wetted perimeter analyses. During the drought of 1995 when stream flows dipped below the 7Q10, water quality declined slightly. Along the White Clay Creek, the Delaware Surface Water Quality Standards indicate the 7Q10 is the minimum flow needed for wastewater assimilation for upstream and downstream point source discharges.

3C3. White Clay Creek at Stanton

The Joint Task Force determined the White Clay Creek at Stanton is a tidal reach which is not appropriate for a wetted perimeter analysis. The fish abundance surveys during the drought of

1995 indicated the presence of species in the study area which are commonly found in brackish water. Short-term adverse impacts to the fishery were not noted due to the low stream flow and high chloride levels. However, during an extended drought, the long-term adverse impacts could be significant. Due to the channel morphology along this tidal reach, the Joint Task Force decided that a wetted perimeter approach was not appropriate. The water quality analyses indicated that the 7Q10 is needed for salinity control to maintain the 250 ppm isochlor downstream from the United Water Delaware intake at Stanton. The Delaware Surface Water Quality Standards require the 7Q10 as the minimum flow necessary for wastewater assimilation for upstream and downstream discharges. Based on these analyses, the Joint Task Force determined that the 7Q10 is the minimum stream flow needed to control salinity, meet Delaware Surface Water Quality Standards, and in turn, prevent long-term impacts to fish habitat along this tidal reach.

3C4. Christina River at Smalley's Pond

Based on analyses of channel geomorphology along the tidal Christina River, the Joint Task Force determined a wetted perimeter analysis was not appropriate for this reach. The Christina River immediately downstream from Smalley's Pond consists of tidal pools with no riffle sections. The water supply intake for United Water Delaware is situated above the dam at Smalley's Pond which is not subject to tidal action. The Joint Task Force determined that the 40 million gallon Smalley's Pond provides sufficient storage volume to maintain stream flow at or above the 7Q10 of 2mgd. Since the Christina River is tidal like White Clay Creek at Stanton, the 7Q10 was determined to be an adequate minimum flow standard to control salinity and meet Delaware Surface Water Quality Standards. In addition, the storage at Smalley's Pond provides sufficient volume to maintain adequate depth and flow for the fishery in and downstream from the pond. Therefore, the 7Q10 is adequate as a minimum flow standard along the Christina River.

CONCLUSIONS

1. All instream uses in the Christina River Basin in Northern New Castle County should be protected by imposition of a 7Q10 minimum flow standard for all withdrawals of 50,000 gallons per day or more,

2. A 7Q10 minimum flow passby requirement for the water supply intakes on the White Clay Creek of the City of Newark and United Water Delaware can be met with supplemental water supply through existing direct and/or indirect interconnection with the City of Wilmington during periods of critical low flow. A 7Q10 minimum flow passby requirement for the water supply intakes operated by the City of Wilmington on the Brandywine Creek may be met if Hoopes Reservoir releases to supply the direct and/or indirect interconnections to the City of Newark and United Water Delaware are not required

3. Substitution on an **interim** basis of the flow required to meet the wetted perimeter lower breakpoint as defined in the Phase 11 study for the riffle areas in the Brandywine for a 7Q10 passby requirement should protect the target species during a **declared drought emergency** and permit the City of Wilmington to provide requested supplemental water supply through interconnection with United Water Delaware and indirectly with the City of Newark through purchased water from either Artesian Water Co. or United Water Delaware. Once a new water supply source is in place for Northern New Castle County as a result of the ongoing Churchman's Marsh Environmental Impact Statement process, the 7Q10 minimum flow passby requirement for the City of Wilmington should prevail.

4. The City of Newark and the City of Wilmington should minimize the diverted flows of the White Clay and Brandywine creeks so that any excess water not required for public water supply purposes remains in the creeks as natural flow.

5. The demonstrated multiple uses of the waters of the Christina River Basin in Northern New Castle County warrant the development of a water resources management plan.

RECOMMENDATIONS

1. The Delaware Department of Natural Resources and Environmental Control and the Water Resources Agency for New Castle County should jointly develop a water resources management plan for the Christina River Basin in Northern New Castle County incorporating the recommendations of the Instream Flow Needs Joint Task Force outlined in Section 2.5 Water Supply and Permit Application Review. The Plan should address the issues of water quantity, quality, target fish species habitat, water conservation and drought management.

2. The Delaware Department of Natural Resources and Environmental Control should require improvement of diversions operated by the City of Wilmington on the Brandywine Creek and the City of Newark on White Clay Creek to minimize the impact on the natural flow of the respective waterways.

3. The Delaware Department of Natural Resources and Environmental Control should seek modification of Delaware River Basin Commission dockets MBNA D-77-25, City of Newark D - CP(S) and United Water Delaware D-91-72 CP and DNREC Water Allocation Permits 80-0018-A (City of Newark) and 90-0013 (United Water Delaware) to reflect the findings of this study and the recommendations developed by the Joint Task Force regarding public water supply withdrawals and operations for the White Clay Creek and the Brandywine creeks.

4. The Delaware Department of Natural Resources and Environmental Control should institute such actions as are necessary to establish a 7Q10 minimum stream flow standard for regulatory purposes for all withdrawals of 50,000 gallons per day or more in the Christina River Basin in Northern New Castle County.

5. The Delaware Department of Natural Resources and Environmental Control should institute such action as will grant the City of Wilmington **interim** relief from a 7Q10 minimum flow passby requirement at its Brandywine intake during a **declared drought emergency** based on the wetted perimeter analysis conducted as part of this study. The diversions to the Brandywine and Wills pump stations should also be limited during such drought emergency.

The interim requirement will remain an option until a new water supply source is developed for Northern New Castle County based on the ongoing Churchman's Marsh Environmental Impact Statement process but in no case to exceed a period of ten (10) years. The Joint Task Force, recognizing the reliance of other purveyors on additional supply by City of Wilmington through interconnections during critical flow conditions pending development of a new source, recommends the establishment of an operating plan for the Christina River Basin in Northern New Castle County to address these complex issues. The development of the plan should be undertaken immediately by the Department of Natural Resources and Environmental Control in cooperation with the Water Resources Agency for New Castle County and incorporated as an appendix to this study.

REFERENCES

1. Delaware Department of Natural Resources and Environmental Control, Division of Water Resources, State of Delaware Surface Water Quality Standards, amended February 26, 1993.

2. Federal Emergency Management Agency, Water Surface Profiles (HEC-2) for Brandywine Creek, Christina River, and White Clay Creek, New Castle County, Delaware, 1989.

3. Nelson, F.A.; Evaluation of Four Instream Flow Methods Applied to Four Trout Rivers in Southwest Montana; Montana Department of Fish, Wildlife, and Parks, 1980.

4. Stream Water Quality Data, City of Wilmington, United Water Delaware, and City of Newark, 1995.

5. U.S. Army Corps of Engineers, Hydrological Engineering Center, HEC-2 Water Surface Profiles, User's Manual, September 1982.

6. U.S. Fish and Wildlife Service, Designing and Negotiating Studies Using IFIM, undated.

7. U.S. Geological Survey, Water Resources Data Maryland and Delaware Water Year 1995, Volume 1, Surface Water Data, 1995.

A. FISH HABITAT/ABUNDANCE SURVEY REPORT

INTRODUCTION

The need for minimum stream flows to protect fish, invertebrates, and other stream dwelling organisms have been well documented throughout the United States (Bain et al. 1989, Bayha 1978). The expansion of human populations in Northern Delaware has brought to the forefront greater awareness of and the need to protect the State's natural resources. Notable among impacts on resources is a heavy dependence on surface water supplies. Lakes and reservoirs built for water storage are limited in New Castle County. Much of the water utilized by municipalities, industry and agriculture is removed directly from streams and rivers.

The Delaware River and Basin Commission (DRBC) imposed a 7Q10 passby requirement on the City of Newark's White Clay Creek water intake in 1991, and on the United Water Delaware's (formerly Wilmington Suburban Water Corporation) intake on White Clay Creek near Stanton in 1993. The 7Q10 requirement was developed to protect aquatic life by maintaining certain water quality levels for streams downstream from point source pollution discharges (i.e., water treatment plants) during low flow conditions. The 7Q10 refers to the lowest flow likely to occur for seven consecutive days, once every 10 years (Yaeck 1995). Stalnaker et al. (1994) stated that this hydrologic technique is inappropriate for establishing instream flows for fish because it does not address the flow requirements of fish. The State of Delaware presently does not have an instream flow standard for protection of stream organisms. The 7Q10 is currently the default standard of protection in the absence of a statewide policy. The goal of this project was to gather data requested by the Instream Flow Needs Joint Task Force that can be incorporated with the information from the Phase I impact assessment and the Phase II wetted perimeter analysis to aid in the determination of a streamflow passby standard in Northern Delaware.

In September 1994, the Water Resources Division of the Delaware Department of Natural Resources and Environmental Control (DNREC) convened an initial meeting of a Joint Task Force to conduct an Instream Flow Needs Analysis for streams in Northern New Castle County (Yaeck 1995). This task force consisted of representatives of Federal and State government agencies, as well as private organizations (Appendix 1). Phase I of the analysis initiated by the Joint Task Force assessed the impact of the 7Q10 passby requirements previously imposed on public water supply intakes. This assessment focused on four major water intakes in Northern Delaware which included: (1) the City of

Newark's public water supply intake on White Clay Creek; (2) the United Water Delaware's public water supply intake on White Clay Creek near Stanton; (3) the City of Wilmington's intake on the Brandywine River; and (4) the United Water Delaware's intake on the Christina River at Smalley's Pond. During Phase I, 7Q10 was determined at each intake, and 7Q10 depths and velocities were calculated for selected study reaches using the HEC-2 hydraulic model. Following the completion of Phase I of the Instream Flow Needs Analysis, the Joint Task Force recommended that a second phase be performed to refine the activities conducted during Phase I.

Phase II of the Instream Flow Needs Analysis included a wetted perimeter analysis to determine what instream flows are necessary to minimally protect all habitat needs of aquatic organisms. Lamb (1989) stated that the wetted perimeter technique examines the narrowest wetted bottom of a stream cross-section or critical areas (typically a riffle) that is estimated to minimally protect all habitat needs. The Joint Task Force requested the assistance of the Delaware Division of Fish and Wildlife to collect additional fish abundance, fish habitat, and water quality information to use in conjunction with the wetted perimeter analysis to determine the adequacy of the 7Q10 to protect aquatic organisms and uses.

METHODS

Field sampling was divided into three main categories: (1) fish sampling; (2) stream physical characteristics; and (3) water quality sampling. Sampling began August 15 and concluded November 1, 1995. Sample section locations (Table 1) were randomly selected by habitat type from the four study reaches described by Yaeck (1995). The study reaches included:

- Brandywine Creek - One and a half mile-long reach adjacent to the Wilmington Water Supply raceway withdrawal at Brandywine Park. The study limits extend from the C & D railroad bridge downstream to the Market Street Bridge.
- White Clay Creek near Stanton - Two mile-long reach adjacent to the United Water Delaware withdrawal at Stanton. The study limits extend from the Route 4 Bridge downstream to Churchmans Marsh.
- White Clay Creek near Newark - One and a half mile-long reach adjacent to the City of Newark water treatment plant near Paper Mill Road.
- Christina River - Two mile-long reach adjacent to the United Water Delaware's intake at Smalley's Pond. The study limits extend from one-half mile upstream from Smalley's Pond downstream to the Route 273 Bridge.

Stream habitat types were classified as either pool, riffle, tidal pool, or dam pool. Naturally occurring pools and riffles were classified as such. Tidal pools were defined as those pools that occurred in tidally influenced areas. The larger, deeper pools located directly upstream from dams were classified as dam pools. The sampling scheme required that each habitat type at each stream be sampled at least once per month under low flow conditions (i.e., at or near the 7Q10) through the month of October. All habitat types on each stream were sampled in September and October. Although only 1/2 of the total sampling days were available in August, most of the habitat types were sampled at least once during that month. Prior to daily sampling, a gaging station was telephoned to obtain a gage height reading, and flows were calculated to insure that sampling occurred under low flow conditions. Flows were determined using rating curves provided by the Delaware Geological Survey. Tidally influenced sample sections were sampled at a low tide. Sample sections defined during Phase I were located using maps, field notes, and GPS coordinates provided by the Water Resources Agency of New Castle County.

FISH SAMPLING

The relative abundance of fish species was determined within 30.5-m sample sections that were selected from the 80 transects previously established in Phase I for all four study reaches. Sample sections less than 30.5-m long were sampled along their entire length. A stratified sampling approach was used to randomly select transects for sampling by the habitat type they intersected. For example, three habitat types existed within Brandywine Creek. They included pool, riffle, and dam pool habitats. Each habitat type was sampled at least once throughout the months of September and October. This same approach was used to sample White Clay Creek at Newark and Stanton, and the Christina River during these months. Since sampling was initiated in the middle of August, each habitat type present in the streams could not be sampled during the month of August.

All fish were sampled using a Smith - Root Model 15-C Backpack Electrofisher set on pulsed D.C. current. Tidal areas were sampled under low tide conditions. Most of the sampling was accomplished by electrofishing on foot, although some sampling (primarily in the dam pools) was performed with the electrofisher mounted in a 3.7-meter flat bottom aluminum boat. The boat and equipment were light enough to portage to the stream in those areas where no boat ramp was available. Two slightly deeper pool sections were sampled using a float tube. Block nets were employed where

possible to eliminate movement of fish out of the sample section. Block nets were not used on the Brandywine River due to excessive stream widths and an abundance of large boulders along the river bottom. Up to four passes were made with the electrofisher at each sample section. Some sections received fewer passes due to sampling problems such as electrofisher failure. For most sample sections, the effective fishing radius was approximately one-half the stream width. Therefore, for sampling purposes, each 1/2 of the stream width in the 30.5-m section was shocked to obtain two sub-samples. The sub-samples were combined to represent one sample (and one full pass). Because of the extensive width of the Brandywine River, several sub-samples were necessary to obtain a complete sample.

Fish were identified and measured. The fish were transported and released far downstream between samples to eliminate repeated sampling of the same fish. The time required for each sample was recorded to determine catch per unit effort. The catch per unit effort was measured as catch per minute (CPM) of electrofishing time. Mean CPM rates were calculated for each species by stream, habitat type and species for four complete passes per sample. Those samples with less than four electrofishing passes were expanded to four passes using proportional weighting from samples with four passes in that habitat type. Weighted mean CPM rates for each species were calculated to reflect mean CPM rates that were weighted by the potential number of sampling sections within the study reach. Sokal and Rohlf's (1995) equation for weighted averages was used to determine these weighted mean CPM rates which were calculated as:

$$\bar{y}_w = \sum_{i=1}^{N} w_i \bar{y}_i \Big/ \sum_{i=1}^{N} w_i$$

where $\bar{y}_w$ = weighted mean CPM for each species by habitat type,

w_i = the potential number of sampling sections of each habitat type in the reach,

$\bar{y}_i$ = the mean CPM for each species by habitat type,

and $\sum_{i=1}^{N} w_i$ = the sum of all habitat sections.

The potential number of sampling sections (w_i) used in the above equation were determined from the lengths of pools, riffles, dam pools and tidal pools measured within each study reach. A stream section was designated as a potential sampling section by determining the total number of possible sampling sections (30.5 m long) of a specific habitat within each study reach. In some situations, a section of a specific habitat (e.g., riffles) was shorter than 30.5 m. A minimum sampling length of 12 m was established for those sections. In other words, those stretches of stream containing a length of specific habitat less than 30.5 m long were still counted as a potential sampling section if their length exceeded 12 m. See *"Percentage of Pools and Riffles"* below for the methods used to measure the lengths of the different habitat types.

Life stages were determined from age-length groupings found in the literature. Length frequency histograms were constructed for the target species of interest in this study using 1.0 mm intervals. Length frequency tables were prepared for the non-target species for addition to the Division's baseline data set from which comparisons can be made and impacts predicted of projects which could potentially affect the fishes in these streams.

STREAM PHYSICAL CHARACTERISTICS

- Percentage of Pools and Riffles

Pools (including natural, dam, and tidal) and riffle lengths were measured to determine the percent pool and percent riffle in each study reach and the potential number of sample sections. A rangefinder was used to measure the lengths of the two habitat types. Excessively long reaches of continuous deeper dam pools and tidal pools were estimated using U.S. Geological Survey topographic maps.

- Stream Width, Depth, and Velocity

Stream width, depth and water velocities were measured immediately following fish sampling. Stream widths were measured to the nearest 3.0 cm along the transect with a fiberglass measuring tape. A Global Flow Probe current meter and measuring rod were utilized to measure stream depths and water velocities. The minimum measuring capacity of this current meter was 9.1 cm/sec. Thus, water velocities that were displayed at 9.1 cm/sec may have been less than 9.1 cm/sec. Stream depths were measured to the nearest 1.0 cm at 1.5-m intervals along the

transect. In water less than 0.6 m deep, velocity was measured at six-tenths of the surface to bottom water depth at 1.5-m intervals across the transect. Mean column velocity was averaged from measurements taken at two-tenths and eight-tenths the water depth at locations with water depths greater than 0.6 m (Hunter 1991). Standard error and 95% confidence intervals were calculated using methods on page 562 in Steel and Torrie (1980).

- Stream Bottom Composition

Stream bottom substrates were characterized using the surface visual analysis method (Platts et al. 1983). The substrates were described using the size ranges of substrate channel materials defined by the American Geophysical Union (AGU) which were modified by Bovee (1986) to include organic materials and bedrock as substrate types. For this study it was appropriate to combine several of the size classes (Table 2). Clay, silt and sand were combined into one size range (.00024 - 2.0mm), as were the fine, medium and coarse gravels (2.0 - 64mm), small and large cobbles (64 - 256mm), small and medium boulders (256 - 1,024mm), and large and very large boulders (1,024 - > 2,048mm). A circular piece of plexiglass glued to the bottom of a 1.5 meter long section of 15 cm diameter PVC pipe was used as a sight tube to estimate substrate percentages on the stream bottom. Substrate composition was measured at 1.5 m intervals along the transect.

WATER QUALITY

Water quality sampling was conducted each sampling day prior to fish sampling. Surface temperature, dissolved oxygen, pH, and conductivity were measured with a Corning Checkmate Modular Testing System.

TARGET SPECIES SELECTION, LITERATURE REVIEW AND DATA VALIDATION

Literature on habitat suitability criteria and species information was reviewed and compiled to provide additional information on target species habitat preferences at various life stages. The literature search for information on habitat suitability focused on species specific habitat variables such as depth, velocity, spawning period, and spawning substrate. Life stage specific information was obtained from the literature for the target species determined by this study, in addition to those species selected in Phase I of the instream flow study. Captured fishes were characterized as juveniles or adults based on published results. Data were utilized from studies that were conducted closest to Delaware to try to maintain regional homogeneity when characterizing the body lengths separating

species life stages. The life stage information was utilized in conjunction with the length frequency histograms to narrow the scope of the literature search to data pertaining to the most abundant specific life stage (i.e., juvenile or adult), and to corroborate the literature findings with the target species information obtained from the field. Habitat suitability criteria and species information were located using sources such as Fisheries Review, Current Contents, Delcat (University of Delaware's Information Technologies), and Absearch (American Fisheries Society's Computer Indices and Abstracts from Professional Journals). When habitat suitability index (HSI) numbers were obtained for a desired species, a suitability index of 0.4 was used as the minimum value below which a parameter is limiting to the species. Instream flow experts from many states including New York, Pennsylvania, California, Georgia, Colorado and South Carolina were contacted in an effort to obtain available "gray" literature that contained habitat suitability information. Examples included state fisheries investigations, Ph.D. dissertations, masters theses, and consultant reports. The inter-library loan program available at most libraries was also utilized during this research.

Species selected during Phase I of the assessment were reviewed to evaluate their appropriateness as target species. This approach was based on the use of the wetted perimeter analysis. The assumption was made that there is a minimum flow that satisfies the need for fish food production, fish passage and spawning. Since riffles were chosen as critical areas for this study, revised target species were selected during this Phase II assessment by ranking species that exhibited a high preference for riffle habitats during these summer/fall months. A species was denoted as having a high preference for riffles if their CPM rate from riffle habitats comprised 85% or more of their total mean CPM rate. The three species exhibiting the highest preference for riffles were selected as potential target species for Brandywine Creek and White Clay Creek near Newark.

Results/Discussion

- Brandywine Creek

A total of 1,440 fish representing 18 species were sampled from the Brandywine Creek (Table 3). Redbreast sunfish *Lepomis auritus* made up 35.7% of the total catch followed by American eel *Anguilla rostrata* (28.0%). Redbreast sunfish and American eel respectively, exhibited the two highest weighted mean CPM rates for the entire reach (Table 4). Smallmouth bass *Micropterus dolomieu* and rock bass *Ambloplites rupestris* were selected as potential target species during Phase I of the Instream Flow Needs Analysis by the Joint Task Force Committee. These two species made up

7.7% and 7.1% of the catch respectively. Although Table 4 shows that these two species exhibited slightly higher mean CPM rates in riffles, they did not meet the criteria for inclusion as a target species in Phase II, and were categorized as a generalist species (i.e., a species which does not prefer a specific habitat type). The three species that exhibited the highest preference (>85% CPM) for riffles in the Brandywine Creek are as follows:

Species	% of mean CPM in riffles
Longnose Dace *Rhinichthys cataractae*	100%
Satinfin Shiner *Cyprinella analostana*	98%
Tesselated Darter *Etheostoma olmstedi*	86%

All the longnose dace collected within the study reach were within the adult size class range shown in Figure 1. The majority of satinfin shiners sampled, illustrated in Figure 2, consisted primarily of adults (90%). No age-length grouping information was available on the tesselated darter (Figure 3). Figures 4 and 5 show the length frequencies of the two potential target species, smallmouth bass and rock bass, selected during Phase I of the instream flow study. Length frequency information on the other species caught in the Brandywine River are illustrated in Table 5.

Mean width, depth, and velocity for each habitat type sampled on the Brandywine Creek are listed in Table 6. Widths ranged from 16.8 - 51.7 m, and depths from 0.01- 1.7 m for all habitat types. As expected, mean velocities were highest in the riffle areas and lowest in the dam pool sections.

The results from the substrate sampling on Brandywine Creek were typical of the habitat types from which they originated. The slower moving dam pool and pool areas consisted primarily of sand, silt and clay (Figure 6), although a fair amount of boulders and cobble were present. The faster flowing riffle areas consisted mainly of cobble, and boulders.

Water temperature, dissolved oxygen (Figure 7), conductivity, and pH (Figure 8) measurements taken on Brandywine Creek indicated that the water quality was generally suitable for general fish health and survival.

Pools comprised 68.4% of the study reach and riffles 31.6%. A total of 1809 meters were measured to determine the percentage of pools and riffles within the study reach.

- Christina River

A total of 383 fish representing 20 species were sampled from the Christina River (Table 7). Two centrarchid species, bluegill *Lepomis macrochirus* and pumpkinseed *Lepomis gibbosus* constituted 36.6% and 16.4% of all species sampled respectively. Length frequency information on all the species sampled is illustrated in Table 8. The Joint Task Force Committee selected white perch *Morone americana* and catfish species (Family Ictaluridae) as target species during Phase I of the Instream Flow Needs Analysis. No catfish species and only one white perch was sampled in the study reach.

No target species were chosen by the Division during Phase II for several reasons which included: (1) the study reach consisted of 100% tidal pool habitat and did not contain any critical riffle habitat areas; (2) species that rely specifically on tidal pool habitat (e.g., killifish) for growth, production and survival were sampled in low numbers or were absent; and (3) the tidal influence in this study reach creates a system too complex for a species-based approach to instream flow at this time.

Table 9 lists the mean widths, depths and velocities calculated for the sample reach. Widths ranged from 7.0 - 12.7 m. Water velocities within the reach were low and never exceeded the current meter minimum reading of 9.1 cm/sec.

Substrate samples obtained from the sample reach consisted primarily of sand, silt and clay (Figure 9), which is typical of tidal habitats. Many of the large materials present (i.e., boulders, cobble, and gravel) were a result of pieces of concrete that had been placed in the stream channel.

Water quality samples obtained from the Christina River (Figures 10,11) met the requirements for general fish health and survival with one exception. A sample obtained on August 28 contained a dissolved oxygen level of 3.70 ppm. Concentrations less than 1.5 ppm can quickly cause mortality (Dove and Nyman 1995). This is of special concern since the Delaware Surface Water Quality Standard for the daily average dissolved oxygen level is 5.5 ppm, with a minimum standard at any time of 4.0 ppm (DNREC, 1993).

There was only one habitat type (i.e., tidal pool) within the study reach.

- White Clay Creek near Newark

A total of 3,017 fish representing 26 species were sampled from White Clay Creek near Newark (Table 10). White suckers *Catostomus commersoni* made up 19.1% of the total number sampled and were dominant in pool habitats. Tesselated darters *Etheostoma olmstedi* were abundant in pool and riffle habitats and constituted 16.5% of the total number sampled.

Common shiner *Luxilus cornutus*, white sucker and tesselated darter exhibited the highest weighted mean CPM for the entire reach respectively (Table 11). The Joint Task Force Committee selected brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* as the species that require minimum flow depths for habitat protection during Phase I of the Instream Flow Needs Analysis. No trout species were sampled in the study reach. The three species that exhibited the highest preference for riffle habitat in the White Clay Creek near Newark are as follows:

Species	%of mean CPM in riffles
Longnose Dace *Rhinichthys cataractae*	100%
Blacknose Dace *Rhinichthys atratulus*	99%
Common Shiner *Luxilus cornutus*	99%

The majority (62%) of longnose dace sampled on White Clay Creek near Newark (Figure 12) consisted of adults. Adults made up 80% and 95% of the total number of blacknose dace (Figure 13) and common shiners (Figure 14) sampled respectively. Table 12 contains length frequency information on the other species sampled.

Mean width, depth, and velocity for each habitat type sampled on White Clay Creek near Newark are listed in Table 13. Stream width ranged from 7.6 m to a maximum of 31.7 m, and stream depths from 0.03 - 2.0 m for all habitat types. Water velocities ranged from 9.1 cm/sec (in a dam pool section) to 435.9 cm/sec (in a riffle section).

Sand, silt, and clay dominated the substrate samples in the slow-moving dam pools and pool habitats on White Clay Creek near Newark (Figure 15). The substrate samples obtained from the higher velocity riffle areas consisted primarily of cobble and gravel.

Water quality attributes measured on White Clay Creek near Newark were conducive to general fish health and survival (Figures 16, 17), although water temperatures in August exceeded the upper maximum temperature tolerance of 27.0°C for the adult brown trout, *Salmo trutta* (Raleigh et al. 1986).

Brown trout represent one of the two trout species (the other being rainbow trout) that are considered recreationally important species by the Division of Fish and Wildlife. This is strictly a put and take fishery, and there has been no evidence of natural reproduction of trout. Based on this, the

showed that the range of depths utilized by the longnose dace ranged from 0.03 - 1.03 m (0.10-3.38 ft) with the average minimum being 0.11 (0.36 ft) to 0.42 m (1.38 ft). Longnose dace were found in velocities of 17 - 182 cm/sec (0.56-5.97 ft/sec). Averaged minimum and maximum velocities selected were 36.6 cm/sec (1.20 ft/sec) and 115.6 cm/sec (3.80 ft/sec) respectively.

The results of the wetted perimeter analysis (supplied by Mr. Richard Greene of DNREC) and how those values relate to the established fish habitat criteria are shown in Table 24. The discharge, flow depth, and velocity at the 7Q10 level, and at the upper and lower wetted perimeter break points are listed for the representative riffle sections. The break points (or sometimes referred to as inflection points) represent the two points on a plot of wetted perimeter versus flow for a stream riffle cross-section (Figure 23), where the rate of increase of wetted perimeter changes (Leathe and Nelson 1989). Below the lower break point, small increases in flow result in a rapidly increasing wetted perimeter and shallower depths (Figure 24). The main premise behind a wetted perimeter analysis is that the flows that occur between the upper and lower wetted perimeter break points should provide adequate habitat for the survival of aquatic organisms. The upper break point represents the flow at (or above) which the amount of available habitat is at an optimum for aquatic organisms. Comparisons were made between the average depth and velocity needs for fish, the 7Q10, and the upper and lower wetted perimeter break points in Table 24 to determine if the depths and velocities at these flow levels are adequate for fish survival during the low flow period. The 7Q10, and upper and lower wetted perimeter break point depths for all stream sections examined from Brandywine Creek and White Clay Creek near Newark are greater than the depth criteria for fish and should provide adequate protection for the target species of fish. The lower wetted perimeter velocity measurement from White Clay Creek Section 53115 was 0.3 cm/sec lower than the established average fish criteria. This small difference was determined to be insignificant by the Joint Task Force members. The 7Q10, and upper and lower wetted perimeter velocity break points for Section 57970 at White Clay Creek at Newark did not meet or exceed the established average fish criteria for velocity of 36.6 cm/sec. The Joint Task Force members concluded that although the 7Q10, and upper and lower wetted perimeter break point values determined during this Phase II effort did not meet or exceed the average velocity criteria values for fish resulting from the literature search, the values did lie within the range of velocity values for species observed during these studies and thus were marginally acceptable.

There was concern by the Task Force members that the habitat suitability and species information collected on the target species were criteria pertaining to "minnow size" species and

would not be adequate to protect recreationally important larger fish that use, but do not necessarily prefer, the riffle areas. Larger species of concern, sampled in the riffle areas of Brandywine Creek, included smallmouth bass, rock bass, and redbreast sunfish. An analysis of the data led to the conclusion that 79% of all smallmouth bass, 60% of all rock bass, and 69% of all redbreast sunfish sampled from riffles were smaller than the largest longnose dace collected in the riffle sections. The larger growing fish species of concern on White Clay Creek near Newark were largemouth bass, rock bass and redbreast sunfish. Of those captured in riffle samples, 100%, 56% and 67% respectively were smaller than the largest longnose dace sampled. The fact that many of these larger growing species that utilize riffle areas during the day were juveniles indicates that an instream flow standard based on the habitat criteria for longnose daces should provide adequate protection during the low flow period for the above game species, at least for the smaller individuals found in riffles in daytime sampling.

In conclusion, based on the information gathered during this study and hydrologic information provided by the Water Resources Agency for New Castle County, the 7Q10 appears adequate to meet the minimal needs of the target species in Brandywine Creek and White Clay Creek at Newark during typical low flow periods (i.e., July-October).

Conclusions / Recommendations

Although this study proved to be useful for examining the adequacy of different low flow regimes on certain parameters important to fish survival within specific tributaries in Delaware, it was not solely designed to establish a "minimum flow standard" protective of all fishes in all systems, and should not be used as such. This study was designed to be used in conjunction with other standard setting practices, for example, those designed to protect water quality (7Q10). If a minimum flow standard based on what is optimal to aquatic organisms, rather than what is needed to uphold water quality standards is desired, other appropriate techniques such as the Instream Flow Incremental Methodology (IFIM) could be used to determine what flow is necessary to protect existing populations during low flow conditions. Data generated in this study could be used as groundwork for a more detailed IFIM study now that it has been established which species are present in these systems and in what habitat types.

Caution also should be applied if the wetted perimeter break point information is to be used to establish a streamflow passby standard. Annear and Conder (1984) noted two drawbacks of the wetted perimeter method: (1) the break points are chosen solely on a subjective basis and recommendations

can vary between investigators; and (2) plots of wetted perimeter that have no clearly defined break point or where multiple break points occur can complicate the interpretation of the data. Further complications may be encountered from streams where the flow is distributed among many channels. These braided reaches are very difficult to model hydraulically (Leathe and Nelson 1989).

These drawbacks are apparent among some of the cross-sections sampled. For example, the plots of wetted perimeter versus flow for Sections 2.94 (Figure 25) and 2.55 (Figure 26) on Brandywine Creek are curved with no clearly defined breakpoints. The absence of obvious break points on these indistinct wetted perimeter plots reduces their utility in predicting the wetted perimeter.

During low flow conditions along several riffle sections of Brandywine Creek during the study period, the entire perimeter of the stream channel was not completely wetted. Braiding patterns within the main channel were apparent, resulting from extremely low flows and the presence of large boulders and rocky substrate along the stream bottom. This braiding effect may have contributed to the complexity of some of these wetted perimeter plots.

Given the caveats that are associated with the wetted perimeter method, and the results obtained from this wetted perimeter effort, the Delaware Division of Fish and Wildlife recommends that a streamflow passby standard in northern Delaware not be based solely on the wetted perimeter results from this study. The intent of this study was to determine the adequacy of the 7Q10 to protect aquatic organisms in streams in New Castle County, not to determine a streamflow passby standard based only on the wetted perimeter results.

This report is an appendix to the Phase II report of the Instream Flow Needs Analysis. Copies of this appendix can be obtained from the Fisheries Section, DNREC- Division of Fish and Wildlife, P.O. Box 1401, 89 Kings Highway, Dover, Delaware, 19903 (contact person: Roy Miller, (302)739-4782). The complete Instream Flow Needs Analysis, Phase I and II reports can be obtained from the Water Supply Section, DNREC-Division of Water Resources, P.O. Box 1401, 89 Kings Highway, Dover, Delaware, 19903 (contact person: Stewart Lovell, (302)739-4793).

Acknowledgments

I wish to acknowledge the efforts of Roy Miller, Mark Zimmerman, and Jared Jacobini of the Fisheries Section for their assistance in conducting field work, and Desmond Kahn for his technical support during this study. Also, a special thanks to Richard Greene and Stewart Lovell of DNREC-Division of Water Resources, Gerald Kauffman of WRANC, consultant Dave Yaeck and other

members of the Instream Flow Joint Task Force for their suggestions and recommendations during this study.

References

Aadland, L.P., C.M. Cook, M.T. Negus, H.G. Drewes, and C.S. Anderson. 1991. Microhabitat preferences of selected stream fishes and community-oriented approach to instream flow assessments. Minnesota Department of Natural Resources, Division of Fish and Wildlife, Investigational Report No. 406, St. Paul, MN.

Allen, K.O., and J.W. Avault. 1970. The effect of salinity on growth of channel catfish. Proceedings of the Southeastern Association of Game and Fish Commissioners 23:319-331.

Annear, T.C., and A.L. Conder. 1984. Relative biases of several fisheries instream flow methods. North American Journal of Fisheries Management 4:531-539.

Bailey, R.M., H.E. Winn, and C.L. Smith. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proceedings of the Academy of Natural Sciences, Philadelphia 106:109-164.

Bartnik, V.G. 1970b. Reproductive isolation between two sympatric species of dace, *Rhinichthys cataractae* and *Rhinichthys atratulus*, in the Mink and Valley Rivers, Manitoba. M.S. Thesis, University of Manitoba, Winnipeg.

Bartnik, V.G. 1970. Reproductive isolation between two sympatric dace, *Rhinichthys atratulus* and *R. cataractae*, in Manitoba. Journal of the Fisheries Research Board of Canada 27:2125-2141.

Bovee, K.D. 1974. The determination assessment, and design of "instream value" studies for the northern Great Plains region. University of Montana, Missoula, MT. Final Report. Environmental Protection Agency, Contract No. 68-01-2413.

Bovee, K.D. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Instream Flow Information Paper 21. U.S. Fish and Wildlife Service Biological Report 86 (7).

Bragg, R.J., and R.H. Stasiak. 1978. An ecological study of the blacknose dace, *Rhinichthys atratulus*, in Nebraska. Proceedings of the Nebraska Academy of Sciences and Affiliated Societies 88:8. (Cited by Trial et al 1983)

Brazo, D.C., C.R. Liston, and R.C. Anderson. 1978. Life history of the longnose dace,

Rhinichthys cataractae, in the surge zone of eastern Lake Michigan near Ludington, Michigan. Transactions of the American Fisheries Society 107:550-556.

Cunjak, R.A., and G. Power. 1986. Winter biology of the blacknose dace, *Rhinichthys atratulus*, in a southern Ontario stream. Environmental Biology of Fishes 17:53-60.

Dahlberg, M.D. 1972. An ecological study of Georgia coastal fishes. Fishery Bulletin 70:323-353.

DNREC 1993. State of Delaware surface water quality standards as amended February 26, 1993. Department of Natural Resources and Environmental Control. Dover, DE.

Dove, L.E. and R.M. Nyman, eds. 1995. Living reources of the Delaware Estuary. Delaware Department of Natural Resources and Environmental Control, Delaware Estuary Program, Dover, DE.

Dovel, W. L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. University of Maryland, Natural Resources Institution Special Report No. 4.

Edwards, E.A., H. Li, and C.B. Schreck. 1983. Habitat suitability index models: longnose dace. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.33.

Facey, D.E., and G.D. Grossman. 1992. The relationship between water velocity, energetic costs, and microhabitat use in four North American stream fishes. Hydrobiologia 239:1-6.

Finger, T.R. 1982. Fish community - habitat relations in a central New York stream. Journal of Freshwater Ecology 1(4):343-352.

Fritz, E.S., and E.T. Garside. 1975. Comparison of age composition, growth, and fecundity between two populations each of *Fundulus heteroclitus* and *Fundulus diaphanus*. Canadian Journal of Zoology 53(4):361-369.

Funderburk, S.L., J.A. Milhursky, S.J. Jordan, and D. Riley. 1991. Habitat requirements for Chesapeake Bay living resources. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Chesapeake Bay Program Office, Annapolis, MD.

Gee, J.H., and T.G. Northcote. 1963. Comparative ecology of two sympatric species of dace (Rhinichthys) in the Fraser River system, British Columbia. Journal of the Fisheries Research Board of Canada 20:105-118.

Gibbons, J.R.H., and J.H. Gee. 1972. Ecological segregation between longnose and blacknose dace (genus *Rhinichthys*) in the Mink River, Manitoba. Journal of the Fisheries Research Board of Canada 29:1245-1252

Hardy, J. D., Jr. 1978. Development of fishes of the Mid-Atlantic Bight. An atlas of egg, larval and juvenile stages, Vol. 2. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-78/12.

Hunter, C.J. 1991. Better trout habitat. A guide to stream restoration and management. Island Press, Washington, D.C.

Johnson, J.H., D.S. Dropkin, and P.G. Shaffer. 1992. Habitat use by a headwater stream fish community in north-central Pennsylvania. Rivers 3(2):69-79.

Jones, P.W., F.D. Martin and J.D. Hardy, Jr. 1978. Development of Fishes of the Mid-Atlantic Bight. An atlas of egg, larval and juvenile stages, Vol. 1. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-78/12.

Kilby, J.D. 1955. The fishes of two gulf coast marsh areas of Florida. Tulane Study of Zoology. 2:175-247. (Cited by Stuber et al 1982)

Lamb, B.L. 1989. Quantifying instream flows: Matching policy and technology. In: Designing and Negotiating Studies using IFIM. U.S. Department of the Interior, Fish and Wildlife Service, Fort Collins, CO.

Leathe, S.A., and F.A. Nelson. 1989. A literature evaluation of Montana's wetted perimeter inflection point method for deriving instream flow recommendations. Montana Department Of Fish, Wildlife and Parks, Helena, MT.

McMahon, T.E., and J.W. Terrell. 1982. Habitat suitability index models: channel catfish. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.2.

Meador, M.R. and W.E. Kelso. 1990. Growth of largemouth bass in low salinity environments. Transaction of the American Fisheries Society 119:545-552.

Miller, R.J. 1964. Behavior and ecology of some North American cyprinid fishes. American Midland Naturalist 72(2):3-13.

Noble, R.L. 1965. Life history and ecology of western blacknose dace, Boone County, Iowa, 1963-1964. Iowa Academy of Sciences 72:282-293.

Page, L.M. 1983. Handbook of darters. T.F.H. Publications, Inc., Neptune City, NJ.

Pardue, G.B. 1983. Habitat suitability index models: alewife and blueback herring. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS/10.58

Perry, W.G. 1973. Notes on the spawning of blue and channel catfish in brackish water ponds. Progressive Fish Culturist 35(3): 164 - 166.

Perry, W.G. and J.W. Avault. 1968. Prelininary experiments on the culture of blue, channel and white catfish in brackish water ponds. Proceedings of the Southeastern Association Game and Fish Commissioners 22:396 - 406.

Platts, W.S., W.F. Megahan and G.W. Minshall. 1983. Method for evaluating stream, riparian, and biotic conditions. U.S. Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report No. INT-138. Logan, UT.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: brown trout, revised. U.S. Department of the Interior, Fish and Wildlife Service Biological Report 82 (10.124)

Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell. 1994. Freshwater Fishes of the Carolinas, Virgina, Maryland, & Delaware. The University of North Carolina Press, Chapel Hill, NC.

Schwartz, F.J. 1958. The breeding behavior of the southern blacknose dace, *Rhinichthys atratulus obtrisus* Agassiz. Copeia 1958:141-143.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Sheldon, A.L. 1968. Species diversity and longitudinal succession in stream fishes. Ecology 49:193-198.

Sigler, W.F., and R.R. Miller. 1963. Fishes of Utah. Utah State Department of Fish and Game, Salt Lake City, UT.

Smith, C.L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation, Albany, NY.

Sokal, R.R., and Rohlf, F.J. 1995. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company, New York.

Stalnaker, C., B.L. Lamb, J. Herriksen, K. Bovee, and J. Bartholow. 1994. The instream flow incremental methodology. A primer for IFIM. National Biological Service, Fort Collins, CO.

Stanley, J.C. and D.S. Danie. 1983. Species profile: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic): white perch. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/11.7.

Steel. R.D.G., and J.H. Torrie 1980. Principles and procedures of statistics. A biometrical approach. McGraw-Hill Publishing Company, New York.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index model: largemouth bass. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.16.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat suitability index models: bluegill. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.8.

Tebo, L.B., Jr., and E.G. McCoy. 1964. Effect of sea-water concentration on the reproduction and survival of largemouth bass and bluegill. Progressive Fish Culturist 26:99-106.

Trial, J.G., C.S. Wade, J.G. Stanley, and P.C. Nelson. 1983. Habitat suitability information: common shiner. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.40.

Weisberg, S. 1986. Competition and coexistence among four estuarine species of *Fundulus*. American Zoological 26:249-257.

Wesche, T.A. and P.A. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. In: Designing and negotiating studies using IFIM. U.S. Fish and Wildlife Service, Fort Collins, CO.

Yaeck, D.C. 1995. Report of the Joint Task Force. Instream Flow Analysis for Northern New Castle County, Delaware. Phase one: 7Q10 assessment. David C. Yaeck Consulting Services, West Chester, PA.

Table1. Sample section locations by water and habitat type for the four study reaches. BW = Brandywine Creek, CC = Christina Creek, WCCN = White Clay Creek at Newark, and WCCS = White Clay Creek near Stanton.

Date Sampled	Water	Habitat Type	Section No.	Location Description*
08-15-95	WCCS	Riffle	14073	First riffle downstream from old Rt. 7 Bridge
08-15-95	WCCS	Pool	15890	First pool downstream from old Rt. 7 Bridge
08-16-95	WCCN	Riffle	53155	Riffle beginning at bridge on Papermill Rd.
08-23-95	WCCN	Pool	56000	Deep pool located at sharp curve on Tweeds Mill Rd.
08-24-95	BW	Riffle	2.55	First riffle upstream from Baynard Blvd.
08-28-95	CC	Tidal Pool	58915	Pool at Smalley's Dam Rd intersection
09-01-95	BW	Pool	2.99	Plunge pool below city dam
09-05-95	WCCN	Riffle	57970	Riffle at approximately 1300 feet downstream from dam at water intake. Marked on west trail - WCC1
09-06-95	WCCN	Pool	58305	Plunge pool below dam at water intake
09-07-95	BW	Riffle	2.94	Riffle at concrete box on east shoreline, below city dam
09-08-95	WCCN	Pool	56623	Located upstream from curve on Tweeds Mill Rd. begins where small tributary enters creek on east side. Marked on west trail - WCC3
09-11-95	WCCS	Tidal Pool	9800	Pool located directly below 1st ravine on the northside of the Artesian Water Company access road off Rd 336D
09-12-95	CC	Tidal Pool	59926	Pool located approximately 600 feet downstream from dam where Smalley's Dam Rd. (on S. side) of river meets the stream (marked on trail)
09-13-95	WCCS	Pool	16430	Pool located 250 feet upstream from RT 4 Bridge
09-14-95	WCCS	Tidal Pool	9750	Pool begins 50 feet downstream from section 9800 and continues downstream where channel narrows
09-20-95	WCCN	Dam Pool	53345	Dam pool located above dam at Paper Mill Rd.
09-28-95	BW	Dam Pool	3.32	Dam pool located 50 feet upstream from upstream end of the Augustine Cutoff Bridge Abutment
09-29-95	BW	Pool	2.93	Pool begins at tributary on east side, below city dam
10-2-95	WCCN	Riffle	55713	Riffle located where Tweeds Mill Rd. meets the creek 1st riffle below curve. Marked on road - WCC4
10-3-95	WCCN	Dam Pool	55360	Pool located 300 feet downstream from section 55713
10-4-95	WCCN	Dam Pool	58375	Pool sampled begins 100 feet upstream from dam at intake
10-10-95	WCCN	Pool	57000	Pool located between two riffles. Directly upstream from Section No. 57970.
10-11-95	WCCS	Pool	15940	Downstream end of section sampled is located 22 feet upstream from confluence with Mill Creek
10-12-95	WCCS	Tidal Pool	10900	Section sampled begins 100 feet upstream from upstream corner of the Hale Byrnes house.
10-13-95	CC	Tidal Pool	59207	Tidal pool located between Section Nos. 59926 and 58915. Marked on south side
10-19-95	BW	Riffle	2.67	1st riffle downstream from Van Buren St. Bridge.
10-20-95	WCCS	Riffle	16180	Riffle located directly under the Route 4 Bridge.
10-31-95	BW	Pool	2.96	Pool located 100 feet downstream from end of riffle at Section No. 2.95
11-01-95	BW	Dam Pool	2.4	Directly under the Baynard Blvd. bridge

* See text for description of the study reaches. Maps indicating the locations of the study reaches and the sampling sections are available in Yaeck, 1995.

Table 2. Generalized substrate classes for use in this instream flow study to determine substrate composition of the stream bottom.

Class Names	Size Range	
	mm	inches
1. Organic detritus		
(log, branches)		
(pine needles)		
(leaf detritus)		
2. Vascular plants		
(Potamogeton)		
(Zanechellia)		
(Ranunculis)		
3. Attached algae		
(Cladophora)		
(Chara)		
(Nitella)		
Inorganic substrate		
4. Clay/silt/sand	0.00024 - 2	9.5E-6 - 7.87E - 2
5. Gravel	2.0 - 64	.08 - 2.5
6. Cobble	64 - 256	2.5 - 10.0
7. Small boulders	256 - 1,024	10.0 - 40.0
8. Large boulders	>1,024	>40.0
9. Bedrock		
(plain, tilted, unfractured,		
jointed, perpendicular, parallel)		

Table 3. The total number of fish sampled by species and habitat type on Brandywine Creek. The lightly shaded areas indicate those species selected as potential target species by the Instream Flow Needs Joint Task Force during Phase I of the instream flow assessment. The darker shaded areas represent those species selected as potential target species during Phase II of the instream flow assessment.

SPECIES	NUMBER SAMPLED IN DAM POOLS	NUMBER SAMPLED IN POOLS	NUMBER SAMPLED IN RIFFLES	TOTAL NUMBER SAMPLED
REDBREAST SUNFISH	147	172	195	514
AMERICAN EEL	22	55	326	403
SMALLMOUTH BASS	8	23	80	111
ROCK BASS	11	37	54	102
SATINFIN SHINER	0	1	76	77
CUTLIPS MINNOW	5	28	36	69
COMMON CARP	2	38	0	38
BLUEGILL	12	9	13	34
WHITE SUCKER	2	24	3	29
PUMPKINSEED	2	9	3	14
TESSELATED DARTER	1	3	10	14
LONGNOSE DACE	0	0	14	14
FALLFISH	0	7	0	7
BLACKNOSE DACE	0	0	4	4
CREEK CHUB	0	0	3	3
WHITE PERCH	0	3	0	3
LARGEMOUTH BASS	2	0	0	2
SPOTTAIL SHINER	0	0	2	2

Table 4. The mean CPM (catch per minute), weighted mean CPM, and SE (standard error) by species and habitat type for 4 electrofishing passes on the Brandywine Creek. The lightly shaded areas indicate those species selected as potential target species by the Instream Flow Needs Joint Task Force during Phase I of the instream flow asessment. The darker shaded areas represent those species selected as potential target species during Phase II of the instream flow assessment.

SPECIES	*MEAN CPM N DAM POOLS N=2	SE	*MEAN CPM IN POOLS N=3	SE	MEAN CPM IN RIFFLES N=3	SE	**WEIGHTED MEAN CPM FOR ENTIRE REACH	SE
REDBREAST SUNFISH	2.654	± 1.333	1.711	± 0.437	1.320	± 0.407	1.933	± 0.266
AMERICAN EEL	0.260	± 0.081	0.432	± 0.132	2.220	± 0.695	0.936	± 0.207
SMALLMOUTH BASS	0.143	± 0.065	0.224	± 0.052	0.609	± 0.177	0.317	± 0.058
ROCK BASS	0.212	± 0.074	0.288	± 0.026	0.341	± 0.261	0.290	± 0.081
CUTLIPS MINNOW	0.055	± 0.018	0.879	± 0.147	0.271	± 0.164	0.194	± 0.064
SATINFIN SHINER	0	0	0.013	± 0.007	0.575	± 0.528	0.186	± 0.153
COMMON CARP	0.017	± 0.017	0.497	± 0.492	0	0	0.164	± 0.145
BLUEGILL	0.105	± 0.105	0.023	± 0.023	0.119	± 0.119	0.083	± 0.087
WHITE SUCKER	0.021	± 0.003	0.091	± 0.054	0.017	± 0.017	0.042	± 0.029
LONGNOSE DACE	0	0	0	0	0.107	± 0.061	0.034	± 0.018
TESSELATED DARTER	0.009	± 0.009	0.005	± 0.005	0.087	± 0.048	0.032	± 0.028
PUMPKINSEED	0.021	± 0.003	0.036	± 0.021	0.018	± 0.010	0.025	± 0.025
SPOTTAIL SHINER	0	0	0	0	0.021	± 0.021	0.007	± 0.007
LARGEMOUTH BASS	0.019	± 0.019	0	0	0	0	0.007	± 0.007
BLACKNOSE DACE	0	0	0	0	0.023	± 0.023	0.007	± 0.007
FALLFISH	0	0	0.020	± 0.020	0	0	0.006	± 0.006
CREEK CHUB	0	0	0	0	0.016	± 0.016	0.005	± 0.005
WHITE PERCH	0	0	0.008	± 0.008	0	0	0.002	± 0.002

* These mean catch per minute rates include samples with less than 4 electrofishing passes that have been expanded (to 4 passes) using proportions from samples with 4 passes in that habitat type.

** These weighted mean catch per minute rates reflect mean CPM rates that have been weighted by the potential number of sampling sites within the study reach. The potential number of sampling sites were determined from the lengths of pools, riffles, and dam pools within the study reach.

Table 5. The length frequency distribution of fish sampled from Brandywine Creek. This table does not include those species designated as potential target species during Phase I and Phase II of the instream flow study. Refer to Figures 1-5 for length frequency information on those species.

	Length Interval (mm)										
Species	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**	**121-140**	**141-160**	**161-180**	**181-200**	**200+**
Redbrest Sunfish	-	28	139	56	102	96	43	34	18	4	-
Cutlips Minnow	-	-	2	5	7	21	18	14	2	-	-
Common Carp	-	-	-	-	-	-	-	-	-	-	22
Bluegill	-	8	16	1	-	2	3	3	1	-	-
White Sucker	-	-	-	1	-	-	-	-	-	-	28
Pumpkinseed	-	-	2	-	1	4	3	4	-	-	-
Fallfish	-	-	-	-	-	-	-	-	-	-	7
Blacknose Dace	-	-	-	4	-	-	-	-	-	-	-
Creek Chub	-	-	-	3	-	-	-	-	-	-	-
White Perch	-	-	-	-	-	-	-	2	1	-	-
Largemouth Bass	-	-	-	1	1	-	-	-	-	-	-
Spottail Shiner	-	2	-	-	-	-	-	-	-	-	-

Table 6. Mean width, depth, velocity, standard error (SE), and range of values for each habitat type sampled on the Brandywine Creek.

HABITAT TYPE	N	MEAN WIDTH (m)	SE	RANGE	N	MEAN DEPTH (m)	SE	RANGE	N	MEAN VELOCITY (cm/s)	SE	RANGE
Dam Pools	2	36.7	± 0.8	(36.0-37.5)	47	0.89	± 0.07	(0.10-1.70)	47	52.4	± 7.0	(0-59.4)
Pools	3	38.6	± 3.4	(33.5-45.0)	69	0.62	± 0.04	(0.10-1.30)	69	33.5	± 15.2	(0-50.9)
Riffles	3	33.0	± 10.1	(16.8-51.7)	60	0.27	± 0.03	(0.01-0.80)	60	67.1	± 31.7	(0-118.6)

Table 7. The total number of fish sampled by species on the Christina River, including the mean CPM (catch per minute) and SE (standard error) for 4 electrofishing passes. The shaded area indicates a species selected as a potential target species by the Instream Flow Needs Joint Task Force during Phase I of the instream flow assessment.

SPECIES	NUMBER SAMPLED IN TIDAL POOLS (BELOW SMALLEY'S POND) N=3	*MEAN CPM IN TIDAL POOLS	SE
BLUEGILL	140	1.870	± 0.494
PUMPKINSEED	63	0.743	± 0.155
BLUEBACK HERRING	42	0.459	± 0.459
REDBREAST SUNFISH	35	0.435	± 0.099
WHITE SUCKER	23	0.343	± 0.189
AMERICAN EEL	21	0.314	± 0.120
ALEWIFE	18	0.193	± 0.085
LARGEMOUTH BASS	12	0.171	± 0.171
TESSELATED DARTER	5	0.081	± 0.065
BANDED KILLIFISH	9	0.051	± 0.051
SATINFIN SHINER	3	0.033	± 0.020
SWALLOWTAIL SHINER	2	0.029	± 0.016
YELLOW PERCH	2	0.026	± 0.015
STRIPED KILLIFISH	1	0.018	± 0.018
SMALLMOUTH BASS	2	0.017	± 0.017
HOGCHOKER	1	0.011	± 0.011
BLACK CRAPPIE	1	0.010	± 0.010
CHAIN PICKEREL	1	0.010	± 0.000
WHITE PERCH	1	0.010	± 0.010
WHITE CRAPPIE	1	0.005	± 0.005

* These mean catch per minute rates reflect those samples with less than 4 electrofishing passes that have been expanded (to 4 passes) using proportions from those samples with 4 passes in that habitat type.

Table 8. The length frequency distribution of fish sampled from the Christinia River.

	Length Interval (mm)										
Species	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**	**121-140**	**141-160**	**161-180**	**181-200**	**200+**
Bluegill	-	11	43	32	24	22	7	1	-	-	-
Pumpkinseed	-	-	14	6	27	11	4	1	-	-	-
Blueback Herring	-	-	-	32	-	-	-	-	-	-	-
Redbreast Sunfish	-	-	2	9	14	7	3	-	-	-	-
White Sucker	-	-	-	-	-	-	-	2	3	3	15
Alewife	-	-	-	-	10	-	-	-	-	-	-
Largemouth Bass	-	-	-	5	2	-	-	-	2	1	2
Tesselated Darter	-	-	4	1	-	-	-	-	-	-	-
Banded Killifish	-	1	2	6	-	-	-	-	-	-	-
Satinfin Shiner	-	-	-	3	-	-	-	-	-	-	-
Swallowtail Shiner	-	-	2	-	-	-	-	-	-	-	-
Yellow Perch	-	-	1	-	-	-	-	1	-	-	-
Striped Killifish	-	-	1	-	-	-	-	-	-	-	-
Smallmouth Bass	-	-	-	-	-	-	1	-	-	-	1
Hogchoker	-	-	-	1	-	-	-	-	-	-	-
Black Crappie	-	-	-	-	-	-	-	1	-	-	-
Chain Pickerel	-	-	-	-	-	-	-	-	1	-	-
White Perch	-	-	-	-	-	-	-	1	-	-	-
White Crappie	-	-	-	1	-	-	-	-	-	-	-

Table 9. Mean width, depth, velocity, standard error (SE), and range of values for the three tidal pool sections sampled on the Christina River.

HABITAT TYPE	N	MEAN WIDTH (m)		SE	Range	N	MEAN DEPTH (m)		SE	Range	N	MEAN VELOCITY (cm/s)		SE	Range
Tidal Pools	3	9.81	±	1.6	(7.0 - 12.7)	17	0.36	±	0.05	(0.03 - 0.8)	17	9.1	±	0.00	(9.1 - 9.1)

Table 10. The total number of fish caught by species and habitat type on White Clay Creek near Newark. The shaded areas indicate those species selected as potential target species during Phase II of the instream flow assessment.

SPECIES	NUMBER SAMPLED IN DAM POOL	NUMBER SAMPLE IN POOLS	NUMBER SAMPLE IN RIFFLES	TOTAL NUMBER SAMPLED
WHITE SUCKER	58	466	53	577
TESSELATED DARTER	25	269	205	499
COMMON SHINER	0	10	350	360
BLACKNOSE DACE	0	6	253	259
SWALLOWTAIL SHINER	30	74	119	223
EASTERN SILVERY MINNOW	0	40	163	203
SATINFIN SHINER	4	31	109	143
REDBREAST SUNFISH	82	39	6	127
AMERICAN EEL	15	43	63	121
LONGNOSE DACE	0	0	107	107
BLUEGILL	54	33	10	97
ROSYSIDE DACE	0	13	44	57
ROCK BASS	17	21	9	47
LARGEMOUTH BASS	19	23	5	47
SPOTTAIL SHINER	0	2	24	26
PUMPKINSEED	9	14	0	23
CREEK CHUB	1	9	13	23
CUTLIPS MINNOW	0	8	13	21
BRIDLE SHINER	19	0	0	19
BROWN BULLHEAD	3	6	0	9
SMALLMOUTH BASS	2	4	1	7
AMERICAN BROOK LAMPRE	1	2	4	7
MARGINED MADTOM	0	4	1	5
SPOTFIN SHINER	0	0	5	5
SEA LAMPREY	1	3	0	4
FALLFISH	0	0	1	1

Table 11. The mean CPM (catch per minute), weighted mean CPM, and SE (standard error) by species and habitat type for 4 electrofishing passes on White Clay Creek near Newark. The shaded areas indicate those species updated as potential target species by the Instream Flow Needs Joint Task Force during Phase II of the instream flow assessment.

SPECIES	*MEAN CPM IN DAM POOLS N=3	SE	*MEAN CPM IN POOLS N=4	SE	*MEAN CPM IN RIFFLES N=3	SE	**WEIGHTED MEAN CPM FOR ENTIRE REACH	SE
COMMON SHINER	0	0	0.072	± 0.034	7.584	± 5.132	1.440	± 0.886
WHITE SUCKER	0.465	± 0.128	3.571	± 2.680	1.610	± 0.851	1.418	± 0.605
TESSELATED DARTER	0.215	± 0.084	1.940	± 1.120	2.912	± 1.849	1.133	± 0.404
SWALLOWTAIL SHINER	0.176	± 0.164	0.568	± 0.351	4.280	± 0.983	1.042	± 0.207
BLACKNOSE DACE	0	0	0.038	± 0.038	3.531	± 2.207	0.673	± 0.381
SATINFIN SHINER	0.024	± 0.024	0.222	± 0.129	2.248	± 0.093	0.490	± 0.035
REDBREAST SUNFISH	0.647	± 0.352	0.287	± 0.070	0.039	± 0.025	0.447	± 0.197
EASTERN SILVERY MINNOW	0	0	0.290	± 0.202	1.665	± 1.229	0.382	± 0.217
AMERICAN EEL	0.118	± 0.066	0.286	± 0.130	1.132	± 0.329	0.348	± 0.073
LONGNOSE DACE	0	0	0	0	1.290	± 0.634	0.299	± 0.110
BLUEGILL	0.386	± 0.219	0.131	± 0.059	0.225	± 0.064	0.295	± 0.123
CREEK CHUB	0.008	± 0.008	0.064	± 0.037	0.828	± 0.659	0.176	± 0.114
ROSYSIDE DACE	0	0	0.089	± 0.080	0.682	± 0.203	0.149	± 0.039
LARGEMOUTH BASS	0.177	± 0.076	0.161	± 0.050	0.048	± 0.032	0.149	± 0.044
ROCKBASS	0.131	± 0.065	0.150	± 0.082	0.059	± 0.059	0.122	± 0.042
BRIDLE SHINER	0.138	± 0.138	0	0	0	0	0.079	± 0.079
SPOTTAIL SHINER	0	0	0.012	± 0.009	0.325	± 0.189	0.064	± 0.033
PUMPKINSEED	0.083	± 0.015	0.062	± 0.047	0	0	0.062	± 0.013
CUTLIPS MINNOW	0	0	0.059	± 0.034	0.170	± 0.075	0.046	± 0.015
AMERICAN BROOK LAMPREY	0.007	± 0.007	0.016	± 0.016	0.073	± 0.037	0.022	± 0.008
BROWN BULLHEAD	0.028	± 0.018	0.021	± 0.021	0	0	0.021	± 0.011
SMALLMOUTH BASS	0.012	± 0.007	0.028	± 0.018	0.010	± 0.010	0.016	± 0.006
SPOTFIN SHINER	0	0	0	0	0.087	± 0.047	0.016	± 0.008
SEA LAMPREY	0.008	± 0.008	0.018	± 0.018	0	0	0.009	± 0.006
MARGINED MADTOM	0	0	0.026	± 0.015	0.010	± 0.010	0.008	± 0.004
FALLFISH	0	0	0	0	0.010	± 0.010	0.002	± 0.002

* These mean catch per minute rates include samples with less than 4 electrofishing passes that have been expanded (to 4 passes) using proportions from samples with 4 passes in that habitat type.

** These weighted mean catch per minute rates reflect mean CPM rates that have been weighted by the potential number of sampling sites within the study reach. The potential number of sampling sites were determined from the lengths of pools, riffles, and dam pools within the study reach.

Table 12. The length frequency distribution of fish sampled from White Clay Creek near Newark. This table does not include those species designated as potential target species during Phase II of the instream flow study. Refer to Figures 12-14 for length frequency information on those species.

	Length Interval (mm)										
Species	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**	**121-140**	**141-160**	**161-180**	**181-200**	**200+**
White Sucker	-	1	12	39	31	32	19	14	14	7	43
Tesselated Darter	-	4	96	33	-	-	-	-	-	-	-
Swallowtail Shiner	1	41	67	41	19	-	-	-	-	-	-
Eastern Silvery Minnow	-	12	24	65	16	3	-	-	-	-	-
Satinfin Shiner	-	7	58	55	2	-	-	-	-	-	-
Redbreast Sunfish	-	15	14	59	23	7	5	-	4	-	-
Bluegill	-	45	16	19	13	2	-	-	2	-	-
Rosyside Dace	-	1	21	31	4	-	-	-	-	-	-
Rock Bass	-	1	13	2	8	11	10	1	-	-	-
Largemouth Bass	-	-	8	25	7	2	1	-	1	3	-
Spottail Shiner	-	1	20	3	2	-	-	-	-	-	-
Pumpkinseed	-	1	4	7	2	2	7	-	-	-	-
Creek Chub	-	-	5	5	9	2	1	1	-	-	-
Cutlips Minnow	-	-	1	10	5	5	-	-	-	-	-
Bridle Shiner	-	18	1	-	-	-	-	-	-	-	-
Brown Bullhead	-	-	-	-	-	-	-	-	-	1	8
Smallmouth Bass	-	-	-	-	1	-	2	-	2	-	2
Margined Madtom	-	-	1	1	1	1	-	1	-	-	-
Spotfin Shiner	-	-	4	-	-	1	-	-	-	-	-
Fallfish	-	-	-	-	-	-	-	-	-	-	1

Table 13. Mean width, depth, velocity, standard error (SE), and range of values for each habitat type sampled on White Clay Creek near Newark.

HABITAT TYPE	N	MEAN WIDTH (m)		SE	RANGE	N	MEAN DEPTH (m)	SE	RANGE	N	MEAN VELOCITY (cm/s)	SE	RANGE
Dam Pools	3	26.9	±	3.0	(21.2 - 31.7)	49	0.95	± 0.08	(0.10 - 2.00)	49	9.1	± 0.00	(9.1 - 9.1)
Pools	4	19.6	±	4.4	(10.5 - 31.4)	49	0.60	± 0.06	(0.03 - -1.40)	49	29.0	± 14.3	(9.1 - 66.7)
Riffles	3	8.7	±	0.7	(7.6 - 10.1)	15	0.16	± 0.02	(0.03 - 0.30)	15	68.1	± 24.1	(9.1 - 107.6)

Table 14. The total number of fish species sampled by species and habitat type on White Clay Creek near Stanton. The shaded areas indicate those species selected as potential target species by the Instream Flow Joint Task Force during Phase I of the instream flow assessment.

SPECIES	NUMBER SAMPLED IN POOLS	NUMBER SAMPLED IN RIFFLES	NUMBER SAMPLED IN TIDAL POOLS	TOTAL NUMBER SAMPLED
WHITE SUCKER	100	8	11	119
BANDED KILLIFISH	1	0	79	80
AMERICAN EEL	32	29	18	79
REDBREAST SUNFISH	39	7	20	66
SWALLOWTAIL SHINER	3	5	56	64
STRIPED KILLIFISH	1	0	60	61
WHITE PERCH	10	0	38	48
TESSELATED DARTER	2	7	35	44
EASTERN SILVERY MINNOW	0	2	35	37
PUMPKINSEED	24	1	5	30
BLUEGILL	14	0	7	21
MUMICHOG	0	0	14	14
CHANNEL CATFISH	11	0	1	12
SATINFIN SHINER	0	4	8	12
ALEWIFE	0	0	11	11
LARGEMOUTH BASS	5	0	3	8
SMALLMOUTH BASS	8	1	1	7
SEA LAMPREY	1	2	3	6
LEAST BROOK LAMPREY	0	0	4	4
BLUEBACK HERRING	0	0	4	4
FALLFISH	3	0	0	3
ROCKBASS	3	0	0	3
BLACKNOSE DACE	0	2	0	2
AMERICAN BROOK LAMPRE	0	0	2	2
SPOTTAIL SHINER	1	2	0	2
STRIPED BASS	1	0	0	1
EASTERN MUDMINNOW	0	0	1	1
GOLDFISH	1	0	0	1
COMMOM CARP	1	0	0	1
YELLOW PERCH	1	0	0	1

Table 15. The mean CPM (catch per minute), weighted mean CPM, and SE (standard error) by species and habitat type for 4 electrofishing passes on White Clay Creek near Stanton. The shaded area indicate those species selected as potential target species by the Instream Flow Needs Joint Task Force during Phase I of the instream flow assessment.

SPECIES	*MEAN CPM IN POOLS N=3	SE	*MEAN CPM IN RIFFLES N=2	SE	*MEAN CPM IN TIDAL POOLS N=3	SE	**WEIGHTED MEAN CPM FOR ENTIRE REACH	SE
STRIPED KILLIFISH	0.022	± 0.022	0	0	1.330	± 1.230	1.047	± 0.948
BANDED KILLIFISH	0.022	± 0.022	0	0	0.797	± 0.461	0.628	± 0.356
EASTERN SILVERY MINNOW	0	0	0.069	± 0.069	0.679	± 0.594	0.534	± 0.460
SWALLOWTAIL SHINER	0	0	0.187	± 0.187	0.665	± 0.570	0.528	± 0.441
TESSELATED DARTER	0.026	± 0.026	0.211	± 0.056	0.626	± 0.149	0.503	± 0.115
WHITE PERCH	0.064	± 0.064	0	0	0.560	± 0.560	0.450	± 0.433
AMERICAN EEL	0.656	± 0.425	0.906	± 0.247	0.190	± 0.097	0.302	± 0.103
REDBREAST SUNFISH	0.630	± 0.358	0.101	± 0.101	0.173	± 0.079	0.251	± 0.085
WHITE SUCKER	0.690	± 0.436	0.202	± 0.090	0.105	± 0.054	0.213	± 0.084
ALEWIFE	0	0	0	0	0.236	± 0.090	0.185	± 0.069
SATINFIN SHINER	0	0	0.150	± 0.070	0.150	± 0.136	0.123	± 0.105
MUMICHOG	0	0	0	0	0.149	± 0.087	0.116	± 0.07
PUMPKINSEED	0.245	± 0.144	0.035	± 0.035	0.055	± 0.031	0.088	± 0.034
BLUEGILL	0.182	± 0.092	0	0	0.064	± 0.053	0.083	± 0.044
LEAST BROOK LAMPREY	0	0	0	0	0.074	± 0.074	0.058	± 0.058
SEA LAMPREY	0.010	± 0.010	0.082	± 0.082	0.056	± 0.056	0.049	± 0.043
BLUEBACK HERRING	0	0	0	0	0.052	± 0.052	0.041	± 0.041
LARGEMOUTH BASS	0.047	± 0.047	0	0	0.037	± 0.037	0.036	± 0.029
AMERICAN BROOK LAMPREY	0	0	0.036	± 0.036	0.033	± 0.033	0.027	± 0.026
CHANNEL CATFISH	0.083	± 0.070	0	0	0.009	± 0.009	0.022	± 0.014
SMALLMOUTH BASS	0.061	± 0.048	0.014	± 0.014	0.009	± 0.009	0.019	± 0.011
FALLFISH	0.052	± 0.043	0	0	0	0	0.009	± 0.007
YELLOW PERCH	0.042	± 0.042	0	0	0	0	0.007	± 0.007
ROCKBASS	0.035	± 0.020	0	0	0	0	0.006	± 0.003
EASTERN MUDMINNOW	0	0	0	0	0.007	± 0.007	0.006	± 0.006
SPOTTAIL SHINER	0.011	± 0.011	0.014	± 0.014	0	0	0.003	± 0.003
BLACKNOSE DACE	0	0	0.076	± 0.076	0	0	0.003	± 0.003
STRIPED BASS	0.004	± 0.004	0	0	0	0	0.001	± 0.001
GOLDFISH	0.004	± 0.004	0	0	0	0	0.001	± 0.001
COMMOM CARP	0.004	± 0.004	0	0	0	0	0.001	± 0.001

* These mean catch per minute rates include samples with less than 4 electrofishing passes that have been expanded (to 4 passes) using proportions from samples with 4 passes in that habitat type.

** These weighted mean catch per minute rates reflect mean CPM rates that have been weighted by the potential number of sampling sites within the study reach. The potential number of sampling sites were determined from the lengths of pools, riffles, and dam pools within the study reach.

Table 16. The length frequency distribution of fish sampled from White Clay Creek near Stanton. This table does not include those species designated as potential target species during Phase I of the instream flow study. Refer to Figures 18 and 19 for length frequency information on those species.

	Length Interval (mm)										
Species	**1-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**	**121-140**	**141-160**	**161-180**	**181-200**	**200+**
White Sucker	-		1	-	6	4	8	13	13	8	66
Banded Killifish	-	5	19	35	11	2	2	-	-	-	-
Redbreast Sunfish	-	3	22	4	22	7	5	1	2	-	-
Swallowtail Shiner	-	2	11	30	21	-	-	-	-	-	-
Striped Killifish	-	34	1	10	1	-	-	-	-	-	-
Tesselated Darter	-	1	10	28	5	-	-	-	-	-	-
Eastern Silvery Minnow	-	3	-	7	6	10	11	-	-	-	-
Pumpkinseed	-	-	3	10	12	2	2	-	1	-	-
Bluegill	-	2	10	4	3	1	-	1	-	-	-
Mummichog	-	-	5	9	-	-	-	-	-	-	-
Satinfin Shiner	-	1	2	8	1	-	-	-	-	-	-
Alewife	-	-	-	3	8	-	-	-	-	-	-
Largemouth Bass	-	-	-	-	1	1	-	-	1	-	5
Smallmouth Bass	-	-	-	-	7	2	-	-	-	-	1
Blueback Herring	-	-	-	4	-	-	-	-	-	-	-
Fallfish	-	-	-	-	-	-	-	-	1	1	1
Rock Bass	-	-	-	1	1	-	1	-	-	-	-
Blacknose Dace	-	1	1	-	-	-	-	-	-	-	-
Spottail Shiner	-	-	2	-	-	-	-	-	-	-	-
Striped Bass	-	-	-	-	-	-	-	1	-	-	-
Eastern Mudminnow	-	-	-	1	-	-	-	-	-	-	-
Goldfish	-	-	-	-	-	-	-	-	-	-	1
Commom Carp	-	-	-	-	-	-	-	-	-	-	1
Yellow Perch	-	-	-	-	-	-	-	-	1	-	-

Table 17. Mean width, depth, velocity, standard error (SE), and range of values for each habitat type sampled on White Clay Creek near Stanton.

HABITAT TYPE	N	MEAN WIDTH (m)	SE	RANGE	N	MEAN DEPTH (m)	SE	RANGE	N	MEAN VELOCITY (cm/s)	SE	RANGE
Tidal Pools	3	12.1	± 3.2	(7.5 - 18.3)	21	0.34	± 0.04	(0.03 - 0.60)	21	32.0	± 18.0	(0 - 67.4)
Pools	3	11.2	± 3.2	(7.5 - 17.7)	20	0.45	± 0.06	(0.20 - 1.00)	20	40.8	± 26.8	(9.1 - 95.1)
Riffles	2	7.8	± 2.7	(5.2 - 10.5)	9	0.24	± 0.05	(0.03 - 0.50)	9	86.6	± 54.6	(0 - 140.8)

Table 18. Species specific salinity tolerance and suitability information obtained from the literature.

Species	Source	Salinity (ppt)	Remarks
Channel Catfish	Perry 1973	< 1.7	Most abundant
	Jones et al. 1978	< 2.0	Spawning requirement (March - July)
	Perry and Avault 1968	2.0 - 11.0	Range of occurrence
	McMahon and Terrell 1982	8.0	HSI = 0.4 Adults
	McMahon and Terrell 1982	8.0	HSI = 0.4 Fry, juveniles
	Allen and Avault 1969	12.0	Salinity tolerance of age 6 mo. to 1 yr.
Bluegill	Stuber et al. 1982	4.0	HSI = 0.4
	Kilby 1955	< 3.6	Preferred salinity
	Kilby 1955	< 5.6	Tolerance level
Largemouth Bass	Meador and Kelso 1990	1.0 - 12.0	Range of occurrence
	Tebo and McCoy 1964	> 1.66	Growth rate declined
	Stuber et al. 1982	4.5	HSI = 0.4 fry
	Tebo and McCoy 1964	6.0	Growth rate = 0
	Stuber et al. 1982	10.0	HSI = 0.4 Juveniles, adults
	Bailey et al. 1954	24.0	Upper range of occurrence
Mummichogs	Fritz and Garside 1974	20.0	High preference of 20 ppt over 8 ppt
	Hardy 1978	0 - 41	Salinity range
White Perch	Jones et al. 1988	0.0 - 2.0	Optimal salinity
	Funderbark et al. 1991	0.0 - 8.0	Larvae and juvenile occurrence
	Dove and Nyman 1995	0.0 - 20	Range of occurence in DE River (juvenile to adult)
	Stanley and Dance 1983	< 1.5	Larval preference
	Stanley and Dance 1983	< 3.0	Juvenile preference
	Finderbark et al. 1991	< 4.2	Spawning requirement (March - June)
	Stanley and Danie 1983	5.0 - 18	Adult occurrence (Chesapeake Bay)
	Dove and Nyman 1995	10.0	Egg tolerance level
	Dove and Nyman 1995	< 30.0	Range of occurence in DE Bay (adults)
Alewife	Dovel 1971	0.0 - 2.0	99% of spawning occurred (March - May) at 0.0 ppt in Chesapeake tributaries
	Dove and Nyman 1995	0.0 - 6.0	Spawning can occur
	Dovel 1971	0.0 - 8.0	Range of occurence for larvae and juveniles
	Dove and Nyman 1995	< 1.0	Most spawning occurs
	Pardue 1983	< 5.0	Optional salinity
	Dove and Nyman 1995	22.0	Egg tollerance level
Sunfish Sp. (Includes redbreast & pumpkinseed)	Jones et al. 1978	< 5.0	Spawning requirement (April - June)
	Jones et al. 1978	11.0	Tolerance level
Striped Killifish	Dahlberg 1972	7.0 - 34.0	Range of occurence
White Sucker	Hardy 1978	2.0	Maximum salinity tolerance for adults
Banded Killifish	Weisburg 1986	0.0	Prefered
	Weisburg 1986	0.0 - 5.0	Range of occurence
Eastern Silvery Minnow	Hardy 1998	8.3	Maximum salinity tolerance for adults

Maximum salinity at WCCS = 1.54 ppt

Table 19. Life history and habitat criteria obtained from the literature on the Longnose Dace.

Species	State/Provence	Source	Depth		Velocity		Spawning Period	Spawning Substrate	Remarks
			Meter	Feet	cm/sec	ft/sec			
Longnose Dace *(Rhinichthys cataractae)*	Various	Edwards et al. 1983	0.22-1.03*	0.72-3.38	21-100+**	0.69-3.28+	April - July	gravel	Category I curves
	BC	Gee and Northcoat, 1963	<0.30	<0.98	-	-	-	-	-
	UT	Sigler and Miller, 1963	<1.0	<3.3	-	-	-	-	-
	Unk.	Edwards et al. 1983	-	-	45-182**	1.48-5.97	-	gravel	Preferred criteria
	N. Great Plains	Bovee, 1974	0.15-0.31*	0.49-1.02	40-150**	1.31-4.92	-	-	Range of occurrence
	NY	Finger, 1982	0.09-0.17*	0.30-0.56	17-26**	0.56-0.85	-	-	Range of occurrence
	MI	Brazo et al. 1978	-	-	-	-	June - July	gravel	Life History information
	MAN.	Gibbons and Gee, 1972	-	-	45+**	1.48+	-	-	-
	MAN.	Bartnik, 1970	-	-	45+**	1.48+	-	-	-
	MN	Aadland et al. 1991	0.03-0.44*	0.10-1.44	43-120+**	1.41-3.94	-	gravel	Category III curves
	MN	Aadland et al. 1991	0.20	0.67	49	1.61	-	gravel	Mean spawning criteria
	NC	Facey and Grossman, 1992	-	-	44**	1.45	-	-	Mean occurrence velocity
	SC,NC,VA,MD,DE	Rohde et al. 1994	-	-	-	-	April - June	gravel	-
	PA	Johnson et al. 1992	0.05-0.15* -	0.16-0.49 -	- 30.7**	- 1.01	- -	- -	76% of total occurrence Mean velocity

Summary:
Range of the pertinent depth information listed above: 0.03 m - 1.03 m (0.10 ft - 3.38 ft)

Range of the velocity information listed above: 17 cm/sec - 182 cm/sec (0.56 ft/sec - 5.97 ft/sec)

*Average of the pertinent depth information listed above: 0.11 m - 0.42 m (0.36 ft - 1.38 ft)

**Average of the velocity information (excluding spawning criteria) listed above: 36.6 cm/sec - 115.6 cm/sec (1.20 ft/sec - 3.8 ft/sec)

Table 20. Life history and habitat criteria obtained from the literature on the Blacknose Dace.

Species	State/Provence	Source	Depth		Velocity		Spawning Period	Spawning Substrate	Remarks
			Meter	Feet	cm/sec	ft/sec			
Blacknose Dace	ONT	Cunjak and Power, 1986	0.70*	2.3	13.3	0.44	-	-	Mean summer values
(Rhinichthys atratulus)	SC,NC,VA,MD,DE	Rohde et al. 1994	-	-	-	-	April - June	Gravel	Natural history information
	NY	Sheldon, 1968	0-0.6+	0-2.0+	-	-	-	-	Range of occurrence
	IA	Noble, 1965	-	-	-	-	May - July	-	-
	VAN	Schwartz, 1958	<0.25	<0.82	-	-	May - July	Gravel	Spawning depths
	MAN	Bartnik, 1970b	-	-	20-45	0.66-1.48	-	Gravel	Reproduction
	NE	Bragg and Stasiak, 1978	-	-	-	-	-	Gravel	-
	MAN	Gibbons and Gee, 1972	-	-	15-45	0.49-1.48	-	-	Greatest densities of adults
	MI	Brazo et al. 1978	-	-	-	-	May - July	Gravel	-
	Various	Trial et al. 1983	0-0.50	0-1.64	-	-	-	-	Category I spawning depths
			-	-	11-58	0.36-1.90	-	-	Average velocities in riffles
	PA	Johnson et al. 1992	0.05-0.15*	0.16-0.49	-	-	-	-	77% of occurrence
			-	-	13.1	0.43	-	-	Mean Velocity

Summary:

*Range of the pertinent depth information listed above: 0.05 m - 0.70 m (0.16 ft - 2.3 ft)

Range of the velocity information listed above: 11 cm/sec - 58 cm/sec (0.36 ft/sec - 1.90 ft/sec)

Table 21. Life history and habitat criteria obtained from the literature on the Common Shiner.

Species	State	Source	Depth		Velocity		Spawning Period	Spawning Substrate	Remarks
			Meter	Feet	cm/sec	ft/sec			
Common Shiner	NY	Smith, 1985	-	-	-	-	May - July	Gravel, Sand	-
(Notropis cornutus)	Various	Trial et al. 1983	-	-	12-34	0.39-1.12	May - July	Sand, Gravel	Category I data
	NY	Miller, 1964	0.013-0.044	0.04-0.14	-	-	-	Sand, Gravel	Spawning depth occurrence
	NY	Sheldon, 1968	0.15-0.60+	0.49-1.97+	-	-	-	-	Range of occurrence
	Can.	Scott and Crossman, 1973	-	-	-	-	May - July	-	-
	SC,NC,VA,MD,DE	Rohde et al. 1994	-	-	-	-	May - July	Gravel	-

Note:
Category I curves are based on literary sources and/or professional opinion.
Category II curves are based on frequency analyses of field data.
Category III (preference) curves are derived from utilization curves which have been corrected for environmental bias.

Table 22. Life history and habitat criteria obtained from the literature on the Tesselated Darter.

Species	State	Source	Depth		Velocity		Spawning Period	Spawning Substrate	Remarks
			Meter	Feet	cm/sec	ft/sec			
Tesselated Darter	NY	Sheldon, 1968	0.15-0.60+	0.49-1.97+	-	-	-	-	Range of occurrence
(Etheostoma olmstedi)	NY	Smith, 1985	-	-	-	-	May - June	-	-
	Unk.	Page, 1983	-	-	-	-	April - June	Underside of stones	-
	SC,NC,VA,MD,DE	Rohde et al. 1994	-	-	-	-	Spring - early Summer	Under rocks, sticks logs etc.	-

Table 23. Life history and habitat criteria obtained from the literature on the Satinfin Shiner.

Species	State	Source	Depth		Velocity		Spawning Period	Spawning Substrate	Remarks
			Meter	Feet	cm/sec	ft/sec			
Satinfin Shiner	PA	Smith, 1985	-	-	-	-	June - August	-	-
(Notropis analostanus)	SC,NC,VA,MD,DE	Rohde et at. 1994	-	-	-	-	May - June	Crevices of rocks and logs	-
	NY	Sheldon, 1968	0.60+	1.97+	-	-	-	-	Range of occurrence

Table 24. Instream flow needs analysis (Phase II) wetted perimeter results and fish habitat criteria for longnose dace in Brandywine Creek and White Clay Creek for comparison to the 7Q10 levels, and the upper and lower wetted perimeter break points. The english units for discharge (cfs), flow depth (ft), and velocity (fps) are listed in parentheses. The average fish criteria is the average minimum value for depth and velocity derived from literary sources (see Table 19).

Stream and Section	Discharge (m3/s)			Flow Depth (m)					Velocity (cm/s)				
	7Q10	Upper WP	Lower WP	7Q10	Upper WP	Lower WP	Avg. Fish Criteria	Range of Fish Criteria	7Q10	Upper WP	Lower WP	Avg. Fish Criteria	Range of Fish Criteria
Brandywine Creek at Wilmington													
2.55	2.2 (76.3)	1.7 (58.5)	0.5 (17.0)	0.30 (0.98)	0.27 (0.89)	0.18 (0.59)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	121.60 (3.99)	114.60 (3.76)	86.60 (2.84)	36.6 (1.20)	17.10-182.00 (0.56-5.97)
2.65	2.2 (76.3)	1.7 (60.3)	0.9 (60.3)	0.36 (1.17)	0.34 (1.12)	0.34 (1.12)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	43.00 (1.41)	39.00 (1.28)	39.00 (1.28)	36.6 (1.20)	17.10-182.00 (0.56-5.97)
2.94	2.2 (76.3)	1.7 (58.5)	0.9 (30.0)	0.27 (0.89)	0.24 (0.80)	0.17 (0.57)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	41.10 (4.35)	126.80 (4.16)	108.80 (3.57)	36.6 (1.20)	17.10-182.00 (0.56-5.97)
White Clay Creek at Newark													
53115	0.3 (11.3)	0.6 (21.6)	0.2 (6.6)	0.23 (0.74)	0.29 (0.95)	0.19 (0.61)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	43.30 (1.42)	53.00 (1.74)	36.30 (1.19)	36.6 (1.20)	17.10-182.00 (0.56-5.97)
55713	0.3 (11.3)	0.3 (11.3)	0.2 (6.6)	0.12 (0.39)	0.12 (0.39)	0.10 (0.32)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	63.10 (2.07)	63.10 (2.07)	60.40 (1.98)	36.6 (1.20)	17.10-182.00 (0.56-5.97)
57970	0.3 (11.3)	0.6 (21.6)	0.3 (8.8)	0.28 (0.92)	0.34 (1.13)	0.26 (0.84)	0.11 (0.36)	0.03-1.03 (0.10-3.38)	18.60 (0.61)	18.60 (0.80)	17.10 (0.56)	36.6 (1.20)	17.10-182.00 (0.56-5.97)

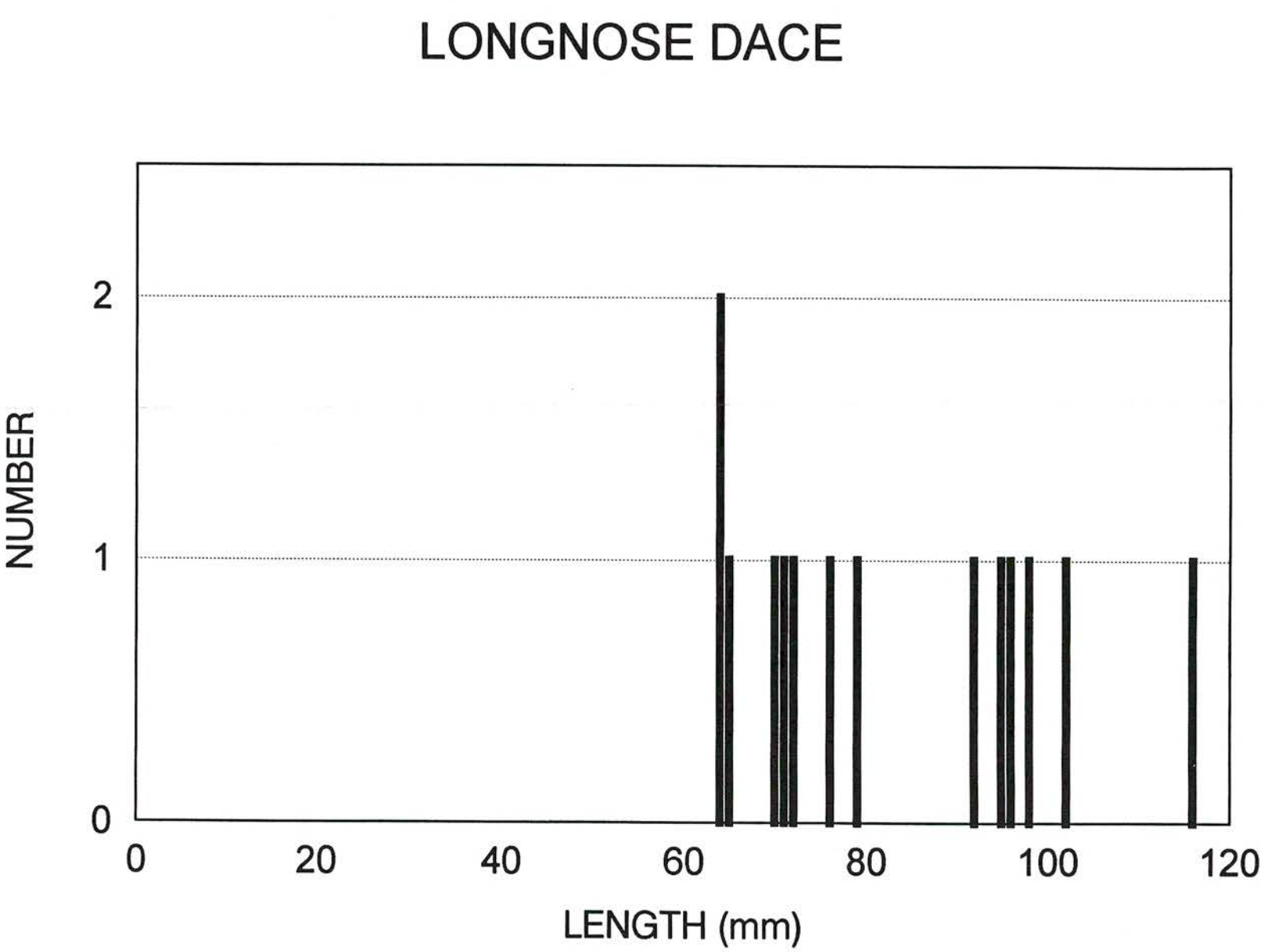


Figure 1. Length frequency of longnose dace measured from Brandywine Creek. All fish sampled were in the adult size class (>63 mm) determined from age-length groupings found in the literature.

SATINFIN SHINER

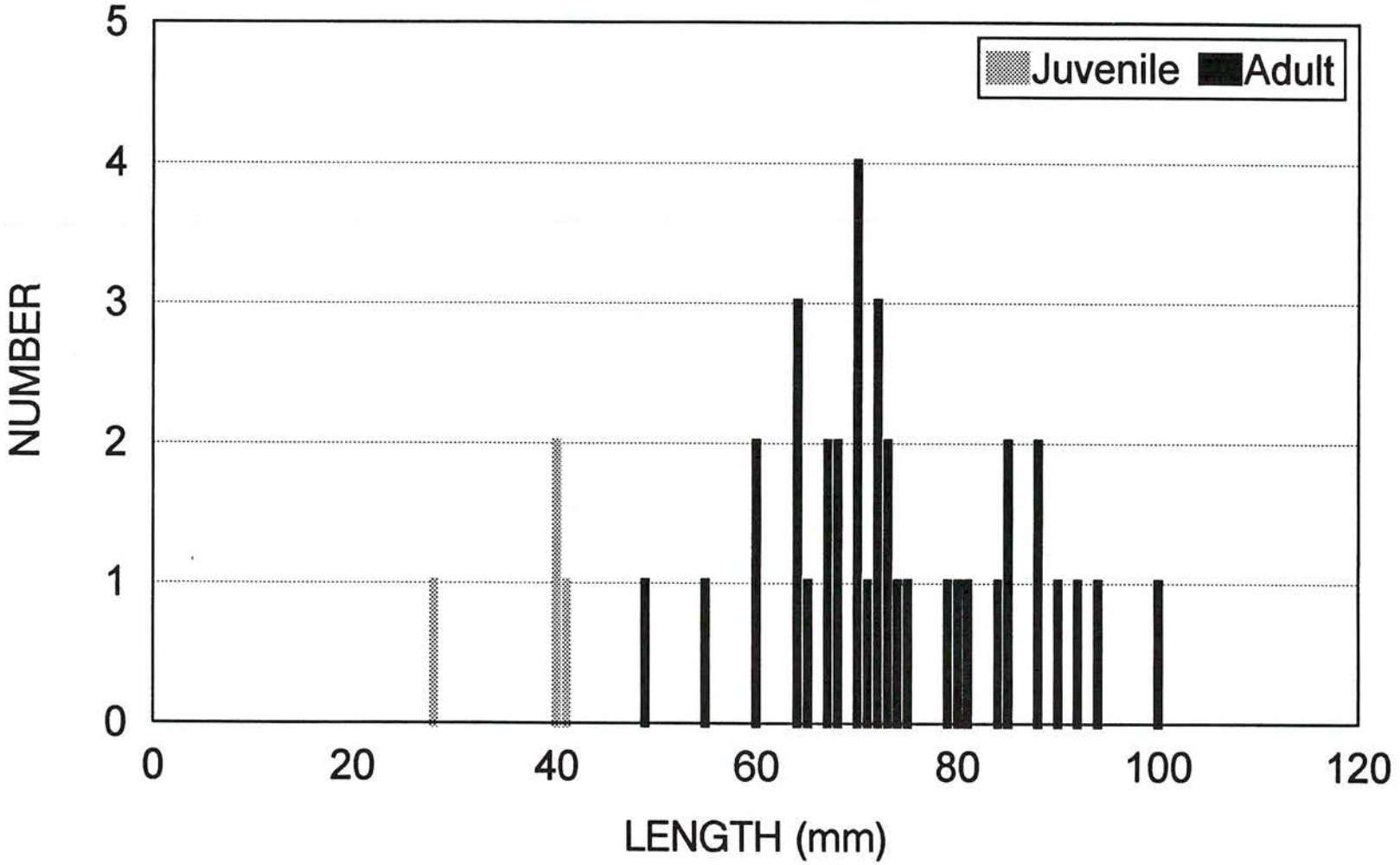


Figure 2. Length frequency of satinfin shiners measured from the Brandywine River and categorized into predetermined size classes conforming to age-length groupings found in the literature.

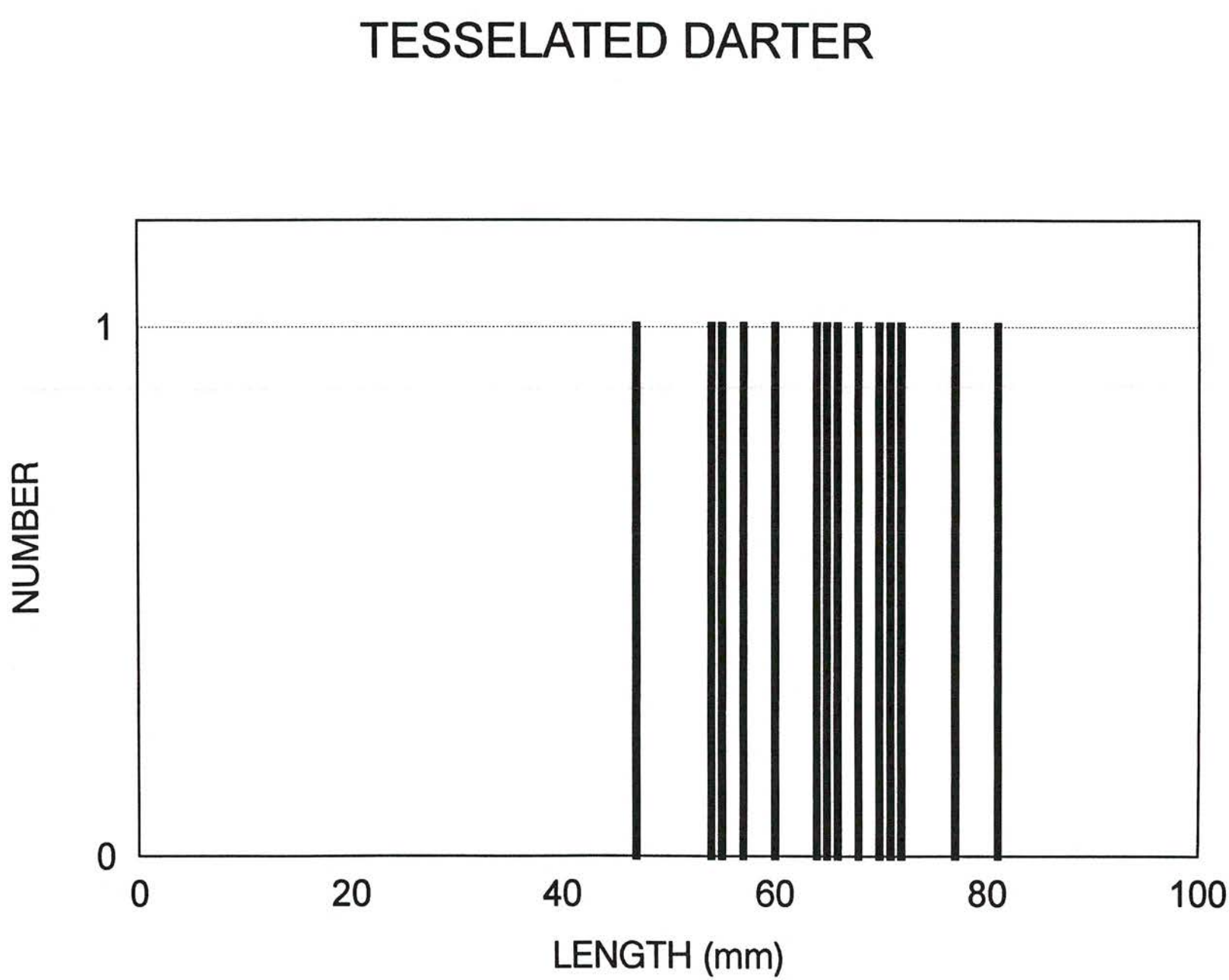


Figure 3. Length frequency of tesselated darters measured from Brandywine Creek.

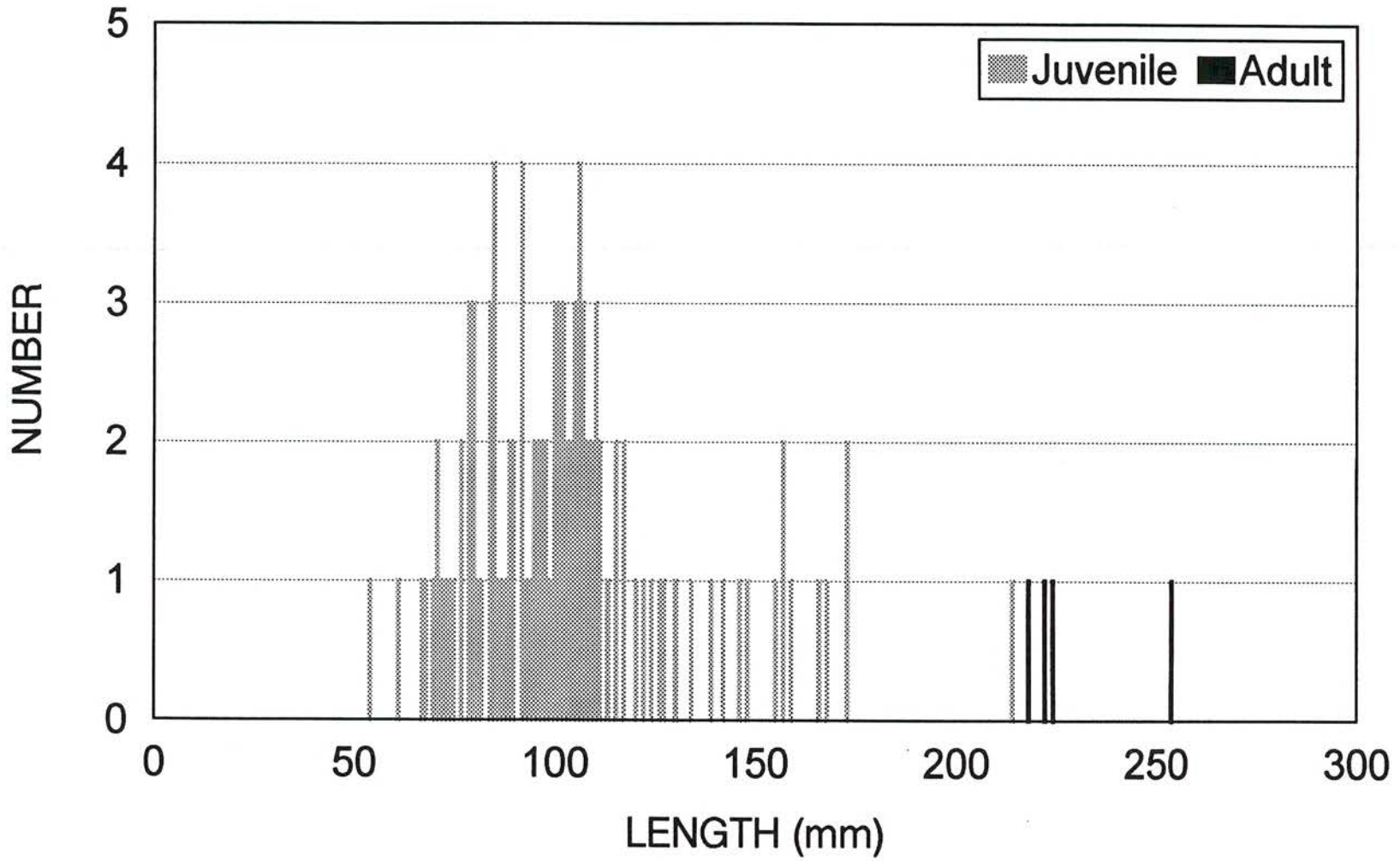


Figure 4. Length frequency of smallmouth bass measured from Brandywine Creek and categorized into predetermined size classes conforming to age-length groupings found in the literature.

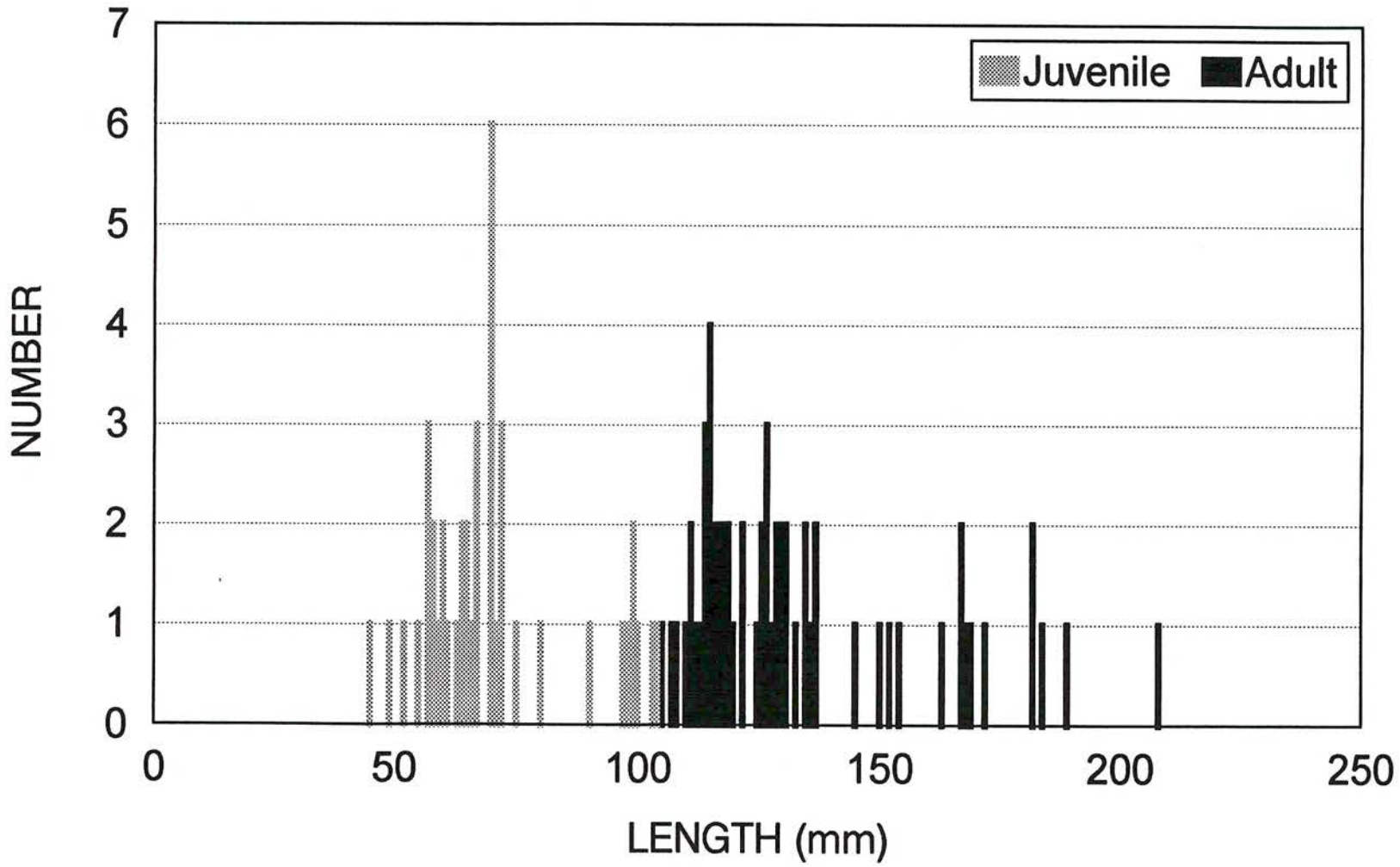


Figure 5. Length frequency of rockbass measured from Brandywine Creek and categorized into predetermined size classes conforming to age-length groupings found in the literature.

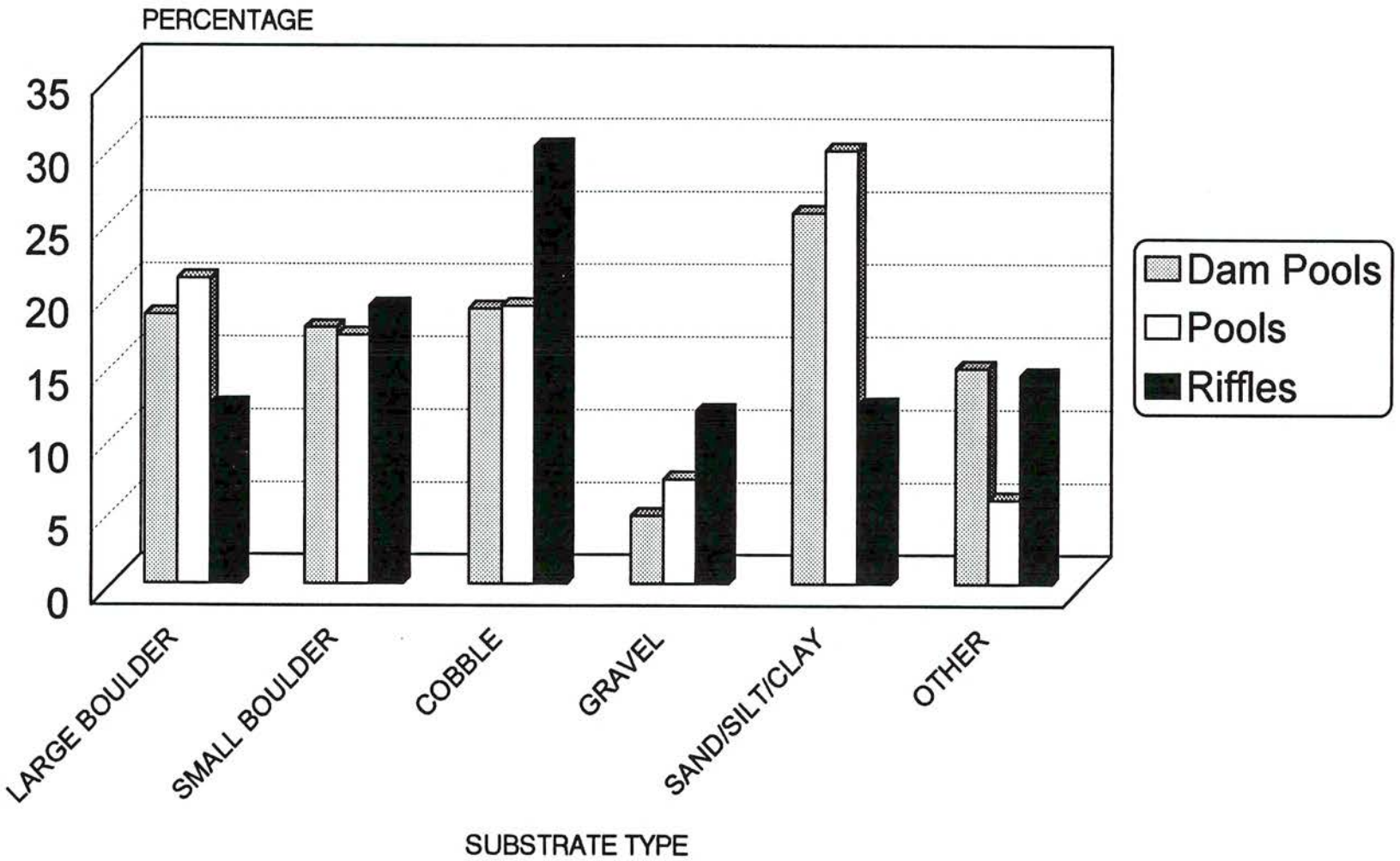


Figure 6. The composition of substrate sampled from dam pools, pools, and riffles on the Brandywine River. The substrate type labeled "other" includes organic detritus, vascular plants, and/ or attached algae.

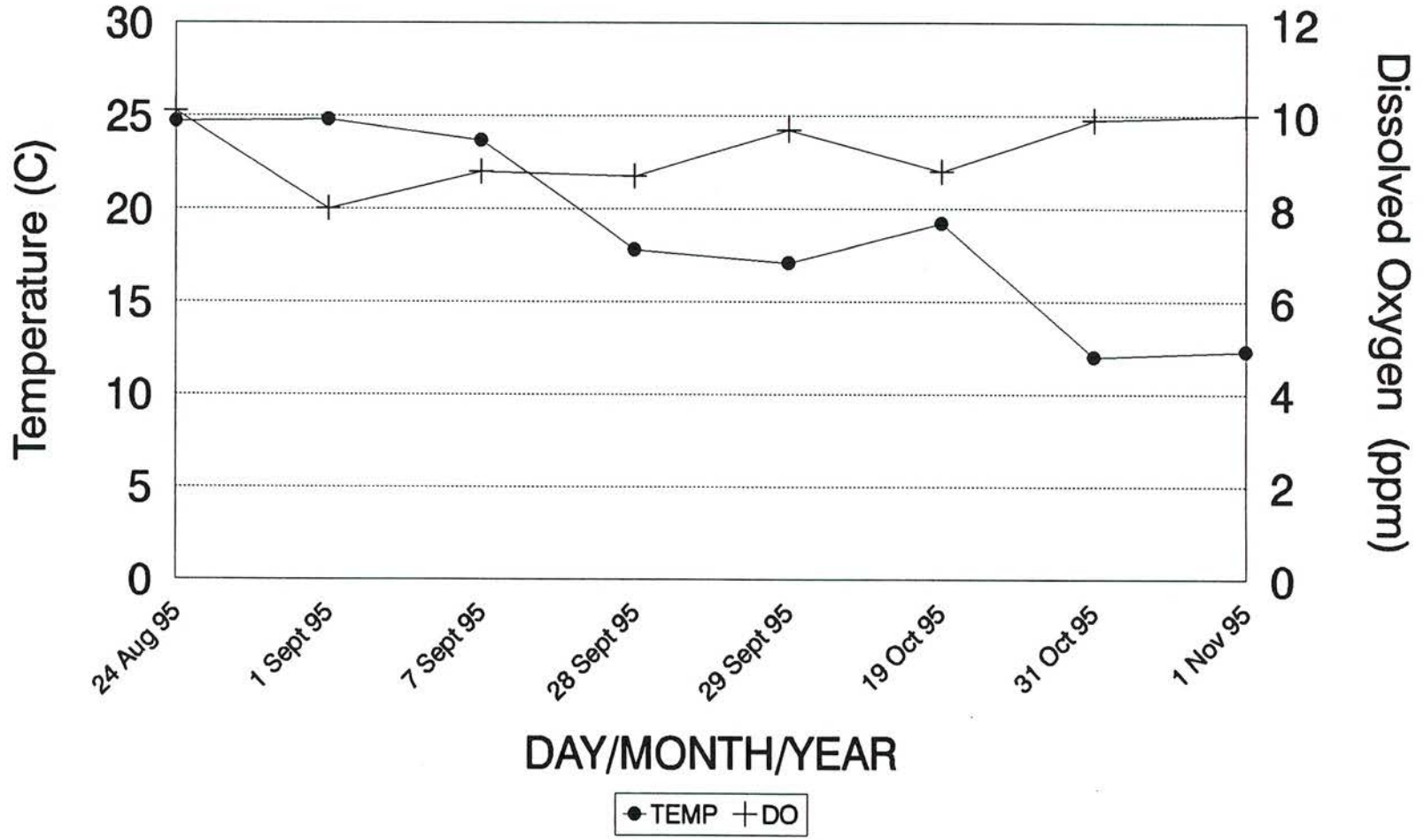


Figure 7. Water temperatures and dissolved oxygen readings recorded on Brandywine Creek.

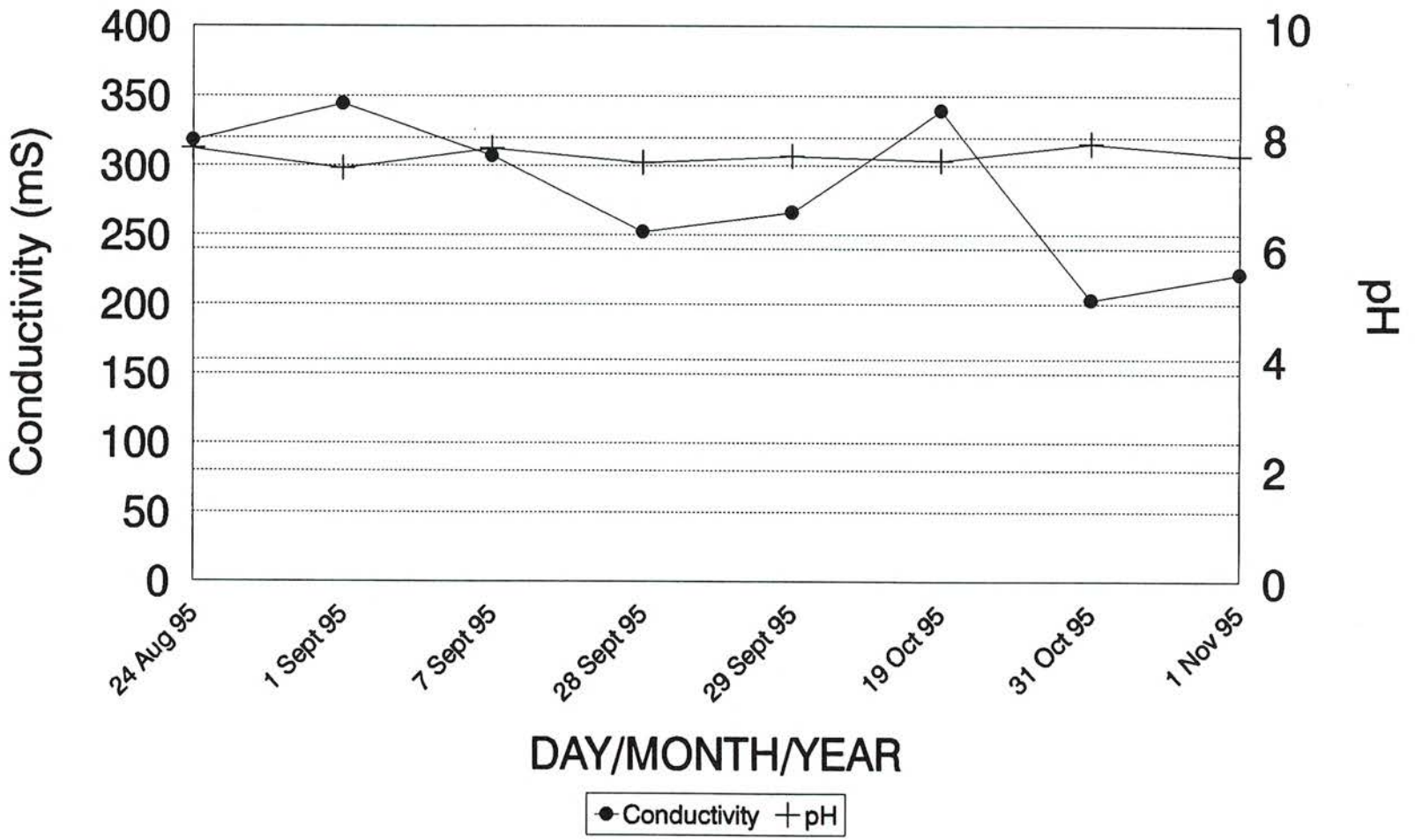


Figure 8. Water conductivity and pH readings recorded on Brandywine Creek.

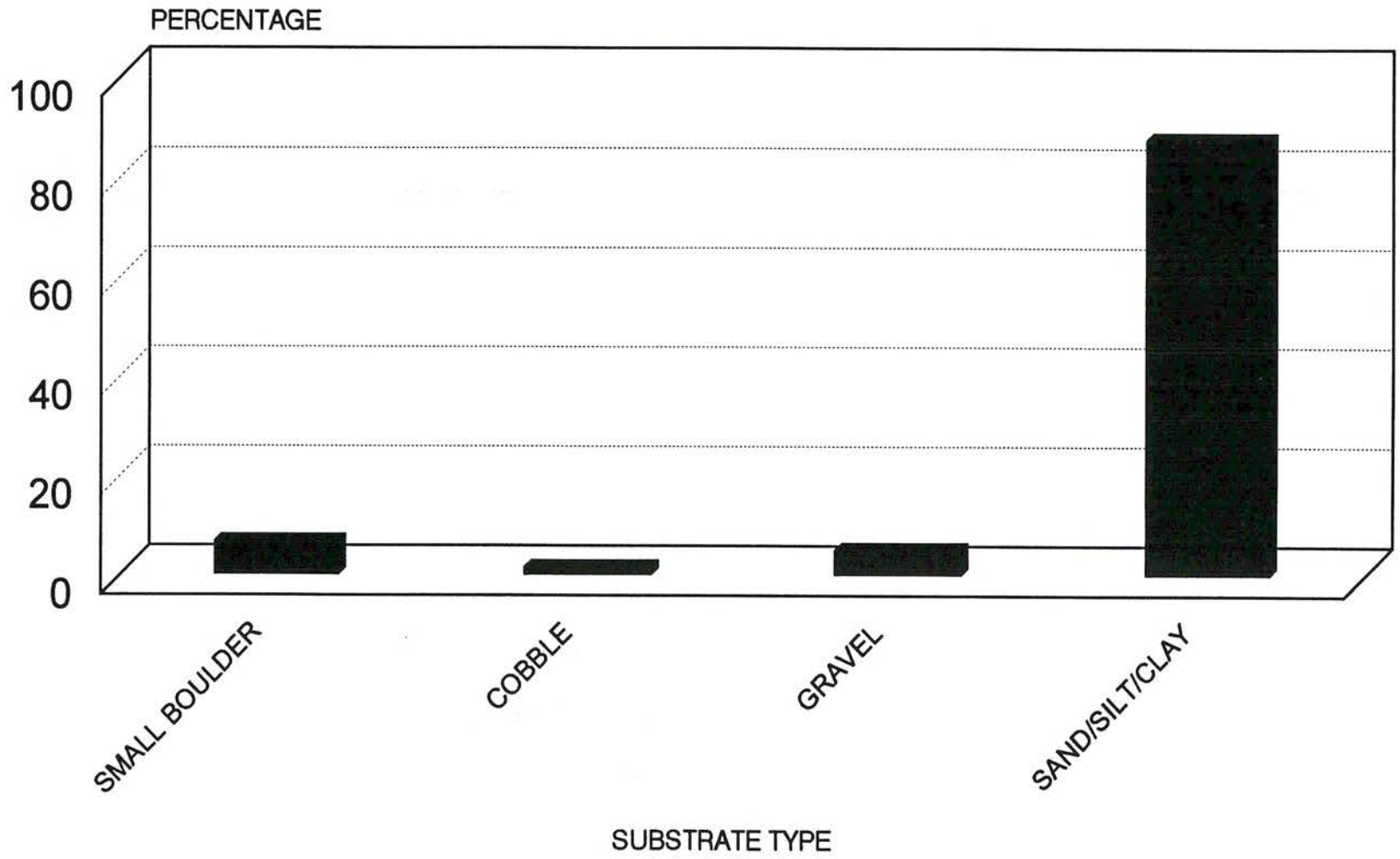


Figure 9. The composition of substrate sampled from tidal pools on the Christina River.

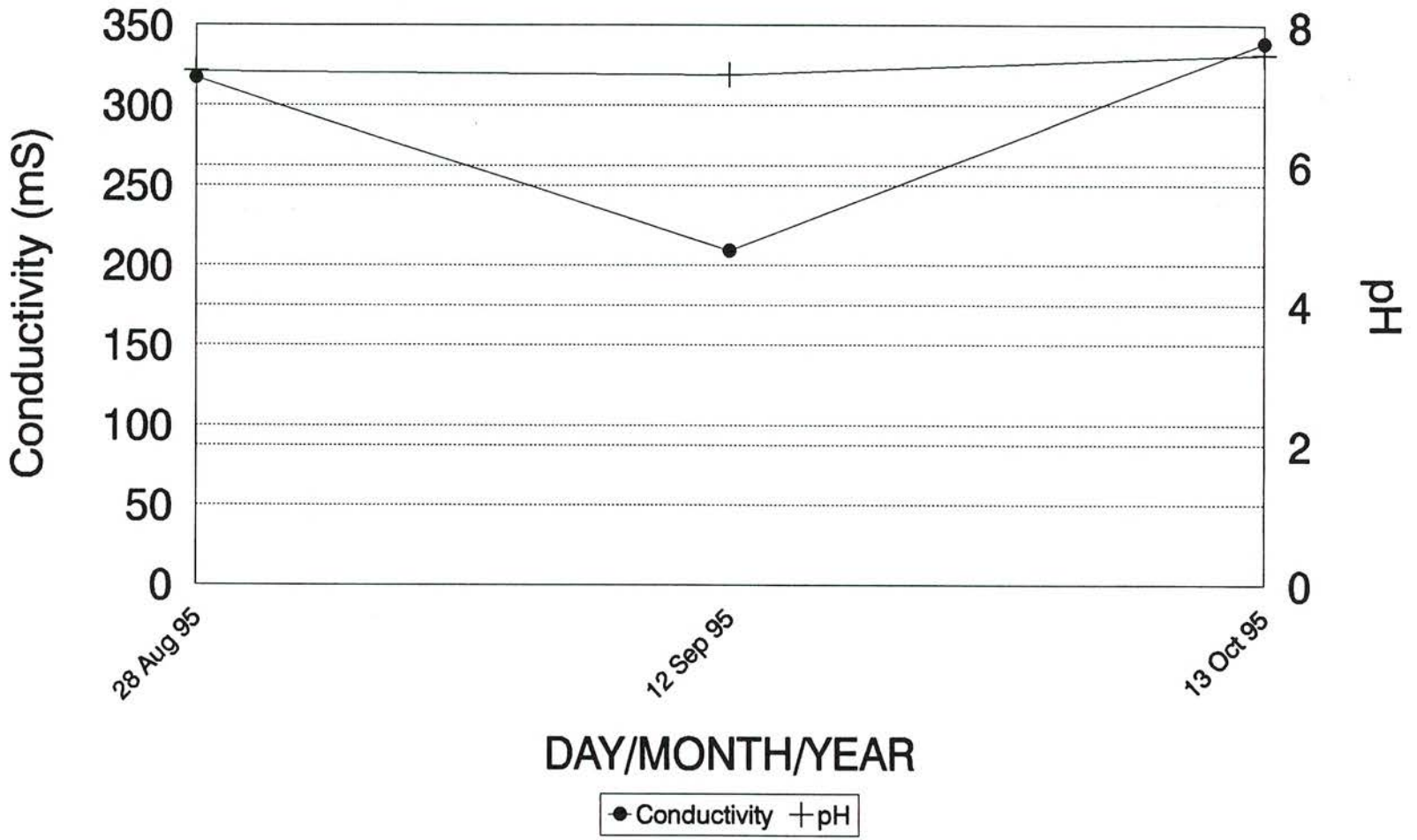


Figure 11. Water conductivity and pH readings recorded on the Christina River.

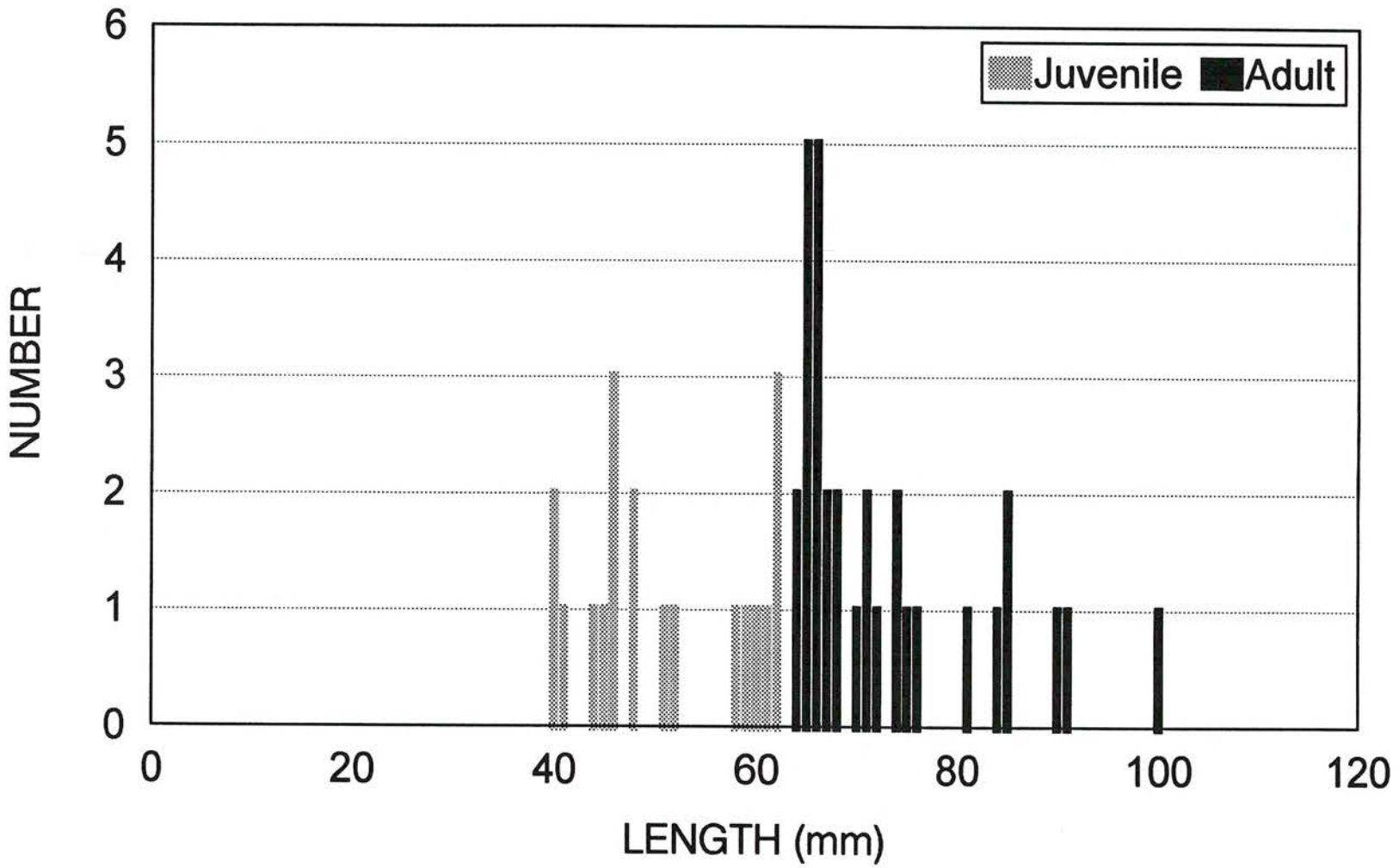


Figure 12. Length frequency of longnose dace measured from White Clay Creek near Newark and categorized into predetermined size classes conforming to age-length groupings found in the literature.

BLACKNOSE DACE

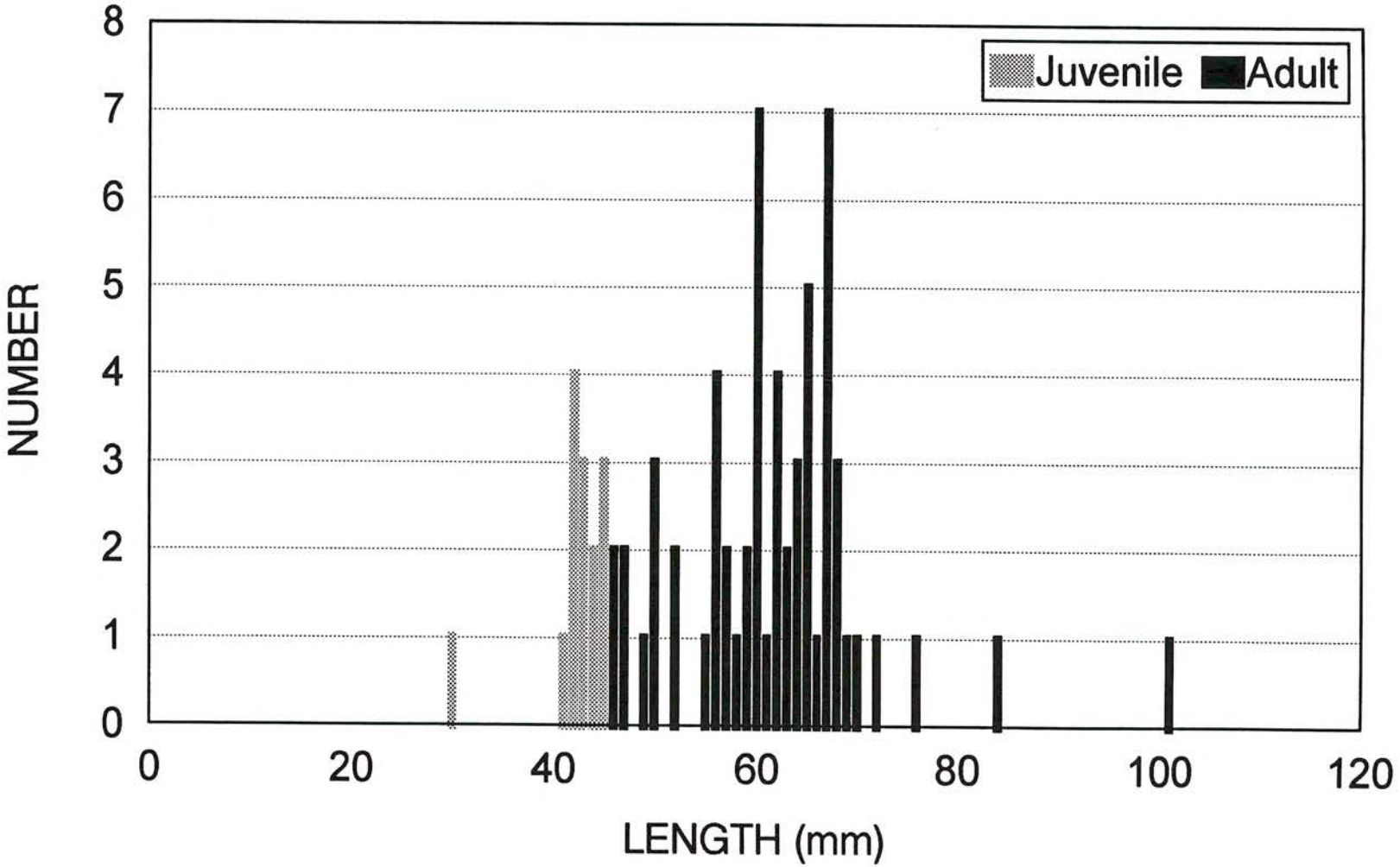


Figure 13. Length frequency of blacknose dace measured from White Clay Creek near Newark and categorized into predetermined size classes conforming to age-length groupings found in the literature.

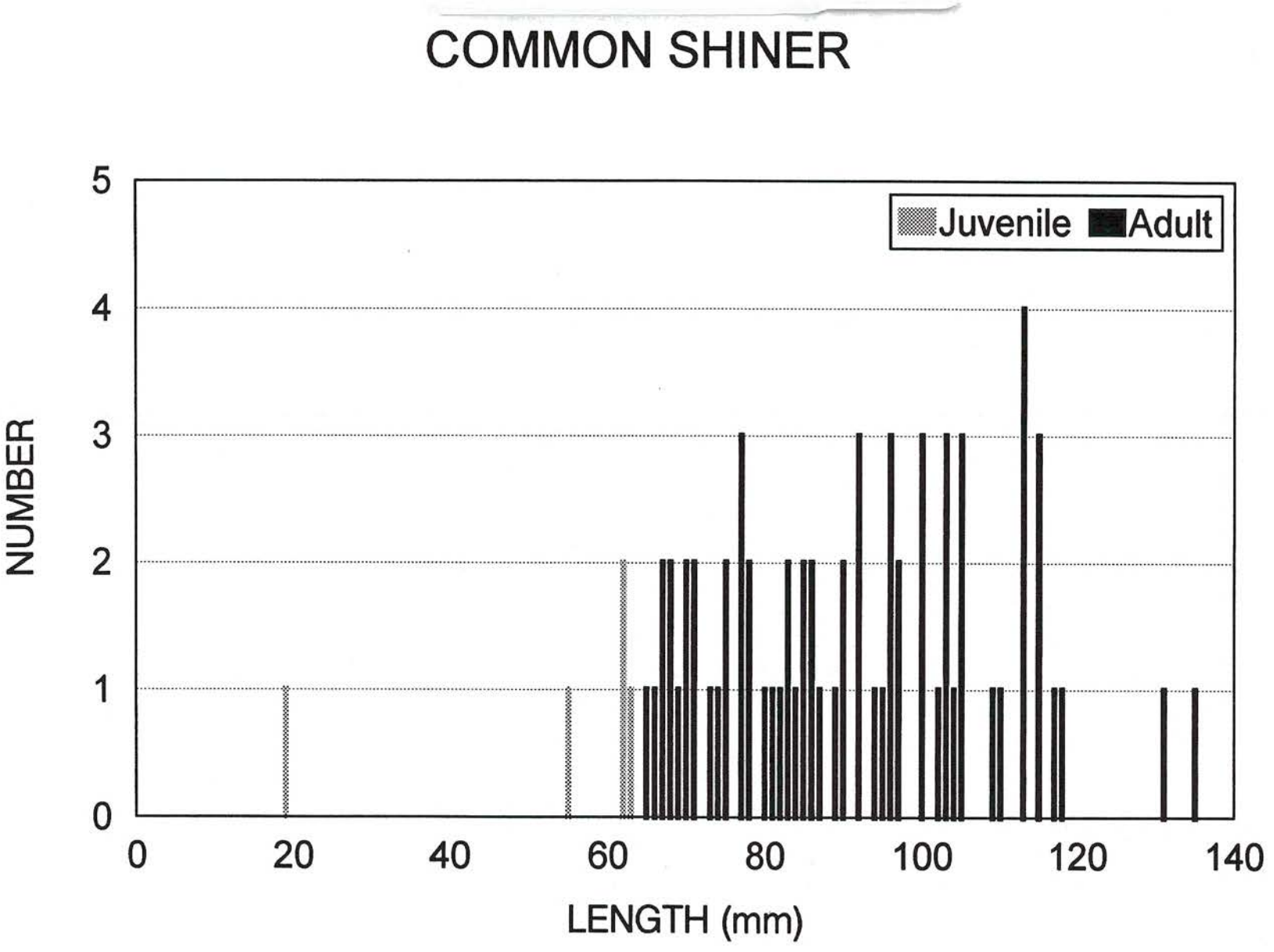


Figure 14. Length frequency of common shiners measured from White Clay Creek near Newark and categorized into predetermined size classes conforming to age-length groupings found in the literature.

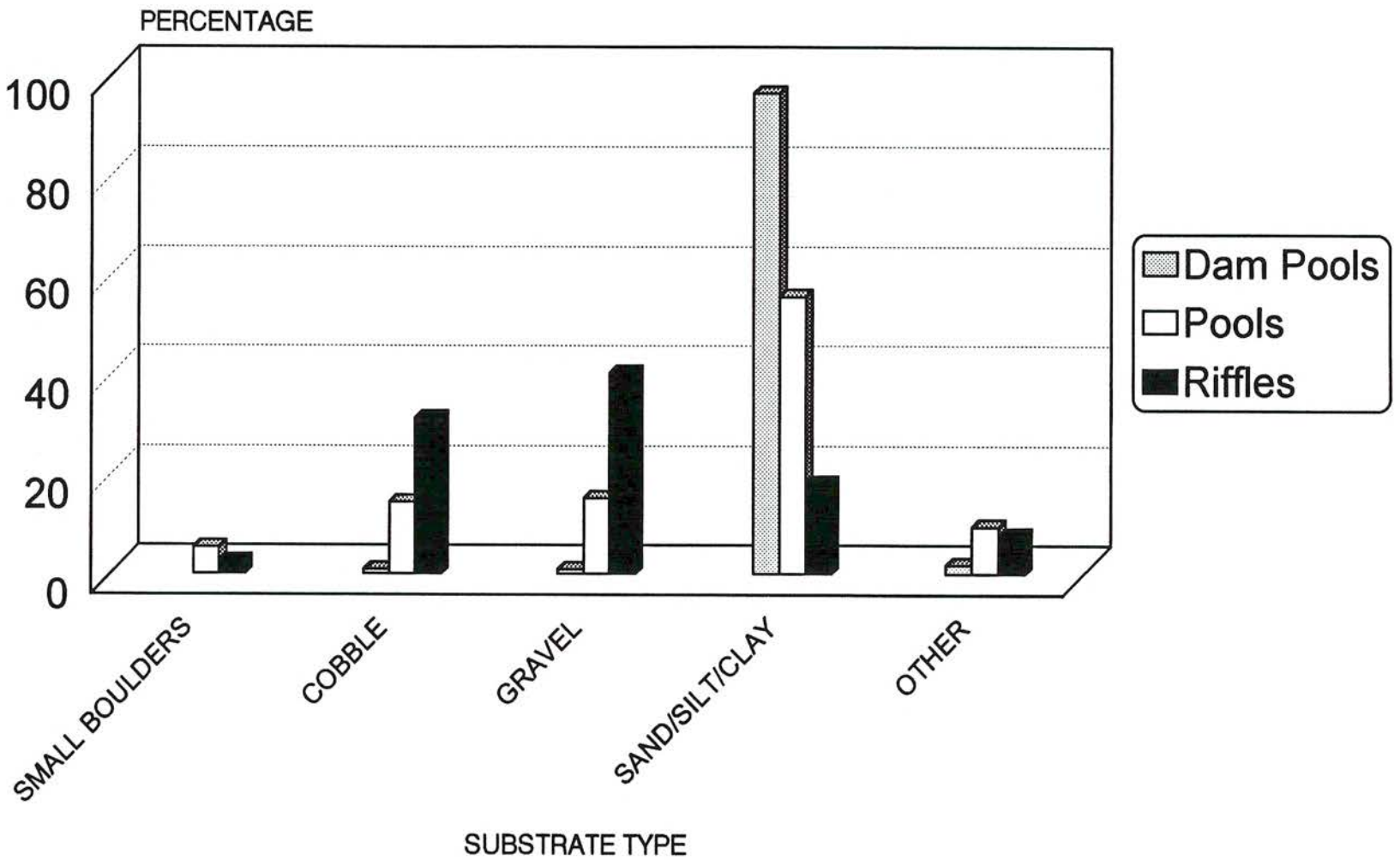


Figure 15. The composition of substrate sampled from dam pools, pools, and riffles on White Clay Creek near Newark. The substrate type labeled "other" includes organic detritus, vascular plants, and/or attached algae.

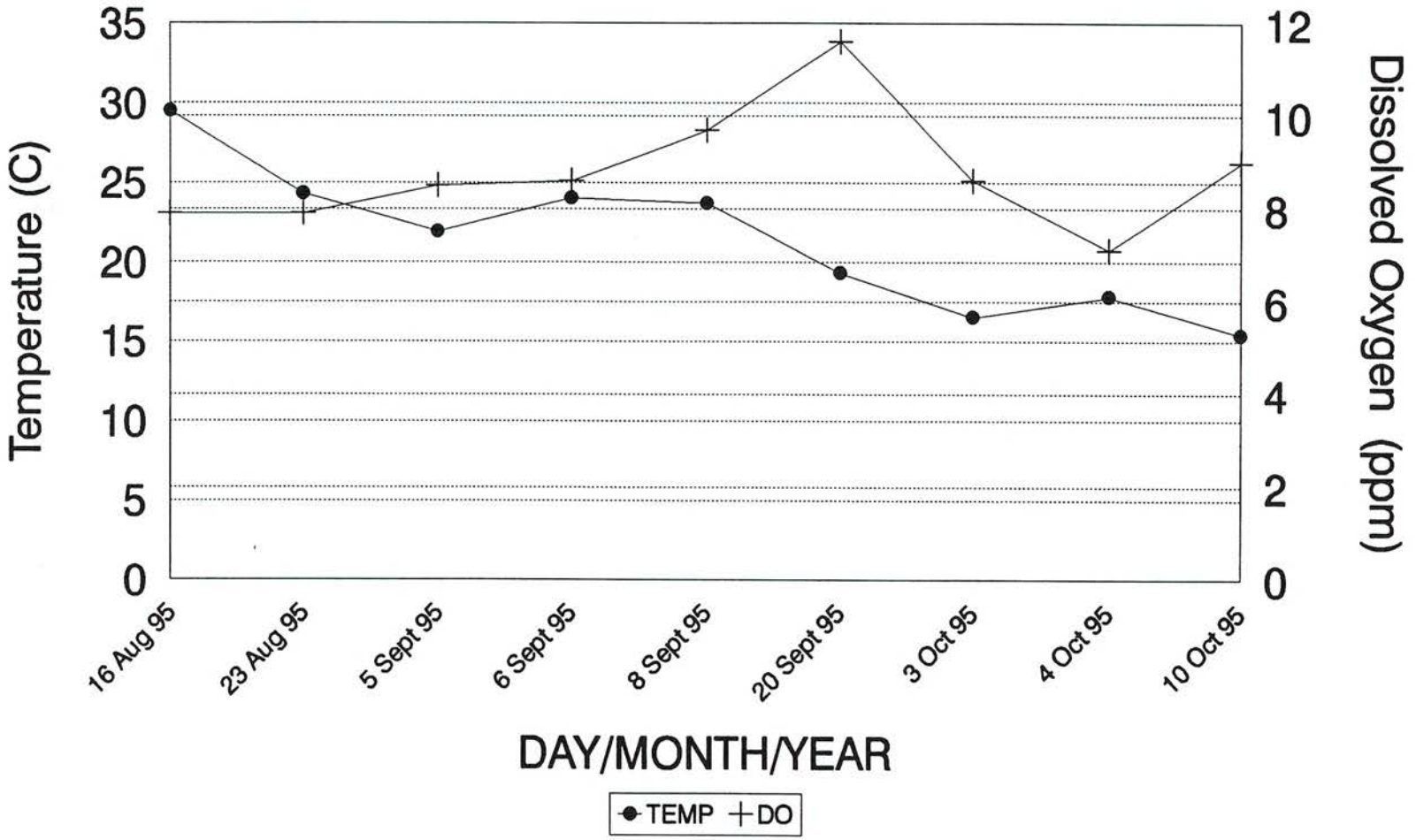


Figure 16. Water temperatures and dissolved oxygen readings recorded on White Clay Creek near Newark.

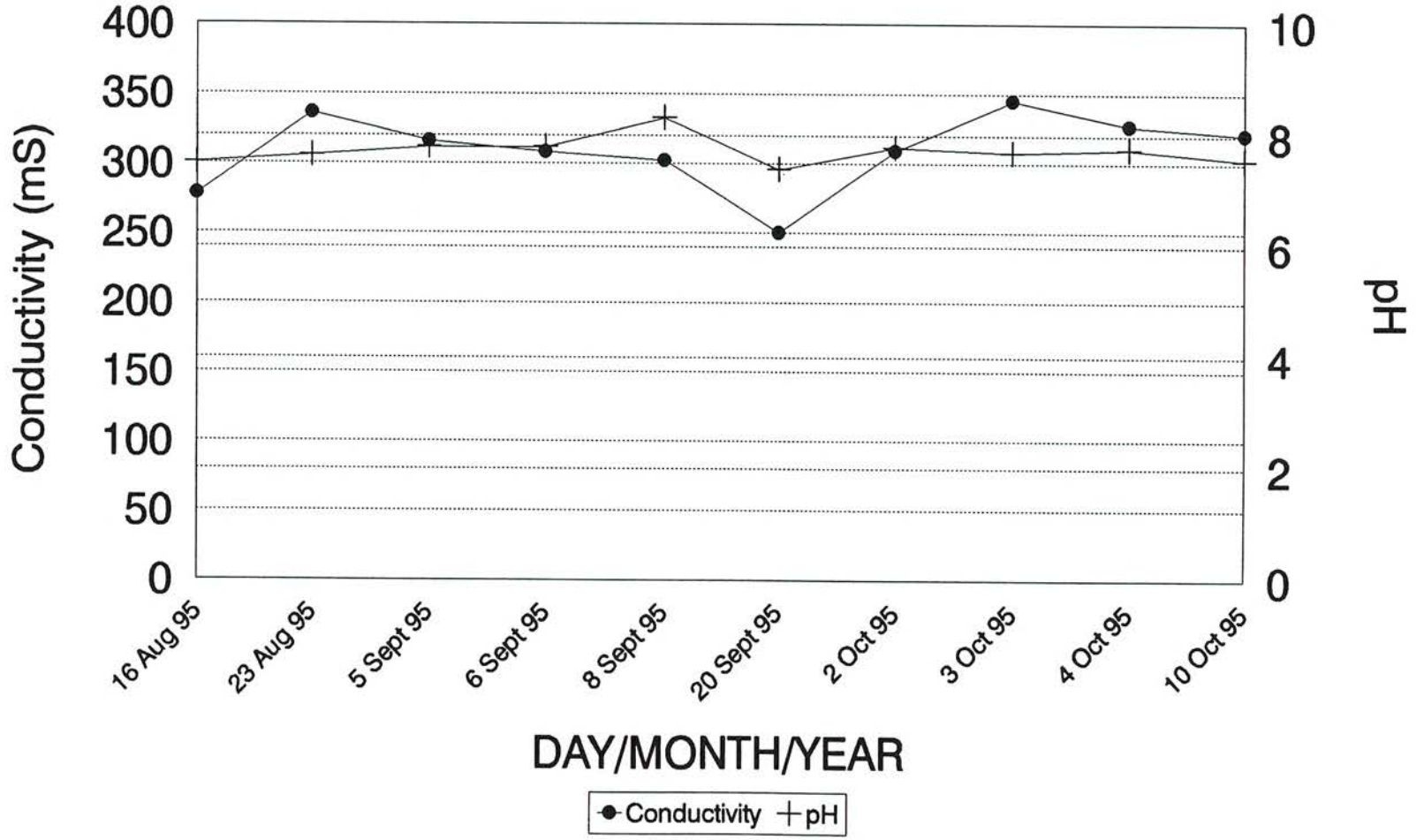


Figure 17. Water conductivity and pH readings recorded on White Clay Creek near Newark.

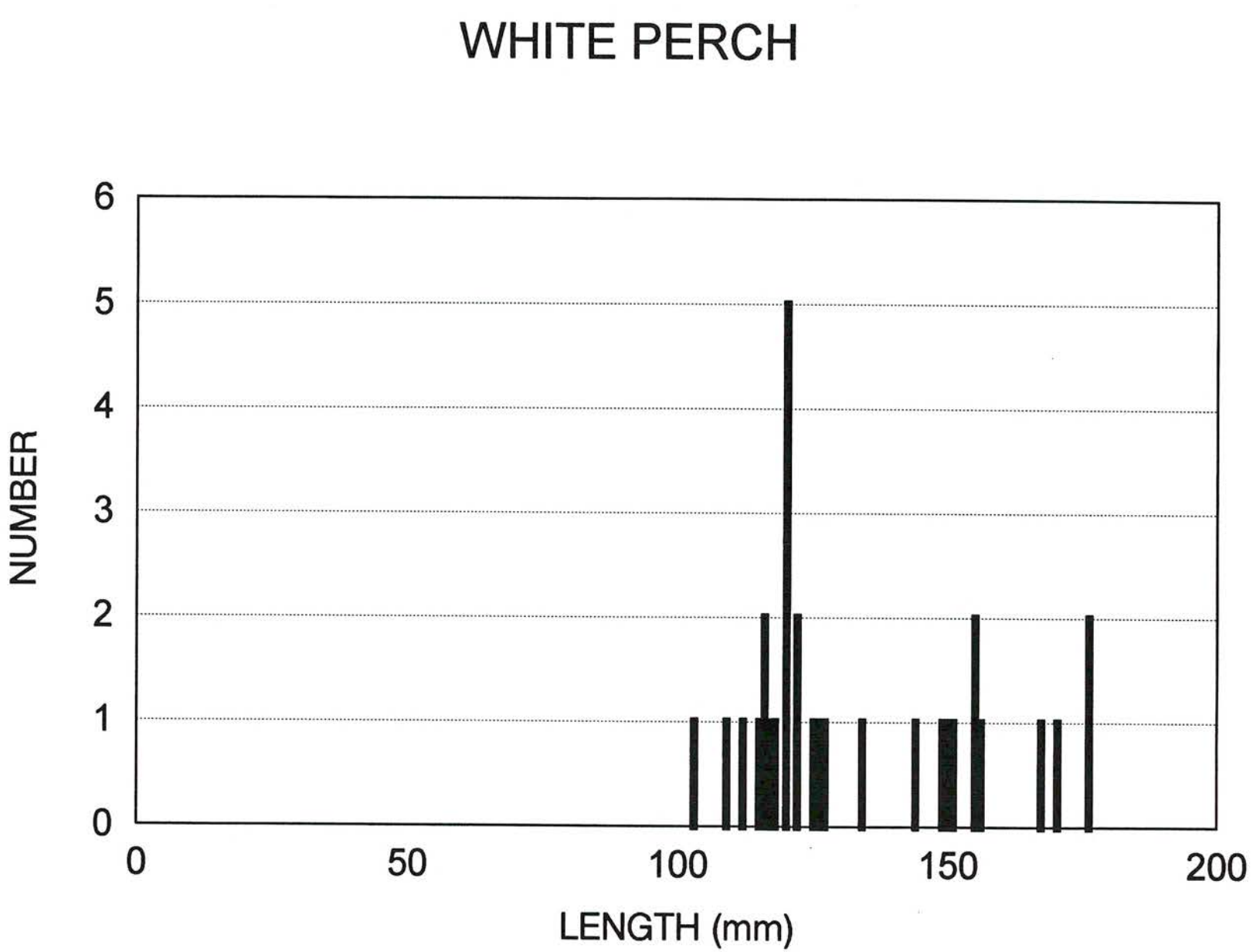


Figure 18. Length frequency of white perch measured from White Clay Creek at Stanton. All fish sampled were in the adult size class (>72 mm) determined from age- length groupings found in the literature.

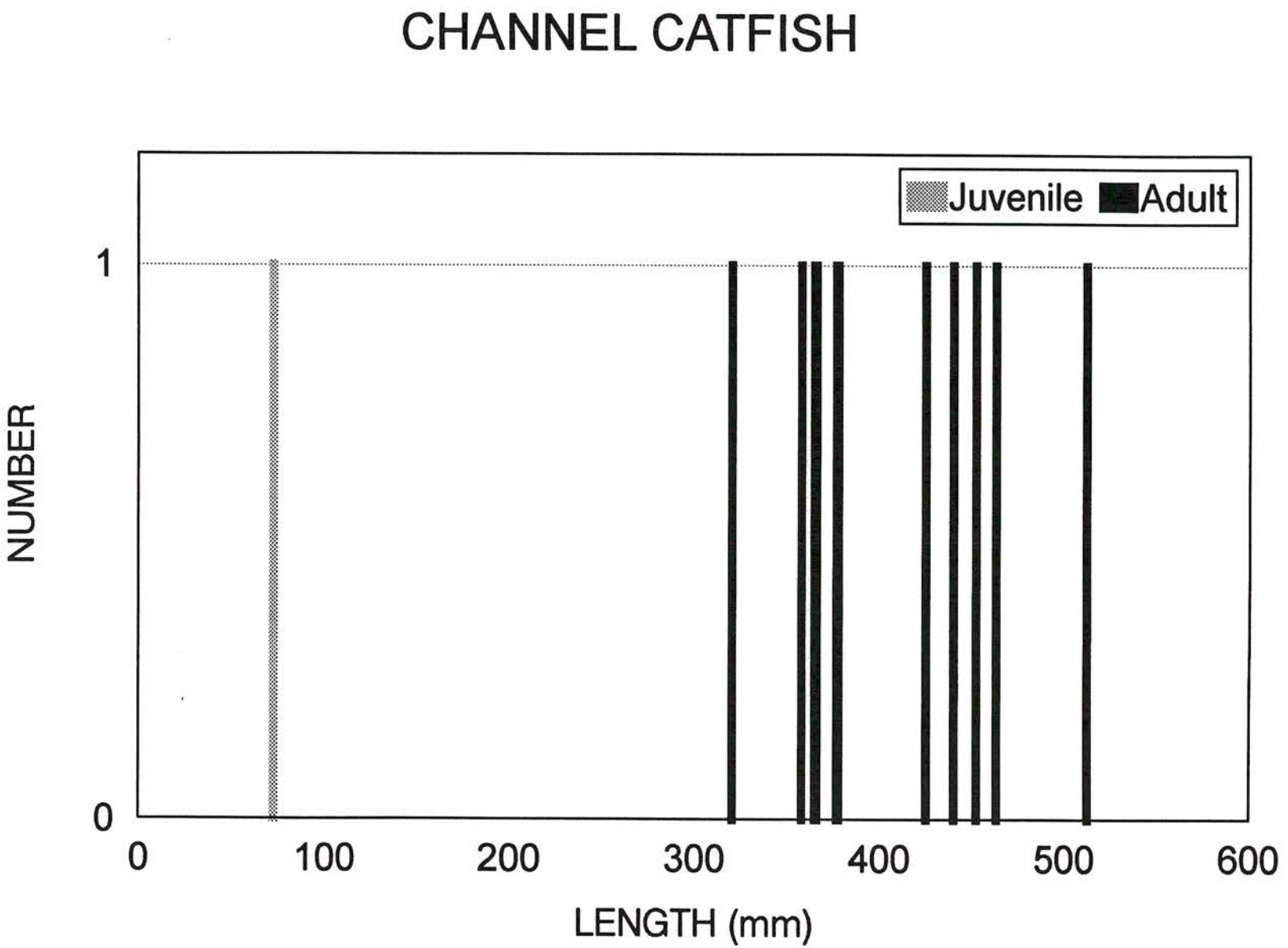


Figure 19. Length frequency of channel catfish measured from White Clay Creek near Stanton and categorized into predetermined size classes conforming to age-length groupings found in the literature.

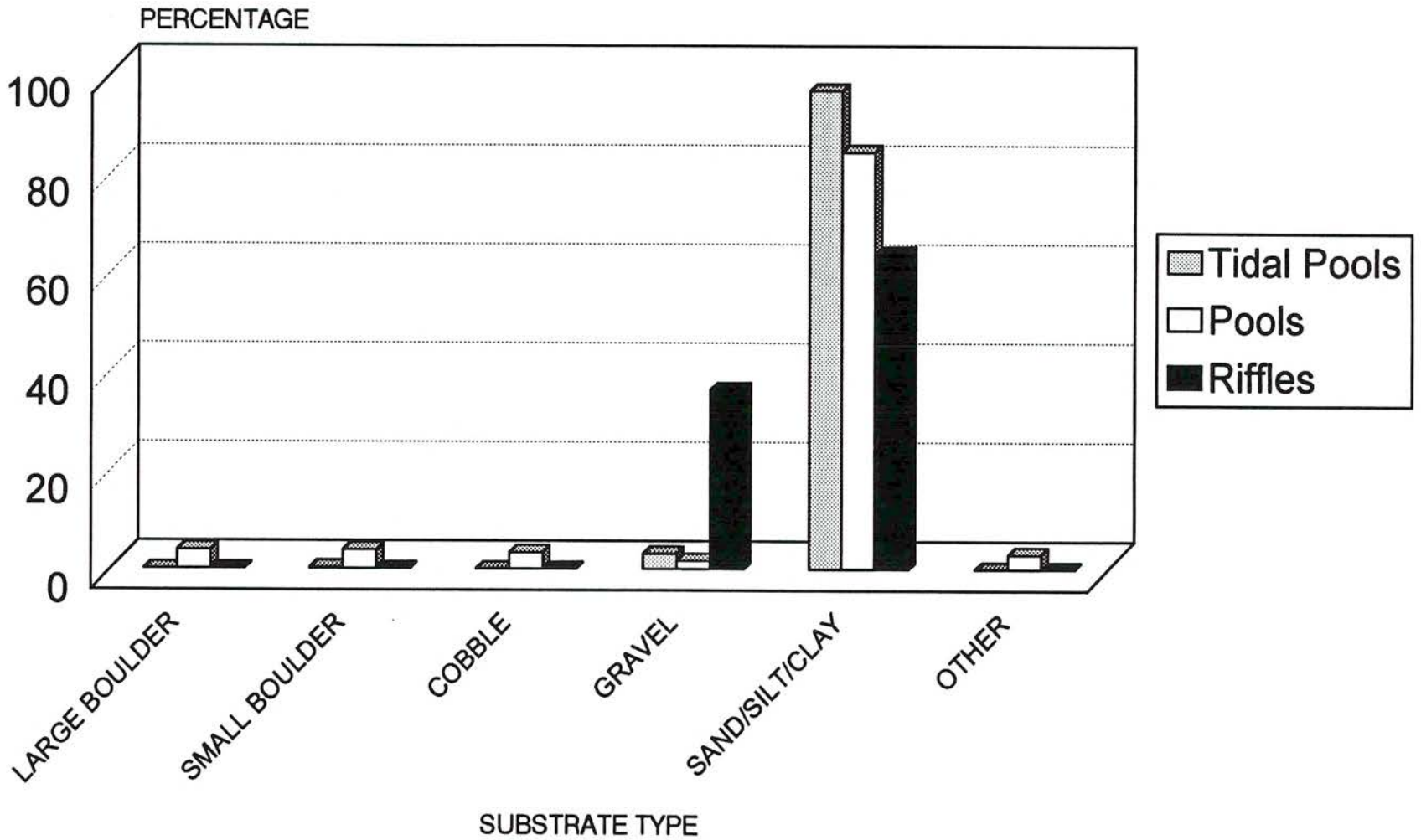


Figure 20. The composition of substrate sampled from tidal pools, pools, and riffles on White Clay Creek near Stanton. The substrate type labeled "other" includes organic detritus, vascular plants, and/or attached algae.

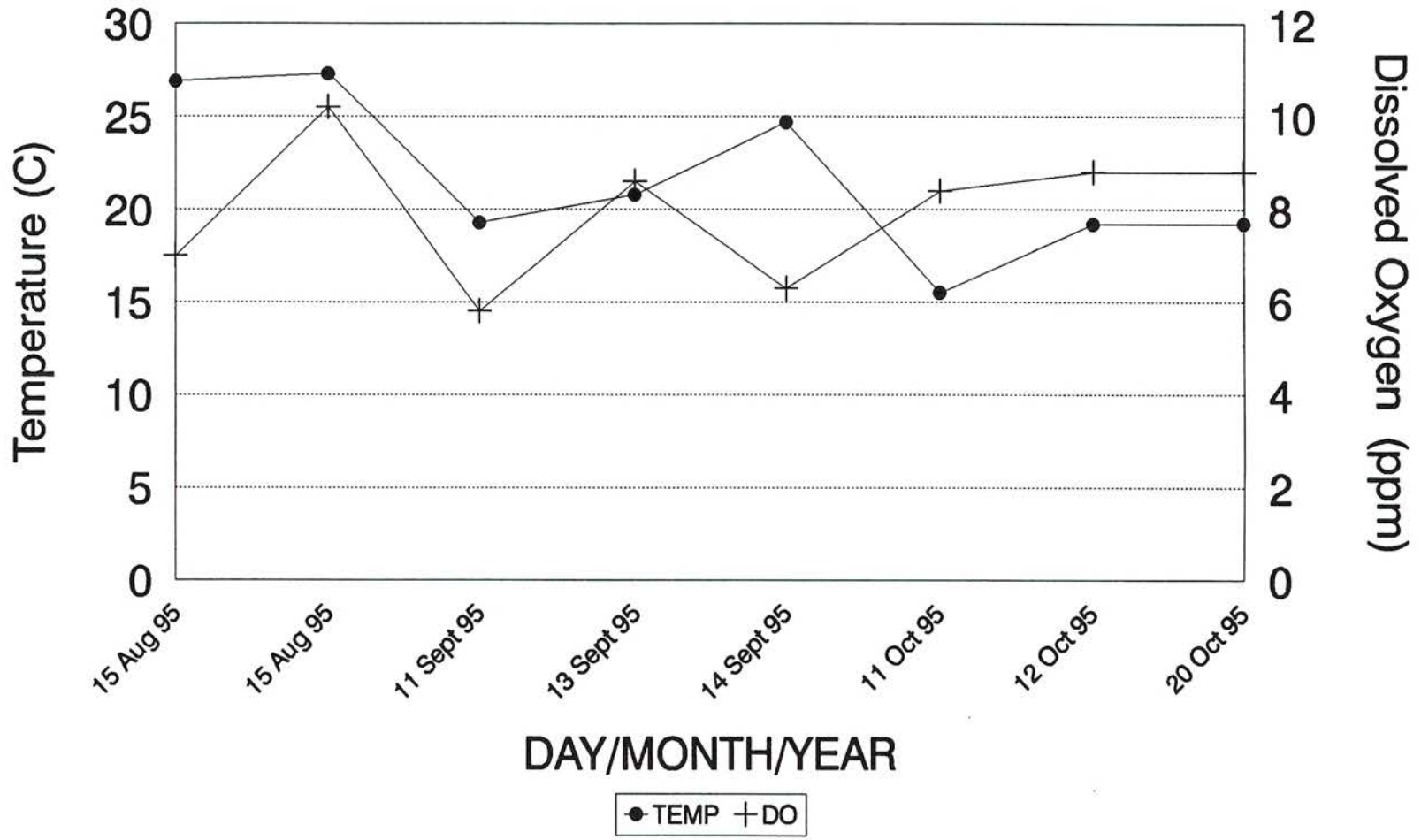


Figure 21. Water temperatures and dissolved oxygen readings recorded on White Clay Creek near Stanton.

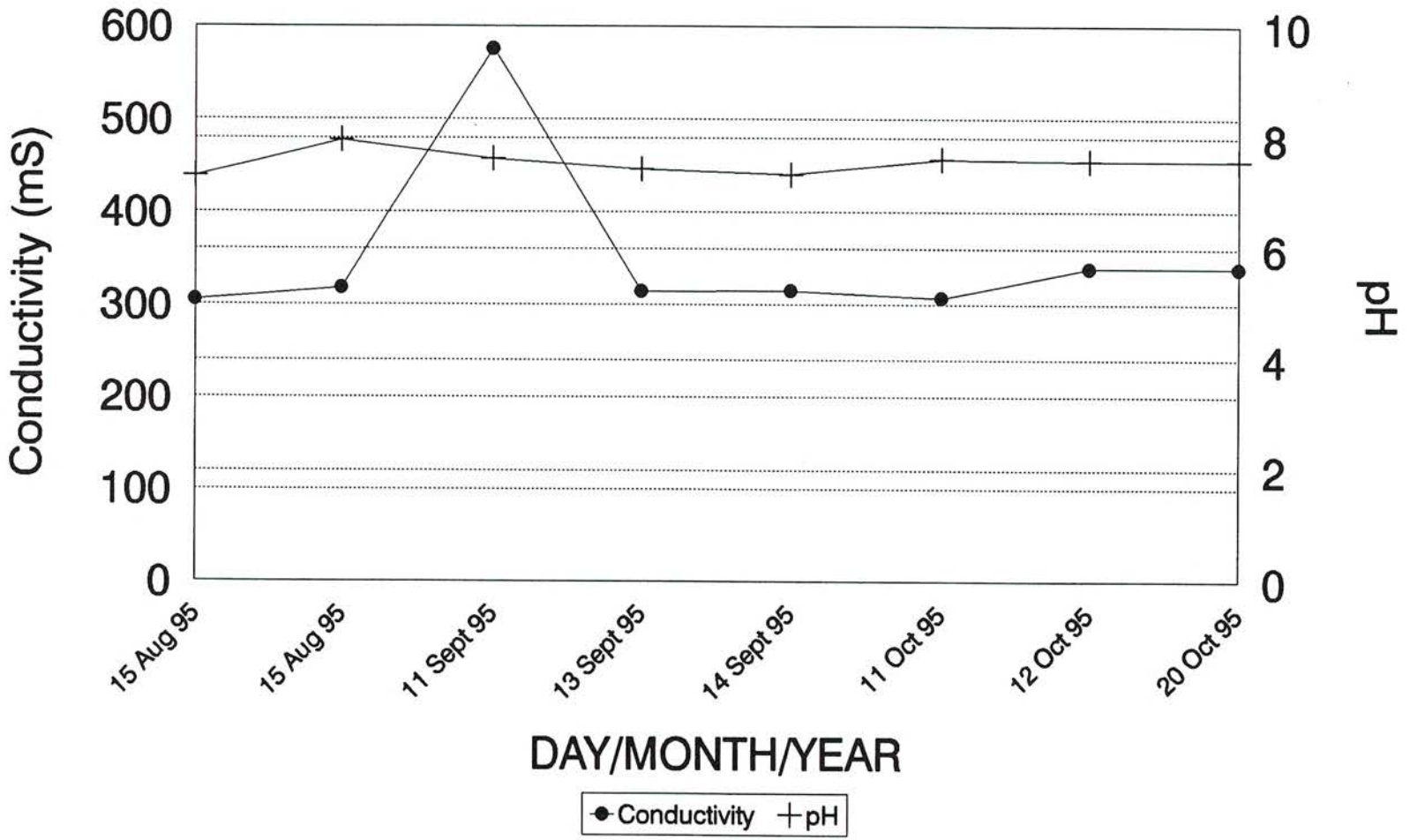


Figure 22. Water conductivity and pH readings recorded on White Clay Creek near Stanton.

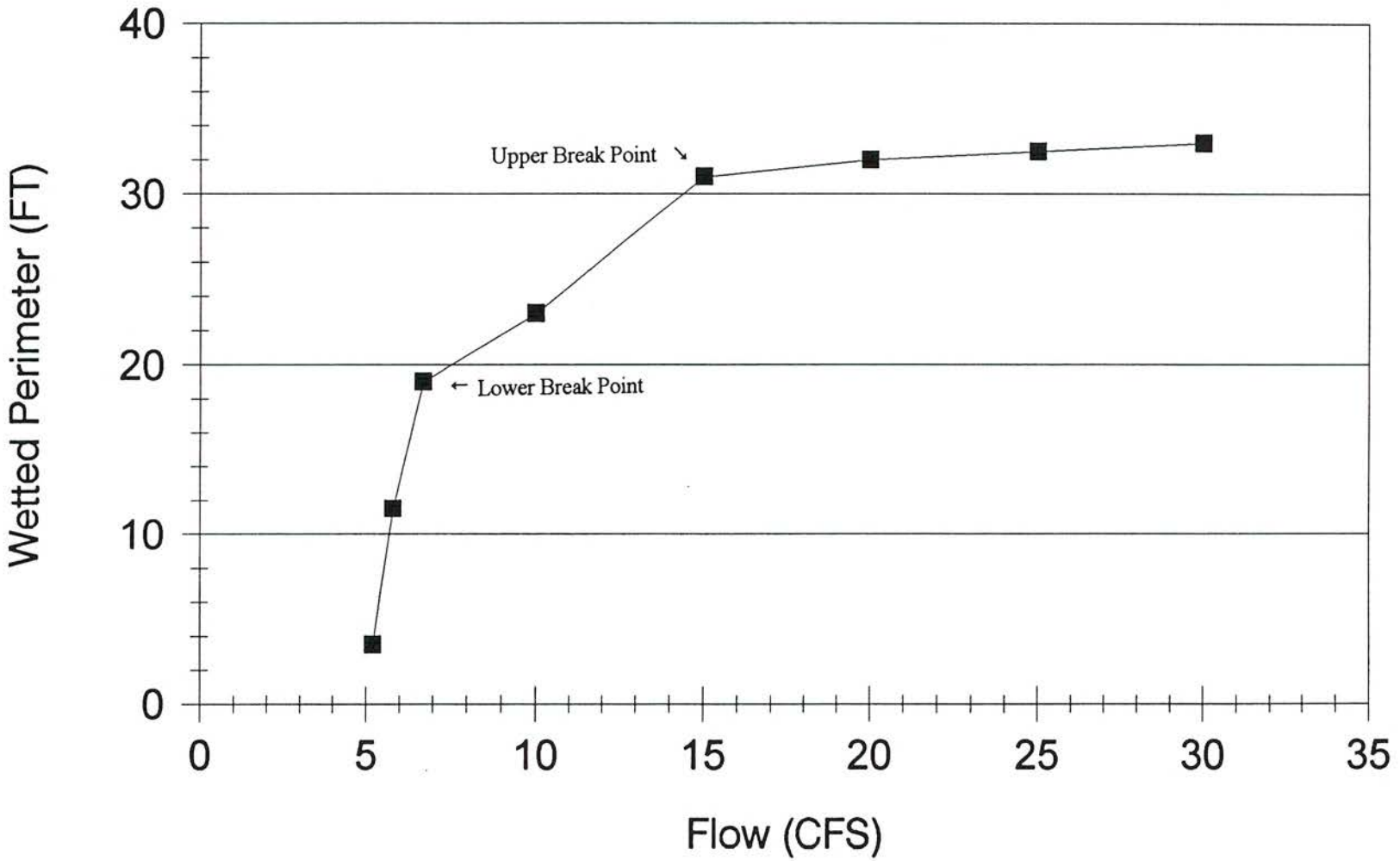


Figure 23. A hypothetical example of a plot of wetted perimeter versus flow for a stream riffle cross-section showing upper and lower wetted perimeter break points.

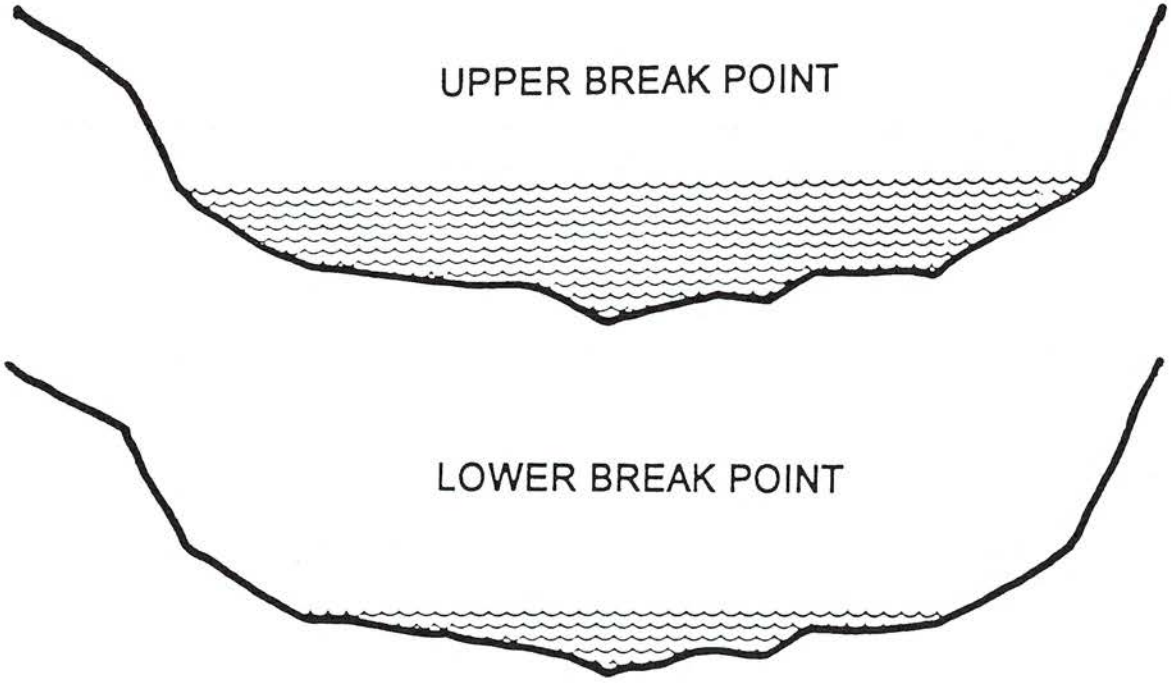


Figure 24. A diagrammatic representation of the flow at the upper and lower wetted perimeter break points obtained from Leathe and Nelson 1989.

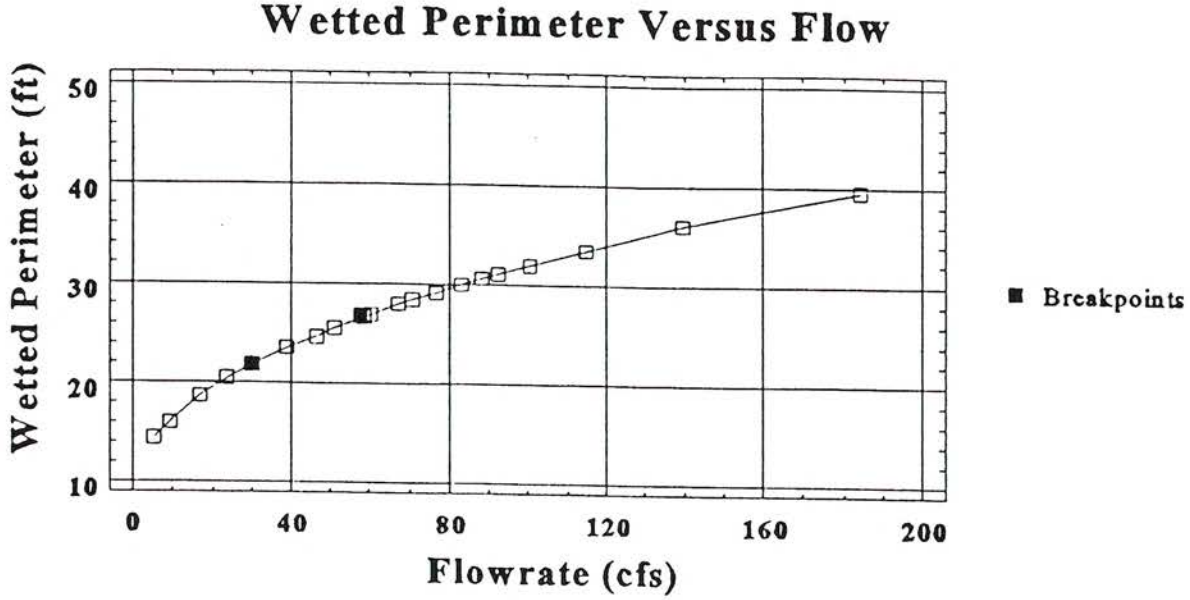


Figure 25. Wetted perimeter plot for Section 2.94 on Brandywine Creek, provided by Richard Greene, DNREC - Division of Water Resources.

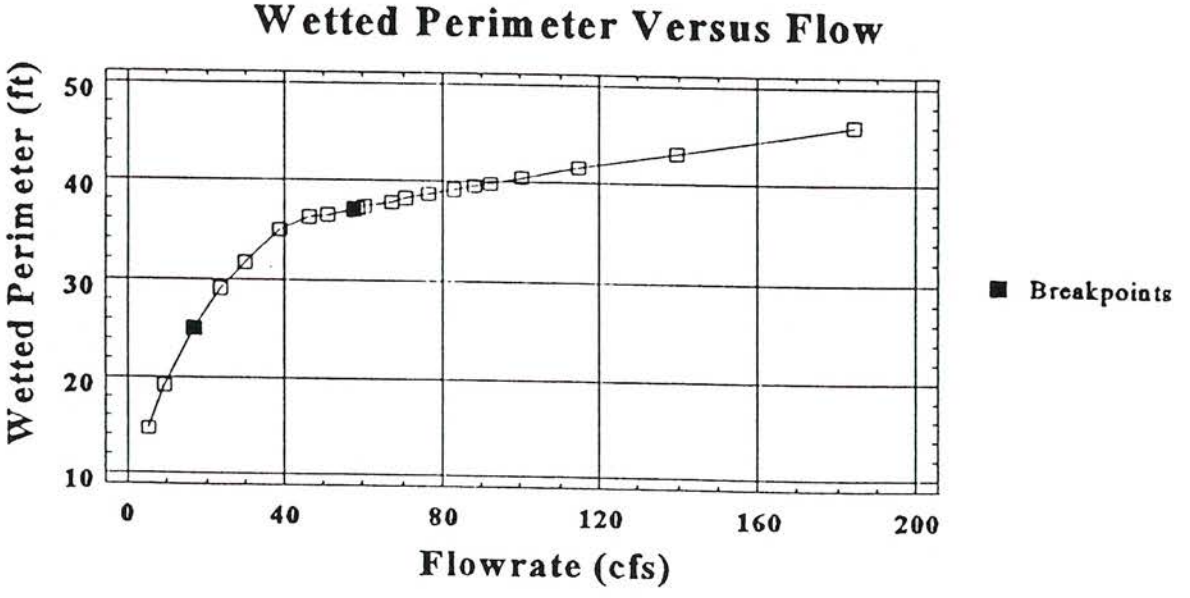


Figure 26. Wetted perimeter plot for Section 2.55 on Brandywine Creek, provided by Richard Greene, DNREC - Division of Water Resources.

Appendix 1

NEW CASTLE COUNTY, DELAWARE
INSTREAM FLOW NEEDS ASSESSMENT
JOINT TASK FORCE

JOINT MEMBERS

Dr. Richard Tortoriello
Operations Branch
DRBC
P.O. Box 7360
W. Trenton, NJ 08628-0360
(609)883-9500

John Talley, P.G.
Delaware Geological Survey
101 Penny Hall
Newark, DE 19711
(302)831-8258

William Gast
Chief, Div. of Water Planning & Alloc.
Bureau of Water Supply & Comm. Health
PaDER
P.O. Box 8467
Harrisburg, PA 17105-8467
(717)787-5017
(717)787-4048

Michael D. Sprague, Director
Public Works Department
City of Wilmington
City/County Building, 6th Floor
800 French Street
Wilmington, DE 19801
(302)571-4220

Bernie Dworsky, Administrator
Water Resources Agency
2701 Capitol Trail
Newark, De 19711
(302)366-7824

Rick Fromouth, P.E.
Operations Branch
DRBC
P.O. Box 7360
W. Trenton, NJ 08628-0360
(609)883-9500 X232

Steven Runkle
Chief, DRB Section
Bureau of Water Supply & Comm. Health
PaDER
P.O. Box 8467
Harrisburg, PA 17105-8467
(717)787-5017
(717)787-4048

Robert Walker, Vice President
Wilmington Suburban Water Corp.
2000 First State Blvd.
P.O. Box 6509
Wilmington, DE 19804
(302)633-5905

Joseph Dombrowski, P.E.
Director of Water and Wastewater
City of Newark
P.O. Box 390
Newark, DE 19711
(302)366-7055

Jerry Kauffman, P.E.
Water Resources Agency
2701 Capitol Trail
Newark, DE 19711
(302)731-7670

Department of Natural Resources
& Environmental Control
89 Kings Hwy.
P.O. Box 1401
Dover, DE 19901

DNREC MEMBERS

Div. of Fish & Wildlife
Fisheries Section

Roy Miller
(302)729-3441

Div. of Water Resources
Watershed Assessment Section

Brad Smith
Rick Greene
(302)739-4590

Div. of Water Resources
Water Supply Section

Stewart Lovell, P.G.
(302)739-4793

CONSULTANT

David C. Yaeck
1633 Christine Lane
West Chester, PA 19380
(610)431-1376

B. HEC-2 WETTED PERIMETER STREAM RIFFLE DATA

[redacted] DRCRWIL2.NAT

T3 MODEL THE 7Q10 = 49.3 MGD = 76.3 CFS

J1	-10	10							-1.53	
J2	-1									
J3	38	43	42	1	8	26	4			
NC	.070	.070	.040	.1	.3					
QT	5	17	24	39	51	76	83	88	100	115
X1	204	15	385	555	0	0	0	0	0	0
GR	4	0	3.3	385	0.2	409	-4.3	428	-4.9	435
GR	-5.3	445	-5.6	455	-6	475	-4.8	485	-5.6	505
GR	-4.7	525	-5.3	535	-4.6	545	16	555	14.3	560
X1	238	10	940	1105	1670	1670	1670	0	0	0
GR	4.4	0	3.1	940	2.4	955	1.1	980	-0.4	1000
GR	2	1100	6.1	1105	9.4	1115	12.6	1145	25	1146
X1	239	11	900	1100	50	50	50	0	0	0
GR	25	0	15	840	7.3	900	4.6	940	9.5	941
GR	8.7	987	4.6	988	4.6	1100	5.8	1120	12.6	1132
GR	25	1133	0	0	0	0	0	0	0	0
X1	240	10	900	1110	50	50	50	0	0	0
GR	25	0	10.4	870	7.6	900	5.6	920	3.6	960
GR	1.5	980	2.6	1100	8	1110	12.6	1127	25	1130
X1	255	19	78.4	189.4	792	792	792			
GR	21.16	0	17.51	20	17.14	40	14.22	56.4	11.02	78.4
GR	10.24	89.4	9.94	99.4	8.89	109.4	8.04	119.4	7.54	129.4
GR	8.14	139.4	7.34	149.4	9.14	159.4	8.84	169.4	9.34	179.4
GR	11.13	189.4	14.42	202.7	16.81	215.1	22.30	228.8		
X1	265	15	520	773	528	528	528	0	0	0
GR	17.8	0	14.32	520	13.41	540	13.61	560	13.41	580
GR	12.6	600	13.71	620	13.51	640	13.11	660	15.38	680
GR	20.5	700	22.41	720	24.15	740	24.43	760	24.69	773
X1	267	27	40	234.1	106	106	106			
GR	22.25	0	20.36	20	19.32	40	17.32	49.1	13.38	60.7
GR	12.11	64.1	11.82	74.1	11.86	84.1	12.19	94.1	11.82	104.1
GR	11.02	114.1	11.57	124.1	11.52	134.1	11.65	144.1	12.09	154.1
GR	12.19	164.1	11.77	174.1	12.00	184.1	12.79	194.1	12.44	204.1
GR	12.69	214.1	12.02	224.1	13.05	234.1	15.26	239.8	16.75	248.8
GR	20.45	257.8	22.96	277.8						
X1	293	21	23.2	154.7	1373	1373	1373			
GR	23.84	0	19.98	3.5	15.00	23.2	14.56	24.7	13.98	34.7

[redacted] DRCRW112.MAP [redacted]

GR	13.67	144.7	15.00	154.7	16.97	167.0	19.45	200.2	20.49	220.2
GR	22.25	240.2								
X1	294	15	157	292	53	53	53	0	0	0
GR	26.4	0	18	143	25.5	144	25.5	157	17.3	158
GR	17.5	170	16	180	16.7	190	13.2	250	13.3	260
GR	15.8	270	16.3	280	17.5	286	20.5	292	25	293
X1	295	16	162	302	50	50	50	0	0	0
GR	57.8	0	36.9	45	34.9	60	35.5	79	28.9	81
GR	25.6	145	29.3	146	29.3	162	23.3	163	23.3	290
GR	24.2	298	29.3	302	31.4	328	31.5	359	38.7	398
GR	84.2	500	0	0	0	0	0	0	0	0
X1	296	26	156	350	50	50	50	0	0	0
GR	57.8	0	49.3	16	41.1	31	34	58	32.9	105
GR	28.6	128	28.2	150	27.9	156	23	160	20.6	170
GR	20.2	180	21.1	190	21.1	210	18.3	230	19.3	250
GR	19.6	270	20	280	19.5	290	20.2	300	19	330
GR	20.6	340	23	342	28	350	29.6	400	34.5	430
GR	84.2	500	0	0	0	0	0	0	0	0
X1	299	22	37.3	158.3	264	264	264			
GR	24.48	0	19.57	18.0	16.88	29.0	15.86	37.3	15.38	38.3
GR	14.76	48.3	15.13	58.3	15.38	68.3	15.05	78.3	15.01	88.3
GR	14.88	98.3	14.67	108.3	13.96	118.3	14.80	128.3	14.63	138.3
GR	14.38	148.3	15.71	158.3	18.40	164.1	19.99	171.7	23.60	180.3
GR	25.52	200.3	26.29	220.3						
X1	305	4	1.0	202.0	500	500	500	0	0	0
GR	30	0	23.5	1.0	23.5	201.0	30	202.0	0	0
X1	332	27	190	315	595	595	595	0	0	0
GR	83	0	66.1	40	65.8	57	64.7	64	61	103
GR	56.6	114	40.5	137	32.5	138	34.2	172	35.5	181
GR	36.9	182	35.1	190	27	198	26.2	202	26	211
GR	25.3	222	25.1	241	25.4	253	24.7	261	26.5	272
GR	25.1	281	26.1	291	27.1	310	28.4	315	38.3	392
GR	49	407	62.6	462	0	0	0	0	0	0
X1	341	21	161	302	450	450	450	0	0	0
GR	85	0	55.8	70	47.1	100	46.8	108	38.3	109
GR	31.1	148	41.3	149	41.3	161	34.8	162	28.9	178
GR	27.9	190	27.6	210	27.1	220	24.1	230	24.3	285
GR	25.1	295	28.1	302	31.8	320	36.3	321	50.6	400

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
GR	85	0	55.8	70	47.1	100	46.8	108	38.3	109
GR	33.7	148	46.7	149	46.7	173	34.3	174	34.9	192
GR	34.3	217	34.1	240	33.6	250	33.5	260	33.5	330
GR	34.1	345	37.2	350	47.9	351	62.5	375	0	0
X1	343	24	110	350	50	50	50	0	0	0
GR	85	0	55.8	70	44	80	37.9	100	36.6	101
GR	32.7	110	30.3	119	29.5	160	29.9	170	29.1	200
GR	28.3	210	26	230	28.7	250	30.4	260	31.4	280
GR	31.4	290	30.3	310	30.9	320	30.8	330	34	338
GR	37.8	350	38.5	358	40.8	364	62.5	375	0	0
X1	368	22	144	342	1320	1320	1320	0	0	0
GR	75	0	39.2	120	50.5	121	49.9	135	46.3	144
GR	42.8	176	43.6	178	41.5	180	42.2	190	41.4	200
GR	40.6	210	40.5	220	39.1	230	39.6	240	39.5	250
GR	41.1	290	41.3	300	42.2	310	42.5	320	42.7	333
GR	49.6	342	81	550	0	0	0	0	0	0
X1	369	18	143	342	50	50	50	0	0	0
GR	75.3	0	50.1	143	48.7	150	46.1	174	49.4	180
GR	49.3	200	48.4	220	48.7	230	47.4	240	48	250
GR	46.7	260	48.2	270	48.7	280	48.9	300	49	320
GR	49.5	330	49.6	342	81	550	0	0	0	0

EJ

ER

SUMMARY PRINTOUT

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
	204.000	76.28	-6.00	-1.53	4.47	.17	130.19
*	238.000	76.28	-.40	.46	.86	3.77	47.18
*	239.000	76.28	4.60	4.84	.24	2.77	119.69
	240.000	76.28	1.50	4.97	3.47	.18	171.81
*	255.000	76.28	7.34	8.32	.98	3.99	38.77
	265.000	76.28	12.60	13.77	1.17	1.41	133.78
	267.000	76.28	11.02	13.81	2.79	.24	176.62
	293.000	76.28	11.71	13.87	2.16	.54	109.78
*	294.000	76.28	13.20	14.12	.92	4.42	29.03
*	295.000	76.28	23.30	23.52	.22	2.67	129.02
	296.000	76.28	18.30	23.65	5.35	.11	183.56
	299.000	76.28	13.96	23.65	9.69	.07	177.71
*	305.000	76.28	23.50	23.66	.16	2.31	200.05
	332.000	76.28	24.70	26.22	1.52	1.17	87.99
	341.000	76.28	24.10	26.34	2.24	.53	75.38
*	342.000	76.28	33.50	33.80	.30	3.00	92.58
	343.000	76.28	26.00	33.96	7.96	.08	230.80

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
*	368.000	76.28	39.10	40.04	.94	3.97	43.17
*	369.000	76.28	46.10	47.58	1.48	4.22	33.41

[redacted] #CCNEWR.NA[redacted]

T3 MODEL THE 7Q10 = 11.27 CFS = 7.3 MGD

J1	-10	10						46.7	
J2	-1	0	-1						
J3	38	43	42	1	8	26	4		
NC	.090	.090	.035	.1	.3				
QT	2	5	8	10	15	19	24	28	31	33
X1	49000	29	155	235	1585	1585	1585			
GR	88	0	84	15	80	30	76	45	72	80
GR	68	100	64	120	60	140	56	150	54.1	155
GR	50.9	158	49.2	166	47.8	169	46.8	175	46	188
GR	45.7	198	45.8	210	47.9	214	50.8	218	51.4	225
GR	52	235	56	255	58.4	400	56	555	56	600
GR	60	685	64	775	68	875	72	998		
X1	050000	31	585	667	1000	1000	1000			
GR	84.9	0	78.9	100	74.4	200	72.4	300	67.4	395
GR	60.7	410	57.7	500	59.3	570	58.6	585	50.4	590
GR	48.9	595	47.9	605	47.8	615	49.1	625	49.0	635
GR	47.4	645	48.9	655	50.4	660	59.1	667	58.8	685
GR	61.4	720	64.1	755	64.6	775	69.1	800	71.1	900
GR	72.6	1000	75.6	1100	77.6	1200	79.1	1300	84.6	1365
GR	90.1	1465								
NC	0	0	0	.3	.5					
X1	050055	27	620	730	55	55	55			
GR	84.9	0	78.9	100	74.4	200	72.4	300	67.4	395
GR	60.7	410	57.7	500	57.7	570	57.5	620	52.0	627
GR	52.4	660	52.4	690	52.6	710	55.8	720	59.1	730
GR	59.0	750	61.4	785	64.1	820	64.6	840	69.1	865
GR	71.1	965	72.6	1065	75.6	1165	77.6	1265	79.1	1365
GR	84.6	1430	90.1	1530						
X1	050090	31	594	678	35	35	35			
GR	84.9	0	78.9	100	74.4	200	72.4	300	67.4	395
GR	60.7	410	57.7	500	57.3	570	57.2	594	52.8	598
GR	51.3	600	50.1	610	50.3	620	50.0	630	49.7	640
GR	49.8	650	49.9	660	52.8	670	59.4	678	61.1	690
GR	61.4	725	64.1	760	64.6	780	69.1	805	71.1	905
GR	72.6	1005	75.6	1105	77.6	1205	79.1	1305	84.6	1370
GR	90.1	1470								
NC	0.09	0.09	0.04	0.1	0.3					

```
[redacted]092[redacted]00[redacted]0 [redacted]88.[redacted]00[redacted]5 0[redacted]3.8[redacted]016[redacted]00[redacted].3[redacted]240[redacted]00[redacted]80[redacted]53.[redacted] [redacted] [redacted] [redacted] [redacted]
GR0080.0000285.5 00077.0000328.4 00074.6000424.5 00072.8000479.4 00067.9000540.0
GR0063.8000613.3 00061.7000644.8 00059.7000701.3 00059.7000762.1 00059.2000780.0
GR0054.7000789.1 00053.3000790.0 00052.8000790.1 00051.6000792.9 00050.8000810.0
GR0051.0000819.1 00053.3000827.0 00057.3000838.0 00059.7000848.0 00067.4000968.1
GR0068.7000980.2 00079.6000994.7 00089.5001008.7 00091.4001015.7 00092.0001039.6
X1052855      34      676      744      810      810      810
GR0092.0000000.0 00086.9000036.7 00084.2000069.5 00081.4000106.2 00080.6000130.7
GR0080.4000145.8 00080.4000158.5 00080.4000177.7 00080.3000183.6 00078.9000232.1
GR0078.4000300.6 00078.3000353.1 00076.9000413.5 00074.0000459.8 00070.5000504.9
GR0067.3000553.8 00066.6000590.3 00063.2000616.3 00063.5000658.8 00062.2000676.0
GR0056.8000686.0 00054.5000689.0 00053.1000701.1 00052.6000710.0 00053.9000726.0
GR0055.3000731.9 00064.7000744.0 00066.3000754.0 00066.3000764.7 00074.8000875.0
GR0075.5000887.8 00075.5000912.4 00078.8000932.2 00092.0000953.5
X1 53155      16     1066     1121      300      300      300
GR    80       0       76      100       72      220       68      850       64      930
GR    60    1050     60.5     1066     56.1     1088     55.6     1097     56.9     1113
GR  61.3    1121       64     1140       76     1320       80     1350       84     1370
GR    88    1395
NC  0.09    0.09     0.04      0.3      0.5
X1 53205       0        0        0       50       50       50        0       .2
X3    10                                                          67       67
SB  1.05    1.56      2.8              63.4        7      972     3.33     55.8     55.8
X1 53244      24      900     1034       39       39       39
X2                      1     66.4       68
X3    10                                                          68       68
BT    24       0     89.0     89.0      100     84.0     84.0      200     79.0     79.0
BT   300    74.0     74.0      400     70.0     70.0      500     68.0     68.0      600
BT  69.0    69.0      700     71.0     71.0      800     73.0     73.0      900     74.0
BT  74.0     901     76.2     66.4      915     76.2     66.3      923     76.2     66.2
BT   957    76.2     66.1      972     76.2     66.2      984     76.2     66.2     1033
BT  76.2    66.0     1034     74.0     74.0     1134     74.5     74.5     1234     78.0
BT  78.0    1334     84.0     84.0     1434     89.5     89.5     1534     95.0     95.0
BT  1634    99.0     99.0
GR  89.0       0     84.0      100     79.0      200     74.0      300     70.0      400
GR  68.0     500     69.0      600     71.0      700     73.0      800     74.0      900
GR  60.9     901     60.9      915     56.7      923     59.0      957     55.8      972
GR  58.2     984     59.4     1033     74.0     1034     74.5     1134     78.0     1234
GR  84.0    1334     89.5     1434     95.0     1534     99.0     1634
```

[redacted] 78[redacted] [redacted] 0 [redacted] 78.[redacted] [redacted] [redacted] 7.8[redacted] [redacted] [redacted] .5 [redacted] 2[redacted] [redacted] 0 [redacted] 39[redacted]

#CCN[redacted]:NA[redacted]

GR 77.0 405 77.0 410 77.0 415 76.5 425 76.8 438
GR 76.4 750 76.5 925 71.3 950 70.3 1065 68.7 1165
GR 68.2 1265 67.5 1345 67.5 1375 64.7 1435 64.2 1440
GR 59.7 1452 58.2 1466 57.2 1470 56.5 1490 56.4 1510
GR 56.6 1530 56.2 1550 57.2 1570 57.7 1590 58.2 1593
GR 60.3 1606 70.4 1616 73.9 1690 76.1 1740 88.4 1890
GR 104.7 1970 120 2060
X1053320 38 1547 1705 40 40 40
GR 78.0 0 78.0 95 77.8 190 77.5 280 77.0 395
GR 77.0 405 77.0 410 77.0 415 76.5 425 76.8 438
GR 76.4 750 76.5 925 71.3 950 70.3 1065 68.7 1165
GR 68.2 1265 67.5 1345 67.5 1375 64.7 1435 65.4 1537
GR 69.1 1538 68.2 1547 62.4 1548 62.4 1580 62.4 1605
GR 62.4 1630 62.4 1655 62.6 1682 64.2 1695 69.0 1705
GR 71.3 1735 73.5 1780 76.1 1837 79.4 1911 88.4 1996
GR 104.7 2070 112.1 2164 114.7 2237
X1053345 31 1380 1559 25 25 25
GR 78 0 76.8 438 76.4 750 76.5 925 71.3 950
GR 70.3 1065 68.7 1165 68.2 1265 67.5 1345 67.5 1375
GR 67 1380 64.2 1385 59.7 1397 58.2 1411 57.2 1415
GR 56.5 1435 56.4 1455 56.6 1475 56.2 1495 57.2 1515
GR 57.7 1535 58.2 1538 60.3 1551 67 1559 69 1605
GR 71.3 1635 73.5 1680 76.1 1737 79.4 1811 88.4 1896
GR 104.7 1970
NC 0 0 0 .1 .3
X1055360 38 1232 1329.1 2015 2015 2015
GR0096.1000000.0 00093.4000038.4 00090.5000109.0 00088.1000160.9 00084.2000222.3
GR0082.3000275.7 00080.6000328.6 00080.2000389.4 00080.6000453.6 00079.7000463.4
GR0079.7000479.8 00079.7000486.8 00079.2000518.1 00077.5000539.5 00076.1000631.4
GR0076.1000702.4 00075.2000771.5 00073.1000830.4 00070.2000911.4 00068.3001002.8
GR0068.2001085.9 00068.2001170.7 00068.2001215.4 00068.2001232.0 00063.1001238.1
GR0062.2001238.2 00060.8001246.0 00060.7001267.9 00060.2001292.1 00063.1001311.0
GR0065.6001317.0 00075.5001329.1 00076.3001344.2 00076.3001355.3 00081.4001371.6
GR0085.9001391.2 00089.6001415.2 00096.0001439.7
X1 55713 19 40 139.9 353 353 353
GR 83.81 0 78.71 40 77.62 40 73.44 44.5 68.71 48.5
GR 63.71 50.2 62.87 60.2 62.87 70.2 62.96 80.2 63.21 90.2
GR 63.31 100.2 62.75 110.2 62.58 120.2 63.95 130.2 67.25 133.1

[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]

GR	69.97	0	70.21	20	71.43	40	68.07	46.0	64.36	50.6
GR	63.40	60.6	62.57	70.6	63.09	80.6	64.35	89.2	64.25	106.2
GR	71.10	119.2	71.89	139.2	79.14	159.2				
X1	57000	24	801	880	377	377	377			
GR	96	0	92	120	88	190	84	320	80	510
GR	76	760	72	761	68	801	65.4	805	64.5	806
GR	63.1	814	63	833	62.5	847	65.4	870	67.9	875
GR	68	880	72	900	73	950	76	1300	80	1325
GR	84	1335	88	1345	92	1360	96	1390		
X1	57030	15	40	121.1	30	30	30			
GR	71.72	0	70.90	20	73.11	40	68.67	46	66.47	54.1
GR	65.18	56.4	63.66	66.4	63.70	76.4	64.10	86.4	64.29	96.4
GR	64.54	106.4	64.90	116.1	66.98	119.3	71.53	121.1	70.51	141.1
X1	57970	15	40	130.4	940	940	940			
GR	72.40	0	72.80	20	74.93	40	73.27	51.60	70.54	57.6
GR	66.56	65.9	65.26	75.9	65.68	85.9	65.64	95.90	66.12	105.9
GR	66.50	110.4	67.92	117.4	71.07	123.3	75.14	130.4	78.20	150.4
X1	058305	24	122	253	335	335	335			
GR	116.8	0	108.8	20	100.8	41	87.5	70	83.2	100
GR	79.5	105	78.2	106	76.5	122	68.6	124	67.1	140
GR	65.7	160	64.4	180	64.5	200	65.7	220	67.9	240
GR	69.2	245	74.3	253	74.8	320	74.9	380	75	460
GR	77.5	500	81	600	89	800	97	1000		
NC	0	0	0	.3	.5					
X1	58345	38	135	527	40	40	40	0		
GR	116.8	0	108.8	20	100.8	41	87.5	70	83.2	100
GR	79.0	135	79.0	155	74.8	156	74.7	180	74.5	205
GR	74.6	230	74.6	256	75.2	257	75.2	258	74.7	272
GR	74.7	289	74.7	293	74.7	305	74.7	347	74.8	402
GR	74.8	412	74.9	482	77.4	527	79.6	582	81.7	637
GR	84.2	722	86.6	772	89.0	822	90.3	852	91.6	862
GR	91.7	872	91.2	882	92.4	889	94.3	972	98.9	1064
GR	104.1	1164	110.0	1264	116.2	1366				
X1	58375	35	125	238	30	30	30	0	0.0	
GR	116.8	0	108.8	20	100.8	41	87.5	70	83.2	100
GR	79.5	105	78.1	106	77.7	125	72.9	128	72.2	145
GR	71.0	165	72.7	185	72.9	205	73.6	225	74.9	235
GR	77.4	238	77.4	262	77.4	263	77.4	300	77.4	301

[redacted] 90[redacted] [redacted]10 [redacted]91.6[redacted] [redacted]0 [redacted]1.7[redacted] [redacted] [redacted].2[redacted] 6[redacted] [redacted].4 [redacted] 64[redacted] [redacted] [redacted] [redacted] [redacted]

GR 94.3 730 98.9 822 104.1 922 110.0 1022 116.2 1124

NC 0 0 0 .1 .3

X1060120 46 517 591 1745 1745 1745

GR0112.0000000.0 00099.7000024.6 00094.0000041.8 00087.4000062.7 00081.4000085.0

GR0079.0000105.2 00077.5000135.8 00079.2000143.0 00079.5000187.7 00079.4000247.6

GR0079.5000284.6 00080.3000320.1 00080.7000357.8 00079.3000375.2 00080.1000401.5

GR0078.3000414.9 00080.6000430.7 00080.7000460.2 00080.6000482.8 00079.2000501.5

GR0078.8000517.0 00075.7000521.9 00072.7000522.1 00072.1000531.0 00072.8000541.0

GR0073.1000554.0 00073.6000571.0 00075.7000585.0 00082.1000591.0 00082.1000615.0

GR0080.2000663.7 00080.2000704.1 00079.8000738.7 00085.6000769.1 00088.8000795.1

GR0088.6000813.8 00087.3000825.9 00091.5000842.3 00091.2000858.6 00091.2000875.6

GR0097.1000890.5 00097.8000920.7 00100.5000969.8 00103.2001000.9 00106.5001051.7

GR0112.0001111.4

X1061250 21 772 863 1130 1130 1130

GR 112 0 100 160 92 300 84 360 84 720

GR 87.7 740 87.6 760 85.8 772 75.3 782 75.1 790

GR 75.1 800 75.1 810 73.8 820 74.3 830 74.3 840

GR 75.3 850 81.7 863 82.4 890 92 910 100 980

GR 112 1100

X1061270 20 775 877 20 20 20

GR 112 0 100 160 92 300 84 360 84 720

GR 87.7 740 87.9 762 85.4 775 76.6 785 76.5 799

GR 76.8 819 76.2 834 76.8 854 77.2 871 81.9 877

GR 82.0 891 82.4 899 92 919 100 989 112 1109

X1061300 26 760 971 30 30 30

GR 112 0 100 160 92 300 84 360 84 720

GR 87.7 740 86.8 760 82.8 765 80.8 778 76.3 883

GR 75.9 890 75.9 900 75.9 910 75.4 920 75.0 930

GR 74.3 940 73.7 950 74.3 960 76.3 970 82.7 971

GR 84.2 980 82.3 983 82.3 990 92 1010 100 1080

GR 112 1200

EJ

ER

SUMMARY PRINTOUT

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
	49000.000	11.30	45.70	46.70	1.00	.46	35.09
*	50000.000	11.30	47.40	48.01	.61	2.65	20.63
*	50055.000	11.30	52.00	52.34	.34	2.35	28.36
	50090.000	11.30	49.70	52.45	2.75	.07	70.33
	52045.000	11.30	50.80	52.46	1.66	.28	33.20
*	52855.000	11.30	52.60	53.11	.51	2.91	15.21
	53155.000	11.30	55.60	56.34	.74	1.42	19.35
	53205.000	11.30	55.80	56.56	.76	1.34	19.78
	53244.000	11.30	55.80	56.57	.77	3.93	7.46
	53280.000	11.30	56.20	56.91	.71	.32	86.04
*	53320.000	11.30	62.40	62.47	.07	1.47	116.31
	53345.000	11.30	56.20	62.51	6.31	.01	164.14
	55360.000	11.30	60.20	62.51	2.31	.10	69.01
*	55713.000	11.30	62.58	62.97	.39	2.07	38.00
	56623.000	11.30	62.57	63.87	1.30	.50	30.29
	57000.000	11.30	62.50	63.92	1.42	.26	48.96
*	57030.000	11.30	63.66	63.97	.31	2.69	18.91

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
	57970.000	11.30	65.26	66.18	.92	.61	37.69
	58305.000	11.30	64.40	66.19	1.79	.14	71.36
*	58345.000	11.30	74.50	74.67	.17	1.72	72.25
	58375.000	11.30	71.00	74.73	3.73	.05	106.83
	60120.000	11.30	72.10	74.73	2.63	.12	56.58
	61250.000	11.30	73.80	74.75	.95	.72	31.65
*	61270.000	11.30	76.20	76.60	.40	2.00	43.65
	61300.000	11.30	73.70	76.67	2.97	.09	95.63

[redacted] wCCSTAN.NAI

```
T3 MODEL THE 7Q10 = 26.6 CFS = 17.2 MGD, Low Tide Elevation = -1.53 ft.
J1    -10      16       0       0       0       0       0       0   -1.53
J2     -1       0                0
J3     38      43      42       1       8      26       4
NC   .090    .090    .035      .1      .3
QT     15     8.8     9.3    17.3    21.0    22.8    26.6    42.1    73.0    84.1
QT     12      15      32      38      50      60
X1   2600      23     680     900       0       0       0
GR     16       0      12      50       8     100      12     400      12     500
GR      8     650       4     680       3     710      .2     720    -.2      730
GR   -5.4     740    -5.5     780    -5.5     800    -5.2     840    -1.8     850
GR   -1.0     860      .6     870       2     890       4     900       8     950
GR      8     970     1.1    1000     1.0    2000
X1   5050      63    3049  3213.8    2450    2450    2450
GR 022.5000393.3   022.7000480.0   023.1000563.8   021.1000642.6   019.3000720.4
GR 016.0000819.1   015.2000893.5   016.0000969.8   012.2001041.0   008.9001138.8
GR 006.7001241.5   007.2001317.6   004.9001415.0   004.0001516.8   003.5001660.6
GR 004.0001733.5   004.9001828.3   004.7001916.7   003.4002014.7   002.5002081.7
GR 003.1002136.1   003.4002286.2   003.8002413.8   004.3002579.0   003.9002726.3
GR 003.9002855.1   005.2002925.7   004.5002981.4   006.0003049.0   002.1003057.1
GR-001.6003067.1  -000.9003093.9  -000.9003112.0  -001.4003135.1  -001.4003158.9
GR 002.1003179.1   022.5003213.8   024.9003269.3   027.0003330.9   027.4003393.0
GR 028.0003468.3   028.0003537.1   028.0003600.3   028.0003643.0   028.0003692.8
GR 028.0003776.1   028.0003839.7   028.0003916.0   028.0003980.8   028.0004029.3
GR 028.0004058.6   028.0004084.6   028.0004150.5   028.0004212.3   028.0004265.1
GR 028.0004308.4   028.0004341.6   032.3004380.5   032.0004440.0   032.8004504.7
GR 034.1004571.4   036.7004640.3   040.0004695.2
X1005425                            375     375     375
X1   6200      32    1794    1921     650     850     775
GR   6.48       0    6.08     212    6.12     282    6.52     354    6.44     414
GR   6.05     491    6.32     627    6.03     780    4.29     839    3.97     998
GR   4.39    1134    5.06    1276    3.77    1427    4.07    1607    3.94    1670
GR   4.23    1766    7.36    1784    6.95    1794    0.88    1797   -1.22    1806
GR  -0.56    1835   -1.90    1871   -2.49    1894   -0.27    1914   -5.17    1921
GR   4.90    1930    1.59    1937    2.36    1943    5.22    1950    4.99    2076
GR   5.74    2164   11.56    2562
X1   7900      35    2675    2832    1600    1000    1700
GR   9.83       0    9.13     113   11.70     249   12.21     332    8.29     396
```

[redacted] 8.[redacted] [redacted]07 [redacted]5.2[redacted] [redacted] [redacted].86[redacted] 1[redacted] WCCSMH.NAL [redacted]38[redacted]15[redacted] [redacted]10 [redacted]167[redacted] [redacted] [redacted] [redacted] [redacted]

GR	4.41	1815	4.90	1969	2.60	2124	4.04	2294	4.83	2431
GR	6.79	2675	3.15	2680	-2.32	2693	-2.60	2701	-1.45	2720
GR	-0.20	2756	1.78	2760	0.18	2803	2.96	2829	7.20	2832
GR	7.70	2838	6.06	2974	4.95	3067	8.85	3076	14.51	3132
X1	9800	13	1750	1875	4375	4375	4375			
GR	12	0	8	40	8	1650	8	1750	6	1755
GR	2.1	1758	-1.4	1762	-1.4	1858	2.1	1865	16	1875
GR	20	1900	24	1950	36	2050				
X1	10800	40	2490	2591	900	1000	1000			
GR	15.22	0	15.94	64	14.50	108	11.81	131	11.18	159
GR	9.85	209	9.34	297	12.28	322	8.17	374	7.56	511
GR	8.21	585	7.09	724	7.71	775	5.56	786	8.83	797
GR	8.94	817	6.72	905	7.69	1077	7.42	1229	7.29	1324
GR	6.56	1520	6.48	1603	6.65	1711	5.99	1901	6.57	2082
GR	7.03	2207	8.38	2314	6.91	2322	8.31	2327	7.79	2386
GR	8.94	2399	7.95	2490	1.52	2503	-1.00	2545	-1.10	2565
GR	0.65	2572	-0.20	2576	1.32	2581	8.17	2591	14.09	2649
X1	10900	33	3091	3194	1100	1100	1100			
GR	15	0	14	171	13	342	12	514	10	857
GR	8	1200	8	1500	8	1800	8	2100	8	2400
GR	6.8	2700	6.5	2750	6.9	2801	7.4	2850	8.3	2897
GR	7.3	2900	8.4	2950	9.2	3001	9.4	3051	8.2	3091
GR	4.8	3099	4.9	3101	2.1	3106	-0.3	3153	-0.9	3164
GR	-1.7	3172	-0.1	3183	8.5	3194	9.3	3204	12.5	3232
GR	15.9	3259	19.4	3287	19.2	3295				
X1	11436	38	2603	2720	460	580	536			
GR	15	0	14	171	13	342	12	514	10	857
GR	8	1200	8	1400	8	1600	8	1800	8	2000
GR	6.9	2200	7.5	2250	8.1	2300	8.4	2350	8.4	2400
GR	8.4	2450	8.8	2500	8.1	2521	10.2	2535	9.0	2560
GR	8.8	2603	2.5	2615	-0.2	2675	-2.1	2700	22.2	2710
GR	9.3	2720	9.1	2725	8.9	2758	10.1	2808	11.3	2858
GR	10.7	2908	9.7	2958	10.0	3008	10.0	3058	11.3	3108
GR	12.4	3167	13.66	3212	14.0	3223				
X1	12320	36	1000	1100	1520	1300	1520			
GR	10.25	0	10.10	50	9.95	100	9.62	200	9.28	300
GR	9.27	400	8.95	500	8.70	600	8.38	700	8.68	800
GR	4.98	830	7.98	900	8.38	1000	1.28	1005	-1.15	1050

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
GR	33.96	1826	33.96	1900	33.96	2000	33.96	2100	33.96	2200
GR	33.96	2216	13.96	2217	13.96	2220	10.09	2225	9.79	2300
GR	12.72	2400								
X1	12560	20	1550	1800	2760	2760	2760			
GR	18.3	0	16	200	16	1100	16	1550	5.4	1552
GR	2.1	1555	.2	1559	-.8	1566	-1	1575	-1.23	1581
GR	-1.33	1690	1	1706	1.6	1708	2.8	1712	7.6	1722
GR	16.0	1800	16	2000	16	2050	16	2550	20	2750
NC	0	0	0	.3	.5					
X1	12660	22	1000	1251	100	100	100			
X3	10							19.6	19.6	
GR	24.6	0	19.6	1000	9.8	1001	9.8	1049	6.1	1055
GR	6.1	1059	5.3	1065	5.3	1110	1.6	1113	1.6	1123
GR	6.6	1129	6.6	1154	-1.3	1156	-1.3	1187	-0.9	1193
GR	-0.9	1208	-0.7	1222	-0.2	1236	7.1	1248	7.1	1250
GR	19.6	1251	24.6	2251						
SB	1.05	1.56	2.8		66	18	1750	7.36	-1.3	-1.3
X1	12703				43	43	43			
X2			1	11.2	19.6					
X3	10							19.6	19.6	
BT	22	0	24.6	24.6	1000	19.6	19.6	1001	22.1	11.2
BT	1049	22.1	11.2	1055	22.1	11.2	1059	22.1	11.2	1065
BT	22.1	11.2	1110	22.1	11.2	1113	22.1	11.2	1123	22.1
BT	11.2	1129	22.1	11.2	1154	22.1	11.2	1156	22.1	11.2
BT	1187	22.1	11.2	1193	22.1	11.2	1208	22.1	11.2	1222
BT	22.1	11.2	1236	22.1	11.2	1248	22.1	11.2	1250	22.1
BT	11.2	1251	19.6	19.6	2251	24.6	24.6			
X1	12753	0	0	0	50	50	50			
X1	12873	45	1068	1201	47	447	120			
GR	24.6	0	19.6	1000	10	1040	8	1051	7	1068
GR	5	1071	3	1076	-0.66	1129	3	1181	5	1190
GR	8	1201	9	1246	10	1263	15	1271	15.2	1275
GR	15	1279	13	1284	12.5	1285	12.5	1340	12.5	1400
GR	12.5	1415	12.5	1430	13	1431	14	1434	14.8	1440
GR	14	1447	10	1453	9	1536	9	1561	10	1568
GR	8	1628	7	1715	7	1903	8	1973	8	2028
GR	8	2092	9	2179	9	2272	9	2540	10	2640
GR	11	2720	12	2755	13	2794	14	2815	15	2819

[redacted]	[redacted]	[redacted]6	[redacted]	1[redacted]	[redacted]	[redacted]9.5	[redacted]	[redacted]3	[redacted]6	[redacted]7	[redacted]63
GR	3	668	9	679	9	691	9	697	10	703	
X1	13843	80	881	980	395	395	395				
GR	20.9	0	20.1	202	20	263	19	325	18	388	
GR	17	417	16	449	15	458	12	473	11	631	
GR	10	686	10	707	11	769	12	793	11	825	
GR	10	838	9	866	8	874	7	881	3	887	
GR	1.6	929	3	970	5	974	10	980	12	1002	
GR	12	1028	12	1074	12	1117	12.8	1140	12	1152	
GR	11.5	1156	11.5	1247	11.5	1297	12	1304	12.8	1318	
GR	12	1335	11.5	1345	11.5	1369	11.5	1387	11.5	1430	
GR	11.5	1462	12	1484	12.5	1492	13	1503	14	1505	
GR	15	1507	15	1510	15.5	1512	15	1515	13	1520	
GR	12.5	1521	12.5	1545	12.5	1570	12.5	1600	12.5	1614	
GR	12.5	1628	13	1631	14	1634	14.8	1640	14	1643	
GR	14	1647	10	1653	9	1736	9	1761	10	1768	
GR	8	1828	7	1915	7	2003	8	2073	8	2228	
GR	8	2292	9	2379	9	2472	9	2740	10	2840	
GR	11	2929	12	2955	13	2994	14	3015	15	3019	
X1	13955	68	1324	1403.1	1202	1202	1202	0	-1.3		
GR	40	0	38.3	31.2	37.2	72.2	35.5	113.9	33.9	148.8	
GR	33	155	31	228	19.9	259	14	271	13.2	329	
GR	11	365	9.5	435	8.8	491	10	555	7.3	589	
GR	8.2	608	7.5	680	7.7	761	8	827	9.1	884	
GR	7.1	902	7.8	982	8.5	1038	8.5	1098	7.4	1144	
GR	7.6	1199	9.8	1290	9.7	1324	8.7	1329	8.4	1332	
GR	5.1	1336	3.2	1337	2.2	1346	1.9	1354	1.7	1362	
GR	1.6	1370	3	1387	4.6	1387.1	5.8	1393	10.6	1403.1	
GR	10.6	1422	10.5	1463	10	1525	10.8	1600	11	1655	
GR	10.2	2049	10.3	2131	11.5	2156	7.7	2170	12.8	2197	
GR	9.9	2216	12	2254	11	2293	13	2317	13.5	2356	
GR	11.9	2409	11.1	2424	8.6	2440	8.7	2451	4.7	2468	
GR	4.7	2475	9.5	2481	9.7	2493	9.7	2511	16	2534	
GR	17.9	2551	20.5	2560	21	2614					
NC	0.08	0.095	0.04	.1	.3						
X1	14073	10	807	903	118	118	118				
GR	12	807	10	816	5	825	4	831	4	834	
GR	1.71	850	3	866	5	869	9	875	9	903	
X1	14990	0	0	0	971	971	971	0	1.3		

[redacted]	158	[redacted]	30	[redacted]	100	[redacted]	0	[redacted]	900	[redacted]
GR	32.3	0	29.8	100	27.3	200	23.8	300	18.8	400
GR	14.8	500	12.3	600	12.8	700	14.8	800	14.8	900
GR	16.3	1000	10.9	1001	8.1	1014	2.5	1026	2.5	1047
GR	2.5	1067	3.5	1081	5.9	1101	8.1	1110	10.4	1119
GR	16.3	1120	14.3	1220	11.3	1320	10.8	1420	11.3	1520
GR	12.3	1620	13.3	1720	13.3	1820	13.8	1920	12.3	2020
X1	15940	0	0	0	50	50	50			
X3	10	0	0	0	0	0	0	10.8	10.8	
SB	1.05	1.56	2.8		119		1012		2.5	2.5
X1	15979				39	39	39			
X2			1	12.9	10.8					
X3	10							10.8	10.8	
BT	30	0	32.3	32.3	100	29.8	29.8	200	27.3	27.3
BT	300	23.8	23.8	400	18.8	18.8	500	14.8	14.8	600
BT	12.3	12.3	700	12.8	12.8	800	14.8	14.8	900	14.8
BT	14.8	1000	16.3	16.3	1001	19.3	12.9	1014	19.3	12.9
BT	1026	19.3	12.9	1047	19.3	12.9	1067	19.3	12.9	1081
BT	19.3	12.9	1101	19.3	12.9	1110	19.3	12.9	1119	19.3
BT	12.9	1120	16.3	16.3	1220	14.3	14.3	1320	11.3	11.3
BT	1420	10.8	10.8	1520	11.3	11.3	1620	12.3	12.3	1720
BT	13.3	13.3	1820	13.3	13.3	1920	13.8	13.8	2020	12.3
BT	12.3									
X1	16180	20	950	1475	201	201	201	0	0.0	0
GR0040.0000000.0		00036.0000150.0		00032.0000250.0		00028.0000350.0		00023.4000450.0		
GR0027.1000950.0		00022.1000951.0		00009.9000968.0		00010.0001038.0		00012.0001154.0		
GR0012.5001269.0		00011.5001311.0		00003.1001316.0		00003.1001360.0		00004.9001361.0		
GR0008.0001383.0		00011.0001441.0		00028.0001474.0		00032.0001475.0		00051.1002875.0		
X1	16270	20	950	1475	90	90	90			
X3	10							23.4	23.4	
GR0040.0000000.0		00036.0000150.0		00032.0000250.0		00028.0000350.0		00023.4000450.0		
GR0027.1000950.0		00022.1000951.0		00009.9000968.0		00010.0001038.0		00012.0001154.0		
GR0012.5001269.0		00011.5001311.0		00003.1001316.0		00003.1001360.0		00004.9001361.0		
GR0008.0001383.0		00011.0001441.0		00028.0001474.0		00032.0001475.0		00051.1002875.0		
SB	1.05	1.56	2.8		213	14	7274	4.46	3.1	3.1
X1	16380				110	110	110			
X2			1	27.0	23.4					
X3	10							23.4	23.4	
BT	20	0	40	40	150	36	36	250	32	32

[redacted] 30[redacted] [redacted] 1 [redacted] 96[redacted] [redacted] [redacted] 2.[redacted] 1[redacted] WCCSTAN:NAT [redacted] [redacted] 0[redacted] 22[redacted] [redacted] 4 [redacted] 32.[redacted] [redacted] [redacted] [redacted] [redacted]

```
BT  24.0    1269    33.0    25.0    1311    33.5    25.5    1316    33.5    25.5
BT  1360    33.9    25.9    1361    33.9    25.9    1383    34.1    26.1    1441
BT  34.7    26.7    1474    35.0    27.0    1475    32.0    32.0    2875    51.1
BT  51.1
X1 16430                            50      50      50
NC      0       0       0      .1      .3
X1 17000      16    1085    1220     570     570     570
GR     36       0      32     600      31     900      28    1000      24    1010
GR     20    1020      16    1040      12    1045    11.5    1085     3.1    1089
GR    3.1    1143     4.9    1144       8    1166      11    1220      26    1360
GR     51    2300
X1 18000      65    1986    2075    1000    1000    1000            -.5
GR0025.5000862.7 00023.9000909.2 00023.1000966.6 00022.0000979.8 00021.9000987.3
GR   20.4  1015.3    17.0  1034.9    15.0  1676.9    14.0    1986    13.9    1987
GR    8.4  2011.1     7.1    2012       6    2013     6.3  2017.9     6.4  2024.9
GR    6.9  2036.9     7.2    2056       6  2061.9     8.4    2066    16.6    2075
GR   21.8  2414.3    22.2  2432.5   22.21  2432.6   22.22  2432.7   22.23  2432.8
GR0021.7002667.9 00022.3002711.5 00023.5002765.3 00024.4002794.2 00025.5002836.5
GR0026.0002881.3 00025.8002925.1 00026.4002950.6 00026.0002979.6 00026.8003021.0
GR0027.1003060.1 00025.3003088.6 00024.1003120.5 00023.6003145.6 00024.0003186.8
GR0023.8003235.9 00026.0003278.3 00026.0003309.7 00026.5003341.4 00026.7003373.3
GR0028.0003401.8 00029.0003432.6 00029.8003463.6 00029.5003499.8 00029.4003544.4
GR0029.8003602.0 00029.8003655.8 00030.7003720.9 00031.6003746.8 00032.5003792.7
GR0032.6003824.2 00031.6003845.5 00030.7003875.0 00031.9003899.9 00032.7003946.7
GR0033.2003982.0 00034.3004020.0 00036.1004049.8 00036.4004110.8 00036.9004147.8
X1 18700       0       0       0     700     700     700       0      .5
X1 21000      20     765     837    2300    2300    2300
GR     32       0      28     300      24     450      20     670      16     760
GR     14     765     8.4     775       7     776     5.7     777     6.0     781
GR    6.1     788     6.6     796     6.9     816     5.7     821     8.2     827
GR   15.6     837      16     845      16    1365      20    1400      24    1800
EJ
```

ER

SUMMARY PRINTOUT

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
	2600.000	26.60	-5.50	-1.53	3.97	.06	120.82
*	5050.000	26.60	-1.60	-1.18	.42	2.56	52.91
	5425.000	26.60	-1.60	-.66	.94	.51	98.66
	6200.000	26.60	-5.17	-.58	4.59	.25	117.22
	7900.000	26.60	-2.60	-.49	2.11	.43	59.12
	9800.000	26.60	-1.40	-.27	1.13	.24	99.53
	10800.000	26.60	-1.10	-.20	.90	1.12	36.77
	10900.000	26.60	-1.70	.34	2.04	.65	43.04
	11436.000	26.60	-2.10	.45	2.55	.58	40.43
	12320.000	26.60	-1.15	.68	1.83	.47	62.01
	12560.000	26.60	-1.33	.71	2.04	.10	146.04
	12660.000	26.60	-1.30	.71	2.01	.20	82.01
	12703.000	26.60	-1.30	.71	2.01	.20	82.00
	12753.000	26.60	-1.30	.71	2.01	.20	82.00
	12873.000	26.60	-.66	.70	1.36	.99	39.29
	13448.000	26.60	.57	1.64	1.07	1.78	27.84
	13843.000	26.60	1.60	2.56	.96	.97	57.01

	SECNO	Q	ELMIN	CWSEL	DEPTH	VCH	TOPWID
	13955.000	26.60	.30	2.66	2.36	.29	50.46
*	14073.000	26.60	1.71	2.56	.85	3.76	16.56
	14990.000	26.60	3.01	4.75	1.74	.94	28.87
	15890.000	26.60	2.50	4.81	2.31	.20	70.79
	15940.000	26.60	2.50	4.81	2.31	.20	70.91
	15979.000	26.60	2.50	4.81	2.31	.20	70.83
	16180.000	26.60	3.10	4.81	1.71	.35	45.97
	16270.000	26.60	3.10	4.81	1.71	.35	45.97
	16380.000	26.60	3.10	4.82	1.72	.34	45.97
	16430.000	26.60	3.10	4.82	1.72	.34	45.98
	17000.000	26.60	3.10	4.84	1.74	.28	55.80
*	18000.000	26.60	5.50	6.20	.70	3.32	24.30
	18700.000	26.60	6.00	7.46	1.46	.67	52.66
	21000.000	26.60	5.70	7.82	2.12	.39	50.71

APPENDIX ~~B~~ C

WATER QUALITY AND USGS STREAM FLOW DATA

C. WATER QUALITY AND USGS STREAM FLOW DATA

WATER QUALITY DATA
BRANDYWINE CREEK AT WILMINGTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
August, 1995

Date August, 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	60.1	31		28	82	7.7		300
2	58.8	30		27	81	7.3		290
3	58.2	32		28	82	7.3		290
4	59.5	32		28	82	7.4		300
5	75.6							
6	130.6							
7	135.7	33		24	75	7.2	350	290
8	89.2	32	6.5	24	75	7.3		300
9	70.4	28		23	73	7.4		260
10	66.6	27	10.0	24	75	7.3		270
11	62.7	34		25	77	7.3		300
12	60.8							
13	71.1							
14	74.3	28		27	81	7.3		310
15	113.8	32		27	81	7.4		310
16	119.6	30		27	81	7.3	240	300
17	69.8	31		27	81	7.3		300
18	60.8	26		28	82	7.3		280
19	57.5							
20	56.2							
21	54.9	30		25	77	7.3		290
22	51.7	32		25	77	7.2	540	310
23	49.8	32		24	75	7.4		310
24	47.2	33		24	75	7.3		310
25	47.2	34		24	75	7.2		330
26	42.7							
27	42.0							
28	43.9	35		24	75	7.3		340
29	47.2	35	6.4	24	75	7.4		330
30	46.5	36		24	75	7.4		340
31	42.0	35		24	75	7.3		330

C:\instrmfl\wqwil.wk4

WATER QUALITY DATA
BRANDYWINE CREEK AT WILMINGTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
September, 1995

Date Sept., 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	36.8	35	8.0	25	77	7.3		340
2	36.8							
3	34.9							
4	34.9							
5	34.9	38		24	75	7.2	79	350
6	34.3	37		23	73	7.4		340
7	34.3	40	9.0	24	75	7.3		340
8	43.9	38	6.4	25	77	7.6		350
9	49.1							
10	42.0							
11	36.8	30		20	68	7.6	130	270
12	34.3	32		20	68	7.1		310
13	33.6	37		23	73	7.1		350
14	40.7	39		22	72	7.2		350
15	45.2	38		22	72	7.1		350
16	36.2							
17	425.9							
18	204.2	20		19	66	6.6	2400	200
19	77.6	17		19	66	6.8		180
20	59.5							
21	55.6	24		22	72	6.9		230
22	96.9	26		21	70	6.8		250
23	148.7							
24	84.0							
25	84.0	32	7.9	18	64	7.2	350	300
26	177.1	28		18	64	7.1		250
27	136.4	29		17	63	7.3		280
28	85.3	27	9.0	18	64	7.1		260
29	71.1	29	10.0	18	64	7.2		270
30	64.0							

C:\instrmfl\wqwil.wk4

WATER QUALITY DATA
BRANDYWINE CREEK AT WILMINGTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
October, 1995

Date Oct., 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	62.7							
2	62.7	31		18	64	7.3	5	310
3	61.4	32		18	64	7.3		310
4	60.8	35		19	66	7.2		310
5	205.5	30		19	66	7.1		310
6	646.3	30		21	70	6.9		260
7	156.4							
8	105.3							
9	90.5							
10	84.0	30		18	64	7.3	240	290
11	84.7	33		19	66	7.3		300
12	75	30		18	64	7.5		310
13	75	40		18	64	6.9		320
14	169.3							
15	441.4							
16	160.9	22	10.0	15	59	6.9	900	230
17	104.7	30		14	57	6.8		250
18	94.4	30		16	61	6.8		260
19	89.8	29	9.0	14	57	7.1		270
20	89.8	30		14	57	6.6		290
21	820.8							
22	775.6							
23	206.8							
24	162.2	35		14	57	6.8	1600	250
25	144.8	36		14	57	6.2		270
26	127.3	36		14	57	6.4		280
27	127.3	38		14	57	7.7		290
28	788.5							
29	346.4							
30	190.0	39	10.2	14	57	7.4	1600	260
31	164.2							

C:\instrmfl\wqwil.wk4

WATER QUALITY DATA
WHITE CLAY CREEK AT NEWARK
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
August, 1995

Date August, 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Water Temp. (C)	Water Temp. (F)	Mean Daily Air Temp (C)	Mean Daily Air Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	7.8			22	72	27	80			
2	7.8					29	85			
3	7.1					28	83			
4	8.4			23	74	29	85			
5	11.6									
6	21.3			21	70	23	74			
7	18.7					22	72			
8	10.3			17	63	22	71			
9	11.0					22	71			
10	11.6					24	76			
11	10.3			19	66	26	78			
12	10.3									
13	8.4			21	70	28	82			
14	8.4					28	82			
15	14.2			21	70	26	79			
16	12.3		8	30	86	26	78	7.5		290
17	9.1					27	80			
18	8.4			22	71	29	84			
19	7.8									
20	6.4									
21	5.8					22	72			
22	6.1			21	69	24	75			
23	5.2		8	25	77	25	77	7.5		340
24	4.5					22	71			
25	4.7			21	70	25	77			
26	4.7									
27	4.8			19	66	25	77			
28	4.7					24	76			
29	5.3			20	68	24	76			
30	5.0					23	74			
31	4.1					25	77			

C:\instrmfl\wqwcnk.wk4

WATER QUALITY DATA
WHITE CLAY CREEK AT NEWARK
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
September, 1995

Date Sept., 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Water Temp. (C)	Water Temp. (F)	Mean Daily Air Temp (C)	Mean Daily Air Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	3.9									
2	4.3									
3	3.8									
4	3.7					22	72			
5	3.8		8.5	18	64	23	74	7.5		320
6	4.2		8.5	24	75	24	76	8.1		305
7	3.8		10	24	75	25	77			300
8	5.4							8.1		
9	3.7									
10	4.8									
11	3.8					17	62			
12	2.9			16	60	19	66			
13	3.8					25	77			
14	5.6					23	74			
15	6.0									
16	4.8									
17	53.0			15	59	19	67			
18	20.7					20	68			
19	9.1					19	66			
20	6.5		11.5	20	68	21	70	7.5		260
21	7.1					23	74			
22	16.2			16	61	19	66			
23	25.9									
24	11.6			15	59	13	56			
25	12.9					17	63			
26	29.7			17	62	15	59			
27	15.5					17	62			
28	11.0									
29	9.7			16	60	16	60			
30	9.1									

C:\instrmfl\wqwcnk.wk4

WATER QUALITY DATA
WHITE CLAY CREEK AT NEWARK
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
October, 1995

Date Oct., 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Water Temp (C)	Water Temp (F)	Mean Daily Air Temp (C)	Mean Daily Air Temp (F)	pH	Coliform Bacteria (CFU/Ml)	Conductivity (mm/hos)
1	9.1			15	59	15	59			
2	9.1		9	15	59	19	67	7.8		300
3	9.1		8.5	16	61	20	68	7.8		350
4	8.4		7	17	63	22	71	7.8		330
5	49.1					22	71			
6	175.8									
7	25.9									
8	18.1			19	66	16	60			
9	15.5					14	58			
10	14.2		9	15	59	16	60	7.5		325
11	12.9					17	62			
12	12.9					19	67			
13	13.6									
14	45.9									
15	109.9			16	60	14	58			
16	27.8					11	52			
17	20.0					11	51			
18	18.1					11	52			
19	17.5					14	57			
20	18.1					17	62			
21	243.7									
22	66.6			13	56	11	51			
23	32.3					14	57			
24	26.5					16	60			
25	23.9					12	54			
26	22.0					11	51			
27	23.3									
28	177.7									
29	44.0			14	57	11	52			
30	29.7					9	48			
31	26.5					9	49			

C:\instrmfl\wqwcnk.wk4

WATER QUALITY DATA
WHITE CLAY CREEK AT STANTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
August, 1995

Date ugust, 199	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Alk. (mg/L)	Hard. (mg/L)
1	27.5	36		25	77	7.7	78	133
2	26.8	35		26	79	7.7	73	119
3	25.4	36		26	79	7.6	83	120
4	30.4	22		19	66	7.9	73	117
5	65.3	33		25	77	7.3	69	127
6	142.9	35		23	73	7.5	66	101
7	72.5	34		20	68	7.6	67	109
8	42	34		20	68	7.6	66	133
9	31.9	36		21	70	7.5	68	110
10	30.4	34		23	73	7.4	64	109
11	29	33		24	75	7.3	73	112
12	28.9	33		25	77	7.6	75	133
13	30.4	38		24	75	7.7	75	110
14	27.5	35		24	75	7.6	80	105
15	40.6	34	10	25	77	6.9	95	126
16	35.4	40		25	77	7.6	86	132
17	31.1	41		25	77	7.6	90	186
18	29	33		24	75	7.6	72	109
19	23.9	39		24	75	7.4	75	119
20	23.2	37		18	64	7.6	56	81
21	23.2	43		22	72	7.3	56	85
22	21	35		22	72	7.6	40	83
23	24.7	64		21	70	7.5	56	90
24	24	42		21	70	7.7	53	66
25	32.7	34		20	68	7.6	51	94
26	32	31		19	66	7.5	56	85
27	22.5	39		20	68	7.7	57	87
28	17.4	33		21	70	7.6	52	110
29	15	42		22	72	7.6	82	140
30	20.3	74		22	72	7.4	62	106
31	17.4	139		21	70	7.3	86	120

WATER QUALITY DATA
WHITE CLAY CREEK AT STANTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
September, 1995

Date Sept., 1995	Discharge (mgd)	Chlorides (ppm)	Sodium (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Alk. (mg/L)	Hard. (mg/L)
1	18.4	600			19	66	7.4	64	91
2	16.8	650			21	70	7.5	77	111
3	12.4	730			18	64	7.5	58	83
4	15.6	620			22	72	7.5	86	118
5	15.3	680	375		21	70	7.5	80	181
6	10.8	850	250		22	72	7.5	85	230
7	10.8	400	410		23	73	7.3	78	183
8	69.2	230			22	72	7.4	75	123
9	16.8	135			22	72	7.3	55	150
10	15.4	160			21	70	7.4	65	105
11	12.3	110		6	19	66	7.3	79	110
12	11.6	114			19	66	7.5	85	152
13	14.4	117		8	21	70	7.5	87	157
14	20.3	30	20	6	23	73	7.3	74	117
15	14.5	46	20		21	70	7.6	52	91
16	12.7	25			19	66	7.6	73	128
17	83	35			19	66	7.4	62	138
18	50.5	25			19	66	7.4	59	98
19	22.4	25			18	64	7.6	64	101
20	17.3	25			19	66	7.6	70	164
21	96.2	25			21	70	7.5	65	95
22	67.8	28			19	66	7.4	58	119
23	44.3	33			16	61	7.3	65	138
24	46.2	32			15	59	7.3	80	132
25	48.3	30			17	63	7.3	65	138
26	87.2	33			17	63	7.4	77	118
27	38.3	35			17	63	7.6	78	110
28	26.8	32			18	64	7.5	71	122
29	22.4	29			16	61	7.6	61	145
30	20.3	33			16	61	7.5	72	143

WATER QUALITY DATA
WHITE CLAY CREEK AT STANTON
INSTREAM FLOW NEEDS ANALYSIS (PHASE II)
October, 1995

Date Oct., 1995	Discharge (mgd)	Chlorides (ppm)	DO (ppm)	Temp (C)	Temp (F)	pH	Alk. (mg/L)	Hard. (mg/L)
1	20.3	38		16	61	7.5	72	143
2	19.6	20		16	61	7.5	67	114
3	19.6	42		17	63	7.6	83	143
4	19.6	25		17	63	7.4	71	126
5	199	29		18	64	7.4	55	99
6	469.4	24		20	68	7.0	63	98
7	64.2	22		20	68	7.1	46	77
8	41.1	36		17	63	7.4	57	107
9	33.9	33		16	61	7.5	60	115
10	31.8	36		15	59	7.3	71	120
11	28.9	37	8	16	61	7.5	79	143
12	27.5	37	9	16	61	7.6	82	138
13	26.8	37		16	61	7.5	81	130
14	259.3	28		17	63	7.3	60	171
15	307.9	27		15	59	7.0	47	114
16	67.9	28		13	55	7.2	60	86
17	31.1	38		11	52	7.3	64	128
18	39.7	33		12	54	7.3	76	167
19	37.6	39		12	54	7.4	74	159
20	470.9	36	9	14	57	7.3	88	156
21	254.2	29		12	54	7.2	54	94
22	92.7	25		12	54	7.2	53	130
23	60.7	39		11	52	7.0	55	106
24	50.5	29		11	52	7.2	66	110
25	47.6	36		13	55	7.4	69	118
26	42.6	23		11	52	7.4	72	80
27	63.4	34		10	50	7.5	71	113
28	569.1	20		15	59	7.5	38	84
29	111.1	26		11	52	7.2	35	105
30	69.3	32		10	50	7.2	60	120
31	58.5	30		11	52	7.1	69	133

APPENDIX D

Summary Statistics for Flow and Water Quality Data During Period July 1, 1995 to October 31, 1995 for Brandywine Creek at Wilmington, White Clay Creek at Newark, and White Clay Creek at Stanton

Interpretation of Correlation and Covariance Matrices

Correlation and Covariance Matrices for Brandywine Creek at Wilmington, White Clay Creek at Newark, and White Clay Creek at Stanton

INTERPRETATION OF CORRELATION AND COVARIANCE MATRICES

Correlation Coefficient Matrix

A correlation coefficient matrix provides a preliminary view of the relationships among variables. Three numbers appear at the intersection of each row and column of the matrix. The first number is the correlation coefficient for the two variables; the second number (in parentheses) is the sample size; and the third value is the p-value (significance level) of the correlation.

Correlation coefficients range from -1 to +1. A positive correlation suggests the 2 variables vary in the same direction (i.e., they are positively correlated), while a negative correlation coefficient suggests that the 2 variables vary in the opposite direction (i.e., they are negatively correlated). Statistically independent variables have an expected correlation coeffient of zero.

Covariance Matrix

A covariance matrix indicates the degree of linear association between the various pairwise variable combinations. If the variables tend to fall above or below their means at the same time, the covariance is positive. If one variable is above its mean while the other is below, the covariance is negative.

BRANDYWINE CREEK AT WILMINGTON

Summary Statistics

	FLOW_cfs	DO_ppm	TEMP_water
Count	123	13	81
Average	186.609	8.46154	72.037
Median	129.97	9.0	75.0
Geometric mean	138.259	8.34471	71.59
Variance	44820.0	2.0459	62.1361
Standard deviation	211.707	1.43035	7.88265
Minimum	51.99	6.4	57.0
Maximum	1269.97	10.2	82.0
Stnd. skewness	16.6712	-0.456716	-1.98645
Stnd. kurtosis	33.3233	-1.00774	-1.52764

	pH_su	CHL_ppm	BACTI_coli
Count	81	81	16
Average	7.23827	30.716	594.625
Median	7.3	30.0	350.0
Geometric mean	7.2322	30.3216	300.636
Variance	0.086642	22.8559	468660.0
Standard deviation	0.29435	4.78078	684.588
Minimum	6.2	17.0	5.0
Maximum	7.9	40.0	2400.0
Stnd. skewness	-3.21538	-1.21512	2.79848
Stnd. kurtosis	3.31317	0.504432	1.79345

	COND_mmhos
Count	81
Average	287.531
Median	290.0
Geometric mean	285.151
Variance	1311.33
Standard deviation	36.2123
Minimum	180.0
Maximum	350.0
Stnd. skewness	-1.43168
Stnd. kurtosis	0.376831

BRANDYWINE CREEK AT WILMINGTON

Correlations

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs		0.4770 (13) 0.0993	-0.1566 (81) 0.1627
DO_ppm	0.4770 (13) 0.0993		-0.6298 (13) 0.0211
TEMP_water	-0.1566 (81) 0.1627	-0.6298 (13) 0.0211	
pH_su	-0.2256 (81) 0.0429	-0.5179 (13) 0.0699	0.5510 (81) 0.0000
CHL_ppm	-0.2259 (81) 0.0426	-0.2366 (13) 0.4364	-0.1659 (81) 0.1388
BACTI_coli	0.6958 (16) 0.0028	0.9053 (4) 0.0947	-0.5415 (16) 0.0303
COND_mmhos	-0.4058 (81) 0.0002	-0.5461 (13) 0.0535	0.1575 (81) 0.1602

	pH_su	CHL_ppm	BACTI_coli
FLOW_cfs	-0.2256 (81) 0.0429	-0.2259 (81) 0.0426	0.6958 (16) 0.0028
DO_ppm	-0.5179 (13) 0.0699	-0.2366 (13) 0.4364	0.9053 (4) 0.0947
TEMP_water	0.5510 (81) 0.0000	-0.1659 (81) 0.1388	-0.5415 (16) 0.0303
pH_su		0.0558 (81) 0.6208	-0.6926 (16) 0.0029
CHL_ppm	0.0558 (81) 0.6208		-0.1645 (16) 0.5427
BACTI_coli	-0.6926 (16) 0.0029	-0.1645 (16) 0.5427	
COND_mmhos	0.2564 (81) 0.0209	0.8219 (81) 0.0000	-0.6390 (16) 0.0077

	COND_mmhos
FLOW_cfs	-0.4058 (81) 0.0002

BRANDYWINE CREEK AT WILMINGTON (cont.)

DO_ppm	-0.5461
	(13)
	0.0535
TEMP_water	0.1575
	(81)
	0.1602
pH_su	0.2564
	(81)
	0.0209
CHL_ppm	0.8219
	(81)
	0.0000
BACTI_coli	-0.6390
	(16)
	0.0077
COND_mmhos	

Correlation
(Sample Size)
P-Value

BRANDYWINE CREEK AT WILMINGTON

Covariances

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs	44820.0 (123)	46.6844 (13)	-150.559 (81)
DO_ppm	46.6844 (13)	2.0459 (13)	-7.38654 (13)
TEMP_water	-150.559 (81)	-7.38654 (13)	62.1361 (81)
pH_su	-8.09908 (81)	-0.126923 (13)	1.27856 (81)
CHL_ppm	-131.745 (81)	-2.08782 (13)	-6.25185 (81)
BACTI_coli	42461.8 (16)	683.333 (4)	-3262.28 (16)
COND_mmhos	-1792.35 (81)	-32.0705 (13)	44.9676 (81)

	pH_su	CHL_ppm	BACTI_coli
FLOW_cfs	-8.09908 (81)	-131.745 (81)	42461.8 (16)
DO_ppm	-0.126923 (13)	-2.08782 (13)	683.333 (4)
TEMP_water	1.27856 (81)	-6.25185 (81)	-3262.28 (16)
pH_su	0.086642 (81)	0.0785031 (81)	-123.633 (16)
CHL_ppm	0.0785031 (81)	22.8559 (81)	-620.867 (16)
BACTI_coli	-123.633 (16)	-620.867 (16)	468660.0 (16)
COND_mmhos	2.73318 (81)	142.29 (81)	-17130.0 (16)

	COND_mmhos
FLOW_cfs	-1792.35 (81)
DO_ppm	-32.0705 (13)
TEMP_water	44.9676 (81)
pH_su	2.73318 (81)
CHL_ppm	142.29 (81)
BACTI_coli	-17130.0 (16)

BRANDYWINE CREEK AT WILMINGTON (cont.)

COND_mmhos	**1311.33**
	(81)

Covariance
(Sample Size)

WHITE CLAY CREEK AT NEWARK

Summary Statistics

	FLOW_cfs	DO_ppm	TEMP_water
Count	123	10	38
Average	31.116	8.8	65.9211
Median	17.99	8.5	66.0
Geometric mean	19.1243	8.72714	65.6809
Variance	2690.58	1.51111	32.399
Standard deviation	51.8708	1.22927	5.69201
Minimum	4.5	7.0	56.0
Maximum	377.0	11.5	77.0
Stnd. skewness	21.0228	1.39867	0.0673262
Stnd. kurtosis	53.6645	1.30568	-1.3904

	TEMP_air	pH_su	COND_mmhos
Count	94	10	10
Average	71.1596	7.71	312.0
Median	74.0	7.65	312.5
Geometric mean	70.3779	7.70648	310.957
Variance	103.834	0.061	701.111
Standard deviation	10.1899	0.246982	26.4785
Minimum	48.0	7.5	260.0
Maximum	86.0	8.1	350.0
Stnd. skewness	-2.57076	0.88689	-0.673104
Stnd. kurtosis	-1.31154	-0.673575	0.187476

WHITE CLAY CREEK AT NEWARK

Correlations

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs		-0.1879 (10) 0.6032	-0.4524 (38) 0.0044
DO_ppm	-0.1879 (10) 0.6032		0.1197 (9) 0.7591
TEMP_water	-0.4524 (38) 0.0044	0.1197 (9) 0.7591	
TEMP_air	-0.2881 (94) 0.0049	-0.1640 (10) 0.6507	0.8392 (38) 0.0000
pH_su	-0.3494 (10) 0.3224	-0.2576 (9) 0.5034	0.1168 (8) 0.7829
COND_mmhos	0.0756 (10) 0.8356	-0.6947 (10) 0.0258	-0.1617 (9) 0.6776

	TEMP_air	pH_su	COND_mmhos
FLOW_cfs	-0.2881 (94) 0.0049	-0.3494 (10) 0.3224	0.0756 (10) 0.8356
DO_ppm	-0.1640 (10) 0.6507	-0.2576 (9) 0.5034	-0.6947 (10) 0.0258
TEMP_water	0.8392 (38) 0.0000	0.1168 (8) 0.7829	-0.1617 (9) 0.6776
TEMP_air		0.0564 (9) 0.8854	-0.1655 (10) 0.6478
pH_su	0.0564 (9) 0.8854		0.1448 (9) 0.7101
COND_mmhos	-0.1655 (10) 0.6478	0.1448 (9) 0.7101	

Correlation
(Sample Size)
P-Value

WHITE CLAY CREEK AT NEWARK

Covariances

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs	2690.58 (123)	-1.29433 (10)	-81.9607 (38)
DO_ppm	-1.29433 (10)	1.51111 (10)	1.09722 (9)
TEMP_water	-81.9607 (38)	1.09722 (9)	32.399 (38)
TEMP_air	-85.5077 (94)	-1.15556 (10)	44.6842 (38)
pH_su	-0.4632 (10)	-0.06875 (9)	0.182143 (8)
COND_mmhos	11.2156 (10)	-22.6111 (10)	-31.3889 (9)

	TEMP_air	pH_su	COND_mmhos
FLOW_cfs	-85.5077 (94)	-0.4632 (10)	11.2156 (10)
DO_ppm	-1.15556 (10)	-0.06875 (9)	-22.6111 (10)
TEMP_water	44.6842 (38)	0.182143 (8)	-31.3889 (9)
TEMP_air	103.834 (94)	0.0708333 (9)	-25.1111 (10)
pH_su	0.0708333 (9)	0.061 (10)	0.875 (9)
COND_mmhos	-25.1111 (10)	0.875 (9)	701.111 (10)

Covariance
(Sample Size)

WHITE CLAY CREEK AT STANTON

Summary Statistics

	FLOW_cfs	DO_ppm	TEMP_water
Count	123	7	123
Average	89.302	8.0	67.3317
Median	49.36	8.0	68.0
Geometric mean	57.7331	7.86779	66.8751
Variance	18474.4	2.33333	58.9258
Standard deviation	135.921	1.52753	7.67631
Minimum	16.71	6.0	50.0
Maximum	880.53	10.0	79.0
Stnd. skewness	18.1469	-0.424264	-2.28247
Stnd. kurtosis	38.6331	-0.601783	-1.19797

	pH_su	CHL_ppm	HARD_ppm
Count	123	123	123
Average	7.4878	74.0569	117.472
Median	7.5	33.0	115.0
Geometric mean	7.48525	41.3107	115.031
Variance	0.0382927	21706.0	629.448
Standard deviation	0.195685	147.33	25.0888
Minimum	6.9	20.0	66.0
Maximum	7.9	850.0	230.0
Stnd. skewness	-1.81175	17.7257	5.33104
Stnd. kurtosis	0.742358	33.1742	6.80397

	ALK_ppm
Count	123
Average	68.7236
Median	71.0
Geometric mean	67.7489
Variance	123.611
Standard deviation	11.1181
Minimum	35.0
Maximum	95.0
Stnd. skewness	-1.98465
Stnd. kurtosis	0.589089

WHITE CLAY CREEK AT STANTON

Correlations

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs		0.3317 (7) 0.4673	-0.2621 (123) 0.0034
DO_ppm	0.3317 (7) 0.4673		-0.0902 (7) 0.8476
TEMP_water	-0.2621 (123) 0.0034	-0.0902 (7) 0.8476	
pH_su	-0.3312 (123) 0.0002	-0.2373 (7) 0.6084	0.4839 (123) 0.0000
CHL_ppm	-0.1440 (123) 0.1120	-0.3936 (7) 0.3823	0.0874 (123) 0.3362
HARD_ppm	-0.0889 (123) 0.3282	0.5461 (7) 0.2048	-0.0167 (123) 0.8542
ALK_ppm	-0.2804 (123) 0.0017	0.8364 (7) 0.0190	0.3275 (123) 0.0002

	pH_su	CHL_ppm	HARD_ppm
FLOW_cfs	-0.3312 (123) 0.0002	-0.1440 (123) 0.1120	-0.0889 (123) 0.3282
DO_ppm	-0.2373 (7) 0.6084	-0.3936 (7) 0.3823	0.5461 (7) 0.2048
TEMP_water	0.4839 (123) 0.0000	0.0874 (123) 0.3362	-0.0167 (123) 0.8542
pH_su		-0.0411 (123) 0.6514	-0.0537 (123) 0.5549
CHL_ppm	-0.0411 (123) 0.6514		0.2763 (123) 0.0020
HARD_ppm	-0.0537 (123) 0.5549	0.2763 (123) 0.0020	
ALK_ppm	0.2211 (123) 0.0140	0.1760 (123) 0.0515	0.5352 (123) 0.0000

	ALK_ppm
FLOW_cfs	-0.2804 (123) 0.0017

DO_ppm	0.8364
	(7)
	0.0190
TEMP_water	0.3275
	(123)
	0.0002
pH_su	0.2211
	(123)
	0.0140
CHL_ppm	0.1760
	(123)
	0.0515
HARD_ppm	0.5352
	(123)
	0.0000
ALK_ppm	

Correlation
(Sample Size)
P-Value

WHITE CLAY CREEK AT STANTON

Covariances

	FLOW_cfs	DO_ppm	TEMP_water
FLOW_cfs	18474.4 (123)	132.65 (7)	-273.471 (123)
DO_ppm	132.65 (7)	2.33333 (7)	-1.0 (7)
TEMP_water	-273.471 (123)	-1.0 (7)	58.9258 (123)
pH_su	-8.80816 (123)	-0.0833333 (7)	0.726865 (123)
CHL_ppm	-2884.16 (123)	-23.1667 (7)	98.8826 (123)
HARD_ppm	-303.13 (123)	15.3333 (7)	-3.22327 (123)
ALK_ppm	-423.778 (123)	9.0 (7)	27.9482 (123)

	pH_su	CHL_ppm	HARD_ppm
FLOW_cfs	-8.80816 (123)	-2884.16 (123)	-303.13 (123)
DO_ppm	-0.0833333 (7)	-23.1667 (7)	15.3333 (7)
TEMP_water	0.726865 (123)	98.8826 (123)	-3.22327 (123)
pH_su	0.0382927 (123)	-1.18619 (123)	-0.263874 (123)
CHL_ppm	-1.18619 (123)	21706.0 (123)	1021.33 (123)
HARD_ppm	-0.263874 (123)	1021.33 (123)	629.448 (123)
ALK_ppm	0.481028 (123)	288.27 (123)	149.279 (123)

	ALK_ppm
FLOW_cfs	-423.778 (123)
DO_ppm	9.0 (7)
TEMP_water	27.9482 (123)
pH_su	0.481028 (123)
CHL_ppm	288.27 (123)
HARD_ppm	149.279 (123)

WHITE CLAY CREEK AT STANTON (cont.)

ALK_ppm	**123.611**
	(123)

Covariance
(Sample Size)

D. WATER SUPPLY ALLOCATION PERMITS AND DOCKETS

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

PUBLIC WATER ALLOCATION

ALLOCATION NO: 90-0013M
EFFECTIVE DATE: July 16, 1993
EXPIRATION DATE: July 16, 2023
MODIFICATION DATE: April 8, 1996

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

UNITED WATER DELAWARE
2000 First State Blvd.
P. O. Box 6508
Wilmington, Delaware 19804

for the withdrawal and use of water from the following water facilities:

Intake ID	Location	Stream	Latitude	Longitude	Maximum Pumping Capacity (gpm)
#1	Pump House No. 1	White Clay Creek	39°42'23"	75°38'44"	14,000
#2	Pump House No. 2	White Clay Creek	39°42'24"	75°38'44"	7,000
#2a	Above Confluence	White Clay Creek	39°42'27"	75°38'47"	7,000

OTHER APPROVALS

1. This allocation shall be reviewed by the Division of Water Resources every five years from the date of this approval.
2. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.
3. Approval for the use of this water for human consumption must be obtained from the Bureau of Environmental Health.
4. Approval for discharge of this water must be obtained from the Division of Water Resources.
5. This approval is subject to modification in accordance with establishment of State instream flow and passby requirements.

EQUIPMENT REQUIREMENTS

1. All intakes must be equipped with appropriate metering equipment in accordance with accepted engineering practice for recording pumping rates and cumulative volumes of withdrawal to a design accuracy of ±5%.

REPORTING PROCEDURE

1. For each intake readings of pumping rates and cumulative volumes of withdrawal must be made and recorded at least daily. This and all other requested information, such as water purchases and sales, is to be recorded on forms provided by the Division of Water Resources and submitted by the permit holder to the Division annually by January 31, or more frequently if requested.

ALLOCATION

1. In any twenty-four (24) hour period withdrawals from these intakes shall not exceed 30,000,000 gallons.

2. In any thirty (30) day period withdrawals from these intakes shall not exceed 900,000,000 gallons.

3. In any twelve (12) month period withdrawals from these intakes shall not exceed 10,950,000,000 gallons.

4. Withdrawals for the facilities listed below shall not exceed the following limits:

Intake #	Permit #	Maximum Capacity (gallons/day)
#1	8005 (below confluence with Red Clay Creek)	20,000,000
#2	8233 (below confluence with Red Clay Creek)	10,000,000
#2a	8241 (above confluence with Red Clay Creek)	10,000,000

5. These intakes may be used only for the purpose of public supply. Any change in the intended use or in the physical characteristics of these facilities must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair water supply facilities in the State of Delaware shall be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. s6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse affects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify the problem.

10. This permit is transferable only if the requirements of the Regulations Governing the Allocation of Water are met and, approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

    This approval is contingent on practice by the permit holder of reasonable and effective efforts to minimize the unnecessary use and/or waste of water. The permit holder must at minimum:

    A. Establish a program of periodic monitoring and evaluation of water usage,

    B. Establish a systematic leak detection and control program which is responsive to high unaccounted for water usage rates, routine maintenance, or discovery of leaks,

    C. Use the best practical methods and devices to conserve water,

    D. Alert employees and customers of the need to conserve water and reduce wasteful usage, including conservation suggestions in water bills, and

13. WATER CONSERVATION MEASURES (cont.)

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

14. CONJUNCTIVE USE OF WATER RESOURCES

This approval is contingent on practice by the permit holder to employ to the greatest practicable extent conjunctive use of available water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: _____
Stewart Lovell, P.G.
Manager
Water Allocations

Date: April 8, 1996

xc: Bureau of Environmental Health
United States Geological Survey
Delaware River Basin Commission

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

PUBLIC WATER ALLOCATION

ALLOCATION NO: 90-0014
EFFECTIVE DATE: April 8, 1996
EXPIRATION DATE: April 8, 2026

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

UNITED WATER DELAWARE
Christiana Water Treatment Plant
2000 First State Blvd.
P. O. Box 6508
Wilmington, Delaware 19804

for the withdrawal and use of water from the following water facilities:

Intake #	Location	Stream	Latitude	Longitude	Maximum Pumping Capacity (gpm)
Pump house #1	Smalley's Pond	Christina River	39°39'12"	75°40'15"	8000

OTHER APPROVALS

1. This approval is subject to review every five years from effective date by the Division of Water Resources.
2. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.
3. Approval for the use of this water for human consumption must be obtained from the Bureau of Environmental Health.
4. Approval for discharge of this water must be obtained from the Division of Water Resources.
5. This approval is subject to modification in accordance with establishment of State instream flow and passby requirements.

EQUIPMENT REQUIREMENTS

1. All facilities must be equipped with appropriate metering equipment in accordance with accepted engineering practice for recording pumping rates and cumulative volumes of pumpage to a design accuracy of ±5%.

REPORTING PROCEDURE

1. For each facility: Readings of pumping rates, and cumulative pumpage must be made and recorded at least daily. This and all other requested information, such as water purchases and sales, is to be recorded on a form provided by the Division of Water Resources and submitted by the permit holder to the Division annually by January 31, or more frequently if requested.

ALLOCATION

1. **In any twenty-four (24) hour period**: Pumpage from this intake may not exceed **6,000,000 gallons**. Total pumpage from all surface water intakes combined must not exceed **36,000,000 gallons**.

2. **In any thirty (30) day period**: Pumpage from this intake may not exceed **180,000,000 gallons**. Total pumpage from all surface water intakes combined must not exceed **1,080,000,000 gallons**.

3. **In any twelve (12) month period**: Pumpage from this intake may not exceed **2,190,000,000 gallons**. Total pumpage from all surface water intakes must not exceed **13,140,000,000 gallons**.

4. Withdrawals for the sources listed below shall not exceed the following limits:

Intake #	Permit #	Maximum Pumping Rate (gallons/day)
Pumphouse #1	8006	6,000,000

5. These intakes may be used only for the purpose of public supply. Any change in the intended use, or in the physical characteristics of this facility must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair of water wells and water supplies in the State of Delaware will be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. s6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse affects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify the problem.

10. This permit is transferable only if the requirements of the Regulations Governing the Allocation of Water are met and, written approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

    This approval is contingent on practice by the permit holder of reasonable efforts to minimize the unnecessary use and/or waste of water. The permittee must:

    A. Establish a program of periodic monitoring and evaluation of water usage,

    B. Establish a systematic leak detection and control program which is responsive to high unaccounted for water usage rates, routine maintenance, or discovery of leaks,

    C. Use the best practical methods and devices to conserve water,

    D. Alert employees and customers of the need to conserve water and reduce wasteful usage, including conservation suggestions in water bills, and

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: Stewart Lovell

Stewart Lovell, P.G.
Manager
Water Supply Section

Date: April 8, 1996

cc: Bureau of Environmental Health
Delaware River Basin Commission
United States Geological Survey

DOCKET NO. D-91-72 CP

DELAWARE RIVER BASIN COMMISSION

Wilmington Suburban Water Corporation
Surface Water Withdrawal Project
New Castle County, Delaware

PROCEEDINGS

This is an application submitted by the Wilmington Suburban Water Corporation and referred to the Commission, pursuant to an Administrative Agreement under Sections 2-3.4 (a) and 2-3.7 of the Administrative Manual - Part II, Rules of Practice and Procedure, by the Delaware Department of Natural Resources and Environmental Control (DNREC) on September 12, 1991, for review of a surface water withdrawal project. The project is subject to approval by the DNREC.

The application was reviewed for inclusion of the project in the Comprehensive Plan and approval under Section 3.8 of the Delaware River Basin Compact. The New Castle County Planning Department has been notified of pending action on this docket and has not expressed objection to approval by the DRBC. Public hearings on this project were held by the DRBC on February 17, 1993, March 24, 1993, June 23, 1993 and August 4, 1993.

DESCRIPTION

Purpose.-- The purpose of this project is to increase the allowable surface water withdrawal at the Wilmington Suburban Water Corporation's (WSWC) existing White Clay Creek intakes.

Location.-- The project intakes (Stanton Intake) are located on the White Clay Creek; Intake No. 1 is approximately 1,000 feet downstream of the confluence of Red Clay Creek, at River Mile 70.7-10.3-2.2, and Intake No. 2 is located just upstream of the confluence of Red Clay Creek at River Mile 70.7 - 10.3 - 2.25. The intakes provide raw water to the adjacent WSWC's Stanton Water Treatment Plant. The facilities are located near Stanton in New Castle County, Delaware at 2000 First State Boulevard.

Service area.-- The WSWC serves a major portion of northern New Castle County and uses two surface water supply sources in the Christina River watershed: the major source being provided via the project intakes on the White Clay Creek and the other the Smalley's Pond intake on the Christina River approximately, 10 river miles upstream of the White Clay Creek confluence with the Christina River. WSWC has 13 interconnections for both active and emergency use, with a 14th underway (between the City of Wilmington and WSWC), which will enable a total maximum transfer of approximately 13.5 mgd from other purveyors (including 2 mgd transferred from systems in Delaware County, Pennsylvania and a planned 10 mgd from the City of Wilmington), and export of 8.5 mgd to other purveyors in New Castle County. A small in-Basin portion of Cecil County, Maryland is proposed to be served by the WSWC in the near future and all the wastewater generated in that service area is expected to return to the Delaware River Basin.

In general, the WSWC service area consists of three districts: an area of approximately 13 square miles just north of the Chesapeake and Delaware Canal and west of the Delaware River, an area of approximately 18 square miles just north of the City of Wilmington and west of the Delaware River, and an area of approximately 21 square miles south of the City of Newark. The three service areas are separated by the service areas of Artesian Water Company and the City of Wilmington. The southernmost service area is supplied by the Smalley's Pond intake.

Physical features.

a. Design criteria.-- The WSWC proposes to increase its withdrawal from its existing Stanton intake on the White Clay Creek. The raw water will be treated at the adjacent Stanton Water Treatment Plant which has the capacity to treat up to 30 million gallons per day (mgd). The WSWC anticipates it will need the entire 30 mgd capacity of the treatment plant for existing and future water demand. The WSWC's White Clay Creek peak month withdrawal has increased steadily from approximately 16 mgd in 1985 to 25.53 mgd in June, 1991.

The Stanton intake, coupled with the WSWC's existing Smalley's Pond intake on the Christina River, constitute the WSWC's entire water supply sources other than via purchases from other in-state and out-of-state purveyors. For emergency use, Hoopes Reservoir can release up to 10 mgd to the Red Clay Creek to enable WSWC to withdraw at its Stanton intake for treatment and distribution during low flows. The Smalley's Pond withdrawal and water treatment plant can provide up to 6 mgd; and, its 1991 peak month use (in August) was 2.33 mgd. This, along with the 25.53 mgd peak month withdrawal at the Stanton intake, brings WSWC's total 1991 peak month water use from its two surface water sources to 27.86 mgd. With inclusion of transfers from other purveyors, the total 1991 peak month water use is approximately 29 mgd. Based on WSWC estimates of population served, the current peak month per capita use is estimated to be 70 gallons per capita per day (gpcd).

In the year 1988, residential use was estimated to be 29% of the total water use with industrial 36%, commercial/institutional 9%, interconnection sales 14%, and unaccounted-for use about 12%. The recent (1991) increased use appears to be a result of growth in residential and interconnection sales.

The unaccounted-for water use increased from an average of about 7 percent in 1978 to 12 percent in 1988, and is currently estimated to be 8 percent after implementation of leak identification and reduction programs by WSWC.

The Water Supply Plan for New Castle County, Delaware, Churchman's EIS, Interim Report Subtask 1.5, Future Water Demands, dated October 11, 1991, projects that, with the implementation of water conservation programs and recently adopted water conserving plumbing code amendments, the WSWC's year 2040 systemwide maximum monthly demand (excluding interconnection sales to other suppliers) should average approximately 28.5 mgd, with maximum daily demand projected at 31.2 mgd. In addition, WSWC presently provides up to 7 mgd to other suppliers via interconnections during its maximum monthly demand period, to enable those water suppliers to meet their customer demands. In 1991, WSWC's maximum monthly water use, including sales to other suppliers, was 28.2 mgd. (An additional 1 mgd is also routinely withdrawn from the White Clay Creek by WSWC for its in-plant maintenance needs). The WSWC's water use has grown faster than previously projected.

To provide for its systemwide water demand, the WSWC plans to improve its Stanton Water Treatment Plant to gain the full use of its 30 mgd water treatment capability. With a planned 10 mgd transfer from the City of Wilmington Brandywine Creek source, 6 mgd from Smalley's Pond, and 3.5 mgd transferred from other purveyors, the WSWC's maximum available water supply during normal flows will be approximately 49.5 mgd.

b. Facilities.-- The project facilities consist of two intakes on the White Clay Creek. Intake No. 1 is on the north bank of White Clay Creek below the confluence of Red Clay Creek and is controlled by Pumphouse No. 1. Intake No. 2 was constructed sometime in the 1960's and is located on the south bank of White Clay Creek above the confluence of Red Clay Creek and is connected by pipe to Pumphouse No. 2. Intake No. 2 is used alone in the event of any stream contamination such as an oil spill, in the Red Clay Creek. Both pumphouses are equipped with traveling screens and two 7,000 gallon per minute capacity pumps.

The Stanton Water Treatment Plant can provide peak treatment capacity of up to 30 mgd and is proposed for improvements to enable it to sustain the average treatment capacity at 30 mgd. The plant provides coagulation, flocculation, sedimentation, filtration and disinfection.

The WSWC's Smalley's Pond facility was constructed in the early 1900's as a 40-million-gallon (mg) reservoir on the Christina River located just southwest of the Route 7 and Old Baltimore Pike intersection. Its current storage capacity was recently restored to its original 40 mg capacity via a WSWC funded dredging project.

The project treatment facilities are above the 100-year flood elevation.

All withdrawals, water service connections, and interconnections with other distribution systems are metered.

Waste water is conveyed to the City of Wilmington regional sewage treatment facility most recently approved by DRBC Docket No. D-69-37 CP (Phase III) on September 24, 1975. The treatment facility has adequate capacity to receive waste water from the proposed project.

Relationship to the Comprehensive Plan.-- The Stanton intake on the White Clay Creek was included in the DRBC Comprehensive Plan via Resolution R-62-14 Addendum 1, "Pre-Existing Projects", adopted July 25, 1962.

The Bethel Township (Delaware County, Pennsylvania) Water Company in Docket No. D-69-172 CP received approval March 17, 1971 to transfer to WSWC 1.5 mgd of finished water purchased from the Chester Water Authority (CWA) in Delaware County, Pennsylvania. The WSWC in Docket No. D-84-10 CP (Supplement No. 2) received approval (good through March 31, 2038) of a water transfer from CWA to WSWC that is not to exceed 60 mg during any 30-day period. The original source of the CWA water is the Susquehanna River Basin and the project was included in the DRBC Comprehensive Plan as an importation of water.

The City of Wilmington transfer of up to 10 mgd of water from its Brandywine Creek source was included in the Comprehensive Plan via Docket No. D-92-29 CP on November 4, 1992.

The policy recommendations of the Water Supply Facility Plan for Northern New Castle County were included in the DRBC Comprehensive Plan via Docket D-84-10 CP on September 25, 1984. The Comprehensive Plan was revised in Supplement No. 1, approved October 28, 1986.

FINDINGS

On October 28, 1986, by Docket No. D-84-10 CP (Supplement No. 1), the DRBC included certain Plan Recommendations of the "Comprehensive Water Supply Plan for Northern New Castle County" into the Comprehensive Plan. Plan Recommendation 2 identified the proposed development of surface water storage supplies with reservoirs at Churchman's Marsh or Thompson Station, both on the White Clay Creek. Plan Recommendation No. 4 deleted the Newark Project, a multi-purpose reservoir project originally proposed to be located on White Clay Creek, approximately 9.8 River Miles above the WSWC's proposed surface water withdrawal increase project. The Churchman's Marsh reservoir project would be located downstream of the project withdrawal, while the Thompson Station reservoir would be located upstream.

At the WSWC's Stanton intake, the White Clay Creek has an estimated 7-consecutive-day, 10-year return period low flow ($Q_{7\text{-}10}$) of 17.2 mgd. To protect the aquatic environment of White Clay Creek, the withdrawal of water should be prohibited whenever the downstream flow is at the $Q_{7\text{-}10}$ or less.

A surface water withdrawal by WSWC was included in the Comprehensive Plan of the DRBC as part of Addendum No. 1 in March 1962. WSWC certified in 1974 that the 1961 capacity at its Stanton intake was 16 mgd.

The WSWC's water use records have shown its existing Stanton intake peak month water use of 25.53 mgd would substantiate a withdrawal of 30.0 mgd to ensure meeting the needs of its current distribution system as well as providing flexibility for its future water supply system.

The City of Newark has a DNREC and DRBC approval to withdraw up to 5.0 mgd at an intake to be located on the White Clay Creek approximately 8.6 River Miles upstream of the WSWC's Stanton intake. Staff estimates that WSWC's proposed 30.0 mgd withdrawal could only be fully made 80 percent of the time with a passby requirement of 17.2 mgd (estimated $Q_{7\text{-}10}$ streamflow plus that which would enable the City of Newark to withdraw 5.0 mgd upstream). Without consideration of the City of Newark's 5.0 mgd withdrawal, the WSWC's Stanton intake has a full 30 mgd withdrawal reliability 84 percent of the time. Between 16 percent to 20 percent of the time, the full 30 mgd as requested by WSWC cannot be taken; therefore, until storage or a supplemental source can be provided, the WSWC should consider the project surface water source as unreliable.

DECISION condition "e" of Docket D-84-10 CP (Supplement 2), Interstate Water Transfer Project from Chester County, Pennsylvania to New Castle County, Delaware, sets forth the following requirements:

"Within 6 months of the date of this docket, the applicant (Delaware Department of Natural Resources and Environmental Control) shall initiate an engineering study to acquire an additional source of water supply for New Castle County, Delaware. Such study shall be completed and the final results and recommendations reported to the Commission within two years of the date of this docket."

"The applicant shall expedite actions to acquire additional water supply sources and shall develop such sources within six years of the date of this docket. The deadline set forth in this condition may be extended with written approval by the Commission upon good cause shown, providing that the applicant demonstrates satisfactory and good faith progress toward compliance with this condition."

Accordingly, the required study was to have been completed by August 2, 1991, and the appropriate water supply source(s) must be developed by August 2, 1995. DNREC has requested that DRBC extend both completion dates of Docket No. D-84-10 CP (Supplement No. 2) condition "e." by three years.

Project withdrawals are used for the purpose of public water supply and the consumptive use is estimated to be 10 percent of the total water use.

DECISION

I. The project, as described above, with modifications specified hereinafter, is hereby added to the Comprehensive Plan.

II. The project is approved pursuant to Section 3.8 of the Compact, subject to the following conditions:

a. Approval is subject to all conditions imposed by the DNREC.

b. The facilities shall be available at all times for inspection by the DRBC.

c. The facilities shall be operated at all times to comply with the requirements of the surface water policies and standards of the DRBC.

d. During any 30-day period, the withdrawal from the project intake on the White Clay Creek shall not exceed 900 million gallons.

e. The applicant shall pay for surface water use in excess of amount shown in Certificate of Entitlement in accordance with the provisions of Resolution No. 74-6, as amended.

f. Beginning three years from the date of this approval, the project withdrawal must not cause the streamflow to be less than 17.2 mgd (estimated Q_{7-10} flow) at the Stanton intake on White Clay Creek. When the streamflow at the intake is less than 17.2 mgd, no water is to be withdrawn and the entire natural flow must be allowed to pass. However, when the water level at the project intake is under the influence of tide, withdrawal will be allowed, provided the water level is not below the elevation established for the Q_{7-10} flow when tide is not influencing streamflow. Further, water released from Hoopes Reservoir may be withdrawn at the project intake equivalent to the quantity of water released from Hoopes Reservoir, taking into consideration the appropriate time of travel between Hoopes Reservoir and the Stanton intake. Within 9 months of the date of approval of this docket, the applicant shall submit an Operating Plan, subject to approval by the Executive Director of the DRBC, which shall outline procedures to demonstrate compliance with all requirements.

g. WSWC shall submit a water conservation plan to DNREC and DRBC. The plan should describe the implementation of the following programs as required by the Commission:

* Source metering (Resolution No. 86-12);
* Service metering (Resolution No. 87-7 Revised);
* Leak detection and repair (Resolution No. 87-6 Revised); and
* Water conservation performance standards for plumbing fixtures and fittings (Resolution No. 88-2 Revision No. 2).

h. The project and surface water intakes shall be metered with an automatic continuous recording device that measures to within 5 percent of actual flow. A record of daily withdrawals shall be maintained, and monthly totals shall be reported to the DNREC annually.

i. The applicant shall develop, adopt, and implement in accordance with the recommendations of the DNREC, a drought or other water supply emergency plan.

j. No new water service connections shall be made to premises connected to sewerage systems which are not in compliance with all applicable water quality standards of the Commission.

k. Nothing herein shall be construed to exempt the applicant from obtaining all necessary permits and/or approvals from other State, Federal or local government agencies having jurisdiction over this project.

l. The area served by this project is limited to the service area as described above. Any expansion beyond this area is subject to review in accordance with Section 3.8 of the Compact.

m. This approval is temporary and will be reviewed within ten years of the date of approval, and unless renewed, this approval shall expire ten years from the date of approval.

n. The issuance of this withdrawal permit shall not create any private or proprietary rights in the water of the Basin and the Commission reserves the right to amend, alter, or rescind any actions taken hereunder in order to insure the proper control, use, and management of the water resources of the Basin.

o. For the duration of any drought emergency declared by the Commission, water service or use by the project applicant pursuant to this approval shall be subject to the prohibition of those nonessential uses specified by the DNREC to the extent that they may be applicable, and to any other emergency resolutions or orders adopted hereafter.

p. The applicant shall cooperate with efforts to complete the current on-going study (Water Supply Plan for New Castle County, Delaware) to find an additional source of water supply for New Castle County. If the current study does not continue to demonstrate progress on the schedule approved by DRBC, the applicant shall find an alternate reliable source of water and make it available by 1997.

q. For a period of up to three years from the date of this approval, whenever the gaged stream flow at the Stanton intake on the White Clay Creek is less than 47.2 mgd, WSWC may withdraw up to 30 mgd, provided that WSWC is making releases from Hoopes Reservoir (to the maximum extent permitted by its agreement with the City of Wilmington) to maintain a passby flow of 17.2 mgd at the point of withdrawal, and provided that mandatory restrictions are being enforced whenever the 17.2 mgd passby flow requirement cannot be met.

BY THE COMMISSION

DATED: August 4, 1993

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

GROUNDWATER MANAGEMENT SECTION
ON-SITE BRANCH
WATER SUPPLY BRANCH

(302) 736 - 4556
(302) 736 - 4761
(302) 736 - 4793

PUBLIC WATER ALLOCATION

ALLOCATION NO: 88-0018-A
EFFECTIVE DATE: December 20, 1990
EXPIRATION DATE: December 20, 2020

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

THE CITY OF NEWARK
P. O. BOX 390, NEWARK, DELAWARE 19715

for the withdrawal and use of water from the following water facility:

Intake	Location	Stream	Latitude	Longitude	Maximum Pumping Capacity (gpm)
White Clay	Curtis Plant	White Clay Creek	39°41'26"	75°44'52"	3500

OTHER APPROVALS

1. Approval for use for this water for human consumption must be obtained from the Bureau of Environmental Health.

2. This approval is subject to review every five years from effective date by the Division of Water Resources.

3. Approval for discharge of this water must be obtained from the Division of Water Resources.

4. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.

EQUIPMENT REQUIREMENTS

1. This intake must be equipped with appropriate metering equipment in accordance with accepted engineering practice for recording pumping rates and cumulative volumes of pumpage to a design accuracy of ±5%.

REPORTING PROCEDURE

1. For this intake readings of pumping rates and cumulative volumes of pumpage must be made and recorded daily. This and all other requested information, such as water purchases and water sales, is to be recorded on forms provided by the Division of Water Resources then submitted to the Division by January 31, or more frequently if requested.

ALLOCATION

1. In any twenty-four hour period: Total pumpage from this intake must not exceed 5,000,000 gallons.
   Total pumpage from all ground- and surface-water facilities combined must not exceed 9,800,000 gallons.

2. In any thirty-day period: Total pumpage from this intake must not exceed 150,000,000 gallons.
   Total pumpage from all ground- and surface-water facilities combined must not exceed 294,000,000 gallons.

3. In any twelve-month period: Total pumpage from this intake must not exceed 1,825,000,000 gallons.
   Total pumpage from all ground- and surface-water facilities combined must not exceed 3,577,000,000 gallons.

4. Withdrawal from the facility listed below must not exceed the following limit

Intake	Permit #	Maximum Pumping Rate (gallons per day)
White Clay	8234	5,000,000

and must adhere to the following conditions.

A. Withdrawal pursuant to this allocation is permitted whenever the simulanteous combined-flow of White Clay Creek and Red Clay Creek (flow*) is equal to or greater than 46.5 cubic feet per second (cfs) [30.0 million gallons per day (mgd)]. However, if flow is less than 46.5 cfs, withdrawal is permitted upon the consent of Wilmington Suburban Water Corporation, Inc. (WSWC), and under such conditions withdrawal must be curtailed as directed by WSWC to the extent and for the purpose of maintaining flow as necessary to meet prevailing demand at WSWC's Stanton intake, except as provided in condition 4B below.

4. (Continued)

B. Upon the first sustained flow of 48.5 cfs (31.3 mgd) for twenty-four consequtive hours after the last withdrawal curtailment, withdrawal may be increased in 1.0 mgd increments. Whenever flow is less than 48.5 cfs, withdrawal may be increased in 1.0 mdg increments with the consent of WSWC.

C. The permit holder must establish a program of regular monitoring of gage and flow readings, which includes increased frequency of such readings as necessary during times of decreased flow, and is fully responsible for regulating withdrawal subject to the above conditions. This monitoring program, and conditions 4A and 4B (above), are subject to respective review and modification by the Division of Water Resources at any time deemed necessary.

5. This facility must be used only for the purpose of public supply. Any change in the permitted use, or in the physical characteristics of this facility must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair of water wells and water facilities in the State of Delaware will be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. Chapter 6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse effects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify such effects.

10. This permit is transferable only if the requirements of the Regulations governing the Allocation of Water are met and, written approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

This approval is contingent on practice by the permit holder of reasonable efforts to minimize the unnecessary use and/or waste of water. The permittee must:

A. Establish a program of periodic monitoring and evaluation of water usage,

B. Establish a systematic leak detection and control program which is responsive to high unaccounted-for water usage rates, routine maintenance, and discovery of leaks,

C. Use the best practical methods and devices to conserve water,

D. Alert customers of the need to conserve water and reduce wasteful usage via, for example, suggestions in water bills and,

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water-sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

13. CONJUNCTIVE USE OF WATER RESOURCES

This approval is contingent on practice of the permit holder to employ to the greatest practicable extent conjunctive use of its available ground and surface water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: Stewart Lovell
Stewart Lovell
Supervisor
Water Allocation Group

Date: December 20, 1990

cc: Bureau of Environmental Health
United States Geological Survey
Delaware River Basin Commission

* subsequent stream-flow values and the term 'flow' are referenced to United States Geological Survey telemetered stream-gages:

01479000, near Stanton, Dela. Lat. 39°41'47", Lon. 75°40'33", and

01480000, at Wooddale, Dela. Lat. 39°45'52', Lon. 75°38'08".

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

GROUNDWATER MANAGEMENT SECTION
ON-SITE BRANCH
WATER SUPPLY BRANCH

(302) 736-4556
(302) 736-4761
(302) 736-4793

PUBLIC WATER ALLOCATION

ALLOCATION NO: 88-0018-B
EFFECTIVE DATE: December 20, 1990
EXPIRATION DATE: December 20, 2020

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

THE CITY OF NEWARK
P. O. BOX 390, NEWARK, DELAWARE 19715

for the withdrawal and use of water from the following water facilities:

Well #	Location	Aquifer	Latitude	Longitude	Maximum Pumping Capacity (gpm)
8	Academy St. & Waterworks Ln.	Columbia	39°40'19"	75°45'03"	140
10	Rte. 72 @ Water Plant	Columbia	39°39'25"	75°45'35"	60
11	Blue Hen Dr. 1000' N. of Bellevue Rd.	Columbia	39°39'14"	75°44'06"	150
13	Rte. 72 @ Water Plant	Columbia	39°39'25"	75°43'35"	180
15	Rte. 72 & Bellevue Rd. @ R.R. Track	Columbia	39°39'01"	75°44'11"	425
17	Old Coochs Bridge Rd. 1600' E. of Rte. 896	Columbia	39°37'39	75°44'19"	150

OTHER APPROVALS

1. Approval for use for this water for human consumption must be obtained from the Bureau of Environmental Health.

2. This approval is subject to review every five years from effective date by the Division of Water Resources.

3. Approval for discharge of this water must be obtained from the Division of Water Resources.

4. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.

5. Well #8 (10001) may not be used prior to written approval from the Bureau of Environmental Health.

EQUIPMENT REQUIREMENTS

1. All wells must be equipped with a meter for recording pumping rates and cumulative volumes of pumpage to a design accuracy of ±5%.

2. All wells must be equipped with the following device for measurement of water levels: a readily accessible 1/2" minimum inner-diameter capped port with drop line. Air-line gages are not permitted.

3. All wells not conforming to requirement #2 (above) must be corrected accordingly within five years of the effective date of this permit.

REPORTING PROCEDURE

1. For each well readings of pumping rates and cumulative volumes of pumpage must be made and recorded daily. Readings of pumping water-levels must be made and recorded at least weekly. This and all other requested information, such as water purchases and water sales, is to be recorded on forms provided by the Division of Water Resources then submitted to the Division by January 31, or more frequently if requested.

ALLOCATION

1. In any twenty-four hour period: Total pumpage from these wells must not exceed 1,600,000 gallons.
Total pumpage from all ground- and surface water facilities combined must not exceed 9,800,000 gallons.

2. In any thirty-day period: Total pumpage from these wells must not exceed 48,000,000 gallons.
Total pumpage from all ground- and surface water facilities combined must not exceed 294,000,000 gallons.

3. In any twelve-month period: Total pumpage from these wells must not exceed 584,000,000 gallons.
Total pumpage from all ground- and surface water facilities combined must not exceed 3,577,000,000 gallons.

4. Withdrawals from the facilities listed below must not exceed the following limits:

Well #	Permit #	Maximum Pumping Rate (gallons per day)	Maximum Pumping Level (feet below land surface)
8	10001	201,600	---
10	10622	86,400	---
11	10003	216,000	---
13	10004	259,200	---
15	00182	612,000	---
17	01508	216,000	---

5. These facilities must be used only for the purpose of public supply. Any change in the permitted use, or in the physical characteristics of this facility must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair of water wells and water facilities in the State of Delaware will be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. Chapter 6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse effects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify such effects.

10. This permit is transferable only if the requirements of the Regulations governing the Allocation of Water are met and, written approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

This approval is contingent on practice by the permit holder of reasonable efforts to minimize the unnecessary use and/or waste of water. The permittee must:

A. Establish a program of periodic monitoring and evaluation of water usage,

B. Establish a systematic leak detection and control program which is responsive to high unaccounted-for water usage rates, routine maintenance, and discovery of leaks,

C. Use the best practical methods and devices to conserve water,

D. Alert customers of the need to conserve water and reduce wasteful usage via, for example, suggestions in water bills and,

12. WATER CONSERVATION MEASURES (continued)

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water-sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

13. CONJUNCTIVE USE OF WATER RESOURCES

This approval is contingent on practice of the permit holder to employ to the greatest practicable extent conjunctive use of its available ground and surface water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: Stewart Lovell
Stewart Lovell
Supervisor
Water Allocation Group

Date: December 20, 1990

cc: Bureau of Environmental Health
United States Geological Survey
Delaware River Basin Commission

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

GROUNDWATER MANAGEMENT SECTION
ON-SITE BRANCH
WATER SUPPLY BRANCH

(302) 736-4556
(302) 736-4761
(302) 736-4793

PUBLIC WATER ALLOCATION

ALLOCATION NO: 88-0018-C
EFFECTIVE DATE: December 20, 1990
EXPIRATION DATE: December 20, 2020

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

THE CITY OF NEWARK
P. O. BOX 390, NEWARK, DELAWARE 19715

for the withdrawal and use of water from the following water facilities:

Well #	Location	Aquifer	Latitude	Longitude	Maximum Pumping Capacity (gpm)
12	Scottfield 1000' E. of Water Plant	Potomac	39°39'27"	75°43'29"	75
14	Rte. 72 200' S. of Water Plant	Potomac	39°39'23"	75°44'04"	325
16	Brookhill Dr. 2000' E. of Rte. 72	Potomac	39°38'52"	75°43'09"	475
19	Rte. 72 & Reybold Rd.	Potomac	39°37'52"	75°43'36"	75

OTHER APPROVALS

1. Approval for use for this water for human consumption must be obtained from the Bureau of Environmental Health.

2. This approval is subject to review every five years from effective date by the Division of Water Resources.

3. Approval for discharge of this water must be obtained from the Division of Water Resources.

4. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.

EQUIPMENT REQUIREMENTS

1. All wells must be equipped with a meter for recording pumping rates and cumulative volumes of pumpage to a design accuracy of ±5%.

2. All wells must be equipped with the following device for measurement of water levels: a readily accessible 1/2" minimum inner-diameter capped port with drop line. Air-line gages are not permitted.

3. All wells not conforming to requirement #2 (above) must be corrected accordingly within five years of the effective date of this permit.

REPORTING PROCEDURE

1. For each well readings of pumping rates and cumulative volumes of pumpage must be made and recorded daily. Readings of pumping water-levels must be made and recorded at least weekly. This and all other requested information, such as water purchases and water sales, is to be recorded on forms provided by the Division of Water Resources then submitted to the Division by January 31, or more frequently if requested.

ALLOCATION

1. In any twenty-four hour period: Total pumpage from these wells must not exceed 1,400,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 9,800,000 gallons.

2. In any thirty-day period: Total pumpage from these wells must not exceed 42,000,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 294,000,000 gallons.

ALLOCATION (continued)

3. In any twelve-month period: Total pumpage from these wells must not exceed 511,000,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 3,577,000,000 gallons.

4. Withdrawals from the facilities listed below must not exceed the following limits:

Well #	Permit #	Maximum Pumping Rate (gallons per day)	Maximum Pumping Level (feet below land surface)
12	10002	108,000	120
14	10005	468,000	106
16	00181	684,000	129
19	31430	108,000	117

5. These facilities must be used only for the purpose of public supply. Any change in the permitted use, or in the physical characteristics of these facilities must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair of water wells and water facilities in the State of Delaware will be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. Chapter 6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse effects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify such effects.

10. This permit is transferable only if the requirements of the Regulations governing the Allocation of Water are met and, written approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

This approval is contingent on practice by the permit holder of reasonable efforts to minimize the unnecessary use and/or waste of water. The permittee must:

A. Establish a program of periodic monitoring and evaluation of water usage,

B. Establish a systematic leak detection and control program which is responsive to high unaccounted-for water usage rates, routine maintenance, and discovery of leaks,

C. Use the best practical methods and devices to conserve water,

D. Alert customers of the need to conserve water and reduce wasteful usage via, for example, suggestions in water bills and,

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water-sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

13. CONJUNCTIVE USE OF WATER RESOURCES

This approval is contingent on practice of the permit holder to employ to the greatest practicable extent conjunctive use of its available ground and surface water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: Stewart Lovell

Stewart Lovell
Supervisor
Water Allocation Group

Date: December 20, 1990

cc: Bureau of Environmental Health
United States Geological Survey
Delaware River Basin Commission

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF WATER RESOURCES
89 KINGS HIGHWAY, P.O. BOX 1401
DOVER, DELAWARE 19903

GROUNDWATER MANAGEMENT SECTION
ON-SITE BRANCH
WATER SUPPLY BRANCH

(302) 736-4556
(302) 736-4761
(302) 736-4793

PUBLIC WATER ALLOCATION

ALLOCATION NO: 88-0018-D
EFFECTIVE DATE: December 20, 1990
EXPIRATION DATE: December 20, 2020

Pursuant to the provisions of 6010f, 7 Del. C., an allocation of water is hereby granted to:

THE CITY OF NEWARK
P. O. BOX 390, NEWARK, DELAWARE 19715

for the withdrawal and use of water from the following water facilities:

Well #	Location	Aquifer	Latitude	Longitude	Maximum Pumping Capacity (gpm)
20	1000' NE. of Curtis Mill by millrace	Wissahickon	39°41'28"	75°44'46"	550
21	200' E. of Paper Mill Rd. 200' N. of Old Paper Mill Rd.	Wissahickon	39°41'27"	75°44'42"	200
23	400' E. of Creek Rd. 1800' N. of old R.R. Bridge	Wissahickon	39°41'46"	75°44'50"	350
25	500' E. of Int. of Fremont Rd. & Rte. 896	Wissahickon	39°41'35"	75°45'13"	150

OTHER APPROVALS

1. Approval for use for this water for human consumption must be obtained from the Bureau of Environmental Health.

2. This approval is subject to review every five years from effective date by the Division of Water Resources.

3. Approval for discharge of this water must be obtained from the Division of Water Resources.

4. This approval is subject to all appropriate regulations and approvals of the Delaware River Basin Commission.

EQUIPMENT REQUIREMENTS

1. All wells must be equipped with a meter for recording pumping rates and cumulative volumes of pumpage to a design accuracy of ±5%.

2. All wells must be equipped with the following device for measurement of water levels: a readily accessible 1/2" minimum inner-diameter capped port with drop line. Air-line gages are not permitted.

3. All wells not conforming to requirement #2 (above) must be corrected accordingly within five years of the effective date of this permit.

REPORTING PROCEDURE

1. For each well readings of pumping rates and cumulative volumes of pumpage must be made and recorded daily. Readings of pumping water-levels must be made and recorded at least weekly. This and all other requested information, such as water purchases and water sales, is to be recorded on forms provided by the Division of Water Resources then submitted to the Division by January 31, or more frequently if requested.

ALLOCATION

1. In any twenty-four hour period: Total pumpage from these wells must not exceed 1,800,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 9,800,000 gallons.

ALLOCATION (continued)

2. In any thirty-day period: Total pumpage from these wells must not exceed 54,000,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 294,000,000 gallons.

3. In any twelve-month period: Total pumpage from these wells must not exceed 657,000,000 gallons.
Total pumpage from all ground- and surface-water facilities combined must not exceed 3,577,000,000 gallons.

4. Withdrawals from the facilities listed below must not exceed the following limits:

Well #	Permit #	Maximum Pumping Rate (gallons per day)	Maximum Pumping Level (feet below land surface)
20	81438	792,000	190
21	81439	288,000	170
23	10006	504,000	126
25	10007	216,000	316

5. These facilities must be used only for the purpose of public supply. Any change in the permitted use, or in the physical characteristics of these facilities must receive prior approval from the Division of Water Resources.

6. All laws and regulations governing the construction, operation, maintenance, and repair of water wells and water facilities in the State of Delaware will be obeyed.

7. Representatives of the Division of Water Resources, Delaware Geological Survey and the U.S. Geological Survey may inspect these facilities, conduct any tests, and collect any samples at any time deemed necessary.

8. This allocation is specifically subject to the requirements of 7 Del. C. Chapter 6031.

9. If the withdrawal of water pursuant to this allocation has significant adverse effects including, but not limited to, reduction of streamflows, lowering of water levels, migration of pollutants, or encroachment of salt water, the Division of Water Resources may require action to rectify such effects.

10. This permit is transferable only if the requirements of the Regulations governing the Allocation of Water are met and, written approval is obtained from the Division of Water Resources.

11. Violations of conditions of this permit are subject to penalties provided in 7 Del. C., Chapter 60.

12. WATER CONSERVATION MEASURES

This approval is contingent on practice by the permit holder of reasonable efforts to minimize the unnecessary use and/or waste of water. The permittee must:

A. Establish a program of periodic monitoring and evaluation of water usage,

B. Establish a systematic leak detection and control program which is responsive to high unaccounted-for water usage rates, routine maintenance, and discovery of leaks,

C. Use the best practical methods and devices to conserve water,

D. Alert customers of the need to conserve water and reduce wasteful usage via, for example, suggestions in water bills and,

E. Develop a contingency plan to be implemented in the event of water shortage emergencies. This plan should include:

1. Identification of emergency water-sources,
2. Priorities of water usage, and
3. Emergency measures to curtail water usage.

13. CONJUNCTIVE USE OF WATER RESOURCES

This approval is contingent on practice of the permit holder to employ to the greatest practicable extent conjunctive use of its available ground and surface water supplies for purposes which include improving the reliability of those supplies, gaining long-term cost effectiveness in the operation of its water supply system, and minimizing potential adverse effects of withdrawals upon the environment.

The permittee must demonstrate compliance with these conditions upon request by the Division of Water Resources.

Signed: Stewart Lovell

Stewart Lovell
Supervisor
Water Allocation Group

Date: December 21, 1990

cc: Bureau of Environmental Health
United States Geological Survey
Delaware River Basin Commission

DOCKET NO. D-90-110 CP (S)

DELAWARE RIVER BASIN COMMISSION

City of Newark
Surface Water Withdrawal Project
New Castle County, Delaware

PROCEEDINGS

This is an application referred to the Commission, pursuant to an Administrative Agreement under Sections 2-3.4 (a) and 2-3.7 of the Administrative Manual - Part II, Rules of Practice and Procedure, by the Delaware Department of Natural Resources and Environmental Control (DNREC) on December 26, 1990, for review of a surface water withdrawal project. The project was approved by the DNREC on December 20, 1990 (Permit No. 88-0018-A), subject to approval by the Delaware River Basin Commission (DRBC).

The application was reviewed for inclusion of the project in the Comprehensive Plan and approval under Section 3.8 of the Delaware River Basin Compact. The New Castle County Planning Department has been notified of pending action on this docket and has not expressed objection to approval by the DRBC. A public hearing on this project was held by the DRBC on May 22, 1991.

DESCRIPTION

Purpose.-- The purpose of this project is to provide an additional source of water supply to the City of Newark's distribution system. The surface water is to be used in conjunction with the City's ground water sources.

Location.-- Surface water is diverted via an existing millrace on White Clay Creek located just west of Route 72 and approximately 1,200 feet upstream of the City of Newark's corporate boundary, in New Castle County, Delaware. The millrace serves the existing Curtis Paper Mill, now owned by James River Corp. The proposed intake will be located at the mill site. The millrace diversion is located at River Mile 70.7 - 10.3 - 10.9.

Service area.-- The applicant's distribution system serves the northwestern corner of New Castle County including all of the City of Newark and outlying areas between Route 95 and the Pennsylvania and Maryland state lines. The service area is shown in a plan entitled "City of Newark-Water Service Area" submitted with the project application.

Physical features.

a. Design criteria.-- The City of Newark proposes to construct a surface water intake and a water treatment plant at the site of the existing Curtis Paper Mill for withdrawal and treatment of up to 5.0 mgd on an average monthly basis.

The City of Newark provides water to an estimated population of 33,000 via 8,000 service connections with an average and maximum water demand of 3.9 mgd (117 mg/30 days) and 5.5 mgd, respectively. The ratio of peak to average day water use is 1.4 and the per capita water use average is 118.2 gpd. The City has projected its water use needs, for a design year 1995 population of 38,000, to average 5.0 mgd, with a peak use requirement of 6.5 mgd. Although this represents a decrease of the peak to average day water use ratio from 1.4 to 1.3, it represents an increase of per capita water use from 118.2 gpd to 131.6 gpd. If the current per capita water use is applied, the 1995 average day water use requirement is 4.5 mgd. Applying the existing peak to average use ratio indicates a 1995 peak use demand of 6.3 mgd.

The Water Supply Plan for New Castle County Delaware, Churchmans EIS, Interim Report Subtask 1.5, Future Water Demands, dated February 13, 1991, reports that with the implementation of future leak detection and water conservation programs, the City of Newark's projected year 2040 daily water demand should average approximately 3.91 mgd.

The City of Newark currently has three interconnections: one with Artesian Water Company (AWC) and two with Wilmington Suburban Water Company (WSWC). The AWC can provide up to 0.75 mgd, from ground water sources, through an interconnection located at Polly Drummond Hill Road. The WSWC can provide up to 1.70 mgd through interconnections at Academy Street and Red Mill Road. The WSWC uses two surface water sources for its supply, with withdrawals from White Clay Creek and the Christina River. The AWC and WSWC are also interconnected and the AWC is interconnected with the cities of Wilmington and New Castle. The WSWC is interconnected with two Pennsylvania sources (Chester Authority and Bethel Township) and with the City of Wilmington. The City of Newark plans another interconnection with the AWC once AWC's interconnection with the Chester Water Authority is complete.

During periods of normal stream flow, surface water will be used to meet the City's demands while its wells recover.

b. Facilities.-- The City of Newark proposes to construct an intake on the millrace which diverts water from White Clay Creek to the Curtis Paper Mill. A package water treatment plant will be constructed at the mill site and will include a chemical feed system for oxidation of iron and manganese, clarification, filtration, chlorination, fluoridation and pH adjustment. The plant will be designed to treat the three types of inflow: ground water only, surface water only, or a combination of both.

Currently, the City has two tanks for up to 1.0 mg of raw water storage and six tanks for up to 7.09 mg of finished water storage.

The City's ground water sources (twelve existing wells together with the two new wells (1.8 mgd) included in Docket D-90-110 CP (G)) can provide 4.8 mgd.

The project facilities are above the 100-year flood elevation.

c. Other.-- Waste water at the proposed water treatment plant will be drained to an on-site settling basin where supernatant will be recycled back to the water treatment plant influent. The settled solids will be disposed of at an approved landfill.

All wells, all water service connections, and all interconnections with other distribution systems are metered.

Waste water from the service area is conveyed to the City of Wilmington sewage treatment plant (STP) most recently approved by DRBC Docket No. D-69-37 CP Phase III on September 24, 1975. The treatment facility has adequate capacity to receive waste water from the proposed project. The City of Wilmington STP discharges to the Delaware River.

Cost.-- The overall cost of this project is estimated to be $3.0 million.

Relationship to the Comprehensive Plan.-- The City of Newark's existing wells were previously included within the Comprehensive Plan by Dockets Nos. D-71-131 CP, D-71-132 CP, and D-77-45 CP.

The policy recommendations of the Water Supply Facility Plan for Northern New Castle County was approved by Docket D-84-10 CP on September 25, 1984. The Comprehensive Plan was revised (in part, by the deletion of the Newark Project) in Supplement 1, approved October 28, 1986. The proposed surface water withdrawal is not a feature of the Water Supply Facility Plan for Northern New Castle County and has not previously been included in the Comprehensive Plan.

FINDINGS

On October 28, 1986, by Docket No. D-84-10 CP (Supplement No. 1), the DRBC included certain Plan Recommendations of the "Comprehensive Water Supply Plan for Northern New Castle County" into the Comprehensive Plan. Plan Recommendation 2 identified the proposed development of surface water storage supplies with reservoirs at Churchman's Marsh or Thompson Station. Plan Recommendation No. 3, identified certain ground water development projects which should proceed, including the Laird Tract well site. Plan Recommendation No. 4 deleted the Newark Project, a multipurpose reservoir project originally proposed to be located on White Clay Creek, approximately 1.1 miles above the proposed surface water withdrawal project. The proposed project withdrawal was not part of the Comprehensive Water Supply Plan for Northern New Castle County, and may conflict with the operation of Churchman's Marsh or Thompson Station Reservoirs or any other alternative water supply facility proposed for New Castle County.

To protect the aquatic environment of White Clay Creek, the withdrawal of water should be prohibited whenever the downstream flow is at the Q_{7-10} or less. In addition, some proportion of the streamflow should remain available for the existing withdrawals downstream. At the City of Newark's proposed intake, the White Clay Creek has an estimated seven-day low flow with a recurrence interval of ten years (Q_{7-10}) of 7.27 mgd (11.27 cfs). At WSWC's Stanton intake, located 8.6 miles downstream of the proposed intake, the estimated Q7-10 for White Clay Creek is 17.2 mgd (26.6 cfs).

A surface water withdrawal by WSWC was included in the Comprehensive Plan of the DRBC as part of Addendum No. 1 in March 1962. WSWC certified in 1974 that the 1961 capacity at its Stanton intake was 16 mgd. Approximately 62 percent of the Q7-10 flow to the Stanton intake is contributed by the White Clay Creek watershed alone (excluding the Red Clay Creek watershed). Of the Q7-10 flow contributed to the Stanton intake from the White Clay Creek watershed alone, 68 percent is from the drainage area above the influence of the City of Newark's proposed intake.

The City of Newark has shown a projected average water demand of 4.5 mgd and a peak of 6.3 mgd for 1995, and an average water demand of 3.91 mgd (with water conservation measures implemented) projected for the year 2040. This would substantiate an average water allocation of 5.0 mgd from the City's combined sources to ensure meeting the needs of its current water distribution system as well as providing flexibility for its future water supply system. Staff estimates that the 4.5 mgd demand could only be met 86 percent of the time with a passby requirement of 14.0 mgd (estimated Q_{7-10} streamflow plus that which would contribute to maintaining 16 mgd available for the WSWC intake downstream) as measured at the required gage (see DECISION condition "e."). Therefore, until supplemental storage can be provided, the City of Newark should consider the project surface source as unreliable.

DECISION condition "e." of Docket D-84-10 CP (Supplement 2), Interstate Water Transfer Project from Chester County, Pennsylvania to New Castle County, Delaware, sets forth the following requirements:

> "Within 6 months of the date of this docket, the applicant [Delaware Department of Natural Resources and Environmental Control] shall initiate an engineering study to acquire an additional source of water supply for New Castle County, Delaware. Such study shall be completed and the final results and recommendations reported to the Commission within two years of the date of this docket.
>
> The applicant shall expedite actions to acquire additional water supply sources and shall develop such sources within six years of the date of this docket. The deadline set forth in this condition may be extended with written approval by the Commission upon good cause shown, providing that the applicant demonstrates satisfactory and good faith progress toward compliance with this condition."

Accordingly, the required study is to be completed by August 2, 1991, and the appropriate water supply source(s) must be developed by August 2, 1995.

Project withdrawals are used for the purpose of public water supply and the consumptive use relative to the Delaware River Basin is estimated to be 10 percent of the total water use.

The project, except where noted above, does not conflict with nor adversely affect the Comprehensive Plan, is physically feasible, and does not adversely influence the present or future use and development of the water resources of the Basin.

DECISION

I. The project, as described above, with modifications specified hereinafter, is hereby added to the Comprehensive Plan.

II. The project is approved pursuant to Section 3.8 of the Compact, subject to the following conditions:

a. Approval is subject to all conditions imposed by the DNREC.

b. The facility shall be available at all times for inspection by the DRBC.

c. The facility shall be operated at all times to comply with the requirements of the DRBC.

d. During any 30-day period, the withdrawal from the proposed project surface water intake shall not exceed 150 million gallons, and the withdrawal from all sources (the project intake plus all wells) shall not exceed 150 million gallons.

e. The applicant shall enter into a contractual agreement with the USGS for monitoring the flow of White Clay Creek at a point immediately downstream of the Laird Track well field, subject to the approval of the Executive Director. Within 90 days of the approval of this Docket, the applicant shall submit to the DRBC a progress report on this contract. The new gage shall be operated when the project withdrawal begins and daily average flow shall be recorded and made available upon request.

f. The applicant shall not withdraw water from White Clay Creek whenever streamflow at the required monitoring gage (see Decision condition "e.") is less than 7.27 mgd (Q_{7-10} flow) plus a proportional amount needed to preserve the water supply needs of WSWC up to its existing DRBC entitlement. At WSWC's full entitlement rate of 16 mgd, the required passby flow will be 14 mgd (7.27 mgd + 6.73 mgd).

g. This approval is temporary and will be reviewed five years from the date of approval or at the time of review of an application for an alternative water supply project in New Castle County, whichever comes first.

h. Each new water service connection shall include a water meter in accordance with the DRBC's Resolution No. 73-1. All existing unmetered water service connections shall include a water meter by April 22, 1997, in accordance with DRBC's Resolution No. 87-7. Water charges for each service connection shall be based in part on metered usage.

i. The proposed project intake, and all existing wells and surface water intakes, shall be metered with an automatic continuous recording device that measures to within 5 percent of actual flow. A record of daily withdrawals shall be maintained, and monthly totals shall be reported to the DNREC annually.

j. Sound practices of excavation, backfill, and reseeding shall be followed to minimize erosion and deposition of sediment in streams.

k. No new water service connections shall be made to premises connected to sewerage systems which are not in compliance with all applicable water quality standards of the Commission.

l. Nothing herein shall be construed to exempt the applicant from obtaining all necessary permits and/or approvals from other State, Federal or local government agencies having jurisdiction over this project.

m. Within 10 days of the date that construction of the project has started, the applicant shall notify the DRBC of the starting date and scheduled completion date.

n. Upon completion of construction of the approved project, the applicant shall submit a statement to the DRBC, signed by the applicant's engineer or other responsible agent, advising the Commission that the construction has been completed in compliance with the approved plans, giving the final construction cost of the approved project, and the date the project is placed in operation.

o. This approval shall expire three years from date below unless prior thereto the applicant has commenced operation of the subject project or has expended substantial funds (in relation to the cost of the project) in reliance upon this approval.

p. The area served by this project is limited to the service area as described above. Any expansion beyond this area is subject to review in accordance with Section 3.8 of the Compact.

q. In accordance with DRBC Resolution No. 87-6 (Revised), the applicant shall implement to the satisfaction of the DNREC, the systematic program to monitor and control leakage within the water supply system. The program shall at a minimum include: periodic surveys to monitor leakage, enumerate unaccounted-for water, and determine the current status of system infrastructure; recommendations to monitor and control leakage; and a schedule for the implementation of such recommendations. The applicant shall proceed expeditiously to correct leakages and unnecessary usage identified by the program.

r. The applicant shall pay for surface water use in accordance with the provisions of Resolution No. 74-6, as amended.

s. The applicant shall develop, adopt and implement, in accordance with the recommendations of the DNREC, a continuous program to encourage water conservation in all types of use within the facilities served by this allocation permit. The applicant will report to the DNREC on the actions taken pursuant to this program and the impact of those actions as requested by that agency.

t. The applicant shall develop, adopt and be prepared to implement, in accordance with the recommendations of the DNREC, a drought or other water supply emergency plan.

u. The applicant shall cooperate with efforts to complete the current on-going study (Water Supply Plan for New Castle County, Delaware) to find an additional source of water supply for New Castle County. If the current study does not continue to demonstrate progress on the schedule approved by DRBC, the applicant shall find an alternate reliable source of water and make it available by 1995.

v. The issuance of this withdrawal permit shall not create any private or proprietary rights in the water of the Basin and the Commission reserves the right to amend, alter or rescind any actions taken hereunder in order to insure the proper control, use and management of the water resources of the Basin.

w. For the duration of any drought emergency declared by the Commission, water service or use by the project applicant pursuant to this approval shall be subject to the prohibition of those nonessential uses specified by the DNREC to the extent that they may be applicable, and to any other emergency resolutions or orders adopted hereafter.

x. No water service connections shall be made to newly constructed premises with plumbing fixtures and fittings that do not comply with water conservation performance standards contained in Resolution No. 88-2 (Revised).

BY THE COMMISSION

DATED: May 22, 1991

DOCKET NO. D-90-110 CP (G)

DELAWARE RIVER BASIN COMMISSION

City of Newark
Ground Water Withdrawal - Wells Nos. 20 and 21
City of Newark, New Castle County, Delaware

PROCEEDINGS

This is an application referred to the Commission, pursuant to an Administrative Agreement under Sections 2-3.4 (a) and 2-3.7 of the Administrative Manual - Part II, Rules of Practice and Procedure, by the Delaware Department of Natural Resources and Environmental Control (DNREC) on December 26, 1990, for an allocation of ground water and review of a ground water withdrawal project. The project was approved by the DNREC on December 20, 1990 (Permit No. 88-0018-D), subject to approval by the Delaware River Basin Commission (DRBC).

The application was reviewed for inclusion of the project in the Comprehensive Plan and approval under Section 3.8 of the Delaware River Basin Compact. The New Castle County Planning Department has been notified of pending action on this docket and has not expressed objection to approval by the DRBC. A public hearing on this project was held by the DRBC on May 22, 1991.

DESCRIPTION

Purpose.-- The purpose of this project is to add new Wells Nos. 20 and 21 in the Laird Tract well field as additional sources of water supply to the City of Newark's water supply system.

The proposed project is closely related to a proposed surface water withdrawal by the City of Newark from White Clay Creek and treatment of the surface water and the ground water from the Laird Tract well field in the proposed Curtis Water Treatment Plant.

Location.-- The City of Newark's existing and proposed wells are located as follows:

Well No.	Latitude (N)	Longitude (W)	Aquifer
8	39°40'19"	75°45'03"	Columbia
10	39°39'26"	75°44'04"	Columbia
11	39°39'14"	75°44'06"	Columbia
13	39°39'27"	75°44'04"	Columbia
15	39°39'01"	75°44'11"	Columbia
17	39°37'39"	75°44'19"	Columbia
12	39°39'32	75°43'43"	Potomac
14	39°39'23"	75°44'04"	Potomac
16	39°38'57"	75°43'24"	Potomac
19	39°37'52"	75°43'36"	Potomac
Laird Tract well field:			
20 (Proposed)	39°41'35"	75°45'11"	Wissahickon
21 (Proposed)	39°41'27"	75°44'42"	Wissahickon
23	39°41'51"	75°45'15"	Wissahickon
25	39°41'40"	75°45'43	Wissahickon

Service area.-- The City of Newark serves water to the City and adjacent surrounding areas. The City's service area is presented on a map entitled "City of Newark - Water Service Area" submitted as part of this application.

Interconnections comprising the water supply regionalization recommendation of the Water Supply Facility Plan for Northern New Castle County, included in the Comprehensive Plan by Docket No. D-84-10 CP, are required to be submitted to the DRBC for review and approval by Decision item "b." of that docket.

Physical features.

a. Design criteria.-- The City of Newark serves water to an estimated population of 33,000 via 8,000 service connections with an average and maximum water demand of 3.9 mgd (117 mg/30 days) and 5.5 mgd, respectively. The 1995 population served is projected to be 38,000 with an average and maximum water demand of 5.0 mgd (150 mg/30 days) and 6.5 mgd.

b. Facilities.-- The City of Newark's existing and proposed wells have the following characteristics:

Well No.	Depth	Screened Interval	Pump Capacity (gpm)	Year Drilled
8	63'	?	140	1940
10	100'	?	60	1969
11	63'	33-63'	150	1969
13	63'	42-62'	180	1969
15	69'	44-59'	425	1969
17	79'	56-69'	150	1971
12	175'	145-175'	75	1956
14	129'	106-126'	325	1964
16	167'	130-145'	475	1969
19	133'	118-133'	75	1974
20 (Proposed)	285'	open hole 102-285'	550	1990
21 (Proposed)	400'	open hole 55-400'	200	1990
23	400'	open hole 70-400'	350	1973
25	419'	open hole ? -419'	150	1973

The City of Newark has interconnections with the Wilmington Suburban Water Company and the Artesian Water Company (emergency only) distribution systems.

All wells, all water service connections, and all interconnections with other distribution systems are metered.

Well water withdrawn will be treated at the proposed Curtis Water Treatment Plant by oxidation of iron and manganese, clarification, filtration, chlorination, fluoridation, and pH adjustment.

The project facilities are above the 100-year flood elevation of White Clay Creek.

c. Other.-- Waste water is conveyed to the City of Wilmington sewage treatment facility most recently approved by DRBC Docket No. D-69-37 CP (3.8) Phase III on September 24, 1975. The treatment facility has adequate capacity to receive waste water from the proposed project.

Cost.-- The overall cost of this project is estimated to be $200,000.

Relationship to the Comprehensive Plan.-- The City of Newark's existing wells were previously included in the Comprehensive Plan by Dockets Nos. D-71-131 CP, D-71-132 CP, and D-77-45 CP.

FINDINGS

On October 28, 1986, by Docket No. D-84-10 CP (Supplement No. 1), the DRBC included certain Plan Recommendations of the "Comprehensive Water Supply Plan for Northern New Castle County" into the Comprehensive Plan. One of these recommendations, Plan Recommendation No. 3, identified certain ground water development projects which should proceed, including the Laird Tract well field. Wells Nos. 20, 21, 23 and 25, which withdraw from the Wissahickon Formation, are Laird Tract wells.

The aquifer evaluation and well field feasibility study of the Wissahickon well field (Laird Tract), prepared by the applicant's geotechnical consultant, estimates that at a withdrawal rate two-thirds of the requested 1250 gpm (1.8 mgd) rate, up to 50 percent of the well field withdrawal would come from White Clay Creek. This withdrawal could seriously impact the flow of White Clay Creek under low-flow conditions.

To protect the aquatic environment of White Clay Creek, the withdrawal of water should be prohibited whenever the downstream flow is at the Q_{7-10} or less. In addition, some proportion of the streamflow should remain available for the existing withdrawals downstream, specifically, that of the Wilmington Suburban Water Company (WSWC) located at Stanton approximately 8.6 miles downstream. At the City of Newark's proposed intake, the White Clay Creek has an estimated seven-day low flow with a recurrence interval of ten years (Q_{7-10}) of 7.27 mgd. At WSWC's Stanton intake, located 8.6 miles downstream of the proposed intake, the estimated Q_{7-10} for White Clay Creek is 17.2 mgd.

A surface water withdrawal by WSWC was included in the Comprehensive Plan of the DRBC as part of Addendum No. 1 in March 1962. WSWC certified in 1974 that the 1961 capacity at its Stanton intake was 16 mgd. Approximately 62 percent of the Q_{7-10} flow to the Stanton intake is contributed by the White Clay Creek watershed alone (excluding the Red Clay Creek watershed). Of the Q_{7-10} flow contributed to the Stanton intake from the White Clay Creek watershed alone, 68 percent is from the drainage area above the influence of the City of Newark's proposed Laird Tract well field.

The project is designed to conform with the requirements of the Ground Water Policy of the DRBC.

The DNREC water allocation is valid for a period of thirty years from date of issue, with review every five years.

Project withdrawals are used for the purpose of public water supply and the consumptive use is estimated to be 10 percent of the total water use.

The project does not conflict with nor adversely affect the Comprehensive Plan, is physically feasible, and does not adversely influence the present or future use and development of the water resources of the Basin.

DECISION

I. The project, as described above, with modifications specified hereinafter, is hereby added to the Comprehensive Plan.

II. The project is approved pursuant to Section 3.8 of the Compact, subject to the following conditions:

a. Approval is subject to all conditions imposed by the DNREC.

b. The wells shall be available at all times for inspection by the DRBC.

c. The wells shall be operated at all times to comply with the requirements of the ground water policies and standards of the DRBC.

d. During any 30-day period, the withdrawal from Wells Nos. 20, 21, 23 and 25 shall not exceed 54 million gallons; the withdrawal from Wells Nos. 12, 14, 16 and 19 shall not exceed 42 million gallons; the withdrawal from Wells Nos. 8, 10, 11, 13, 15 and 17 shall not exceed 48 million gallons, and the withdrawal from all wells shall not exceed 144 million gallons.

e. The applicant shall enter into a contractual agreement with the USGS for monitoring the flow of White Clay Creek at a point immediately downstream of the Laird Tract well field, subject to the approval of the Executive Director. Within 90 days of the approval of this Docket, the applicant shall submit to the DRBC a progress report on this contract. The new gage shall be operational when the project withdrawal begins and daily average flow shall be recorded and made available upon request.

f. The applicant shall not withdraw water from the Laird Tract Wells whenever streamflow at the required monitoring gage (see Decision condition "e.") is less than 7.27 mgd (Q_{7-10} flow) plus a proportional amount needed to preserve the water supply needs of WSWC up to its existing DRBC entitlement. At WSWC's full entitlement rate of 16 mgd, the required passby flow will be 14 mgd (7.27 mgd + 6.73 mgd).

If the applicant is able to demonstrate that the pumping of the Laird Tract wells will not further reduce the natural low flow of White Clay Creek, the applicant may petition the Executive Director for relief from the Laird Tract well pumping restriction to the extent that the natural low flow will not be further reduced by the well withdrawals.

g. The proposed wells shall be equipped with readily accessible capped ports and drop pipes so that water levels may be measured under all conditions. Existing wells are to be similarly equipped, where possible, with readily accessible ports and drop pipes as required by the DNREC.

h. Each new water service connection shall include a water meter in accordance with the DRBC's Resolution No. 73-1. All existing unmetered water service connections shall include a water meter by April 22, 1997, in accordance with DRBC's Resolution No. 87-7. Water charges for each service connection shall be based in part on metered usage.

i. The proposed wells, and all existing wells and surface water intakes, shall be metered with an automatic continuous recording device that measures to within 5 percent of actual flow. A record of daily withdrawals shall be maintained, and monthly totals shall be reported to the DNREC annually.

j. Sound practices of excavation, backfill, and reseeding shall be followed to minimize erosion and deposition of sediment in streams.

k. No new water service connections shall be made to premises connected to sewerage systems which are not in compliance with all applicable water quality standards of the Commission.

l. Nothing herein shall be construed to exempt the applicant from obtaining all necessary permits and/or approvals from other State, Federal or local government agencies having jurisdiction over this project.

m. Upon completion of construction of the approved project, the applicant shall submit a statement to the DRBC, signed by the applicant's engineer or other responsible agent, advising the Commission that the construction has been completed in compliance with the approved plans, giving the final construction cost of the approved project, and the date the project is placed in operation.

n. This approval shall expire three years from date below unless prior thereto the applicant has commenced operation of the subject project or has expended substantial funds (in relation to the cost of the project) in reliance upon this approval.

o. The area served by this project is limited to the service area as described above. Any expansion beyond this area is subject to review in accordance with Section 3.8 of the Compact.

p. In accordance with DRBC Resolution No. 87-6 (Revised), the applicant shall implement to the satisfaction of the DNREC, the systematic program to monitor and control leakage within the water supply system. The program shall at a minimum include: periodic surveys to monitor leakage, enumerate unaccounted-for water, and determine the current status of system infrastructure; recommendations to monitor and control leakage; and a schedule for the implementation of such recommendations. The applicant shall proceed expeditiously to correct leakages and unnecessary usage identified by the program.

q. The applicant shall develop, adopt and implement, to the satisfaction of the DNREC, a continuous program to encourage water conservation in all types of use within the facilities served by this allocation permit. The applicant will report to the DNREC on the actions taken pursuant to this program and the impact of those actions as requested by that agency.

r. The applicant shall develop, adopt and be prepared to implement, to the satisfaction of the DNREC, a drought or other water supply emergency plan.

s. This approval is temporary and will be reviewed five years from the date of approval, and unless renewed, this approval shall expire.

t. The issuance of this withdrawal permit shall not create any private or proprietary rights in the water of the Basin and the Commission reserves the right to amend, alter or rescind any actions taken hereunder in order to insure the proper control, use and management of the water resources of the Basin.

u. If the construction or operation of this project significantly affects or interferes with any domestic or other existing wells, the applicant, at its own cost, shall provide an alternate supply of water or other mitigating measures.

v. For the duration of any drought emergency declared by the Commission, water service or use by the project applicant pursuant to this approval shall be subject to the prohibition of those nonessential uses specified by the DNREC to the extent that they may be applicable, and to any other emergency resolutions or orders adopted hereafter.

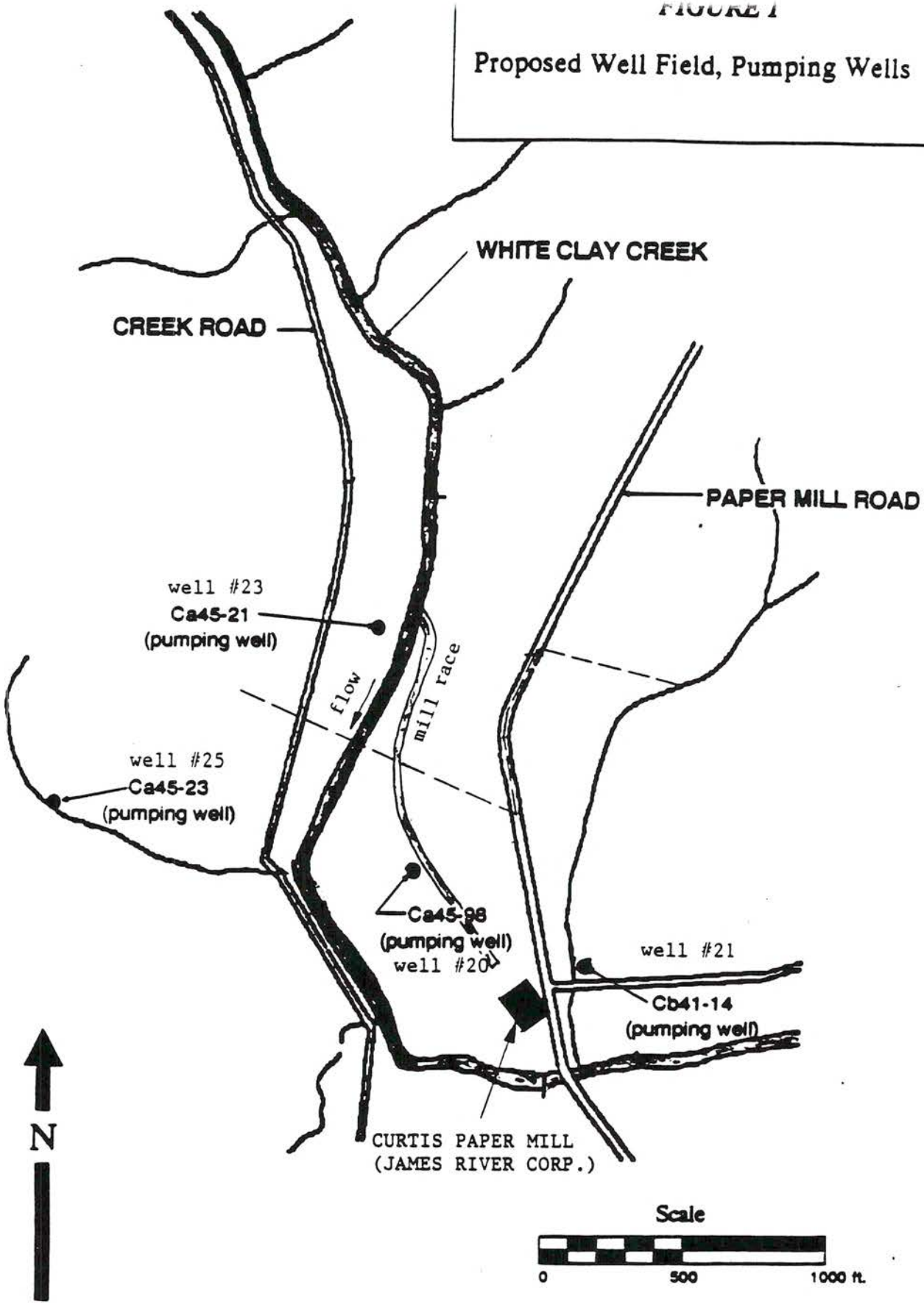
w. No water (or sewer) service connections shall be made to newly constructed premises with plumbing fixtures and fittings that do not comply with water conservation performance standards contained in Resolution No. 88-2 (Revised).

BY THE COMMISSION

DATED: May 22, 1991

FIGURE 1

Proposed Well Field, Pumping Wells



DOCKET NO. D-77-25

DELAWARE RIVER BASIN COMMISSION

The DuPont Country Club - Louviers Golf Course
Increased Surface Water Withdrawal
New Castle County, Delaware

PROCEEDINGS

This is an application referred to the Commission, pursuant to an Administrative Agreement under Sections 2-3.4 (a) and 2-3.7 of the Administrative Manual - Part II, Rules of Practice and Procedure, by the Delaware Department of Natural Resources and Environmental Control on March 28, 1977, for review of a surface water withdrawal project. The application was reviewed for approval under Section 3.8 of the Delaware River Basin Compact. A public hearing on this project was held by the Delaware River Basin Commission on April 27, 1977.

The project was approved by the Delaware Department of Natural Resources and Environmental Control on January 3, 1977, subject to approval by the Delaware River Basin Commission. The New Castle County Planning Department and the Delaware State Historic Preservation Officer have been notified of pending action on this docket and have not expressed objection to approval by the Delaware River Basin Commission.

DESCRIPTION

Purpose.-- The purpose of this project is to provide an increase in surface water withdrawal to irrigate additional areas of the golf course.

Location.-- The Louviers Golf Course is near Milford Crossroads, New Castle County, Delaware. Irrigation water, and service water for the Club House and an engineering test center and office building is withdrawn from White Clay Creek at river mile 70.73 - 10.0 - 12.7.

Service area.-- The increased water withdrawal will be used only to irrigate fairways, tees and greens.

Physical features.

a. Design criteria.-- The 18 hole golf course has 32.7 acres of fairways and .3 acres of tees and greens. The tees, greens and, in some areas, approaches to the greens, have been irrigated with a maximum daily average of 44,000 gallons a day. The applicant ates that this amount of water is inadequate to sustain fairway grass and requests approval withdraw an average of 225,000 gallons a day for all irrigation uses.

b. Facilities.-- The existing manual irrigation facilities were installed in 1955. e applicant proposes to install an automatic irrigation system for optimum water utilization to serve all tees, fairways and greens. Water may be used up to 8 hours a day. A 650 gpm 94 mgd) pump will replace one of unknown capacity. It will be independent of a pump at supplies water to a filtration plant which in turn supplies water to other facilities and is located in the same pump house.

Cost.-- The overall cost of this project is estimated to be $150,000.

FINDINGS

The Delaware Department of Natural Resources and Environmental Control has ncluded the following conditions in its approval of the water withdrawal.

1. The water withdrawal from White Clay Creek shall not exceed 225,000 gallons per day during the months of April through October.

2. During any period of drought or water shortage the water withdrawal from White Clay Creek for the Louviers Golf Course shall cease.

3. If flow conditions prevail that cannot sustain water withdrawal for both the Louviers golf course and the Wilmington Suburban Water Treatment Plant, then the Louviers golf course water withdrawal will be reduced to the point where Wilmington Suburban Water Company can withdraw the quantity of water needed for public supply.

4. Failure to adhere to these provisions will result in revocation of authorization for this diversion.

The project does not conflict with nor adversely affect the Comprehensive Plan. It provides beneficial use of the water resources, is financially and physically feasible, conforms to accepted public policy, and does not adversely influence the present or future use and development of the water resources of the Basin.

There are no properties listed in the National Register of Historic Places on the proposed project site or directly adjacent that will be affected by the action of the Delaware River Basin Commission.

DECISION

The project is approved pursuant to Section 3.8 of the Compact, subject to the following conditions:

a. Approval is subject to all conditions imposed by the Delaware Department of Natural Resources and Environmental Control.

b. The facility shall be available at all times for inspection by the Delaware River Basin Commission.

c. The proposed withdrawal shall be metered and the record of daily withdrawals shall be available to the Delaware River Basin Commission upon request.

d. The project sponsor shall pay for surface water use (in excess of amount shown in Certificate of Entitlement) in accordance with the provisions of Resolution No. 74-6.

e. The area served by this project is limited to the service area as described above. Any expansion beyond this area is subject to review in accordance with Section 3.8 of the Compact.

f. This approval shall expire three years from date below unless prior thereto the sponsor has expended substantial funds (in relation to the cost of the project) in reliance upon this approval.

g. Whenever the flow at U.S.G.S. Gage No. 01478500 near the project site falls below the seven-day once in ten-year low flow of White Clay Creek, 7.3 cfs (4.7 mgd); water shall not be withdrawn for the irrigation of Louviers Golf Course.

BY THE COMMISSION

DATED: April 27, 1977

E. PROPOSED TIDAL CAPTURE STRUCTURE UNITED WATER DELAWARE

UNITED WATER DELAWARE
TIDAL CAPTURE STRUCTURE
NEW CASTLE COUNTY, DELAWARE

PERMIT APPLICATION REPORT

October 1996

Prepared for:

United Water Delaware
2000 First State Boulevard
Wilmington, DE 19804

Prepared by:

Duffield Associates, Inc.
Consultants in the Geosciences
5400 Limestone Road
Wilmington, Delaware 19808

W.O. 2039.CJ.28

I. INTRODUCTION

This permit application is the culmination of a process which started in 1990. In May of that year, the Wilmington Suburban Water Corporation (WSWC), now United Water Delaware (UWD), applied to the Delaware Department of Natural Resources and Environmental Control (DNREC) for an allocation to withdraw 30.0 million gallons per day from White Clay Creek at its Stanton plant. The request was made to comply with a new Delaware River Basin Commission (DRBC) requirement on allocation permits.

On September 12, 1991, the withdrawal application was submitted by DNREC to the DRBC. The DRBC issued its Findings and Decision on August 4, 1993. The principal findings were:

1. At the WSWC Stanton intake, the White Clay Creek has an estimated 7-consecutive-day, 10-year return period low flow (7Q10) of 17.2 mgd.
2. To protect the aquatic environment of White Clay Creek, the withdrawal of water should be prohibited whenever the downstream flow is at the 7Q10 or less.
3. DRBC staff estimated the WSWC's proposed 30.0 mgd withdrawal could only be fully achieved 80 percent of the time with a concurrent withdrawal of 5.0 mgd by the City of Newark at its upstream water treatment plant intake.
4. Without the City of Newark's 5.0 mgd withdrawal, WSWC's Stanton intake has full 30.0 mgd withdrawal capability 84 percent of the time.
5. Between 16 to 20 percent of the time, the full 30.0 mgd withdrawal requested by WSWC cannot be taken.
6. Until storage or a supplemental source can be provided, WSWC should consider the Stanton intake surface water source as unreliable.

The DRBC decision contained the following:

1. Beginning in August 1996, WSWC withdrawals must not cause the stream flow to be less than 17.2 mgd (7Q10) at the Stanton plant intake on White Clay Creek.
2. Whenever the stream flow at the intake is less than 17.2 mgd, no water is to be withdrawn and the entire natural stream flow must be allowed to pass.
3. However, when the water level at the project intake is under the influence of the tide, withdrawal will be allowed, provided the water level in White Clay Creek at the Stanton intake is not below the elevation established for the 7Q10 flow when the tide is not influencing stream flow.

(Note: The DRBC decision also contained several stipulations which would apply during the 1993-96 interim period and are not pertinent to this application.)

Thus, the issue facing WSWC, now UWD, at its Stanton intake on White Clay Creek was how to withdraw up to 30.0 mgd, 365 days per year to meet its customer demand and, at the same time, to allow a minimum 17.2 mgd pass-by flow to comply with DRBC directives. Under historic natural flow conditions, White Clay Creek at Stanton has not been able to provide sufficient flow to enable a 30.0 mgd withdrawal with a pass-by of 17.2 mgd approximately 20 percent of the time.

A supplemental source of fresh water, therefore, would be required to satisfy the combined water supply needs and pass-by requirement. The potential supplemental sources include:

1. Water available in White Clay Creek during flood tide
2. Releases from Hoopes Reservoir
3. In-stream storage
4. Off-stream storage
5. Some combination of the above

II. EVALUATION OF ALTERNATIVE SOLUTIONS

In July 1993, the WSWC retained Duffield Associates of Wilmington, Delaware to conduct a study to determine the optimum solution to meet the water company's withdrawal requirements in conformance with the DRBC stipulations. Duffield Associates identified both intermediate operating procedures to increase water availability for the period 1993-1996, and long-term solutions to meet the water-withdrawal requirements beyond 1996. This permit application deals with the proposed long-term solutions.

The one factor that offered the most feasible solution to the problem is the almost inexhaustible quantity of water available to the UWD Stanton plant in the semi-daily flood tide. Aside from extreme climatic events that might affect the flood-tide water quality, the needed 30.0 mgd withdrawal rate is available for approximately 12 hours per day during high-tide periods. With sufficient storage of flood-tide water, the needed 30 mgd would be available on a continuous basis. This approach proved to be the most feasible and the project proposed below is the recommended solution to the problem. The evaluation of alternative solutions considered can be found in a report appended to the permit application and entitled "Wilmington Suburban Water Corporation Stanton Water Treatment Plant 7Q10 Study" (Appendix A).

The principal conclusion of the report was that a tidal capture system, with 10 million gallons of net storage, would allow WSWC to withdraw 30 mgd on a continuous basis. The only limitation on this conclusion is the potential for elevated chloride levels in the tidal water under extreme climatic conditions.

III. PROJECT DESCRIPTION

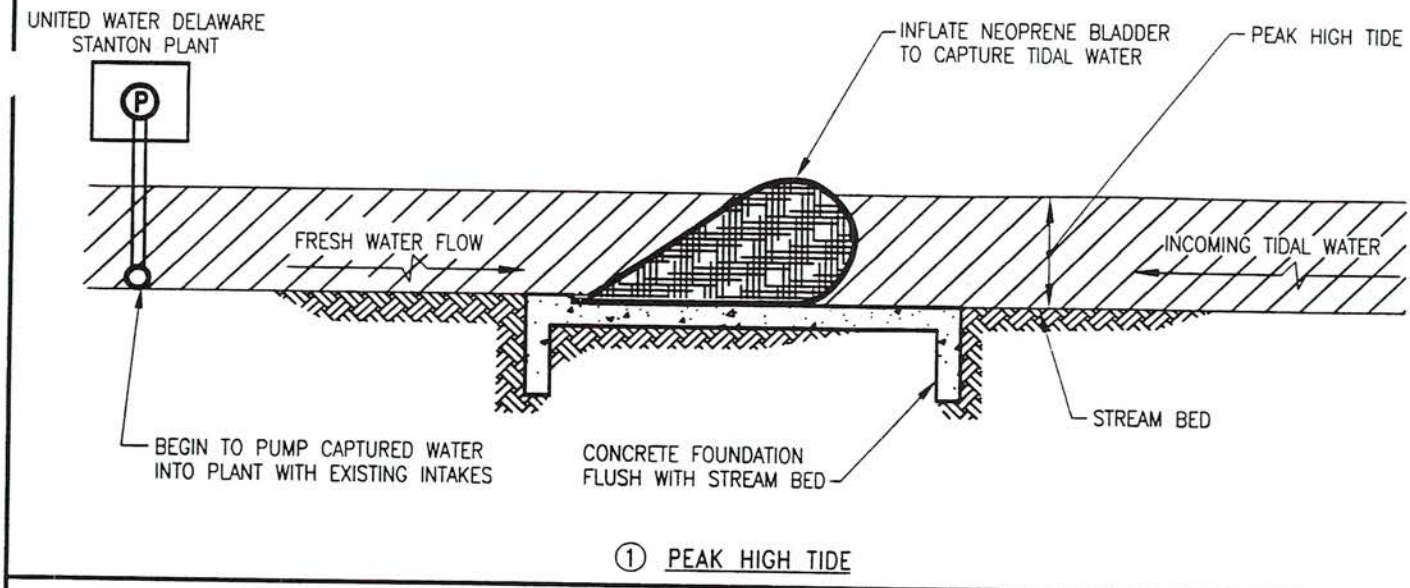
A. GENERAL

The key element in the proposed project is the utilization of an inflatable Tidal-Capture Structure (TCS) across White Clay Creek. The concept is relatively simple: an inflatable structure, constructed of Neoprene, will capture the flood tide by inflation at the point of maximum tidal elevation and remain inflated during the recession of the tide. When the downstream water level reaches the low-tide extreme, the structure will be deflated and the stream channel returned to its natural state (See Figure 1). During the period of inflation, UWD could withdraw impounded water at a rate dependent on the volume of tidal water captured behind the inflated structure. The variables associated with this concept are the high-tide elevation, the location of the tidal-capture structure which determines the volume of water that can be captured, and the natural stream flow in White Clay Creek during operation of the tidal-capture structure. The environmental considerations associated with the proposed project will be discussed as each of the above variables is described.

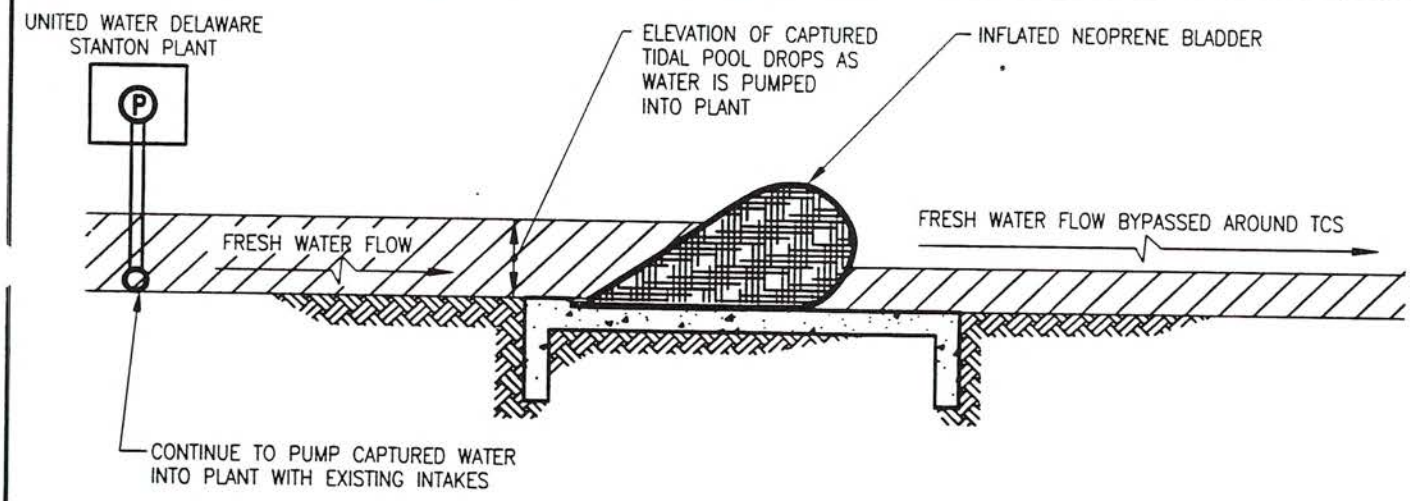
B. TIDAL RANGE

The typical, daily tidal range in the White Clay Creek at the Stanton Plant (on August 7, 1996) is shown in Figure 2. Data from the USGS stream gage at the Stanton Plant indicates that during the low-flow season (typically June through November), the average daily high-high tide elevation is approximately 4.2 feet, and the average low-high tide elevation is approximately 3.6 feet. Normal (non-storm related) high-tide elevations at the plant can range from approximately 2.5 feet to 5.5 feet. Thus, the high tide elevation is an independent variable which affects the volume of tidal water captured for any given flood tide.

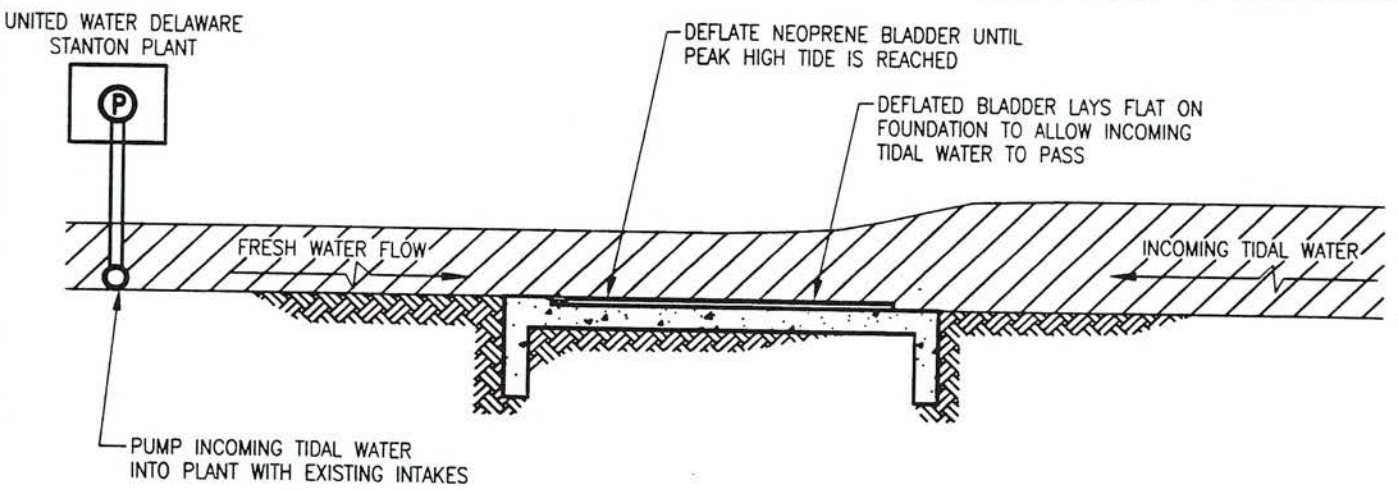
In between the two daily high tides, the White Clay Creek at Stanton experiences the "absence of tide," rather than a true low tide. During the absence of tide periods, the water surface elevation in the stream is determined by the rate of fresh water flow in the creek. Due to differences in the stream bed elevation between the Stanton Plant and the TCS site, fresh water flow elevations are lower at the TCS site than at the plant. High-tide elevations, however, are slightly higher at the TCS site than at the plant, due to the tidal gradient from the Delaware River.



① PEAK HIGH TIDE



② END OF HIGH TIDE PERIOD



③ BEGINNING OF NEXT HIGH TIDE PERIOD

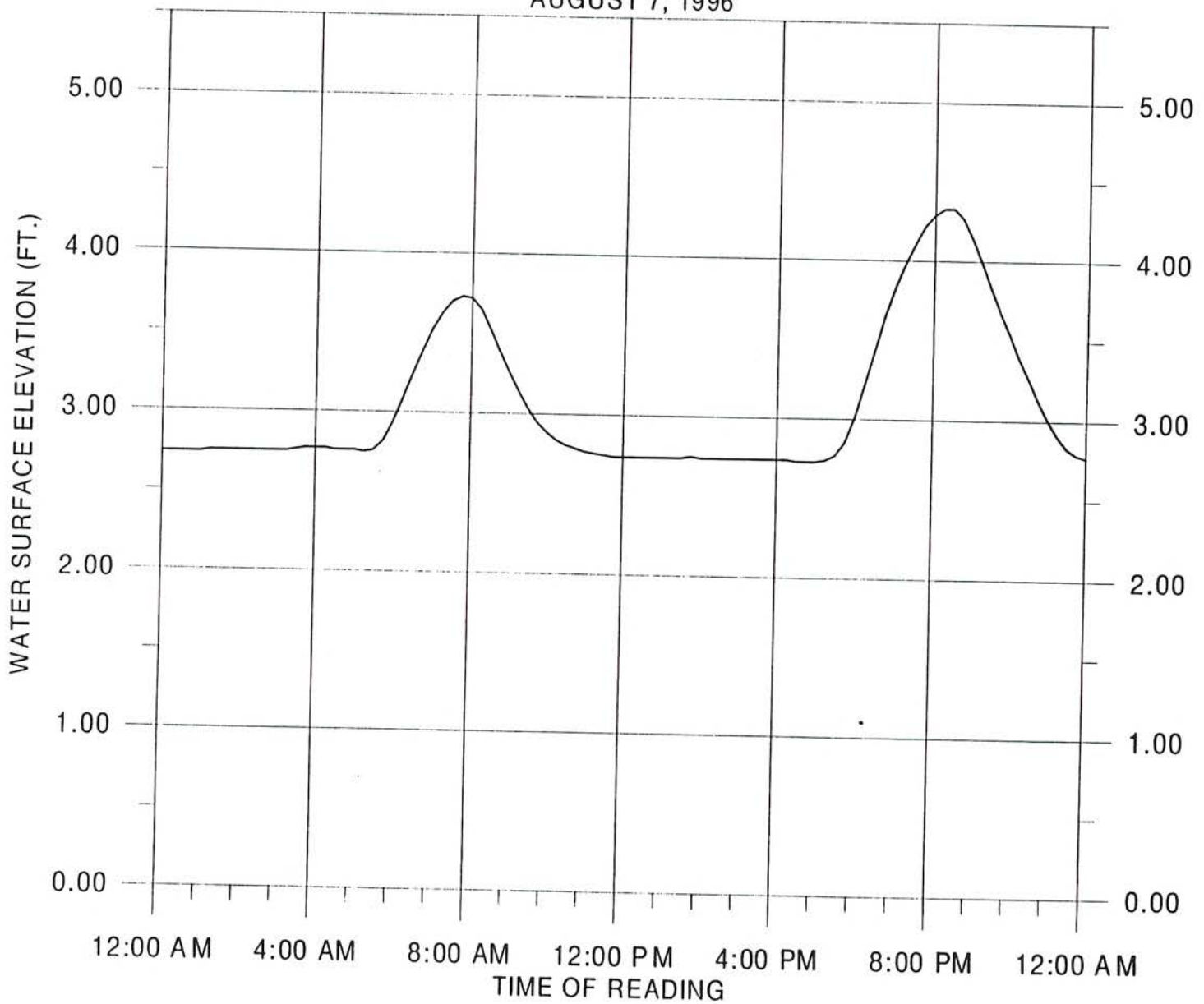
W.O. 2039.CJ.28
SEPTEMBER 1996
DUFFIELD ASSOCIATES, INC.

CONCEPTUAL CROSS SECTIONS

NOT TO SCALE

FIGURE 1

FIGURE 2
DAILY TIDAL CYCLE AT UNITED WATER DELAWARE STANTON PLANT
AUGUST 7, 1996



NOTE: DATA IS FROM THE U.S.G.S. STREAM GAGE ON WHITE CLAY CREEK AT STANTON (STATION NO. 1480025).

W.O. 2039.CJ
DUFFIELD ASSOCIATES, INC
SEPTEMBER 1996

In order to record stream and tidal elevations at the TCS site, a pressure transducer was installed in White Clay Creek at the site in August 1996. Data acquired at this monitoring station will be correlated with data from the USGS gage at the plant and used in the final design of the TCS. The typical daily tidal cycle at the TCS site (for August 22, 1996) is shown on Figure 3. Data acquired to date from the TCS site is contained in Appendix B of this report.

From an environmental standpoint, the project will not increase the elevation of the tide upstream at any time during operation. The structure simply captures the water that the high tide supplies without any backwater effect.

The TCS operating cycle does reduce the tidal elevation rate of recession by spreading the time of recession over approximately 8.5 hours versus nature's approximately 4.5 hours (at the average high tide elevation of 4.0).

C. LOCATION

The goal of capturing a net of 10 mg of fresh tidal water behind the structure is most dependent on the location of the site on White Clay Creek. The farther downstream the TCS is located, the greater the volume of water that can be stored. The reach of the creek potentially available for the structure extends from the Stanton water plant to the area somewhat upstream of Churchman's Marsh. Section IV of this report discusses site selection for the TCS.

D. NATURAL STREAM FLOW

The drainage area of the White Clay Creek between the Stanton Plant and the TCS site, a distance of about 2,000 feet as measured along the creek, is approximately 0.14 square miles. This represents an increase of less than 0.01 percent when added to the drainage area at the USGS gage at the plant, which is 157.8 square miles. Since this increase in drainage area is insignificant, stream flow data recorded at the plant is still valid at the TCS site.

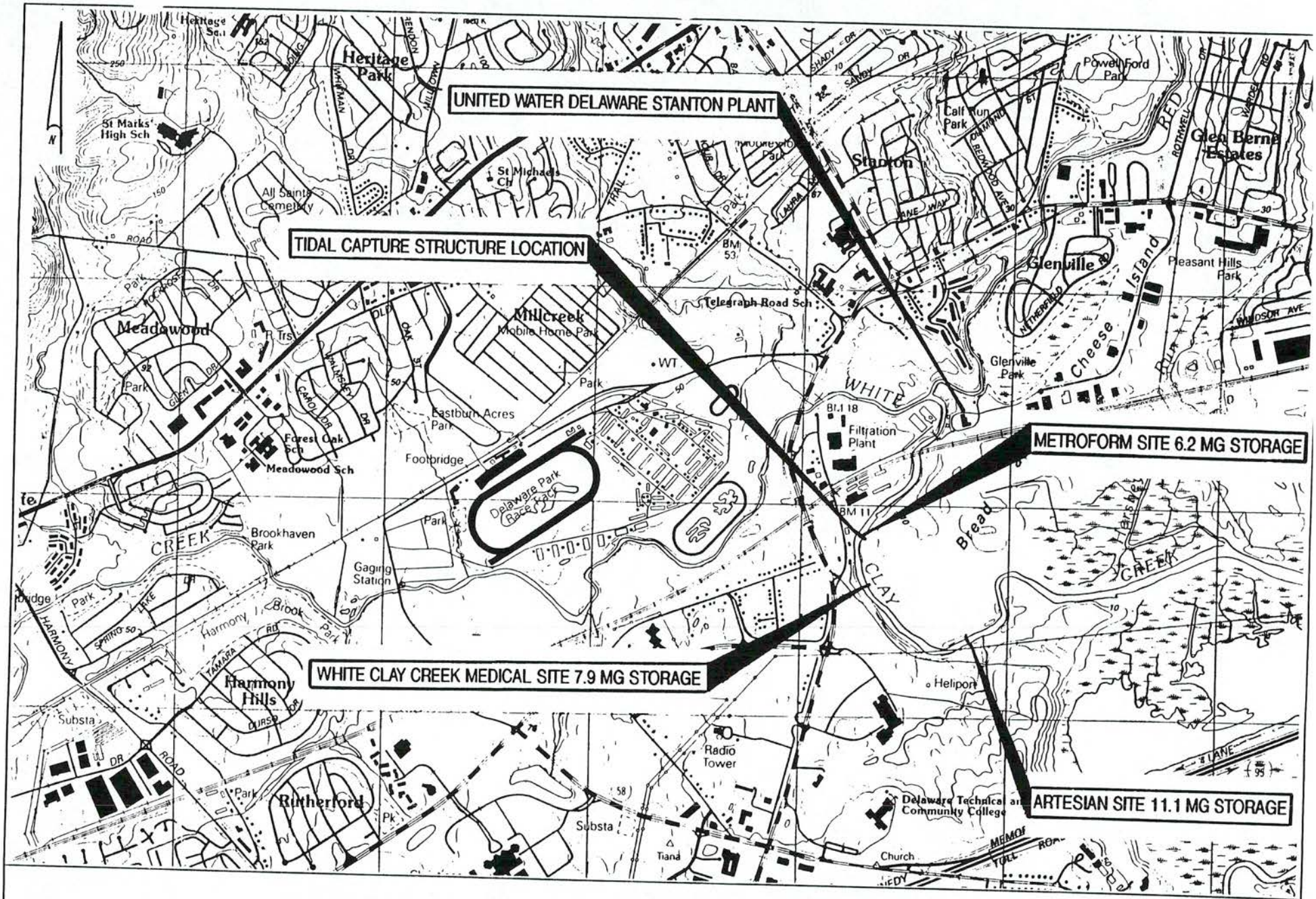
The Stanton Plant water intake receives fresh water from the White and Red Clay drainage basins in an approximately 65/35 ratio. The combined mean discharge of those creeks at Stanton is about 205 cfs or 132 mgd. However, the instantaneous historic low flow at Stanton is about 9 cfs (5.8 mgd) or about 5 percent of the annual mean flow.

Based on historic data, the critical flow period for this project is between June and November. Typically, the mean flow in White Clay Creek drops below 200 cfs in June and does not rise above 200 cfs until December. Historically, October has

been the most critical month with a mean monthly flow of only 155 cfs or 74 mgd. The mean flow data can be misleading since there is significant variability with time from the mean. In the case of the White and Red Clay Creeks at Stanton, the 7Q10 requirement of 17.2 mgd, plus the UWD withdrawal requirements of 30 mgd (total of 47.2 mgd), is exceeded only 84 percent of the time. In other words, the total discharge requirements are not met 16 percent of the time or an average of 58 days per year. It is this fact which led UWD to seek the supplemental storage needed to bridge the gap between natural stream flow and its withdrawal requirements.

In October 1993, the 7Q10 stream flow elevation at the Stanton plant was estimated to be 2.39 feet, based on USGS in-stream measurements taken during the absence of tide (see Appendix A). In September 1994, the 7Q10 flow elevation at the plant was estimated to be 2.03 feet, again based on USGS in-stream measurements (see Appendix C). At the reference cross section used by the USGS for the in-stream measurements, the low point in the stream bed is approximately elevation 1.2, whereas at the TCS site, the low point is approximately 0.25, or a difference of 0.95 feet as compared with the plant. This sloping stream bed results in lower fresh water flow elevations at the TCS site, as compared with the plant. Since specific 7Q10 elevation measurements have not been made at the TCS site, an elevation of 1.0 has been assumed to represent the 7Q10 flow elevation at the TCS site. This assumes that under low-flow conditions, the water surface profile is essentially parallel to the stream bed.

With respect to the pass-by requirement of 7Q10 or the natural stream flow, whichever is less, the proposed project will provide for a controlled discharge of freshwater from storage during operation of the tidal capture structure. This controlled release will be accomplished with a pass-by sluice at one end of structure with multiple gates to regulate the releases. The releases will maintain the environmental balance between the fresh water discharge from upstream with the tidal flow from downstream. Moreover, since the structure will be deflated for two distinct periods daily, the water flow in the stream channel will be completely unaffected during that time. Even with maximum utilization of the tidal capture structure during extreme low-flow conditions, fish passage and other natural phenomena will be completely unimpeded for two periods every 24 hours during the days that the TCS is operational.



NOTE: THIS LOCATION MAP IS ADAPTED FROM THE U.S.G.S. TOPOGRAPHIC MAP, 7.5 MINUTE SERIES, FOR NEWARK EAST, DEL. (1993).

W.O. 2039.CJ.28
SEPTEMBER 1996
DUFFIELD ASSOCIATES, INC.

TIDAL CAPTURE STRUCTURE SITE
SCALE: 1" = 2000'

FIGURE 4