Thermal Variance Request for the Point Pleasant Diversion NPDES Permit PA-0052221

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RMC ENVIRONMENTAL SERVICES

Opening Day of Trout Season 1990 on the East Branch at Lenape Park in Sellersville

EXECUTIVE SUMMARY

The NPDES Permit PA-0052221 issued to Philadelphia Electric Company (PECo) for the water diversion discharge to the East Branch Perkiomen Creek from Bradshaw Reservoir (a component of the Point Pleasant Diversion Project) presently contains temperature limits which PECo is seeking to have eliminated from the permit. This document is a 316(a) demonstration in support of the request for removal of temperature limits from the NPDES permit, and it is in accordance with a Study Plan approved by the Pennsylvania Department of Environmental Resources (PA DER). The objective of this demonstration is to prove the acceptability of the diversion without cooling and, therefore, the elimination of all temperature limits from the NPDES permit.

An extensive record of water quality and aquatic ecology data is available for the East Branch and forms the basis of this demonstration. Lack of an adequate temperature record for the East Branch required an intensive temperature and meteorological data collection effort during summer 1992 to support a thermal modelling study. The model was required to provide detailed temperature predictions for the East Branch under the two agreed upon pre/post-diversion Study Cases which are evaluated in this document. Study Case I is the pre-diversion, unaugmented flow condition; Study Case II is post-diversion flow augmentation but without any cooling.

Modelled temperatures for the two Study Cases are evaluated with respect to certain Representative Important Species (RIS) of fish. The RIS are three warmwater resident species (smallmouth bass, white sucker, and spotfin shiner) and two stocked trout species (rainbow trout and brown trout). This demonstration evaluates the RIS in terms of observed absence of prior appreciable harm and future continued protection based on predicted (modelled) thermal conditions both with and without diversion discharge to the stream.

The thermal modelling study consisted of two parts. First, continuous measurements of temperature made at twelve locations in the East Branch during summer 1992 were used with hydrological and meteorological data from the same period to calibrate the thermal model. Second, the calibrated model was used to simulate East Branch temperatures for the period October 1983 through September 1992.

This demonstration utilizes considerable background data which exist concerning diversion operations since 1989; ongoing aquatic ecological sampling programs for water quality, benthic macroinvertebrates, and fishes since the early 1980's; stream erosion monitoring; and creel surveys during the trout stocked fishery since 1987.

Under the Study Plan approved by PA DER, certain decision criteria will be applied in the analysis of the request for a thermal variance. This demonstration is to be judged successful if it shows that there will be continued, substantially similar reproductive success and growth of the warmwater RIS for Study Case II as compared to Study Case I. Three decision criteria apply to the trout RIS: continuation of the successful trout stocked fishery, lack of exclusion from an unacceptably large area of the stream, and continued survival and harvest of the stocked trout under Study Case II (diversion without cooling) stream temperature conditions.

The temperature model shows that diurnal amplitudes and hourly rates of change of the temperatures at all diversion flows are much smaller than without diversion for the upper end of the East Branch study area and approach the no diversion case at the mid to lower end of the study area. This indicates that the water diversion will improve the overall thermal regime and will increase the fish habitat of the stream. The maxima of the maximum temperatures are at zero diversion flow for the upper end of the East Branch study area. At the lower end of the study area, the maxima are approximately equal to the maxima at zero diversion flow. Mean daily temperatures with diversion flows are higher than those without the diversion at the upper end of the study area and become almost the same as the non-diversion temperatures in about 2.5 to 5 km downstream due to natural surface heat exchange and tributary inflows.

The modelling results were evaluated with respect to suitable temperatures and time periods for important life history functions (reproductive success, growth, and adult survival) of the warmwater RIS for both Study Case conditions. Diversion has no potential to alter reproductive success and growth of the RIS fishes. Each of the three warmwater RIS fishes maintained successful reproducing populations in the East Branch during the pre-diversion period and continued to do so in the flow augmented period. Successful populations of these RIS also inhabit the Delaware River in the vicinity of Point Pleasant which shows that the Delaware River thermal regime is suitable for long-term survival of these RIS. Temperatures at the upper range of tolerance for the several life stages of these species are not attained in the pre-diversion case and will not be during diversion operation. There is no thermal enhancement of the receiving stream such that Upper Incipient Lethal Temperatures are experienced and no threat of cold-shock due to emergency curtailment of diversion flow.

None of the temperature changes predicted due to operation of the diversion will preclude the continued success of the established spring trout stocked fishery for rainbow and brown trout. Stream habitat is enhanced due to the overall beneficial effects of increased stream flow in the unimpounded sections of the trout stocking area.

The predicted temperature conditions will not exclude trout from unacceptably large portions of the trout fishing area during the period when trout are stocked and have a high probability of actually being in the stream in sufficient numbers to sustain a successful fishery.

The survival and harvest of trout in the stocked trout fishing area will not be materially affected by the temperature changes experienced at any of the diversion flows modelled. The onset of upper incipient lethal temperatures occurs well after substantially all trout have been harvested from the stream.

In summary, the temperature limitations can be removed from the NPDES permit without significant impact to the stream. This 316(a) demonstration successfully proves that the diversion without temperature limitation meets the decision criteria for both the warmwater and trout RIS. The diversion will improve the stream habitat and enhance the aquatic community.

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1.0 INTRODUCTION/OVERVIEW

The report which follows is a demonstration in support of a thermal variance request for NPDES Permit PA-0052221, referred to as a 316(a) demonstration. The new studies conducted in support of this demonstration and this report are in accordance with a Study Plan submitted to and approved by the Pennsylvania Department of Environmental Resources (PA DER), which agency issued the NPDES permit and has regulatory authority to modify permit limits. The format of this report follows the organization of the Study Plan which is included in Section 10.

The first section of this report describes the project, objective of the demonstration, and data availability and limitations. Section 2 states the objectives of the demonstration while Section 3 describes the thermal modelling study needed to fully describe the thermal conditions of the stream under the two study cases evaluated in this demonstration: Study Case I, no diversion and no cooling; Study Case II, diversion flow without cooling. The fourth section provides a review of existing background information on diversion operation and ongoing water quality and biological sampling programs. Section 5 describes the decision criteria toward which this document is focused. The temperature modelling study is described in Section 6 while Section 7 presents the results of the modelling study and evaluates the Resident Important Species (RIS) in terms of Study Case I and II stream temperature conditions. The final text section of this document is the evaluation of decision criteria in Section 8.

1.1 Description of the Point Pleasant Diversion Project

The Point Pleasant Diversion Project, located in Bucks County, can deliver up to 71 cubic feet per second (cfs) of Delaware River water to Philadelphia Electric Company's (PECo) Limerick Generating Station (LGS) near Pottstown, Pennsylvania (Figure 1.1-1). The Diversion consists of an intake and pumphouse on the Delaware River at Point Pleasant, a pipeline to Bradshaw Reservoir, a pumphouse and a pipeline to a discharge structure built in the headwaters of the East Branch Perkiomen Creek (East Branch), the open channels of the East Branch and part of the Perkiomen Creek, an intake and pumphouse on the Perkiomen Creek at Graterford, and a pipeline to LGS.

Provisions have been made to disinfect water diverted to the East Branch as needed to comply with a fecal coliform limitation in the NPDES permit, and to cool the water as required by permit temperature criterion. These actions are accomplished by bacteriostatic ozone generator and water chiller installed in the Water Processing Facility (WPF) located near Bradshaw Reservoir.

Operation of the Point Pleasant Diversion began in August 1989 with a system testing program containing staged increases in rate of water discharge to the East Branch to the maximum of 71 cfs. Rate of discharge to the East Branch is regulated by Water Obstruction and Encroachment Permit E09-077A issued by PA DER, which provides the following conditions:

1) All changes in the rate of diversion must be accomplished gradually (which minimizes scour and flushing as diversion is increased, and rapid dewatering and stranding of fish as diversion is reduced);

2) Diversion must cease when flow in the East Branch at the United States Geological Survey (USGS) gaging station at Bucks Road downstream of the discharge point is ≥ 125 cfs, a trigger level set to prevent flood aggravation; and,

3) During the period of the year when the diversion is normally needed at LGS, a 27 cfs minimum flow must be maintained at Bucks Road, while 10 cfs must be maintained during the remainder of the year.

1.2 Permit History - Permit Temperature Limits

On 14 July 1988 the PA DER, Bureau of Water Quality Management, issued NPDES Permit PA-0052221 to Philadelphia Electric Company for the discharge from Bradshaw Reservoir to the East Branch Perkiomen Creek. Discharge to the East Branch commenced on 2 August 1989 upon receipt of Permit No. 0989204 from PA DER concerning the storage of hydrogen peroxide in trailers at Bradshaw Reservoir for addition to the discharge as a bactericide.

Temperature permit conditions on the discharge to the East Branch are stated in the NPDES permit, Part C - Other Requirements B, as follows:

The following requirements apply with respect to the thermal impact of the discharge from Outfall 001 upon the East Branch of Perkiomen Creek.

(1) For the period 15 February through 31 July, the discharge shall not cause a rise of stream temperature when the ambient stream temperature is 74 F or above; nor cause more than a 5 F rise above ambient temperature until stream temperature reaches 74 F; nor cause a change of stream temperature by more than 2 F during any one-hour period.

(2) For the period 1 August through 14 February, the discharge shall not cause a rise of stream temperature when the ambient stream temperature is 87 F or above; nor cause more than a 5 F rise above ambient temperature until stream temperature reaches 87 F; nor cause a change of stream temperature by more than 2 F during any one-hour period.

In late September 1989, ground was broken for the construction of the WPF which is located downstream of the Bradshaw Reservoir. The WPF is equipped with chillers and cooling towers to adjust the temperature of the diversion water to meet the permit limits. The WPF is also equipped with ozone generating equipment for bacterial control. Starting in the summer of 1990, the WPF has operated to modify the discharge to meet the limits of the NPDES permit.

1.3 Alternative Temperature Limit Requested

This document presents and justifies a request for the elimination of temperature limits for the discharge of Delaware River water to the East Branch. This request for a thermal variance is permitted under §316(a) of the Federal Water Pollution Control Act, 33 USC §1251-1387 if

temperature limits imposed on a discharge by the NPDES permit are more restrictive than necessary to protect a balanced, indigenous aquatic community.

1.3.1 316(a) Study Plan Developed and Approved

PECo developed and submitted to PA DER a Study Plan in draft form entitled "Draft Study Plan for Thermal Variance Request in Regards to the Point Pleasant Diversion NPDES Permit PA-0052221." A copy of the final Study Plan which was approved by PA DER via letter (Ulanoski to Beck 26 January 1993) is included as Appendix A (Section 10).

1.4 Existing Biological and Thermal Data Availability

PECo conducted extensive studies of the Delaware River and East Branch prior to construction, during construction, and after commencement of operation of the Point Pleasant Diversion. Water quality studies of the Delaware River and water quality and ecological studies of the East Branch have been conducted since the early 1970's, although for the most part the applicable comprehensive and recent data since 1980 are used in this report (see Section 4.4). Discharge measurements of the East Branch were available from the USGS gage located at Bucks Road. Temperature data for the East Branch and Delaware River were available only as point-in-time measurements taken coincident with biological and water quality collections. Existing biological and water quality data are presented and summarized in a series of reports required by the NPDES permit and submitted previously to PA DER. Section 4.4 of this report presents a list of these reports and summaries of information appropriate for this 316(a) demonstration.

1.5 Temperature Data Limitations and Need for a Modelling Study

Because a continuous record of temperatures for the East Branch and Delaware was not available as existing information, PECo undertook an intensive temperature and meteorological data collection effort during summer 1992 to support a thermal modelling study. The modelling study was intended to provide detailed temperature predictions for the East Branch under no diversion conditions and for several flow conditions during diversion operation. The 1992 temperature and meteorological monitoring and the thermal modelling study are described fully in Sections 3.2 and 6.0 of this document, respectively.

1.6 Demonstration Type

This is a combination Type I and Type II 316(a) demonstration as provided for in the approved Study Plan. A Type I demonstration deals with Absence of Prior Appreciable Harm and utilizes actual results obtained by studying the effects of an operating thermal discharge. A Type II demonstration is predictive and represents the permittee's best estimate of what will happen as a result of discharge operation. It is primarily used in instances where there has been insufficient opportunity to observe the effects of the discharge. Representative Important Species (RIS) are utilized in both types of demonstrations where it is inappropriate or unjustifiable to

evaluate discharge effects on all species and where protection of the RIS will reasonally assure protection of other fishes in the stream. The RIS approved by PA DER for evaluation in this demonstration are representative of the community of fishes in the stream in terms of their thermal sensitivity, biological requirements, recreational value, and importance in the food chain. This 316(a) demonstration will present and summarize existing biological, water quality, and hydrology data in combination with 1992 temperature observations and the 1992 temperature modelling study to provide a thorough, comprehensive analysis of the thermal effects of the diversion on the East Branch as specified in the Study Plan.

1.6.1 Type I - Absence of Prior Appreciable Harm

In that the Point Pleasant Diversion has operated since August of 1989, it is appropriate to consider the thermal effects of operation on the East Branch aquatic community. Since August 1989, the diversion has operated without cooling except for the periods from about mid-June through 31 July in 1990 and 1992 and from mid-May through 31 July in 1991. Therefore, the aquatic community has experienced the diversion thermal conditions for over 3 years with the exception of limited cooling noted above. Sufficient information exists to assess absence of prior appreciable harm to the East Branch for operation of the Diversion during winter, early spring, late summer, and fall from August 1989 to the present. Appreciable harm is defined in the 316(a) Guidance Manual as:

- Substantial increase in abundance or distribution of any nuisance species.
- Substantial decrease of formerly indigenous species, other than nuisance species.
- Changes in community structure to resemble a simpler successional stage.
- Unaesthetic appearance or odor.
- Elimination of an established or potential economic or recreational use.
- Reduction of the successful completion of life cycles of indigenous species.
- Substantial reduction of community heterogeneity.

1.6.2 Type II - Protection of Representative Important Species (RIS)

Three warmwater fish species and two trouts were selected as representative important species for the East Branch. Smallmouth bass, white sucker, and spotfin shiner were selected for evaluation of life cycle thermal tolerance because they are representative of the thermal requirement of most of the other year-round resident fishes. In addition, smallmouth bass is recreationally valuable in the sport fishery. White sucker, although less attractive recreationally, is widely distributed in the East Branch and representative of bottom dwelling fishes. Spotfin shiner is representative of minnows which serve as a forage base for larger piscivorous fishes and is abundant in the East Branch. Brown trout and rainbow trout were selected for evaluation of adult growth and survival. Both are seasonal residents of the stream and are stocked in spring to support a put-and-take trout fishery.

This demonstration evaluates these RIS in terms of observed absence of prior appreciable harm and future continued protection based on predicted (modeled) thermal conditions both with and without diversion discharge to the stream.

1.7 Major Statutory and Regulatory References

The major statutory and regulatory references relating to this thermal variance request are section 316(a) of the Federal Water Pollution Control Act, 33 U.S.C. §§1251-1387, 1326 (a), and section 97.82 (a) (2) of PA DER's regulations, 25 PA Code §97.82 (a) (2), adopted pursuant to authority granted to PA DER under Pennsylvania's Clean Streams Law, PA State Ann. tit. 35, §§691.1-691.701, and requiring consideration by PA DER of a section 316(a) demonstration. Other relevant references include 25 PA Code §93.7, providing the specific water quality criteria for which a variance is being requested, and 40 C.F.R. §125.72, the federal regulations interpreting section 316(a).

Additionally, the Draft 316(a) Technical Guidance Manual, issued by the United States Fish and Wildlife Service - National Power Plant Team on 11 December 1975, was used as the reference for content and organization.

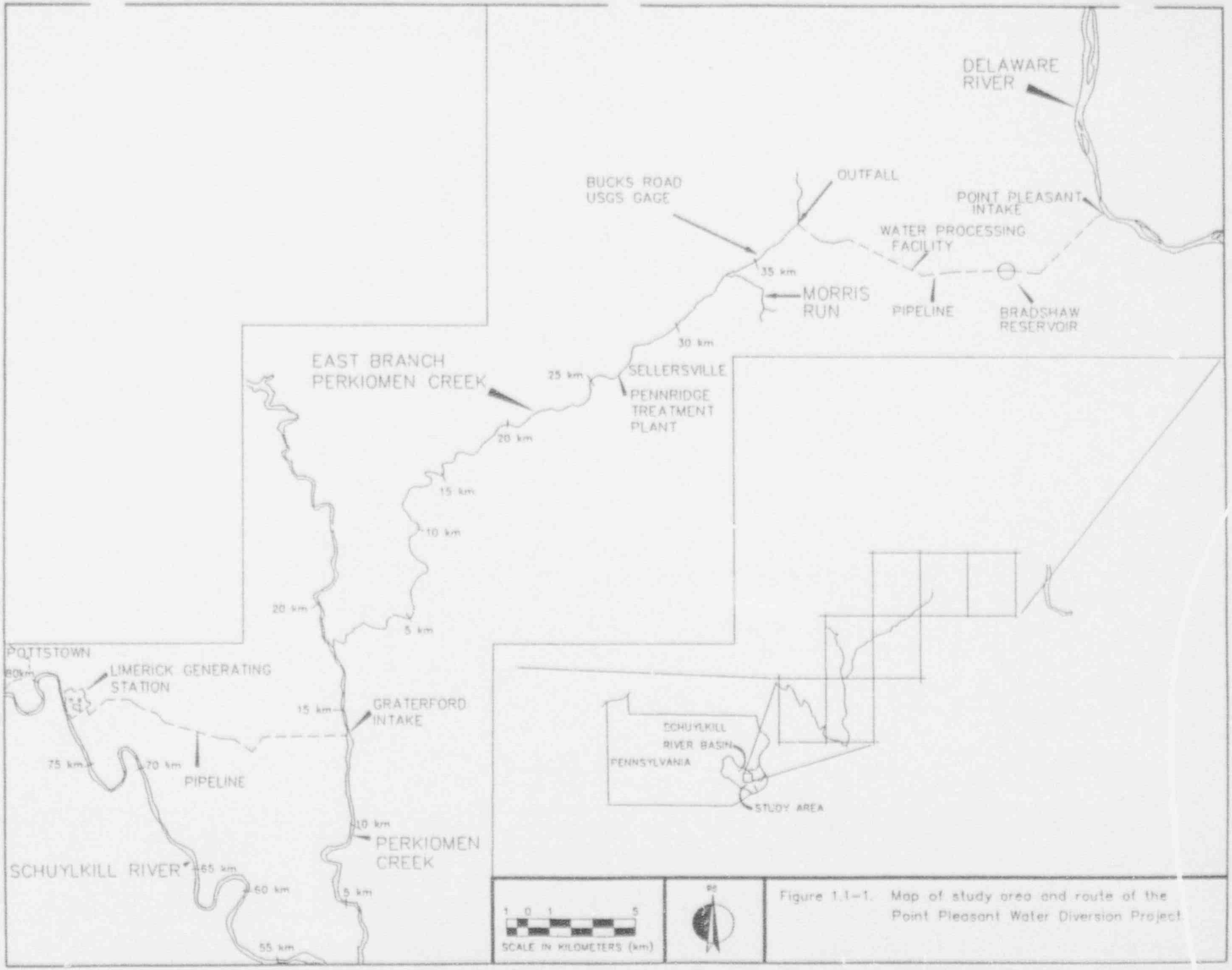

Figure 1.1-1. Map of study area and route of the Point Pleasant Water Diversion Project

2.0 OBJECTIVES OF THE THERMAL VARIANCE REQUEST

This thermal variance request, 316(a) demonstration, will describe and evaluate the thermal regime of the East Branch for the previously existing ambient conditions (Study Case I, no diversion discharge) and for operation of the diversion without any cooling by the WPF (Study Case II). The objective of this effort is to demonstrate the acceptability of diversion without cooling and, therefore, support the elimination of all temperature limits from the NPDES permit applicable to this discharge.

3.0 METHODS

3.1 Conditions to be Evaluated

Under the agreement reached between PECo and PA DER, two study cases were to be evaluated in this 316(a) demonstration. Study Case I is the naturally occurring thermal regime of the East Branch prior to Diversion operation. In other words, no Diversion and, obviously, no cooling by the WPF. Study Case II is the thermal regime of the East Branch with the Diversion in operation, but without the cooling needed to comply with the present NPDES permit temperature limits.

3.2 Thermal Modelling Study

Although instantaneous temperature measurements made at approximately 2-week intervals for over 10 years are available for the East Branch, this database was insufficient to evaluate either study case. Therefore, J.E. Edinger Associates, Inc. (JEEAI), Wayne, Pennsylvania, was contracted to conduct a thermal modelling study of the upper East Branch.

The thermal modelling study consisted of two parts. First, continuous measurements of temperature made at twelve locations in the East Branch during summer 1992 were used with hydrological and meteorological data from the same period to calibrate the thermal model. Second, the calibrated model was used to simulate East Branch temperatures for the period 1983-92. The modelling study is described in greater detail in Section 6.0 of this document.

The detailed temperature measurements of the East Branch and meteorological data for the study area were collected by Advanced Aquatic Technology Associates (AATA), Fort Collins, Colorado and RMC. AATA established a temperature monitoring network employing replicated continuous recording thermometer/data loggers at twelve locations (Table 3.2-1 and Figure 3.2-1). In addition, recording meteorological stations were established at the division outfall and at the Pennridge Wastewater Treatment Plant in Sellersville. Data were collected 1 June through 30 September 1992 and are reported in AATA (1992a).

3.3 Existing Biological, Water Quality, and Hydrology Studies

Study methods for all existing biological, water quality, and hydrologic data used in this report are described in the Pre-diversion and Post-diversion Aquatic Biological Assessment Reports (PECo 1989, 1990, and 1991) and are summarized where appropriate in Sections 4.0 and 7.0 of this report.

Table 3.2-1. Stream temperature and meteorological monitoring stations, 1 June through 30 September 1992. Table is reproduced from AATA (1992a).

Station Location			Equipment Installed
T-1	-	Upstream of Discharge	C, W, A, R, B, E
T-2	-	at Outfall Structure	C, W, A, R, RH, WS, WD, P, S, E
T-3	-	Bucks Road Gage	C, W, A, R, B, E
T-4	-	Route 313 Bridge	C, W, A, R, B, E
T-5	-	Branch Road Bridge	C, W, A, R, B, E
T-6	-	Callowhill Road Bridge	C, W, A, R, B, E
T-7	-	Walnut Street Bridge	C, W, A, R, B, E
T-8	-	Sellersville Pool	C, W, A, R, B, E
T-9	-	Main Street Bridge	C, W, A, R, B, E
T-10	-	Pennridge WWTP	C, A, RH, WS, WD, P, S, E
T-11	-	Morris Run-Quarry Road	C, W, A, R, B, E
T-12	-	Morris Run-Blue School Road	C, W, A, R, B, D, E

C = Campbell Scientific Datalogger
WS = 014A Wind Speed Sensor
A = Campbell 107 Air Temperature Probe
WD = 024A Wind Direction Sensor
W = Campbell 107B Water Temperature Probe
R = Ryan TempMentor
S = MSX10R Solar Panel
B = Battery Pack
P = LI200S Pyranometer
E = CR10 Enclosure
D = Druck Pressure Transducer

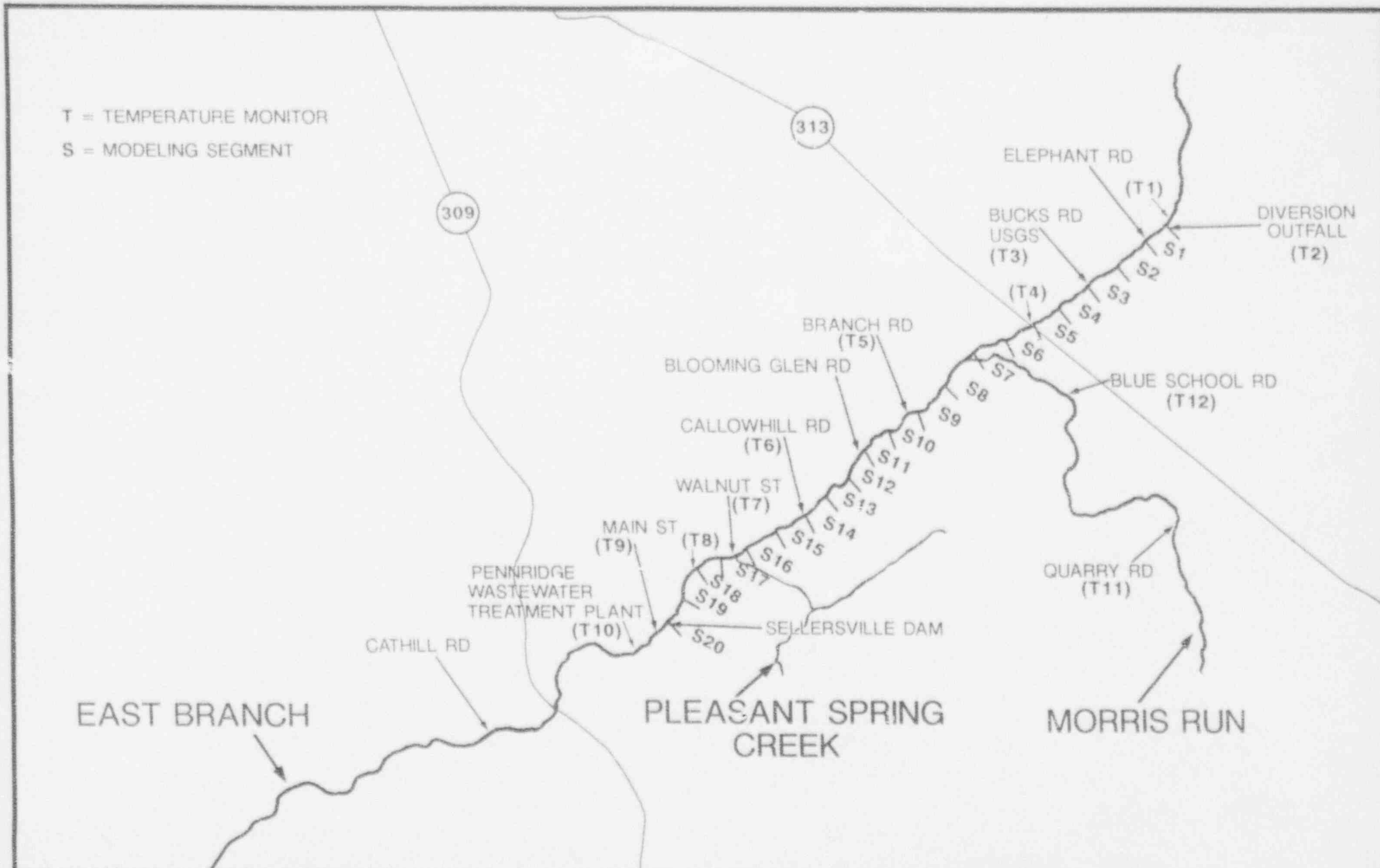

FIGURE 3.2-1 **STREAM TEMPERATURE MONITOR LOCATIONS AND THERMAL MODELLING SEGMENTS**	**SCALE** 1 0 1 MILES	**RMC** ENVIRONMENTAL SERVICES	**SPRING CITY, PA** **(215)948-4700**

4.0 BACKGROUND INFORMATION

4.1 Mixing Zone Discussion/Overview

The concept of mixing zone does not apply to the Diversion discharge to the East Branch. The volume and rate of flow for the discharge is large compared to East Branch flow in the headwaters (mean annual flow of 6 cfs for water years 1984-1988), such that during diversion operation, even at its minimum flow of 10 cfs, the stream is essentially fully mixed immediately below the point of discharge. For the purposes of this 316(a) demonstration, it is assumed that there is no mixing zone and that the East Branch is fully mixed at the point of discharge.

4.2 Diversion Flow Compliance Record

The Point Pleasant Diversion Project consists of two pumping stations. The Point Pleasant Pumping Station takes water from the Delaware River (elevation of approximately 80 feet) and pumps it to Bradshaw Reservoir (elevation of approximately 420 feet). The portion of the Bradshaw Reservoir capacity that is allocated for drinking water supply flows by gravity from Bradshaw Reservoir to the North Branch Neshaminy Creek. The portion of the Bradshaw Reservoir capacity that is conveyed by the East Branch Transmission Main (EBTM) to the East Branch must be pumped by units in Bradshaw Reservoir Pump House. The water must be forced over a near-by ridge (elevation of approximately 520 feet). Beyond the ridge crest, flow is by gravity in the EBTM to the WPF during the WPF operating season, or directly to the discharge structure on the East Branch. Loss of power or mechanical failure at either the Point Pleasant or Bradshaw Reservoir pumping stations can reduce or curtail discharge via the EBTM.

Overall the diversion has a very good compliance record, although both Bradshaw and Point Pleasant pumping stations experienced some start-up loss of function relating to the pumps and/or associated control circuitry in 1989. During the spring of 1990, the Point Pleasant facility experienced mechanical difficulties which resulted in reduced pumpage to Bradshaw and to the EBTM. Table 4.2-1 is a summary of the mechanical/control difficulties experienced by the water transfer system. Table 4.2-1 does not reflect any reductions or stoppage of flows to the EBTM in response to high natural flow (> 125 cfs) in the East Branch.

A more detailed overview of pump operations, including high flow events and short term outages is presented in Section 4.5. Tables 4.5-6 through 4.5-9 illustrate that after the shakedown period of August 1989 through late April 1990 during which both the Bradshaw and Point Pleasant systems were "de-bugged," the system has proven to be a reliable source of diversion water. Since the discharge is not heated, short term loss of flow will not critically impact the biota of the East Branch, including the RIS, because there is no rapid drop in temperature (cold shock) which has occurred at conventional cooling water discharges.

4.3 QA/QC Program

RMC Environmental Services, Inc. adheres to a formal, documented Quality Assurance Program that defines policies and procedures to ensure that all work is of the highest technical quality and meets contractual and regulatory requirements. RMC's staff routinely follow reviewed and approved procedures to assure validity and quality of data collection and analytical results. These operating procedures, which are prepared by responsible staff and approved through management, are based on sound scientific techniques from standard sources. To assure that quality is maintained throughout the company on all projects, RMC employs a Manager of Quality Assurance who reports directly to the Chief Operating Officer of the firm. RMC's Quality Assurance Program is documented in the Corporate Quality Assurance Manual, which is available upon request. JEEAI and AATA, both firms with national reputations, also adhere to quality assurance programs.

The programs for all three firms are reflected in all phases of this 316(a) demonstration, including proper calibration and placement of instrumentation, data collection, selection and application of the thermal model, and interpretation of the model runs. The specifics of Quality Assurance and Quality Control for the Modelling Study are presented in Section 6.0 of this report and for the 1992 Temperature Monitoring Study in AATA (1992a) which is included in this report as Appendix B (Tab 11).

4.4 Ongoing Aquatic Ecological Sampling Programs

RMC continues to conduct several aquatic ecological sampling programs related to the Point Pleasant Diversion Project that were initiated in the 1980's (Table 4.4-1). These sampling programs include water quality, benthic macroinvertebrates, and fish studies. The latter consists of sampling small and large fishes by seine and electrofishing, respectively, as well as study of growth parameters, and characteristics of the recreational fishery via creel survey. Most of these efforts are focussed on the East Branch, although water quality sampling is conducted in the Delaware River near Point Pleasant. Results of these studies are presented in a series of reports that were prepared beginning in 1984 (Table 4.4-2).

4.4.1 Water Quality

4.4.1.1 NPDES Sampling at the Outfall

Water quality sampling for the Point Pleasant Diversion Project under the NPDES permit began in August 1989. The permit requirements are listed in Table 4.4-3. Grab samples are collected twice monthly at the outfall to the East Branch and analyzed for total aluminum, cadmium, dissolved and total iron, mercury, total nickel, total phenolics, and total zinc. Fecal coliform monitoring requires that grab samples are collected at the outfall on five consecutive days monthly. Temperature, dissolved oxygen, and pH are measured continuously in the Bradshaw Reservoir pumphouse using a Martek Instruments Mark XVIII Ultrapure Water Monitoring System.

4.4.1.2 Biweekly Water Quality Sampling Program

Water quality sampling in the Delaware River at Point Pleasant began in 1980 and is on-going. Water quality sampling in the East Branch at Branch Road, Catnill Road, and Garges Road began in 1983 and is on-going. These stations are shown in Figure 4.4-1. The suite of parameters and the frequency at which they are measured at these stations are shown in Table 4.4-4.

4.4.2 Benthic Macroinvertebrates

Benthic macroinvertebrate sampling on alternate months began at six locations in the East Branch in 1983 and is on-going. These stations include one located upstream of the outfall (Control) and five located downstream (Elephant Road, Callowhill Road, Sellersville, Cathill Road, and Moyer Road). They are shown in Figure 4.4-2.

4.4.3 Fisheries

4.4.3.1 Seine

Seine survey of minnows and young sport and panfishes of the East Branch began in 1981 and continues to date. Montʰly surveys are conducted at seven stations located downstream of the outfall (Elephant Road, Callowhill Road, Sellersville, Cathill Road, Moyer Road, Camp WaWa Road, and Garges Road) and at one station located on Morris Run. They are shown in Figure 4.4-3.

4.4.3.2 Electrofishing

Collection of large fish by electrofishing for population estimates began in 1981 and is on-going. Spring and fall collections are made at seven stations located in the East Branch downstream of the outfall (Elephant Road-Upper Pool, Elephant Road-Lower Pool, Covered Bridge, Cathill Road, Moyer Road, Camp Wawa Road, and Garges Road). They are shown in Figure 4.4-4.

4.4.3.3 Age and Growth

Studies of age and growth of four species (white sucker, smallmouth bass, redbreast sunfish, and green sunfish) have been conducted during 1981, 1983, 1984, 1985, 1988, 1990, and 1992. Samples of scales of these species are collected in fall electrofishing efforts at five of the seven stations located downstream of the outfall.

4.5 Pump Operations

The period of August through September 1990 was a shake-down period for the Bradshaw Reservoir pumps and associated controls. Discharge to the East Branch is governed by a Water

Obstruction and Erosion Permit E09-077A issued by the PA DER which mandated a phased start-up of the diversion flow. The permit mandated a two phased start-up with several stages associated with each phase as summarized in Table 4.5-1.

The Bradshaw Reservoir pump log summary of discharges to the East Branch for 1989 is presented in Table 4.5-2 with the 1990 record presented in Table 4.5-3. Similar operating summaries for 1991 and 1992 are presented in Tables 4.5-4 and 4.5-5, respectively. The monthly average and daily maximum flows in Tables 4.5-2 through 4.5-5 were obtained from the monthly Discharge Monitoring Reports submitted by LGS to PA DER.

Weekly Consumptive Water Source records have been provided by Limerick Generating Station personnel. The daily entries in the weekly summary include the Bradshaw Reservoir discharge record (pump logs) which has been used for several sections of this submittal. For the period of record (September 1989 through December 1992) the weekly summaries total approximately 160 pages. The weekly summaries are available upon request.

4.6 Bucks Road Gage Record

Tables 4.6-1 through 4.6-4 present the USGS Bucks Road discharge records for 1989 through 1992, respectively. The Bucks Road discharge record reflects the start-up and testing from August through December 1989 (Table 4.6-1), Point Pleasant Pump difficulties in early 1990 (Table 4.6-2) and routine operations (including WPF) for 1991 and 1992 (Table 4.6-3 and 4.6-4, respectively). The Bucks Road discharge record reflects flow from Bradshaw Reservoir plus natural stream flow. The pump log summaries and the Bucks Road record indicate that steady flows were maintained in the East Branch due to operation of the Point Pleasant Diversion.

4.7 Summary of Erosion Monitoring Cross-sections from 105 Permit Study

PA DER, Division of Waterways and Storm Water Management issued a Water Obstruction and Encroachment Permit (E09-077A) on 12 February 1988 permitting Philadelphia Electric Company to

> construct and maintain an outfall structure, energy dissipator and channel stabilization along the left bank of the East Branch at a point approximately 800 feet upstream from L.R.09090 in Bedminster Township, Bucks County.

Special Condition M1 of the permit mandates a staged start-up of the discharge in Phase I (Start-up and supply water for one Limerick Unit) to the East Branch as follows:

Stage	Time Frame	Maximum Discharge Rate (cfs)
1	at least 30 days	10
2	at least 30 days	20
3	thereafter	27.1

Pump operations were as follows:

2 August	Start-up - Stage 1 (10 cfs)
18 September	Begin Stage 2 (20 cfs)
1 November	Begin Stage 3 (27 cfs)

A monitoring plan including monumented stations (see Table 4.7-1 and Figure 4.7-1) was submitted to PA DER as required by Special Condition M2 which included the terms that surveyed transects be monitored after a minimum 30 day discharge at any given stage, plus surveyed transects after flows at Bucks Road exceeded 238 cfs (estimated one year flood). During Phase I transects were surveyed as follows:

19, 21 July 1989	Pre-operational
16, 17 August	High flow (+700 cfs)
12, 13 September	End Stage 1 (10 cfs)
27, 28 September	High flow (+2,000 cfs)
25, 26 October	End Stage 2 (20 cfs)
20, 21 November	End Stage 3 (27 cfs)

The monitoring plan also requires twice weekly visual inspections of the transects and general environs. Each transect is compared to the photo-index for any change. Any changes observed, based on the best judgement of the field inspector, were photographed and noted in a bound field inspection survey book. Upon development, the photographs were permanently captioned and archived. The field inspector notified the project manager of the changes. The visual surveys were conducted on 4, 8, 11, 14, 16, 22, 24, 29, and 31 August, 6, 8, 13, 15, 20, 22, 25, and 28 September, 3, 5, 9, 12, 16, 20, 23, 26, and 30 October, and 2, 6, 9, 13, 17, 20, 22, 27, and 30 November.

Two storm events occurred during August and September 1989. Heavy rains on 15 August and Hurricane Hugo on 20 September 1989 were responsible for flood flows. The flow on 20 September, 2,040 cfs at 1400 hours, established the record high mean daily discharge recorded at the Bucks Road gage since the gage was installed in October 1983.

The operation of the water diversion system, including the natural flood flow of August and September 1989, resulted in only minor changes to the East Branch. All observed changes were within the tolerances established in the monitoring plan. A report including copies of the Phase I survey results was submitted to PA DER Division of Waterways and Stormwater Management, Harrisburg, Pennsylvania on 21 December 1989.

The Phase II start-up (water supply for two Limerick units) commenced on 1 March 1990. Pump operations were as follows:

1 March	Restart spring testing (45 cfs)
19 March	Begin full flow test (67 cfs)
23 March	Reduce flow because of Point Pleasant problems
9 July	Restart full flow test (60 to 63 cfs)
24 September	Complete full flow test

During Phase II, transects were surveyed as follows:

3, 4 January 1990	After one day test at full flow (67 cfs)
31 January, 1 February	High flow
26, 27 February	Prior to spring restart
19, 20 March	End 45 cfs test
11 May	High flow
30, 31 May	High flow
25, 26 June	High flow
9, 10 August	Mid-point of full flow test
26, 27 September	End of full flow test

Copies of the Phase II survey results were transmitted to PA DER and DRBC after each survey. The survey results demonstrated that operation at all flow rates up to full project flow have not resulted in material changes to the East Branch. A report summarizing all of the Phase II observations was submitted to PA DER, Harrisburg.

Quarterly observations and one high flow event continued until September 1991. Transects were surveyed as follows:

10, 12 October 1990	High flow event (442 cfs)
20 December 1990	End of quarter
20, 21 March 1991	End of quarter
26, 27 June 1991	End of quarter
27, 30 September 1991	End of quarter

Pump operations were as follows:

1 November 1991	Decrease flow to winter minimum (10 cfs)
10 April 1992	Increase flow to support Limerick

4.8 NPDES Temperature Compliance Record

The Bradshaw Reservoir discharge to the East Branch has an overall excellent temperature compliance record, although it exceeded, for short durations, the permit limit of 74 F on seven occasions in 1990 (the start-up year of the WPF), on nine occasions in 1991 (record high summer temperatures) and no occasions during 1992. No observable impacts to the biota of the East Branch were attributable to the temperature fluctuations.

All exceedances were of small magnitude (often only 0.1 F) and very short duration. Despite WPF normal startup difficulties and occasionally severe weather (1991 was a record for the number of days in which air temperature exceeded 90 F), the period of exceedance represents only a very small time out of permit compliance.

The following paragraphs present a brief overview of the temperature excursions.

29 through 30 June 1990 - Several short term temperature violations (less than 30 minutes) due to warm ambient air temperatures causing overheating and pump trips at the Bradshaw Reservoir pump house. With a pump trip at Bradshaw, the chillers at the WPF unloaded. With the re-start of the Bradshaw pumps, a time lag for the chillers to pick up the load as flow increased resulted in some short term (usually less than 30 minutes) exceedances at the WPF discharge.

2 July 1990 - An automobile accident resulted in a loss of power at the WPF for approximately 1.5 hours.

4, 5, 6, 9, and 10 July 1990 - Temperature transients caused by equipment trips and power loss.

28 May 1991 - High vibration in the 'C' chiller at the WPF resulted in a temperature excursion at the WPF of approximately 45 minutes (0215 through 0300 hours). The maximum temperature recorded at the discharge was 74.3 F which slightly exceeded the permit limit of 74 F.

29 June 1991 - All three chillers at the WPF tripped due to a failure of a logic control unit (LCU) at approximately 1450 hours. Attempts to restart the chillers were unsuccessful. At approximately 1533 hours, the 'B' and 'C' pumps at Bradshaw tripped. Maximum discharge temperature was 78.07 F at 1700 hours at a flow of 34 cfs in the East Branch. At 1800 hours, the discharge temperature was 66.11 F at a flow of 13 cfs. This temperature reduction was a result of the restart of the 'A' chiller combined with the operation of one Bradshaw pump. Temperature noncompliance continued until 2100 hours in that the discharge temperatures changed more than 2 F in a one hour period during adjustments to the pump and the 'A' chiller.

Discussions with the Delaware River Basin Commission (DRBC) and PA DER led to the conclusion that all three Bradshaw pumps should be operated to minimize environmental impact on the receiving stream. With changing atmospheric conditions (rainfall and nighttime) the 'A' and 'B' chillers maintained discharge temperatures below the permit limit.

30 June 1991 - At approximately 0800 hours the discharge temperature exceeded the permit limit due to the unavailability of the 'C' chiller due to continuing LCU problems. The highest instantaneous temperature reading was 75.7 F at 1200 hours. The operators decided to reduce flow from Bradshaw to reduce discharge temperatures and augment Schuylkill River water supply with a release from the Tamaqua Reservoir. Temperatures were within permit limits by 1600 hours. The LCU on the 'C' chiller was replaced on 1 July 1991.

7 July 1991 - An electric storm caused a loss of power to the WPF. Discharge temperatures exceeded permit limits from 1400 to 1600 hours with a maximum temperature of 75.7 F.

19 July 1991 - Another electric storm resulted in a loss of power to the WPF with temperature exceeding permit limits between 1300 and 1500 hours. Maximum temperature observed was 74.1 F.

21 July 1991 - Between 1200 and 2300 hours, due to extreme ambient conditions, the discharge temperature exceeded the permit limit of 74 F. Maximum temperature was 75.5 F. A moderation of ambient conditions resulted in the restoration of temperatures within the permit limits.

23 July 1991 - Extreme ambient conditions again resulted in temperature exceedances between 1200 and 2200 hours. The maximum temperature recorded was 75.7 F. All three WPF chillers and three cooling towers were operating.

At approximately 1700 hours an electrical storm caused a loss of power to Bradshaw. Two pumps were restarted at 2200 hours.

25 July 1991 - Between 0300 and 0500 hours, due to an inability to remotely shutdown the Bradshaw pumps, the discharge temperature exceeded permit limits with a maximum temperature of 74.5 F. One of the Bradshaw pumps was manually shut down at 0500 which allowed the WPF to regain temperature compliance.

26 July 1991 - An electric storm caused a power loss to both the WPF and Bradshaw Reservoir. Temperatures exceeded permit limitations between 1800 and 2000 hours with a maximum temperature of 74.4 F. Restart of the pumps and chillers restored compliance.

1992 - Repairs/modifications prior to the 1992 cooling season, including an operable variable flow mode, resulted in remote operation of the WPF and Bradshaw Reservoir by the Limerick Generating Station Main Control Room. The electrical/mechanical modifications and repairs plus less demanding ambient conditions during most of the 1992 cooling season resulted in no temperature exceedances during the chilling season.

4.9 Economic and Recreational Value

Economic and recreational use of the East Branch was observed by RMC coicident with biological studies for over 20 years. In addition, several formal surveys were conducted. This information is summarized below.

4.9.1 Existing Creel Survey Data on Trout Stocked Fishery (TSF)

A new fishery for stocked trout was created in 1987 by the introduction of nearly 6,000 hatchery trout into 3.5 miles of East Branch near Sellersville, Pennsylvania. Although the stream had been classified by the PA DER for use as a stocked trout stream for many years, 1987 was the first year in at least a decade that the Pennsylvania Fish and Boat Commission (PFBC) released trout in the East Branch. The East Branch has received trout each year since 1987.

The 3.5 miles of stream stocked during 1987 and 1988 was divided into a 1.5 mile stream reach extending upstream from the Pennridge Sewage Treatment Plant to the Walnut Street Bridge (Trout Stocking Area I), and a 2.0 mile stretch which began at the upper edge of Area I and extended upstream to Branch Road north of Sellersville (Trout Stocking Area II) (Figure 4.9-1).

Area III, which was stocked for the first time in 1989, is located about 12.5 miles downstream from Area I. This area is 2 miles in length. All three areas have been stocked in all years since 1989. Area I is stocked prior to the trout season and twice during the season. Area II is stocked on both inseason restocking dates for Area I. Area III is stocked inseason twice. In 1990, an originally unscheduled stocking was made on 8 June, when 3,500 trout (mostly brown

trout) were stocked in Areas I and II. Stockings have usually consisted of rainbow trout and brown trout in an approximately 3:1 ratio.

An intensive creel survey was designed to estimate angler use, trout harvest rates, and total number of trout caught on selected days. Surveys were conducted for 5 days in 1987, 9 days in 1988, 23 days in 1989, 12 days in 1990, 18 days in 1991, and 18 days in 1992. The number of days of survey effort was variable depending upon weather and flooding conditions (which greatly affected angler effort) and the rapidity with which anglers depleted the stocked trout. The number of stockings also affected the number of surveys. Survey dates were concentrated on opening weekend and after inseason stockings.

Results of trout creel surveys conducted beginning in 1987 and continuing to the present substantiate rapid depletion of stocked trout from the stream. A large percentage of stocked trout are removed long before high temperature becomes lethal to trout. This effect is particularly evident on the opening weekend of the trout season when 79 to 99% of the preseason stockings are harvested (Table 4.9-1). In 1990, when opening-day angler effort (5,882 angler-hours) far exceeded any other year, approximately 97% of stocked trout were removed on opening day.

Over the six years of the trout creel survey from 34% to 60% of trout were harvested annually during the actual hours of conducted surveys. It is likely that substantially all of the trout that were not observed to be harvested during the surveys were harvested on the days which were not surveyed. Surveys were terminated for the season when angler rates declined to the point which indicated virtually all trout had been harvested.

Electrofishing was used immediately after completion of surveys in two years to corroborate depletion of stocked trout. Only two trout were captured during an extensive electrofishing survey of Area I and II conducted in May 1987. In 1990, an electrofishing survey of the Sellersville dam pool in Area I on 5 July did not yield any trout, nor were dead or dying trout observed on a day when water temperatures were measured between 78.8 and 82.4 F during the day. Further upstream in Area II (which is free-flowing and well-shaded compared to Area I) a total of five brown trout were collected during an electrofishing survey which covered approximately 500 meters of stream. Thus, a few trout did escape harvest in 1990, at least in Area II which is more lightly fished than Area I. However, these fish were almost assuredly part of the special inseason stocking of 8 June, which occurred at a time when many local anglers have abandoned trout fishing for the season. Brown trout, which comprised nearly 100% of the 8 June stocking but typically only about 25% of other stockings, also tend to be more difficult for anglers to catch than rainbow trout.

Estimated angler-hours for the trout season are presented in Table 4.9-1. Since these estimates are for surveyed time periods only, it is likely that actual annual totals were in the range of 50% to 100% higher, depending upon the number of days surveyed in a given year. Therefore, since 1989, when two inseason stockings were made across all three areas (I, II, and III), it is likely that actual angler-hours expended annually for trout have been in the range of 20,000 to 25,000.

The number of opening-day anglers was exceptionally high in 1990 (5,882 angler-hours on opening day and 1,151 anglers present in Area I at 9:00 a.m.). This year was the first year that the diversion had been operated during opening day. The additional flow was apparently very attractive to anglers. However, the crowded conditions and lower catch rate <u>per angler</u> that occurred on opening day 1990 (1,151 anglers fishing for 2,200 trout) may have discouraged

some anglers as angler-hours on opening day declined to 4,696 and 3,508 in 1991 and 1992, respectively.

4.9.2 Existing General Angler Use - Pre-diversion

The most abundant source of information about pre-diversion recreational activity on the East Branch are a series of creel surveys and conducted by RMC during 1980, 1981, 1983, and 1985 (RMC 1984, RMC 1986).

During the spring and summers of 1980, 1981, 1983, and 1985 a creel survey was conducted on the East Branch in order to characterize the recreational fishery prior to operation of the water diversion. From its headwaters to its confluence with the Perkiomen Creek, the East Branch is crossed frequently by roads that provide access for fishermen. In addition, many public recreation areas abutt the creek. A stratified random roving creel survey was utilized to count and interview anglers.

Estimates of total fishing pressure were calculated for each month and year of the study. An estimated 39,383 angler-hours were expended during the four years surveyed. Fishing pressure was much lower in 1980 than in 1981 and 1983 when it was similar between years. Pressure in 1985 was intermediate between 1980 and 1981/1983 levels. In all years there was a general pattern of increased pressure from May through June or July, followed by a decline in August through September.

Conservatively, these values represent an average rate of fishing pressure of about 275 angler-hours per kilometer of stream per year (angler-hr/km/yr), which is a low rate for warmwater streams. However, fishing effort is not uniformly distributed among access points. The stream reach through Sellersville and Perkasie is used relatively heavily by fisherman; approximately 40% of all anglers interviewed were fishing the 3.5-km reach (about 10% of the study area) between Callowhill Road and the Sellersville Municipal Garage.

In comparison, only 18 anglers in four years were interviewed upstream of Sellersville and none upstream of Schwenks Mill Road (E32880). Of 975 anglers interviewed during the 4-yr survey, only nine (0.9%) were interviewed at Branch Road or upstream. Prior to diversion, the creek above Branch Road was characterized by low flow and semi-stagnant pools during much of the year.

Fisheries collections showed that for most species mean sizes of fish were smaller than downstream; age and growth analysis showed that not only did fishes grow slower in this upstream section of the creek but that mean age of individuals of some species such as white sucker and redbreast sunfish were lower than in downstream sections. The lower mean age indicates that higher natural mortality was occurring and/or fish were migrating downstream as they became older and larger.

During the period 1975-1983, only 15 smallmouth bass among 27,968 total seined fish were collected at Branch Road or upstream, and no smallmouth bass were collected among 4,159 total fish seined from this area from 1984 through 1990. During the period 1980-1983, only 1 of 822 smallmouth bass collected stream-wide by electrofishing was collected upstream of Branch Road. Among interviewed anglers who stated a preference for species they wished to catch, smallmouth bass ranked first.

Therefore, the shallow, non-flowing pools, small average size of fish, and dearth of smallmouth bass upstream of Branch Road all contributed to the extremely low angling effort expended there and documented by the creel surveys.

4.9.3 Water Contact Sport Observation

During many thousand hours of creel surveys, water quality, benthos, and fisheries collections from the East Branch since 1980, a very limited amount of water contact recreation has been observed by RMC personnel. Prior to the diversion, this type of activity was very rare and seemed confined to youngsters swimming in some of the downstream areas impounded by low-head dams. Subsequent to diversion, this type of activity, although still relatively rare, seems to have increased, particularly in upstream areas.

Although an apparent increase in water contact recreation has occurred, it is only partially attributable to increased flows. Improvement to and extensions of municipal parks at several locations along the East Branch have greatly increased access to and familiarity with the creek at several locations, particularly the East Rockhill Township Park between Blooming Glen and Callowhill Roads. This park has provided parking and a paved walking path that is utilized by many dozens of people daily throughout much of the year.

4.10 Rare, Threatened, and Endangered Species

In over 20 years of field studies, RMC biologists have never observed any state or federally listed rare, threatened, or endangered animal or plant species in the East Branch. In order to substantiate the absence of such species in the study area, data requests were sent to the state and federal agencies responsible for these species: the Pennsylvania Fish and Boat Commission, the Pennsylvania Game Commission, PA DER's Pennsylvania Natural Diversity Inventory (PNDI), and the US FWS. Summaries of the responses follow:

The Pennsylvania Fish and Boat Commission reported that presently none of the fishes, amphibians, or reptiles they list as endangered or threatened are known to occur in or in the immediate vicinity of the study area.

The US FWS stated that, except for occasional transient species such as the bald eagle and peregrine falcon, no federally listed or proposed threatened or endangered species under their jurisdiction are known to exist in the study area.

The Pennsylvania Fish and Wildlife database contains records of the New Jersey chorus frog and bog turtle (PA Endangered) possibly occurring in or near the study area. It also contains records of osprey (PA Endangered) occurring near the study area. However, there are no records of this species occurring close enough to the study area to be impacted by the project. Their occurrence may depend on season, habitat type, and individual movements or migration patterns. The database also lists 44 species of special concern found throughout Bucks and Montgomery Counties. These species of special concern may potentially occur within the study area, based on records of these animals inhabitating particular habitat types within each county.

To date, no information has been received from PA DER concerning the PNDI database.

4.11 Evaluation of Pre/Post-Operational Lack of Harm to Balanced Stream Communities

Special condition K, Part C, of the NPDES permit requires conduct of post-diversion aquatic biology assessments (ABAs) for submission to PA DER. The permit states

> K. Upon commencement of the diversion, the permittee shall conduct a post-diversion aquatic biology assessment. The permittee shall submit to the Department prior to the start of field work a study plan including sampling locations, survey techniques, and chemical and biological protocols. The permittee shall file with the Department a report for each of the first two years and every two years thereafter describing the results of such studies and any changes in the ecology that occur. The permittee shall take any mitigating steps indicated as necessary by such studies in conformance with plans submitted to the Department.

Discharge from the Bradshaw Reservoir to the East Branch began in August 1989, thus making 1989 the first operational year from the standpoint of permit compliance. In accordance with a study plan submitted to and approved by PA DER, RMC prepared on behalf of PECo two post-diversion ABAs which fulfilled the NPDES permit requirement for 1989 and 1990, the first two operational years (PECo 1990 and PECo 1991). Data obtained from studies conducted in 1991 and 1992 are being evaluated and will appear in a combination two year ABA that is in preparation.

Post-diversion ABAs are based on the results of several studies which were conducted prior to diversion and which were continued after the diversion began to operate (Table 4.4-1). Findings related to benthic macroinvertebrates and fish are summarized below.

4.11.1 Benthic Macroinvertebrates

The macroinvertebrate community present in the upper East Branch prior to operation of the Point Pleasant Diversion was typical of southeastern Pennsylvania streams displaying intermittent flow conditions. Taxa such as the mayfly Caenis and the stonefiles Allocapnia and Amphinemura, which are tolerant of such conditions, dominated a community of lesser population density compared to that present further downstream in perennial flow reaches. Although present, taxa which favor perennial flow conditions, such as the net-spinning caddisflies Chimarra and Hydropsyche, did not represent a large component of the macroinvertebrate community in the upper East Branch.

By November 1990, the macroinvertebrate community present in the upper East Branch had begun to change in response to augmented stream flow from the Point Pleasant Diversion. This change was most apparent within several hundred meters of the discharge, with lesser effect observed further downstream. The taxa that favor flowing water and/or improved water quality (i.e., Chimarra and Hydropsyche) increased in abundance, whereas population density of others that prefer intermittent or low flow conditions (i.e., Allocapnia and Amphinemura) diminished. One macroinvertebrate taxon, the amphipod Gammarus, apparently was introduced. It is common in the Delaware River near Point Pleasant, but not seen previously in the East Branch.

None of the observed changes to the macroinvertebrate community structure could be considered detrimental. Certainly, no appreciable harm as defined under 316(a) Demonstration Type I (see Section 2.6.1) was observed in the upper East Branch. Population densities of individual taxa have fluctuated, some taxa have increased, others decreased. However, the macroinvertebrate community present in the upper East Branch under enhanced stream flow conditions due to operation of the Point Pleasant Diversion is a diverse assemblage of taxa present, as a whole, in numbers substantially greater than observed previously.

4.11.2 Fish

Prior to diversion, the fish community of the East Branch varied significantly from the headwaters at Elephant Road (E36690) to the confluence with Perkiomen Creek. The fish community at Elephant Road was dominated by a mixture of displaced pond species (largemouth bass, golden shiner, green sunfish, pumpkinseed, and bluegill sunfish); two species found throughout the EBPC, white sucker and redbreast sunfish; a marginal headwater species, the redfin pickerel; as well as the creek chubsucker; and the bluntnose minnow.

Results of post-diversion monitoring indicate that the predicted change in the fish community structure in the headwaters of the East Branch is occurring. A rapid displacement of the existing headwater community as indicated by sharply reduced numbers of fish collected by both seining and electrofishing has occurred.

Prior to augmentation, most of the resident large fishes of the headwaters were members of a group adapted to low velocity environments; and low velocity areas were greatly reduced by maximum augmentation (PECo 1991). Numbers of golden shiner, green sunfish, pumpkinseed, bluegill, and largemouth bass collected at Elephant Road have dropped steadily in recent years. These species, when present in streams, generally prefer slow-flowing weedy areas. This type of habitat has been largely eliminated. Several minnow species capable of responding favorably to the increased flow regime had been present prior to augmentation, and spotfin, comely, and common shiners subsequently comprised over 60% of seine catch at Elephant Road during 1990 and 1991.

Prior to augmentation (1986, 1987, and 1988), the spotfin shiner populations at Elephant Road comprised < 10% of the total seining catch. Results of post-operational monitoring indicate that the spotfin shiner has become an important component of the small fish community, comprising roughly half of the seine catch in the headwaters of the East Branch. The fathead minnow also has increased in number subsequent to augmentation. Coincident with the increase of fathead minnow, the bluntnose minnow catch has declined in recent years. These two closely related species (both genus Pimephales) do not co-exist well.

Marked changes between preaugmentation and post-augmentation fish communities downstream have not been evident. Some minor trends are presented below. Streamwide results of post-diversion monitoring (1990 and 1991) indicate total numbers of spotfin shiners are increasing. Prior to the diversion, this species comprised the majority of the catch by seine. As a result of the increased flows, spotfin shiner total numbers are at an all time high within most sections of the East Branch. Another species favored by increased streamflow, the tessellated darter, also has steadily increased in the East Branch seine catch. Smallmouth bass, an important sport fish of the East Branch fish community, were more frequently collected in 1990 and 1991 than in 1987-1989, a favorable response to augmented flows of the East Branch. Seine catch of

golden shiner, green sunfish, pumpkinseed, and bluegill exhibited a streamwide decreasing trend. Electrofishing results indicate streamwide increases of smallmouth bass, margined madtoms, white suckers, and yellow bullhead. Fishes decreasing streamwide post-diversion, as determined by electrofishing, include creek chubsucker, pumpkinseed, bluegill, golden shiner, and green sunfish. Fish species exhibiting little change streamwide by electrofishing include redbreast sunfish and largemouth bass.

There are no changes to the East Branch fish community which indicate any thermally-induced prior appreciable harm as defined in the 316(a) Demonstration Type I Guidance (see Section 1.6.1).

Table 4.2-1 Bradshaw Reservoir Discharge Overview

Date	Mechanical/Control Difficulty
<u>1989</u>	
2 - 9 August	testing at various flows
9 - 15 August	pump problems
16 August - 6 September	testing at various flows
6 - 7 September	pump problems
7 September - 23 October	testing at various flows
24 October - 1 November	Point Pleasant outage
1 - 20 November	testing at various flows
20 - 21 November	Point Pleasant Outage
21 - 31 December	testing at various flows
<u>1990</u>	
1 January - 1 March	conservation flow
1 - 9 March	testing at various flows
10 - 12 March	pump trips
12 - 23 March	testing at various flows
24 March	Point Pleasant capability limited to 37 cfs
24 March - 9 April	testing at various flows
9 - 23 April	Point Pleasant outage
24 April - 31 December	testing at various flows
<u>1991</u>	
1 January - 21 September	operation normal
21 September	Bradshaw Logic Control Unit problem
21 September - 31 December	operation normal
<u>1992</u>	
1 January - 31 December	operation normal

Table 4.4-1. Aquatic ecological sampling programs conducted in relation to the Point Pleasant Diversion Project by RMC Environmental Services, Inc.

Program	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
<u>Delaware River</u>													
Water Quality	X	X	X	X	X	X	X	X	X	X	X	X	X
<u>East Branch</u>													
<u>Perkiomen Creek</u>													
Water Quality				X	X	X	X	X	X	X	X	X	X
Benthic Macroinvertebrates				X	X	X	X	X	X	X	X	X	X
Seine		X	X	X	X	X	X	X	X	X	X	X	X
Electrofishing		X	X	X	X	X	X	X	X	X	X	X	X
Age and Growth		X		X	X	X			X		X		X
Creel Survey	X	X		X		X		X	X	X	X	X	X
Bucks Road Gage					X	X	X	X	X	X	X	X	X

Table 4.4-2 Reports describing results of East Branch aquatic ecological sampling programs

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Philadelphia Electric Company. 1989. Bradshaw Reservoir NPDES Permit PA-0052221 Reports and Studies. Report to Pennsylvania Department of Environmental Resources, Harrisburg.

Philadelphia Electric Company. 1990. Post-diversion aquatic biology assessment for 1989. NPDES Permit PA-0052221 Reports and Studies. Report to Pennsylvania Department of Environmental Resources, Harrisburg.

Philadelphia Electric Company. 1991. Post-diversion aquatic biology assessment for 1990. NPDES Permit PA-0052221 Reports and Studies. Report to Pennsylvania Department of Environmental Resources, Harrisburg.

RMC Environmental Services. 1984. Progress Report: Non-radiological Environmental Monitoring for Limerick Generating Station, 1979-1983. Prepared for Philadelphia Electric Company, Pennsylvania.

RMC Environmental Services. 1985. Progress Report: Non-radiological Environmental Monitoring for Limerick Generating Station, 1984. Prepared for Philadelphia Electric Company, Pennsylvania.

RMC Environmental Services. 1986. Progress Report: Non-radiological Environmental Monitoring for Limerick Generating Station, 1985. Prepared for Philadelphia Electric Company, Pennsylvania.

RMC Environmental Services. 1987. Progress Report: Non-radiological Environmental Monitoring for Limerick Generating Station, 1986. Prepared for Philadelphia Electric Company, Pennsylvania.

RMC Environmental Services. 1988. Progress Report: Non-radiological Environmental Monitoring for Limerick Generating Station, 1987. Prepared for Philadelphia Electric Company, Pennsylvania.

Table 4.4-3 NPDES Permit PA-0052221 limits for Bradshaw Reservoir Outfall 001

Parameter	Average monthly mg/l	Maximum daily mg/l	Instantaneous maximum
Aluminum, Total	0.4	2.0	
Cadmium	0.00076	0.0022	
Dissolved Iron	--	0.3	
Iron, Total	1.5	7.5	
Mercury	Non-detectable	Non-detectable	
Nickel, Total	0.052	0.26	
Phenolics, Total	0.005	0.01	
Zinc, Total	0.1	0.5	
Temperature			
(Feb 15 to Jul 31)			74 F (23.3 C)
(Aug 1 to Feb 14)			87 F (30.6 C)
Fecal Coliforms			
(May 1 to Sep 30)	Geometric average of 200 colonies/100 ml		
(Oct 1 to Apr 30)	Geometric average of 2,000 colonies/100 ml		
Dissolved Oxygen			
(Feb 15 to Jul 31)	Minimum daily average of 6.0 mg/l No value less than 5.0 mg/l		
(Aug 1 to Feb 14)	Minimum daily average of 5.0 mg/l No value less than 4.0 mg/l		
pH	Within 6.0 and 9.0 Standard Units at all times		

Table 4.4-4 Analytic parameters and methods for water quality monitoring - Delaware River at Point Pleasant and East Branch Perkiomen Creek

Parameter	Detection limit (mg/l)	EPA method[a]
Aluminum[d]	0.07	202.1
Cadmium[d]	0.0002	213.2
Calcium[e]	1.5	215.1
Chromium[c]	0.002	218.2
Copper[c]	0.002	220.2
Iron[d]	0.002	236.1
Lead[c]	0.002	239.2
Magnesium[e]	0.3	242.1
Manganese[c]	0.1	243.1
Mercury[d]	0.0002	245.1
Nickel[d]	0.003	249.2
Potassium[e]	0.05	258.1
Sodium[e]	0.36	273.1
Zinc[d]	0.02	289.1
Alkalinity, Total as $CaCO_3$[e]	2.8	310.2
Ammonia, Nitrogen[e]	0.011	350.1
Chemical Oxygen Demand[c]	7.4	410.4
Chloride[e]	2.2	325.2
Cyanide, Total (water)[c]	0.009	335.3
Hardness as $CaCO_3$[c]	10	130.1
Nitrate, Nitrogen[e]	0.2	353.2
Nitrite, Nitrogen[c]	0.01	353.2
Ortho Phosphate Phosphorus[e]	0.03	365.1
Phenolics (water)[d]	0.002	420.2
Sulfate[e]	3.4	375.2
Fecal Coliform (MF)[d]	1 colony/100 ml	[b]
Biochemical Oxygen Demand[c]	0.1	405.1
Carbon, Total Organic[c]	1	415.1
Dissolved Oxygen[d]	NA	360.1
pH[d]	NA	150.0
Specific Conductance[e]	NA	120.1
Temperature[d]	NA	170.1
Total Dissolved Solids[c]	10	160.1
Total Phosphate Phosphorus[c]	0.03	365.1
Total Suspended Solids[e]	4	160.2
Turbidity[c]	0.2	180.1

[a]U.S. EPA. 1983. Methods for Chemical Analysis of Water and Waste.
[b]U.S. EPA. 1978. Microbiological Methods for Monitoring the Environment.
[c]After November 1991 - Once annually at Point Pleasant.
[d]After November 1991 - Bi-weekly at Point Pleasant and Cathill Road.
[e]After November 1991 - Once per month at Point Pleasant, Branch Road, Cathill Road, and Garges Road.

Table 4.5-1 Phased Start-up of Bradshaw Reservoir Discharge to the East Branch

Phase	Stage	Maximum Flow (cfs)	Dates
I	1	10	2 August - 18 September 1989
	2	20	19 September - 1 November 1989
	3	27	1 November - 27 December 1989
II	1	45	1 March - 19 March 1990
	2[a]	67	19 March - 24 September 1990

[a]Difficulties at the Point Pleasant Pump required reduced discharge from late March to early July 1990. Phase II Stage 2 testing recommenced from 9 July through 24 September 1990.

Table 4.5-2 Bradshaw Reservoir Pump Log Summary - 1989

Month/ Day	Flows - DMR (cfs) Month Average	Daily Maximum	Pump Log Comments[a]
August	4.65	10.85	
2			initiate pumping
September	7.86	21.11	
October	17.25	20.15	
November	25.33	27.13	
December	23.34	35.06	

[a]Due to the initial start-up and testing of the individual pumps, Bradshaw Reservoir controls and the remote (LGS) controls, no attempt has been made to summarize the numerous operating configurations for 1989.

Table 4.5-3 Bradshaw Reservoir Pump Log Summary - 1990

Month/Day	Flows - DMR (cfs) Month Average	Daily Maximum	Pump Log Comments[a]
January	9.46	10.23	
24-25			pumps off - high flow EBPC
29-30			pumps off - high flow EBPC
February	9.89	10.63	
10			pumps off - high flow EBPC
11			restart
16			pumps off - electrical modification
March	42.05	67.84	
1			begin Phase II - 45 cfs
10-11			pump trip - line fault
12			restart
19			Phase II - Stage 2 - 67 cfs
24			Point Pleasant Pump problems - flow reduced to 23 cfs
April	16.32	36.49	
3			pumps off - high flow EBPC
4			restart
9			pumps off - Point Pleasant pump problems - 0 cfs
24			restart - 23 cfs
May	28.01	34.75	
5			pumps off - high flow EBPC
6			restart
10			pumps off - high flow EBPC
11			restart
30-31			pumps off - high flow EBPC
June	36.38	42.75	
1			restart
July	46.24	65.02	
August	60.25	63.63	
September	59.64	62.59	
October	41.45	45.49	
November	10.04	11.49	conservation flow - 10 cfs
December	9.59	10.01	
4			pumps off - high flow EBPC
5			restart
24			pumps off - high flow EBPC
25			restart
30			pumps off - high flow EBPC
31			restart

Table 4.5-4 Bradshaw Reservoir Pump Log Summary - 1991

Month/Day	Flows - DMR (cfs) Month Average	Daily Maximum	Pump Log Comments[a]
January	9.86	10.34	
11			pumps off - high flow EBPC
12			restart
February	10.00	10.04	
March	9.87	10.00	
April	21.70	38.44	
May	42.16	44.49	
June	49.27	61.13	
July	53.48	59.44	
August	56.48	59.81	
September	57.24	61.57	
19			pump trip - 1120 hours - logic control problem restart - 2310 hours
October	56.37	58.95	
November	55.94	56.89	
December	42.41	59.86	
4			pumps off - high flow EBPC
5			restart

Table 4.5-5 Bradshaw Reservoir Pump Log Summary - 1992

Month/Day	Flows - DMR (cfs) Month Average	Daily Maximum	Pump Log Comments[a]
January	18.35	42.32	
7			slow reduction to 10 cfs
February	9.50	9.86	
March	9.56	10.12	
11			pumps off - 0347 hours - high flow EBPC restart 1800 hours
27			pumps off - high flow EBPC restart same day
April	14.52	33.19	
23			slow increase in pump rate
May	33.77	47.97	
June	30.47	34.16	
4-5			pumps off - high flow EBPC
6			restart
July	48.69	56.68	
August	55.20	57.07	
September	54.48	57.13	
26			short outage due to Storm Danielle
October	48.0	57.58	
November	25.98	45.77	
3			slow reduction to 27 cfs
25			slow reduction to 10 cfs
December	9.50	10.93	conservation flow

Table 4.6-1 Mean daily East Branch Perkiomen Creek discharge (cu ft/sec) measured at the Bucks Road US Geological Survey gage in 1989.

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	1.90	3.30	2.40	17.00	1.50	1.20	2.00	0.91	0.40	23.00	24.00	35.00
02	2.00	2.60	2.00	7.80	33.00	0.96	1.50	2.10	0.48	38.00	31.00	34.00
03	2.00	3.30	2.00	8.10	7.30	0.73	1.20	13.00	0.41	28.00	32.00	34.00
04	1.60	2.40	2.00	7.10	3.90	1.60	1.20	13.00	0.36	21.00	32.00	34.00
05	0.99	1.80	2.50	5.80	18.00	0.97	25.00	11.00	0.30	21.00	31.00	34.00
06	1.00	1.70	5.70	26.00	99.00	1.40	11.00	14.00	N/A	21.00	30.00	29.00
07	1.10	1.50	5.10	12.00	26.00	19.00	5.30	11.00	N/A	21.00	30.00	26.00
08	6.90	0.99	3.40	7.00	8.60	9.90	4.50	11.00	12.00	21.00	31.00	27.00
09	6.50	0.76	3.40	5.20	5.40	44.00	2.10	10.00	11.00	21.00	37.00	30.00
10	3.30	0.59	4.50	3.90	87.00	31.00	1.50	9.60	11.00	21.00	35.00	30.00
11	2.70	0.59	9.60	3.10	41.00	5.70	1.20	10.00	11.00	19.00	32.00	28.00
12	14.00	0.54	14.00	2.60	14.00	3.10	0.80	16.00	11.00	20.00	32.00	34.00
13	11.00	0.44	8.40	2.30	8.20	24.00	10.00	91.00	N/A	21.00	31.00	26.00
14	4.40	1.90	7.20	2.00	5.50	7.00	3.60	25.00	N/A	21.00	N/A	26.00
15	42.00	7.20	7.80	13.00	4.50	13.00	1.60	151.00	N/A	21.00	N/A	26.00
16	12.00	11.00	4.90	24.00	87.00	25.00	2.80	38.00	N/A	21.00	38.00	26.00
17	6.30	3.30	3.40	8.10	64.00	12.00	3.10	28.00	N/A	32.00	29.00	26.00
18	4.50	2.10	10.00	4.40	13.00	4.90	1.90	17.00	N/A	29.00	32.00	27.00
19	4.10	1.70	8.90	4.10	6.00	2.90	2.10	10.00	25.00	75.00	32.00	26.00
20	3.50	1.60	4.60	2.90	3.80	2.10	3.50	5.10	411.00	123.00	25.00	24.00
21	2.40	58.00	27.00	2.50	2.80	20.00	2.20	6.30	37.00	34.00	12.00	20.00
22	1.60	39.00	8.40	2.20	2.10	32.00	1.50	12.00	11.00	29.00	35.00	24.00
23	1.60	12.00	4.90	1.80	3.90	46.00	1.20	2.60	10.00	21.00	34.00	N/A
24	1.60	4.80	39.00	1.60	13.00	40.00	0.81	1.60	18.00	20.00	34.00	N/A
25	1.70	2.50	24.00	1.50	5.10	10.00	0.65	0.87	24.00	16.00	34.00	24.00
26	2.10	2.30	9.20	1.50	3.10	5.00	0.69	0.66	35.00	19.00	35.00	25.00
27	3.60	2.60	5.80	1.30	4.70	19.00	0.51	0.56	24.00	20.00	35.00	26.00
28	2.30	2.20	4.50	1.10	3.20	5.60	0.43	0.56	20.00	N/A	41.00	26.00
29	2.10		3.90	1.10	1.90	7.60	0.37	0.62	21.00	N/A	36.00	N/A
30	8.80		13.00	1.60	1.50	3.00	0.33	0.63	23.00	N/A	36.00	20.00
31	6.30		38.00		1.30		1.30	0.50		22.00		N/A
Minimum	0.99	0.44	2.00	1.10	1.30	0.73	0.33	0.50	0.30	16.00	12.00	20.00
Mean	5.35	6.17	9.34	6.09	18.69	13.29	3.09	16.57	32.36	28.54	32.00	27.67
Median	2.70	2.25	5.70	3.50	5.50	7.30	1.50	10.00	11.50	21.00	32.00	26.00
Maximum	42.00	58.00	39.00	26.00	99.00	46.00	25.00	151.00	411.00	123.00	41.00	35.00

Table 4.6-2 Mean daily East Branch Perkiomen Creek discharge (cu ft/sec) measured at the Bucks Road US Geological Survey gage in 1990.

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	35.00	17.00	31.00	39.00	36.00	30.00	35.00	51.00	62.00	44.00	9.90	N/A
02	19.00	N/A	48.00	40.00	34.00	41.00	33.00	55.00	62.00	44.00	N/A	N/A
03	16.00	N/A	48.00	49.00	33.00	35.00	33.00	61.00	62.00	44.00	N/A	N/A
04	N/A	N/A	48.00	39.00	34.00	40.00	29.00	57.00	62.00	44.00	N/A	N/A
05	14.00	20.00	48.00	43.00	89.00	40.00	18.00	N/A	61.00	44.00	9.90	N/A
06	N/A	17.00	47.00	39.00	40.00	39.00	28.00	N/A	60.00	44.00	9.90	N/A
07	13.00	16.00	48.00	42.00	37.00	22.00	45.00	N/A	61.00	44.00	9.90	N/A
08	12.00	15.00	48.00	41.00	36.00	28.00	45.00	61.00	N/A	46.00	9.90	N/A
09	N/A	14.00	48.00	25.00	36.00	45.00	32.00	N/A	N/A	98.00	11.00	N/A
10	34.00	N/A	37.00	N/A	68.00	37.00	27.00	N/A	60.00	45.00	54.00	N/A
11	26.00	N/A	2.80	N/A	46.00	29.00	37.00	N/A	60.00	44.00	N/A	11.00
12	17.00	N/A	24.00	4.30	39.00	38.00	54.00	62.00	60.00	44.00	N/A	11.00
13	N/A	N/A	41.00	3.10	84.00	35.00	N/A	51.00	60.00	44.00	12.00	11.00
14	13.00	N/A	48.00	2.70	48.00	28.00	N/A	58.00	60.00	44.00	12.00	10.00
15	N/A	17.00	48.00	32.00	39.00	49.00	N/A	61.00	59.00	44.00	11.00	16.00
16	N/A	16.00	45.00	8.90	38.00	44.00	36.00	61.00	58.00	43.00	11.00	24.00
17	N/A	N/A	49.00	5.50	34.00	43.00	47.00	N/A	58.00	43.00	11.00	14.00
18	N/A	N/A	54.00	N/A	36.00	142.00	54.00	N/A	58.00	53.00	11.00	31.00
19	17.00	14.00	47.00	N/A	23.00	288.00	38.00	66.00	58.00	46.00	11.00	21.00
20	N/A	13.00	67.00	2.80	23.00	226.00	38.00	N/A	58.00	46.00	10.00	14.00
21	N/A	19.00	72.00	4.00	23.00	42.00	46.00	N/A	58.00	44.00	N/A	24.00
22	23.00	N/A	70.00	3.30	26.00	41.00	47.00	N/A	60.00	44.00	N/A	22.00
23	18.00	35.00	65.00	2.50	N/A	40.00	N/A	N/A	60.00	65.00	11.00	31.00
24	N/A	34.00	38.00	8.10	N/A	40.00	52.00	N/A	59.00	45.00	13.00	59.00
25	N/A	17.00	38.00	25.00	23.00	36.00	55.00	59.00	58.00	46.00	11.00	17.00
26	74.00	14.00	38.00	34.00	23.00	N/A	58.00	59.00	46.00	46.00	11.00	14.00
27	24.00	13.00	38.00	25.00	23.00	31.00	55.00	64.00	35.00	45.00	11.00	12.00
28	20.00	13.00	38.00	34.00	23.00	31.00	55.00	64.00	42.00	44.00	11.00	13.00
29	77.00		38.00	33.00	186.00	30.00	58.00	62.00	43.00	44.00	N/A	14.00
30	69.00		41.00	34.00	50.00	35.00	58.00	62.00	43.00	22.00	N/A	50.00
31	21.00		44.00		17.00		58.00	62.00		10.00		70.00
Minimum	12.00	13.00	2.80	2.50	17.00	22.00	18.00	51.00	35.00	10.00	9.90	10.00
Mean	28.53	17.88	45.06	24.20	43.00	55.34	43.37	59.78	56.54	45.26	12.93	23.29
Median	20.00	16.00	47.00	32.50	36.00	39.00	45.00	61.00	59.50	44.00	11.00	16.00
Maximum	77.00	35.00	72.00	49.00	186.00	288.00	58.00	66.00	62.00	98.00	54.00	70.00

Table 4.6-3 Mean daily East Branch Perkiomen Creek discharge (cu ft/sec) measured at the Bucks Road US Geological Survey gage in 1991.

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	16.00	9.20	8.10	10.00	42.00	43.00	55.00	[illegible]	59.00	56.00	57.00	58.00
02	13.00	8.60	8.20	9.60	40.00	33.00	58.00	[illegible]	59.00	N/A	57.00	58.00
03	11.00	8.70	21.00	9.00	40.00	25.00	51.00	59.00	59.00	57.00	57.00	93.00
04	10.00	8.70	36.00	8.60	[illegible]	25.00	58.00	N/A	59.00	57.00	57.00	41.00
05	9.00	8.60	15.00	8.60	43.00	23.00	59.00	59.00	51.00	57.00	57.00	N/A
06	9.70	15.00	20.00	9.40	62.00	25.00	58.00	59.00	58.00	57.00	57.00	40.00
07	11.00	26.00	27.00	11.00	53.00	25.00	50.00	59.00	54.00	57.00	57.00	44.00
08	9.20	15.00	12.00	11.00	45.00	25.00	57.00	59.00	59.00	57.00	57.00	45.00
09	N/A	11.00	10.00	16.00	44.00	34.00	N/A	60.00	60.00	57.00	57.00	46.00
10	24.00	10.00	9.60	23.00	44.00	54.00	58.00	60.00	59.00	57.00	57.00	61.00
11	15.00	9.40	9.20	26.00	44.00	58.00	58.00	60.00	60.00	57.00	57.00	49.00
12	69.00	8.60	9.00	26.00	43.00	59.00	58.00	60.00	60.00	57.00	57.00	46.00
13	27.00	8.60	9.00	23.00	40.00	58.00	50.00	59.00	60.00	57.00	57.00	48.00
14	14.00	15.00	10.00	23.00	43.00	58.00	58.00	58.00	54.00	57.00	57.00	47.00
15	14.00	11.00	18.00	25.00	45.00	57.00	58.00	58.00	60.00	57.00	57.00	34.00
16	78.00	8.70	13.00	26.00	44.00	53.00	59.00	58.00	60.00	58.00	57.00	44.00
17	36.00	8.10	10.00	26.00	43.00	56.00	58.00	58.00	60.00	66.00	57.00	44.00
18	15.00	8.10	38.00	28.00	44.00	58.00	57.00	58.00	N/A	60.00	57.00	43.00
19	12.00	11.60	18.00	25.00	44.00	58.00	45.00	46.00	21.00	58.00	57.00	N/A
20	11.00	19.00	12.00	25.00	43.00	58.00	41.00	48.00	53.00	58.00	56.00	N/A
21	13.00	11.00	10.00	81.00	43.00	58.00	42.00	49.00	58.00	46.00	58.00	N/A
22	10.00	9.90	9.50	42.00	33.00	58.00	43.00	56.00	58.00	52.00	82.00	N/A
23	9.40	8.90	29.00	32.00	39.00	58.00	36.00	58.00	58.00	57.00	60.00	N/A
24	9.00	8.30	21.00	44.00	41.00	58.00	47.00	58.00	59.00	57.00	62.00	N/A
25	8.50	8.60	15.00	37.00	41.00	59.00	50.00	58.00	57.00	57.00	60.00	N/A
26	8.10	8.60	12.00	N/A	41.00	58.00	41.00	56.00	58.00	57.00	60.00	N/A
27	8.10	8.30	22.00	27.00	42.00	58.00	55.00	52.00	58.00	36.00	58.00	N/A
28	8.40	8.10	15.00	26.00	[illegible]	57.00	59.00	52.00	57.00	40.00	58.00	N/A
29	8.30		11.00	24.00	43.00	45.00	58.00	53.00	57.00	57.00	58.00	N/A
30	9.00		16.00	36.00	40.00	49.00	58.00	53.00	54.00	57.00	58.00	N/A
31	14.00		11.00		40.00		59.00	[illegible]		55.0[illegible]		N/A
Minimum	8.10	8.10	8.10	8.60	33.00	23.00	36.00	46.00	21.00	36.00	56.00	34.00
Mean	17.06	10.71	15.63	24.77	43.06	48.10	53.13	56.40	56.52	55.60	58.43	49.47
Median	11.00	8.80	12.00	25.00	43.00	57.00	57.50	58.00	58.00	57.00	57.00	46.00
Maximum	78.00	26.00	38.00	81.00	62.00	59.00	59.00	60.00	60.00	66.00	82.00	93.00

Table 4.6-4 Mean daily East Branch Perkiomen Creek discharge (cu ft/sec) measured at the Bucks Road US Geological Survey gage in 1992.

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
01	43.00	11.00	12.00	13.00	33.00	35.00	N/A	58.00	56.00	58.00	44.00	13.00
02	43.00	11.00	12.00	12.00	41.00	N/A	30.00	N/A	56.00	58.00	44.00	13.00
03	43.00	11.00	12.00	12.00	47.00	34.00	34.00	39.00	51.00	55.00	54.00	12.00
04	N/A	11.00	12.00	12.00	47.00	N/A	35.00	58.00	45.00	56.00	32.00	12.00
05	N/A	11.00	11.00	N/A	47.00	N/A	36.00	58.00	54.00	57.00	31.00	13.00
06	N/A	11.00	11.00	11.00	40.00	N/A	43.00	58.00	56.00	58.00	37.00	12.00
07	N/A	11.00	16.00	11.00	29.00	35.00	43.00	58.00	56.00	58.00	31.00	12.00
08	N/A	10.00	16.00	N/A	35.00	31.00	43.00	58.00	56.00	53.00	29.00	12.00
09	N/A	10.00	13.00	N/A	38.00	N/A	44.00	58.00	56.00	58.00	28.00	12.00
10	N/A	10.00	21.00	11.00	48.00	N/A	42.00	48.00	55.00	52.00	28.00	12.00
11	N/A	10.00	62.00	12.00	35.00	N/A	51.00	43.00	55.00	62.00	28.00	213.00
12	N/A	9.30	19.00	11.00	33.00	N/A	55.00	47.00	56.00	63.00	28.00	N/A
13	N/A	10.00	15.00	11.00	32.00	N/A	54.00	56.00	56.00	60.00	61.00	N/A
14	N/A	10.00	13.00	11.00	31.00	N/A	51.00	58.00	56.00	57.00	33.00	17.00
15	18.00	14.00	12.00	10.00	30.00	N/A	50.00	58.00	56.00	28.00	30.00	15.00
16	15.00	20.00	12.00	10.00	34.00	33.00	56.00	58.00	55.00	40.00	29.00	14.00
17	13.00	13.00	11.00	11.00	N/A	33.00	58.00	58.00	56.00	57.00	28.00	75.00
18	13.00	13.00	N/A	12.00	32.00	33.00	48.00	51.00	56.00	33.00	26.00	23.00
19	13.00	16.00	N/A	13.00	32.00	33.00	57.00	56.00	56.00	28.00	27.00	18.00
20	12.00	16.00	16.00	11.00	32.00	33.00	58.00	58.00	56.00	28.00	27.00	19.00
21	12.00	14.00	17.00	11.00	32.00	34.00	58.00	58.00	56.00	28.00	27.00	16.00
22	12.00	13.00	16.00	16.00	32.00	33.00	58.00	58.00	56.00	34.00	31.00	15.00
23	18.00	13.00	18.00	27.00	32.00	N/A	58.00	57.00	56.00	44.00	121.00	14.00
24	23.00	13.00	16.00	30.00	32.00	N/A	59.00	57.00	56.00	44.00	41.00	14.00
25	13.00	14.00	16.00	34.00	32.00	N/A	59.00	56.00	56.00	44.00	36.00	13.00
26	12.00	29.00	36.00	34.00	32.00	34.00	58.00	56.00	33.00	44.00	21.00	13.00
27	11.00	16.00	38.00	31.00	32.00	34.00	59.00	56.00	54.00	44.00	21.00	12.00
28	11.00	14.00	18.00	26.00	32.00	34.00	59.00	56.00	57.00	44.00	16.00	12.00
29	11.00	13.00	15.00	26.00	32.00	33.00	58.00	56.00	56.00	44.00	14.00	13.00
30	11.00		13.00	28.00	32.00	N/A	58.00	56.00	57.00	44.00	14.00	16.00
31	11.00		14.00		40.00		N/A	56.00		44.00		17.00
Minimum	11.00	9.30	11.00	10.00	29.00	31.00	30.00	39.00	33.00	28.00	14.00	12.00
Mean	17.90	13.01	17.69	16.93	35.20	33.47	50.76	55.27	54.60	47.74	33.97	23.17
Median	13.00	13.00	15.00	12.00	32.00	33.00	55.00	57.00	56.00	44.00	29.00	13.00
Maximum	43.00	29.00	62.00	34.00	48.00	35.00	59.00	58.00	57.00	63.00	121.00	213.00

Table 4.7-1 Erosion monitoring station locations

No.	General Location
3	350 feet downstream of USGS gage (Bucks Road)
4	Immediately downstream of USGS gage (Bucks Road)
7A	650 feet upstream of USGS gage (Bucks Road)
9	1,350 feet upstream of USGS gage (Bucks Road)
12	500 feet downstream of Elephant Road
12A	200 feet downstream of Elephant Road
13A	200 feet upstream of Elephant Road
13B	300 feet upstream of Elephant Road
14A	200 feet upstream of outfall

Table 4.9-1 Elements of the trout stock fishery on the East Branch Perkiomen Creek, 1987-1992 (Harvest and effort estimates apply to surveyed periods only)

	1987	1988	1989	1990	1991	1992
Number of trout stocked	6,000	9,495	10,700	14,200	12,000	12,000
Number of trout stocked (pre-season)	2,300	2,200	2,200	2,200	2,200	2,200
% of pre-season stocking harvested during opening weekend	91%	79%	99%	97%[1]	92%	88%
Number of survey days (includes half days)	5	9	23	12	18	18
Number of days between opening date and last survey date	10	30	44	58	37	38
Date of last survey[2]	25 April	15 May	28 May	10 June	19 May	25 May
Angler-hours-opening day (Area I only)	2,894	3,671	2,656	5,882	4,696	3,508
Angler-hours for season (Areas I, II, III[3])	6,618	11,157	14,811	10,192	14,189	13,749

[1]Harvest based on opening day only - virtually all fish were caught that day.
[2]Date by which angler effort and harvest rate had declined to low levels, usually about 0.1 trout/hr and 50 angler-hrs per day, respectively.
[3]Area III was first stocked in 1989 and continues to be stocked annually.

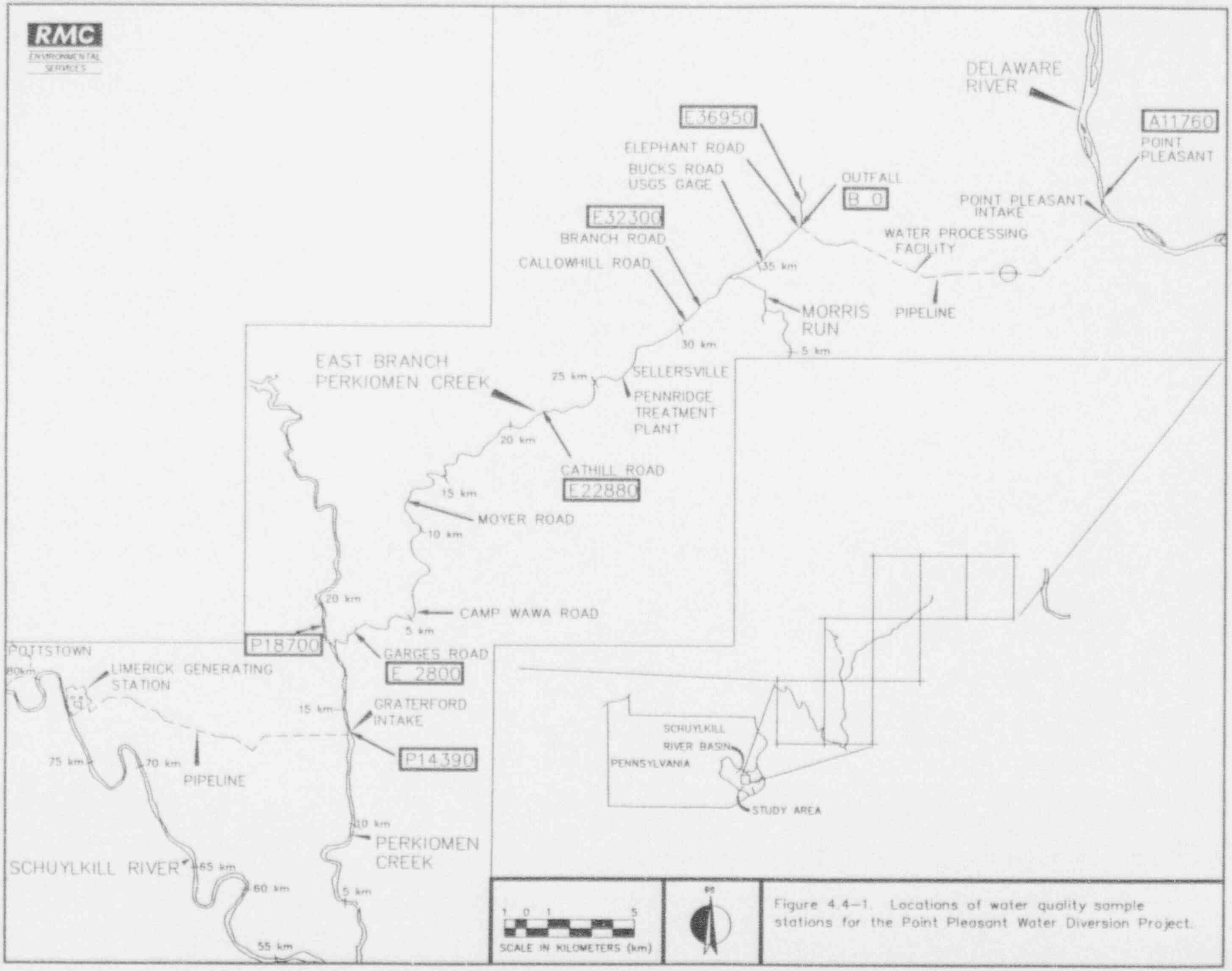

Figure 4.4-1. Locations of water quality sample stations for the Point Pleasant Water Diversion Project.

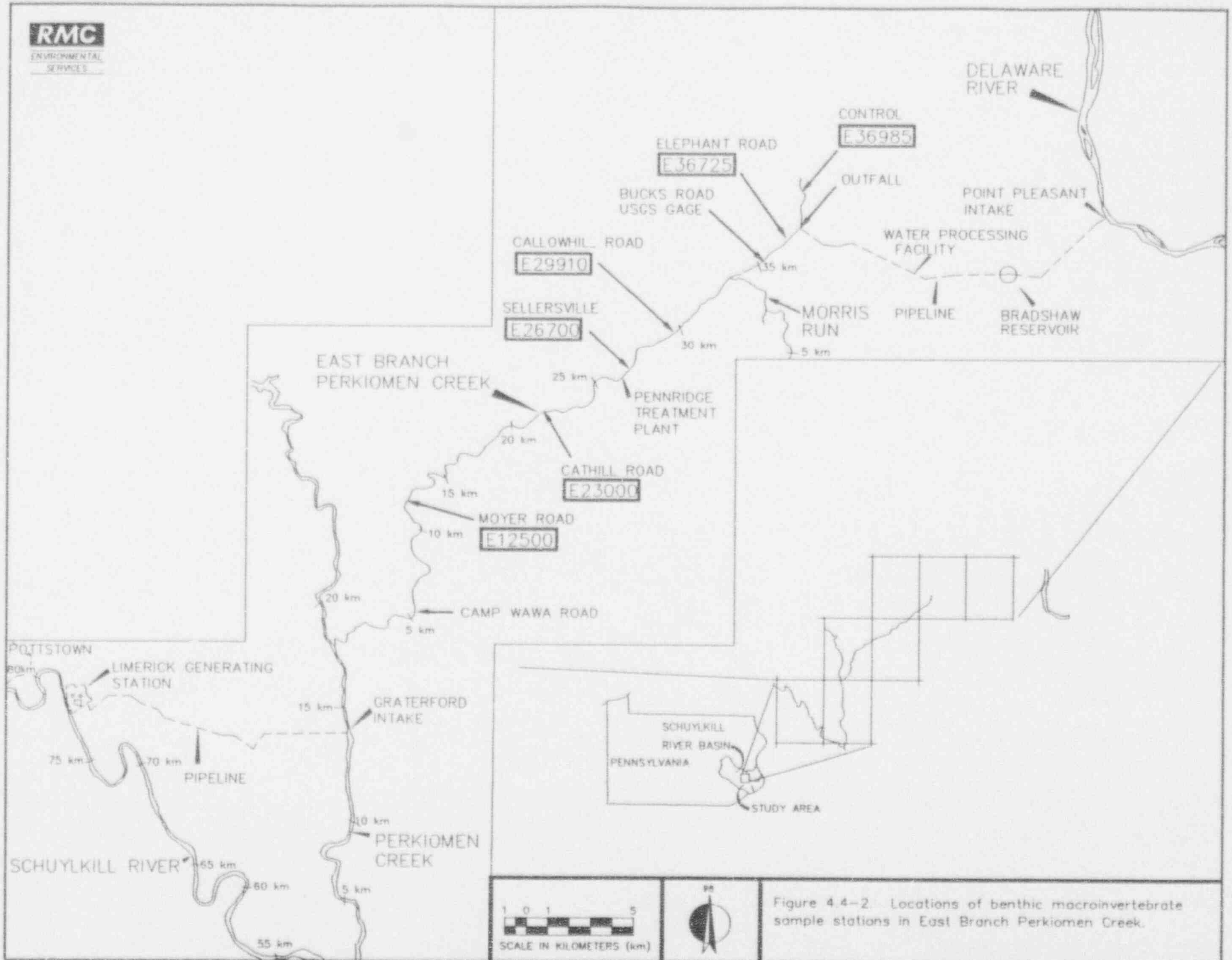

Figure 4.4-2. Locations of benthic macroinvertebrate sample stations in East Branch Perkiomen Creek.

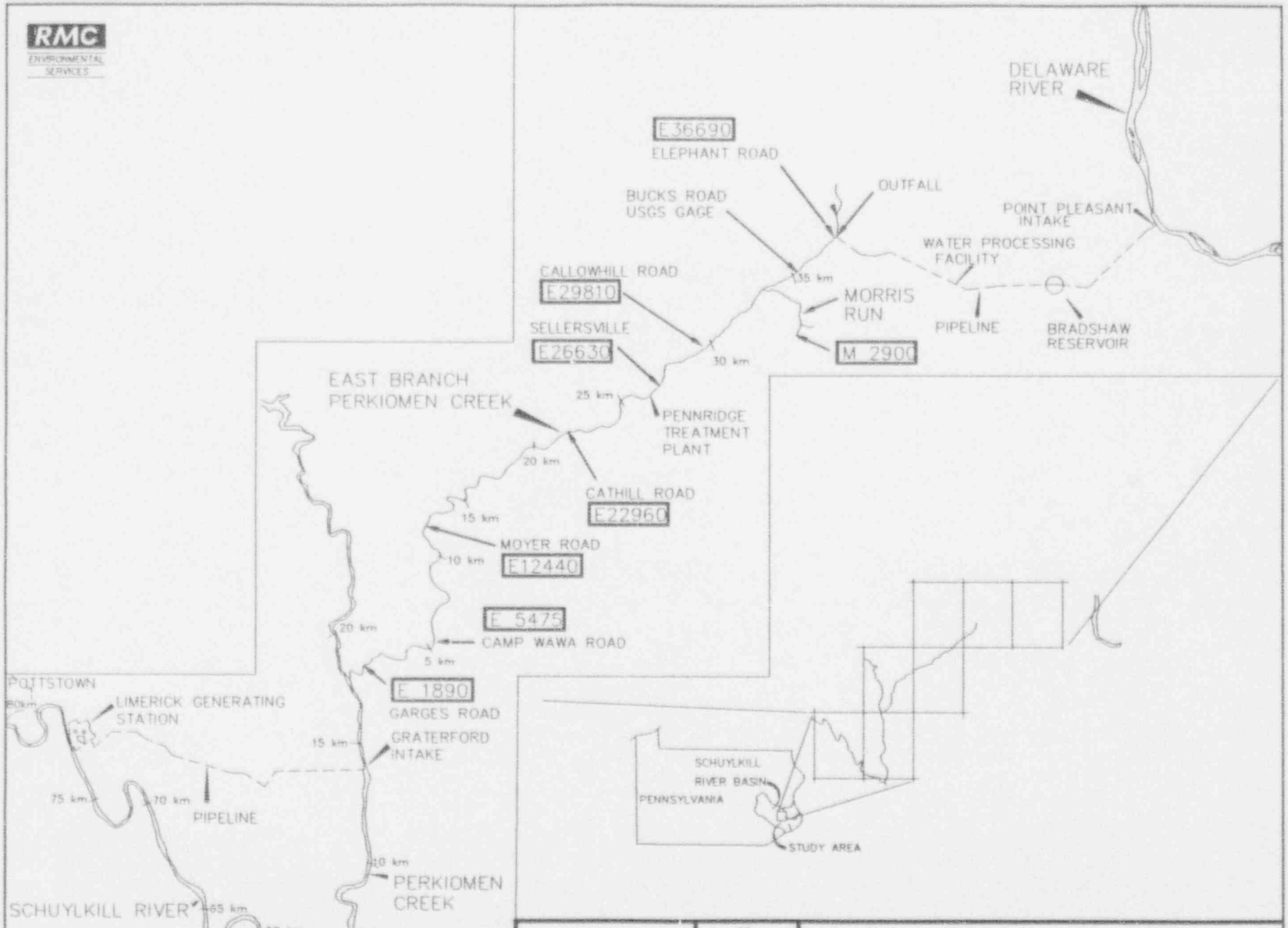

Figure 4.4–3. Locations of fish seine stations in East Branch Perkiomen Creek.

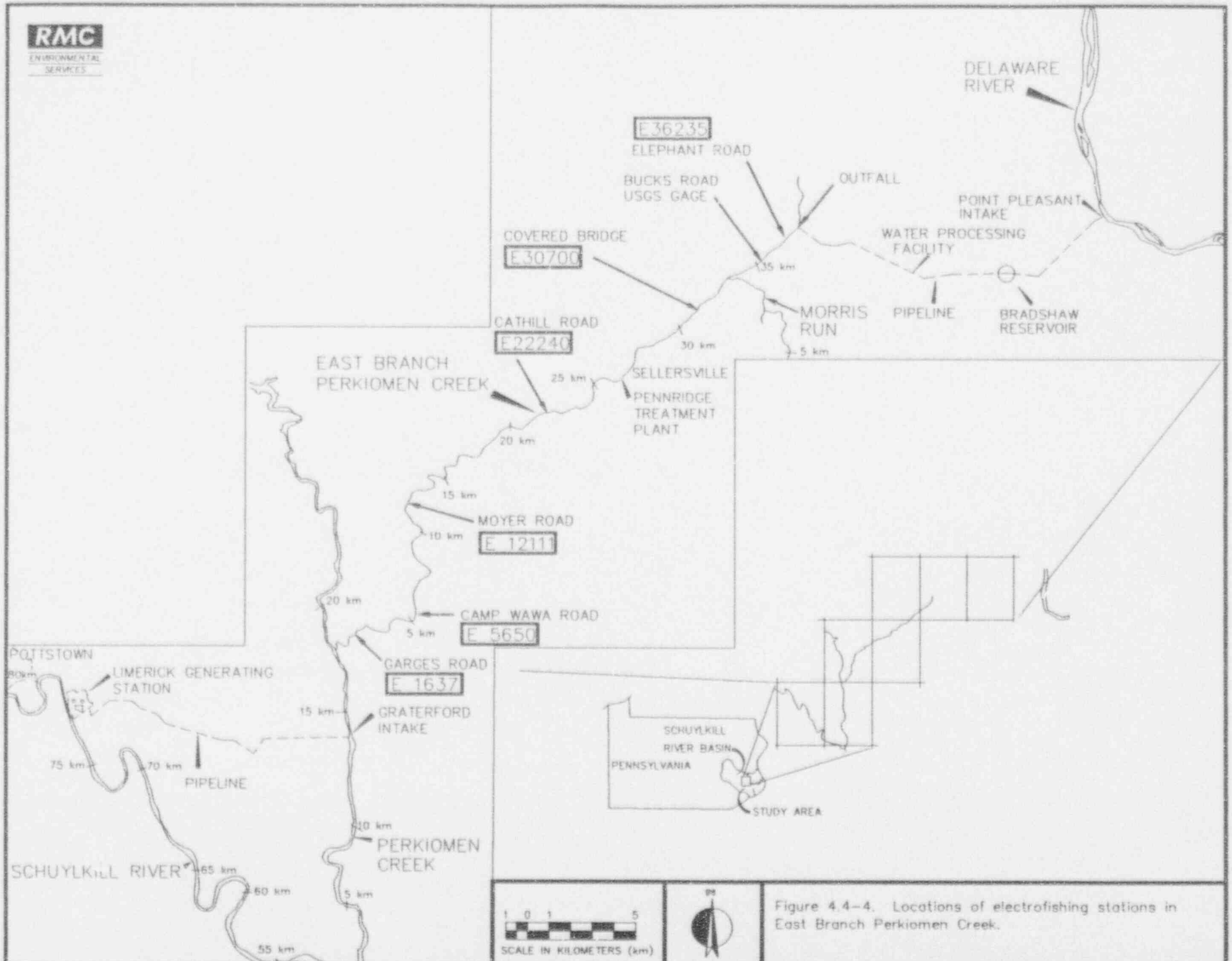

Figure 4.4-4. Locations of electrofishing stations in East Branch Perkiomen Creek.

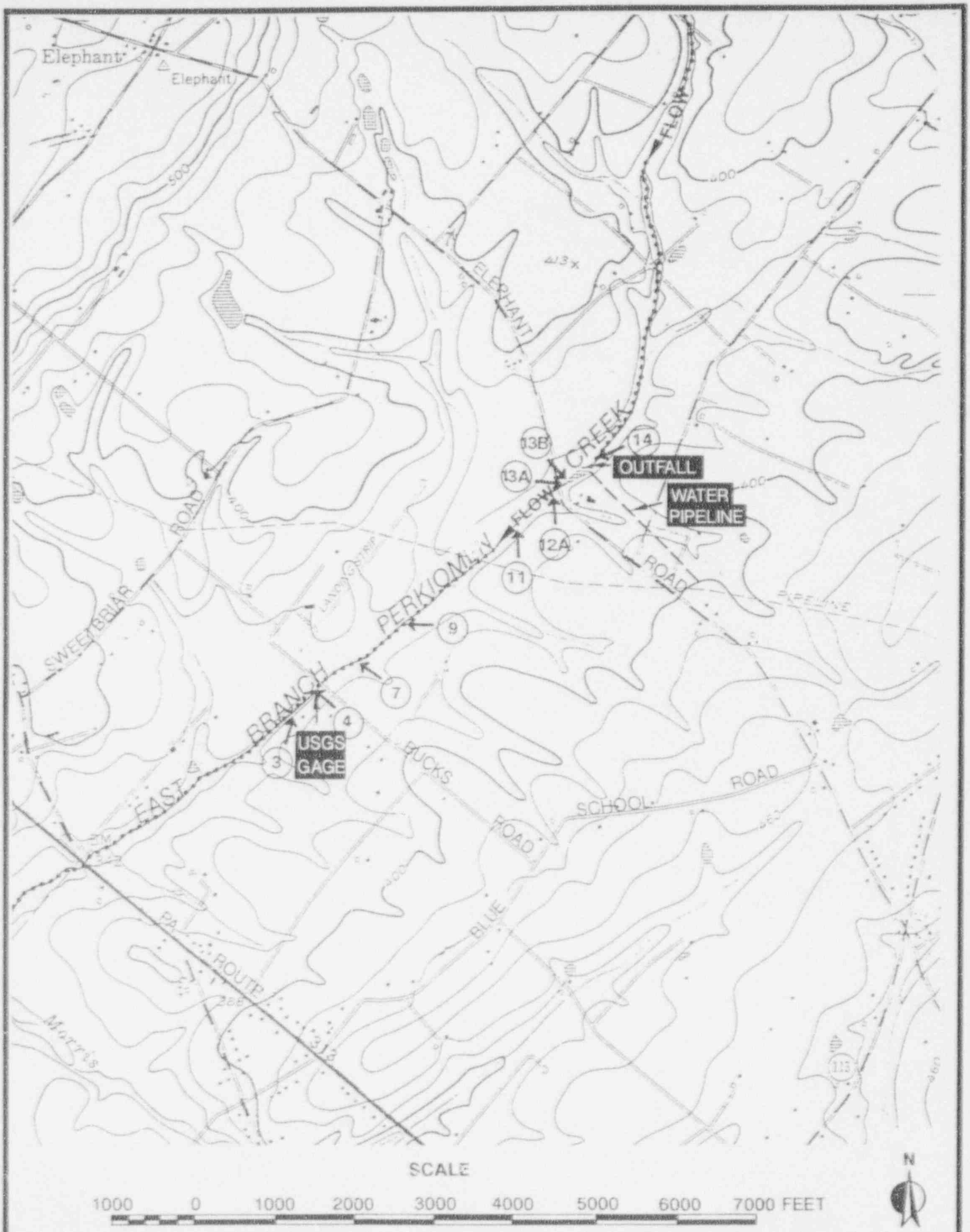

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Figure 4.7-1 VICINITY MAP. SEDIMENTATION AND EROSION MONITORING TRANSECTS.

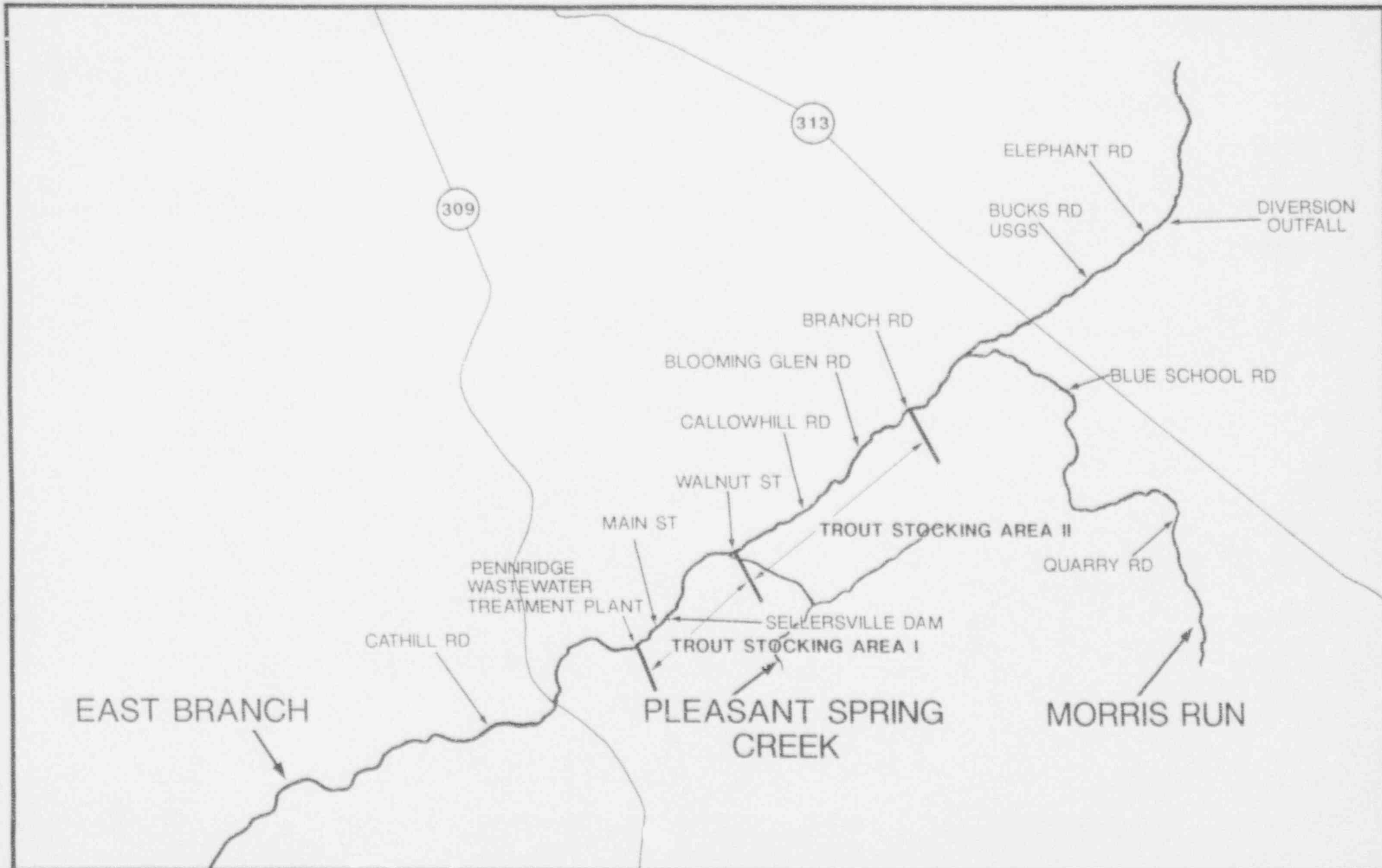

FIGURE 4.9-1 **TROUT STOCKING AREAS I AND II (PFBC)**

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5.0 DECISION CRITERIA

The section below specifies the decision criteria to be applied for this thermal variance. These criteria were developed by PECo and approved by the PA DER. The thermal variance demonstration will be a combination Type I, Type II demonstration: Type I defined as the absence of prior appreciable harm and Type II defined as protection of Representative Important Species. The following list of decision criteria was developed as applicable to the Bradshaw Reservoir 316(a) thermal variance request.

- Warmwater RIS (smallmouth bass, white sucker, and spotfin shiner)
  1. reproductive success and growth

- Trout RIS (rainbow trout and brown trout)
  1. preclusion of trout stock fishery
  2. exclusion from unacceptably large area
  3. survival and harvest

Each of these decision criteria is more fully described below.

5.1 Warmwater RIS Reproductive Success and Growth

It will be the intent of the thermal variance request to demonstrate, through comparisons of the thermal regime in Study Case I (no diversion/no chilling) and Study Case II (diversion without chilling), that the deletion of thermal limits will not eliminate or impair existing use of the stream for successful reproduction or growth of the following warmwater RIS fishes: smallmouth bass, white sucker, and spotfin shiner. The decision criterion will be the quantitative and qualitative demonstration of similar reproductive success and growth history when comparing Study Case I versus Study Case II. The comparisons will be made using the observed and predicted thermal regimes for each study case, pre-diversion (Study Case I) observations of RIS fish reproductive success and growth history, a comparison of Study Case II thermal regime with the observed reproductive success and growth history of Delaware River fish (which exist in a thermal regime similar or identical to Study Case II), and lastly a comparison of published observations of reproductive success and growth history of smallmouth bass, white sucker, and spotfin shiner compared to the predicted and observed study case II thermal regime. A successful demonstration of the criterion will be the continued, substantially similar reproductive success and growth for Study Case II as was observed and described in Study Case I. An unsuccessful demonstration of the criterion will be elimination of RIS species due to Study Case II thermal regime or an observation of significantly lower reproductive success or growth history attributable to Study Case II thermal regime.

5.2 Trout RIS

Three decision criteria apply to the representative important species brown trout and rainbow trout, which are the fish released by the Pennsylvania Fish and Boat Commission (PFBC) for the trout stocked fishery in the East Branch Perkiomen Creek.

5.2.1. Preclusion of Trout Stock Fishery

This decision criterion relates to the preclusion of a trout stock fishery (TSF) when comparing the thermal regimes of Study Case I versus Study Case II. The study will evaluate Study Case II for feasibility of a TSF against PFBC guidelines for an acceptable stream reach for trout stocking. A successful demonstration of the criterion will result if a trout stocked fishery is feasible (i.e. not excluded or absent) as a result of thermal modification attributable to Study Case II to the same extent as it was feasible under Study Case I.

5.2.2. Exclusion from Unacceptably Large Area

This criterion deals with exclusion from an unacceptably large area as a result of thermal modification of the study area when comparing Study Case II versus I. The study will evaluate the quantity of acceptable TSF habitat available for Study Case I and Study Case II based on PFBC guidelines and other published criteria. A successful demonstration of the decision criterion will result if the length of stream reach with a thermal regime acceptable for stocked trout survival and harvest under Study Case II is not materially smaller than the area acceptable habitat under the Study Case I thermal regime.

5.2.3. Survival and Harvest

Decision criterion 3 for trout is concerned with the survival and harvest of stocked trout during the period 1 March through 31 July. Extensive observations of trout survival and harvest exist for Study Case I. The study will estimate trout survival and harvest for Study Case II based on Study Case I creel surveys and thermal modifications to stream reach expected for Study Case II. A successful demonstration will result if Study Case II trout survival and availability for harvest is similar both in duration and quantity to that of Study Case I. More specifically, when evaluating this criterion for a successful demonstration: (1) in terms of time, no material detrimental effect will be observable on the timing and duration of trout stocked fishery survival and harvest under Study Case II as compared with Study Case I, (2) in terms of quantity, similar numbers of trout will be available in Study Case II as were available in Study Case I assuming the PFBC makes similar numbers available for stocking.

5.3 Final Evaluation of Decision Criteria

If a successful result is obtained for the Warmwater RIS and Trout RIS Decision Criteria as presented above, then the NPDES permit will be modified to eliminate all thermal limits for discharge of Bradshaw Diversion water to the East Branch Perkiomen Creek.

6.0 TEMPERATURE MODELLING STUDY

The purpose of the temperature model of the upper reach of the East Branch is to provide credible estimates of water temperature for past and future flow and meteorological conditions for two cases: no diversion and diversion without cooling. In particular, the model provides (1) detailed daily means, maxima, minima and rates of change of temperature along the study reach for 1983 to 1992, for which a complete set of observations are not available; and, (2) detailed temperatures for an examination of spatial and temporal distributions at different diversion flows (10, 27 and 54 cfs) for comparison to the no diversion case.

The computed temperatures, along with temperature observations, are to be used in conjunction with data on the aquatic community to assess the impact of the temperature regimes for the two cases. The following table summarizes operating conditions and data availability over time for the temperature study.

SOURCES OF TEMPERATURE DATA				
Operating conditions	Period			
	10/83 to 7/89	8/89 to 4/92	5/92 to 9/92	Projections into the future
No diversion	**bi-weekly observations, except 1988;** modelled	modelled		modelled
Diversion with cooling[1]	not required	**bi-weekly observations**	**intensive observations**	not required
Diversion without cooling	modelled	modelled		modelled

[1]Please note that Diversion with cooling is not evaluated as a study case, but 1992 observations were used to develop the temperature model.

The bi-weekly observations consist of temperature observations made by RMC coincident with biological monitoring. The intensive observations include continuous, hourly average flow records, temperatures and meteorological data at 12 stations within the study reach. The intensive data collection effort is reported in AATA (1992a).

The modelled reach extends 10 km downstream from the outfall of the East Branch Transmission Main (EBTM) on the upper East Branch to the Main Street bridge in Sellersville (Figure 3.2-1). As described in RMC (1989a), this reach of the East Branch has a low gradient and is dominated by riffle and run regimes with man-made pools at the lower end. Natural mean monthly flows range from 0 to 15 cfs, as measured at the Bucks Road USGS gage located in the upper part of the study reach.

The model was applied to and calibrated for the period of intensive observations (5/92 to 9/92) using the two onsite meteorological stations installed at each end of the East Branch study reach, as well as observed flows and temperatures. The model is described in Section 6.1; application and calibration of the model to the East Branch is described in Section 6.2.

The completed model was then applied to the historical period (8/83 to 9/92), which included both pre- and post-diversion operating conditions. The application of the model to the historical period required the development of a sub-model that provides time varying boundary condition data to the model. The most important boundary condition data are the temperatures of the outfall at the head of the East Branch. These boundary condition data were directly observed during the intensive data collection period, but needed to be computed from indirect data for the model application to the historical period.

A sub-model was developed to compute the temperature of Delaware River water piped to and stored in Bradshaw Reservoir and subsequently discharged to the East Branch. This sub-model makes use of meteorological data to compute surface heat exchange in Bradshaw Reservoir. Because of its small size and retention time, a fully-mixed computation could be used to compute the Bradshaw Reservoir heat budget. The sub-model was calibrated using Bradshaw Reservoir temperature observations. Other components of the sub-model include an estimator for Point Pleasant intake temperatures; a computation of heat transfer through the walls of the East Branch Transmission Main; computation of lag times through both segments of the EBTM; and, an estimator of headwater and tributary temperatures. The sub-model also is described in Section 6.2.

Model results are summarized in Section 6.3; they are discussed in Section 7.1.

6.1 Model Description

The model divides the East Branch study reach into 20 equal length segments in each of which flows and temperatures are computed. The segment flows and temperatures also vary in time and the model computes these values hourly, beginning from an observed initial condition. To carry the computations through time, boundary condition data that describe the changing rates and temperatures of inflows to the system (e.g., the diversion) and the changing weather conditions must be supplied to the model. For the period of intensive observations (5/92 to 9/92) for which the model was calibrated, these boundary condition data were measured. For the historical period (10/83 to 9/92) for which simulations of various diversion rates were made, some of the boundary condition data needed to be synthesized from other sources. In particular, meteorological data from an offsite source needs to be assessed, and the temperature of the diversion water as it travels from Point Pleasant to Bradshaw Reservoir and from Bradshaw to the outfall needs to be computed from meteorological data, bathymetric data at Point Pleasant and in Bradshaw, and pipeline length, diameter and materials.

The following sections describe the heat transport computation that is basis of the model, the computation that relates depth and width in the model to flows, and the calculation of the transfer of heat exchange at the water surface which is the dominant heat exchange process for surface water flows. The series of computations used to compute the diversion temperature are described in the last section.

6.1.1 Heat Transport Computation

For purposes of temperature modelling, the East Branch Perkiomen Creek can be considered a narrow, mildly sloped stream. Temperatures are nearly uniform laterally and vertically along the channel in comparison to the longitudinal and temporal temperature variations being studied. The appropriate model for this situation is the one-dimensional, time varying advective heat transport model as given in Edinger, et al. (1974). The model has been used and refined since its derivation and is, for example, the basis of the heat transport model published in Chaudhry, et al. (1983). It has been further developed and maintained by JEEAI through numerous applications.

The basic formulation of the one-dimensional advective heat transport model is

$$\partial(DT)/\partial t + \partial(QT)/\partial A = R_n/(\rho \cdot Cp) + q_t \cdot T_t/A \tag{1}$$

where T is the water temperature (C); D is the temporally and spatially varying depth (m); Q is the temporally and spatially varying flow ($m^3\ s^{-1}$); A is the time varying surface area of a stream segment (m^2); R_n is the net rate of surface heat exchange ($W\ m^{-2}$); q_t is the tributary inflow rate ($m^3\ s^{-1}$); T_t is the tributary inflow temperature (C); ρ is the density of water (1000 $kg\ m^{-3}$) and Cp is the specific heat of water (4186 $J\ kg^{-1}\ C^{-1}$).

In Equation 1, the first term on the left is the change in heat storage with time and the second term is the difference in heat flow out of and into a segment. On the right hand side, the first term is surface heat exchange and the second term is tributary inflow.

Equation 1 is solved using an implicit computational procedure that allows realistic time steps over short stream reaches relative to the surface heat exchange computations. The implicit computation accommodates both low and high stream flows without the need to use very small time steps. The implicit computational form of Equation 1 is developed for stream segments numbered from i=1 in the head waters with i increasing downstream. The present time variables (those being computed on the new time step) are identified by a prime ('). With these assumptions, Equation 1 becomes

$$\begin{aligned}&[D'(i) \cdot T'(i) - D(i) \cdot T(i)]/\Delta t + [Q'(i) \cdot T'(i) - Q'(i-1) \cdot T'(i-1)]/\Delta A'(i)\\ &\quad = R_n'(i)/\rho Cp + q_t'(i) \cdot T_t'(i)/\Delta A'(i)\end{aligned} \tag{2}$$

which can be solved directly to iterate for T'(i) in the downstream direction as

$$\begin{aligned}T'(i) = {} &[D(i) \cdot T(i)/\Delta t + Q'(i-1) \cdot T'(i-1)/\Delta A'(i) + R_n'(i)/\rho Cp\\ &+ q_t'(i) \cdot T_t'(i)/\Delta A'(i)]/[D'(i)/\Delta t + Q'(i)/\Delta A'(i)]\end{aligned} \tag{3}$$

where Q'(1) and T'(1) are specified at the head of the stream reach as known boundary conditions.

6.1.2 Geometry and Flow Computation

Within each segment, the model requires the segment surface area and depth as a function of flow. These geometric properties can be determined from time varying hydraulic flow computations (Quick and Pipes, 1975; Chaudhry, et al., 1983) or, for short reaches, from field measurements. For the East Branch Perkiomen Creek, the geometry was determined as a function

of flow from field measurements of channel cross-section obtained during an instream flow study and additional cross-sectional measurements. The depth (D) and width (W) are related to flow using the following relationships (Richards, 1982)

$$D = aD \cdot (Q)^{bD} \tag{4}$$

$$W = aW \cdot (Q)^{bW} \tag{5}$$

The surface area of each segment, $\Delta A(i)$, is determined as $W(i) \cdot \Delta x(i)$ where $\Delta x(i)$ is the length of the segment. The segment length can vary along the stream.

The flows are iterated downstream as

$$Q'(i) = Q'(i-1) + q_t'(i) - \Delta x(i) \cdot dD(i)W(i)/\Delta t \tag{6}$$

where the last term is the change in storage in the reach and $q_t'(i)$ is the tributary inflow. The tributary inflows $q_t'(i)$ are determined from either gaged flows such as the diversion and the Morris Run flow or by proportioning drainage areas to the drainage areas of known gaged flows.

The downstream flow out of the segment, $Q'(i)$, is iterated from Equations (4), (5) and (6) using a Newton-Raphson technique that is solved in the following manner. The null function from Equation 6 is

$$\begin{aligned} F(Q'(i)) &= Q'(i) - Q'(i-1) - q_t'(i) \\ &+ \Delta x(i)/\Delta t \cdot (aD(i) \cdot aW(i))(Q'(i))^{(bD+bW)} - \Delta x(i)/\Delta t \cdot D(i) \cdot W(i) \end{aligned} \tag{7}$$

where $D(i)$ and $W(i)$ are the depth and width of the segment at the old time step. The derivative function is

$$F'(Q'(i)) = 1 + \Delta x(i)/\Delta t(aD \cdot aW) \cdot (bD + bW) \cdot (Q'(i))^{(bD+bW-1)} \tag{8}$$

from which the increment of $Q'(i)$ on each iteration is determined from $F(Q'(i))/F'(Q(i))$.

6.1.3 Surface Heat Exchange Computation

The net rate of surface heat exchange, R_n in Equation 1, is computed for each segment within the computational time steps of Equation 3 so that the non-linear processes of surface heat exchange are accurately evaluated. Surface heat exchange is incorporated in the model using the term by term surface heat exchange relationship. For this relationship, the net rate of surface heat exchange is given as

$$R_n = (R_s + R_a - R_{sr} - R_{ar}) - (R_b + R_e + R_c) \tag{9}$$

where R_n ($W\ m^{-2}$) is the net rate of surface heat exchange; R_s is incoming shortwave radiation; R_a is incoming atmospheric radiation; R_{sr} and R_{ar} are reflected shortwave and longwave radiation; R_b is back radiation from the water surface; R_e is evaporative heat loss; and, R_c is conductive heat exchange. The individual terms are evaluated from the meteorological data of shortwave solar radiation, cloud cover, air temperature, dew point temperature, windspeed and atmospheric pressure. The methods of evaluation of the terms in Equation 9 are from Wunderlich (1972),

Edinger, et al. (1974), Jirka, et al. (1978), Octavio, et al. (1980), Adams, et al. (1987) and Adams, et al. (1990).

The short-wave solar radiation rate, R_s, is either measured with a pyroheliometer, as during the May through September 1992 intensive data collection period, or is computed from relationships based on solar angle, the solar constant, opacity and cloud cover as given in Wunderlich (1972); Paily, et al., (1974); Ryan and Stolzenbach (1972); Kerr (1986); and, Environmental Protection Agency (1971). For a stream R_s needs to be corrected for each segment for canopy cover which may vary with the season. Canopy cover for the upper East Branch has been estimated on various occasions by RMC (1991). The reflected portion of short-wave solar radiation, R_{sr}, is computed as a function of solar angle.

The long-wave atmospheric radiation, R_a, is computed from the black-body radiation law as empirically corrected for atmospheric moisture content. The reflected long-wave atmospheric radiation, R_{ar}, is taken as a fraction of R_a. Back radiation from the water surface, R_b, is computed from the fourth-power black-body radiation law and is a function of the water surface temperature.

Evaporative heat loss, R_e, is computed from the relationship of

$$R_e = f(W) \cdot (es(T) - ea) \quad (10)$$

where f(W) is the evaporative wind speed function, es(T) is the saturation vapor pressure at the water surface and ea is the atmospheric vapor pressure. The saturation vapor pressure at the water surface is a complex function of water surface temperature and atmospheric pressure. The atmospheric vapor pressure is a function of dew point temperature and atmospheric pressure or relative humidity and air temperature.

Conductive heat loss, R_c, is computed from the relationship of

$$R_c = Cb \cdot f(W) \cdot (T - Ta) \quad (11)$$

where Cb is the Bowen ratio, f(W) is the evaporative windspeed function, T is the water surface temperature, and Ta is the air temperature.

The evaporative wind speed function, f(W), has many different forms depending on the particular application, and the windspeed itself, W, may require adjustment between an observation point and the stream segments being modelled. A field investigation of the meteorological stations on the upper East Branch indicated that the anemometers are subject to the same type of wind shading as the stream and corrections to the windspeed would not be required. It is expected that periods of low and zero wind speeds are an important part of the record and a wind speed function should be chosen that is not zero at zero wind-speed. The evaporative wind speed function which most closely fits these requirements is the Brady, Graves and Geyer function (Edinger, et al., 1974).

6.1.4 Bradshaw Reservoir Sub-Model Description

This sub-model computes the change in temperature of Delaware River water in transit from the Point Pleasant intake to the outfall at the upper end of the East Branch study reach. The components of the model are the estimation of Point Pleasant intake temperatures, surface heat

exchange in Bradshaw Reservoir, and heat transfer to and from the soil surrounding the pipeline. Additionally, estimates of headwater and tributary temperatures are required for the historical period simulations.

Bradshaw Reservoir

The Bradshaw Reservoir is modelled as a fully-mixed waterbody. The rate of change in temperature and volume can be written in terms of the inflows and outflows and net rate of surface heat exchange as

$$\frac{d(V_b T_b)}{dt} = Q_i T_i - Q_o T_o + \frac{R_n A}{\rho c_p} \tag{12}$$

and

$$\frac{dV_b}{dt} = Q_i - Q_o \tag{13}$$

where V_b is the Bradshaw Reservoir volume (110×10^3 m^3); T_b is the Bradshaw Reservoir temperature (C); Q_i, T_i is the Delaware River pumping to Bradshaw Reservoir (m^3 s^{-1}) and temperature (C); Q_o, T_o is the Bradshaw Reservoir withdrawal rate (m^3 s^{-1}) and temperature (C); R_n is the net rate of surface heat exchange as a function of shortwave solar radiation, air temperature, dew point temperature, wind speed, water surface temperature and surface area (W m^{-2}); ρ is the density of water (1000 kg m^{-3}); and, C_p is the specific heat of water at constant pressure (4186 J kg^{-1} C^{-1}).

Since the EBTM system is operated so that the volume of Bradshaw is very nearly constant, Equation 13 is not needed and Equation 12 reduces to

$$D_b \frac{dT}{dt} = \frac{QT_i - QT_o}{A} + \frac{R_n}{\rho c_p} \tag{14}$$

where D_b is the Bradshaw Reservoir average depth (4 m); Q is the pumping rate through Bradshaw Reservoir (m^3 s^{-1}); and A_b is the Bradshaw Reservoir area (27.7×10^3 m^2).

This equation is solved numerically by integrating forward in time. The temperature from the Delaware River to Bradshaw Reservoir is corrected for time of travel through the pipeline as is the temperature from Bradshaw Reservoir to the East Branch outfall.

Heat Transfer Through the EBTM

Heat transfer computations through the walls of the EBTM between the water and the ground were developed for inclusion in the sub-model. The model for heat exchange along the pipeline is

$$\rho c_p \cdot Q \cdot dT/dl = \pi \cdot Dp \cdot Kp \cdot (Tg-T)/tp \qquad (15)$$

where Dp is the pipeline diameter; Kp is the heat conductivity of the wall of the pipe; tp is the pipe wall thickness; and, Tg is the ground temperature. For a source water temperature of Ts (at the Delaware or Bradshaw Reservoir) and for a constant ground temperature, the temperature at the end of the pipeline is

$$T = Ts \cdot \exp(-rL) + Tg \cdot (1-Exp(-rL)) \qquad (16)$$

where L is the length of the pipeline and

$$r = \pi \cdot Dp \cdot Kp/(\rho Cp \cdot Q \cdot tp) \qquad (17)$$

6.2 Model Application and Calibration

The model application to the East Branch for the calibration period included the following steps: (1) developing the East Branch geometric parameters for use in the model from available cross-sectional data, (2) organizing the time varying input data for error checking and access by the model, and (3) developing simulation procedures for producing output directly comparable to the temperature observations for the intensive data collection period. The model calibration for the intensive data collection period consisted of adopting a base case and comparing the mean of computed minus observed temperatures from the base case with other cases. The other cases were sensitivity studies with different meteorological data and model depths.

6.2.1 Geometry

The model divides the study reach into a number of equal length segments in each of which mass continuity and heat budget computations are performed. The study reach begins at Meter No. E36950 above the confluence with the Perkiomen Creek and ends at Meter No. E26700. By dividing the 10.25 km reach into 20 equal segments, a segment length of 512.5 m was obtained. Twenty segments provides adequate resolution of the reach in terms of representing hydrographic features such as the larger man-made pools at the lower end of the reach, distinguishing among the eight instream AATA recorders, and permitting model set up without extensive field work. The measured meter numbers were gathered from base maps provided by RMC and were augmented with additional data from other RMC field studies. The segment boundaries are shown in Figure 3.2-1 and Table 6.2-1, which also show landmarks and intensive data collection period monitoring locations.

For each of the model segments, the relationship of width and depth with flow needs to be quantified for the relationships given in Equations 4 and 5. The coefficients aD, bD, aW and bW must be determined from field data. Two sets of field observations were available: the 1989

Instream Flow Incremental Methodology (IFIM) study (RMC, 1989b) and the erosion assessment studies. The IFIM study reaches were located from Meter No. E36500 to E36025 and from Meter No. E30650 to E29900. The erosion study reach was downstream of the outfall, Meter No. E32375 to E32265. The observations were not well distributed among the segments. For example, segments 1, 2, 3, 13 and 14 had many observations over a large range of flows, but certain segments (6 through 8) had no observations at all. It was not possible to measure widths and depths at every segment because of limited access to some private properties. It was also not possible to take measurements over a large range of flows in time for this study. Two methods were adopted to supply the required data. First, new field studies were initiated at sites that were accessible and were also important because there were no existing observations nearby or because they represented reaches in which geometric properties would be significantly different from the existing observations (e.g., the pools near Sellersville). Second, geometric properties from measured reaches were applied to nearby reaches. Included in the model geometry are minimum depths and widths developed from data. These values permit the model to continue to function with standing water when flows are extremely low. Table 6.2-2 shows the best fits of the data and the segments over which the fits were applied.

A second set of required geometric data are tributary drainage areas. These areas were used to increment flow along the East Branch in proportion to the flows measured at Morris Run. They were measured as follows: the area upstream of the EBTM outfall, $5.6 \times 10^6\ m^2$; Morris Run drainage area into model segment 8, $16.3 \times 10^6\ m^2$; Pleasant Spring Creek drainage area into model segment 17, $23.1 \times 10^6\ m^2$. The latter area is especially important as it represents the major inflow into the lower part of the study reach.

6.2.2 Time Varying Input Data for Calibration

The model requires upstream and tributary inflows and inflow temperatures to compute the transport of heat as shown in Equation 3. The computation of surface heat exchange as water is transported downstream requires meteorological data representative of conditions at the water surface. For the calibration period, these boundary condition data of inflows, inflow temperatures and meteorological data were measured. For the historical period, inflow temperatures were synthesized from other data sources and the meteorological data were obtained from an offsite station. Time-varying data for the historical period are discussed in Section 6.2.5 "Sub-model Calibration".

The flow, temperature and meteorological data vary with time and need to be provided to the model as the model moves in time through the simulation period. This function is accomplished by labeling each record with a date that is easily manipulated by the model. This date is the two-digit year concatenated with the Julian day; the hour is represented by a fraction of the day added to the number. Thus noon on July 1, 1992 is 92183.50, with the units for this synthetic date written as year|day. A Julian day calendar that can be used to translate between dates in the synthetic and month-day-year formats is given as Table 6.2-3.

The available flow data for the intensive data collection period used for the model calibration includes diversion flows from the EBTM, flow measured at the USGS station at Bucks Road, and flow measured on the Morris Run (AATA station T12). The period for which the flow data are available is 92153 (June 1, 1992) to 92272 (September 28, 1992). The USGS data were available as either 15 minute or daily average values. Since the USGS flow data to be used for

the historical simulations are daily, it is appropriate to use the daily average USGS data for the calibration.

Inflows upstream of the diversion outfall and Pleasant Spring Creek inflows were estimated by proportioning these flows to the observed Morris Run flows on the basis of drainage area. Due to a monitor breakdown, the Morris Run flow data were not available before 92205.625 (July 23, 1992, 3 pm). Since the model could not be run without an upstream inflow, an alternate method of computing the upstream inflow was needed. One alternative is to compute the upstream flow as the difference between the USGS gage data and the EBTM diversion flows. Since the EBTM diversion flow data were taken hourly, it would be necessary to use the 15-minute USGS data to make this computation. A comparison of the diversion flow and the USGS data showed that the reported diversion flows exceeded the USGS Bucks Road flows on occasion, thus making the inflow computed for the drainage area above the outfall negative.

An alternate method to obtain flows at the head of the model for the calibration period is to use the USGS gaged flows at Bucks Road as the inflow for the first model segment. This procedure recognizes that in the short distance between the outfall and Bucks Road, very little additional drainage area is added, especially with respect to the large diversion flows. Thus during the calibration period the combined upstream inflow and diversion as represented by the measured flows at the USGS Bucks Road gage were used at the head of the model.

For the period of missing Morris Run flows, a value of 1.75 cfs was assumed for use in the tributary calculations. This value is the average Morris Run flow for the calibration period; observations showed that the Morris Run inflow rate was very nearly constant over this period. However, for the two days of the spring freshet (there was a large freshet that began on June 5, 1992 and ended on June 6, 1992 and that reached a peak of 270 cfs), the upstream drainage area inflow was computable from the diversion flows and the Morris Run flows for this period were inferred from this upstream flow on a unit drainage area basis. This action was taken so that each of the tributaries in the model had realistic flows for the period of the freshet.

The Bucks Road USGS flow data were missing for the period 92162 to 92167 inclusive. For these days, the flow was assumed to be constant at 31 cfs. This value was obtained by using last observed value prior to the missing data period.

Temperature data were taken simultaneously with the flow data, and, in addition, thermistors located as shown in Table 6.2-1 provided temperature data in the East Branch for comparison to the model results. The temperature data were recorded as hourly averages. The temperature data at T3 (Bucks Road) was used to represent the upstream temperature in the model and the recorder at T12 (Morris Run) was used to represent the temperature of the two tributary inflows.

Meteorological data is available at the upper and lower ends of the study reach (AATA, 1992a, stations T2 and T10). These data were also recorded as hourly averages. In addition, National Climatic Data Center data for Allentown-Bethlehem-Easton Airport (ABEA) data were available (National Climatic Data Center, NCDC, 1992a and 1992b). The AATA meteorological data included the following variables: air temperature, relative humidity, wind speed and direction, solar radiation and precipitation. For the surface heat exchange calculation, dew point temperature is required and can be computed from air temperature and relative humidity. The ABEA data included all the AATA variables, with the exception of solar radiation and with dew point provided directly instead of humidity. Cloud cover observations at ABEA were used to

compute solar radiation using relationships described in Wunderlich (1972); Paily, et al., (1974); Ryan and Stolzenbach (1972); Kerr (1986); and, Environmental Protection Agency (1971).

The TD1440 format data from NCDC consisted of hourly data available on magnetic tape for the period January 1973 through July 1992. For the period August through September 1992, LCD format data was used. The LCD format data is published within six weeks of the end of the monthly data collection period, and thus was available sooner than the magnetic tape format data, with takes three months. However, the LCD format consists of 3-hourly data. For the simulations with the ABEA meteorological data, these two NCDC streams were combined.

Response temperature is the temperature a body of water of specific depth would have if subjected only to surface heat exchange (Equation 14, with the inflow and outflow terms removed). The response temperature is a good integrator of the meteorological variables that are important to surface heat exchange. Figure 6.2-1 shows response temperatures computed from all three available meteorological data sets and shows that they produce comparable water temperatures. For the purposes of this study, the three response temperature records are identical and indicate that insofar as surface heat exchange is concerned, any one of the three would provide acceptable estimates. For the base simulation, T2 was used for the upper half of the model segments, and T10 for the lower half.

Another parameter to be defined was the cover function assigned to each segment to reduce direct solar radiation due to canopy shading. For the base case segments 1 to 10 were taken as 50% covered and segments 11 to 20 as 30% covered (RMC 1991, Table 8-42). For the base case the depth functions used the coefficients as shown in Table 6.2-2. Since there was also some uncertainty in the depth functions for the lower model segments, particularly at flows out of the range of those observed, variation in the coefficients was tested in the calibration simulations.

6.2.3 Simulation Methods

The model was run for the calibration period at 60 minute time steps. The model produces temperatures at each segment at each time step. Thus for the 119 day study period, 2856 computed temperatures at each of 20 segments, a total of 57120 temperatures, are available. The model output was formatted for this application to produce time series of temperatures at locations corresponding to the AATA temperature recorders. The model was also coded to produce instantaneous temperatures at each segment written for specific times. This type of output, referred to as a snapshot, is useful for studying specific events.

When linked with the AATA observations the model time series output produced plots of observed and computed temperatures for comparison. A statistical comparison was also made in which the mean of the difference between computed and observed values was computed for each recorder. On the basis of the plots and the statistical summaries, the calibration procedure could be used to make choices among the parameters.

6.2.4 Calibration

The calibration procedure consisted of establishing a base simulation and then modifying the way time varying data was incorporated into the model (i.e., choosing one meteorological data set or the other or a combination of the two) or the way model parameters were defined in the

model (i.e., testing the geometric chosen to represent the width and depth of the East Branch). Visual inspection of graphs of the computed and observed values and comparison of the mean of computed minus observed values were used to test the success of each calibration simulation.

Standards for successful calibration depend on both the accuracy of the data used for the comparison and the use to which the simulation results are put. The AATA temperature observation program has a monitoring accuracy of 0.2 C, meaning any particular observation will be within ±0.4 C of its true value (AATA, 1992a). Temperature computations for use in biological evaluations need not be any more accurate than the field observations that go into thermal tolerance data, generally ±1 C or more. Applications of previous transport models of the type used here report various accuracies: Chaudhry, et al., (1983), errors of up to 2 C; Zimmerman and Dortch (1988), up to 3 C; and, James, et al. (1991), mean errors of 0.5 C. For the model application to the East Branch, successful calibration is defined as simulation results with mean errors less than 0.5 C.

Base Simulation

The base simulation is defined as the model run for the calibration period (5/92 to 9/92) using the geometric and time varying data as described in Sections 6.2.1 and 6.2.2. Output from the model was compared to each of the 57120 observations both graphically and by computing the mean of computed minus observed paired values. These values are shown for each of the AATA stations in Table 6.2-4. The mean values of the differences are already within the calibration limits as defined for this application.

Sensitivity Analyses

Examination of the base simulation results showed that the model hourly temperatures were within ±1 C except for one occasion when computed temperatures were lower than those observed by as much as 3 C for periods of less than four hours. To investigate this excursion, the snapshot output of the model was examined beginning at the upper end of the study reach. It was found that the computed lower temperatures were the result of intense atmospheric cooling due to high wind speeds recorded at T2. These higher wind speeds were not observed either at T10 or ABEA. The inspection of the site confirmed that the T2 site was more open for wind than was the East Branch, which is generally wind sheltered. Tables 6.2-5 and 6.2-6, which show computed minus observed results for model runs using meteorological data from T10 and T2 throughout the study reach, respectively, demonstrate that the use of T10 produces better agreement with observations for the calibration period. The T10 site was located in a wind sheltered area typical of the East Branch study area.

A related test was to use ABEA data instead of either the T2 or T10 or a combination of both. This test was necessary because only ABEA data would be available for the historical simulation period (October 1983 to September 1992). The mean differences for this case are shown in Table 6.2-7. This table shows that the performance of the model is only slightly degraded from the previous best case shown in Table 6.2-5. Some of this degradation is due to the use of the three-hourly meteorological data for the last two months of the study period, necessitated by the unavailability of the hourly format data in time for use in this study. (Hourly data is available for nearly the entire historical period.) Overall model performance for the ABEA

data alone is still within the calibration limits defined earlier; these results increase confidence in the model performance for historical simulations.

Another sensitivity test was made to try to examine the larger amplitude variations shown by the model in the diagrams in Figures 6.2-7 and 6.2-8 at the lower stations, T8 (Sellersville) and T9 (Rt. 309 bridge). These amplitudes are related to thermal inertia and could be varied by changing the depth function at the lower segments. The difficulty with this adjustment is that the amplitude errors are not consistent, with some periods calling for decreased depths, and some for increased depths. The depths at segments 17 to 20 were increased by 50% and the mean differences (Table 6.2-8) as well as the visual model-data fits, became poorer in the lower reach, but unchanged in the upper reach, as expected.

A close examination of the lower station results show that it is only June results for the station located at the Rt. 309 bridge (T9) in which the observed amplitudes are damped. This damping is not seen in the months of July, August and September for this station. More importantly, this damping is not seen at the immediately upstream station (Sellersville, T8) for the month of June. This station is just 800 meters above the Rt. 309 bridge station, and the station to station comparison indicates some discrepancy between the observations for the month of June at T9.

The model geometry was left unchanged as a result of this sensitivity test and the measured geometry was used without any changes in the model.

Model Calibration Results

Figures 6.2-2 through 6.2-8 show the comparison of the computed and observed values at monitoring stations T3 through T9 for the final calibration run, which uses T10 meteorological data and the observed depth and width functions. The comparison show nearly perfect agreement in the mean, as expected from the computed minus observed statistics shown in Table 6.2-5. However, the model results are generally low at the minima (nighttime cooling period) and often high at the maxima (daytime heating period). Since it is the daily maxima that are of concern in the biological assessment, a comparison of computed and observed daily maxima can be made. The mean of the differences between the daily maximum computed and observed temperature for each recorder and for the recorders taken together is as follows:

Segments	AATA recorder	Mean difference between daily maximum computed and observed temperatures, C
3	T3	0.1
5	T4	0.1
10	T5	0.0
14	T6	0.0
17	T7	0.0
19	T8	-0.3
20	T9	-0.2
	Overall mean	0.0

These mean differences are well within the limits of acceptability defined earlier.

The sensitivity results demonstrate that the observed parameters used to represent the East Branch geometry in the model are adequate to give accurate temperature predictions. The sensitivity tests also show that use of the meteorological data from the station located at T10 permits the model to better reproduce observed temperatures. The results of the sensitivity tests further show that the ABEA data can be used directly in the simulations for the historical period without adjustment.

6.2.5 Sub-model Calibration

The application of the model to the historical period requires the development of a sub-model that provides time varying boundary condition data that was not measured during this period. The historical period is defined as 10/83 to 9/92. Time-varying boundary condition data for the model calibration period (5/92 to 9/92), as discussed in Section 6.2.2, were provided by an intensive monitoring network that continuously recorded inflow rates and inflow temperatures at the diversion outfall at the upper end of the East Branch study reach.

The largest inflow to the East Branch during the intensive data collection period was the diversion flow from the Delaware River at Point Pleasant, which is routed through a series of pipelines to Bradshaw Reservoir, the water chilling facility and finally to the outfall in the headwaters of the East Branch. Because the outfall temperatures were monitored, neither Delaware River temperatures, nor the changes in temperature of the water as it was piped to the outfall, were required for the model calibration. However, for simulations of the historical period (which become the basis for projections into the future), these water temperatures and changes in temperature need to be predicted with some certainty. The temperatures of the headwater inflows and the two tributary inflows (Morris Run and Pleasant Spring Creek) are also required for the historical simulations.

Estimation of Outfall Temperatures Without Supplemental Cooling

The East Branch model when run for other than observed conditions (historical hydrologic and meteorological data and different levels of diversion flows) requires the development of a sub-model that computes the temperature of Delaware River water piped to and stored in Bradshaw Reservoir and subsequently discharged to the East Branch. Several procedures need to be developed in order to complete this sub-model: an estimator for Delaware River temperatures at the Point Pleasant intake; computations of heat transfer as the pumped water travels through the pipeline segments that make up the EBTM; and, calculation of surface heat exchange in Bradshaw Reservoir. For calibration, the following data sets are available: operator logs of temperature recorded every two hours at Point Pleasant and every hour at Bradshaw Reservoir for the period September 1989 through September 1992 and continuous monitoring of the Point Pleasant temperatures for the period April 1989 through March 1990. There were intermittent observations during the period 1983 to 1989 (every two weeks or less frequently) but these were of little use in calibrating temperatures at the required hourly time scale.

Point Pleasant Intake Temperatures

In the absence of a continuous record of Delaware River temperatures for the historical simulation period of October 1983 to September 1992 (which coincide with the availability of East Branch USGS discharge data and therefore fix the dates for the historical simulations), temperatures in the Delaware need to be estimated. The estimates need to reproduce not only the annual cycle of temperature, but also the diurnal cycle due to daily heating and cooling. An appropriate estimator is the response temperature, Equation 14 with the inflow and outflow terms removed. Response temperatures are temperatures of a waterbody of specified depth responding only to atmospheric heating and cooling. Meteorological data to compute the surface heat exchange terms in Equation 14 are fixed with the selection of the Allentown-Bethlehem-Easton Airport (ABEA) data, so that the only adjustment parameter for this equation is the waterbody depth.

Operator log data taken every two hours are available for the period August 1989 through October 1992. Delaware River data (AATA, 1992b) were taken for the North Penn and North Wales Water Authorities (NPNW) for a single year, April 1989 through March 1990, using a continuous recorder similar to that used for the monitoring stations in the intensive data collection period on the East Branch. The NPNW Delaware River data were reported every hour. There also was an Endeco continuous temperature monitor that provided data for the period April 1989 through September 1989. Since this period was contained within the Delaware River data period, and since the records agreed closely, it was decided to use the NPNW Delaware River data for further analysis.

Response temperatures for several depths were computed and plotted against both the Point Pleasant log data and the Delaware River observations. There was some disagreement between the NPNW Delaware River data and the operator log data for the period when these observations overlapped: the Delaware River data exceeded the operator log data by 1 to 2 C. The NPNW Delaware River data set was considered more reliable since it agreed closely with the Endeco data and because the log data contained many obvious errors. The NPNW Delaware River data set was therefore adopted for the Point Pleasant temperature calibration. The calculated response temperature using a two meter depth agreed well with the NPNW Delaware River data, reproducing both the annual cycle and the diurnal amplitude of the observations, and was adopted for use in the Bradshaw Reservoir sub-model.

Bradshaw Reservoir Discharge Temperatures

The Bradshaw temperature computation uses for input the Point Pleasant intake temperature, the pipeline heat transfer and lag and surface heat exchange in Bradshaw itself. The computation of Bradshaw temperatures is more important than either of the individual components, as these temperatures are directly used in the model to represent the temperature of the diverted water without supplemental cooling. To verify the successful computation of Bradshaw temperatures, observations in the form of hourly operator logs of temperature and flow rate are available for the period 1989 through 1992. Bradshaw Reservoir is the last observation point before the supplemental cooling facility, and since supplemental cooling operation is not to be included in the historical simulations, the Bradshaw temperature (with the lag time due to flow through the second pipeline segment) becomes the outfall temperature. Equation 14 was used to compute Bradshaw Reservoir temperatures. Inflow and outflow rates were available from the Limerick Generating Station (LGS) operator logs.

Figures 6.2-9 through 6.2-12 show fits of computed Bradshaw temperature with the operator logs. Computed values are in general higher than those observed, with the exception of the July period in 1990 and the June and July period in 1991, when the operator logs did not show a seasonal rise in temperature. This rise is generally present in the Point Pleasant temperature logs and, therefore, the Bradshaw low temperature periods are most likely due to operator error or equipment malfunction. The use of the computed Bradshaw temperatures for the historical period adds a considerable degree of conservatism to the computations, with the diverted water temperature overestimated by as much as 2 C on some occasions.

Pipeline Heat Loss Evaluation and Time of Travel

Heat transfer through the pipeline segment from Bradshaw Reservoir to the outfall on the East Branch was evaluated for possible inclusion in the sub-model. A similar computation for heat transfer through the segment from Point Pleasant to Bradshaw was not required, as the calibration of the Bradshaw component of the model includes any pipeline heat transfer effects. The model for heat exchange along the pipeline is given in Equations 16 and 17.

The length of the pipeline segment of the EBTM from Bradshaw Reservoir to the East Branch is 23140 ft with a diameter of 42 in and 12400 ft with a diameter of 48 in. The heat transfer formula shows that the change in temperature is a function of the surface area of the pipe ($\pi \cdot Dp \cdot L$), thus the effective diameter over the full 35,540 ft would be 44.2 in. The pipe is 1.5 in thick concrete with a thin steel liner. Heat transfer is much more rapid through the steel liner than the concrete wall and therefore, the heat transfer coefficient for concrete governs. Concrete pipe has a wall coefficient of heat transfer of 6 to 9 $Btu \cdot in/(ft^2 \cdot F \cdot h)$ (Hodgman, et al., pg. 2442); the higher value is used in the computations. The temperature drop through the pipeline for different assumed ground temperatures was computed to be on the order of 1 C or less for the lowest diversion flow. However, in a comparison of observed Bradshaw temperatures with observed outfall temperatures (Figure 6.2-13) recorded during the intensive data collection period, only a very small temperature drop could be demonstrated. For this reason, the completed sub-model did not include the pipeline heat transfer computation.

The lag times through the pipeline system are important. These can easily be calculated by computing the pipeline volume in each segment and dividing by the diversion rate. The pipeline volumes are as follows:

pipeline segment from Point Pleasant to Bradshaw Reservoir: 216,937 ft^3

pipeline segment from Bradshaw Reservoir to the outfall: 378,456 ft^3.

For a diversion rate of 10 cfs, the lag time from Point Pleasant to Bradshaw is 6 hours and for the maximum diversion rate of 54 cfs, the lag time is one hour. The corresponding lags for the second segment are 11 hours and 2 hours, respectively. The lag computation in the sub-model is incorporated by storing 24 hours of Point Pleasant and Bradshaw Reservoir temperatures in an array, computing the lag time based on the actual (or for the historical simulations, the estimated) diversion flow, and extracting from the stored temperatures the temperature currently required at the end of either pipeline segment. Thus for a diversion rate of 54 cfs, the inflow temperature to Bradshaw is the one computed for Point Pleasant one hour earlier, and the East Branch outfall temperature is the one computed for Bradshaw two hours earlier.

Estimation of Headwater and Tributary Temperatures

The Bradshaw Reservoir sub-model computes outfall temperatures for the complete East Branch temperature model. There are two other inflows for which temperatures were observed for the 1992 calibration simulations and for which temperatures must be computed for the historical simulations: headwater inflows and tributary inflows, namely Morris Run and Pleasant Spring Creek. These temperatures can also be estimated using response temperatures, but in this case shallower depths were examined to better represent the higher amplitudes in these small stream temperatures. Based on observations made during a field trip in October 1992, it was decided also to use a shading factor for solar radiation when computing the upstream (AATA Station T1) temperatures, but allow 100% solar radiation incidence in the computation of the Morris Run and Pleasant Spring Creek temperatures.

Figures 6.2-14 and 6.2-15 show the comparison of observed and computed upstream and tributary temperatures, respectively, to those observed during the intensive data collection period. The estimates capture both the annual cycle of temperature and the observed diurnal amplitudes. These estimates are important to the historical simulations in the ratio of headwater and tributary inflow to the diversion flow.

Estimation of Natural Inflows

The natural inflow to the upper end of the East Branch is recorded at the Bucks Road gage by the USGS from 10/83 to 7/89. Once the diversion began in September 1989, however, the discharge recorded at the gage included both the natural flow and the diversion. The natural flow is also used to compute the tributary inflow rates for the Morris Run and the Pleasant Spring Creek, by proportioning these flows to the ratio of their respective drainage areas:

East Branch upstream of the outfall, 5.6×10^6 m^2

East Branch at Bucks Road USGS gage, 10.5×10^6 m^2

Morris Run, 16.3×10^6 m^2

Pleasant Spring Creek, 23.1×10^6 m^2.

The natural flow for the period after the diversion begins was computed by subtracting the daily average diversion flow (as recorded on the operator logs) from the observed Bucks Road USGS flow. Because of uncertainty in the log data, the observed diversion flows sometimes exceeded the Bucks Road gage flows. In these cases, the natural flow was assumed to be 0.1 cfs.

Sub-model Calibration Results

Reproduction of Bradshaw Reservoir temperatures is important for successful simulations of the historical period. Computed Bradshaw temperatures follow the observations closely, but, as shown in Figures 6.2-9 to 6.2-12, overestimate those temperatures by up to 2 C. This result adds to the conservatism in the model.

An important feature of the Bradshaw record, both observed and as computed with the sub-model, is the dampened diurnal temperature cycle relative to headwater temperatures. This result is due to the large thermal inertia of the Reservoir, i.e., the large mass of water undergoing diurnal heating and cooling. The headwaters of the East Branch are shallow and therefore respond quickly to atmospheric heating and cooling.

There is a very slight temperature decrease through the pipeline; this decrease is very small relative to temperature changes in Bradshaw Reservoir and was not included in the model. Nevertheless its exclusion adds addition conservatism to the results of the historical simulations.

6.3 Model Output

Time varying temperatures along the East Branch are required for the historical simulation period of October 1983 through September 1992 for the case of no diversion flow and diversion flows of 10, 27 and 54 cfs. The time period is determined by the availability of USGS flow data at Bucks Road. This gage is used to estimate inflows to the head of the East Branch as well as tributary inflows. The only other time varying boundary condition data used directly for the historical period simulations are the meteorological data from ABEA, used to construct upstream and tributary inflow temperatures, Bradshaw Reservoir temperatures, and surface heat exchange on the East Branch.

The model was used to compute hourly temperatures at each of the 20 model segments for this time period and for each diversion flow. These results require further summary for use in the biological studies. The summaries chosen were maximum daily temperatures, mean daily temperatures, minimum daily temperatures and rates of temperature change at each model segment along the stream over the nine years of analysis for each diversion flow. Also required for the impact assessment were water surface widths in each of the model segments.

The computed maximum daily and mean daily temperatures over the period of October 1983 to September 1992 have been subjected to a duration analysis which determines the temperature in each year that is equalled or exceeded for durations of 1, 7, 14 , 21 and 28 days. This analysis has been carried out for each case of diversion flows at three stations along the East Branch for three time periods: the entire year; the permit-mandated TSF protection period, 15 February through 31 July; and 15 April through 31 May, when trout are actually in the stream and available for harvest. The results of these analyses are summarized Section 7.1. They are used to determine the annual frequencies and durations of temperatures for each case for use in the biological studies.

Table 6.2-1. Layout of model segments along the East Branch with landmarks and thermistor locations.

Segment	From location given as East Branch meter no.	To location given as East Branch meter no.	Landmarks	Thermistor number and location given as East Branch meter no.
1	E36950.0	E36437.5	Discharge	T2 (E36950)
2	E36437.5	E35925.0		
3	E35925.0	E35412.5	Bucks Rd.	T3 (E35580)
4	E35412.5	E34900.0		
5	E34900.0	E34387.5	Route 313	T4 (E34450)
6	E34387.5	E33875.0		
7	E33875.0	E33362.5		
8	E33362.5	E32850.0	Morris Run	(T11 and T12 on Morris Run)
9	E32850.0	E32337.5		
10	E32337.5	E31825.0	Branch Rd.	T5 (E32200)
11	E31825.0	E31312.5		
12	E31312.5	E30800.0		
13	E30800.0	E30287.5		
14	E30287.5	E29775.0	Callowhill Rd.	T6 (E29800)
15	E29775.0	E29262.5		
16	E29262.5	E28750.0		
17	E28750.0	E28237.5	Walnut St. Pleasant Springs Creek	T7 (E28550)
18	E28237.5	E27725.0		
19	E27725.0	E27212.5	Sellersville	T8 (E27500)
20	E27212.5	E26700.0	Rt. 309 bridge	T9 (E26700)

Table 6.2-2. Model segment width and depth coefficients, minimum values of width and depth and solar radiation shading.

Segments	1 to 5	6 to 9	10 to 12	13 to 16	17 to 20
From	Discharge	Route 313	Branch Rd.	Covered Bridge	Walnut Street
To	Route 313	Branch Rd.	Covered Bridge	Walnut Street	Rt. 309 Bridge
aW	8.22	8.76	13.62	10.45	30.00
bW	0.105	0.083	0.100	0.058	0.000
Minimum Width (m)	5.0	5.6	6.3	9.0	26.0
aD	0.47	0.23	0.52	0.43	0.8
bD	0.408	0.230	0.333	0.246	0.000
Minimum Depth (m)	0.2	0.2	0.2	0.5	0.6
shading	0.5	0.5	0.5 for segment 10; 0.3 for segments 11 and 12	0.3	0.3
aD=0.80 for segment 8 where Morris Run enters the East Branch					

Table 6.2-3. Julian Days.

Normal Year

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	1	32	60	91	121	152	182	213	244	274	305	335	1
2	2	33	61	92	122	153	183	214	245	275	306	336	2
3	3	34	62	93	123	154	184	215	246	276	307	337	3
4	4	35	63	94	124	155	185	216	247	277	308	338	4
5	5	36	64	95	125	156	186	217	248	278	309	339	5
6	6	37	65	96	126	157	187	218	249	279	310	340	6
7	7	38	66	97	127	158	188	219	250	280	311	341	7
8	8	39	67	98	128	159	189	220	251	281	312	342	8
9	9	40	68	99	129	160	190	221	252	282	313	343	9
10	10	41	69	100	130	161	191	222	253	283	314	344	10
11	11	42	70	101	131	162	192	223	254	284	315	345	11
12	12	43	71	102	132	163	193	224	255	285	316	346	12
13	13	44	72	103	133	164	194	225	256	286	317	347	13
14	14	45	73	104	134	165	195	226	257	287	318	348	14
15	15	46	74	105	135	166	196	227	258	288	319	349	15
16	16	47	75	106	136	167	197	228	259	289	320	350	16
17	17	48	76	107	137	168	198	229	260	290	321	351	17
18	18	49	77	108	138	169	199	230	261	291	322	352	18
19	19	50	78	109	139	170	200	231	262	292	323	353	19
20	20	51	79	110	140	171	201	232	263	293	324	354	20
21	21	52	80	111	141	172	202	233	264	294	325	355	21
22	22	53	81	112	142	173	203	234	265	295	326	356	22
23	23	54	82	113	143	174	204	235	266	296	327	357	23
24	24	55	83	114	144	175	205	236	267	297	328	358	24
25	25	56	84	115	145	176	206	237	268	298	329	359	25
26	26	57	85	116	146	177	207	238	269	299	330	360	26
27	27	58	86	117	147	178	208	239	270	300	331	361	27
28	28	59	87	118	148	179	209	240	271	301	332	362	28
29	29		88	119	149	180	210	241	272	302	333	363	29
30	30		89	120	150	181	211	242	273	303	334	364	30
31	31		90		151		212	243		304		365	31

Table 6.2-3. Julian Days (continued).

Leap Year

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	1	32	61	92	122	153	183	214	245	275	306	336	1
2	2	33	62	93	123	154	184	215	246	276	307	337	2
3	3	34	63	94	124	155	185	216	247	277	308	338	3
4	4	35	64	95	125	156	186	217	248	278	309	339	4
5	5	36	65	96	126	157	187	218	249	279	310	340	5
6	6	37	66	97	127	158	188	219	250	280	311	341	6
7	7	38	67	98	128	159	189	220	251	281	312	342	7
8	8	39	68	99	129	160	190	221	252	282	313	343	8
9	9	40	69	100	130	161	191	222	253	283	314	344	9
10	10	41	70	101	131	162	192	223	254	284	315	345	10
11	11	42	71	102	132	163	193	224	255	285	316	346	11
12	12	43	72	103	133	164	194	225	256	286	317	347	12
13	13	44	73	104	134	165	195	226	257	287	318	348	13
14	14	45	74	105	135	166	196	227	258	288	319	349	14
15	15	46	75	106	136	167	197	228	259	289	320	350	15
16	16	47	76	107	137	168	198	229	260	290	321	351	16
17	17	48	77	108	138	169	199	230	261	291	322	352	17
18	18	49	78	109	139	170	200	231	262	292	323	353	18
19	19	50	79	110	140	171	201	232	263	293	324	354	19
20	20	51	80	111	141	172	202	233	264	294	325	355	20
21	21	52	81	112	142	173	203	234	265	295	326	356	21
22	22	53	82	113	143	174	204	235	266	296	327	357	22
23	23	54	83	114	144	175	205	236	267	297	328	358	23
24	24	55	84	115	145	176	206	237	268	298	329	359	24
25	25	56	85	116	146	177	207	238	269	299	330	360	25
26	26	57	86	117	147	178	208	239	270	300	331	361	26
27	27	58	87	118	148	179	209	240	271	301	332	362	27
28	28	59	88	119	149	180	210	241	272	302	333	363	28
29	29	60	89	120	150	181	211	242	273	303	334	364	29
30	30		90	121	151	182	212	243	274	304	335	365	30
31	31		91		152		213	244		305		366	31

Table 6.2-4. Table of the mean of the differences between computed and observed temperatures for the base case, computed as the mean of the pairs (computed value minus observed value). The met data set from AATA T2 was used for model segments 1 to 10 and from T10 for segments 11 to 20.

Segments	AATA recorder	Mean difference between computed and observed temperatures, °C
3	T3	-0.1
5	T4	-0.2
10	T5	-0.3
14	T6	-0.3
17	T7	-0.1
19	T8	-0.2
20	T9	-0.4
overall mean		-0.24

Table 6.2-5. Table of the mean of the differences between computed and observed temperatures, computed as the mean of the pairs (computed value minus observed value) for the case of using AATA T10 throughout the East Branch study reach to represent meteorological conditions.

Segments	AATA recorder	Mean difference between computed and observed temperatures, °C
3	T3	-0.1
5	T4	-0.2
10	T5	-0.3
14	T6	-0.2
17	T7	-0.1
19	T8	-0.2
20	T9	-0.4
	overall mean	-0.19

Table 6.2-6. Table of the mean of the differences between computed and observed temperatures, computed as the mean of the pairs (computed value minus observed value) for the case of using AATA T2 throughout the East Branch study reach to represent meteorological conditions.

Segments	AATA recorder	Mean difference between computed and observed temperatures, °C
3	T3	-0.1
5	T4	-0.2
10	T5	-0.3
14	T6	-0.3
17	T7	-0.2
19	T8	-0.4
20	T9	-0.6
	overall mean	-0.29

Table 6.2-7. Table of the mean of the differences between computed and observed temperatures, computed as the mean of the pairs (computed value minus observed value) for the case of using ABEA data throughout the East Branch study reach to represent meteorological conditions.

Segments	AATA recorder	Mean difference between computed and observed temperatures, °C
3	T3	-0.1
5	T4	-0.2
10	T5	-0.3
14	T6	-0.3
17	T7	-0.2
19	T8	-0.3
20	T9	-0.5
	overall mean	-0.25

Table 6.2-8. Table of the mean of the differences between computed and observed temperatures, computed as the mean of the pairs (computed value minus observed value) for the case of using AATA T10 throughout the East Branch study reach to represent meteorological conditions. The depths at segments 17-20 were increased by 50%.

Segments	AATA recorder	Mean difference between computed and observed temperatures, °C
3	T3	-0.1
5	T4	-0.2
10	T5	-0.3
14	T6	-0.2
17	T7	-0.1
19	T8	-0.2
20	T9	-0.4
	overall mean	-0.20

Figure 6.2-1 Response Temperatures Computed From Data at Three Meteorological Stations: T2, T10, and ABEA

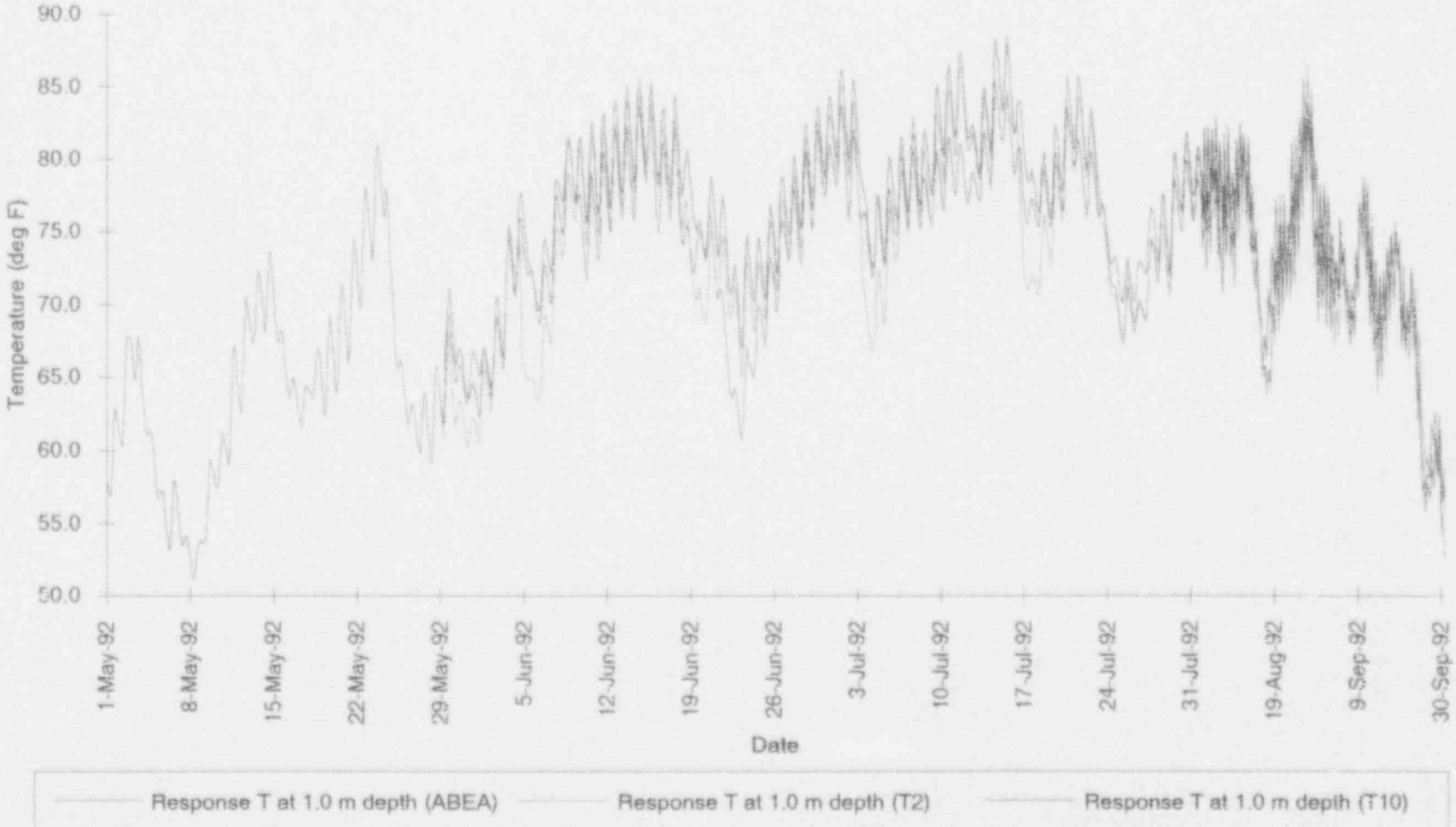


Figure 6.2-2

Comparison Between Observed Temperatures at Bucks Rd. (Station T3)
and Predicted Temperatures at Model Segment 3
For the Period 1-Jun to 27-Sept. 1992

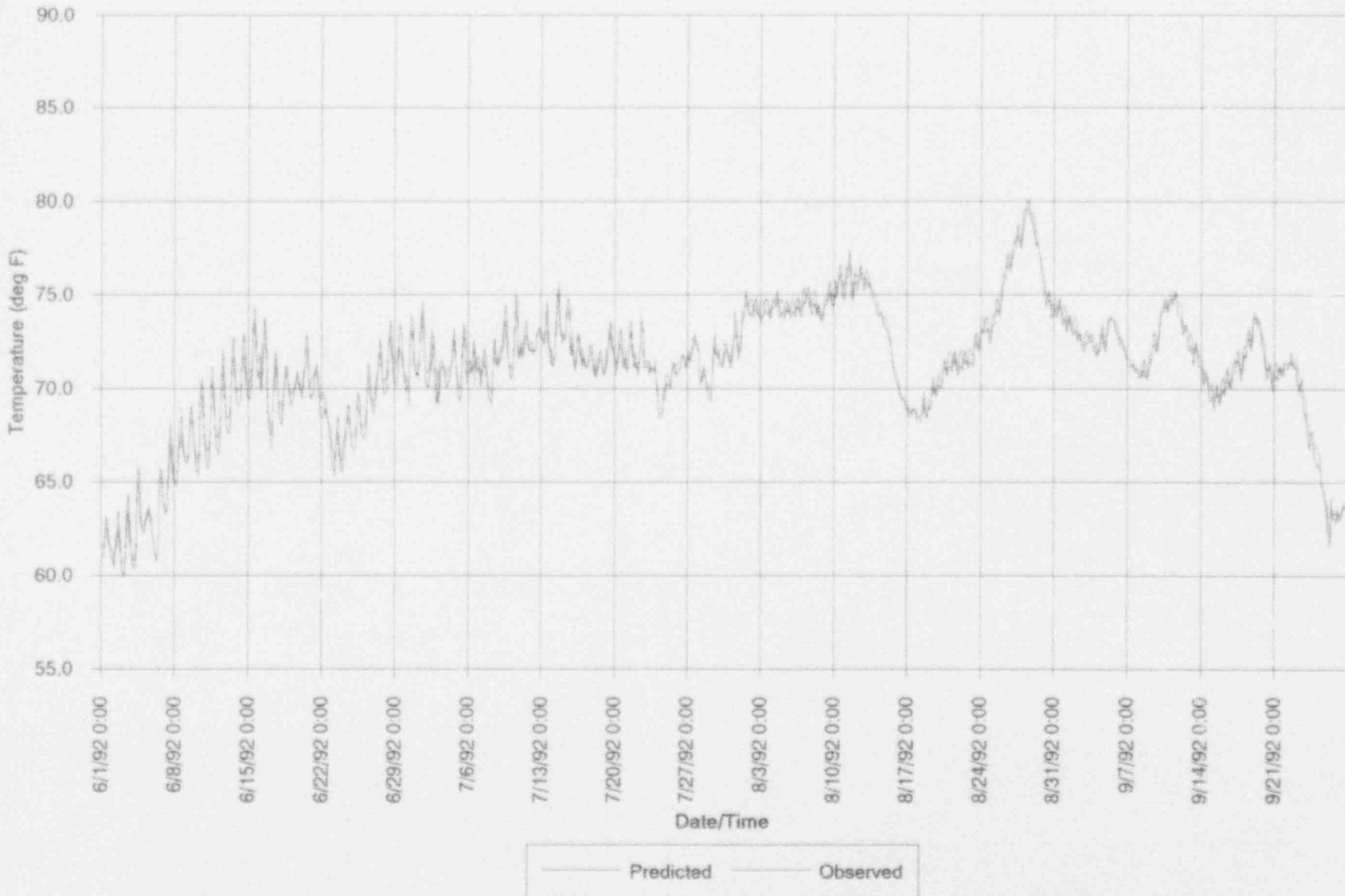


Figure 6.2-3

Comparison Between Observed Temperatures at Route 313 (Station T4)
and Predicted Temperatures at Model Segment 5
For the Period 1-Jun to 27-Sept. 1992

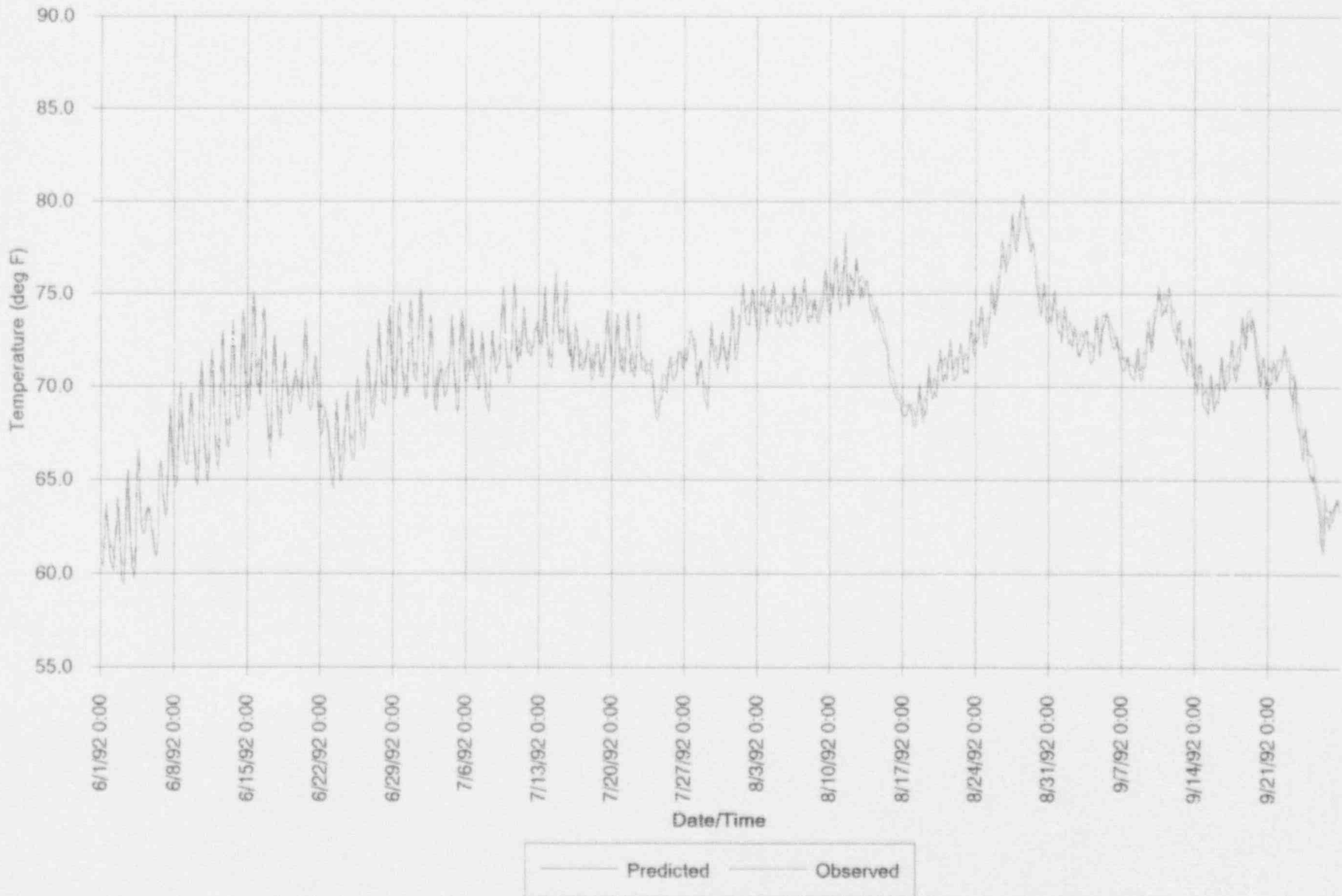


Figure 6.2-4

Comparison Between Observed Temperatures at Branch Rd. (Station T5)
and Predicted Temperatures at Model Segment 10
For the Period 1-Jun to 27-Sept, 1992

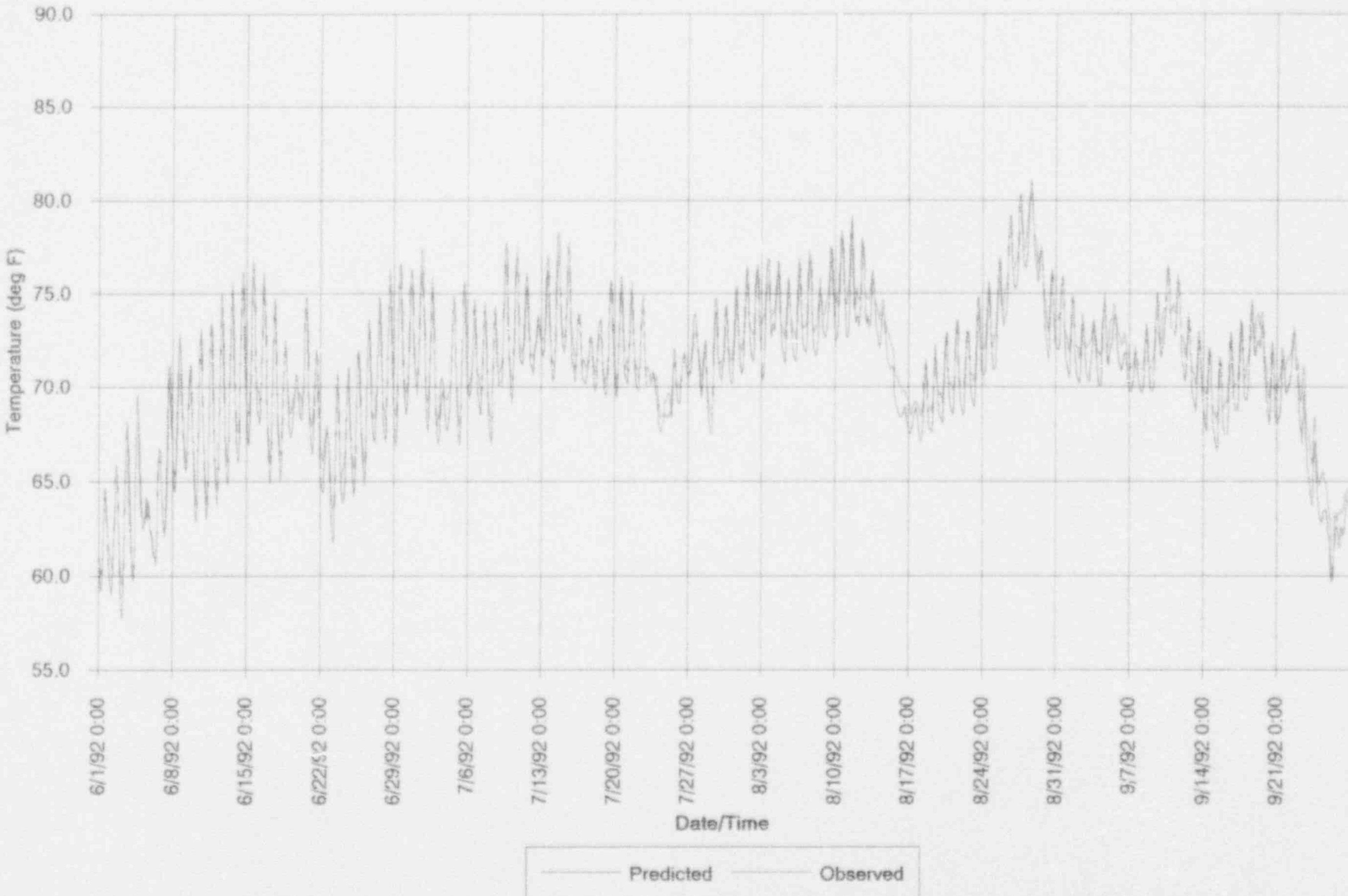


Figure 6.2-5

Comparison Between Observed Temperatures at Callowhill Rd. (Station T6)
and Predicted Temperatures at Model Segment 14
For the Period 1-Jun to 27-Sept. 1992

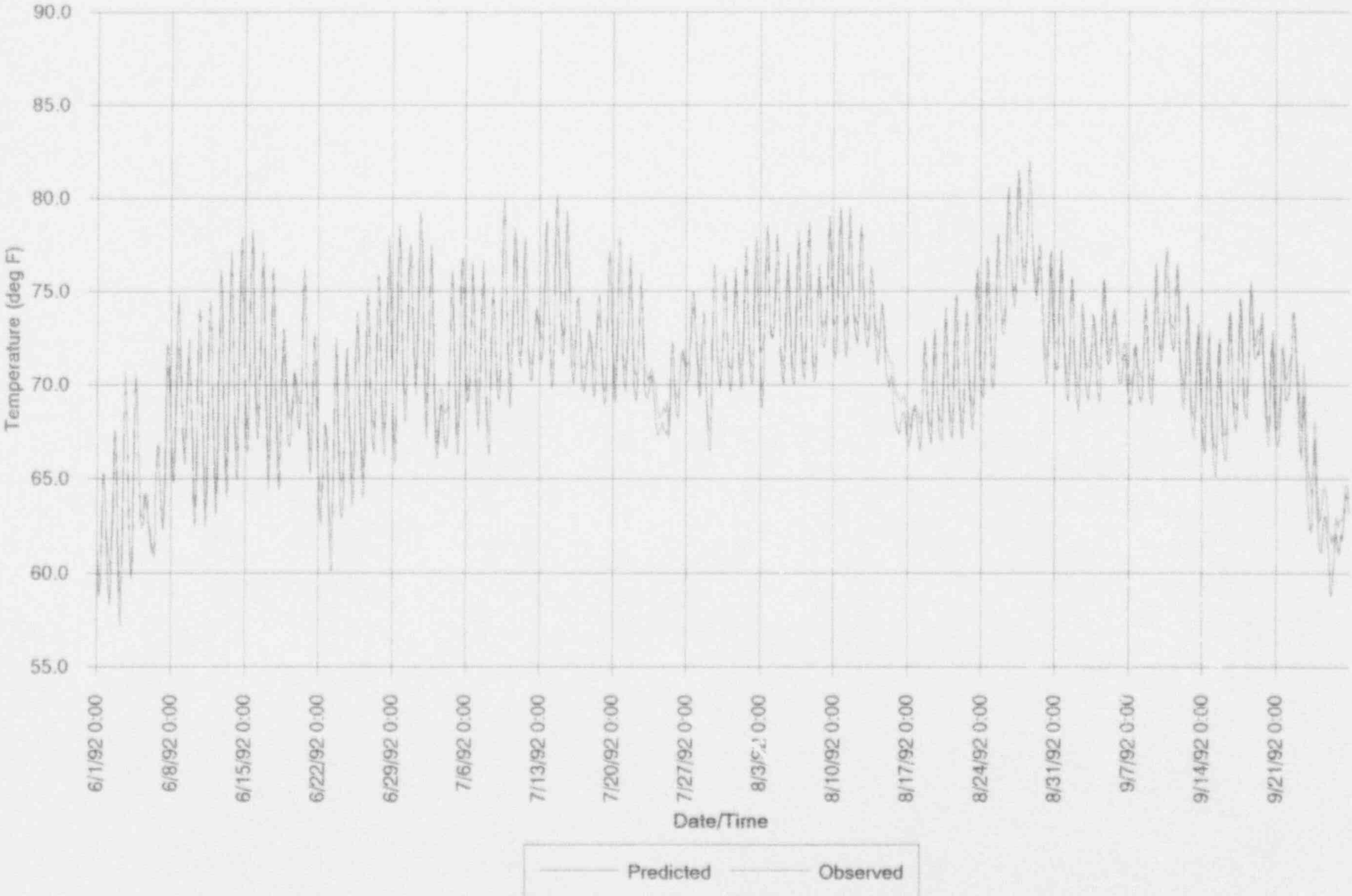


Figure 6.2-6

Comparison Between Observed Temperatures at Walnut St. (Station T7) and Predicted Temperatures at Model Segment 17 For the Period 1-Jun to 27-Sept, 1992

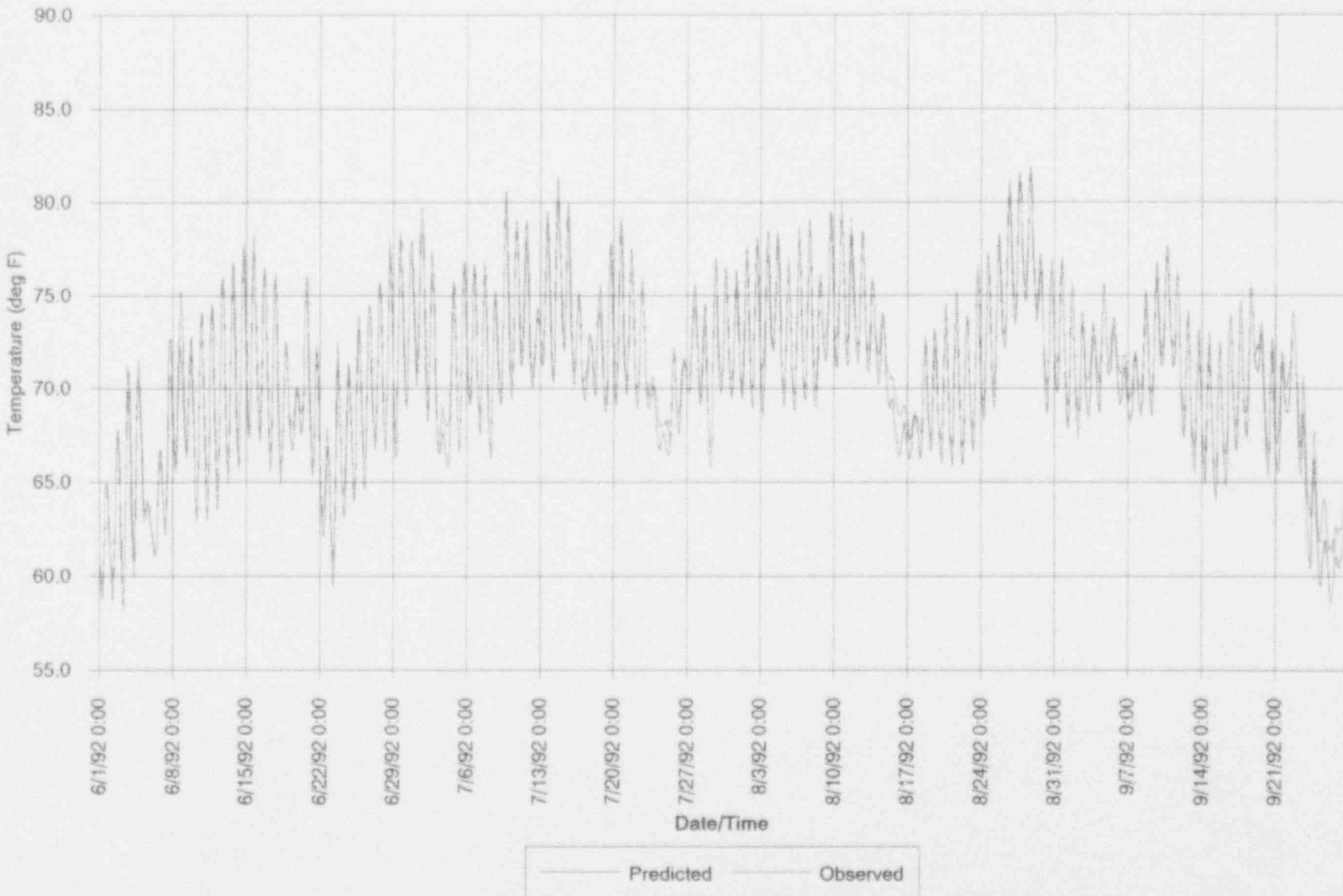


Figure 6.2-7

Comparison Between Observed Temperatures at Sellersville Pool (Station T8)
and Predicted Temperatures at Model Segment 19
For the Period 1-Jun to 27-Sept, 1992

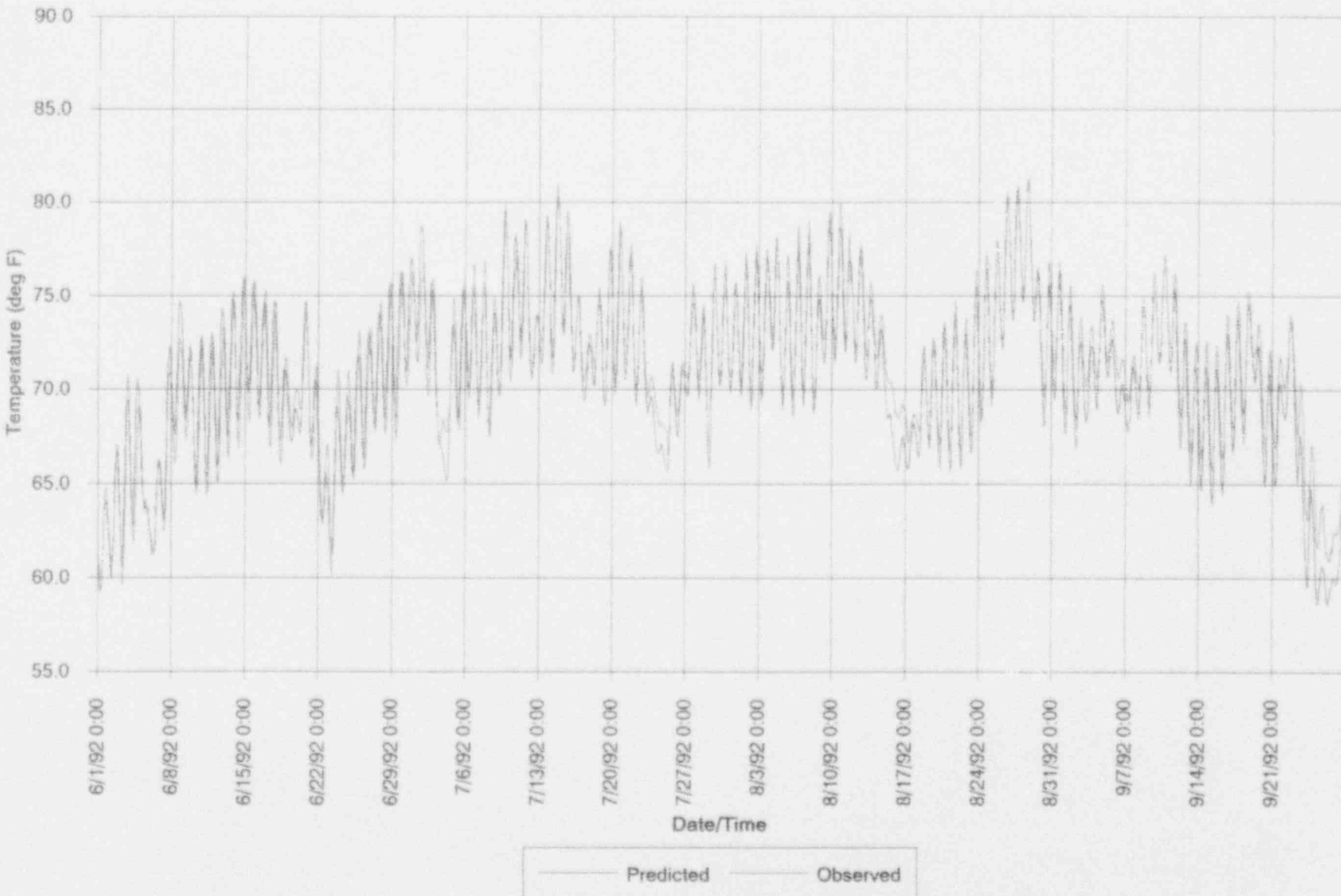


Figure 6.2-8

Comparison Between Observed Temperatures at Route 309 (Station T9)
and Predicted Temperatures at Model Segment 20
For the Period 1-Jun to 27-Sept, 1992

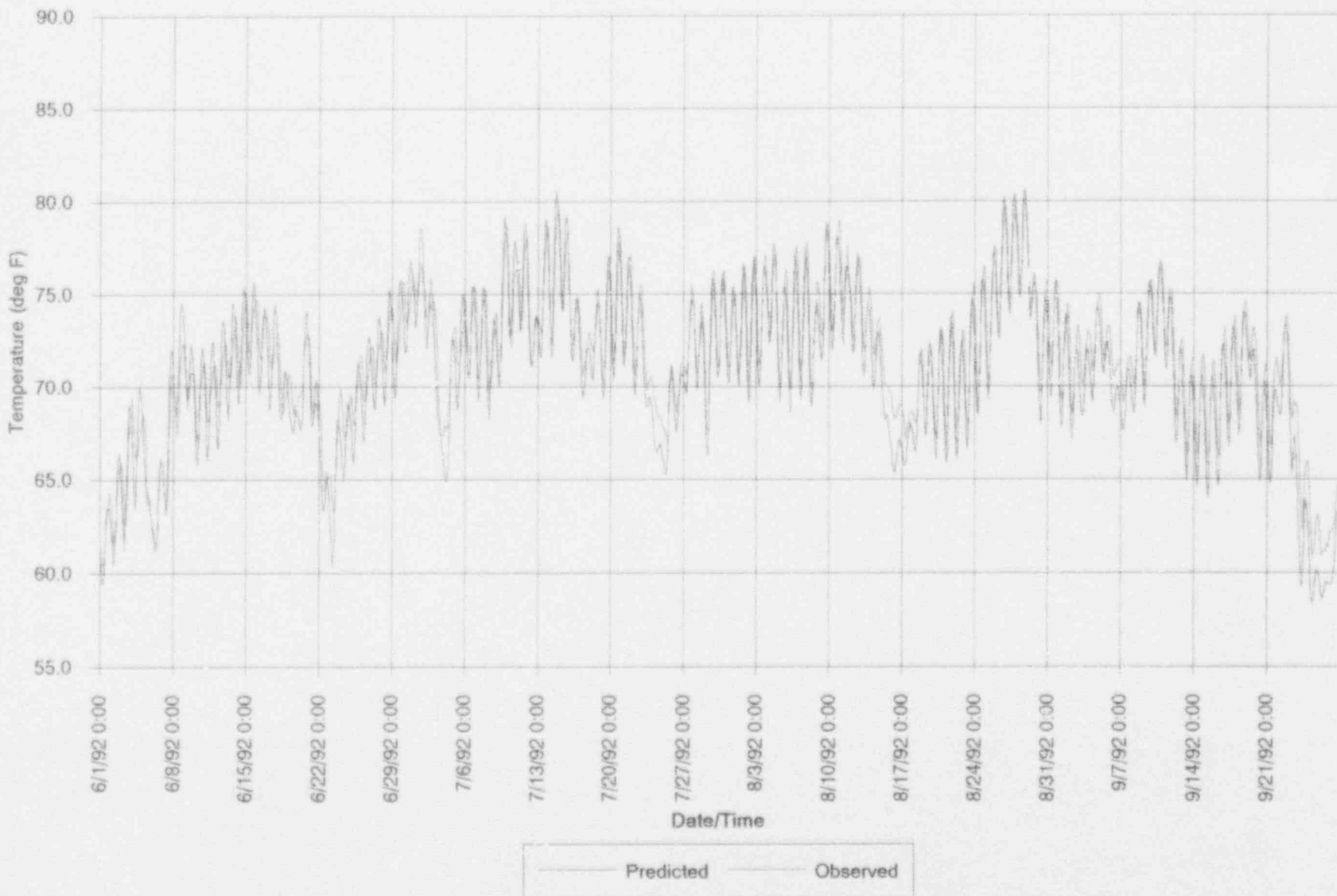


Figure 6.2-9 Observed and Computed Bradshaw Reservoir Temperatures
For Late Spring, Summer and Early Fall 1989.

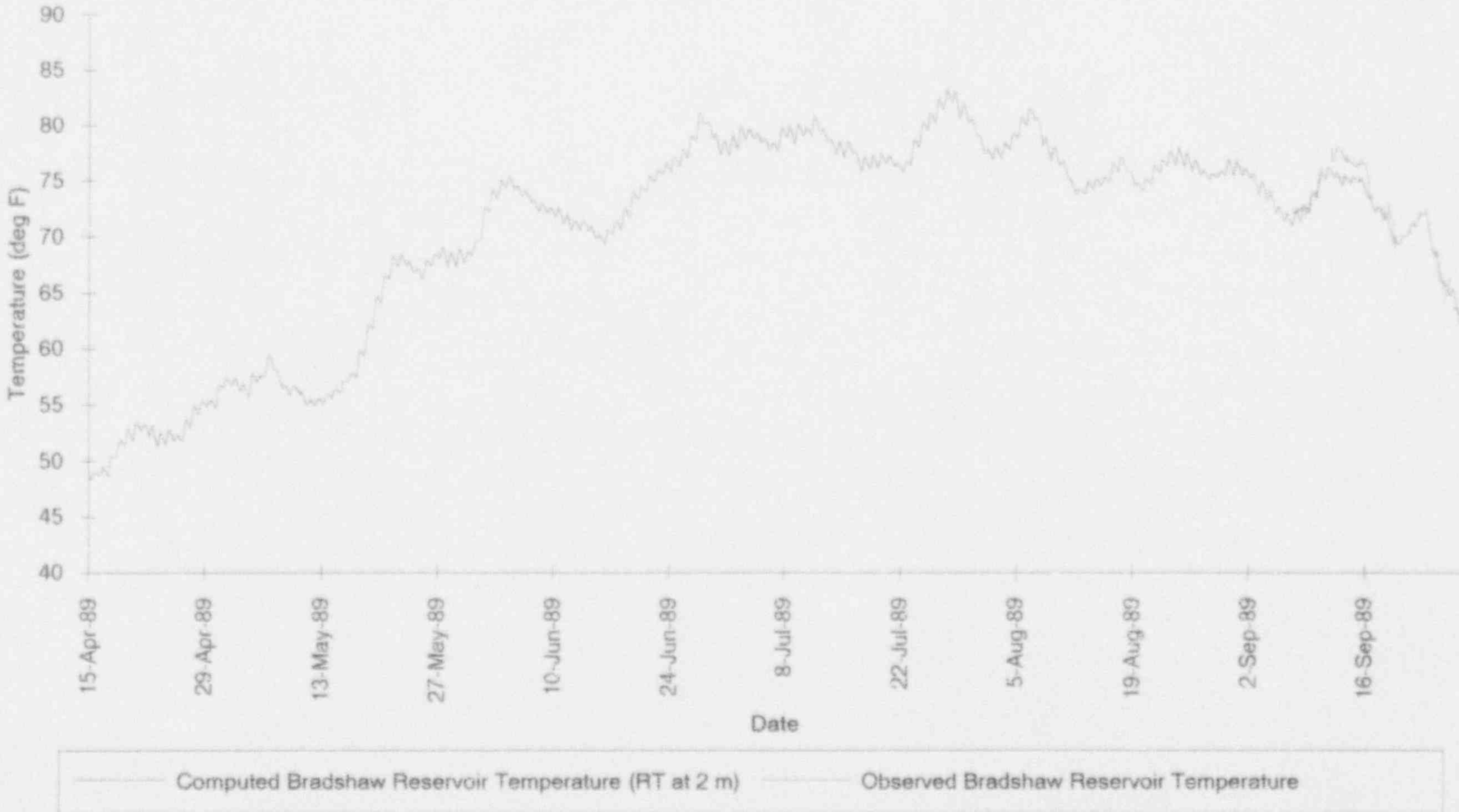


Figure 6.2-10 Observed and Computed Bradshaw Reservoir Temperatures
For Late Spring, Summer and Early Fall 1990.

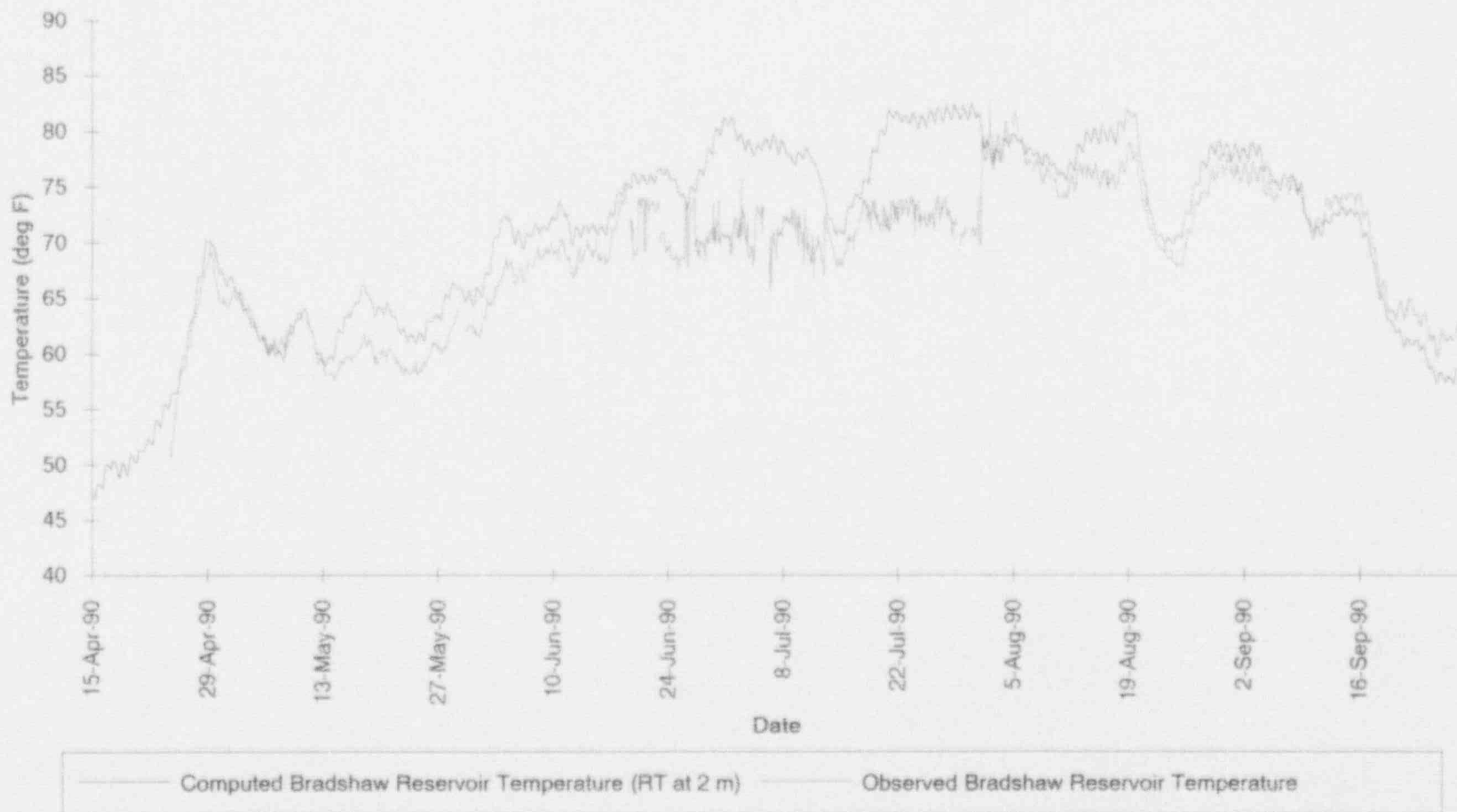


Figure 6.2-11 Observed and Computed Bradshaw Reservoir Temperatures For Late Spring, Summer and Early Fall 1991.

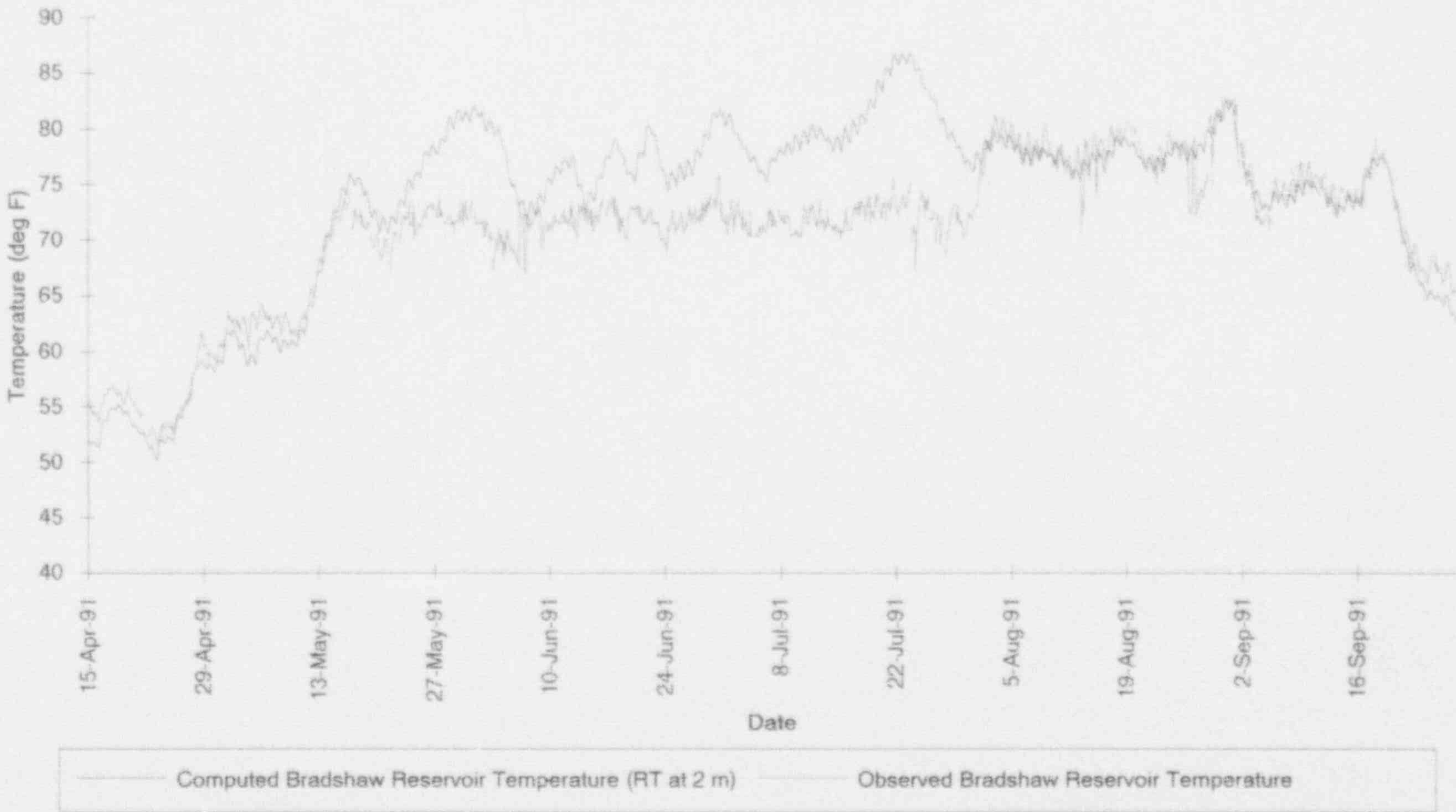


Figure 6.2-12 Observed and Computed Bradshaw Reservoir Temperatures
For Late Spring, Summer and Early Fall 1992.

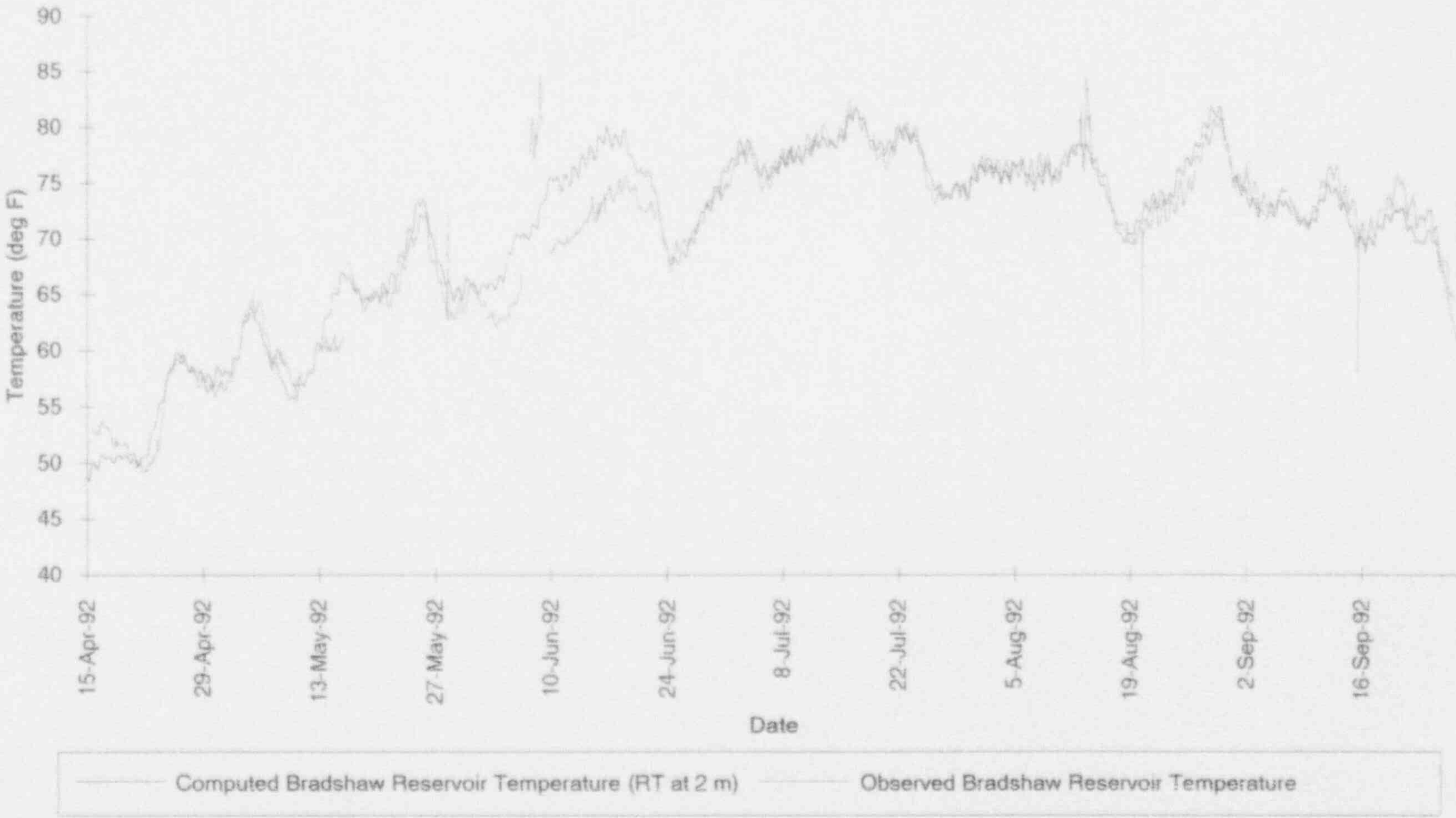


Figure 6.2-13 Observed Bradshaw Reservoir and Outfall Temperatures
For the Intensive Data Collection Period

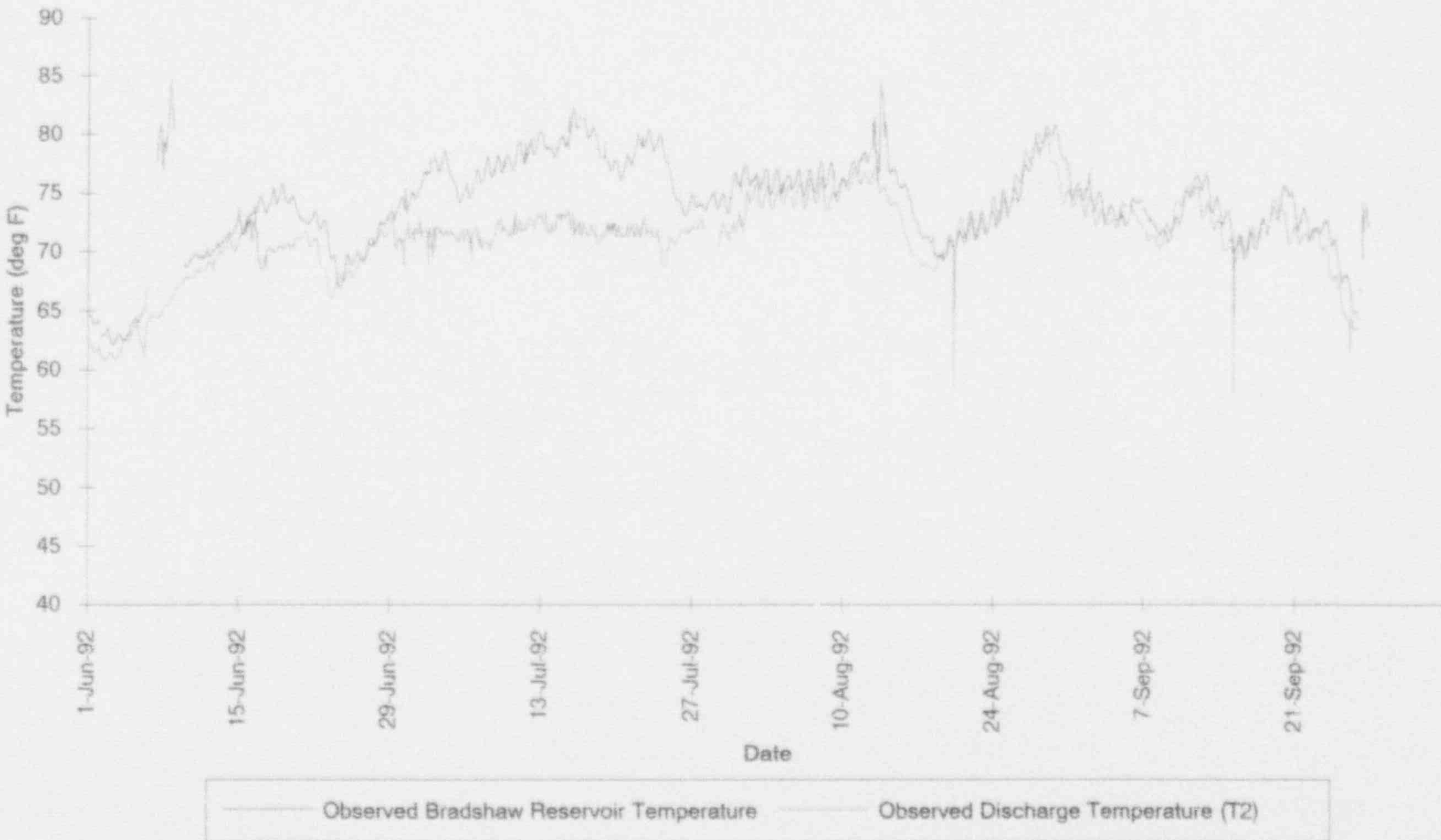


Figure 6.2-14 Observed and Computed Upstream Inflow Temperatures

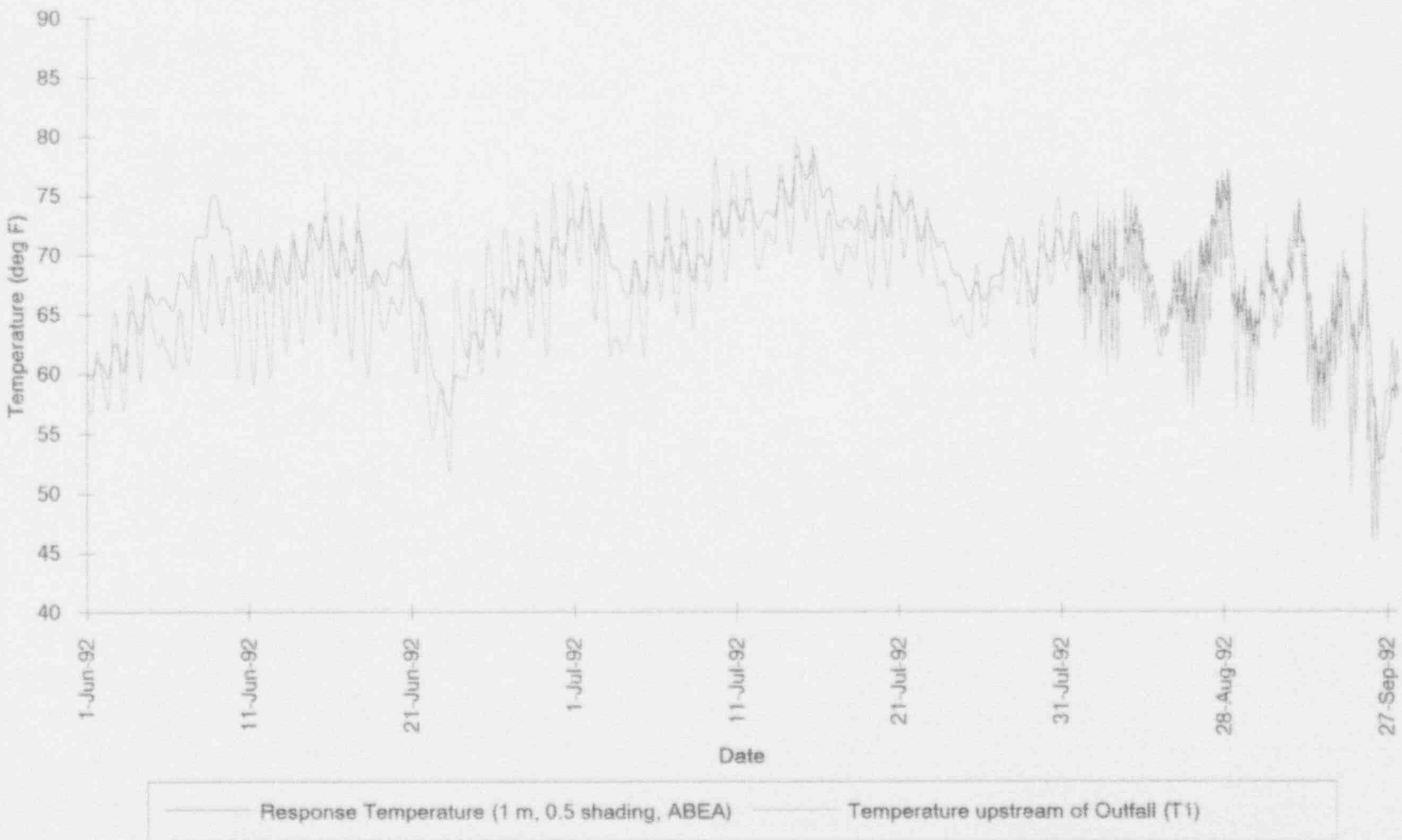
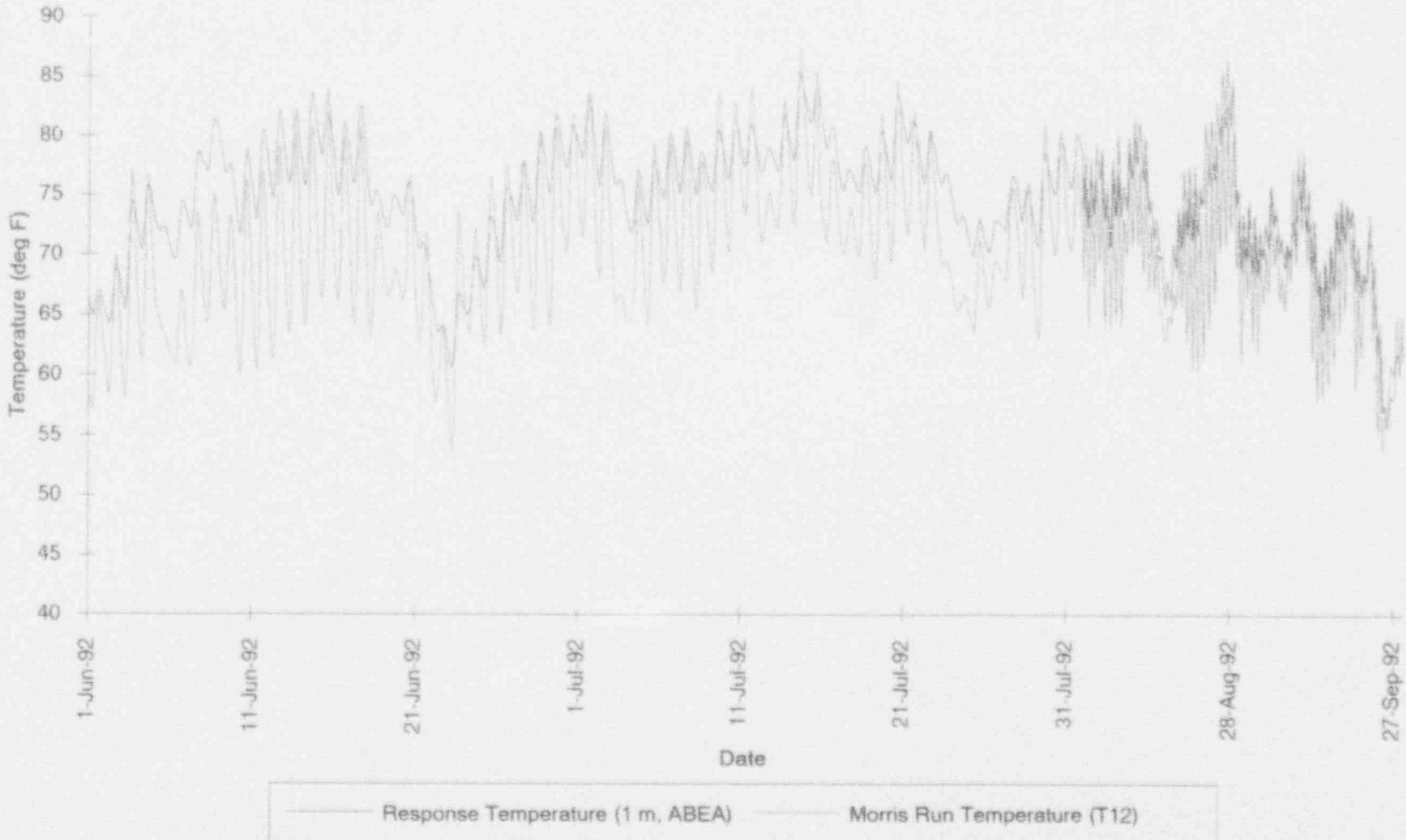


Figure 6.2-15 Observed and Computed Upstream Tributary Temperatures



7.0 RESULTS AND DISCUSSION

The following sections discuss general features of temperature distributions generated by the predictive model and evaluate certain time periods and representative stream locations with reference to relevant biological issues and the previously agreed upon decision criteria. Because of the large amount of information provided by the model, the results have been classified and summarized in several ways to compare and contrast the two Study Cases.

7.1 Discussion of the Temperature Model Results

The temperature model results are available hourly from 1 October 1983 through 26 September 1992 for each of the twenty stream segments. The major features of the temperature distributions to be examined are their spatial and temporal variations for diversion flows of 10, 27, and 54 cfs and how they compare to the zero diversion flow case. These are first examined on an hourly basis from the July 1992 results and then on a statistical basis for the hourly results from 1984 through 1992. The July 1992 period is chosen for examination because complete data were available during this period and because it would be typical of a warm weather period. Other months can be similarly examined from the results of Figures 6.2-2 through 6.2-8 for actual diversion flows. The statistical comparisons are based on duration and frequency analyses of the hourly temperatures.

7.1.1 Time Series Comparisons of Results

The diversion temperatures into the East Branch without the chillers operating would be the same as the temperatures from Bradshaw Reservoir. The headwater temperatures in the East Branch without the diversion would be similar to those recorded at T1 (upstream of the outfall). These temperature data are shown in Figure 7.1-1 for July 1992. The observed diurnal amplitudes of the diversion temperatures are much smaller than those for the observed headwater temperatures because Bradshaw Reservoir is deeper than the headwater of East Branch and diurnal temperature amplitudes vary approximately inversely with depth. Similarly, the diurnal amplitudes of the much larger mainstream Delaware River are less than those of the much smaller, shallower headwater East Branch. Shown on Figure 7.1-1 is the computed Bradshaw Reservoir temperature which is in excellent agreement with the observed temperatures. The Bradshaw Reservoir temperatures are higher than the headwater temperatures in July.

The time series of model results for July 1992 are given for representative stream Segments 2, 10, and 19 in Figure 7.1-2 through Figure 7.1-5 which show the temperatures for the no diversion case and for the 10, 27 and 54 cfs diversion cases. Segment 2 is located immediately below the EBTM near Elephant Road (Figure 3.2-1) and was selected as representative of the headwaters of the East Branch. Segment 10, located near Branch Road Bridge, was selected as representative of the flowing stream habitat in the upper limit of the trout stocked fishery (TSF) area. Segment 19, at Sellersville, was selected as representative of pool habitat prevalent in the TSF area at Sellersville. These results show:

- Differences in temperatures among the three different diversion cases at any of the segments are much less than between any diversion case and the no diversion case.

At Segment 2, the July 1992 model results are almost identical to the observed data given in Figure 7.1-1 in that the temperatures at zero diversion flow are similar to the headwater temperatures at T1 and that the temperatures with the diversion are similar to the Bradshaw Reservoir temperatures.

The diurnal amplitudes with the diversion cases increase in the downstream direction to approach the no diversion case temperature amplitudes due to the natural processes of surface heat exchange and tributary inflows.

The mean temperatures with the diversion cases decrease in the downstream direction to become almost the same as the temperatures without the diversion in about 2.5 to 5 km from the discharge due to surface heat exchange and tributary inflows.

The maximum temperatures of the diversion cases decrease in the downstream direction to become the same as the no diversion case within about 2.5 to 5 km from the outfall.

These conclusions can be further examined on a more general basis by comparison to the results from the durational statistical analysis given below.

7.1.2 Duration Results

The duration statistics (mean and standard deviations from nine years of record for each duration) are derived from computed hourly temperatures for the years of 1984 through 1992. They are presented for model Segments 2, 10, 19 at each of the different diversion flows in Table 7.1-1 for the maximum daily temperatures and Table 7.1-2 for the mean daily temperatures on an annual basis and in Tables 7.1-3 and 7.1-4 for the period 15 February through 31 July. These results allow describing how the temperatures change with diversion flow, distance downstream and duration.

Change in maximum temperature with diversion and duration.

The maxima of the maximum temperatures are at the zero diversion (or natural) flow for each duration for the upper end of the East Branch study area. At the lower end of the study area (Segment 19), the maxima at the highest diversion flow, are approximately equal to the maxima at zero diversion. The maximum temperatures for all the diversion cases are nearly the same.

Change in mean daily temperature with diversion and duration at each segment.

At Segment 2, the mean daily temperatures with the diversion flows are higher than those without the diversion but are almost the same over all the diversion flows. At Segment 10, the mean daily temperatures with the diversion are almost the same as those without the diversion for the short durations of seven days or less. At Segment 19, the mean daily temperatures over all the flows are almost the same for each duration. Thus, the mean daily temperatures with the diversion become more similar to non-diversion temperatures in the downstream direction.

7.1.3 Frequency-Duration Results

The return period of the means of the duration temperatures given in Tables 7.1-1 through 7.1-4 is 2.33 years based on a Gumbel distribution. The Gumbel probability function is

$$P(y)=1-Exp[-Exp(-y)]$$

where P(y) is the probability of a temperature at a given duration being equalled or exceeded; and, y=(T-B)/A where T is the temperature, A=Sd/1.283 where Sd is the standard deviation for a given duration and B=Md-0.45*Sd where Md is mean temperature for a given duration. The return period is 1/P(y).

The Gumbel probability function allows estimating temperatures at different return periods over each duration for each case of location and diversion flow. These results allow determining the annual frequency with which critical temperatures might be equalled or exceeded for given durations as a method to determine what the effects of temperatures might be like over future years. The results are given for segments 2, 10 and 19 respectively in Tables 7.1-5, 7.1-6, and 7.1-7 for the maximum daily temperatures and in Tables 7.1-8, 7.1-9, and 7.1-10 for mean daily temperatures on an annual basis. Tables 7.1-11 through 7.1-16 show the same results for the specific time period representing the Trout Stocking Season (15 February through 31 July). Figures 7.1-6 through 7.1-8 show the percentage of days exceeding temperatures for separate periods of 15 April through 1 June and 15 February through 1 August for Segments 2, 10, and 19, respectively (see Section 7.5). The change in temperatures with diversion flows, duration and location are the same for each return period as they were for the maximum temperature and mean daily temperatures given in Table 7.1-1 and Table 7.1-2.

7.2 Summarized Model Results for Biological Evaluation

The model output was classified and summarized for representative stream sections and key time periods to facilitate the biological comparison of Study Cases I and II. The data summaries are confined to the time frame 1 March through 31 October to focus on the period of major biological activity in the East Branch Perkiomen Creek. Data are only presented for stream Segments 2, 10, and 19 in most instances.

7.2.1 Maximum and Minimum Temperatures

Daily maximum and minimum temperatures calculated by the thermal model for three representative stream segments (2, 10, and 19) and four diversion rates (0, 10, 27, and 54 cfs) were grouped by week for the period 1 March through 31 October, providing data populations of up to 63 temperatures (7 days per week x 9 years). The maximum and minimum temperature extremes for each weekly population are presented in Figures 7.2-1 through 7.2-9.

Segment 2 - variation in predicted weekly maximum-minimum temperature extremes is considerably less at all diversion flows (Study Case II) than under natural flow conditions with no diversion (Study Case I) (Figures 7.2-1 through 7.2-3). The distribution of predicted temperatures for all diversion rates falls completely within the distribution of predicted natural flow conditions with no diversion.

Segment 10 - the variation in predicted maximum-minimum temperatures is considerably less at all diversion flows than under natural flow conditions with no diversion (Figures 7.2-4 through 7.2-6). The distribution of predicted temperatures for all diversion cases is greater than was observed for Segment 2, but continues to fall completely within the distribution of predicted unaugmented flow conditions. The range of expected temperatures contracts as diversion flow increases from 10 to 27 to 54 cfs, particularly minimum temperatures. Reduction in maximum temperature extreme is most pronounced during the period March to mid-May as diversion is increased from 10 to 27 cfs.

Segment 19 - the variation in predicted maximum-minimum temperatures is almost equal to that predicted for no diversion flow (Figures 7.2-7 through 7.2-9). The expected temperature range contracts as diversion flow increases from 10 to 27 to 54 cfs, particularly during the period March to early May. Expected minimum temperatures increase somewhat beginning in early April and extending through October.

7.2.2 Daily Change in Temperatures (Diurnal Variation)

Daily maximum and minimum temperatures calculated by the thermal model were used to determine daily, or diurnal temperature variation (Figure 7.2-10 through 7.2-21). In this instance weekly descriptive statistics were generated from a data population consisting of up to 63 daily temperature ranges within each week of the March through October period.

Segment 2 - predicted diurnal amplitude is far greater without diversion than with even 10 cfs additional flow. With no diversion, mean values exceed 10 F and maximum values exceed 20 F. At diversion flows of 10, 27, and 54 cfs mean diurnal variation does not exceed 3 F and maximum values exceeding 5 F are uncommon.

Segment 10 - predicted diurnal variation with diversion is reduced compared to the no diversion condition. The degree of reduction in all cases is less than predicted at Segment 2, and there is more variation predicted between diversion flows 10, 27, and 54 cfs than at Segment 2 as the augmented stream more closely mimics the thermal characteristics of the pre-diversion condition.

Segment 19 - predicted diurnal variation without flow addition is substantially less than at Segments 2 and 10, and very similar for the diversion and no diversion flow rates. The difference in mean daily temperature change between no diversion and 54 cfs is less than 2 F.

7.2.3 Daily Mean and Daily Maximum Temperatures

Daily mean temperatures were determined from the predictive thermal model and grouped by week to provide populations of up to 63 values per week. Mean, maximum, minimum, and upper and lower confidence limits (two standard deviations on either side of the mean) were determined for these weekly populations and are graphically presented by stream segment and diversion rate in Figure 7.2-22 through 7.2-33.

These data also show that diversion flows moderate the natural high variability in temperature characteristic of the natural stream and that this moderating influence is less effective

downstream (especially at Segment 19) as the stream tends to have similar thermal characteristics whether or not diversion flows are imposed on the stream.

The mean weekly temperatures for the four flow conditions are presented in combination by stream segment (Figures 7.2-34 through 7.2-36). These figures show that flow augmentation has a warming effect that is most evident at Segment 2 from mid-March through October but barely discernible at Segment 19 until stream temperatures begin to decrease after July. At Segment 10 the warming effect is intermediate and hardly evident until after May. The mean temperatures with the diversion flows decrease in the downstream direction to become almost the same as the mean temperatures without diversion by Segment 19.

Plots of the weekly mean of the daily maximum temperatures (a mean based on up to 63 daily maximums for each week, 7 days x 9 years) show virtually no difference with or without diversion until after temperatures peak in late July (Figures 7.2-37 through 7.2-39).

7.2.4 Hourly Rate of Temperature Change

Maximum hourly rate of change in temperature for each day in the 9-year study period were grouped by week to yield populations of up to 63 values (7 values for each week x 9 years). Descriptive statistics were determined for these weekly populations and are displayed on Figure 7.2-40 through 7.2-51. The mean daily maximum hourly rate of change in temperature for the four flow conditions are presented in combination by stream segment in Figures 7.2-52 through 7.2-54.

These data show that without diversion the free-flowing stream, represented by Segments 2 and 10, experiences highly variable temperatures and that diversion flows moderate this variability. A similar conclusion is evident from the temperature range and diurnal variation data discussed previously. The average maximum hourly rate of temperature change under the no diversion case from May through September exceeds 2 F and commonly ranges to 4 F and higher. Diversion flows serve to moderate the variability to a mean rate of change of 1 F or less at 27 and 54 cfs. The impounded stream reach, represented by Segment 19, is naturally much less variable than the free-flowing segments and diversion flows have little moderating effect even at 54 cfs.

7.3 Thermal Requirements of RIS

An extensive volume of fisheries literature concerning thermal preference/tolerance of various species exists, much of it published in the 1970's and early 1980's in response to nation-wide interest in power plant heated effluent discharge issues. This literature was reviewed by the US FWS and incorporated into a series of publications that describe Habitat Suitability Information for several species, including all of the RIS for this demonstration except spotfin shiner. The data in the appropriate numbers of these "HSI Blue Books" (issued 1983-1986) form the basis for discussion of thermal requirements of the other four RIS (smallmouth bass, white sucker, rainbow trout, and brown trout) below, since these data are generally and widely accepted by the natural resource and regulatory agencies.

Temperature is only one of the criteria defining habitat selection or suitability for fishes. Others include flow rate, gradient, substrate composition, streamside and subsurface cover,

dissolved oxygen and pH levels, and predator and prey populations. Although this demonstration necessarily concentrates on temperature, other habitat variables, particularly flow, must be considered in the context of biological evaluation. Flow is a major consideration in the upper East Branch because prior to diversion, the creek upstream of Sellersville-Perkasie, and especially above the Morris Run confluence just upstream of Branch Road (Segment 10), had very low base flows during extended periods from late spring through fall. During these periods the stream would be reduced to a series of small, nearly isolated pools. The low flows upstream of Segment 10 and lack of sufficient public access were the two factors that argued most strongly against use of the reach above Branch Road for a Trout Stocked Fishery. Lack of sufficient flow in the pre-diversion case was shown to be a prime limiting habitat variable in a habitat suitability simulation study performed for PECo (RMC 1989b). This study showed that the increased flows characteristic of the diversion were necessary to create the type of flowing stream habitat preferred by brown and rainbow trout.

To evaluate the results of temperature research studies pertinent to the RIS which were published more recently, a computerized literature search covering the period 1984 through 1992 was conducted of the following databases: NTIS, Aquatic Science Abstracts, Water Resources Abstracts, and Electric Power Database. The search did not yield any new findings that were judged preferable to those in the HSI Blue Books. Since an HSI Blue Book is not available for spotfin shiner, the search for this species was expanded to include research published prior to 1984. Data from several sources are used to evaluate this species.

7.3.1 Smallmouth Bass

The original range of the smallmouth bass (Micropterus dolomieui) extended from the Great Lakes south to northern Georgia and Alabama, east to the Appalachian range, and west to eastern Oklahoma. The species has been widely introduced outside of this range in the Northeast and areas west of the Mississippi drainage.

Smallmouth bass usually spawn over a period of 6 to 10 days in spring to early summer, usually mid-April to July. The specific spawning period is dependent upon such criteria as geographical location, water temperature, and photoperiod and angle of incidental sunlight. Nest building and spawning occur when the water temperature is 55 to 70 F, but most activity occurs at or above 59 F with most egg deposition occurring at 61 to 65 F. Smallmouth bass spawn on rocky lake shoals, river shallows, or backwaters. Up to 40% of the nests do not produce viable young due to sudden shifts in temperature, changes in water level, and fungal infections. This species may move from impoundments into creeks or tributaries to spawn.

Optimum riverine habitat is characterized by cool, clear, midorder streams > 34 feet wide with abundant shade and cover. Smallmouth bass also prefer deep pools, moderate current, and a gravel or rubble substrate. They require more than 6 ppm dissolved oxygen for optimal growth. This species can tolerate periods of high turbidity, although long term turbidity and siltation will reduce or displace a population.

Temperature preference and avoidance ranges for smallmouth bass vary considerably depending on acclimation temperature (Table 7.3-1). Adult bass in the laboratory preferred temperatures of 82.4 to 87.8 F. Upper lethal temperatures for adults are above 90 F.

Smallmouth bass fry grow faster at higher temperatures. The optimum temperature range for growth in the laboratory was 77 to 84.2 F. The upper lethal temperature is 100.4 F. Maximum growth for juvenile smallmouth bass occurred at 82.4 to 87.8 F. The upper lethal temperature for juveniles is 95.0 F.

7.3.2 White Sucker

The white sucker (Catostomus commersoni) is a highly adaptable species occurring in lakes, ponds, rivers, and streams of all sizes. The white sucker can be found in lacustrine and riverine environments from the Mackenzie River, Hudson Bay drainage, and the Labrador Peninsula; south along the Atlantic coast to western Georgia; along the northern extremes of the Gulf States to northern Oklahoma; north through sections of Colorado, Wyoming, and Montana; and through Alberta, north-central British Columbia, and southeastern Yukon territory. This species is the most tolerant of all suckers (catostomids) to diverse environmental factors, and can exist under conditions of low dissolved oxygen, high turbidity, siltation, and the presence of various organic and inorganic pollutants (PP&L 1986).

White suckers start their upstream spawning migration in spring when daily maximum water temperatures reach 50 F. The migration continues until the water temperature approaches 64 F. Fish move considerable distances upstream, seeking shallow water (8 to 10-in depth) with medium sized gravel substrates, and current velocities between 0.5 and 0.6 in sec^{-1}. Transitional boundaries at pool-run/riffle interfaces are favored as spawning habitat. The fertilized eggs adhere to the gravel in riffles or shift downstream and adhere to the substrate in areas with low water velocity. White sucker fry emerge about 9 to 11 days after spawning and drift downstream at night.

White suckers have broad temperature tolerance and avoidance ranges, and optimum temperatures vary geographically (Table 7.3-1). Experimental evidence suggests a 75 F optimum summer water temperature for adults. Different authors report several maximum temperatures for suckers. A temperature of 88.9 F has been reported as the critical thermal maximum, and 88.2 F as the upper lethal temperature for suckers acclimated at 78.8 F. The upper lethal temperature limits for juveniles was reported as 87.8 F, and the optimal growth range for both juveniles and adults is 50 to 82.2 F. White sucker larvae occur in water temperatures of 55.4 to 82.4 F. The upper lethal limit for larvae was reported at 89.6 F.

Optimum habitat conditions for the species are described, although white suckers are considered non-selective habitat users. Stream populations of white suckers reach maximum abundance in low to moderate gradient streams. Studies of Schuylkill River fish indicated that the white sucker prefers a fast water habitat and is less likely to be found in quiet water (PECo 1981).

White suckers avoided areas in reservoirs where dissolved oxygen (D.O.) levels were $\leq$ 2.4 mg/L, but specific information on adult and juvenile D.O. requirements are lacking. It has been reported that embryos could not survive D.O. levels $\leq$ 1.2 mg/L and that growth of fry was reduced at D.O. levels $<$ 2.5 mg/L.

7.3.3 Spotfin Shiner

Spotfin shiner (Notropis spilopterus) is distributed from the Mississippi drainage through the glacial lake outlets to Atlantic coastal streams. It is now common from the Hudson River to headwaters of the Potomac (Cooper 1983). Spotfin shiners are common to habitats from fast flowing streams to clear, weedy lakes; however, spotfin shiner prefer flowing waters and are especially abundant in large rivers. The species is also common in small warmwater streams characterized by low gradients and sand, gravel and rubble substrates. This minnow is tolerant of high temperatures, turbidity, and siltation (PECo 1981).

The following life history discussion is based on information provided in PECo (1981), PP&L (1986), and Brungs and Jones (1977). Spawning begins in early May as stream temperatures reach 58 F, and continues through late August (Table 7.3-1). Preferred spawning temperatures lie between 70 and 75 F. Males select and defend a spawning site located in moderately deep sections of runs and pools where submerged objects (i.e., logs and tree roots) exist. No nest is constructed and eggs are deposited within crevices. Utilization of crevices provides substantial advantages over other reproductive methodologies employed by stream fishes, including enhanced egg fertilization and protection of eggs from predator and siltation.

Hatching occurs in 5 to 6 days at 72 F. Larvae begin schooling immediately and continue this behavior as juveniles and adults. All life stages inhabit unvegetated sections of pools and deep, slow runs over sand, gravel and rubble substrates.

The spotfin shiner displays a wide thermal tolerance, indicated by its preference for warmwater streams and rivers. Reproduction begins in May and continues until August, with a range of spawning temperatures of 57.9 to 80 F.

The temperature preferred by adults is 86 F. The critical thermal maximum for juvenile and adults is between 95 F (Cherry et al. 1975) and 96.5 F (Cherry et al. 1977, PECo 1981). The upper temperature limit for optimal juvenile and adult growth is 88.3 F.

7.3.4 Rainbow Trout

Rainbow trout (Onchorynchus mikisii) are native to the Pacific Coast drainages inland as far as the Rockies and from the Rio del Presidio River in Mexico to the Kuskokwin River in Southwestern Alaska. They are now the most widely introduced fish species, and their current range extends from the Arctic Circle to 55°S latitude in southernmost South America.

Rainbow trout is commonly stocked in spring to provide put and take trout fishing opportunities in warmwater streams like the East Branch which naturally became too warm to sustain trout throughout the summer.

Optimal rainbow trout riverine habitat is characterized by clear, cold water; a silt-free rocky substrate; and a combination of pool and riffle areas with sections of slow, deep water. They prefer well-vegetated stream banks, abundant instream cover, and relatively stable water flow and temperature regimes.

Upper incipient lethal temperature (UILT) is used in this demonstration as a numerical criterion which is generally accepted for evaluation of fish survival at high temperatures (Brungs

and Jones 1977). It is the upper lethal temperature at which 50% of a sample of individuals would survive indefinitely (days) after acclimation at some other (lower) temperature. The 50% figure results from the common practice in laboratory testing (e.g., bioassays) in which the test result is expressed as an effective concentration or lethal concentration which affects 50% of the test organisms, an EC_{50} or LC_{50}, respectively. Most of the published literature is calculated at 50% survival. The published UILTs for the RIS are evaluated in comparison to weekly mean temperatures derived from the temperature modelling study. The UILT for adult rainbow trout is identified in the US FWS Habitat Suitability Information document (Raleigh et al. 1984) as 77 F.

7.3.5 Brown Trout

The brown trout (Salmo trutta) is a native of Europe and was first introduced into the United States in 1883. It is now found throughout the United States due to stocking and sustains active trout fishing programs in many states.

Optimal brown trout riverine habitat is characterized by clear, cool to cold water, a relatively silt-free rocky substrate, and a pool and riffle-run habitat combination with areas of deep water. Brown trout prefer well-vegetated, stable stream banks and require abundant stream cover with relatively stable annual water flow and temperature regimes.

Temperature is probably the single most important environmental variable determining the geographic distribution of suitable brown trout streams. The UILT for adult brown trout is identified in the US FWS Habitat Suitability Information document (Raleigh et al. 1986) as 80.6 F.

7.4 Warmwater RIS Reproductive Success and Growth

Augmentation of flow in the East Branch began in August 1989. Because long-term monitoring has characterized the warmwater fish community that existed without flow augmentation, it is appropriate to examine the results of pre-diversion fish community monitoring during the years 1981-1989 to evaluate Study Case I with regard to the warmwater RIS (smallmouth bass, white sucker, and spotfin shiner). The objectives of this monitoring effort were to describe species composition, abundance, and spatial-temporal variation within the fish community, and to relate community attributes to natural and anthropogenic changes in habitat and flow regime.

Seining and electrofishing capture techniques were used in combination to effectively sample all fish species and juvenile and adult life stages from the variety of habitats found in the East Branch. Locations on the stream are identified with an alphanumeric designator such as E32300: E stands for East Branch Perkiomen Creek, the number represents the distance in meters upstream from the mouth. Temperature model Segment 2 is equivalent to E36300 (Elephant Road), Segment 10 is equivalent to E32300 (Branch Road), and Segment 19 is equivalent to E26630 (Sellersville) (Figures 3.2-1, 4.4-3, and 4.4-4).

7.4.1 Study Case I - No Diversion

7.4.1.1 Smallmouth Bass

The smallmouth bass was found throughout the East Branch during 1981-1989, with the exception of areas upstream of E32300 (Branch Road - Segment 10). The scarcity of smallmouth bass in the upper section of the East Branch was briefly discussed in Section 4.9. It was likely due to unsuitable habitat components related to low-flow, shallow-pool conditions prevalent throughout much of the year.

Fish collections made prior to operation of the diversion (1987 through 1989) revealed a decrease in the abundance of smallmouth bass at electrofishing station E30614 (between Segments 10 and 19) compared to previous years, particularly for bass longer than 150 mm. This decrease was likely due to the intense fishing pressure of the stocked trout fishery initiated in 1987. Smallmouth bass were impacted both by harvest and by delayed mortality caused by handling and hook damage from being caught and released. The impact of the 1987-1989 (pre-diversion) trout fishery on smallmouth bass extends from Branch Road downstream to Sellersville.

Therefore, the combined effect of natural limiting factors upstream of Branch Road and angler depletion from Branch Road to downstream of Sellersville has resulted in a scarcity of smallmouth bass anywhere in this reach.

Successful reproduction of smallmouth bass in the East Branch during the period 1981-1989 has been shown annually by seine collections. Young-of-year smallmouth bass usually comprise a small fraction of total seine catch (<1%) at station E26630 or upstream. Young smallmouth bass downstream of E26630 constitute a greater percentage of total catch exceeding 20 to 50% of catch at a given station in exceptional years. Patterns in the data reveal that unusually high natural flows that occur during spring and early summer have a deleterious effect on reproductive success of smallmouth bass. High flows in May and June may disrupt spawning and later high flows may decrease survival of eggs and larval smallmouth.

Growth of smallmouth bass in the East Branch from 1981-1989 was less than was documented for most other northern U.S. streams (Carlander 1977). Mean annual back-calculated growth increments determined by scale reading for 588 smallmouth bass collected from the East Branch from 1981 to 1988 are presented in Table 7.4-1. Availability of optimal habitat for growth of East Branch smallmouth bass was low prior to flow augmentation due to stream size and flow characteristics during much of the growing season. Growth rates were very similar among stations and did not show the upstream-to-downstream increase characteristic of other species studied.

7.4.1.2 White Sucker

The white sucker is found in all life stages throughout the East Branch. Data suggest that adult white suckers are quite mobile and move considerable distances, particularly upstream to spawn and downstream to deeper pools subsequent to spawning. Most suckers collected at the headwater stations (E36235 and E36300) are Age 0 or Age 1, with occasional spawned-out adults collected in April or May. Very few white suckers older than Age 2 are collected at headwater stations in the summer or fall.

White suckers spawn early in the East Branch, usually between mid-March and mid-April. They can have a protracted spawning period if conditions are less than favorable. Collection of young white sucker in lower East Branch seine collections during 1981-1989 tended to be sporadic. However, they often comprised 2% to 24% of the total annual catch at middle and upstream stations. The distribution of adult white sucker ages determined by scale reading indicates that year-class or age group strength is highly variable, as was reported for smallmouth bass, although individuals from expected year-classes are always present in the population.

During 1981-1918 young white suckers grew rapidly compared to most other East Branch fishes (Table 7.4-1). White suckers in the East Branch tend to be relatively long-lived and 5 and 6-year old fish are not uncommon.

7.4.1.3 Spotfin shiner

The spotfin shiner is a minnow that is consistently the most abundant forage fish collected by seine in the East Branch. It has often comprised over 50% to 70% of minnows collected annually. The relative abundance of spotfin is generally least at the extreme headwater station (E36690 - Segment 2). Little is known about growth rates of spotfin shiner in the East Branch. However, reproduction and growth during 1981-1989 has been sufficient to ensure its dominance in the minnow community.

7.4.2 Study Case II, Diversion Operation

7.4.2.1 Observation of Warmwater RIS during Diversion Operation - August 1989 through 1992

The Diversion operated from 1 August 1989 through 1992 with a temperature limit of 74 F from 15 February to 1 August of each year. Cooling operations were initiated between 16 May and 23 June and continued through 31 July of each year. Flow in the East Branch was augmented without cooling from 1 August through mid-May or early June of each year from 1989 to 1992. Therefore, the aquatic community was exposed to the Study Case II thermal regime for nine or ten months in each year.

Aquatic biological sampling conducted during this period indicates that the aquatic communities and survival, growth, and reproduction of the three warmwater RIS fishes were not adversely affected by augmented flows and the resulting thermal modification of the stream.

Excellent year-class production by smallmouth bass in 1990 and 1991 compared to 1988 and 1989 indicate that flow stability and the absence of frequent spates during critical spawning and incubation periods are important to smallmouth bass reproductive success and in the East Branch.

An evaluation of the growth of smallmouth bass subsequent to diversion is difficult due to a combination of factors. Since samples are taken every two years, only data from one full year of post-diversion growth (1990) are available. Also, the frequent flooding that occurred during 1989 severely impacted both the size and composition of sample and the growth of smallmouth bass. The 1989 year-class of smallmouth bass was exceptionally small, limiting the sample size. Two and three-year old smallmouth showed impeded growth in 1989. The smaller size of these older

smallmouth as a result of the year of diminished growth may have affected their subsequent growth. Overall, incremental growth during 1990 was mixed with second year growth 8 mm greater, third year growth 12 mm less, fourth year growth 21 mm less, fifth year growth 26 mm greater, and sixth year growth 32 mm greater than 1981-1988 means. Only one fish each was present in the latter two age-groups.

Abundance of young white sucker, as determined by seine collections, increased considerably during 1990 and 1991 from depressed levels in 1988 and 1989. Growth of white sucker in 1990 as determined by scale-reading was exceptional. Annual length increments were 50, 37, 20, 15, and 15 mm greater than second through sixth year mean growth increments, respectively, during 1981-1988. Large increases in densities of available macroinvertebrate food items likely were responsible for these increased growth increments.

7.4.2.2 Delaware as Surrogate for EBPC Study Case II

The three warmwater RIS are widely distributed in North America (Section 7.3). The Delaware River basin is located near the center of the distribution range for all three warmwater fish and these species are ubiquitous within the Delaware River basin. Sampling conducted by RMC in 1989 verified the existence of populations of the three RIS species (spotfin shiner, white sucker, and smallmouth bass) in the Delaware River in the vicinity of the Point Pleasant Diversion intake (Philadelphia Electric Company 1990).

The existence of these reproducing populations is proof that the Delaware River temperature regime, as well as other habitat factors, is suitable for long term survival of these fishes. Natural temperature variations in the main stem Delaware River (diversion source) and in the East Branch, a Delaware River tributary, are within tolerance ranges of the three RIS as shown by their extensive distribution within the Delaware River basin. Therefore, the warmwater RIS populations that exist in the East Branch will be equally able to survive and thrive under the temperature conditions inherent to water diverted from the Delaware River as they are in the Delaware itself and its other warmwater tributaries.

7.4.2.3 Predictive Thermal Impacts of Diversion to RIS

Time periods predicted for smallmouth bass, white sucker, and spotfin shiner spawning and growth and maintenance were determined from the weekly statistics of the daily mean temperature (Figures 7.2-22 through 7.2-33).

Smallmouth Bass

Study results indicate no material reduction of or elimination of any smallmouth bass life stage in the representative stream segments evaluated (2, 10, and 19) due to thermal modifications resulting from flow augmentation at 10, 27, and 54 cfs.

Smallmouth reproduction in the East Branch, and in Pennsylvania in general, ends by late May or early June (RMC 1984-1988 and PECo 1989-1991). This is evident by the abandonment of spawning redds by males prior to opening of the bass fishing season during the third week of June. This opening date was selected by the PFBC to protect redd-defending adults from fishing

pressure that could negatively affect reproductive success. However, heavy angling pressure previously described for stocked trout (Section 4.9) has had considerable negative impact on the bass population in the trout stocked section of EBPC. The temperature model results were evaluated to compare the duration of optimal temperature for spawning and growth and maintenance of embryos and larvae in the three representative stream segments for the pre-diversion and post-diversion flows (Table 7.4-2). Predicted temperatures identify no differences in optimal period for smallmouth bass spawning or growth and maintenance of embryos and larvae in stream Segments 10 and 19, and a one week increase in stream Segment 2 due to earlier warming.

A similar evaluation was performed to compare predicted optimal temperature periods for growth and maintenance of smallmouth bass fry (Table 7.4-3). For the base case of the ambient stream without flow augmentation, optimal temperature was not achieved in Segments 2 and 10, and was achieved for only one week in Segment 19. Increases in optimal temperature periods for growth and maintenance of smallmouth bass fry were between 1 and 7 weeks with flow augmentation. The amount of increase in optimal temperature periods decreased with distance from the diversion outfall and increased with flow in Segments 10 and 19.

Predicted periods of optimal temperature for growth and maintenance of juvenile and adult smallmouth bass were increased between 1 and 5 weeks due to flow addition (Table 7.4-4). The amount of increase in optimal temperature periods increased with flow in all segments.

The UILT for smallmouth bass ranges from 90.1 F for adults to 100.4 F for larvae and fry (Table 7.3-1). Predicted daily mean temperatures do not exceed 85 F for any segment or discharge rate. There is no potential impact with either the base case or diversion case because the UILT is not attained.

The mean and range of diurnal and maximum hourly temperature variations decrease in comparison to the no diversion case at all diversion rates and stream segments except at Segment 19 at 54 cfs (Figures 7.2-10 through 7.2-21 and 7.2-40 through 7.2-51). Differences in mean and range of daily temperature variation for this segment and flow are less than 1 F, and differences in mean and range of maximum hourly temperature variation in this segment are less than 0.25 F. This decrease in predicted hourly and daily temperature variation with diversion is beneficial or non-impairing for indigenous warmwater and trout RIS. While the diversion is in operation, fish will not have to adjust to the extreme temperature variability inherent to natural flows in the East Branch.

White Sucker

The model results indicate no significant reduction of or elimination of any white sucker life stage due to thermal modifications resulting from flow augmentation at 10, 27, and 54 cfs.

Periods of optimal temperatures for white sucker spawning and growth and maintenance of embryos were predicted for the 12 combinations of three stream segments (2, 10, 19) and four flows (0, 10, 27, 54 cfs) beginning with the onset of suitable weekly mean temperatures and ending on 30 May (Table 7.4-5). White sucker spawning ends by late May as indicated by consistent collection of juvenile or young white suckers in large numbers in seine samples by early June (RMC 1984-1988 and PECo 1989-1992). Additionally, Bassett (1957) reports a 5 to 11 day incubation period for white sucker embryos at temperatures between 56.5 and 64.4 F. Jones et al.

(1978) reported that white suckers develop to the juvenile life stage within a 2 to 4 week period after spawning. Thus, a 30 May termination date for spawning and embryo development is reasonable.

There is no decrease in optimal period for white sucker spawning and growth and maintenance of embryos due to flow augmentation.

Periods of optimal temperatures for growth and maintenance of white sucker fry increase in all stream segments with flow augmentation (Table 7.4-6). The increase in optimal temperature period decreased with distance downstream and increased with higher diversion flows in Segment 19.

Time periods available for growth and maintenance of juvenile and adult white suckers were similar for the three stream segments and four discharge rates (Table 7.4-7). There is no adverse impact of diversion water on the optimal thermal period for growth and maintenance of juvenile and adult white suckers. The optimal period is increased up to 3 weeks.

Upper incipient lethal temperatures for white sucker range from 75.2 F for embryos to 89.6 F for larvae and fry (Table 7.3-1). Maximum predicted daily mean temperatures for all stream segments and discharge rates evaluated do not reach the upper tolerance temperature (75.2 F) for white sucker embryos during the embryo development period identified above. Maximum predicted daily mean temperatures for all stream segments and discharge rates over the entire period evaluated do not exceed 85 F and therefore, are well below the UILT for white sucker juveniles and adults.

Spotfin Shiner

Model results indicate no reduction or elimination of any spotfin shiner life stage due to thermal modifications resulting from flow augmentation at 10, 27, or 54 cfs.

Periods of optimal temperatures for reproduction of spotfin shiner and growth and maintenance of embryos, larvae, and fry were determined for the three stream segments and four discharge rates (Table 7.4-9). Temperatures used to determine these optimal thermal periods were 70 F (PP&L 1986) and 80 F (Robbins and Mathur 1976), respectively.

Predicted temperatures indicate an increase in the optimal period of up to 8 weeks for spotfin shiner spawning and development of embryo, larvae, and fry in all stream segments with flow augmentation. The amount of increased time decreased with distance from the diversion outfall and in Segments 10 and 19 increased with discharge.

Determination of time periods available for optimal growth and maintenance of juvenile and adult spotfin shiners were based on mean weekly temperatures of 70 F (PP&L 1986) to 90 F, 6 degrees below the identified thermal maximum (Cherry et al. 1975, Cherry et al. 1977) (Table 7.3-1). Predicted temperatures identify an increase in the thermally optimal period of 0 to 12 weeks for growth and maintenance of juveniles and adults for all stream segments with additional discharge. The magnitude of the increased optimal period decreased with distance from the discharge. In Segments 10 and 19, optimal duration increased with discharge rates.

Upper incipient lethal temperatures identified for juvenile and adult spotfin shiners is 95 F (Cherry et al. 1975) (Table 7.3-1). Maximum predicted daily mean temperatures for all stream segments and discharge rates evaluated do not exceed 85 F. Thus, upper thermal tolerance temperatures for all stream segments and discharge rates are not a concern.

7.5 Evaluation of Thermal Effects on RIS - Trout

7.5.1 Study Case I - No Diversion

Segments 10 and 19 were selected for evaluation of temperature effects on rainbow and brown trout because they are representative of the trout stocked fishery stream sections upstream of Rt. 309. Segment 10 is located just downstream of Branch Road bridge and is representative of the free-flowing stream reach upstream of the impounded waters at Perkasie and Sellersville. It is at the upstream end of the PFBC's Trout Stocking Area II (Figure 4.9-1). Segment 19 is located in Sellersville within the impounded waters of Lenape Park in the middle of the PFBC's Trout Stocking Area I.

The East Branch was stocked with trout in 1987, 1988, and 1989 prior to the start of diversion operation. Trout have been stocked between Pennridge Wastewater Treatment Plant at Segment 20 and Branch Road (Segment 10). Details of the number of fish stocked and harvested are presented in Section 4.9 of this report.

It is apparent that the PFBC is satisfied that this section of the East Branch meets their guidelines for a candidate trout stocking stream:

- a candidate stream should have at least two continuous miles of open fishing water,
- stream width should be greater than 10 feet through 15 June,
- a minimum flow of 2 cfs should exist through 15 June, and
- maximum stream temperature should be less than 74 F through 15 June.

The East Branch upstream of Branch Road has not been stocked, either prior to or during diversion operation. Angler access to this portion of the creek is restricted by private property. The upper reach does not meet all of the criteria for stocking now and prior to the initiation of flow augmentation did not meet the criteria with respect to stream width and minimum flow.

In summary, prior to flow augmentation, the East Branch from Pennridge Wastewater Treatment Plant to Branch Road provided a successful trout stocked fishery (TSF) (Section 4.9). The portion of stream above Branch Road was not a TSF and is therefore not evaluated. Comparisons of TSF for Study Case I (no diversion) with Study Case II (diversion with no cooling) are limited to the reach from Segments 10 to 20 because there was no TSF upstream of Branch Road in Study Case I and trout have not been stocked there for Study Case II evaluation.

7.5.2 Study Case II - Diversion, No Cooling

7.5.2.1 Suitability of East Branch Downstream of Branch Road as a TSF

Considering that PFBC TSF guidelines exclude streams that achieve or exceed 74 F prior to 15 June (Section 7.5.1), it is appropriate to evaluate the first occurrence of this temperature. Examination of predicted daily mean temperatures for the 9 modelled years reveals that the average date on which stream temperatures achieved or exceeded 74 F was 7 June at Segment 10 and 4 June at Segment 19 for the no diversion case (Table 7.5-1). The 15 June criterion was achieved under the no diversion case in just 2 of 9 years at both segments. In 1985 and 1990, when the no diversion case achieved the 15 June guideline, the three diversion cases (10, 27, and 54 cfs) also fulfilled the criteria (Table 7.5-1). On average, it took longer for the stream to reach 74 F with all diversion flows than without flow augmentation at Segment 10. At Segment 19 the stream attained an average 74 F one day sooner with 10 cfs additional flow, but at 27 cfs and 54 cfs it took 1 and 3 days longer, respectively.

In summary, there is no material difference between Study Case I (no diversion) and Study Case II (flow augmentation) in suitability of the East Branch as a TSF based upon attainment or exceedance of the 74 F temperature guidelines for a TSF.

7.5.2.2 Potential Exclusion from the TSF Area

The entire length of the East Branch TSF area from Segment 10 to Segment 20 was evaluated in terms of the number of days that this reach was thermally available to rainbow trout and brown trout. Model results of 9 years of daily mean and daily maximum temperatures for each segment for each of the four flow conditions were compared to the UILT criterion for each species to determine the thermal acceptability of a given segment for trout survival and harvest during the spring TSF season. Availability in terms of kilometer-days was evaluated for the period 15 March through 1 July when trout are actually present or have a high probability of being present in the stream as well as the longer period extending from 15 February through 1 August which coincides with the full TSF period defined in Pennsylvania's water quality standards and imposed on the diversion discharge in the present NPDES permit. Several years of creel survey studies conducted by RMC show that during the trout fishing season stocked trout are harvested very quickly from the East Branch and that by the end of June very few fish are left for harvest (see Section 4.9).

This evaluation shows that during the period from 15 March through 1 July when trout are stocked and have a high probability of actually being in the stream, the number of available kilometer-days for both trout is fractionally greater with flow augmentation than without based on daily mean temperatures (Figure 7.5-1). This same pattern is evident based on consideration of daily maximum temperatures (Figure 7.5-2).

When the entire TSF period is examined, there are more available kilometer-days at 10 cfs as compared to no diversion flow for both species based on both mean and maximum daily temperatures (Figures 7.5-1 and 7.5-2). For brown trout, habitat availability is about the same at 27 and 54 cfs as with no flow augmentation based on both temperature measures. Habitat availability for rainbow trout in both temperature cases at 27 and 54 cfs is just fractionally less than with no flow augmentation.

Thus, it is evident from this analysis that trout are not excluded from an unacceptably large portion of the East Branch TSF area as a result of flow augmentation. The length of stream predicted to have a thermal regime acceptable for stocked trout survival and harvest under all three discharge rates is not materially smaller than the area acceptable under the no diversion thermal regime.

7.5.2.3 Potential Diversion Thermal Impact to TSF Duration and Timing

The successful TSF in the East Branch depends to a great extent on the ability of the stream to sustain trout long enough for them to be harvested by anglers. Trout stocked before the season opens remain in the stream for usually 4 or 5 weeks until opening day when most are removed within 24 to 48 hours. Those stocked during the trout season are just as quickly removed by anglers.

Initally, the predicted daily mean temperature exceedance frequency distributions for the major trout fishing period of 15 April through 1 June were examined with respect to exceedance of the UILT applicable to rainbow and brown trout at representative Segments 10 and 19 for the unaugmented stream and the three modelled pumpages (Figures 7.1-7 and 7.1-8). These indicated essentially identical patterns with or without diversion at Segments 10 and 19. Inclusion of the additional months of June and July indicated more frequent exceedance of the UILTs with diversion than without at Segment 10 but essentially no differences at Segment 19.

Further analysis of the thermal ability of the TSF area to sustain trout focused on when the daily mean temperature first attained or exceeded the UILTs. It is appropriate to evaluate the UILTs in relation to mean temperatures, rather than instantaneous or daily maxima, because the UILTs are based on laboratory tests of several days duration.

Rainbow trout survival in the TSF area of the East Branch will theoretically be enhanced as indicated by the predicted date that daily mean temperatures achieve or exceed the UILT of 77 F (Table 7.5-2). The model predicts an average of 8 to 9 additional days at temperatures below the UILT in Segment 10 (all discharge rates). At Segment 19 no days are gained at 10 cfs but 5 and 12 days, are gained at 27 and 54 cfs, respectively. Theoretically, rainbow trout survival in the stream would be enhanced by these temperature differences. However, the high harvest rates described in Section 4.9 imply few trout would actually remain in the stream by these dates anyway.

Similarly, brown trout survival in the TSF area of the East Branch will also not be materially affected. Although the model predicts temperatures will achieve or exceed the UILT (80.6 F) an average of 3 to 6 days earlier in Segment 10 with flow augmentation than without, the lost days occur well after substantially all trout have been harvested (Table 7.5-3). Likewise, the days gained in Segment 19 also occur after substantially all trout have been harvested from the stream.

7.5.2.4 TSF Survival and Harvest

The survival of trout in the East Branch is enhanced by diversion flows which reduce the wide daily temperature fluctuations characteristic of the unaugmented stream. The mean and range of diurnal and maximum hourly temperature variations decrease in comparison to the no discharge

case at all flow augmentation rates at the three stream segments evaluated, except at Segment 19 at 54 cfs (Figures 7.2-10 through 7.2-21 and 7.2-40 through 7.2-51). Differences in mean and range of daily temperature variation for this exception are less than 1 F, and differences in mean and range of maximum hourly temperature variation in this segment are less than 0.25 F. This decrease in predicted hourly and daily temperature variation with diversion is beneficial for the two trout RIS. They will not have to adjust to the extreme temperature variations characteristic of natural flows in the East Branch.

Creel surveys conducted prior to and after initiation of diversion operation provide an empirical basis for evaluation of diversion effect on survival and harvest of stocked trout. The Point Pleasant diversion was operated without cooling for the first time while trout angling was occurring in 1990. Operation of chillers did not begin until testing commenced on 31 May 1990 and the chillers were not brought on-line fulltime until 7 July 1990. It is apparent from creel survey data that the flow augmented stream was attractive to anglers. The greatest number of anglers ever observed during an East Branch creel survey was present at 9:00 a.m. on opening day: 1,151 anglers within a 1.5-mile stretch of stream at Sellersville. Fishing pressure was so intense that an estimated 97% of 2,200 preseason stocked trout were harvested by the end of opening day.

Angler effort remained relatively high compared to previous years in subsequent weeks and trout stocked on 14 May 1990 were substantially depleted by 20 May 1990 when daily harvest rate decreased to less than one trout per angler hour.

The season was extended in 1990 when there was an unusual availability of surplus hatchery fish and acceptable stream conditions prompted the PFC to release an additional 3,500 trout (between Rt. 309 and Branch Road) on 8 June. High harvest rates determined by creel surveys on 8, 9, and 10 June indicated rapid depletion of trout during this period. A 5 July electrofishing survey (see Section 4.9) corroborated that very few trout remained in the creek.

Virtually all stocked trout had been harvested prior to or coincident with initiation of chiller operations in the three years (1990, 1991, and 1992) that flows of the East Branch were augmented (Table 7.5-4). The survival and harvest of the stocked trout have not been impaired by diversion operation without cooling (Study Case II). The Study Case II thermal regime for all three flow rates is a demonstrably acceptable TSF.

Table 7.1-1 Duration statistics (mean and standard deviations) derived from computed maximum daily temperatures for the years 1984 through 1992 for model segments 2, 10, 19 for each diversion flow for the full year.

Segment 2 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	87.4	87.2	83.7	82.0	80.8	79.6
	Stdev	1.90	1.81	2.01	2.08	2.10	1.94
10.0	Mean	83.4	83.5	81.8	80.7	80.1	79.4
	Stdev	2.25	2.31	1.89	1.85	1.79	1.74
27.0	Mean	83.2	83.2	81.8	80.7	80.0	79.3
	Stdev	2.27	2.25	1.89	1.80	1.72	1.67
54.0	Mean	83.4	83.5	82.0	80.9	80.2	79.6
	Stdev	2.22	2.22	1.88	1.79	1.74	1.70

Segment 10 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	88.2	88.1	85.0	83.1	81.7	80.7
	Stdev	1.78	1.81	1.73	1.94	1.89	1.75
10.0	Mean	86.6	86.5	84.1	82.6	81.6	80.7
	Stdev	1.98	1.90	1.81	1.87	1.70	1.54
27.0	Mean	85.4	85.3	83.3	82.1	81.3	80.5
	Stdev	2.16	2.24	1.87	1.84	1.78	1.61
54.0	Mean	84.6	84.6	82.7	81.5	80.8	80.1
	Stdev	2.22	2.12	1.83	1.84	1.74	1.69

Segment 19 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	85.3	85.2	82.3	80.8	79.8	79.0
	Stdev	2.31	2.28	1.94	1.92	1.84	1.80
10.0	Mean	85.2	85.0	82.2	80.8	79.7	78.9
	Stdev	2.13	2.08	1.90	1.86	1.75	1.75
27.0	Mean	84.8	84.7	82.3	81.0	80.0	79.2
	Stdev	2.22	2.15	1.80	1.83	1.63	1.66
54.0	Mean	85.5	85.5	83.2	82.0	81.1	80.3
	Stdev	2.18	2.00	1.81	1.79	1.69	1.59

Table 7.1-2 Duration statistics (mean and standard deviations) derived from computed mean daily temperatures for the years 1984 through 1992 for model segments 2, 10, 19 for each diversion flow for the full year.

Segment 2 — Mean daily temperature, F

Diversion (cfs)		1-d Max.	1	7	14	21	28
			Durations, days				
0.0	Mean	79.5	79.4	77.1	75.7	74.7	73.8
	Stdev	1.70	1.88	1.53	1.78	1.76	1.72
10.0	Mean	82.2	82.2	80.7	79.7	79.0	78.3
	Stdev	2.25	2.18	1.80	1.85	1.78	1.72
27.0	Mean	82.7	82.8	81.1	80.1	79.4	78.8
	Stdev	2.27	2.25	1.85	1.74	1.75	1.70
54.0	Mean	82.8	82.8	81.3	80.2	79.5	78.9
	Stdev	2.23	2.22	1.84	1.72	1.69	1.66

Segment 10 — Mean daily temperature, F

Diversion (cfs)		1-d Max.	1	7	14	21	28
			Durations, days				
0.0	Mean	81.3	81.2	78.1	76.8	75.6	74.7
	Stdev	1.84	1.70	1.70	1.81	1.90	1.80
10.0	Mean	80.9	80.9	78.7	77.7	76.8	76.1
	Stdev	2.06	1.93	1.74	1.76	1.68	1.55
27.0	Mean	81.6	81.6	79.8	78.8	78.0	77.4
	Stdev	2.08	2.15	1.75	1.73	1.66	1.61
54.0	Mean	82.1	82.0	80.4	79.3	78.7	78.0
	Stdev	2.16	2.15	1.76	1.71	1.67	1.66

Segment 19 — Mean daily temperature, F

Diversion (cfs)		1-d Max.	1	7	14	21	28
			Durations, days				
0.0	Mean	82.5	82.4	79.8	78.5	77.5	76.7
	Stdev	1.95	1.99	2.02	1.78	1.88	1.87
10.0	Mean	82.4	82.3	79.8	78.5	77.5	76.7
	Stdev	1.87	1.86	1.86	1.74	1.87	1.80
27.0	Mean	82.1	82.1	79.8	78.6	77.8	77.0
	Stdev	2.09	2.05	1.73	1.67	1.71	1.66
54.0	Mean	82.0	82.0	80.0	79.0	78.2	77.6
	Stdev	2.09	2.11	1.72	1.73	1.69	1.58

Table 7.1-3 Duration statistics (mean and standard deviations) derived from computed maximum daily temperatures for the years 1984 through 1992 for model segments 2, 10, 19 for each diversion flow for February 15 through July 31.

Segment 2 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	87.1	86.8	83.0	80.7	78.9	77.4
	Stdev	1.71	1.67	2.02	1.97	1.93	1.70
10.0	Mean	82.9	83.0	81.3	79.9	78.6	77.2
	Stdev	1.77	1.79	1.60	1.45	1.61	1.56
27.0	Mean	82.7	82.8	81.2	79.9	78.5	77.3
	Stdev	1.70	1.70	1.61	1.41	1.51	1.67
54.0	Mean	83.0	83.0	81.5	80.1	78.9	77.6
	Stdev	1.66	1.67	1.56	1.45	1.54	1.76

Segment 10 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	87.9	87.7	84.0	81.7	80.3	78.8
	Stdev	1.73	1.79	2.04	1.87	1.69	1.47
10.0	Mean	86.0	86.1	83.3	81.4	80.2	79.0
	Stdev	1.76	1.76	1.74	1.38	1.54	1.68
27.0	Mean	84.9	84.9	82.6	81.2	79.9	78.6
	Stdev	1.69	1.83	1.64	1.48	1.61	1.51
54.0	Mean	84.1	84.1	82.1	80.7	79.5	78.2
	Stdev	1.74	1.72	1.60	1.42	1.59	1.69

Segment 19 — Maximum daily temperature, F

Diversion (cfs)		1-d Max.	Durations, days 1	7	14	21	28
0.0	Mean	85.0	84.8	81.6	79.8	78.5	77.2
	Stdev	2.25	2.28	1.89	1.65	1.60	1.49
10.0	Mean	84.8	84.6	81.5	79.8	78.5	77.3
	Stdev	2.01	2.03	1.85	1.66	1.63	1.69
27.0	Mean	84.5	84.2	81.6	80.0	78.9	77.5
	Stdev	2.02	2.08	1.82	1.44	1.50	1.47
54.0	Mean	85.1	85.0	82.5	81.0	79.9	78.6
	Stdev	1.81	1.74	1.44	1.43	1.58	1.48

Table 7.1-4 Duration statistics (mean and standard deviations) derived from computed mean daily temperatures for the years 1984 through 1992 for model segments 2, 10, 19 for each diversion flow for February 15 through July 31.

Segment 2 — Mean daily temperature, F

Diversion (cfs)		Durations, days: 1-d Max.	1	7	14	21	28
0.0	Mean	79.0	78.8	76.2	74.6	73.1	71.7
	Stdev	1.20	1.39	1.73	1.65	1.69	1.59
10.0	Mean	81.8	81.9	80.3	78.9	77.4	76.1
	Stdev	1.67	1.73	1.46	1.41	1.39	1.65
27.0	Mean	82.2	82.3	80.7	79.3	78.0	76.7
	Stdev	1.65	1.66	1.56	1.42	1.45	1.77
54.0	Mean	82.3	82.3	80.9	79.4	78.1	76.9
	Stdev	1.63	1.64	1.49	1.43	1.50	1.69

Segment 10 — Mean daily temperature, F

Diversion (cfs)		Durations, days: 1-d Max.	1	7	14	21	28
0.0	Mean	80.7	80.4	77.3	75.6	74.2	73.0
	Stdev	2.20	2.04	1.87	1.80	1.80	1.72
10.0	Mean	80.5	80.4	78.0	76.8	75.5	74.3
	Stdev	1.91	1.77	1.59	1.45	1.48	1.45
27.0	Mean	81.2	81.1	79.2	78.0	76.7	75.6
	Stdev	1.68	1.64	1.56	1.36	1.44	1.65
54.0	Mean	81.6	81.6	79.8	78.6	77.4	76.2
	Stdev	1.64	1.62	1.52	1.43	1.43	1.66

Segment 19 — Mean daily temperature, F

Diversion (cfs)		Durations, days: 1-d Max.	1	7	14	21	28
0.0	Mean	82.1	81.9	79.3	77.6	76.3	74.8
	Stdev	1.88	1.90	1.87	1.69	1.57	1.70
10.0	Mean	81.9	81.7	79.1	77.6	76.2	74.8
	Stdev	1.75	1.73	1.75	1.71	1.58	1.68
27.0	Mean	81.6	81.5	79.1	77.7	76.5	75.2
	Stdev	1.82	1.76	1.61	1.61	1.41	1.57
54.0	Mean	81.6	81.6	79.4	78.2	77.0	75.8
	Stdev	1.77	1.75	1.50	1.44	1.41	1.61

Table 7.1-5 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 2 for the full year.

Segment 2
No diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	87.4	87.2	83.7	82.0	80.8	79.6
Period(yr)	Stdev	1.90	1.81	2.01	2.08	2.10	1.94
2		87.1	86.9	83.4	81.7	80.5	79.3
5		88.8	88.5	85.1	83.5	82.3	81.0
10		89.9	89.6	86.3	84.7	83.5	82.1
20		90.9	90.6	87.4	85.9	84.7	83.2

Segment 2
10 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	83.4	83.5	81.8	80.7	80.1	79.4
Period(yr)	Stdev	2.25	2.31	1.89	1.85	1.79	1.74
2		83.0	83.1	81.5	80.4	79.8	79.1
5		85.0	85.2	83.2	82.0	81.4	80.7
10		86.3	86.5	84.3	83.1	82.4	81.7
20		87.6	87.8	85.3	84.2	83.4	82.6

Segment 2
27 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	83.2	83.2	81.8	80.7	80.0	79.3
Period(yr)	Stdev	2.27	2.25	1.89	1.80	1.72	1.67
2		82.8	82.8	81.5	80.4	79.7	79.0
5		84.8	84.8	83.2	82.0	81.2	80.5
10		86.2	86.1	84.3	83.0	82.2	81.5
20		87.4	87.4	85.3	84.1	83.2	82.4

Segment 2
54 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	83.4	83.5	82.0	80.9	80.2	79.6
Period(yr)	Stdev	2.22	2.22	1.88	1.79	1.74	1.70
2		83.0	83.1	81.7	80.6	79.9	79.3
5		85.0	85.1	83.4	82.2	81.5	80.8
10		86.3	86.4	84.5	83.2	82.5	81.8
20		87.5	87.6	85.5	84.2	83.4	82.8

Table 7.1-6 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 10 for the full year.

Segment 10
No diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	88.2	88.1	85.0	83.1	81.7	80.7
Period(yr)	Stdev	1.78	1.81	1.73	1.94	1.89	1.75
	2	87.9	87.8	84.7	82.8	81.4	80.4
	5	89.5	89.4	86.2	84.5	83.1	82.0
	10	90.5	90.5	87.3	85.6	84.2	83.0
	20	91.5	91.5	88.2	86.7	85.2	84.0

Segment 10
10 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	86.6	86.5	84.1	82.6	81.6	80.7
Period(yr)	Stdev	1.98	1.90	1.81	1.87	1.70	1.54
	2	86.3	86.2	83.8	82.3	81.3	80.4
	5	88.0	87.9	85.4	83.9	82.8	81.8
	10	89.2	89.0	86.5	85.0	83.8	82.7
	20	90.3	90.0	87.5	86.1	84.8	83.6

Segment 10
27 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	85.4	85.3	83.3	82.1	81.3	80.5
Period(yr)	Stdev	2.16	2.24	1.87	1.84	1.78	1.61
	2	85.0	84.9	83.0	81.8	81.0	80.2
	5	87.0	86.9	84.6	83.4	82.6	81.7
	10	88.2	88.2	85.7	84.5	83.6	82.6
	20	89.4	89.5	86.8	85.5	84.6	83.5

Segment 10
54 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	84.6	84.6	82.7	81.5	80.8	80.1
Period(yr)	Stdev	2.22	2.12	1.83	1.84	1.74	1.69
	2	84.2	84.3	82.4	81.2	80.5	79.8
	5	86.2	86.1	84.0	82.8	82.1	81.3
	10	87.5	87.4	85.1	83.9	83.1	82.3
	20	88.7	88.6	86.1	84.9	84.0	83.3

Table 7.1-7 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 19 for the full year.

Segment 19
No diversion

Maximum daily temperature, F

		1-d Max.	Durations, days 1	7	14	21	28
Return	Mean	85.3	85.2	82.3	80.8	79.8	79.0
Period(yr)	Stdev	2.31	2.28	1.94	1.92	1.84	1.80
2		84.9	84.8	82.0	80.5	79.5	78.7
5		87.0	86.8	83.7	82.2	81.1	80.3
10		88.3	88.2	84.8	83.3	82.2	81.3
20		89.6	89.5	85.9	84.4	83.2	82.4

Segment 19
10 cfs diversion

Maximum daily temperature, F

		1-d Max.	Durations, days 1	7	14	21	28
Return	Mean	85.2	85.0	82.2	80.8	79.7	78.9
Period(yr)	Stdev	2.13	2.08	1.90	1.86	1.75	1.75
2		84.8	84.7	81.9	80.5	79.4	78.6
5		86.7	86.5	83.6	82.1	81.0	80.2
10		88.0	87.7	84.7	83.2	82.0	81.2
20		89.2	88.9	85.7	84.3	83.0	82.2

Segment 19
27 cfs diversion

Maximum daily temperature, F

		1-d Max.	Durations, days 1	7	14	21	28
Return	Mean	84.8	84.7	82.3	81.0	80.0	79.2
Period(yr)	Stdev	2.22	2.15	1.80	1.83	1.63	1.66
2		84.4	84.3	82.0	80.7	79.7	78.9
5		86.4	86.2	83.6	82.3	81.2	80.4
10		87.7	87.5	84.6	83.4	82.1	81.4
20		88.9	88.7	85.7	84.4	83.0	82.3

Segment 19
54 cfs diversion

Maximum daily temperature, F

		1-d Max.	Durations, days 1	7	14	21	28
Return	Mean	85.5	85.5	83.2	82.0	81.1	80.3
Period(yr)	Stdev	2.18	2.00	1.81	1.79	1.69	1.59
2		85.1	85.2	82.9	81.7	80.8	80.0
5		87.1	86.9	84.5	83.3	82.3	81.4
10		88.3	88.1	85.6	84.3	83.3	82.4
20		89.6	89.2	86.6	85.3	84.3	83.3

Table 7.1-8 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 2 for the full year.

Segment 2
No diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	79.5	79.4	77.1	75.7	74.7	73.8
Period(yr)	Stdev	1.70	1.88	1.53	1.78	1.76	1.72
2		79.2	79.1	76.8	75.4	74.4	73.5
5		80.7	80.8	78.2	77.0	76.0	75.0
10		81.7	81.9	79.1	78.0	77.0	76.0
20		82.7	82.9	80.0	79.0	78.0	77.0

Segment 2
10 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.2	82.2	80.7	79.7	79.0	78.3
Period(yr)	Stdev	2.25	2.18	1.80	1.85	1.78	1.72
2		81.8	81.8	80.4	79.4	78.7	78.0
5		83.8	83.8	82.0	81.0	80.3	79.5
10		85.1	85.0	83.0	82.1	81.3	80.5
20		86.4	86.3	84.1	83.2	82.3	81.5

Segment 2
27 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.7	82.8	81.1	80.1	79.4	78.8
Period(yr)	Stdev	2.27	2.25	1.85	1.74	1.75	1.70
2		82.3	82.4	80.8	79.8	79.1	78.5
5		84.3	84.4	82.4	81.4	80.7	80.0
10		85.7	85.7	83.5	82.4	81.7	81.0
20		86.9	87.0	84.6	83.3	82.7	82.0

Segment 2
54 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.8	82.8	81.3	80.2	79.5	78.9
Period(yr)	Stdev	2.23	2.22	1.84	1.72	1.69	1.66
2		82.4	82.4	81.0	79.9	79.2	78.6
5		84.4	84.4	82.6	81.4	80.7	80.1
10		85.7	85.7	83.7	82.4	81.7	81.1
20		87.0	86.9	84.7	83.4	82.7	82.0

Table 7.1-9 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 10 for the full year.

Segment 10
No diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.3	81.2	78.1	76.8	75.6	74.7
Period(yr)	Stdev	1.84	1.70	1.70	1.81	1.90	1.80
2		81.0	80.9	77.8	76.5	75.3	74.4
5		82.6	82.4	79.3	78.1	77.0	76.0
10		83.7	83.4	80.3	79.2	78.1	77.0
20		84.7	84.4	81.3	80.2	79.1	78.1

Segment 10
10 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	80.9	80.9	78.7	77.7	76.8	76.1
Period(yr)	Stdev	2.06	1.93	1.74	1.76	1.68	1.55
2		80.6	80.6	78.4	77.4	76.5	75.8
5		82.4	82.3	80.0	79.0	78.0	77.2
10		83.6	83.4	81.0	80.0	79.0	78.1
20		84.7	84.5	81.9	81.0	79.9	79.0

Segment 10
27 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.6	81.6	79.8	78.8	78.0	77.4
Period(yr)	Stdev	2.08	2.15	1.75	1.73	1.66	1.61
2		81.3	81.2	79.5	78.5	77.7	77.1
5		83.1	83.1	81.1	80.0	79.2	78.6
10		84.3	84.4	82.1	81.1	80.2	79.5
20		85.5	85.6	83.1	82.0	81.1	80.4

Segment 10
54 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.1	82.0	80.4	79.3	78.7	78.0
Period(yr)	Stdev	2.16	2.15	1.76	1.71	1.67	1.66
2		81.7	81.6	80.1	79.0	78.4	77.7
5		83.7	83.5	81.7	80.5	79.9	79.2
10		84.9	84.8	82.7	81.5	80.9	80.2
20		86.1	86.0	83.7	82.5	81.8	81.1

Table 7.1-10 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 19 for the full year.

Segment 19
No diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.5	82.4	79.8	78.5	77.5	76.7
Period(yr)	Stdev	1.95	1.99	2.02	1.78	1.88	1.87
2		82.2	82.1	79.5	78.2	77.2	76.4
5		83.9	83.8	81.3	79.8	78.9	78.0
10		85.0	85.0	82.4	80.8	80.0	79.1
20		86.1	86.1	83.6	81.8	81.0	80.2

Segment 19
10 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.4	82.3	79.8	78.5	77.5	76.7
Period(yr)	Stdev	1.87	1.86	1.86	1.74	1.87	1.80
2		82.1	82.0	79.5	78.2	77.2	76.4
5		83.7	83.6	81.1	79.8	78.8	78.0
10		84.8	84.7	82.2	80.8	79.9	79.0
20		85.9	85.8	83.3	81.7	81.0	80.1

Segment 19
27 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.1	82.1	79.8	78.6	77.8	77.0
Period(yr)	Stdev	2.09	2.05	1.73	1.67	1.71	1.66
2		81.8	81.8	79.5	78.3	77.5	76.7
5		83.6	83.6	81.0	79.8	79.0	78.2
10		84.8	84.8	82.1	80.8	80.0	79.2
20		86.0	85.9	83.0	81.7	81.0	80.1

Segment 19
54 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.0	82.0	80.0	79.0	78.2	77.6
Period(yr)	Stdev	2.09	2.11	1.72	1.73	1.69	1.58
2		81.7	81.7	79.7	78.7	77.9	77.3
5		83.5	83.5	81.2	80.2	79.4	78.7
10		84.7	84.8	82.2	81.3	80.4	79.7
20		85.9	85.9	83.2	82.2	81.4	80.5

Table 7.1-11 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 2 for February 15 through July 31.

Segment 2
No diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	87.1	86.8	83.0	80.7	78.9	77.4
Period(yr)	Stdev	1.71	1.67	2.02	1.97	1.93	1.70
	2	86.8	86.5	82.7	80.4	78.6	77.1
	5	88.3	88.0	84.5	82.1	80.3	78.6
	10	89.3	89.0	85.6	83.3	81.4	79.6
	20	90.3	89.9	86.8	84.4	82.5	80.6

Segment 2
10 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.9	83.0	81.3	79.9	78.6	77.2
Period(yr)	Stdev	1.77	1.79	1.60	1.45	1.61	1.56
	2	82.6	82.7	81.0	79.7	78.3	76.9
	5	84.2	84.3	82.5	80.9	79.8	78.3
	10	85.2	85.3	83.4	81.8	80.7	79.2
	20	86.2	86.3	84.3	82.6	81.6	80.1

Segment 2
27 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.7	82.8	81.2	79.9	78.5	77.3
Period(yr)	Stdev	1.70	1.70	1.61	1.41	1.51	1.67
	2	82.4	82.5	80.9	79.7	78.3	77.0
	5	83.9	84.0	82.4	80.9	79.6	78.5
	10	84.9	85.0	83.3	81.7	80.5	79.5
	20	85.9	86.0	84.2	82.5	81.3	80.4

Segment 2
54 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	83.0	83.0	81.5	80.1	78.9	77.6
Period(yr)	Stdev	1.66	1.67	1.56	1.45	1.54	1.76
	2	82.7	82.7	81.2	79.9	78.6	77.3
	5	84.2	84.2	82.6	81.1	80.0	78.9
	10	85.2	85.2	83.5	82.0	80.9	79.9
	20	86.1	86.1	84.4	82.8	81.8	80.9

Table 7.1-12 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 10 for February 15 through July 31.

Segment 10
No diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	87.9	87.7	84.0	81.7	80.3	78.8
Period(yr)	Stdev	1.73	1.79	2.04	1.87	1.69	1.47
2		87.6	87.4	83.7	81.4	80.0	78.6
5		89.1	89.0	85.5	83.0	81.5	79.9
10		90.2	90.0	86.7	84.1	82.5	80.7
20		91.1	91.0	87.8	85.2	83.5	81.5

Segment 10
10 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	86.0	86.1	83.3	81.4	80.2	79.0
Period(yr)	Stdev	1.76	1.76	1.74	1.38	1.54	1.68
2		85.7	85.8	83.0	81.2	79.9	78.7
5		87.3	87.4	84.6	82.4	81.3	80.2
10		88.3	88.4	85.6	83.2	82.2	81.2
20		89.3	89.4	86.5	84.0	83.1	82.1

Segment 10
27 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	84.9	84.9	82.6	81.2	79.9	78.6
Period(yr)	Stdev	1.69	1.83	1.64	1.48	1.61	1.51
2		84.6	84.6	82.3	81.0	79.6	78.4
5		86.1	86.2	83.8	82.3	81.1	79.7
10		87.1	87.3	84.7	83.1	82.0	80.6
20		88.1	88.3	85.7	84.0	82.9	81.4

Segment 10
54 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	84.1	84.1	82.1	80.7	79.5	78.2
Period(yr)	Stdev	1.74	1.72	1.60	1.42	1.59	1.69
2		83.8	83.8	81.8	80.5	79.2	77.9
5		85.4	85.3	83.3	81.7	80.6	79.4
10		86.4	86.3	84.2	82.6	81.6	80.4
20		87.3	87.3	85.1	83.3	82.5	81.4

Table 7.1-13 Annual frequencies with which the maximum daily temperature is equalled or exceeded for given durations for segment 19 for February 15 through July 31.

Segment 19
No diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	85.0	84.8	81.6	79.8	78.5	77.2
Period(yr)	Stdev	2.25	2.28	1.89	1.65	1.60	1.49
2		84.6	84.4	81.3	79.5	78.2	77.0
5		86.6	86.4	83.0	81.0	79.7	78.3
10		87.9	87.8	84.1	82.0	80.6	79.1
20		89.2	89.1	85.1	82.9	81.5	80.0

Segment 19
10 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	84.8	84.6	81.5	79.8	78.5	77.3
Period(yr)	Stdev	2.01	2.03	1.85	1.66	1.63	1.69
2		84.5	84.3	81.2	79.5	78.2	77.0
5		86.2	86.1	82.8	81.0	79.7	78.5
10		87.4	87.2	83.9	82.0	80.6	79.5
20		88.5	88.4	85.0	82.9	81.5	80.5

Segment 19
27 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	84.5	84.2	81.6	80.0	78.9	77.5
Period(yr)	Stdev	2.02	2.08	1.82	1.44	1.50	1.47
2		84.2	83.9	81.3	79.8	78.7	77.3
5		86.0	85.7	82.9	81.0	80.0	78.6
10		87.1	86.9	84.0	81.9	80.9	79.4
20		88.3	88.1	85.0	82.7	81.7	80.2

Segment 19
54 cfs diversion

Maximum daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	85.1	85.0	82.5	81.0	79.9	78.6
Period(yr)	Stdev	1.81	1.74	1.44	1.43	1.58	1.48
2		84.8	84.7	82.3	80.8	79.6	78.4
5		86.4	86.3	83.5	82.0	81.0	79.7
10		87.5	87.3	84.4	82.9	82.0	80.5
20		88.5	88.2	85.2	83.7	82.8	81.4

Table 7.1-14 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 2 for February 15 through July 31.

Segment 2
No diversion

		Mean daily temperature, F					
			Durations, days				
		1-d Max.	1	7	14	21	28
Return	Mean	79.0	78.8	76.2	74.6	73.1	71.7
Period(yr)	Stdev	1.20	1.39	1.73	1.65	1.69	1.59
	2	78.8	78.6	75.9	74.3	72.8	71.4
	5	79.9	79.8	77.4	75.8	74.3	72.8
	10	80.6	80.6	78.5	76.8	75.3	73.8
	20	81.2	81.4	79.4	77.7	76.3	74.7

Segment 2
10 cfs diversion

		Mean daily temperature, F					
			Durations, days				
		1-d Max.	1	7	14	21	28
Return	Mean	81.8	81.9	80.3	78.9	77.4	76.1
Period(yr)	Stdev	1.67	1.73	1.46	1.41	1.39	1.75
	2	81.5	81.6	80.1	78.7	77.2	75.8
	5	83.0	83.1	81.3	79.9	78.4	77.3
	10	84.0	84.2	82.2	80.7	79.2	78.3
	20	84.9	85.1	83.0	81.5	80.0	79.2

Segment 2
27 cfs diversion

		Mean daily temperature, F					
			Durations, days				
		1-d Max.	1	7	14	21	28
Return	Mean	82.2	82.3	80.7	79.3	78.0	76.7
Period(yr)	Stdev	1.65	1.66	1.56	1.42	1.45	1.77
	2	81.9	82.0	80.4	79.1	77.8	76.4
	5	83.4	83.5	81.8	80.3	79.0	78.0
	10	84.4	84.5	82.7	81.2	79.9	79.0
	20	85.3	85.4	83.6	81.9	80.7	80.0

Segment 2
54 cfs diversion

		Mean daily temperature, F					
			Durations, days				
		1-d Max.	1	7	14	21	28
Return	Mean	82.3	82.3	80.9	79.4	78.1	76.9
Period(yr)	Stdev	1.63	1.64	1.49	1.43	1.50	1.69
	2	82.0	82.0	80.7	79.2	77.9	76.6
	5	83.5	83.5	82.0	80.4	79.2	78.1
	10	84.4	84.4	82.8	81.3	80.1	79.1
	20	85.3	85.4	83.7	82.1	80.9	80.1

Table 7.1-15 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 10 for February 15 through July 31.

Segment 10
No diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.3	81.2	78.1	76.8	75.6	74.7
Period(yr)	Stdev	1.84	1.70	1.70	1.81	1.90	1.80
	2	81.0	80.9	77.8	76.5	75.3	74.4
	5	82.6	82.4	79.3	78.1	77.0	76.0
	10	83.7	83.4	80.3	79.2	78.1	77.0
	20	84.7	84.4	81.3	80.2	79.1	78.1

Segment 10
10 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	80.9	80.9	78.7	77.7	76.8	76.1
Period(yr)	Stdev	2.06	1.93	1.74	1.76	1.68	1.55
	2	80.6	80.6	78.4	77.4	76.5	75.8
	5	82.4	82.3	80.0	79.0	78.0	77.2
	10	83.6	83.4	81.0	80.0	79.0	78.1
	20	84.7	84.5	81.9	81.0	79.9	79.0

Segment 10
27 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.6	81.6	79.8	78.8	78.0	77.4
Period(yr)	Stdev	2.08	2.15	1.75	1.73	1.66	1.61
	2	81.3	81.2	79.5	78.5	77.7	77.1
	5	83.1	83.1	81.1	80.0	79.2	78.6
	10	84.3	84.4	82.1	81.1	80.2	79.5
	20	85.5	85.6	83.1	82.0	81.1	80.4

Segment 10
54 cfs diversion

Mean daily temperature, F

		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.1	82.0	80.4	79.3	78.7	78.0
Period(yr)	Stdev	2.16	2.15	1.76	1.71	1.67	1.66
	2	81.7	81.6	80.1	79.0	78.4	77.7
	5	83.7	83.5	81.7	80.5	79.9	79.2
	10	84.9	84.8	82.7	81.5	80.9	80.2
	20	86.1	86.0	83.7	82.5	81.8	81.1

Table 7.1-16 Annual frequencies with which the mean daily temperature is equalled or exceeded for given durations for segment 19 for February 15 through July 31.

Segment 19
No diversion

		Mean daily temperature, F					
		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	82.1	81.9	79.3	77.6	76.3	74.8
Period(yr)	Stdev	1.88	1.90	1.87	1.69	1.57	1.70
2		81.8	81.6	79.0	77.3	76.0	74.5
5		83.5	83.3	80.6	78.8	77.4	76.0
10		84.6	84.4	81.7	79.8	78.3	77.0
20		85.6	85.4	82.8	80.8	79.2	78.0

Segment 19
10 cfs diversion

		Mean daily temperature, F					
		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.9	81.7	79.1	77.6	76.2	74.8
Period(yr)	Stdev	1.75	1.73	1.75	1.71	1.58	1.68
2		81.6	81.4	78.8	77.3	75.9	74.5
5		83.2	82.9	80.4	78.8	77.3	76.0
10		84.2	84.0	81.4	79.8	78.3	77.0
20		85.2	84.9	82.4	80.8	79.1	77.9

Segment 19
27 cfs diversion

		Mean daily temperature, F					
		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.6	81.5	79.1	77.7	76.5	75.2
Period(yr)	Stdev	1.82	1.76	1.61	1.61	1.41	1.57
2		81.3	81.2	78.8	77.4	76.3	74.9
5		82.9	82.8	80.3	78.9	77.5	76.3
10		84.0	83.8	81.2	79.8	78.3	77.2
20		85.0	84.8	82.1	80.7	79.1	78.1

Segment 19
54 cfs diversion

		Mean daily temperature, F					
		Durations, days					
		1-d Max.	1	7	14	21	28
Return	Mean	81.6	81.6	79.4	78.2	77.0	75.8
Period(yr)	Stdev	1.77	1.75	1.50	1.44	1.41	1.61
2		81.3	81.3	79.2	78.0	76.8	75.5
5		82.9	82.9	80.5	79.2	78.0	77.0
10		83.9	83.9	81.4	80.1	78.8	77.9
20		84.9	84.9	82.2	80.9	79.6	78.8

Table 7.3-1. Optimal growth and upper tolerance temperatures identified for life stages of warmwater representative important species.

	Smallmouth Bass		White Sucker		Spotfin Shiner	
	Optimal Growth	Upper Tolerance	Optimal Growth	Upper Tolerance	Optimal Growth	Upper Tolerance
Reproduction	55 - 69.8	-	50 - 68	-	70 - 80	-
Growth/Maintenance						
Embryos	55.4 - 77	-	50 - 68	75.2	70 - 80	-
Larvae	55.4 - 77	100.4	60.8 - 82.4	89.6	70 - 80	-
Fry	77 - 84.2	95	60.8 - 82.4	89.6	70 - 90	-
Juvenile	82.4 - 87.8	95	50 - 82.5	87.8	70 - 90	-
Adult	50 - 83	90.1	50 - 82.5	88.9	70 - 90	95

Table 7.4-1 Mean back-calculated lengths (mm) at annulus and annual growth increments for smallmouth bass and white sucker for all collections from East Branch Perkiomen Creek during 1981-1988.

Species	Number of specimens		Length at annulus I		II		III		IV		V		VI
Smallmouth	588		95		156		203		251		275		285
bass		Increments		61		47		48		24		10	
White	1,255		87		159		227		274		319		350
sucker		Increments		72		68		47		45		31	

Table 7.4-2. Time periods available for smallmouth bass reproduction in 3 EBPC stream segments under various diversion discharge rates based upon the critical temperature range of 55 to 70 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	2-May	-	4-Jul	10	
	10	2-May	-	6-Jun	6	-4
	27	25-Apr	-	30-May	5	-5
	54	25-Apr	-	30-May	5	-5
10	0	2-May	-	27-Jun	9	
	10	2-May	-	13-Jun	7	-2
	27	2-May	-	6-Jun	6	-3
	54	2-May	-	6-Jun	6	-3
19	0	25-Apr	-	13-Jun	8	
	10	25-Apr	-	13-Jun	8	0
	27	25-Apr	-	13-Jun	8	0
	54	25-Apr	-	6-Jun	7	-1

Table 7.4-3. Time periods available for growth and maintenance of smallmouth bass embryos and larvae in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 55.4 to 77 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	2-May	-	3-Oct	23	
	10	2-May	-	24-Oct	16 *	-7
	27	2-May	-	24-Oct	15 *	-8
	54	2-May	-	24-Oct	15 *	-8
10	0	2-May	-	3-Oct	23	
	10	2-May	-	17-Oct	24 *	1
	27	2-May	-	17-Oct	21 *	-2
	54	2-May	-	17-Oct	19 *	-4
19	0	2-May	-	10-Oct	23 *	
	10	2-May	-	10-Oct	23 *	0
	27	2-May	-	17-Oct	24 *	1
	54	2-May	-	17-Oct	21 *	-2

* - week(s) lost due to weekly mean temperatures exceeding 77 degrees F

Table 7.4-4. Time periods available for growth and maintenance of smallmouth bass fry in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 77 to 84.2 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0		-		0	
	10	11-Jul	-	22-Aug	7	7
	27	11-Jul	-	22-Aug	7	7
	54	11-Jul	-	22-Aug	7	7
10	0		-		0	
	10	25-Jul	-	25-Jul	1	1
	27	11-Jul	-	8-Aug	5	5
	54	11-Jul	-	22-Aug	7	7
19	0	25-Jul	-	25-Jul	1	
	10	25-Jul	-	25-Jul	1	0
	27	25-Jul	-	25-Jul	1	0
	54	18-Jul	-	8-Aug	4	3

Table 7.4-5. Time periods available for growth and maintenance of smallmouth bc juveniles and adults in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 50 to 83 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	25-Apr	-	17-Oct	26	
	10	25-Apr	-	31-Oct	28	2
	27	18-Apr	-	31-Oct	29	3
	54	18-Apr	-	31-Oct	29	3
10	0	25-Apr	-	17-Oct	26	
	10	25-Apr	-	24-Oct	27	1
	27	25-Apr	-	31-Oct	28	2
	54	25-Apr	-	31-Oct	28	2
19	0	25-Apr	-	24-Oct	27	
	10	25-Apr	-	24-Oct	27	0
	27	25-Apr	-	31-Oct	28	1
	54	25-Apr	-	31-Oct	28	1

Table 7.4-6. Time periods available for white sucker reproduction and growth and maintenance of embryos in 3 EBPC stream segments under various diversion rates based upon the critical temperature range of 50 to 68 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		Available Time Period End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	25-Apr	-	13-Jun	9	
	10	25-Apr	-	30-May	6	-3
	27	25-Apr	-	30-May	6	-3
	54	18-Apr	-	30-May	7	-2
10	0	25-Apr	-	13-Jun	9	
	10	25-Apr	-	6-Jun	8	-1
	27	25-Apr	-	30-May	7	-2
	54	25-Apr	-	30-May	7	-2
19	0	25-Apr	-	30-May	7	
	10	25-Apr	-	30-May	7	0
	27	25-Apr	-	30-May	7	0
	54	25-Apr	-	30-May	7	0

Table 7.4-7. Time periods available for growth and maintenance of white sucker fry in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 60.8 to 82.4 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		Available Time Period End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	23-May	-	26-Sep	19	
	10	16-May	-	10-Oct	22	3
	27	16-May	-	10-Oct	22	3
	54	16-May	-	10-Oct	22	3
10	0	16-May	-	26-Sep	20	
	10	16-May	-	3-Oct	21	1
	27	16-May	-	3-Oct	21	1
	54	16-May	-	3-Oct	21	1
19	0	16-May	-	26-Sep	20	
	10	16-May	-	26-Sep	20	0
	27	16-May	-	3-Oct	21	1
	54	16-May	-	3-Oct	21	1

Table 7.4-8. Time periods available for growth and maintenance of white sucker juveniles and adults in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 50 to 82.2 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	2-May	-	17-Oct	25	
	10	25-Apr	-	31-Oct	28	3
	27	25-Apr	-	31-Oct	28	3
	54	25-Apr	-	31-Oct	28	3
10	0	25-Apr	-	17-Oct	26	
	10	25-Apr	-	24-Oct	27	1
	27	25-Apr	-	31-Oct	28	2
	54	25-Apr	-	31-Oct	28	2
19	0	25-Apr	-	24-Oct	27	
	10	25-Apr	-	24-Oct	27	0
	27	25-Apr	-	24-Oct	27	0
	54	25-Apr	-	31-Oct	28	1

Table 7.4-9. Time periods available for spotfin shiner reproduction and growth and maintenance of embryos and larvae in 3 EBPC stream segments under various diversion rates based upon the critical temperature range of 70 to 80 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	4-Jul	-	22-Aug	8	
	10	6-Jun	-	19-Sep	16	8
	27	6-Jun	-	19-Sep	16	8
	54	6-Jun	-	19-Sep	16	8
10	0	20-Jun	-	22-Aug	10	
	10	20-Jun	-	5-Sep	12	2
	27	6-Jun	-	12-Sep	15	5
	54	6-Jun	-	12-Sep	15	5
19	0	13-Jun	-	29-Aug	12	
	10	13-Jun	-	29-Aug	12	0
	27	13-Jun	-	5-Sep	13	1
	54	6-Jun	-	12-Sep	15	3

Table 7.4-10. Time periods available for growth and maintenance of spotfin shiner juveniles and adults in 3 EBPC stream segments under various diversion discharge rates based upon optimal temperature range of 70 to 90 degrees F.

Stream Segment	Diversion Discharge	Available Time Period Begin		End	Elapsed Time (weeks)	Discharge Effect (weeks)
2	0	11-Jul	-	15-Aug	6	
	10	6-Jun	-	19-Sep	18	12
	27	6-Jun	-	19-Sep	18	12
	54	6-Jun	-	19-Sep	18	12
10	0	20-Jun	-	22-Aug	10	
	10	20-Jun	-	5-Sep	12	2
	27	6-Jun	-	12-Sep	17	7
	54	6-Jun	-	12-Sep	17	7
19	0	13-Jun	-	29-Aug	12	
	10	13-Jun	-	29-Aug	12	0
	27	13-Jun	-	5-Sep	13	1
	54	6-Jun	-	12-Sep	15	3

Table 7.5-1

Difference among dates that predicted daily mean temperatures in EBPC Segments 10 and 19 achieved or exceeded 74 degrees F at diversion rates of 0, 10, 27, and 54 cfs.

SEGMENT 10

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	7-Jun	8-Jun	1	9-Jun	2	9-Jun	2
1985	14-Jul	6-Jul	-8	6-Jul	-8	6-Jul	-8
1986	1-Jun	31-May	-1	31-May	-1	31-May	-1
1987	29-May	30-May	1	1-Jun	3	1-Jun	3
1988	30-May	15-Jun	16	16-Jun	17	16-Jun	17
1989	1-Jun	1-Jun	0	21-Jun	20	21-Jun	20
1990	18-Jun	18-Jun	0	18-Jun	0	18-Jun	0
1991	25-May	25-May	0	25-May	0	25-May	0
1992	8-Jun	8-Jun	0	8-Jun	0	13-Jun	5
Average:	7-Jun	8-Jun	1.0	11-Jun	3.7	12-Jun	4.2

SEGMENT 19

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	7-Jun	7-Jun	0	7-Jun	0	8-Jun	1
1985	24-Jun	24-Jun	0	24-Jun	0	24-Jun	0
1986	30-May	19-May	-11	30-May	0	30-May	0
1987	30-May	30-May	0	29-May	-1	30-May	0
1988	30-May	30-May	0	30-May	0	15-Jun	16
1989	1-Jun	1-Jun	0	1-Jun	0	1-Jun	0
1990	17-Jun	18-Jun	1	18-Jun	1	18-Jun	1
1991	15-May	15-May	0	25-May	10	25-May	10
1992	7-Jun	8-Jun	1	8-Jun	1	8-Jun	1
Average:	4-Jun	3-Jun	-1.0	5-Jun	1.2	7-Jun	3.2

Table 7.5-2

Difference among dates that predicted daily mean temperatures in EBPC Segments 10 and 19 achieved or exceeded 77 degrees F at diversion rates of 0, 10, 27, and 54 cfs.

SEGMENT 10

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	8-Jun	9-Jun	1	10-Jun	2	10-Jun	2
1985	16-Jul	15-Jul	-1	14-Jul	-2	14-Jul	-2
1986	16-Jun	7-Jul	21	7-Jul	21	7-Jul	21
1987	30-May	20-Jun	21	20-Jun	21	19-Jun	20
1988	21-Jun	21-Jun	0	20-Jun	-1	20-Jun	-1
1989	21-Jun	22-Jun	1	22-Jun	1	23-Jun	2
1990	5-Jul	5-Jul	0	29-Jun	-6	29-Jun	-6
1991	28-May	28-May	0	28-May	0	28-May	0
1992	8-Jun	14-Jul	36	13-Jul	35	12-Jul	34
Average:	16-Jun	25-Jun	8.8	24-Jun	7.9	24-Jun	7.8

SEGMENT 19

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	8-Jun	8-Jun	0	9-Jun	1	9-Jun	1
1985	14-Jul	14-Jul	0	14-Jul	0	14-Jul	0
1986	1-Jun	1-Jun	0	1-Jun	0	7-Jul	36
1987	30-May	30-May	0	30-May	0	19-Jun	20
1988	16-Jun	16-Jun	0	16-Jun	0	20-Jun	4
1989	2-Jun	2-Jun	0	21-Jun	19	22-Jun	20
1990	29-Jun	29-Jun	0	29-Jun	0	29-Jun	0
1991	28-May	28-May	0	28-May	0	28-May	0
1992	8-Jun	8-Jun	0	1-Jul	23	1-Jul	23
Average:	11-Jun	11-Jun	0.0	16-Jun	4.8	23-Jun	11.6

Table 7.5-3

Difference among dates that predicted daily mean temperatures in EBPC Segments 10 and 19 achieved or exceeded 80.6 degrees F at diversion rates of 0, 10, 27, and 54 cfs.

SEGMENT 10

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	10-Aug	16-Jul	-25	15-Jul	-26	15-Jul	-26
1985	14-Aug	14-Aug	0	14-Aug	0	21-Jul	-24
1986	29-Jul	1-Aug	3	1-Aug	3	1-Aug	3
1987	9-Jul	11-Jul	2	11-Jul	2	11-Jul	2
1988	20-Jul	10-Jul	-10	10-Jul	-10	10-Jul	-10
1989	27-Jun	27-Jun	0	27-Jun	0	27-Jun	0
1990	1-Aug	1-Aug	0	1-Aug	0	1-Aug	0
1991	21-Jul	20-Jul	-1	19-Jul	-2	19-Jul	-2
1992	1-Aug	1-Aug	0	1-Aug	0	1-Aug	0
Average:	25-Jul	21-Jul	-3.4	21-Jul	-3.7	18-Jul	-6.3

SEGMENT 19

	0 cfs	10 cfs		27 cfs		54 cfs	
Year	First Date	First Date	Days Gained	First Date	Days Gained	First Date	Days Gained
1984	9-Jun	10-Jun	1	11-Jun	2	13-Jun	4
1985	15-Aug	15-Aug	0	14-Aug	-1	14-Aug	-1
1986	8-Jul	8-Jul	0	1-Aug	24	1-Aug	24
1987	10-Jul	9-Jul	-1	9-Jul	-1	11-Jul	1
1988	7-Jul	7-Jul	0	7-Jul	0	10-Jul	3
1989	27-Jun	27-Jun	0	27-Jun	0	27-Jun	0
1990	1-Aug	1-Aug	0	1-Aug	0	1-Aug	0
1991	19-Jul	19-Jul	0	19-Jul	0	19-Jul	0
1992	1-Aug	1-Aug	0	1-Aug	0	1-Aug	0
Average:	14-Jul	14-Jul	0.0	17-Jul	2.7	17-Jul	3.4

Note: In years when Daily-Mean Temperature never reached 80.6 deg F, the critical date (August 1) identified in the NPDES permit for the EBPC diversion was used.

Table 7.5-4 Key dates relating stocked trout harvest in the Branch Road to Sellersville stream reach and Point Pleasant Diversion operation.

Key Dates	1987	1988	1989	1990	1991	1992
Last Stocking Date	4/23	5/3	5/11	6/8	5/9	5/13
Last Creel Survey[1]	4/25	5/15	5/28	6/10	5/19	5/25
Increase of diversion flow greater than 10 cfs (observed)	--	--	--	3/1 (45 cfs)	≈ 4/2 (21 cfs)	4/10 (14 cfs)
Initial Operation of Cooling[2] (observed)	--	--	--	6/23	5/16	6/12
First prediction of daily mean Temperature ≥ 74 F						
Branch Road (Segment 10)						
No Diversion	5/29	5/30	6/1	6/18	5/25	6/8
10 cfs	5/30	6/15	6/1	6/18	5/25	6/8
27 cfs	6/1	6/16	6/21	6/18	5/25	6/8
54 cfs	6/1	6/16	6/21	6/18	5/25	6/13
Sellersville (Segment 19)						
No Diversion	5/30	5/30	6/1	6/17	5/15	6/7
10 cfs	5/30	5/30	6/1	6/18	5/15	6/8
27 cfs	5/29	5/30	6/1	6/18	5/25	6/8
54 cfs	5/30	6/15	6/1	6/18	5/25	6/8

[1] Last Creel Survey date is that time at which cumulative harvest, angler effort, and angler catch rate indicate substantially all trout have been harvested.

[2] Cooling initiated at about 72 F as measured at Water Processing Facility to assure compliance at diversion outfall. Operation mandated by current NPDES permit requirement to maintain discharge instantaneous maximum temperature ≤ 74 F.

Figure 7.1-1 Observed Bradshaw Reservoir and East Branch Headwater Temperatures For July 1992.

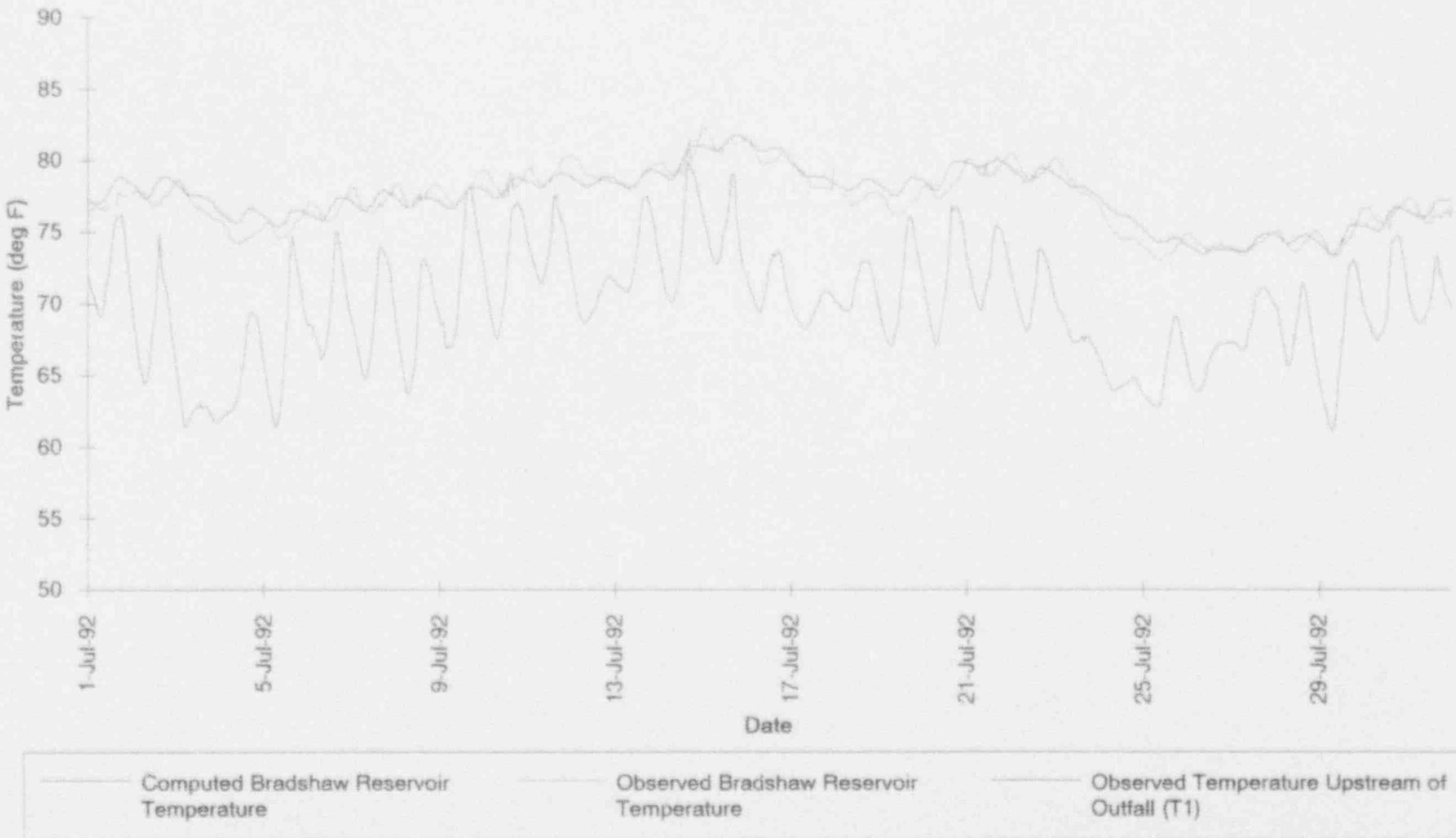


Figure 7.1-2 Time Series of Model Results for July 1992 for Model Segment 2 for the No Diversion Case and for the 10, 27 and 54 cfs Diversion Cases

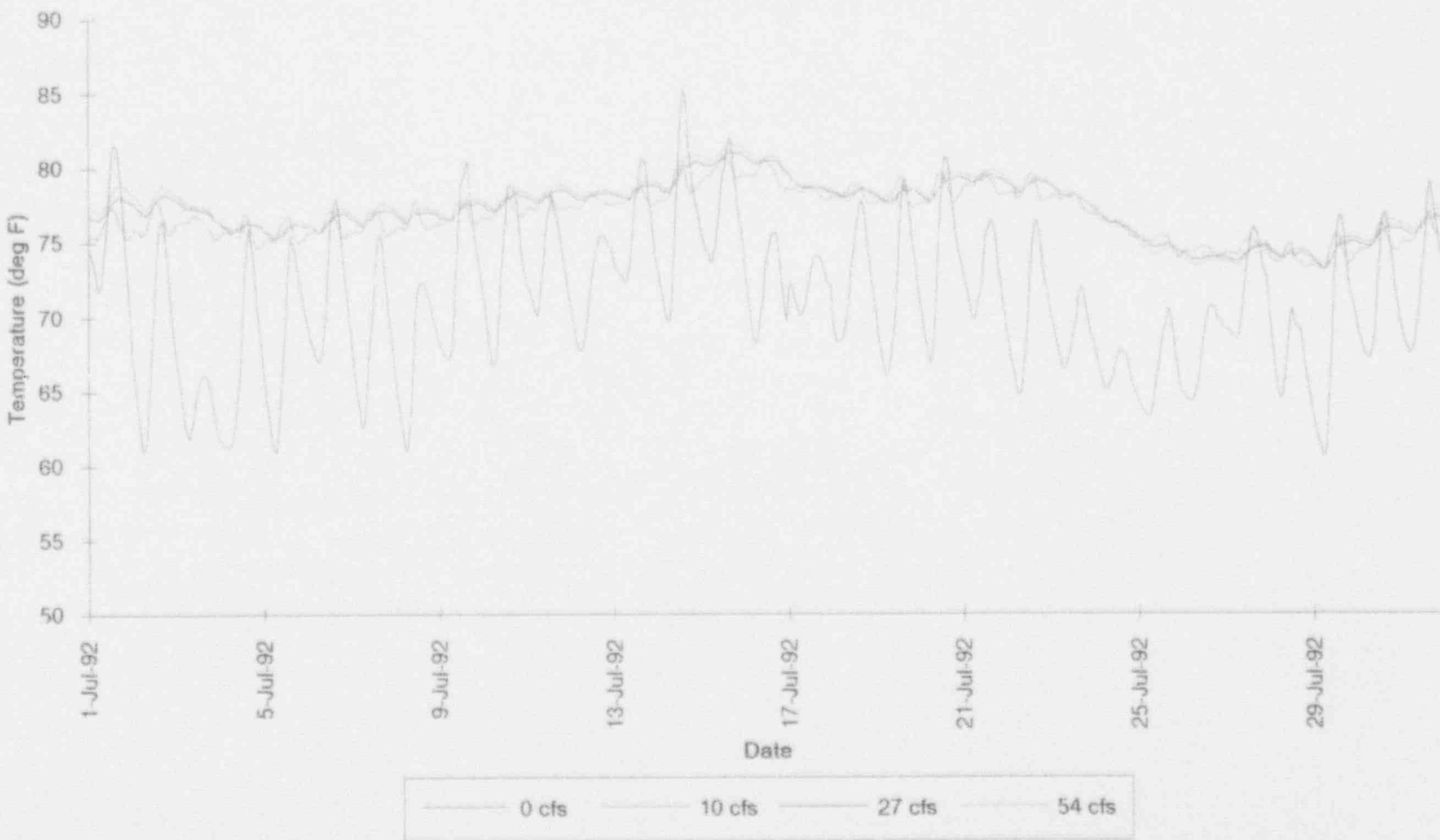


Figure 7.1-3 Time Series of Model Results for July 1992 for Model Segment 5 for the No Diversion Case and for the 10, 27 and 54 cfs Diversion Cases

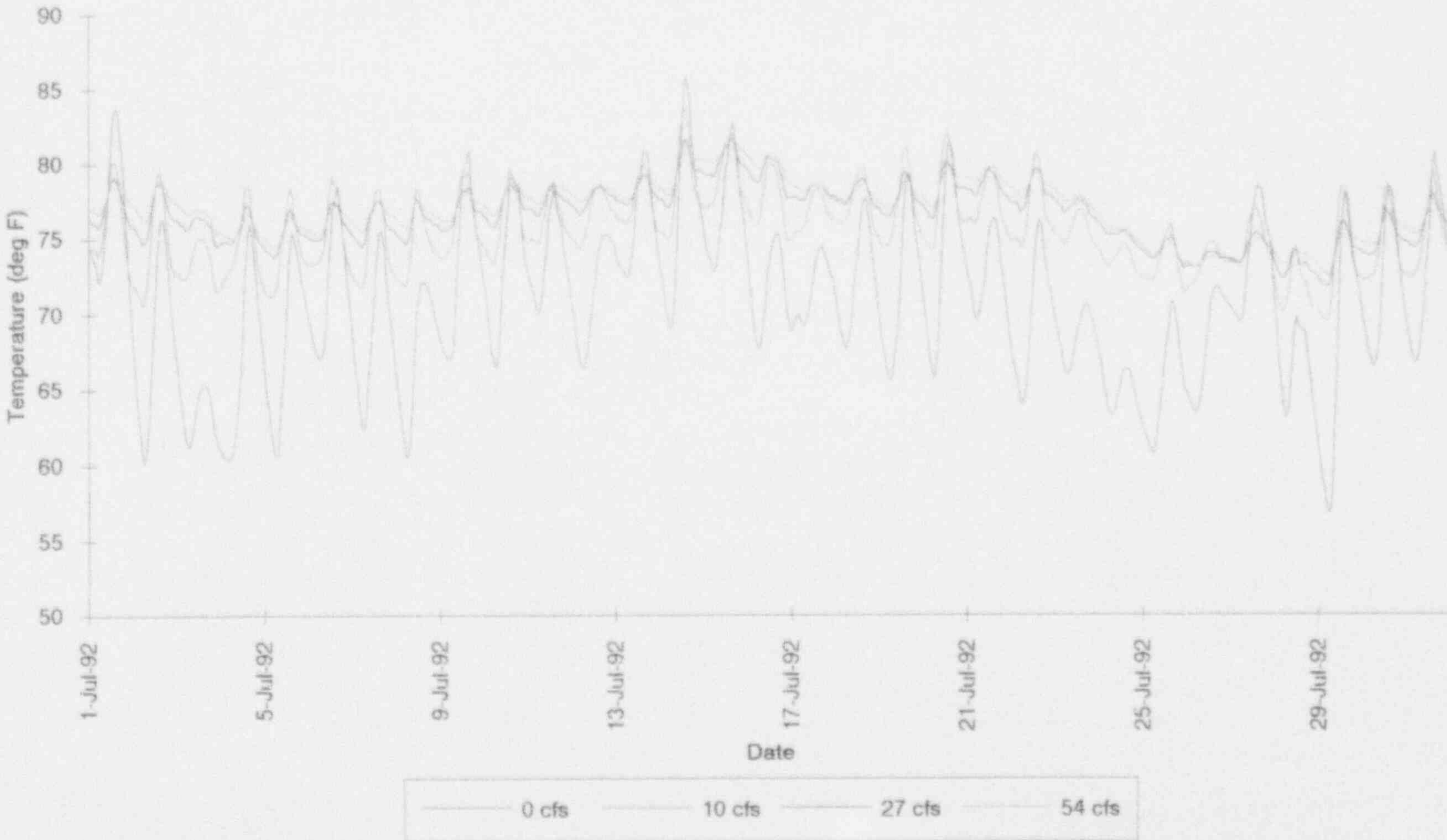


Figure 7.1-4 Time Series of Model Results for July 1992 for Model Segment 10 for the No Diversion Case and for the 10, 27 and 54 cfs Diversion Cases

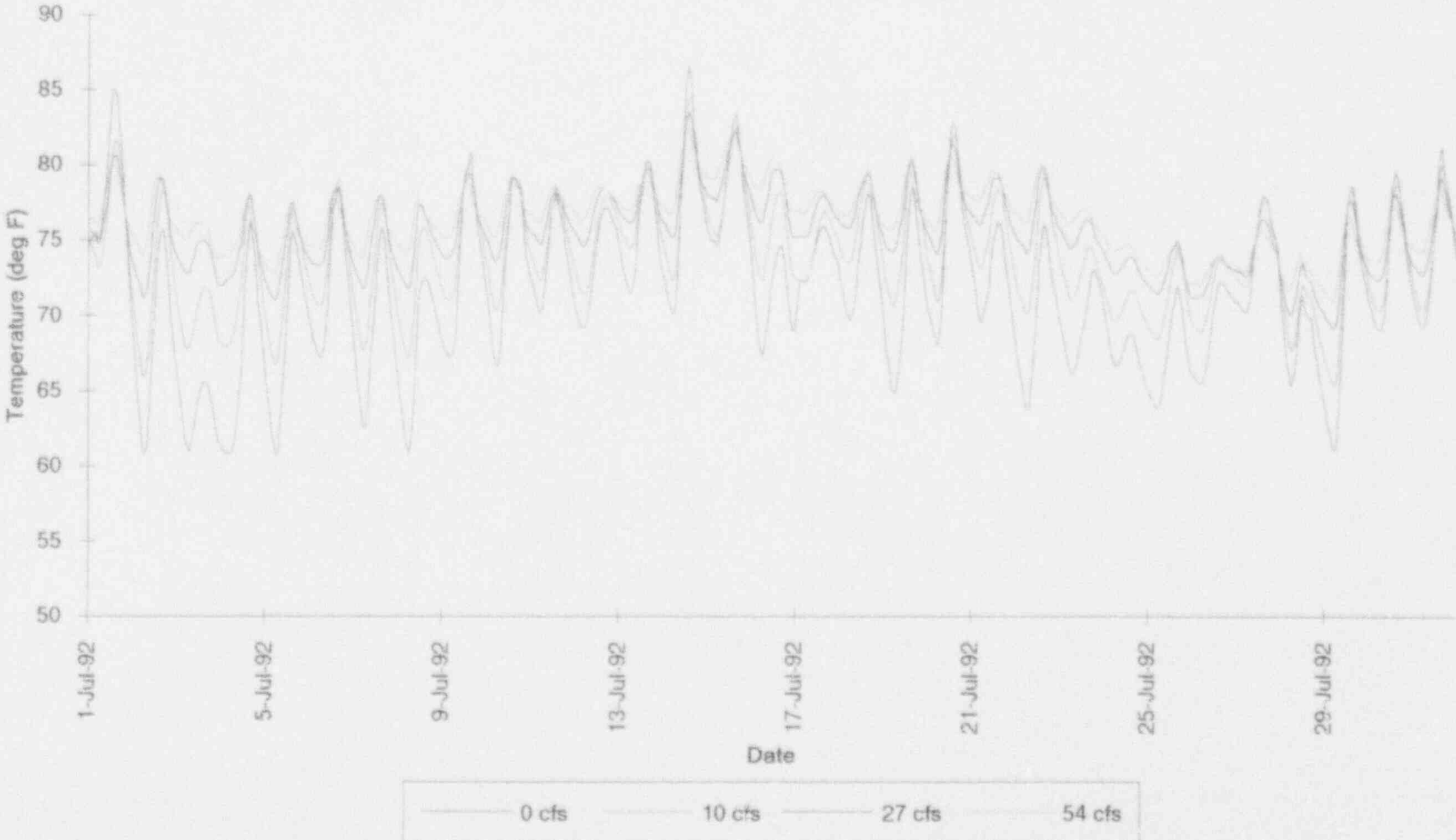


Figure 7.1-5 Time Series of Model Results for July 1992 for Model Segment 19 for the No Diversion Case and for the 10, 27 and 54 cfs Diversion Cases

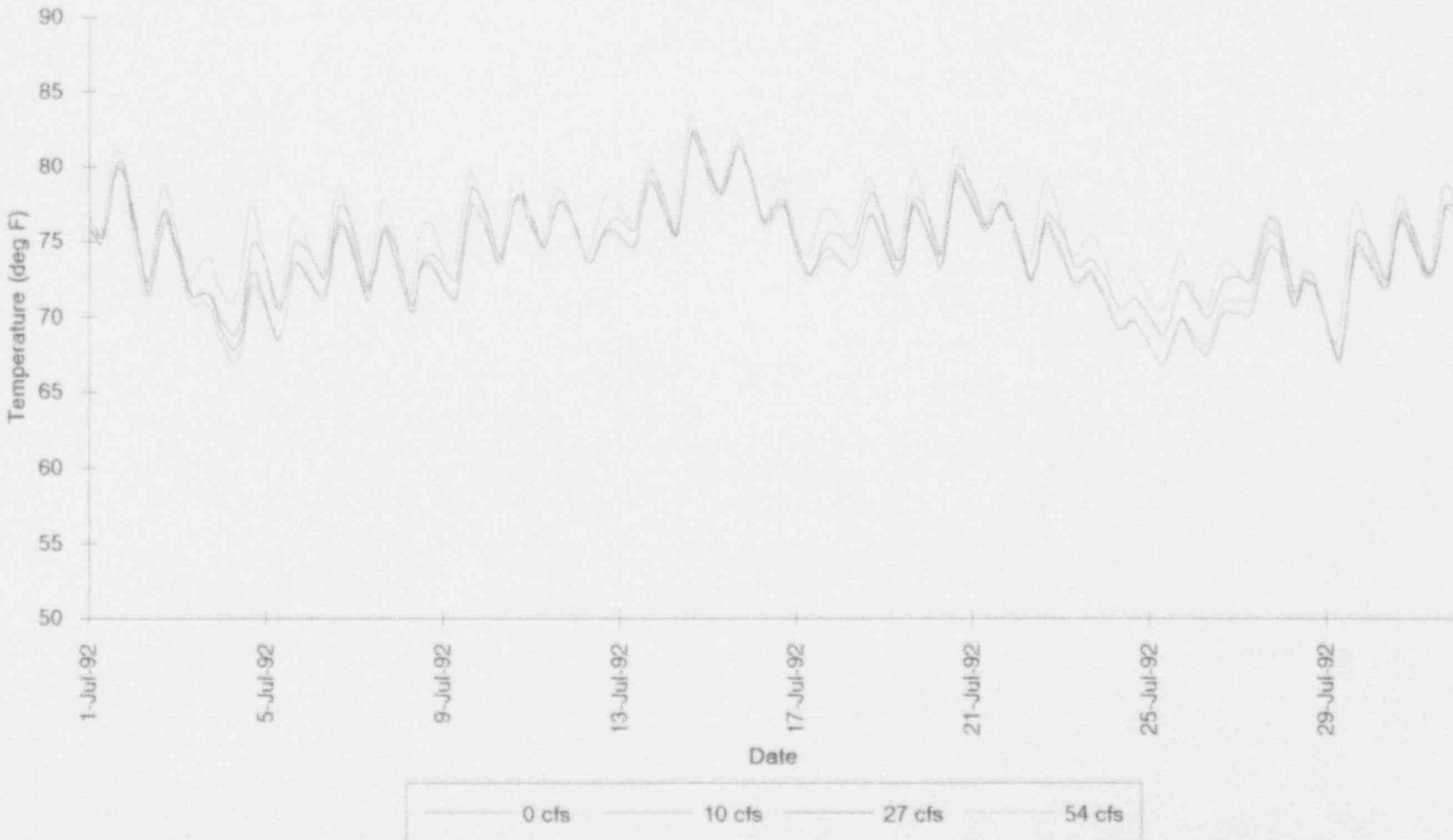
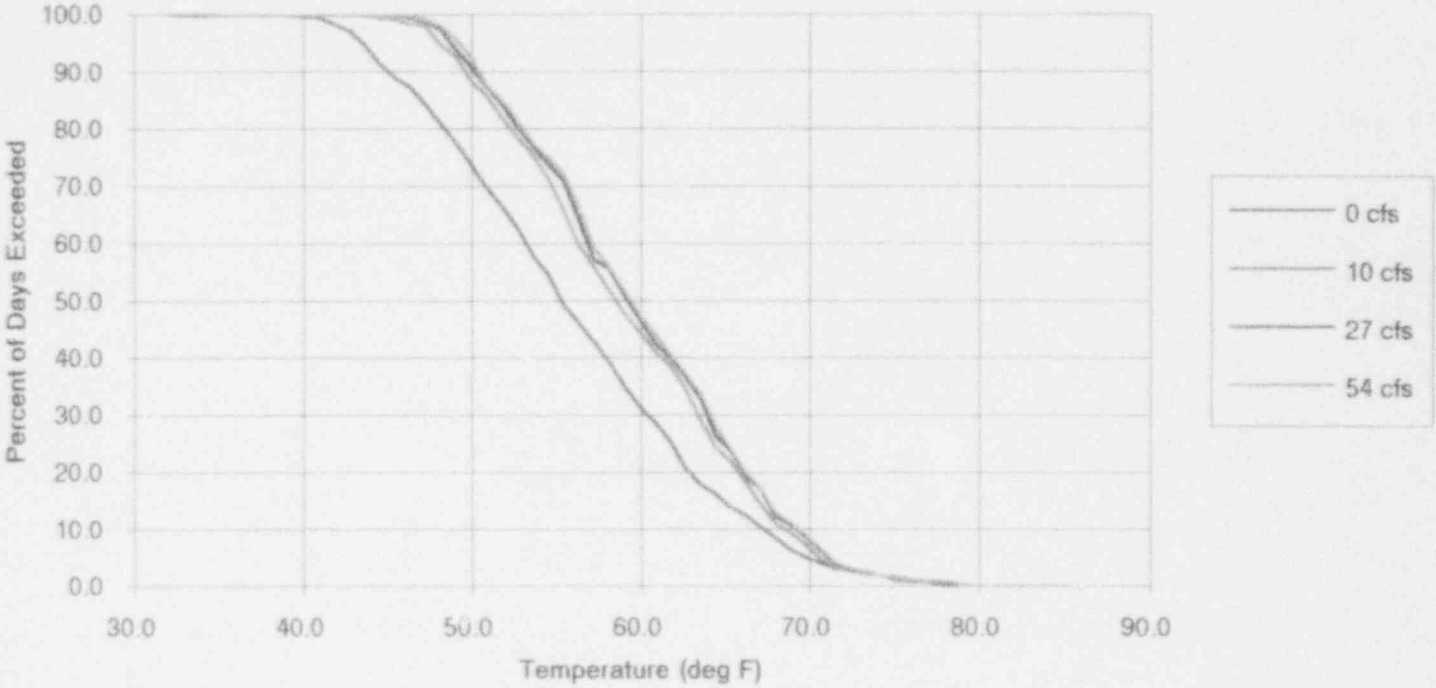


Figure 7.1-6

Segment 02
Predicted Temperature Frequencies at Four Diversion Rates
For the Period 15-Apr to 1-Jun



Segment 02
Predicted Temperature Frequencies at Four Diversion Rates
For the Period 15-Feb to 1-Aug

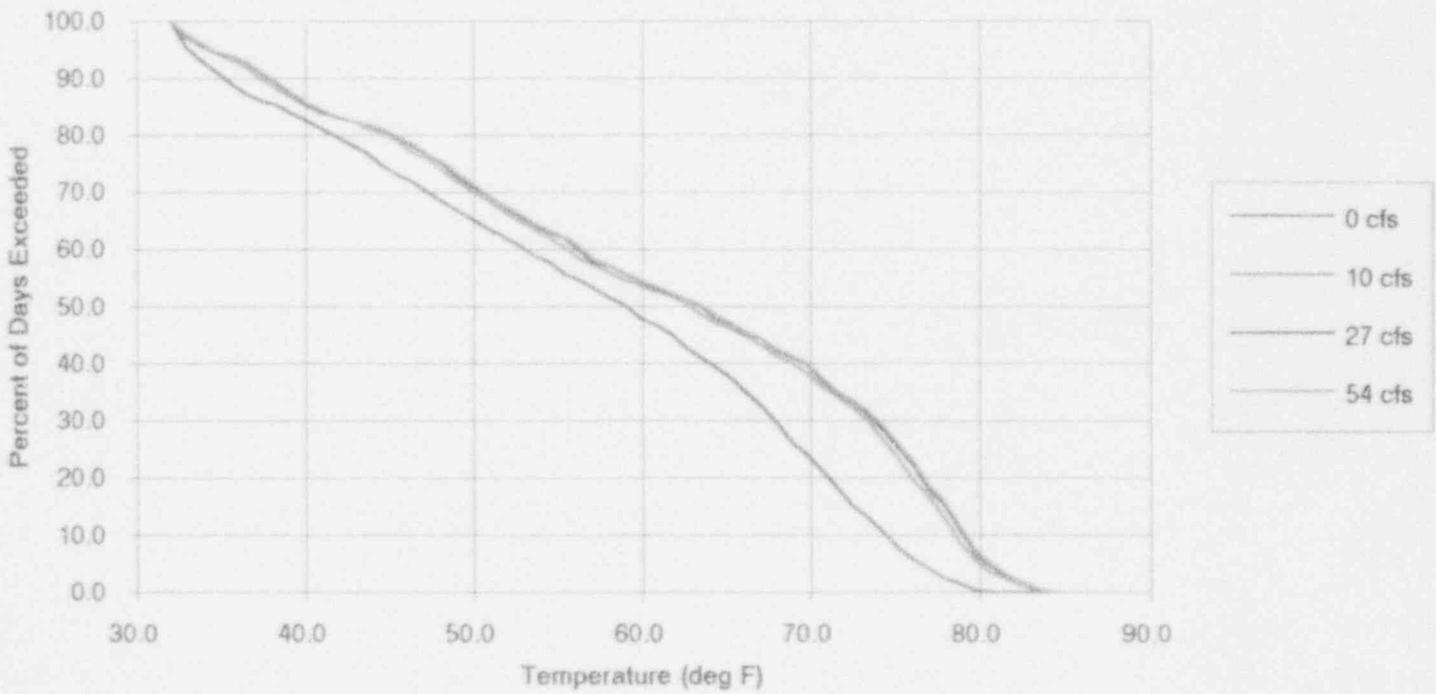
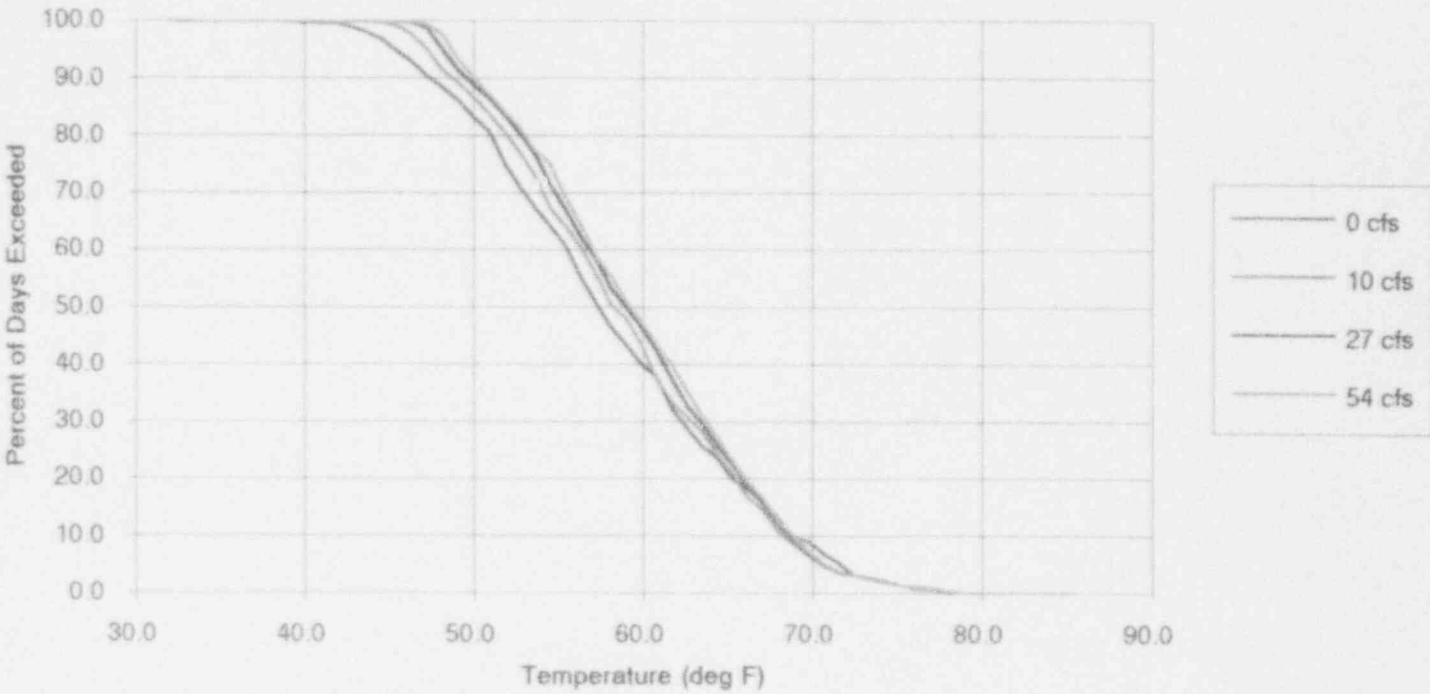


Figure 7.1-7
Segment 10
Predicted Temperature Frequencies at Four Diversion Rates
For the Period 15-Apr to 1-Jun



Segment 10
Predicted Temperature Frequencies at Four Diversion Rates
For the Period 15-Feb to 1-Aug

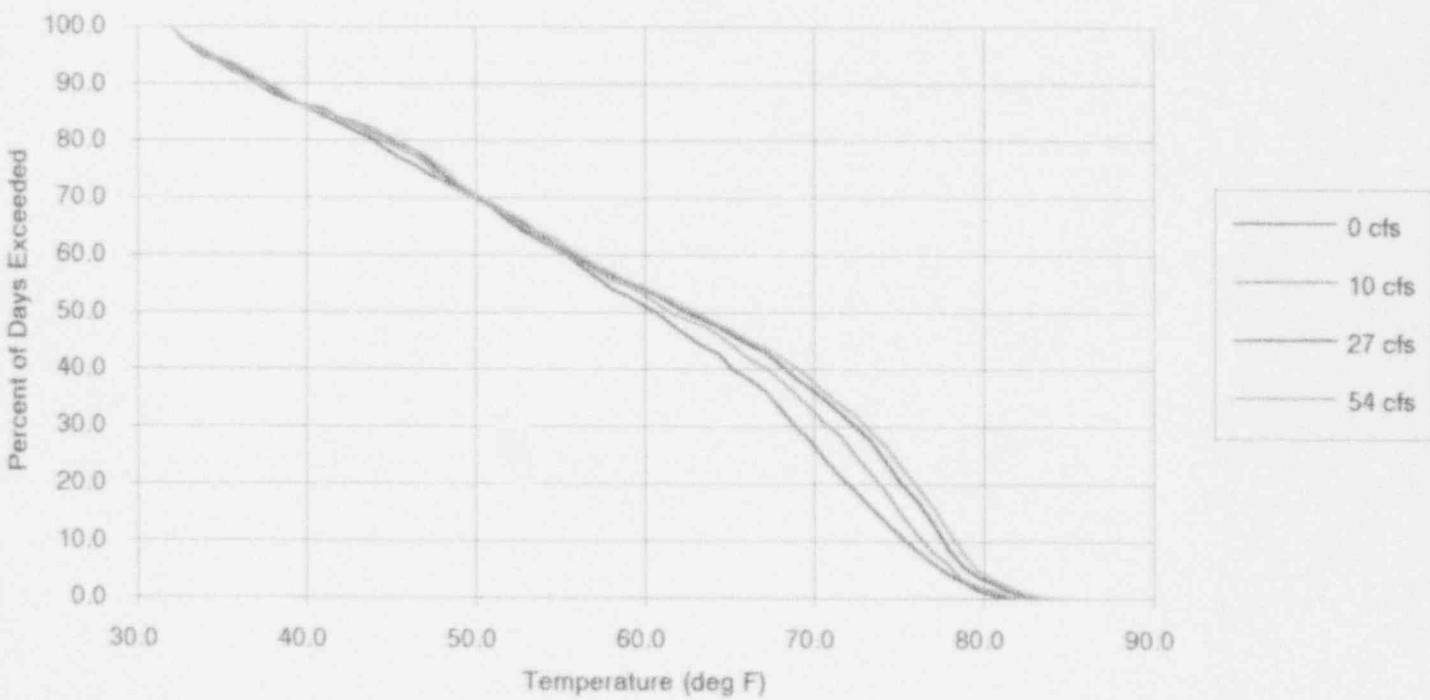
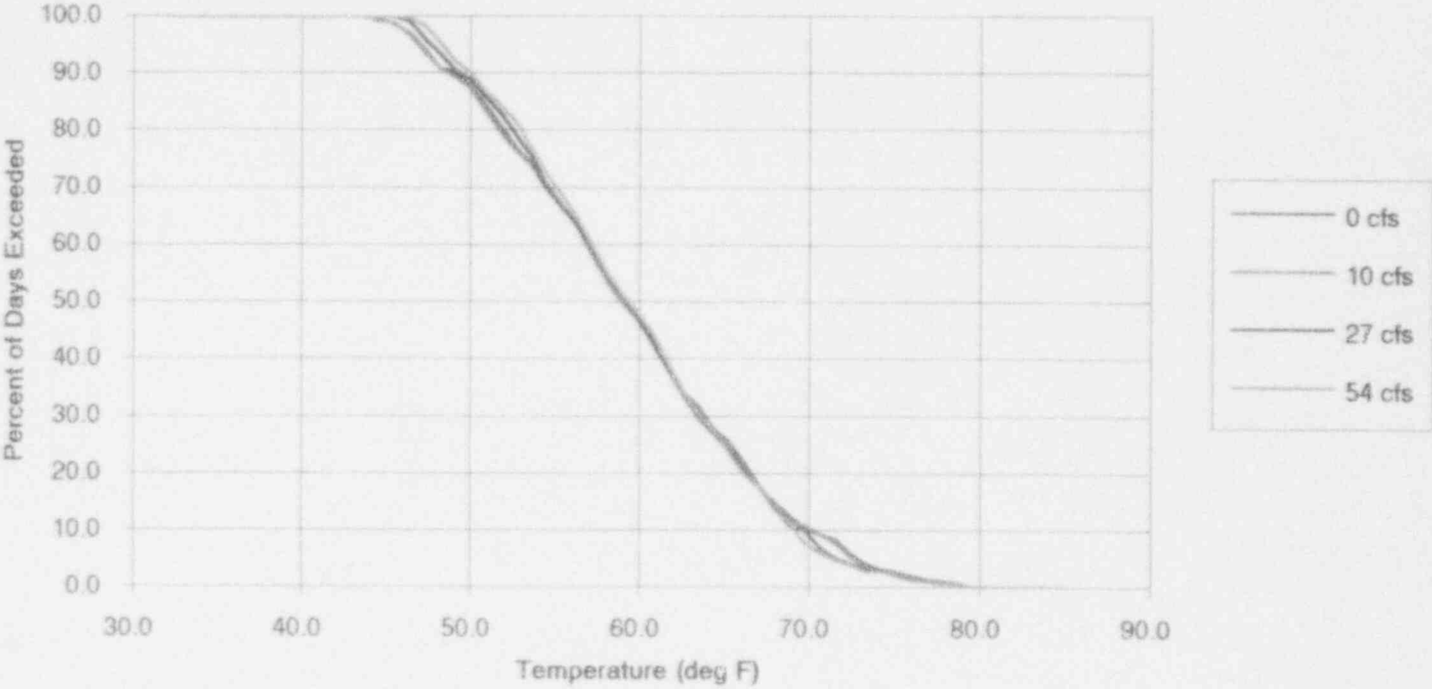


Figure 7.1-8

Segment 19

Predicted Temperature Frequencies at Four Diversion Rates

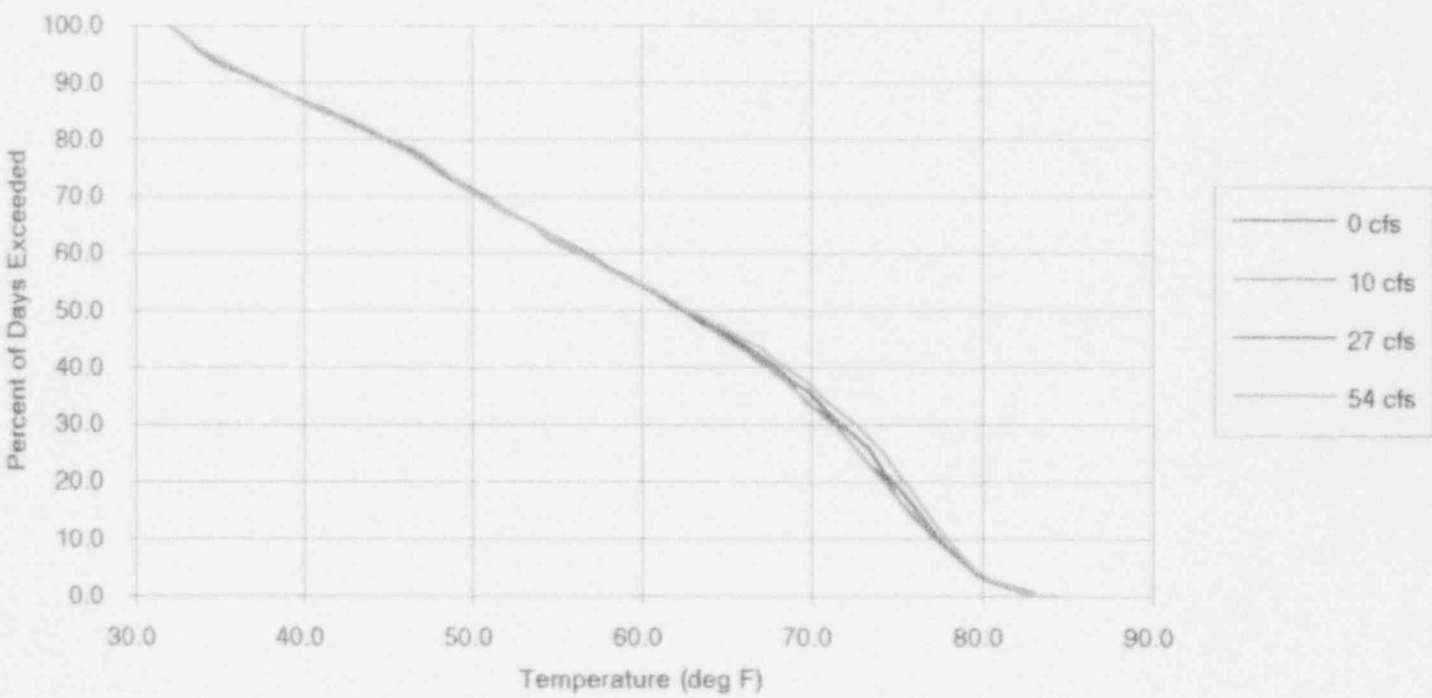
For the Period 15-Apr to 1-Jun



Segment 19

Predicted Temperature Frequencies at Four Diversion Rates

For the Period 15-Feb to 1-Aug



East Branch Perkiomen Creek

Figure 7.2-1

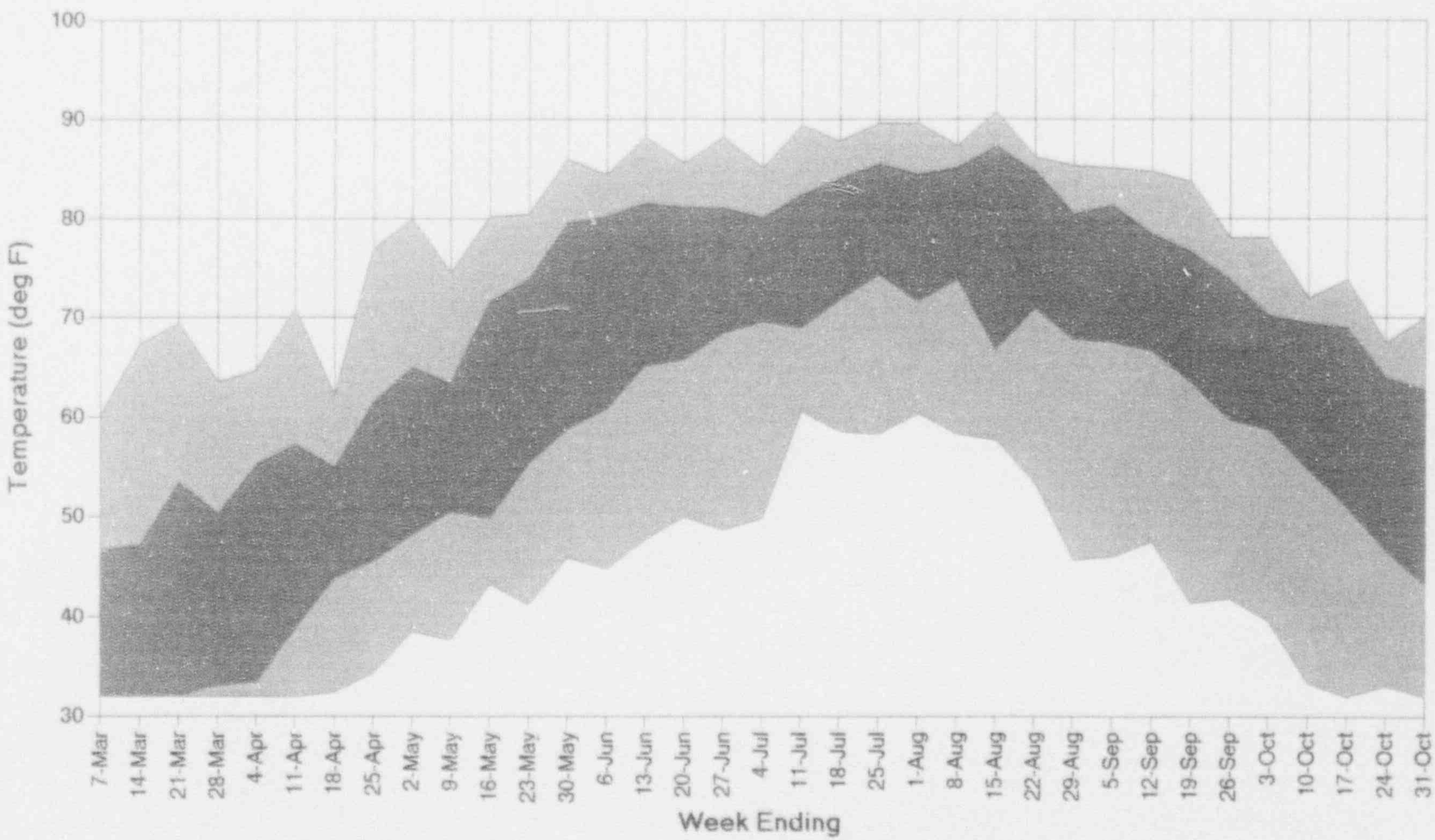
Segment 02

0 vs. 10 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 10 cfs diversion rate.



East Branch Perkiomen Creek

Figure 7.2-2

Segment 02

0 vs. 27 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 27 cfs diversion rate.

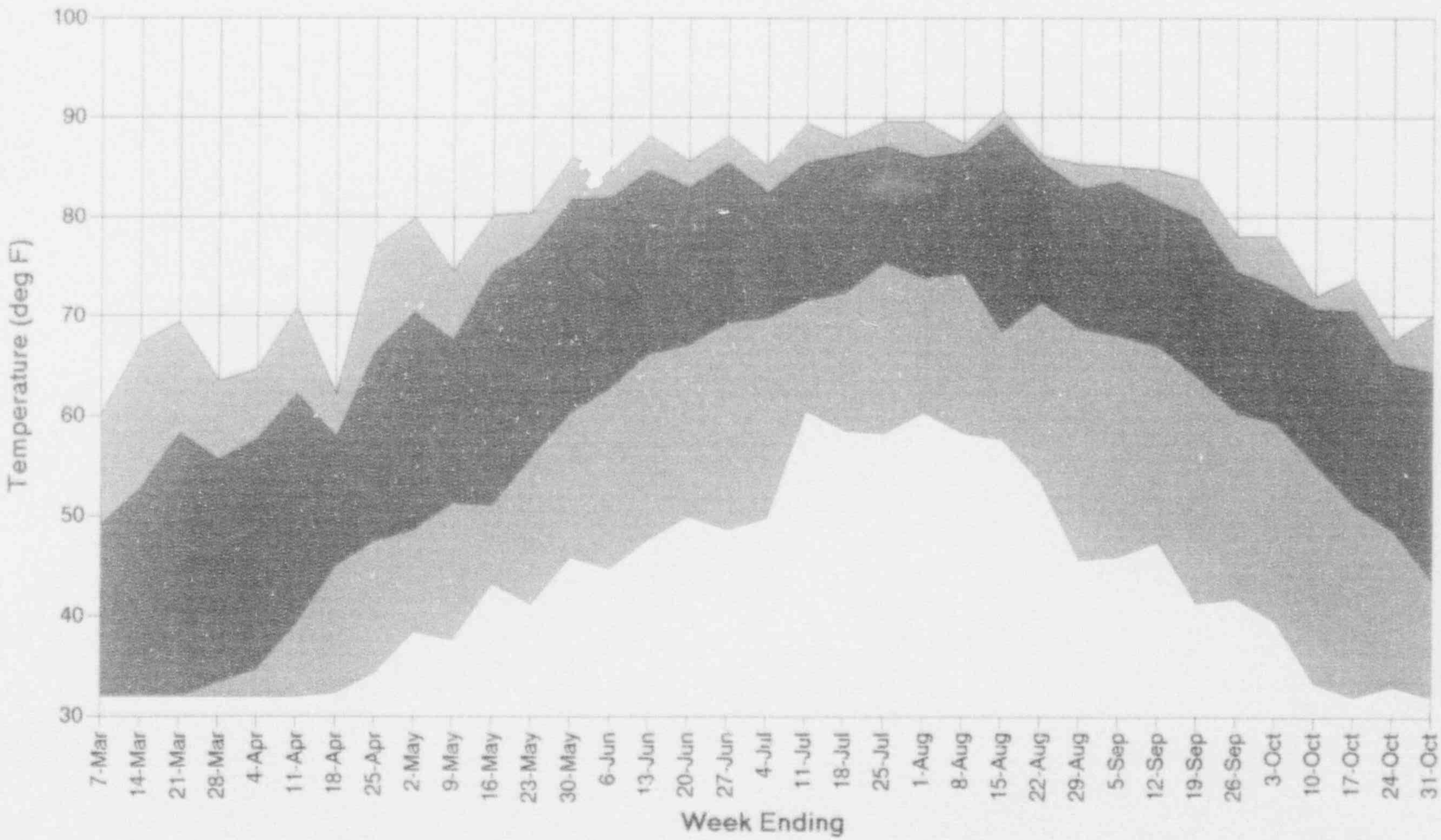


Figure 7.2-3

Segment 02

0 vs. 54 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 54 cfs diversion rate.

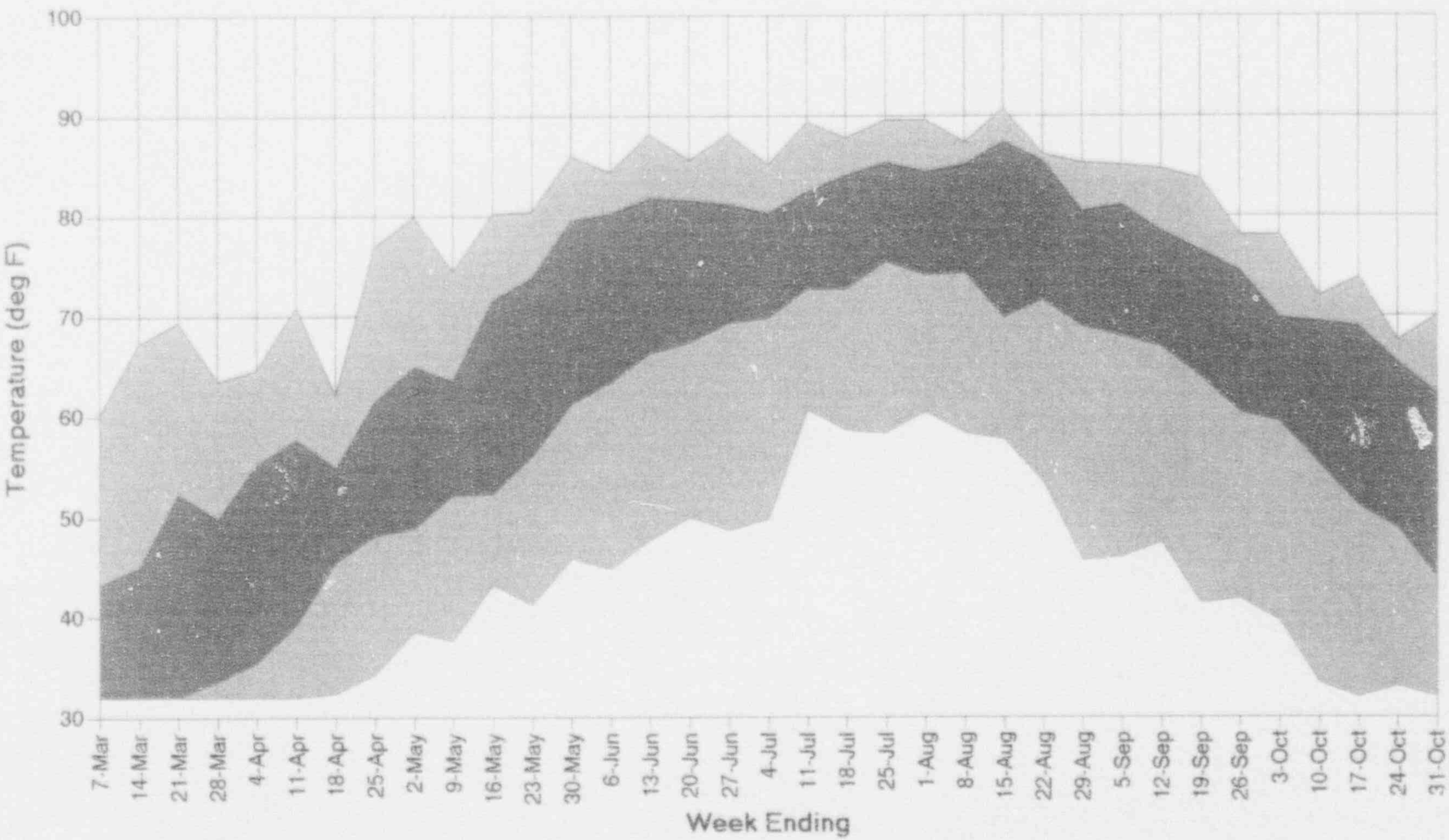


Figure 7.2-4

Segment 10

0 vs. 10 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 10 cfs diversion rate.

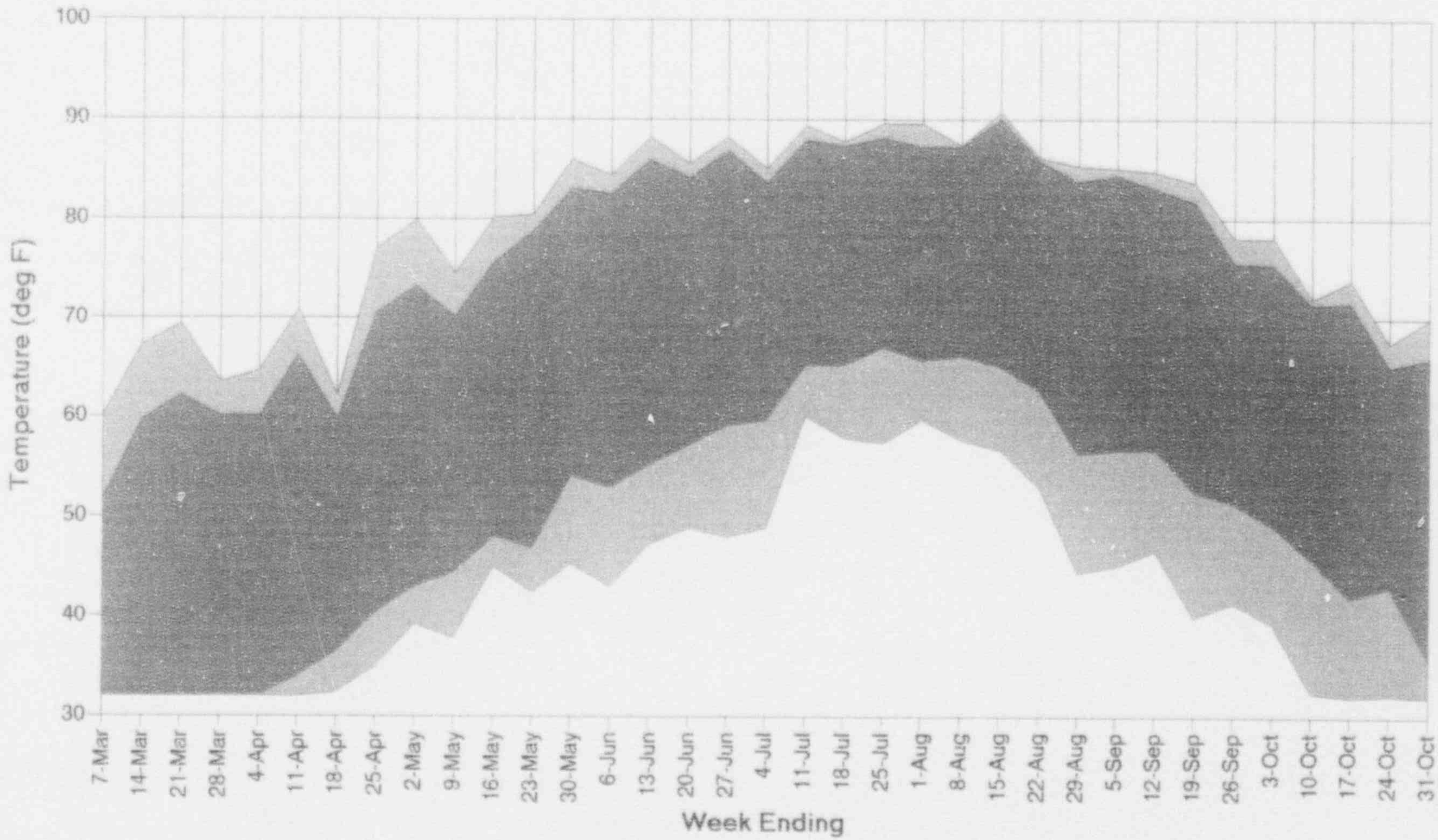


Figure 7.2-5

Segment 10

0 vs. 27 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 27 cfs diversion rate.

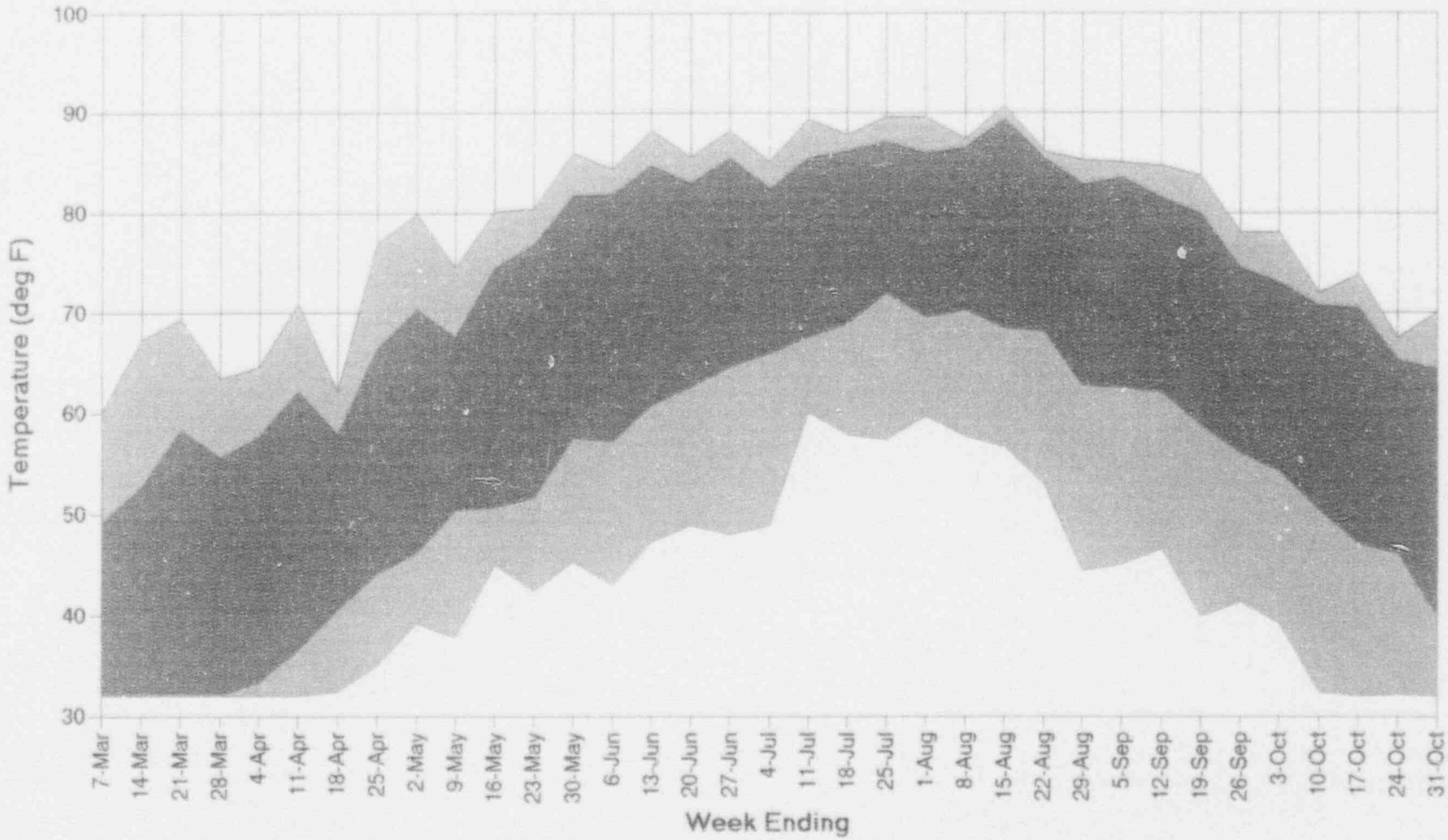


Figure 7.2-6
Segment 10
0 vs. 54 cfs
Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992
The light blue area shows temperature variation with 0 cfs diversion rate.
The dark blue area shows temperature variation with 54 cfs diversion rate.

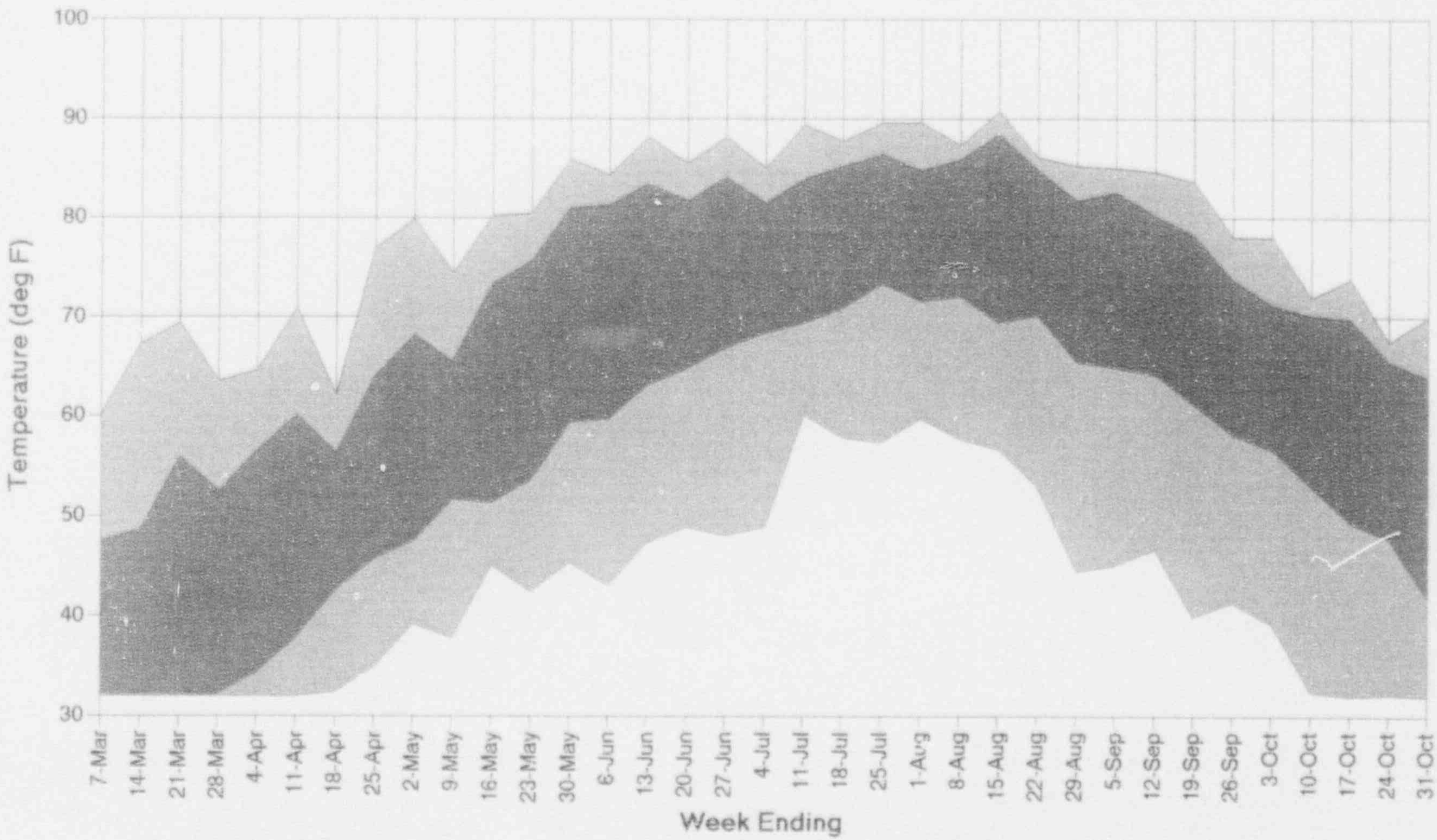


Figure 7.2-7

Segment 19

0 vs. 10 cfs

Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992

The light blue area shows temperature variation with 0 cfs diversion rate.

The dark blue area shows temperature variation with 10 cfs diversion rate.

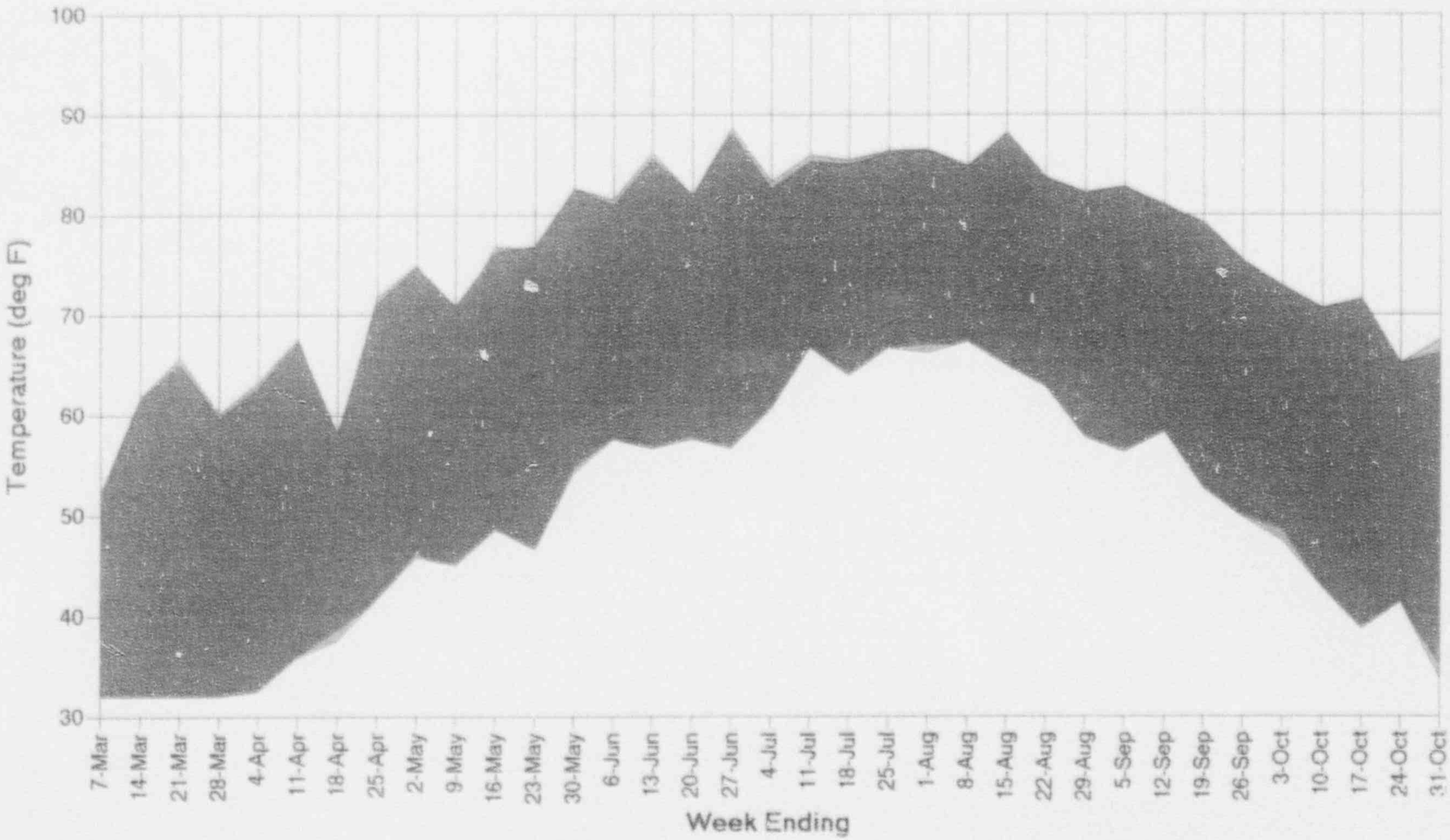


Figure 7.2-8
Segment 19
0 vs. 27 cfs
Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992
The light blue area shows temperature variation with 0 cfs diversion rate.
The dark blue area shows temperature variation with 27 cfs diversion rate.

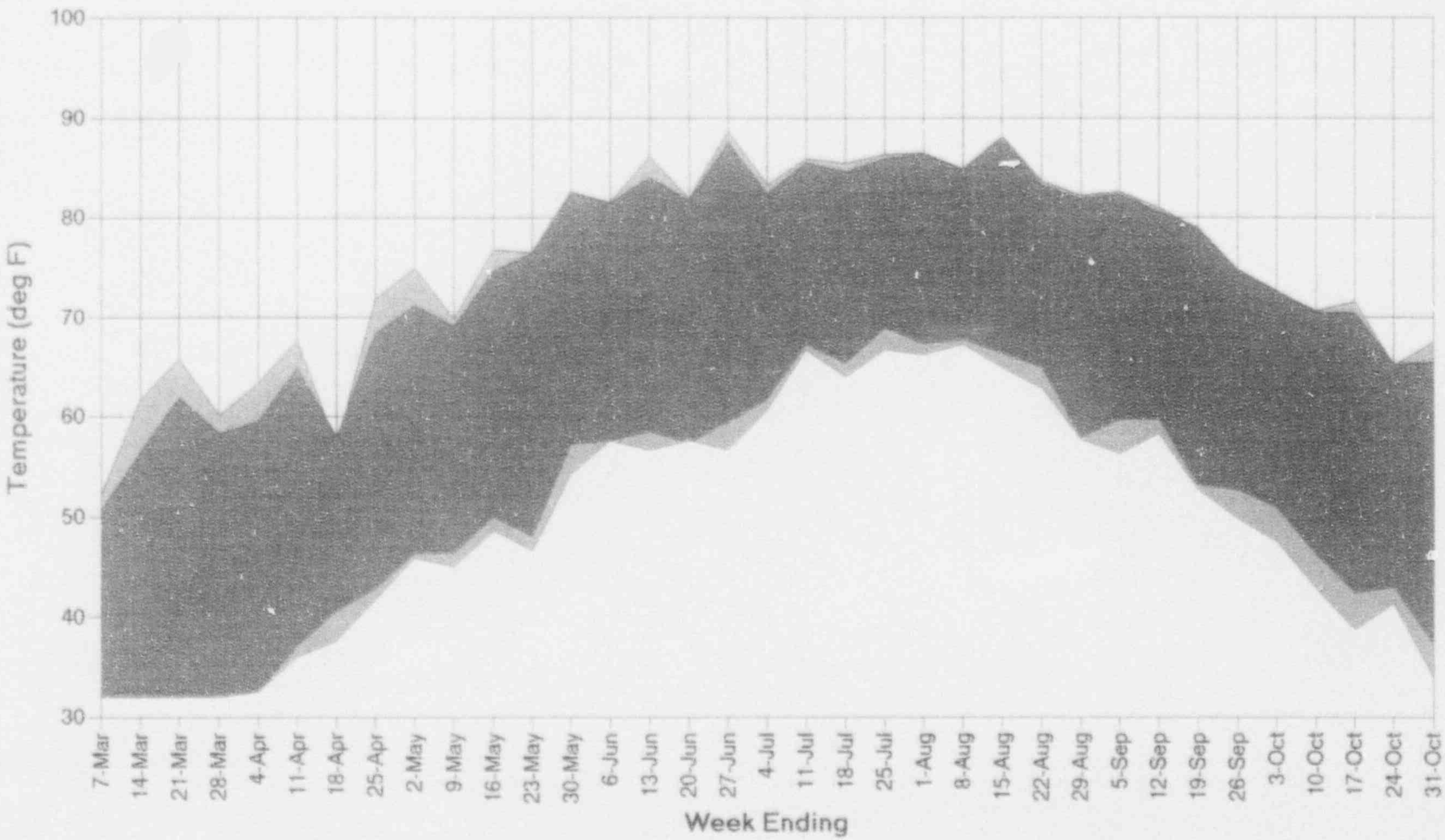


Figure 7.2-9
Segment 19
0 vs. 54 cfs
Weekly Predicted Extreme Temperature Ranges for the period Oct 1983 - Sept 1992
The light blue area shows temperature variation with 0 cfs diversion rate.
The dark blue area shows temperature variation with 54 cfs diversion rate.

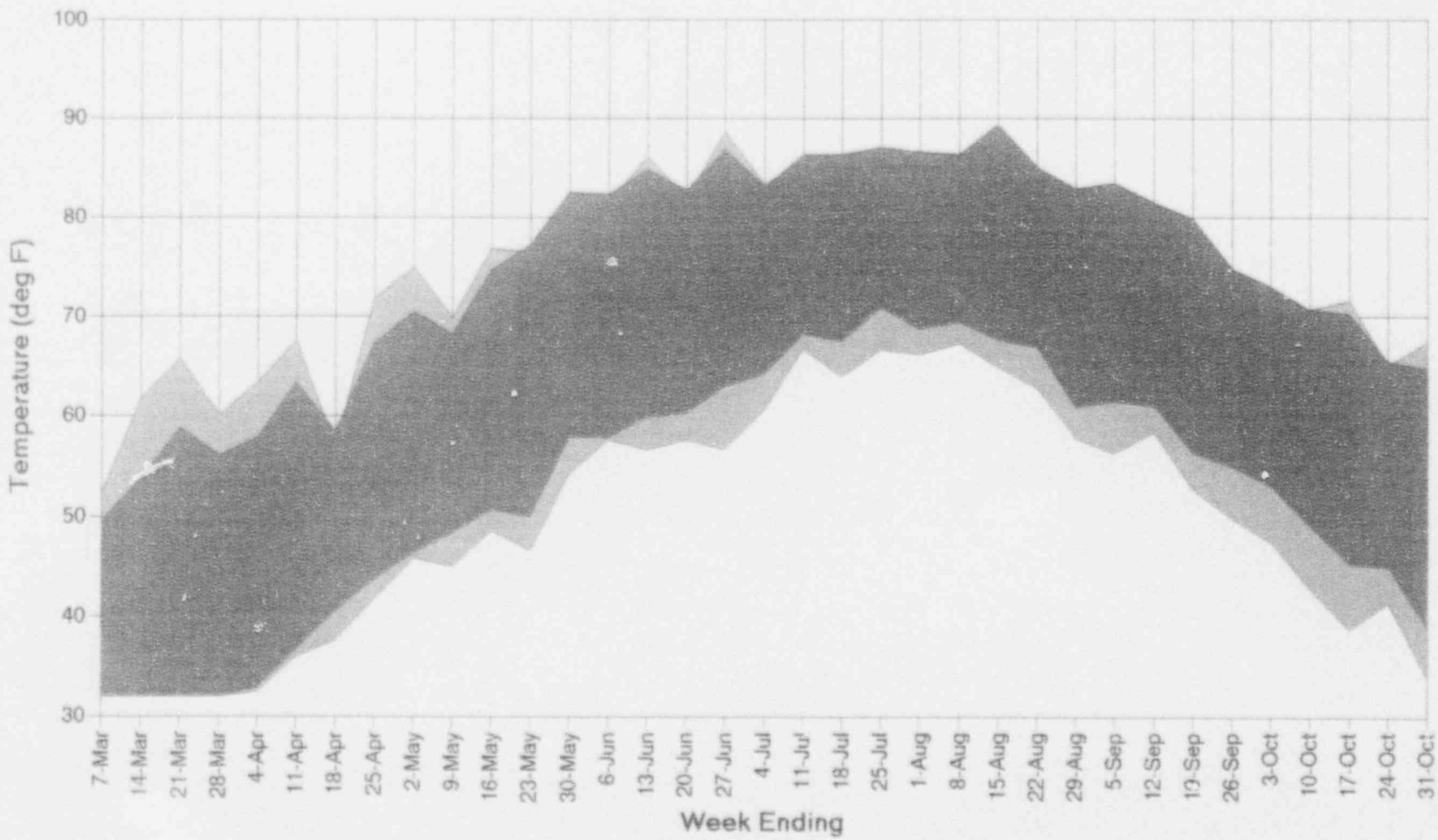


Figure 7.2-10

Segment 02 at 0 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

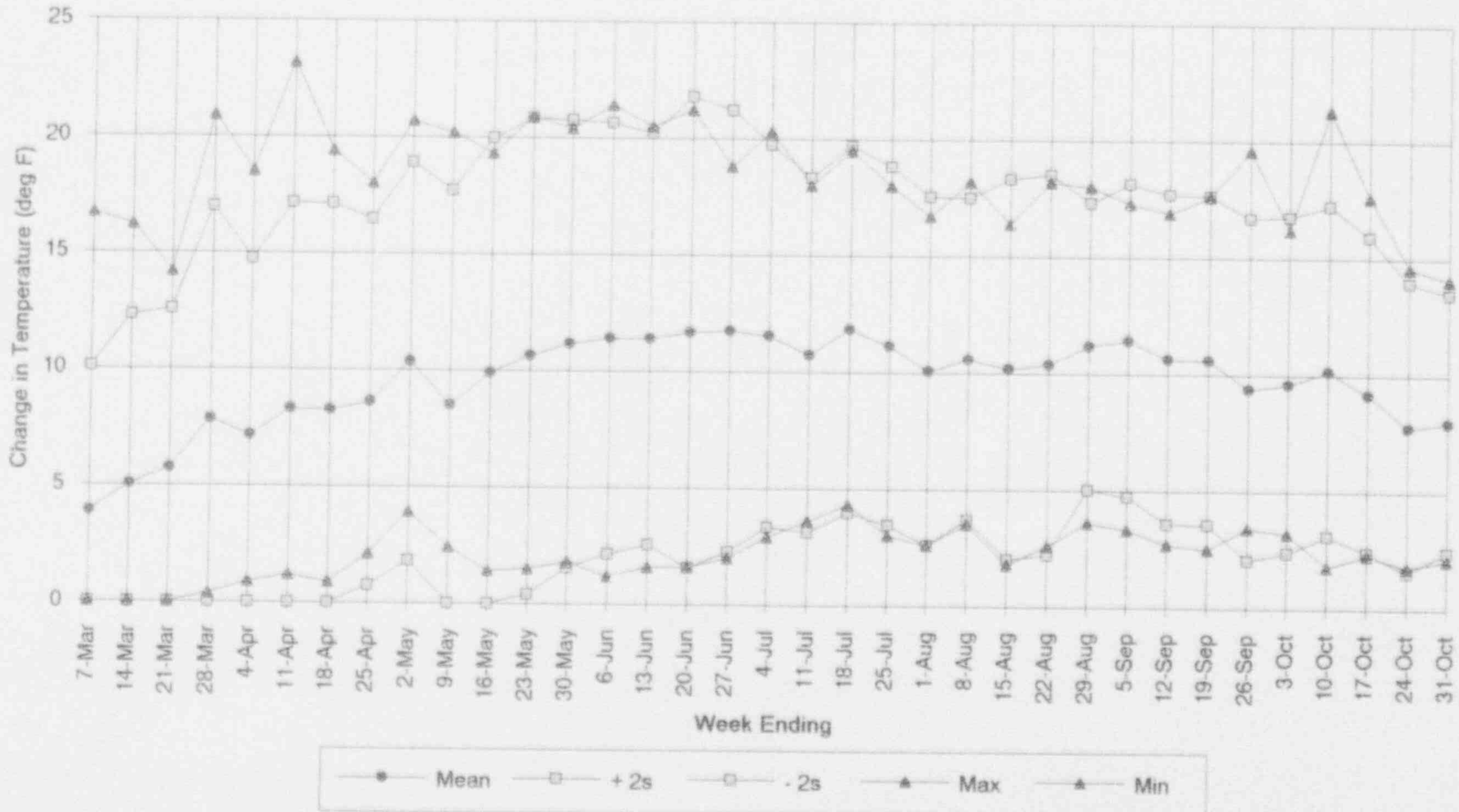


Figure 7.2-11

Segment 02 at 10 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

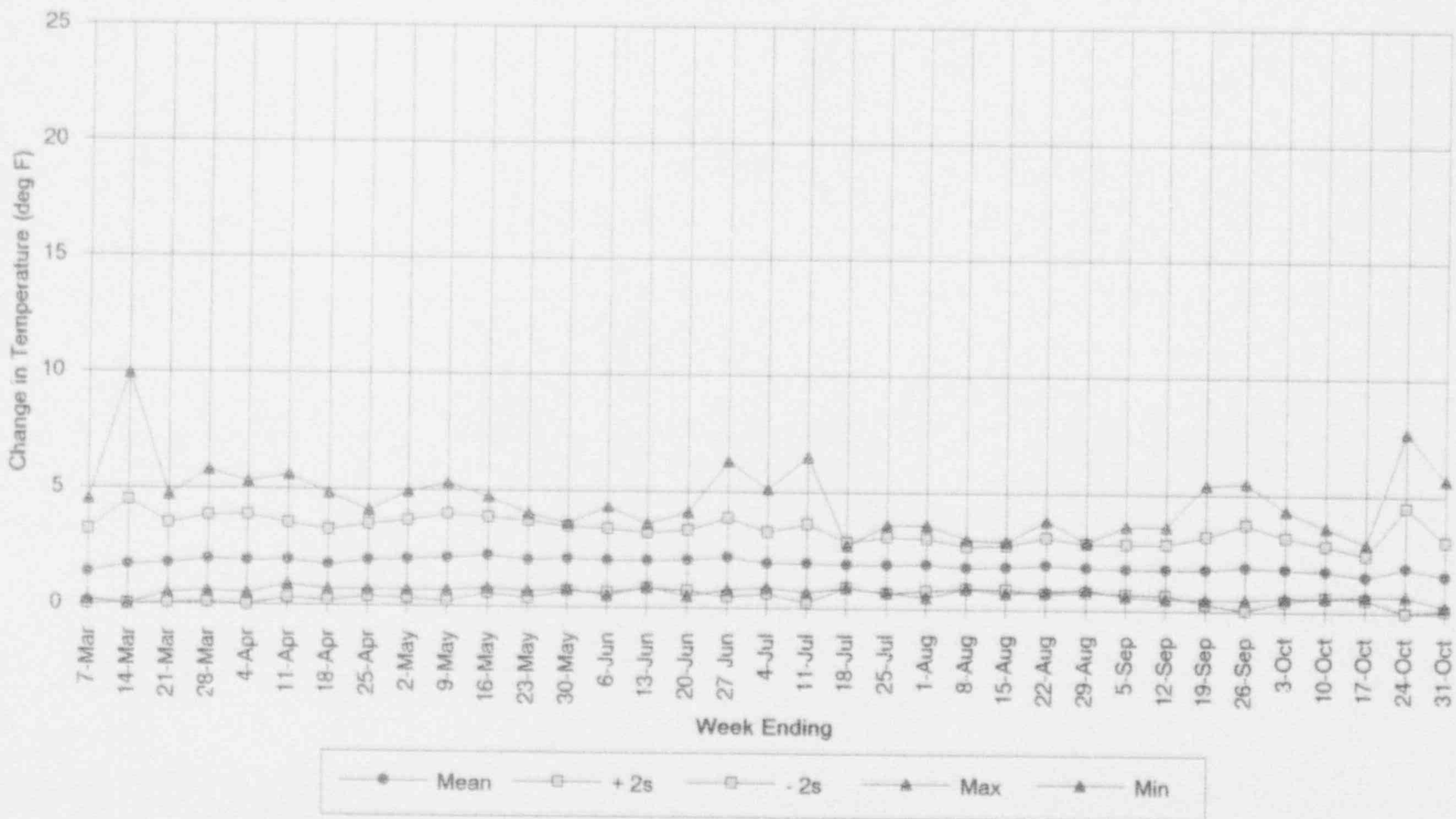


Figure 7.2-12

Segment 02 at 27 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

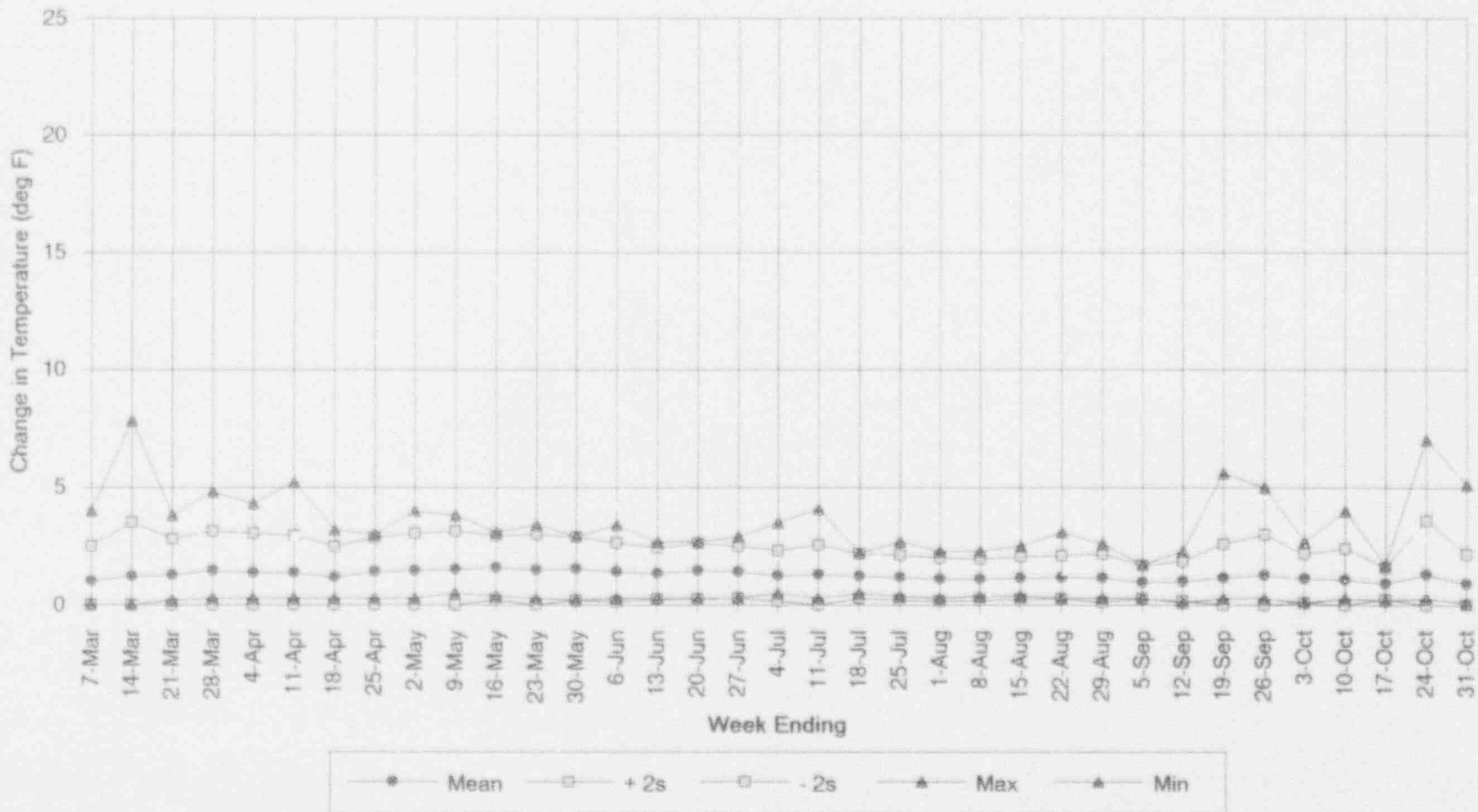


Figure 7.2-13

Segment 02 at 54 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

Figure 7.2-14

Segment 10 at 0 cfs Diversion Rate

Weekly Statistics Describing Diurnal Variation of Predicted Temperature

For the Period Oct 1983 - Sept 1992

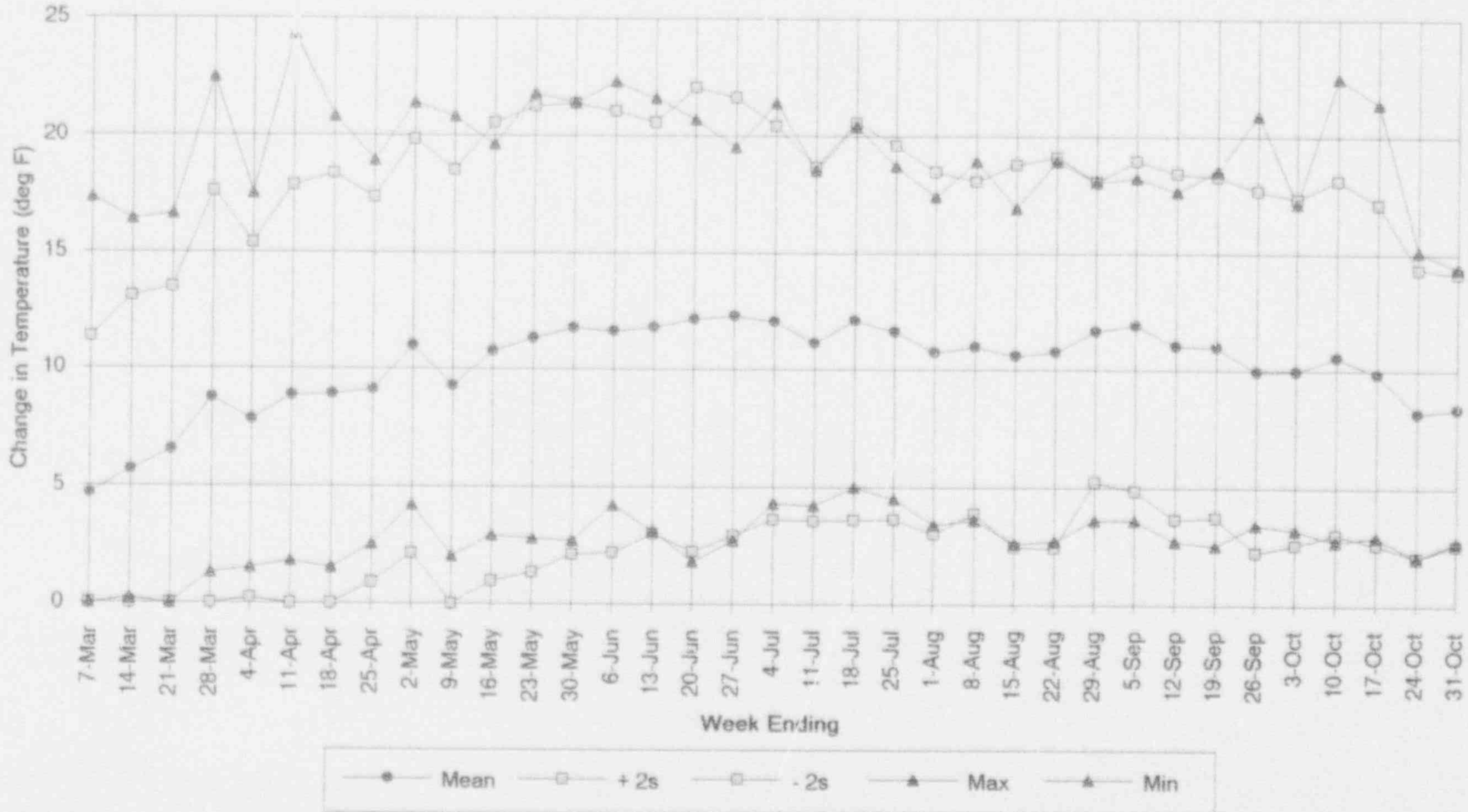


Figure 7.2-15

Segment 10 at 10 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

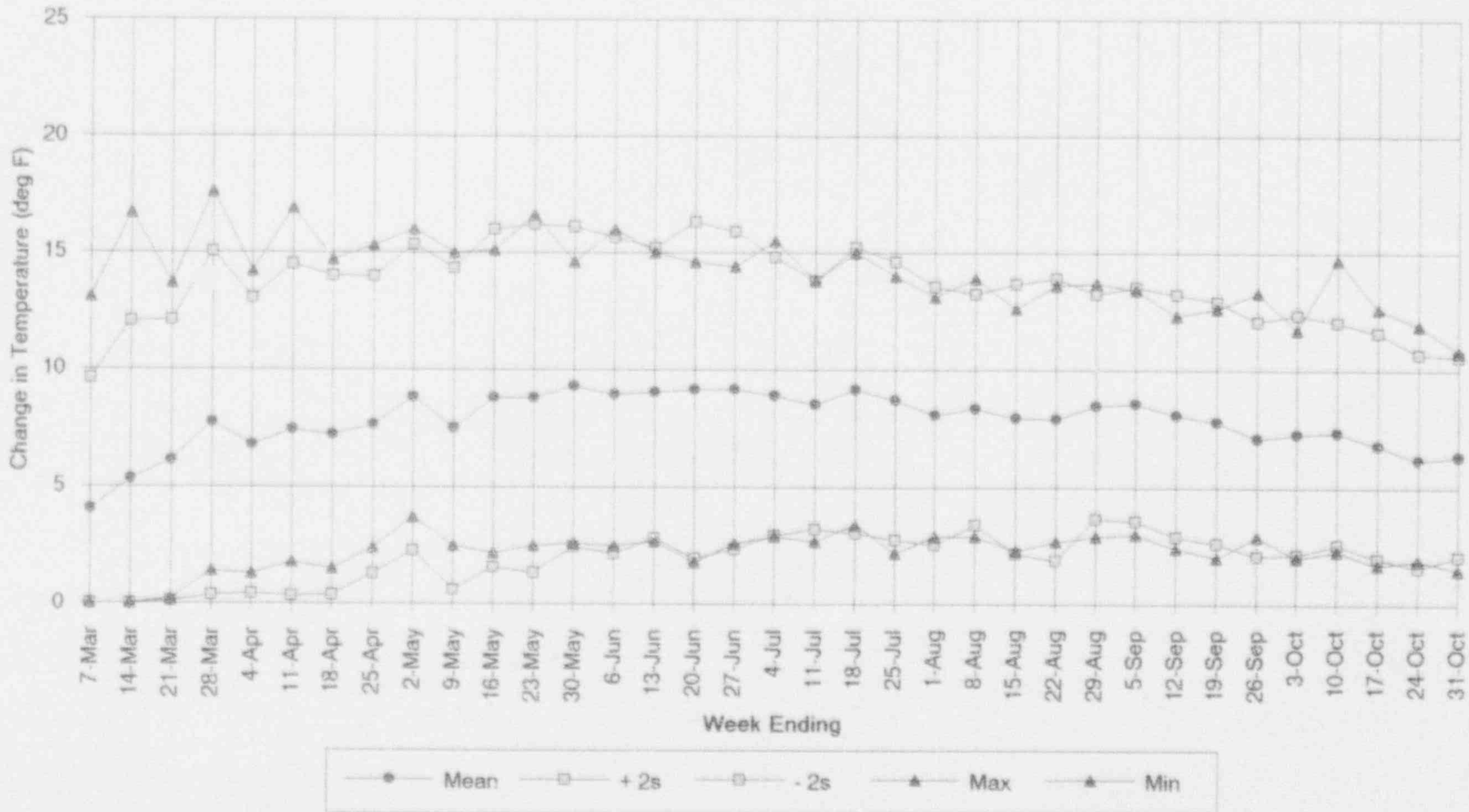


Figure 7.2-16

Segment 10 at 27 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

Figure 7.2-17

Segment 10 at 54 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

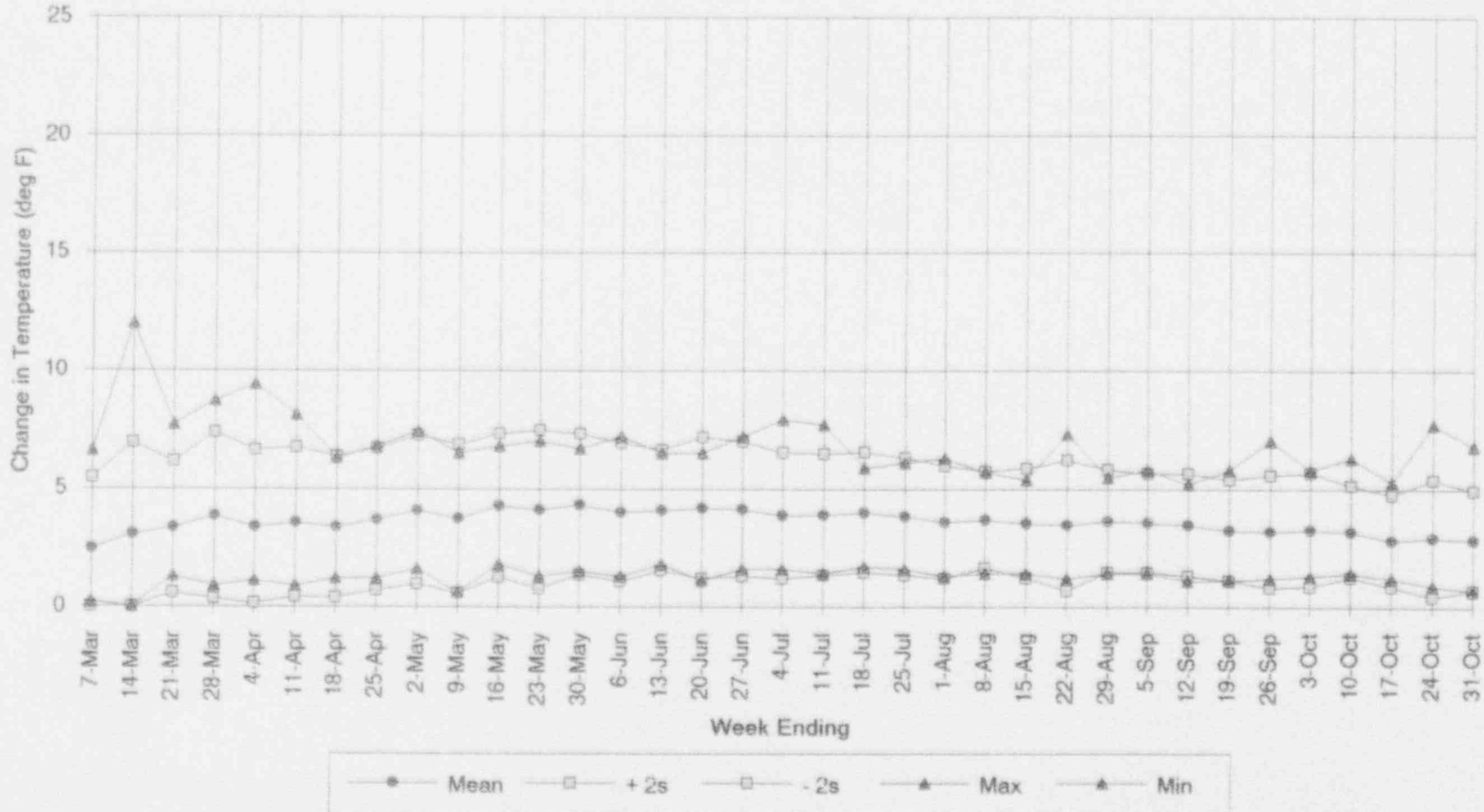


Figure 7.2-18

Segment 19 at 0 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

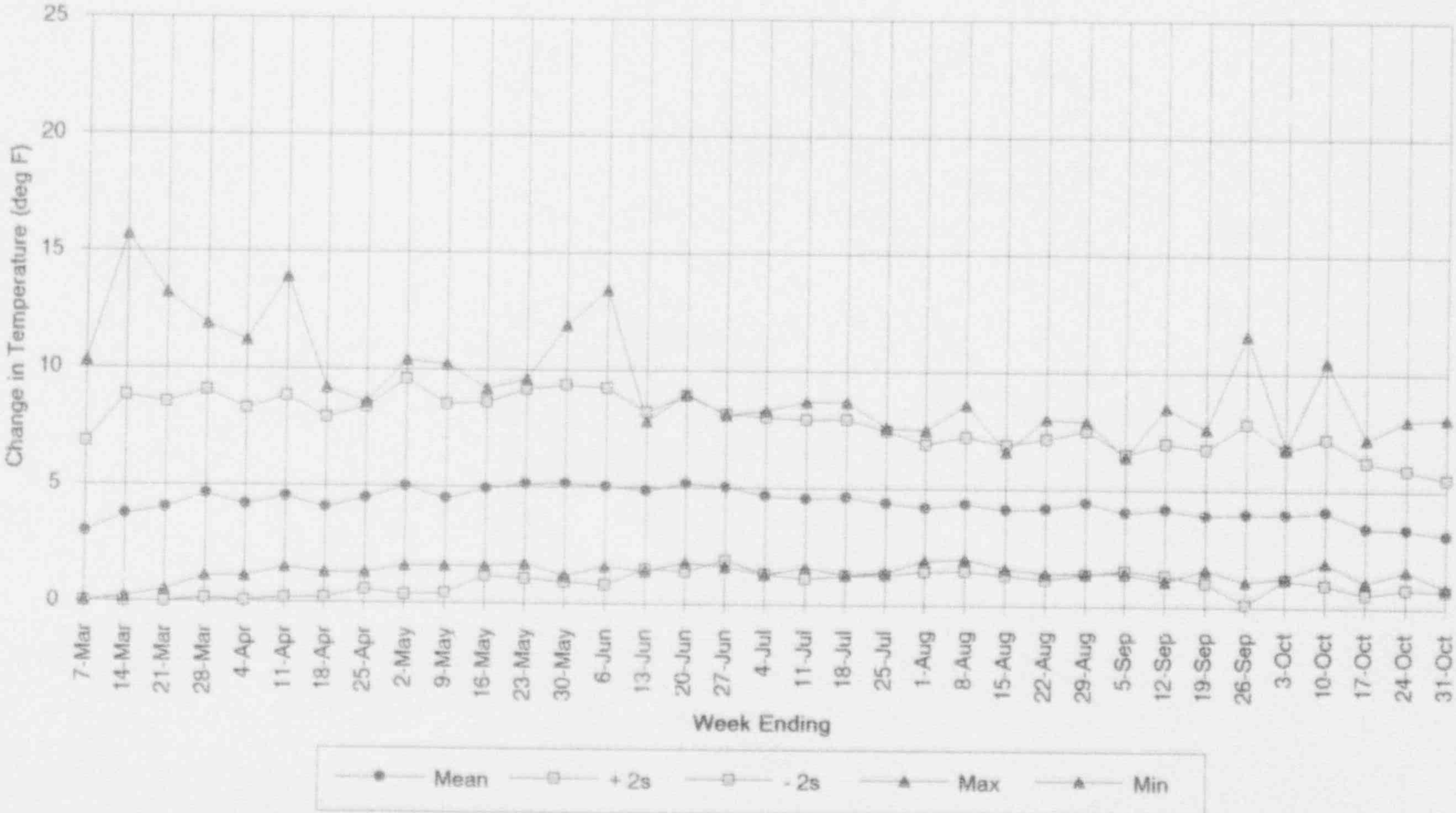


Figure 7.2-19

Segment 19 at 10 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992

Figure 7.2-20

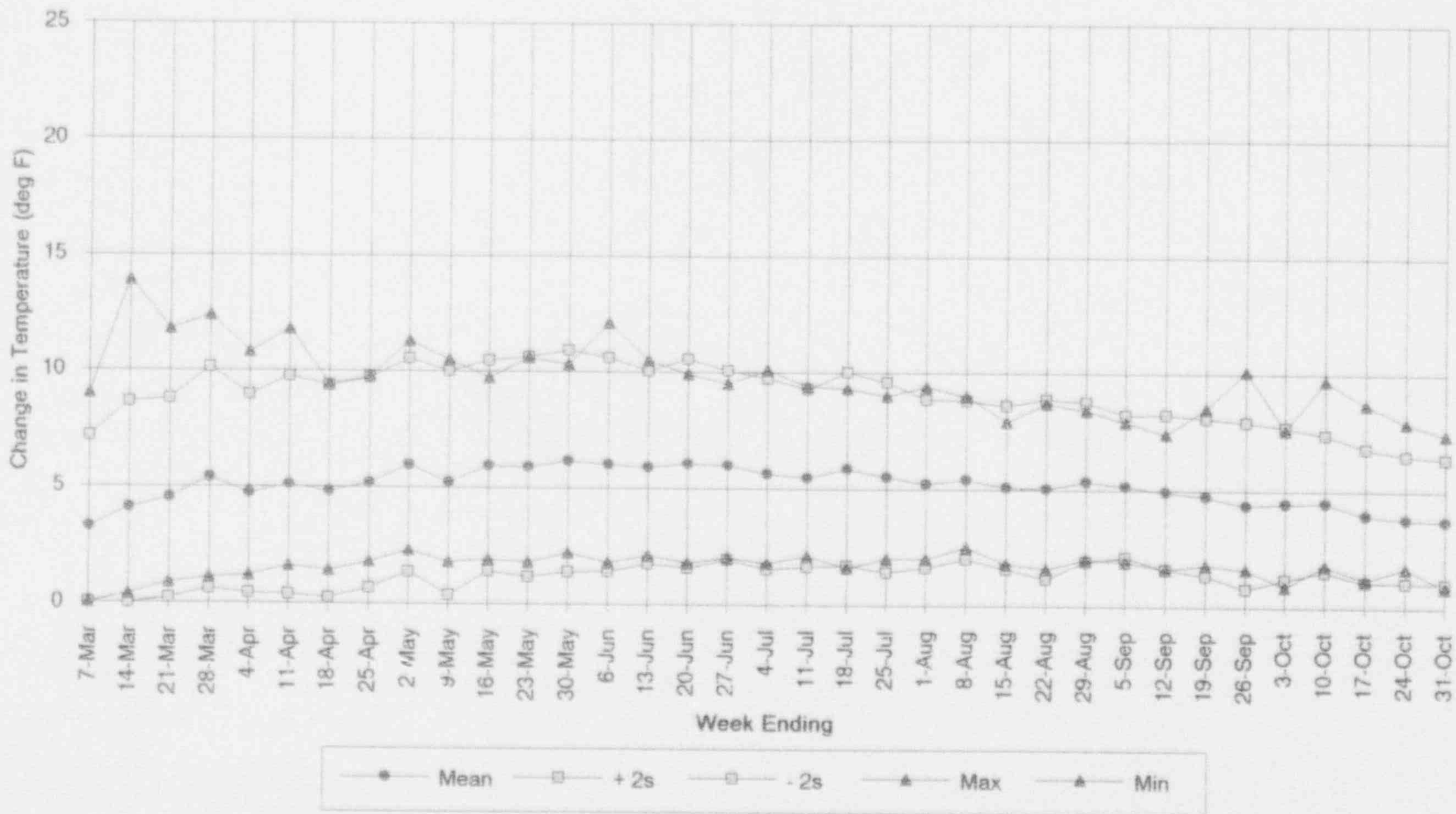
Segment 19 at 27 cfs Diversion Rate

Weekly Statistics Describing Diurnal Variation of Predicted Temperature

For the Period Oct 1983 - Sept 1992

Figure 7.2-21

Segment 19 at 54 cfs Diversion Rate
Weekly Statistics Describing Diurnal Variation of Predicted Temperature
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-22

Segment 02 at 0 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

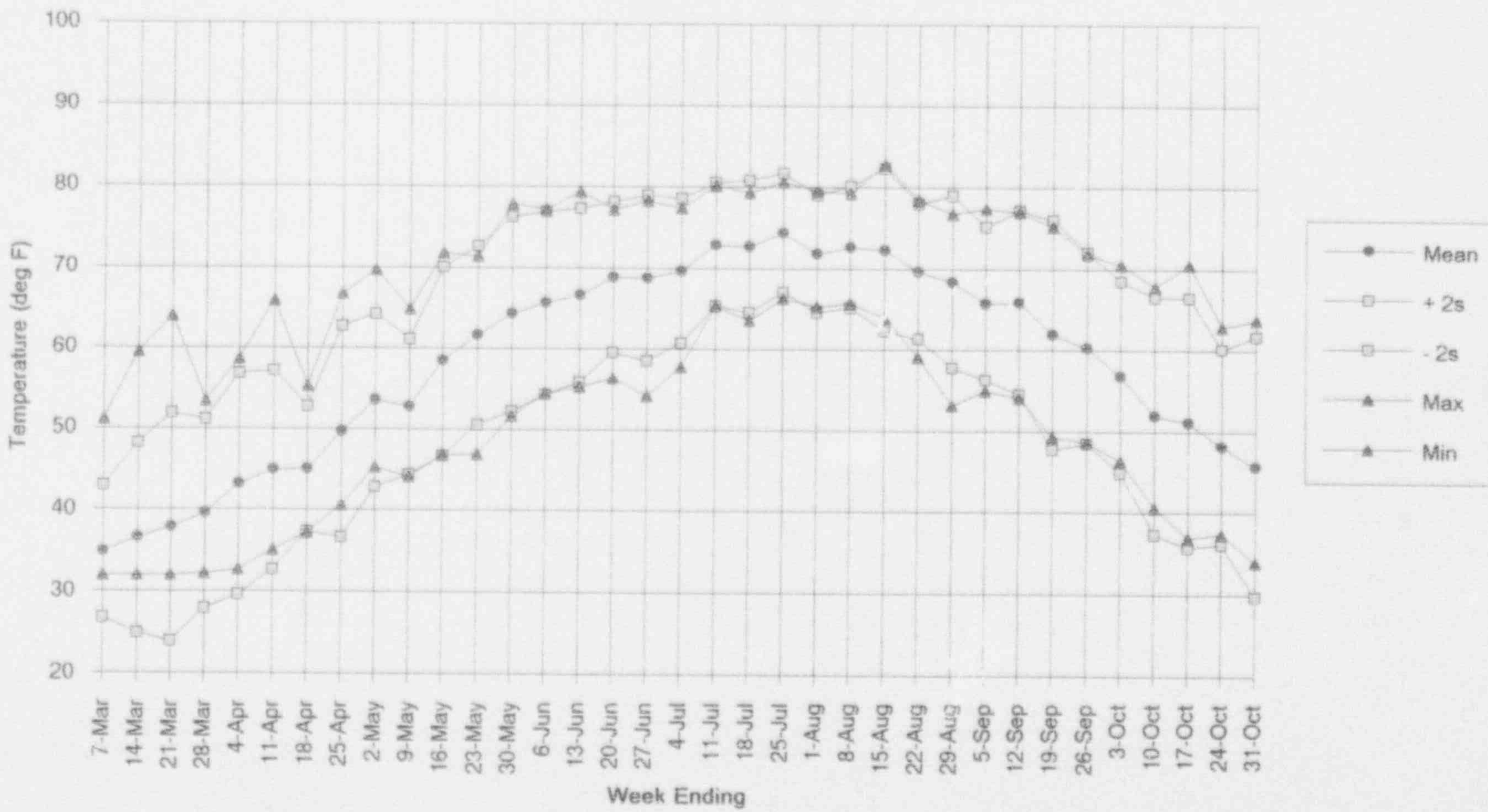
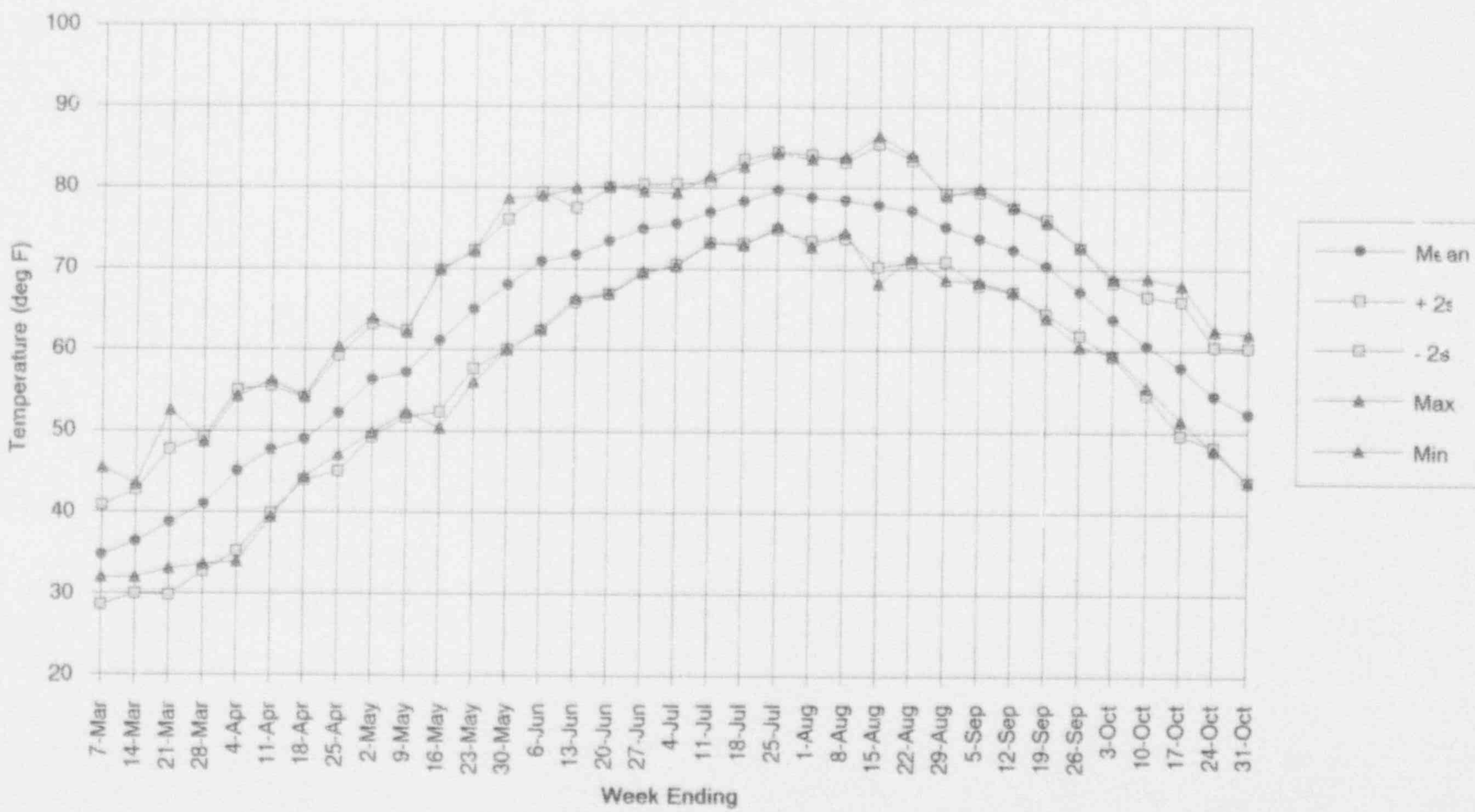


Figure 7.2-23

Segment 02 at 10 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-24
Segment 02 at 27 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

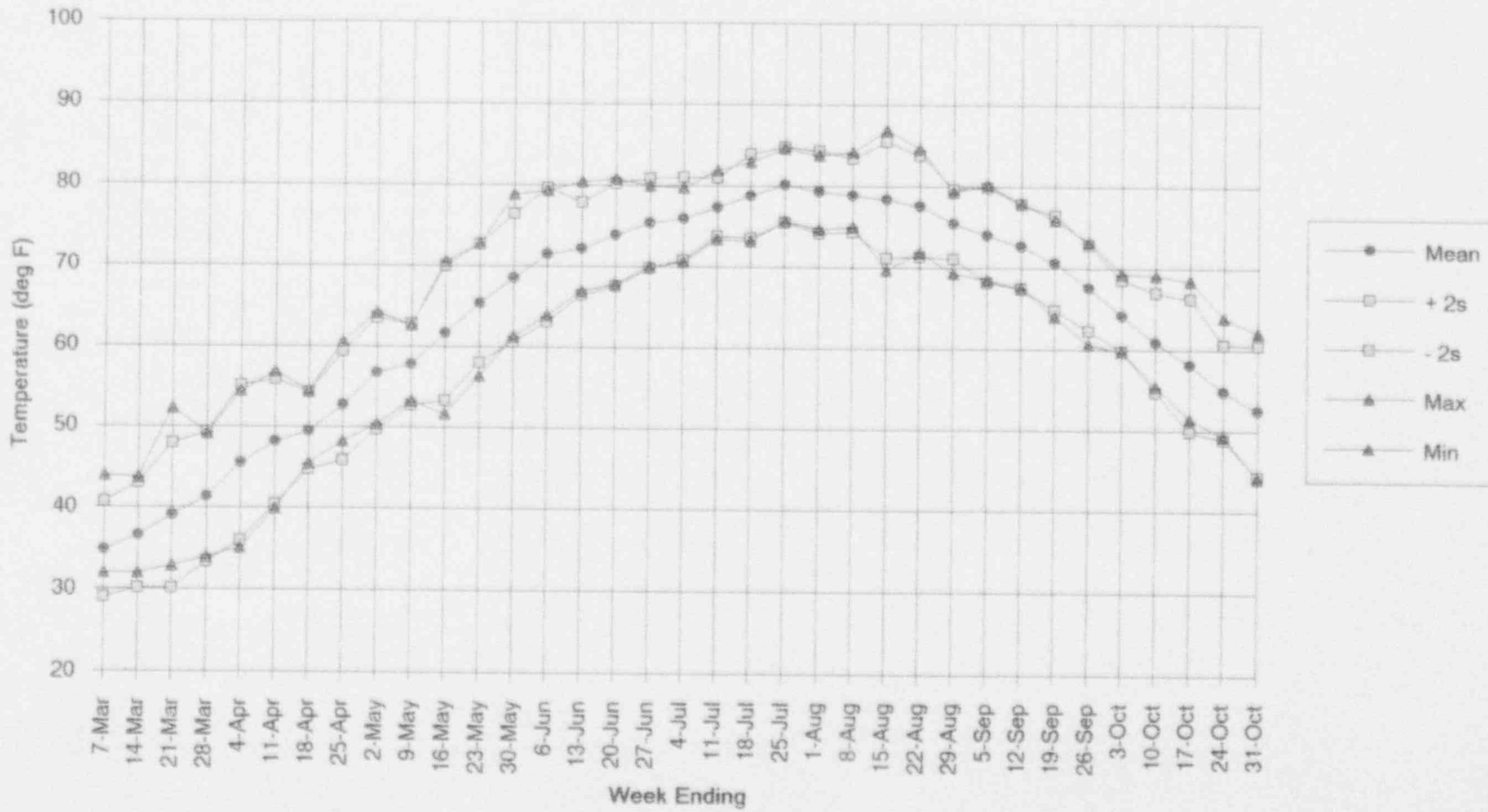


Figure 7.2-25

Segment 02 at 54 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

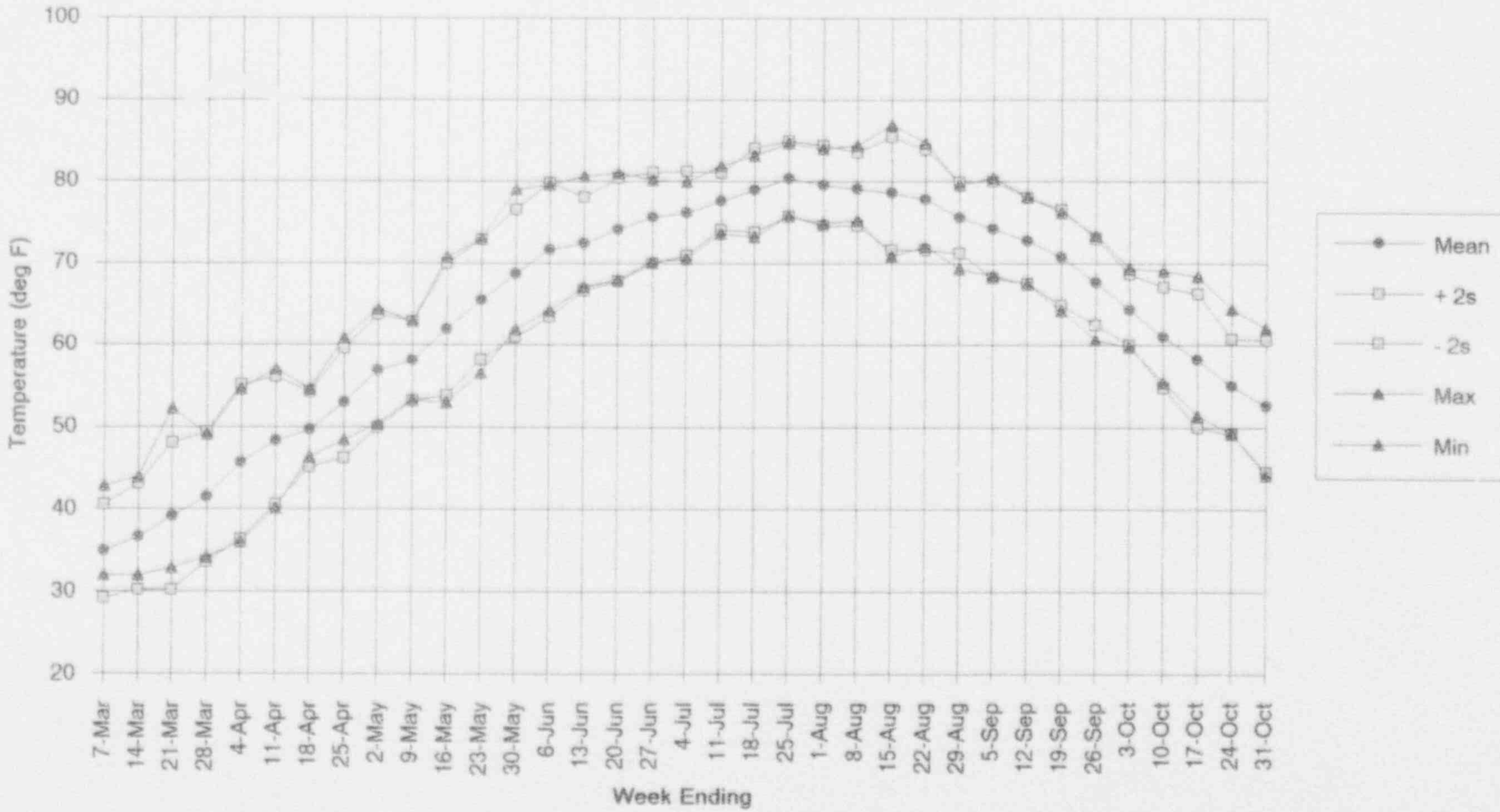


Figure 7.2-26

Segment 10 at 0 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

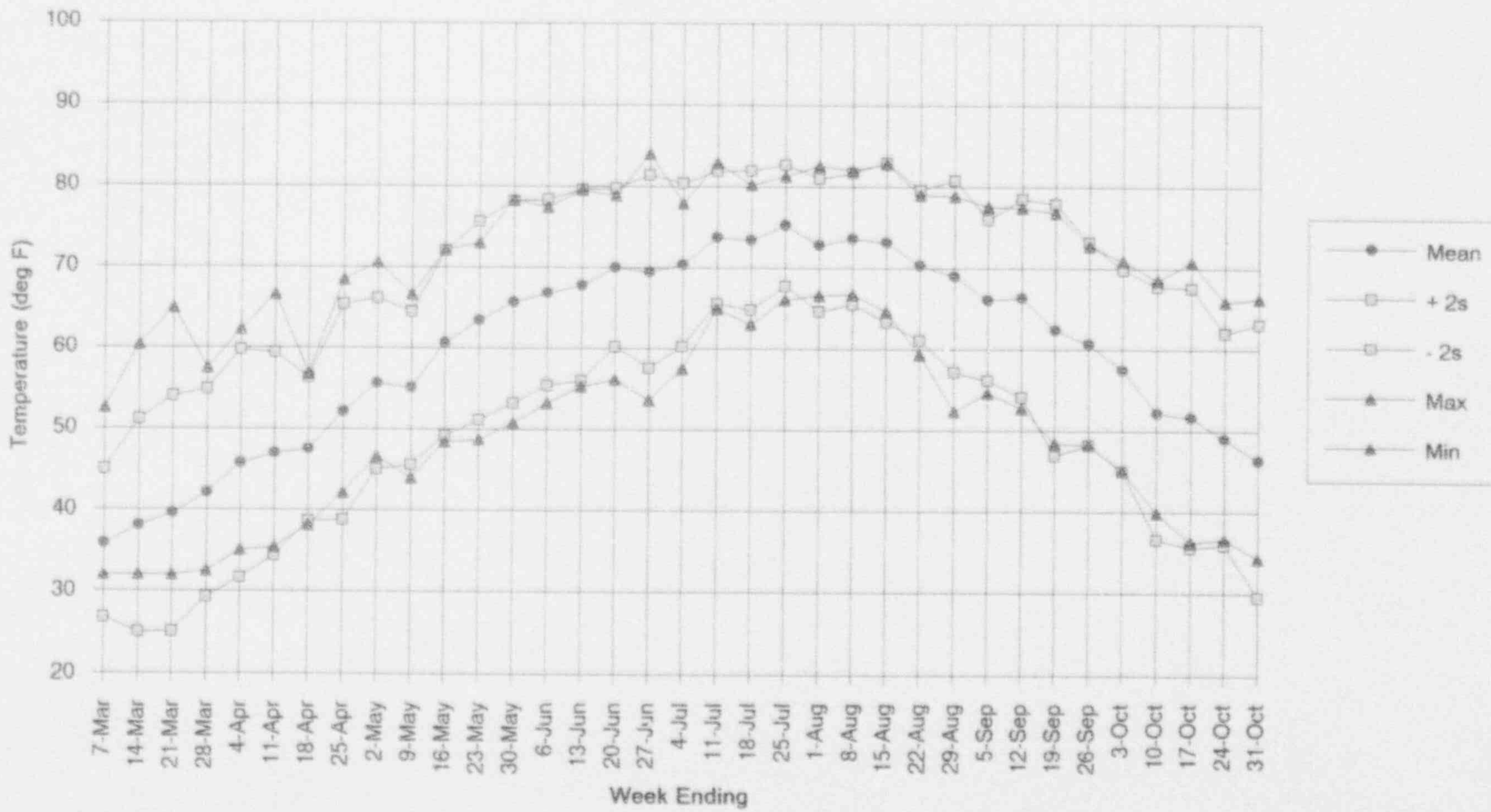


Figure 7.2-27

Segment 10 at 10 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

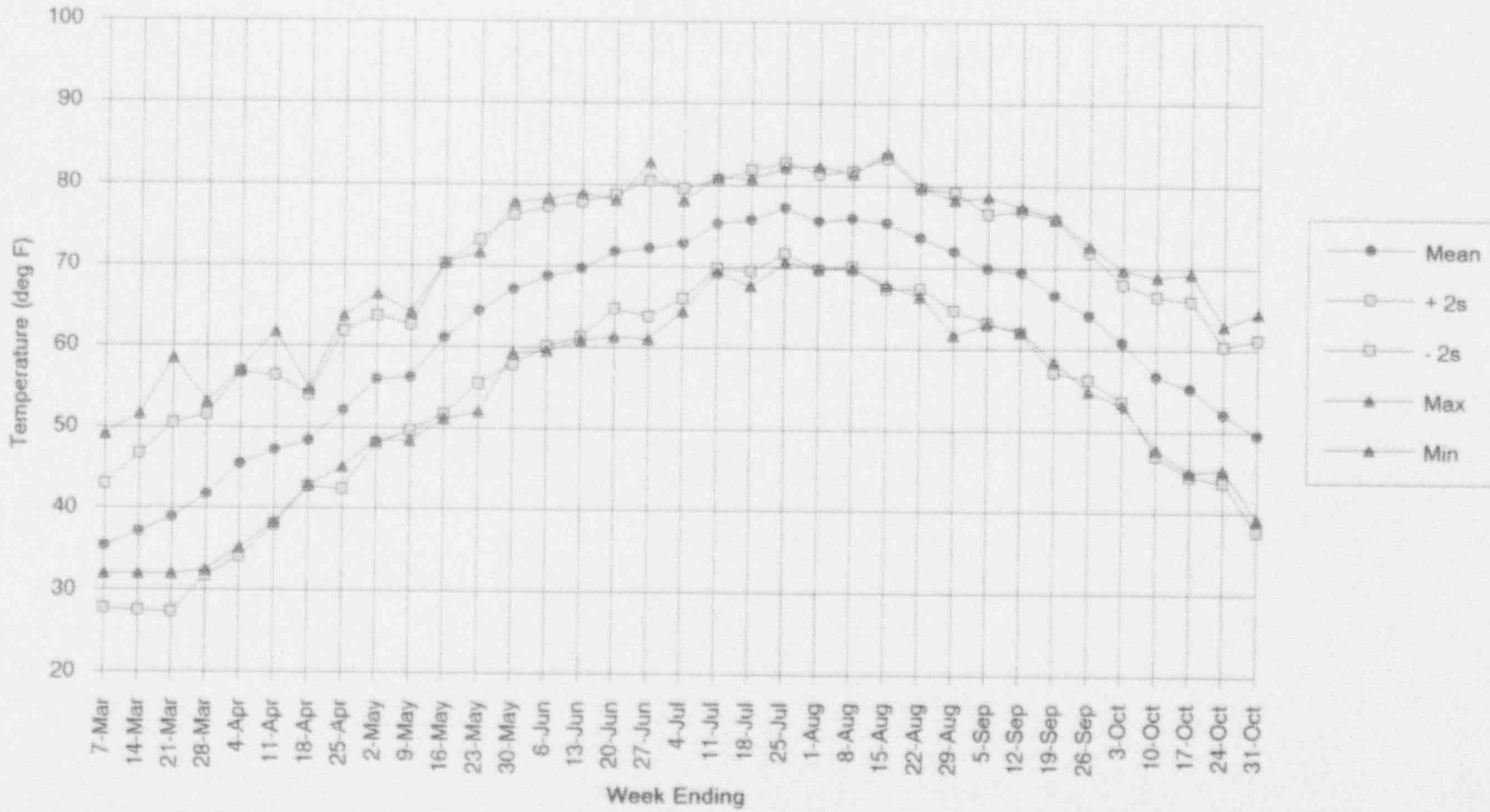


Figure 7.2-28

Segment 10 at 27 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

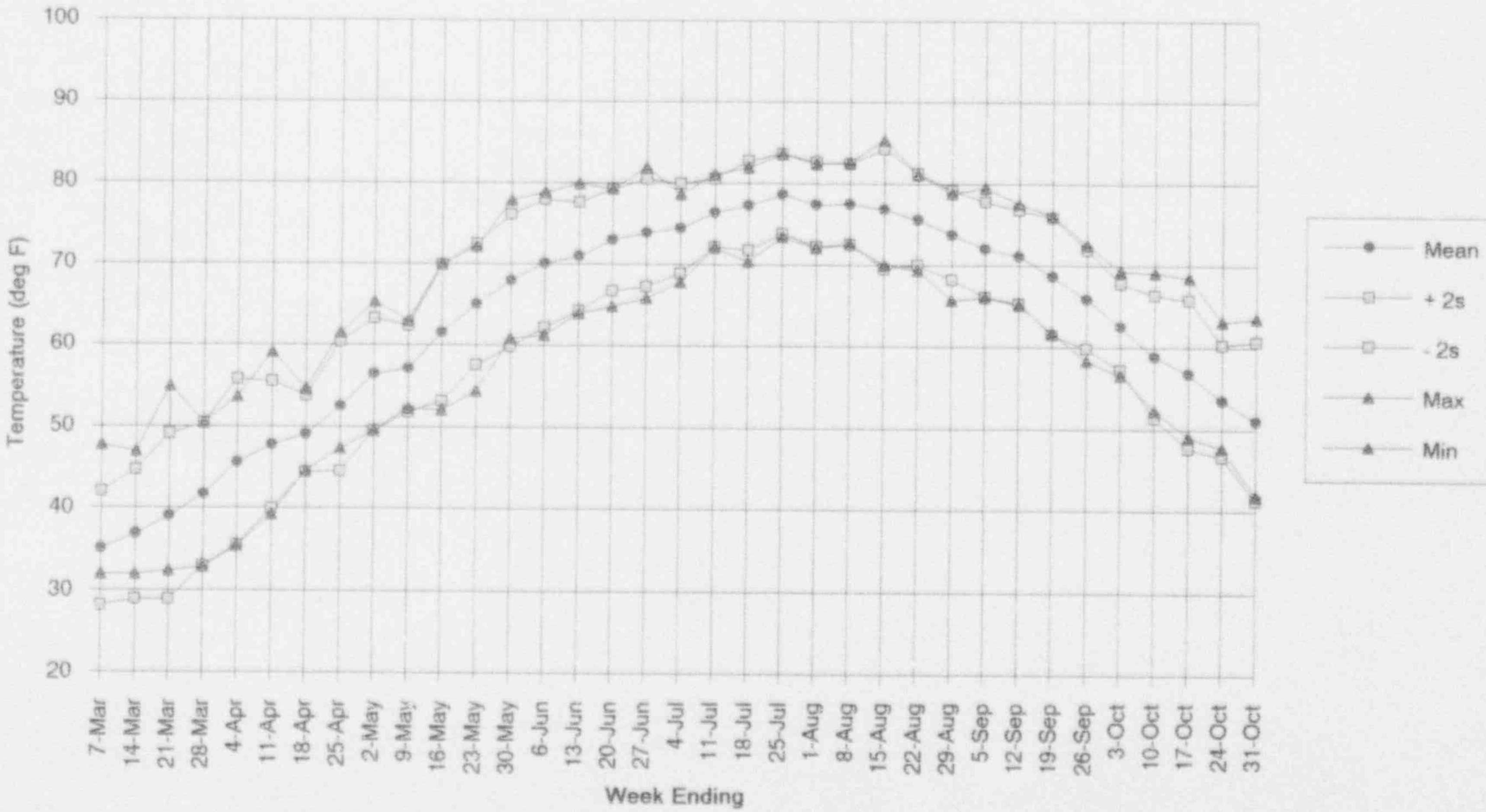


Figure 7.2-29

Segment 10 at 54 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

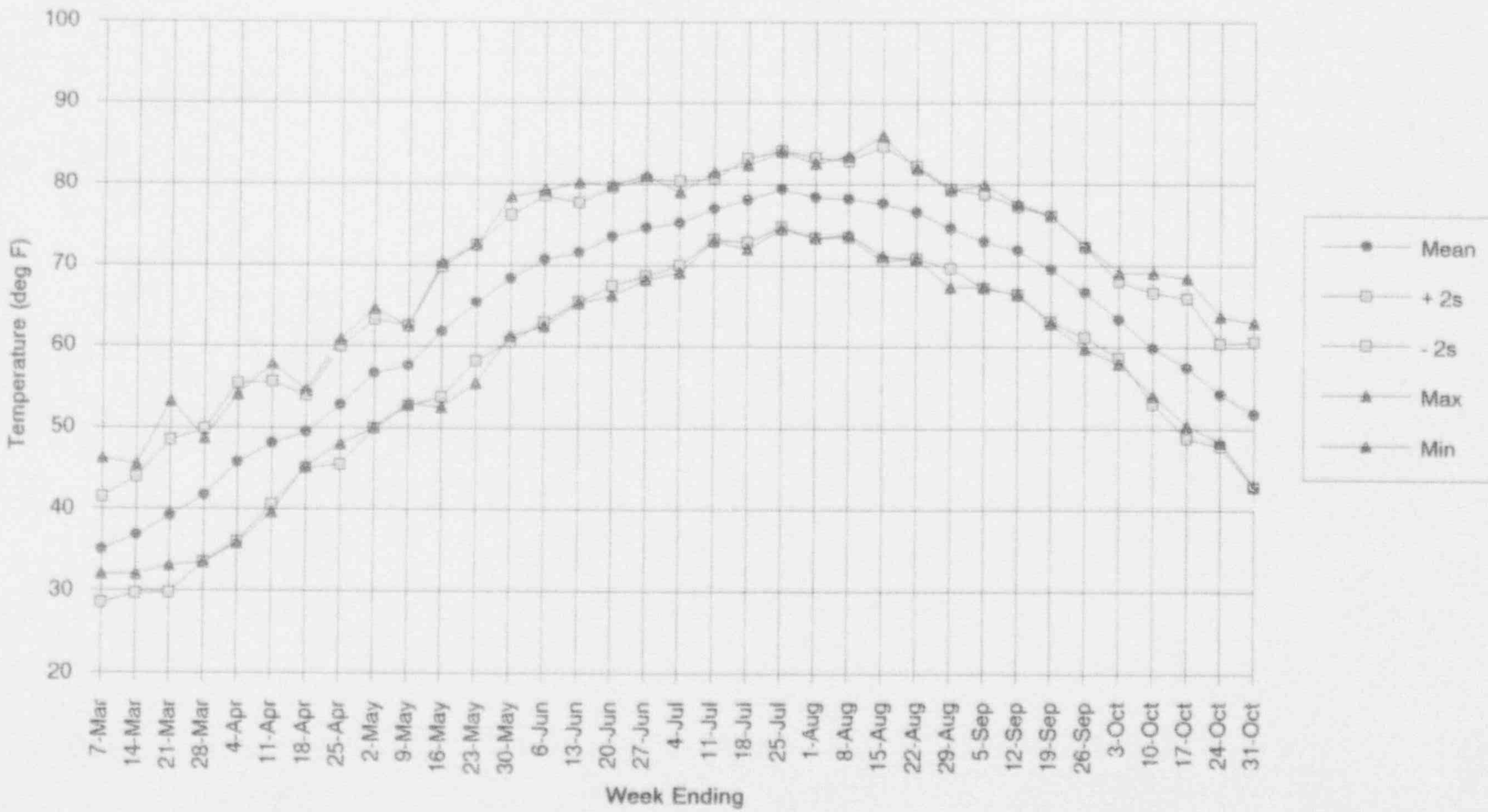
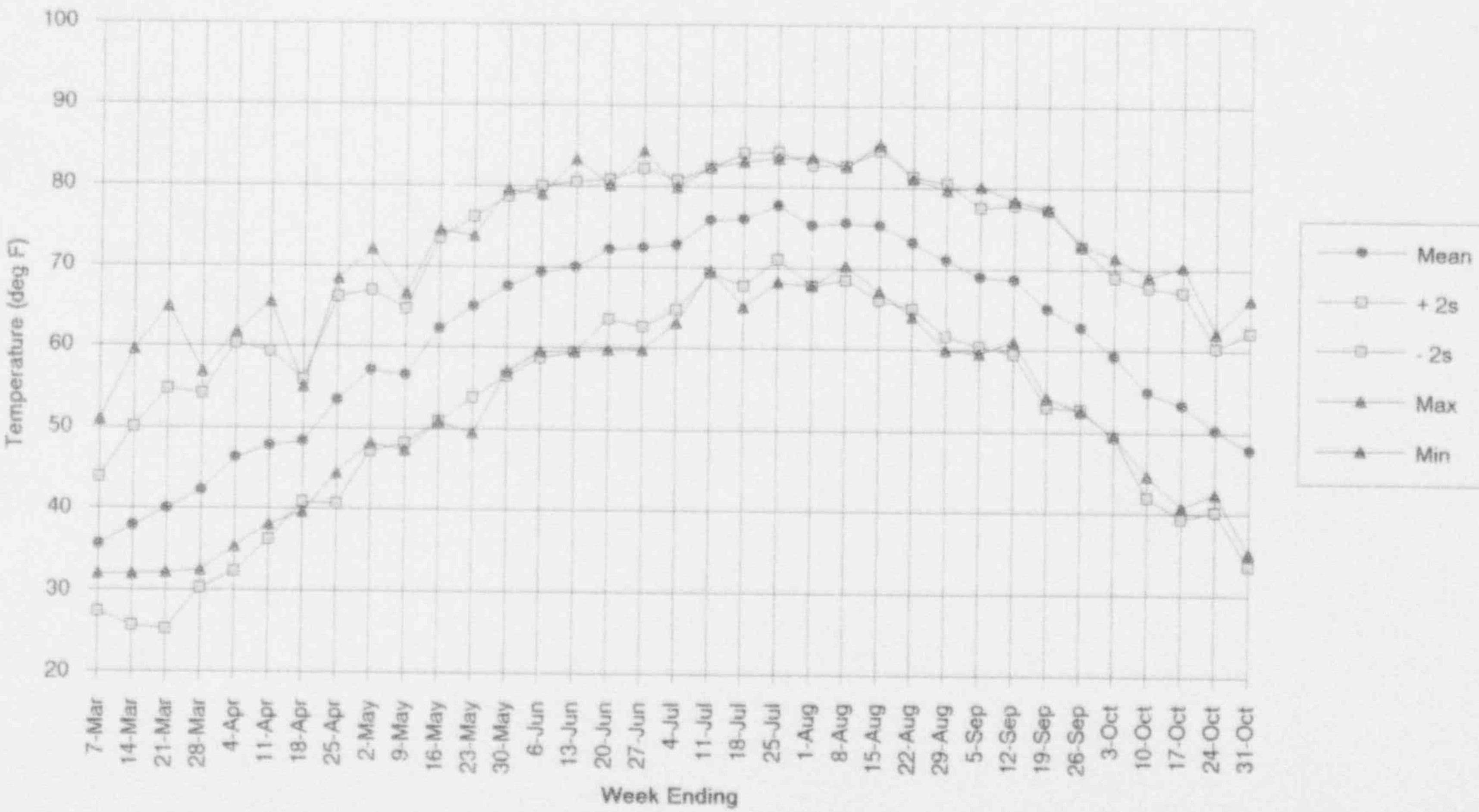


Figure 7.2-30

Segment 19 at 0 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-31

Segment 19 at 10 cfs Diversion Rate

Weekly Statistics Describing Daily Mean of Predicted Temperatures

For the Period Oct 1983 - Sept 1992

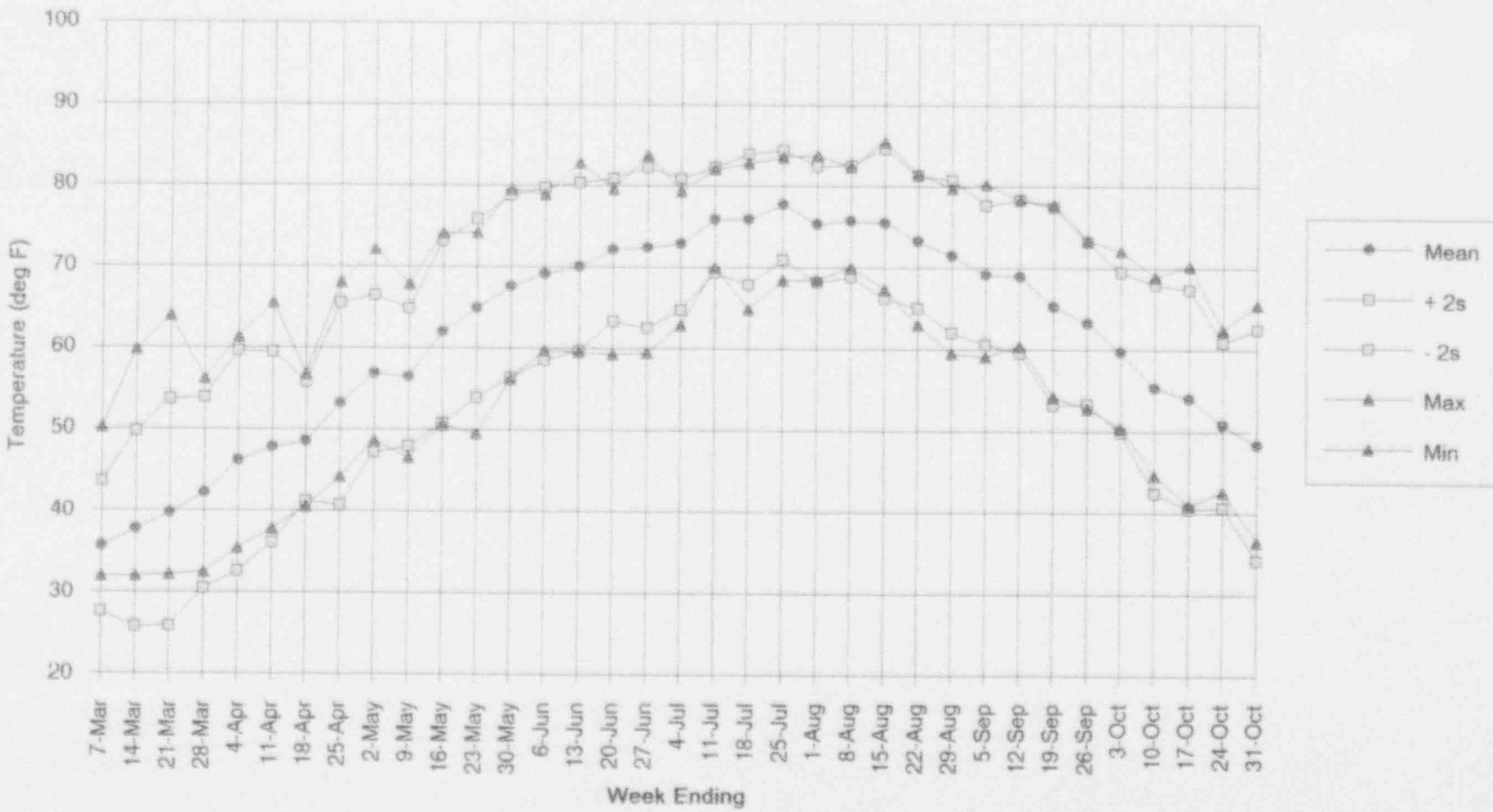
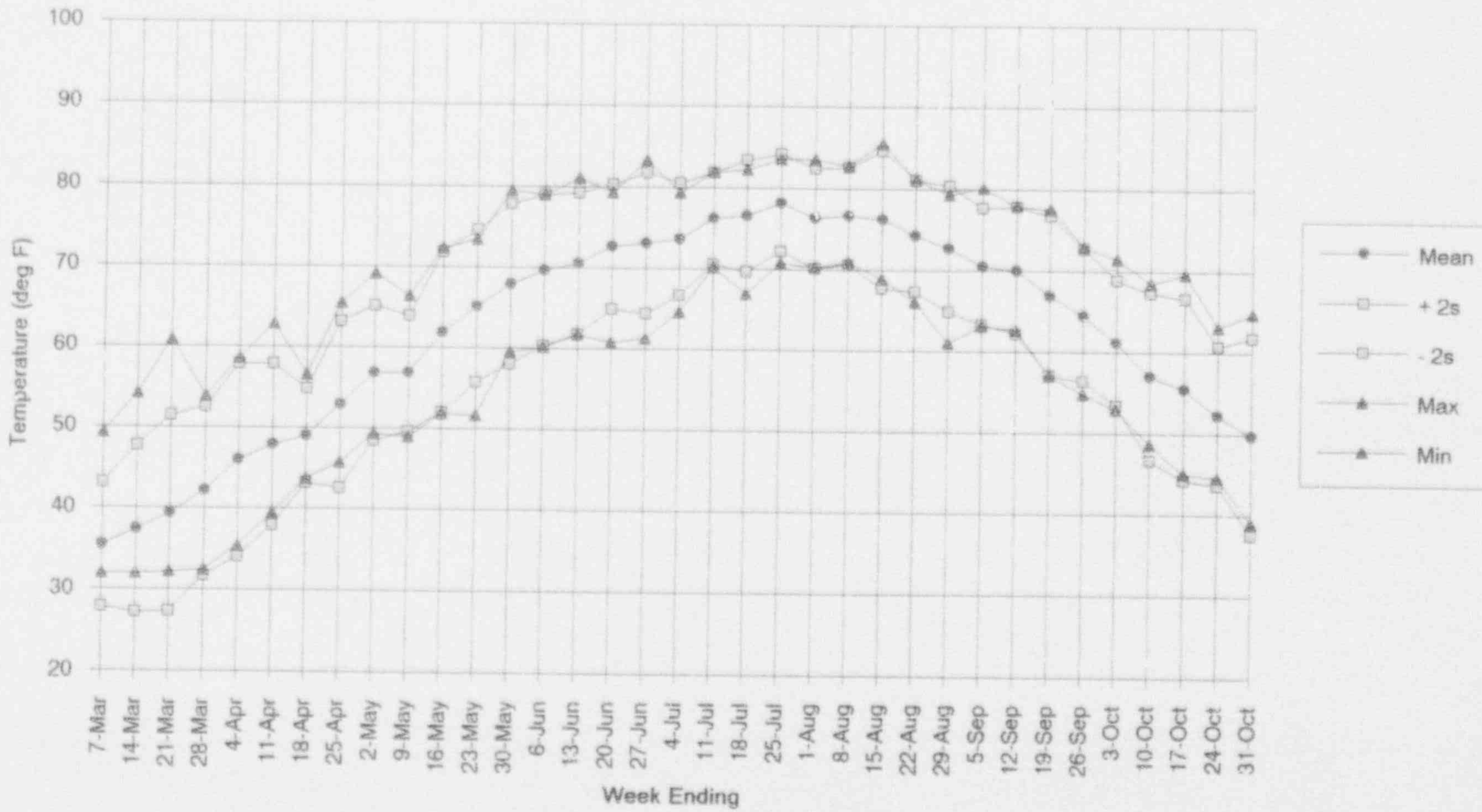


Figure 7.2-32
Segment 19 at 27 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-33

Segment 19 at 54 cfs Diversion Rate
Weekly Statistics Describing Daily Mean of Predicted Temperatures
For the Period Oct 1983 - Sept 1992

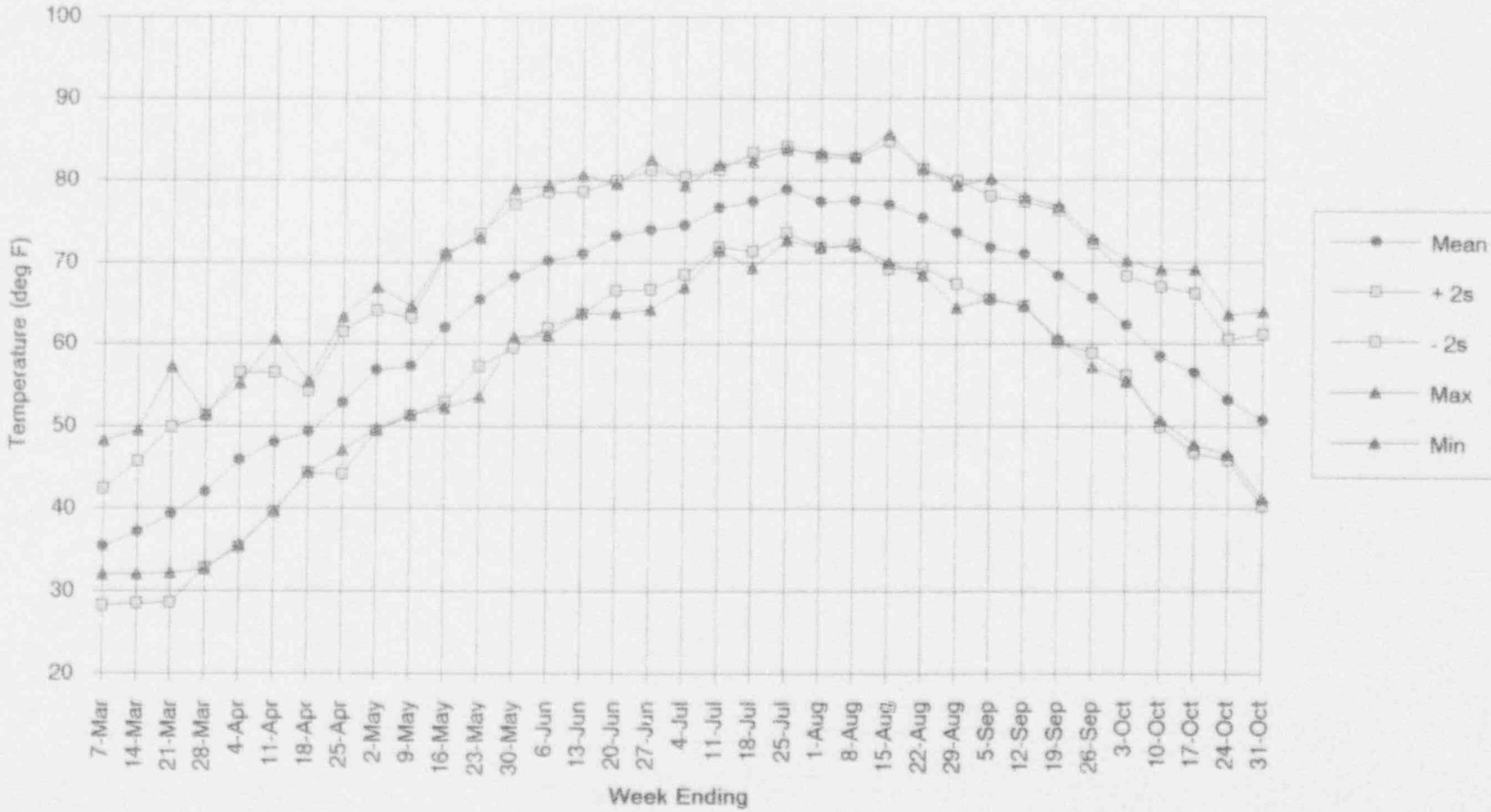


Figure 7.2-34
Segment 02
Comparison Among Predicted Weekly Mean Temperatures at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

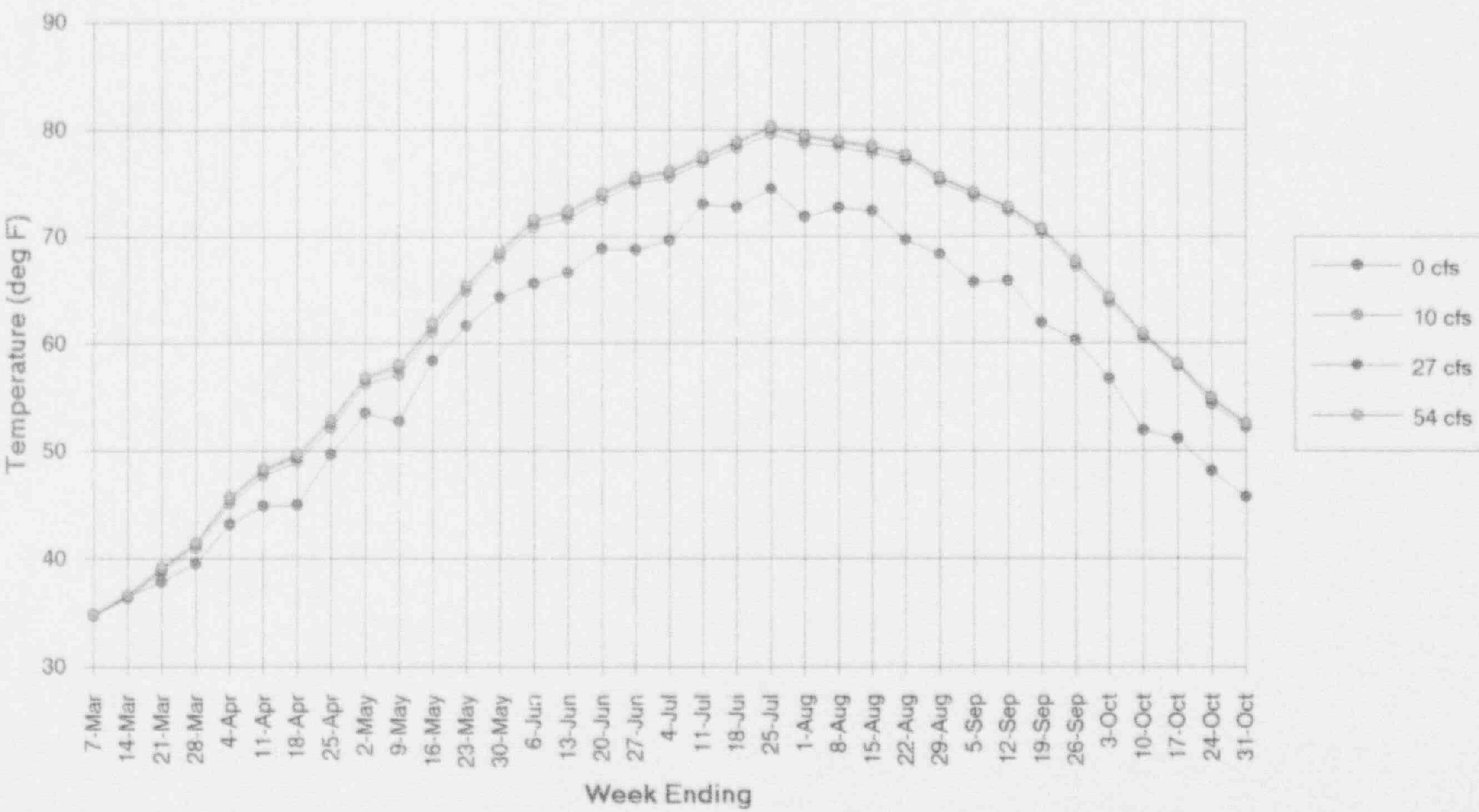


Figure 7.2-35
Segment 10
Comparison Among Predicted Weekly Mean Temperatures at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

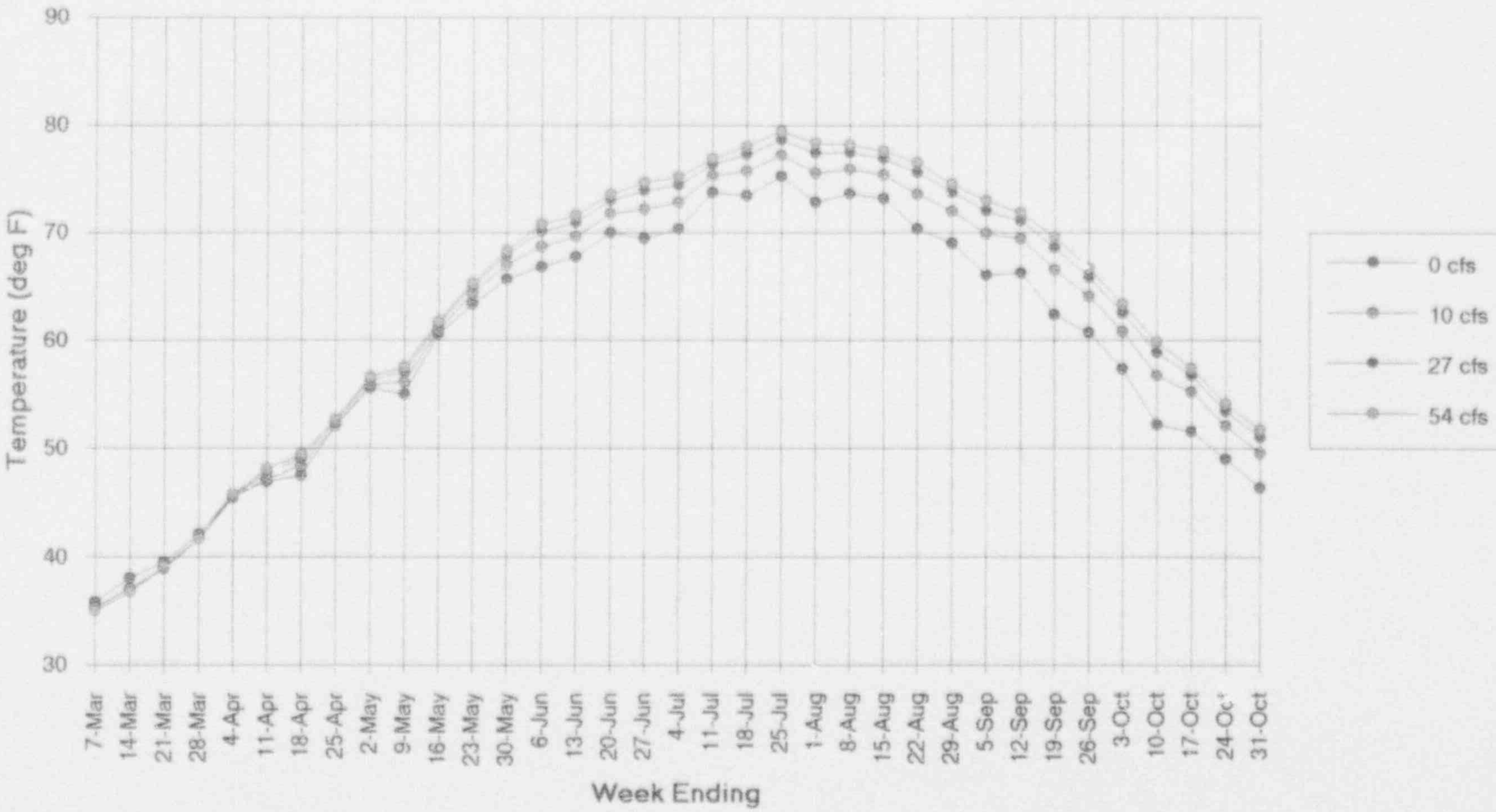


Figure 7.2-36
Segment 19
Comparison Among Predicted Weekly Mean Temperatures at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

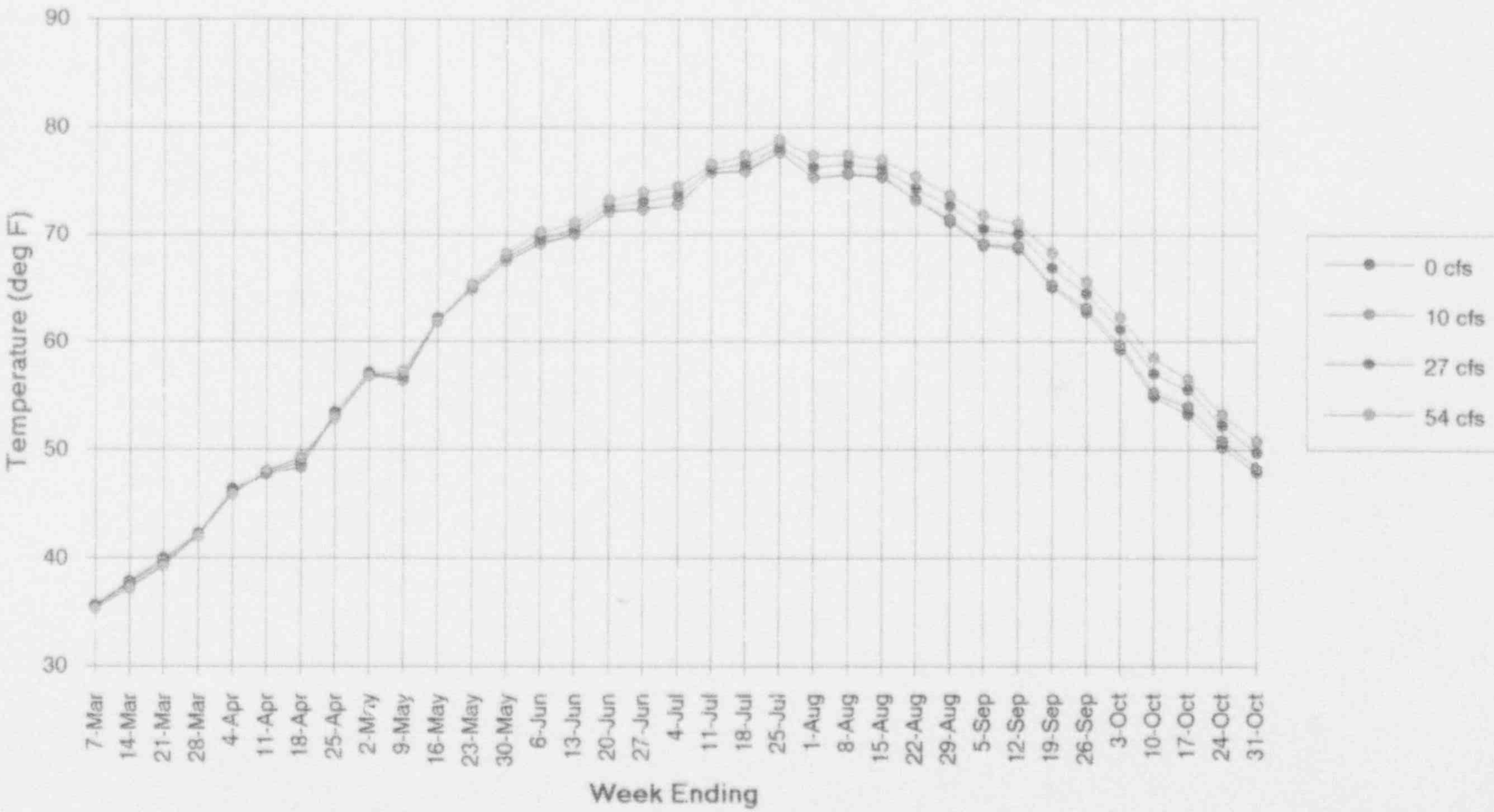


Figure 7.2-37
Segment 02
Comparison Among Weekly Means of Predicted Daily Maximum Temperatures
at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

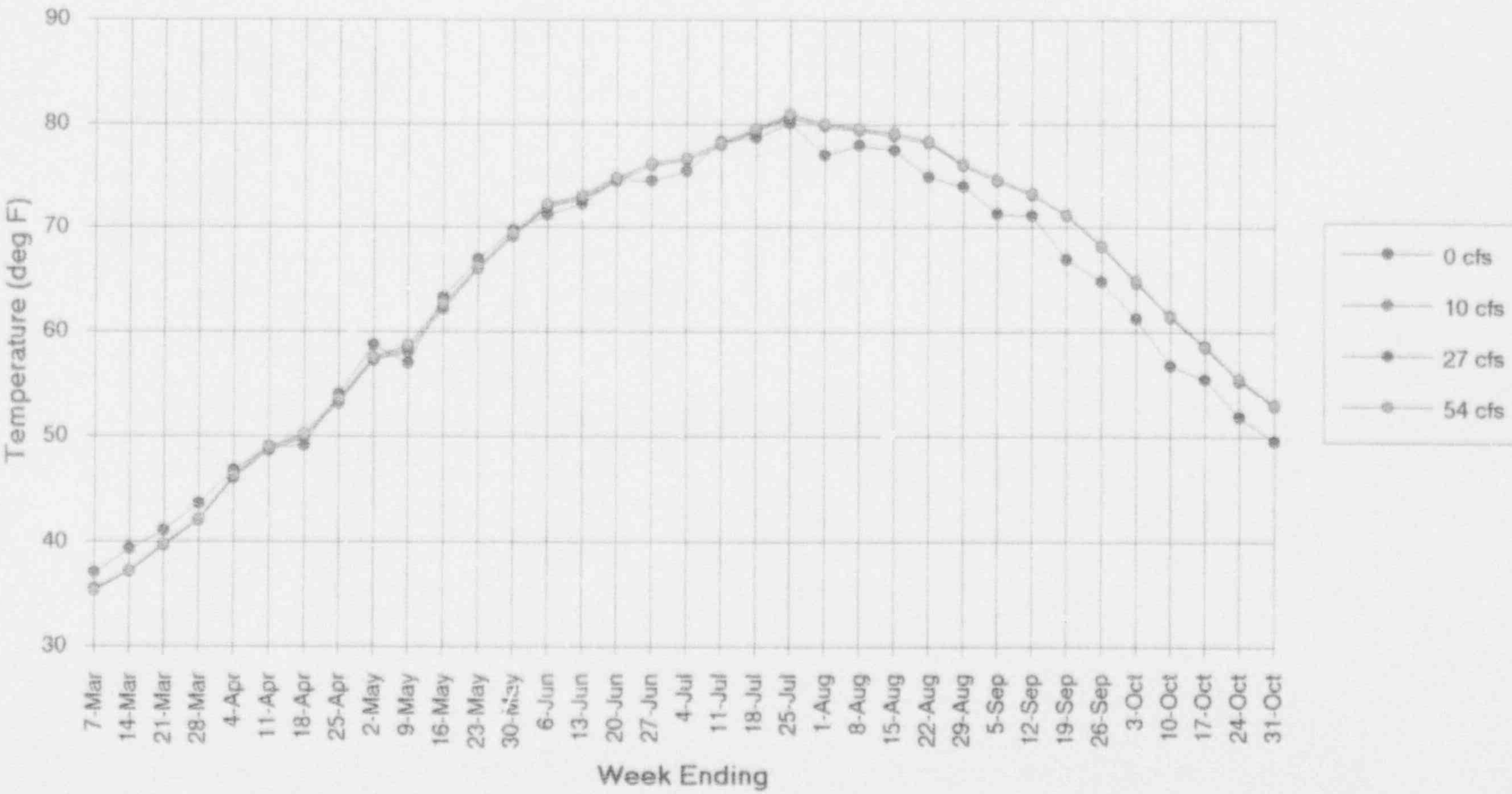


Figure 7.2-38
Segment 10
Comparison Among Weekly Means of Predicted Daily Maximum Temperatures
at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

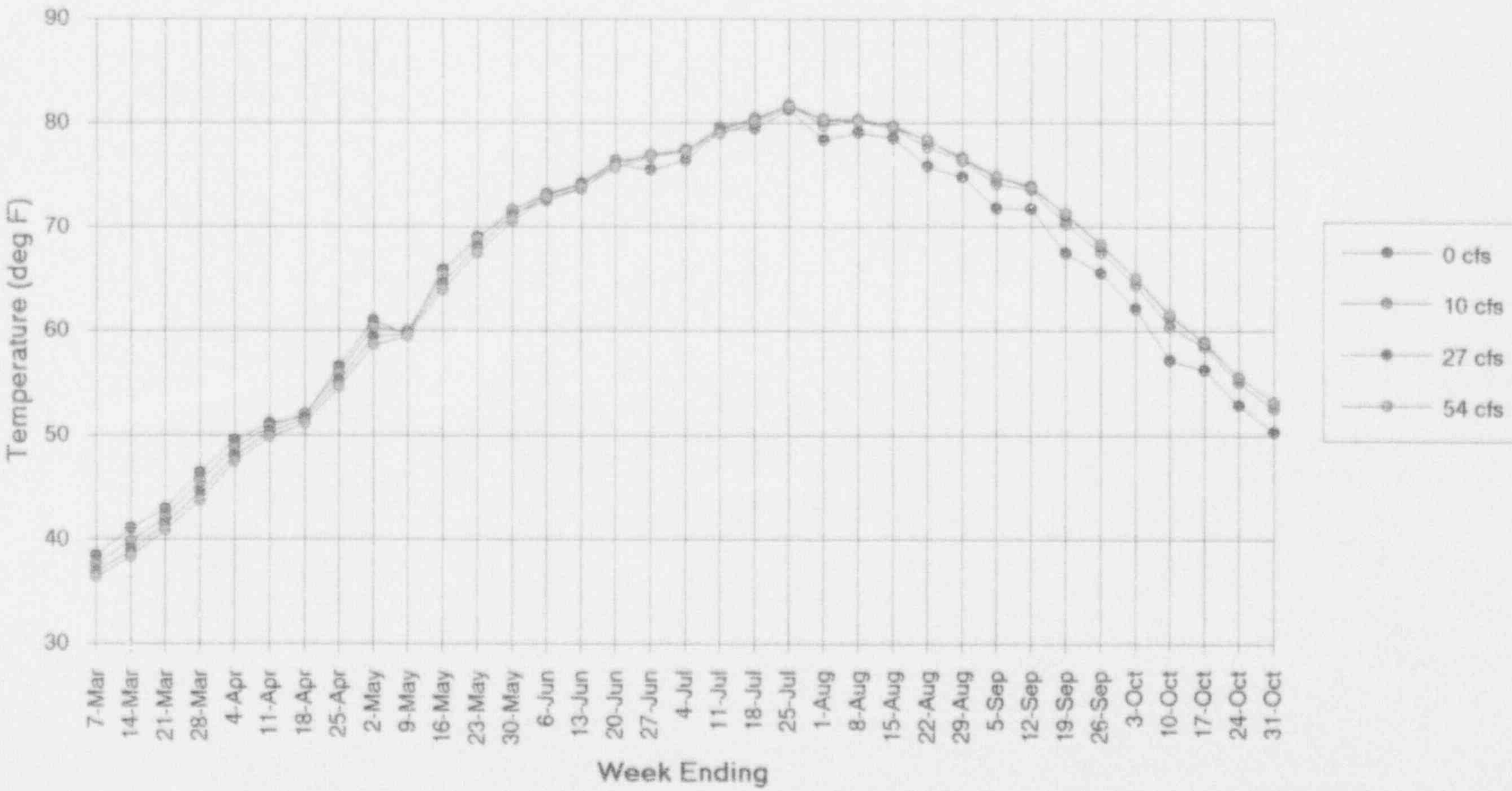
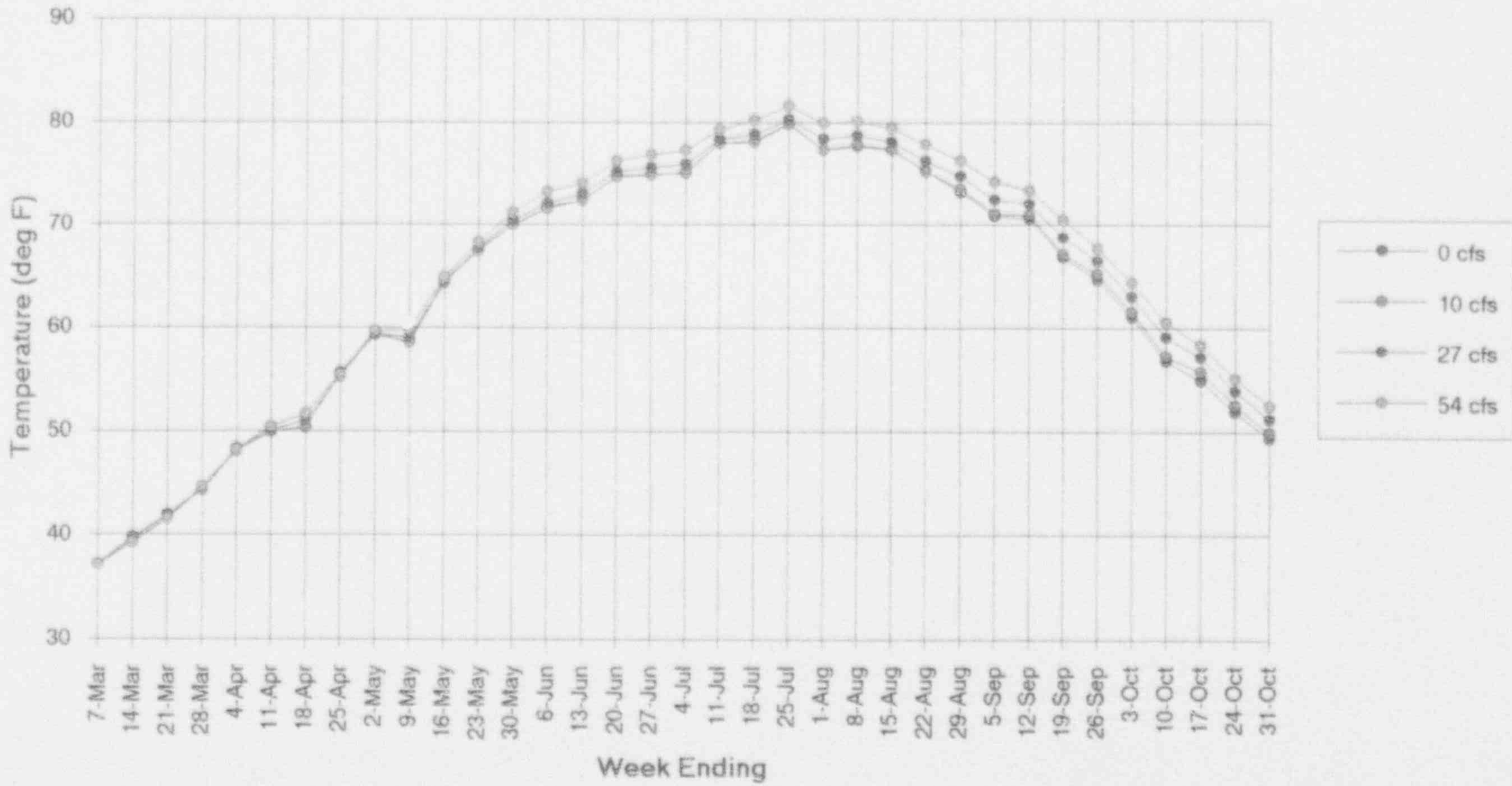


Figure 7.2-39
Segment 19
Comparison Among Weekly Means of Predicted Daily Maximum Temperatures
at Four Diversion Rates
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-40

Segment 02 at 0 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

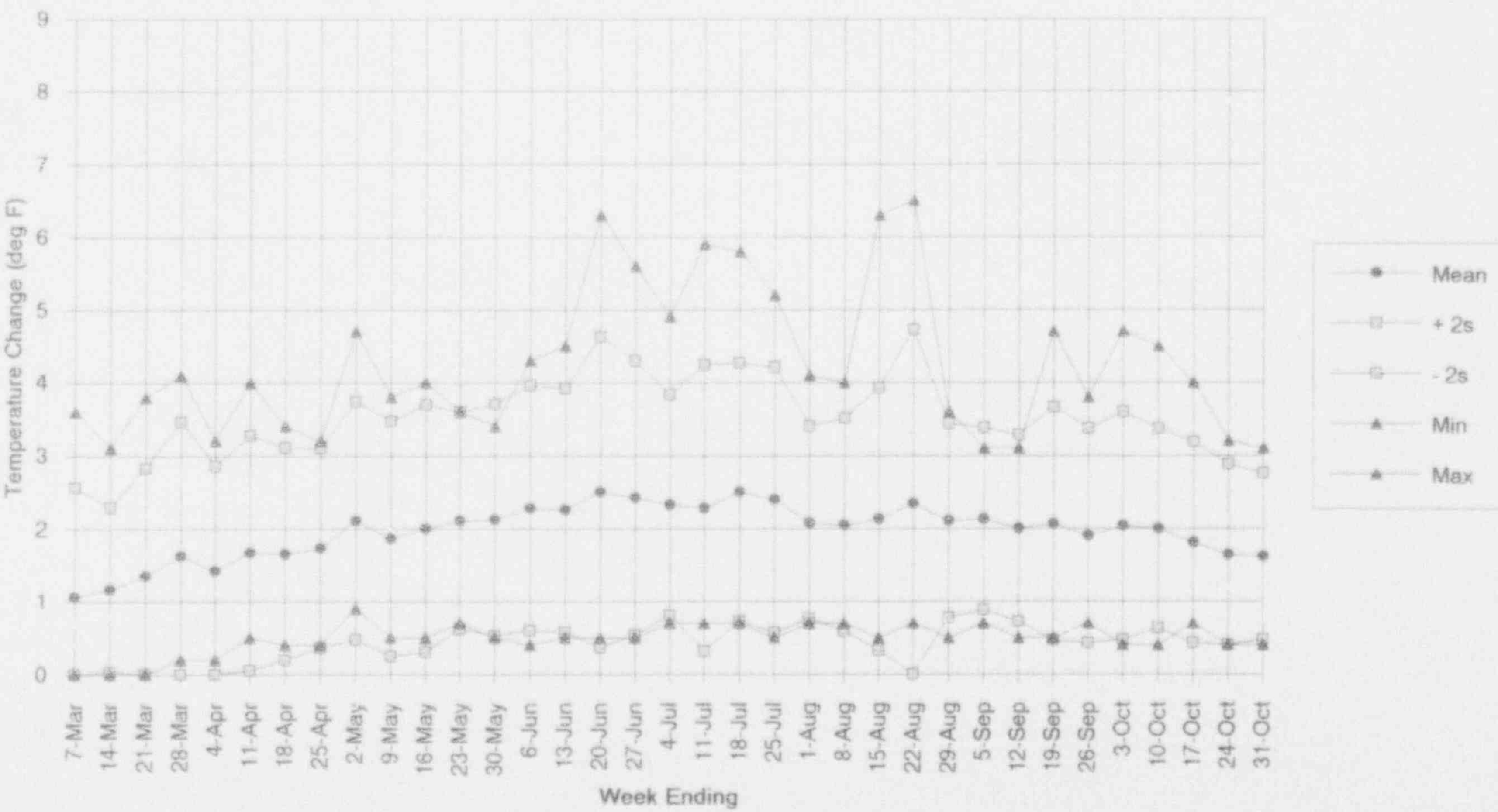


Figure 7.2-41

Segment 02 at 10 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

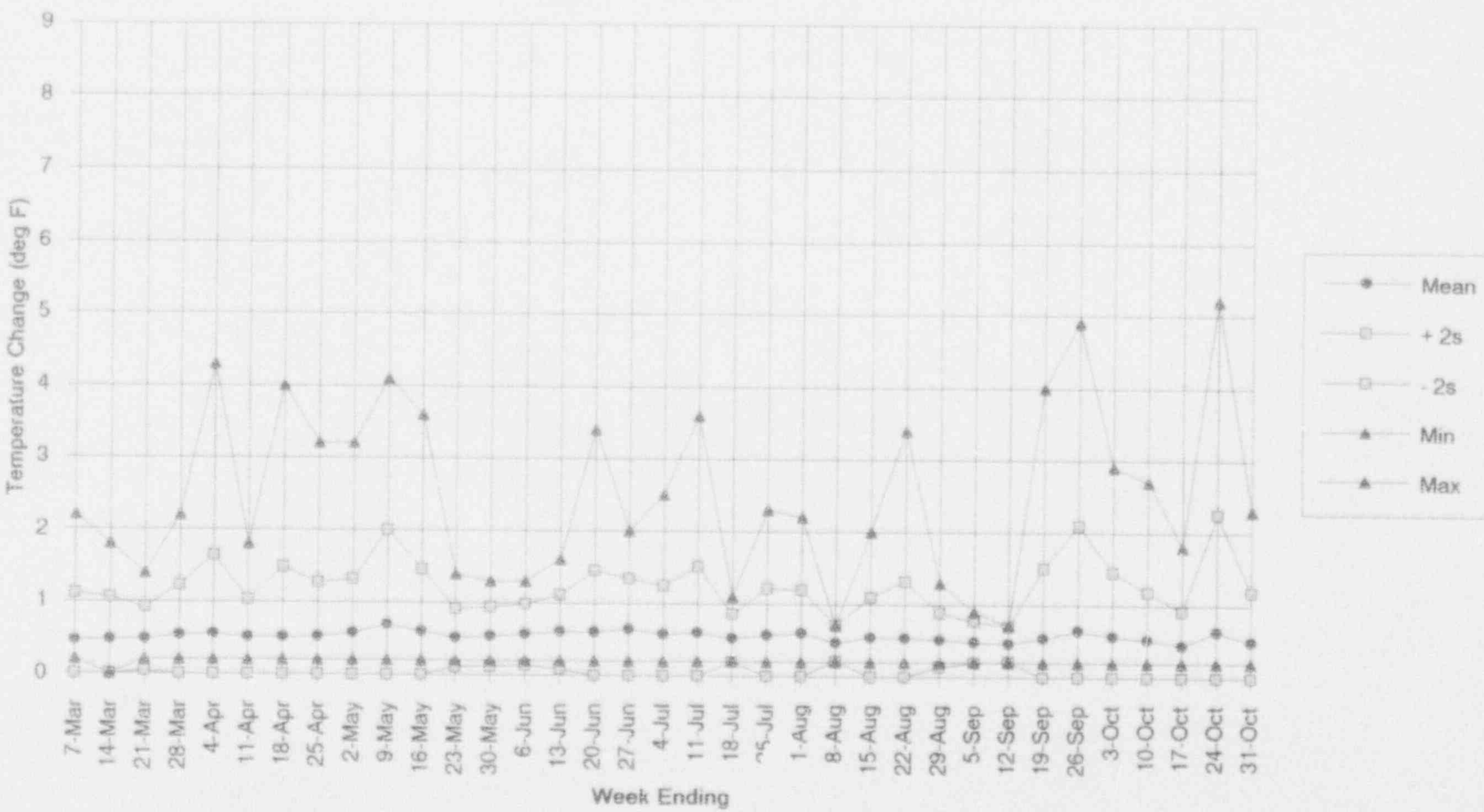
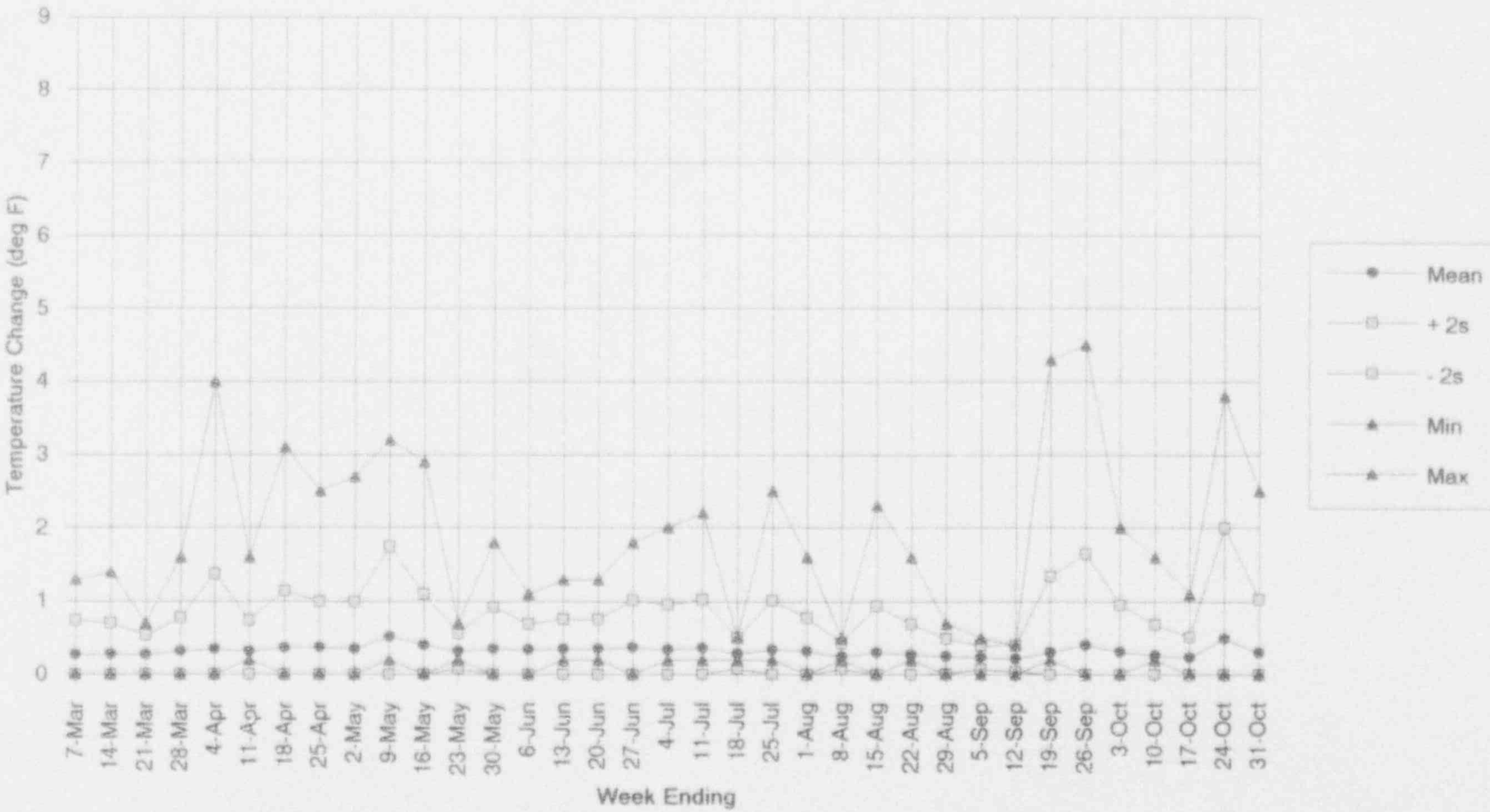


Figure 7.2-42

Segment 02 at 27 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-43

Segment 02 at 54 cfs Diversion Rate

Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change

For the Period Oct 1983 - Sept 1992

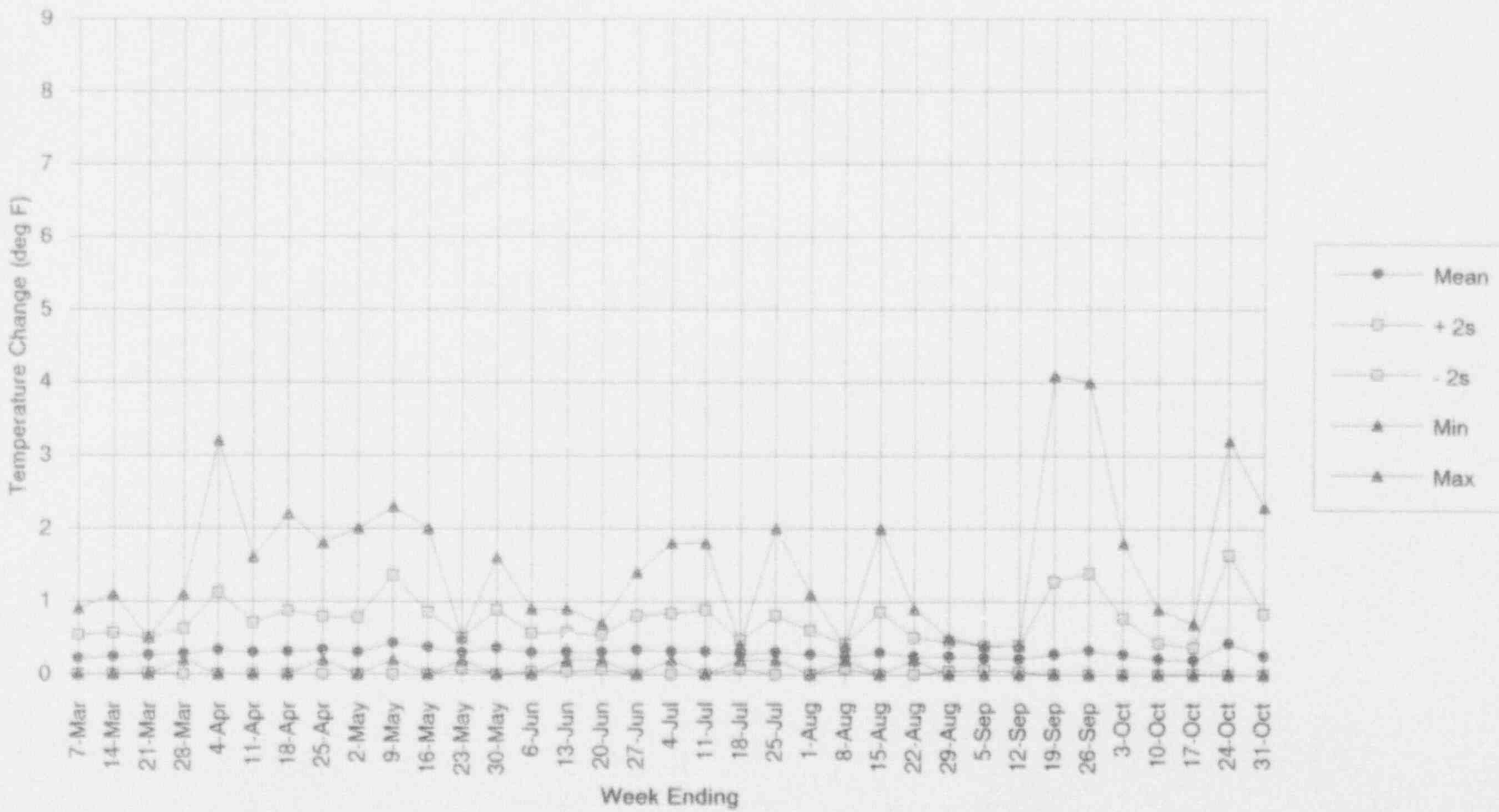
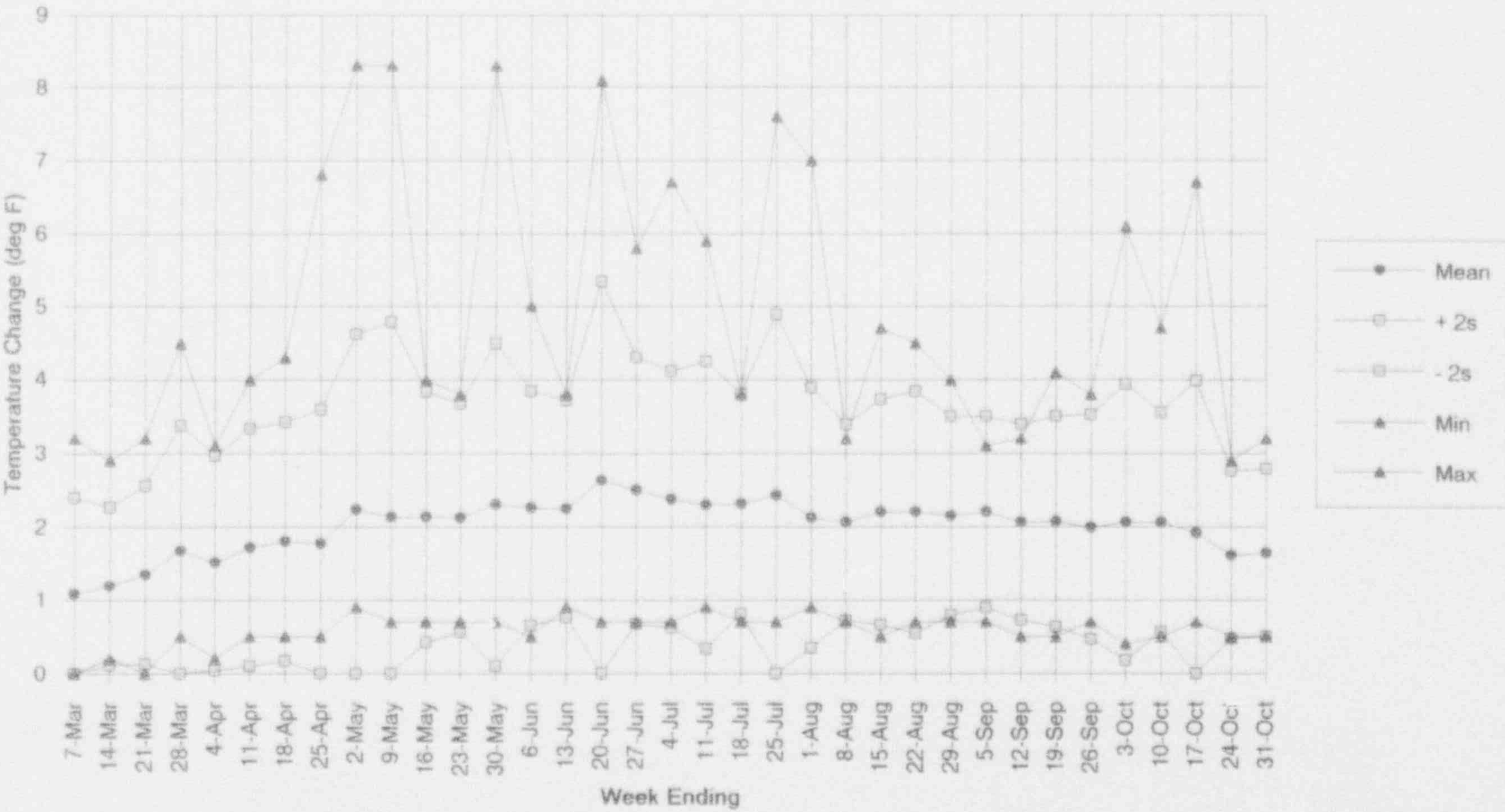


Figure 7.2-44

Segment 10 at 0 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992



East Branch Perkiomen Creek

Figure 7.2-45

Segment 10 at 10 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

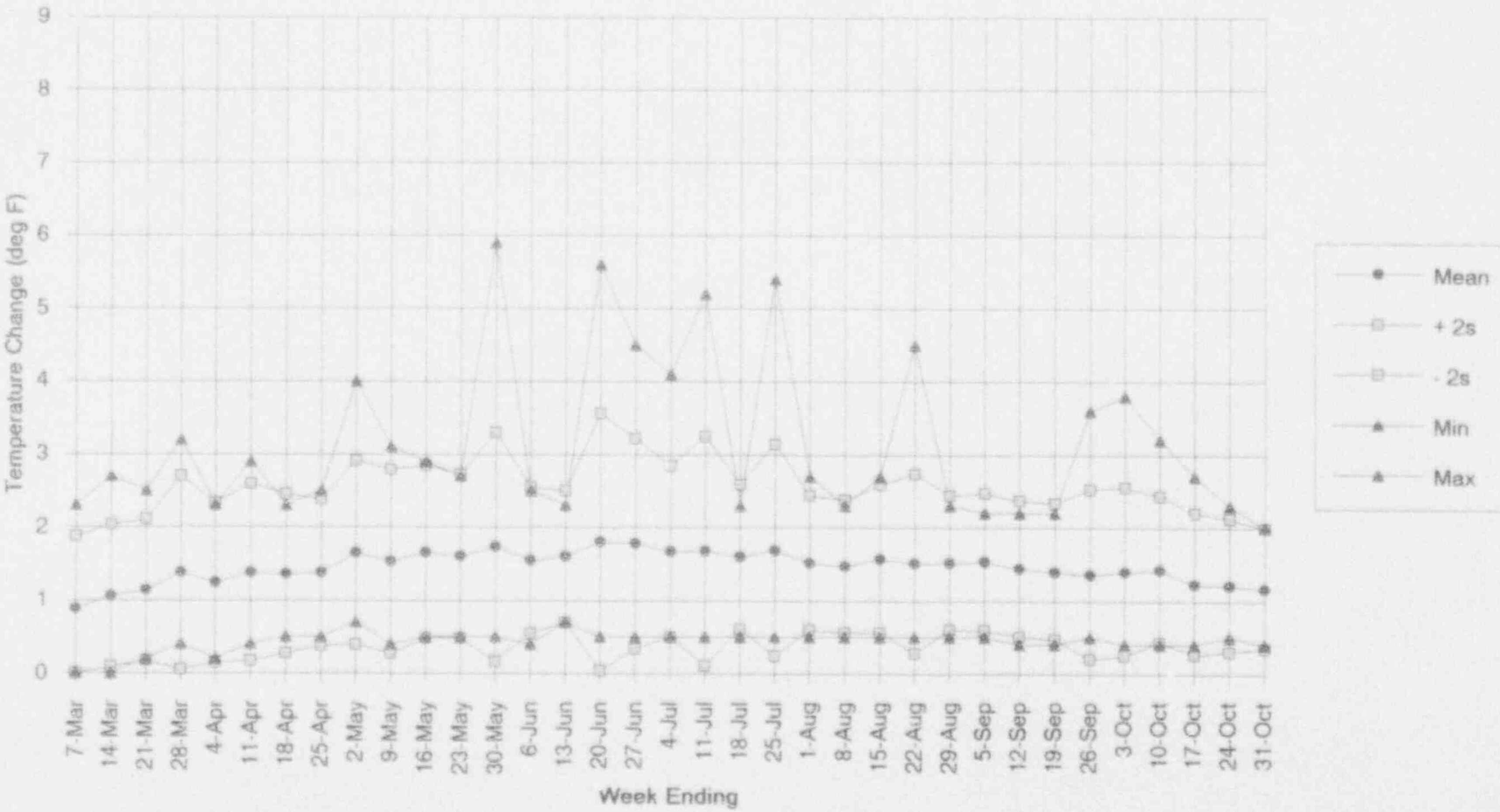


Figure 7.2-46

Segment 10 at 27 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

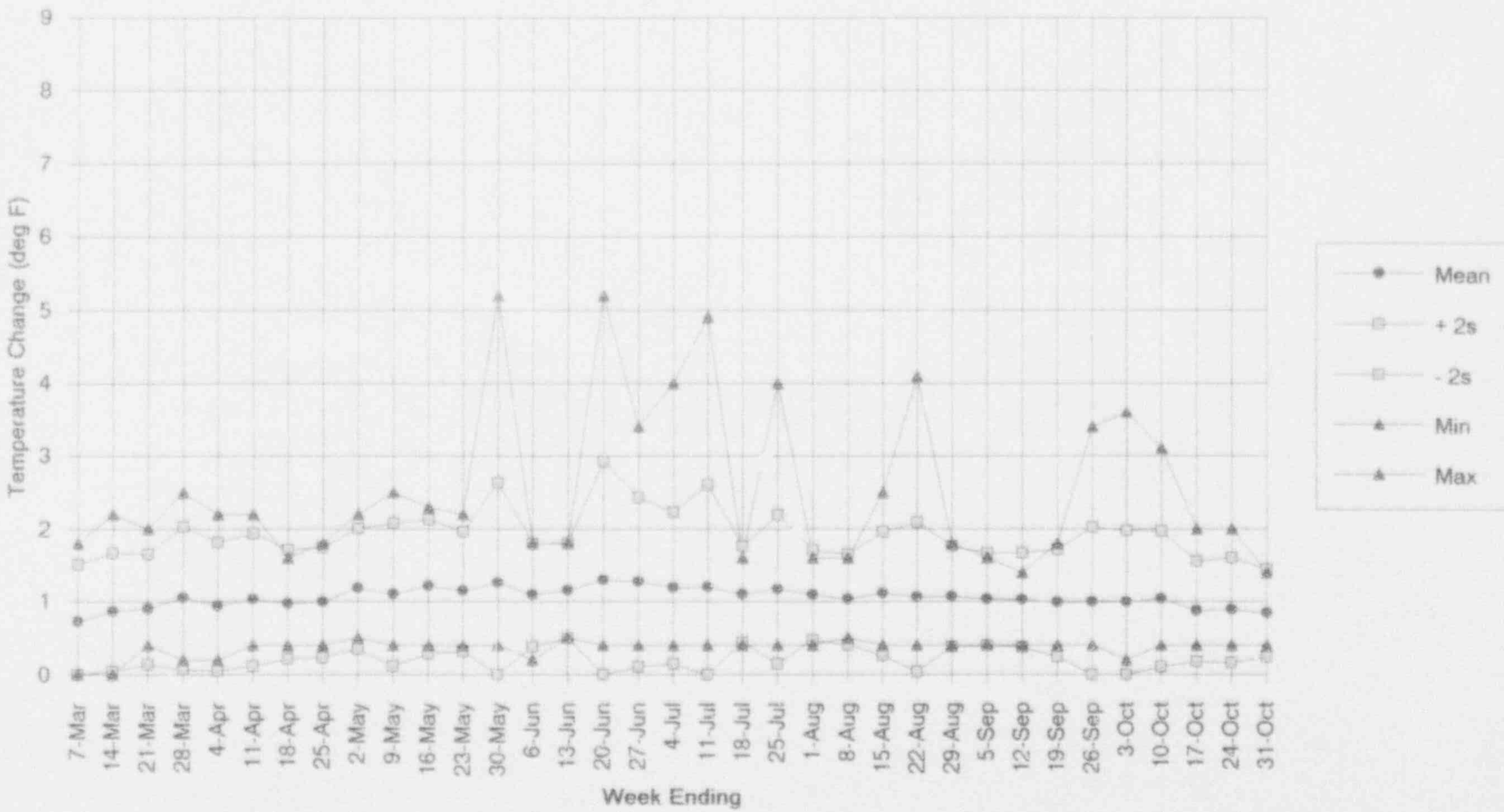


Figure 7.2-47

Segment 10 at 54 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

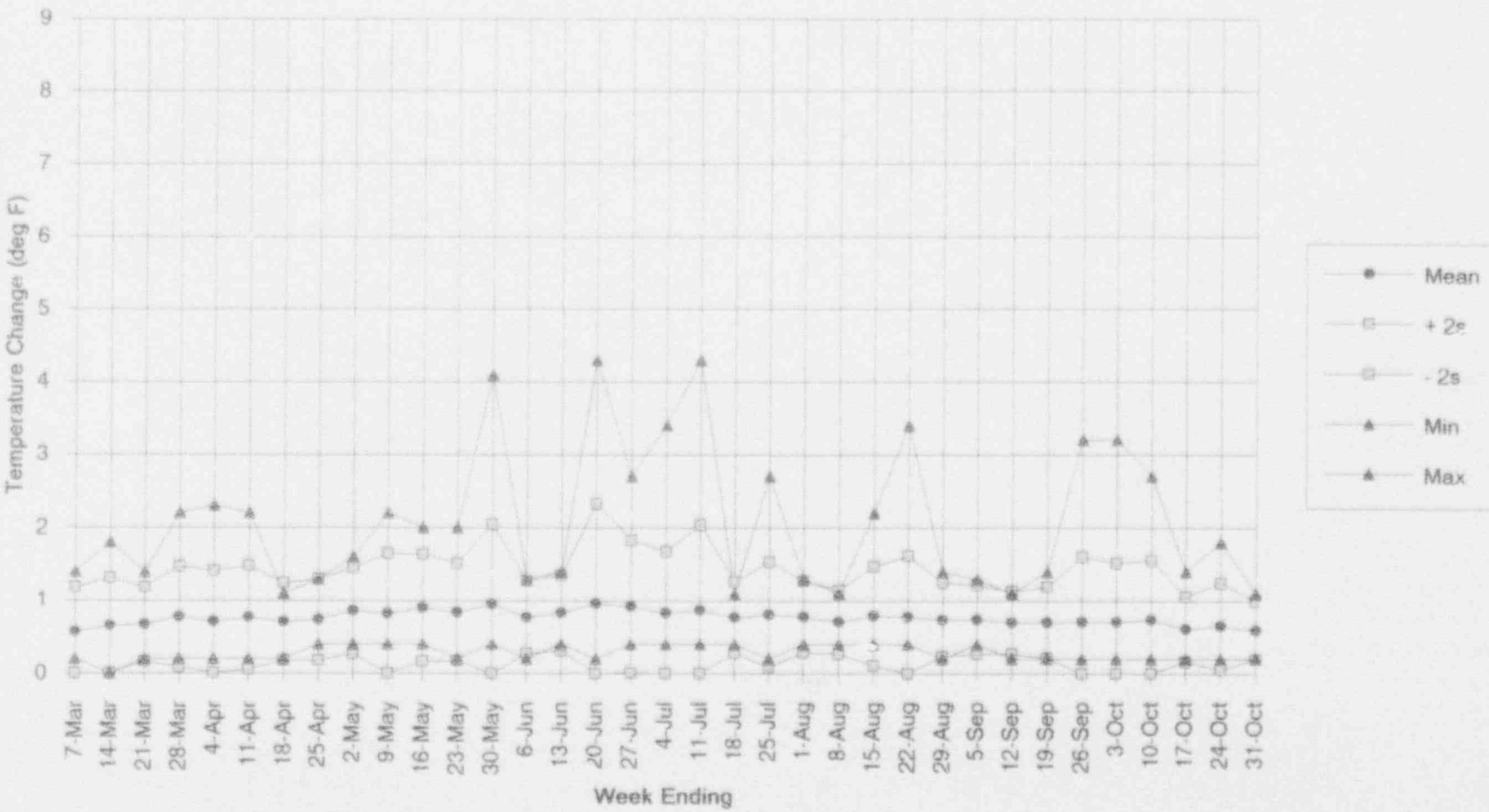


Figure 7.2-48

Segment 19 at 0 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

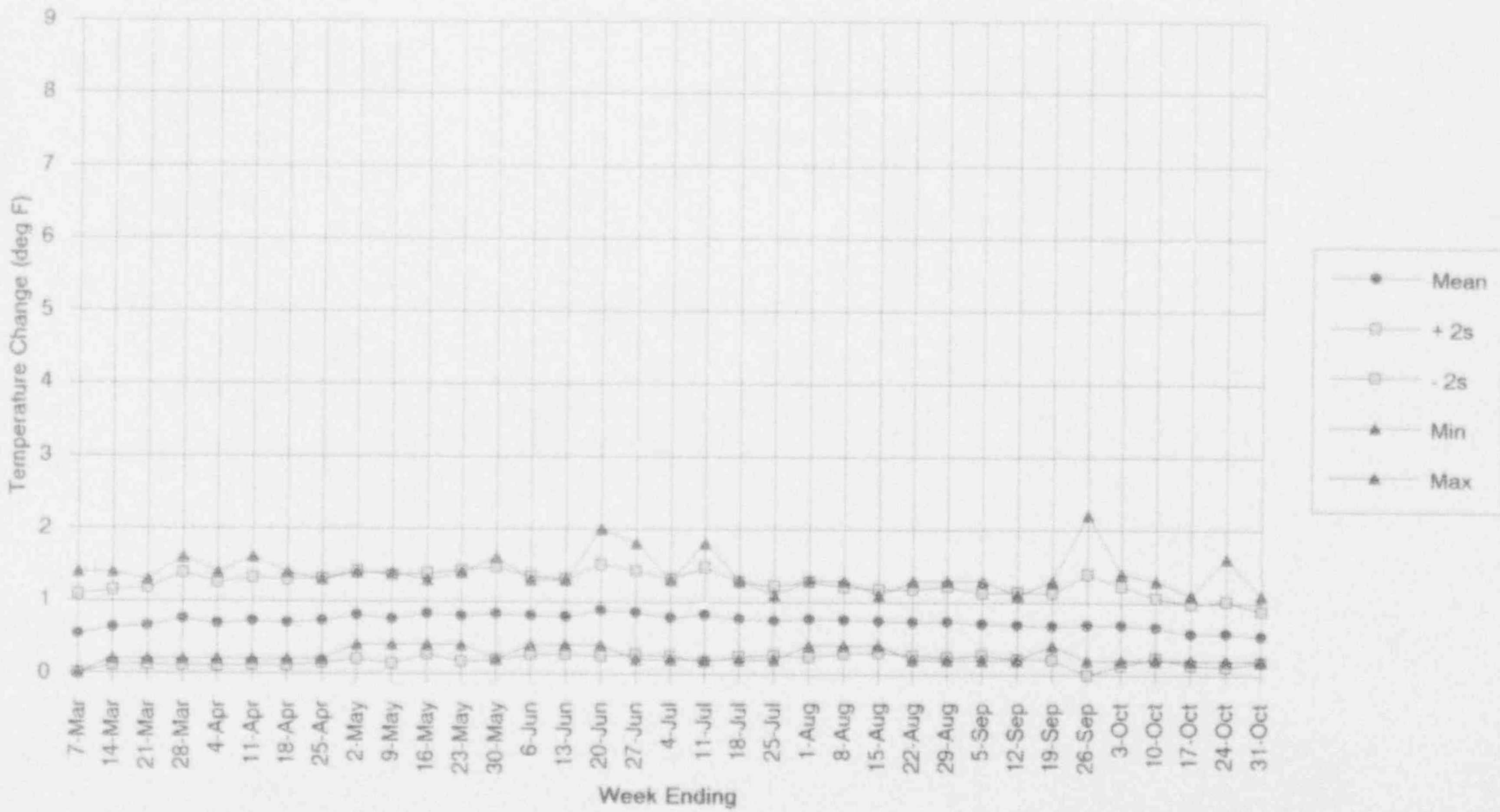


Figure 7.2-49

Segment 19 at 10 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

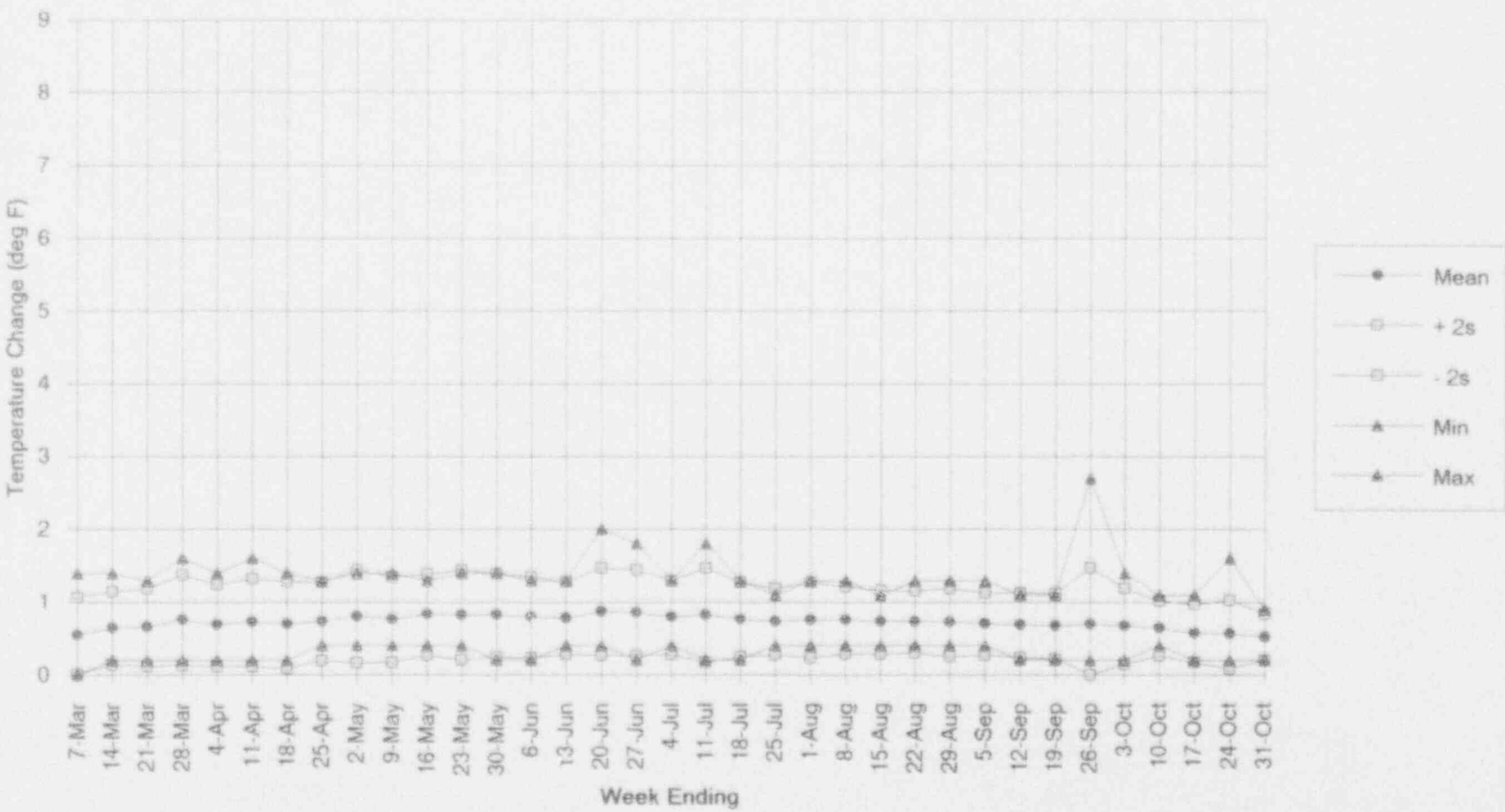


Figure 7.2-50

Segment 19 at 27 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

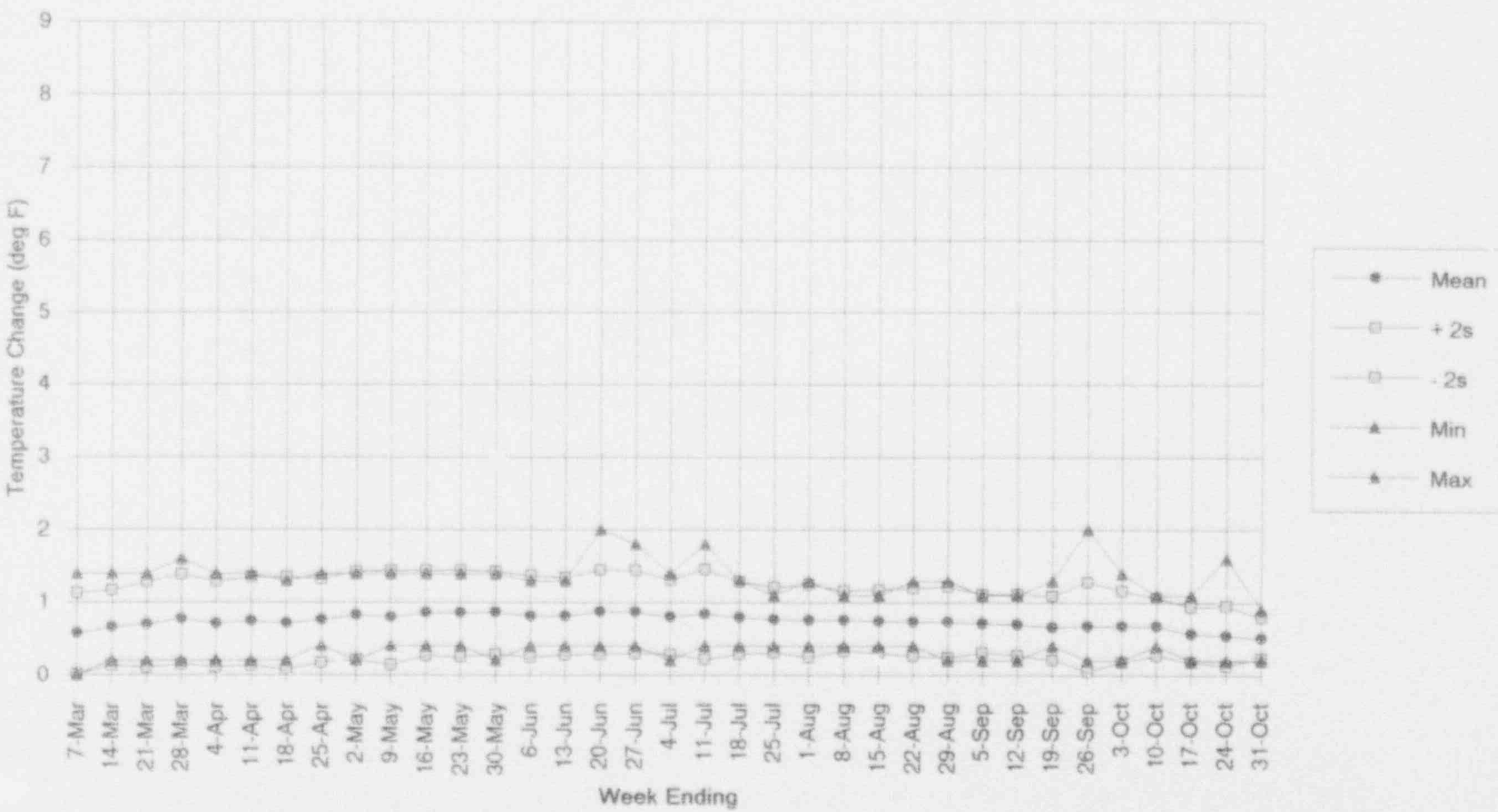


Figure 7.2-51

Segment 19 at 54 cfs Diversion Rate
Weekly Statistics Describing Predicted Maximum Hourly Rate of Temperature Change
For the Period Oct 1983 - Sept 1992

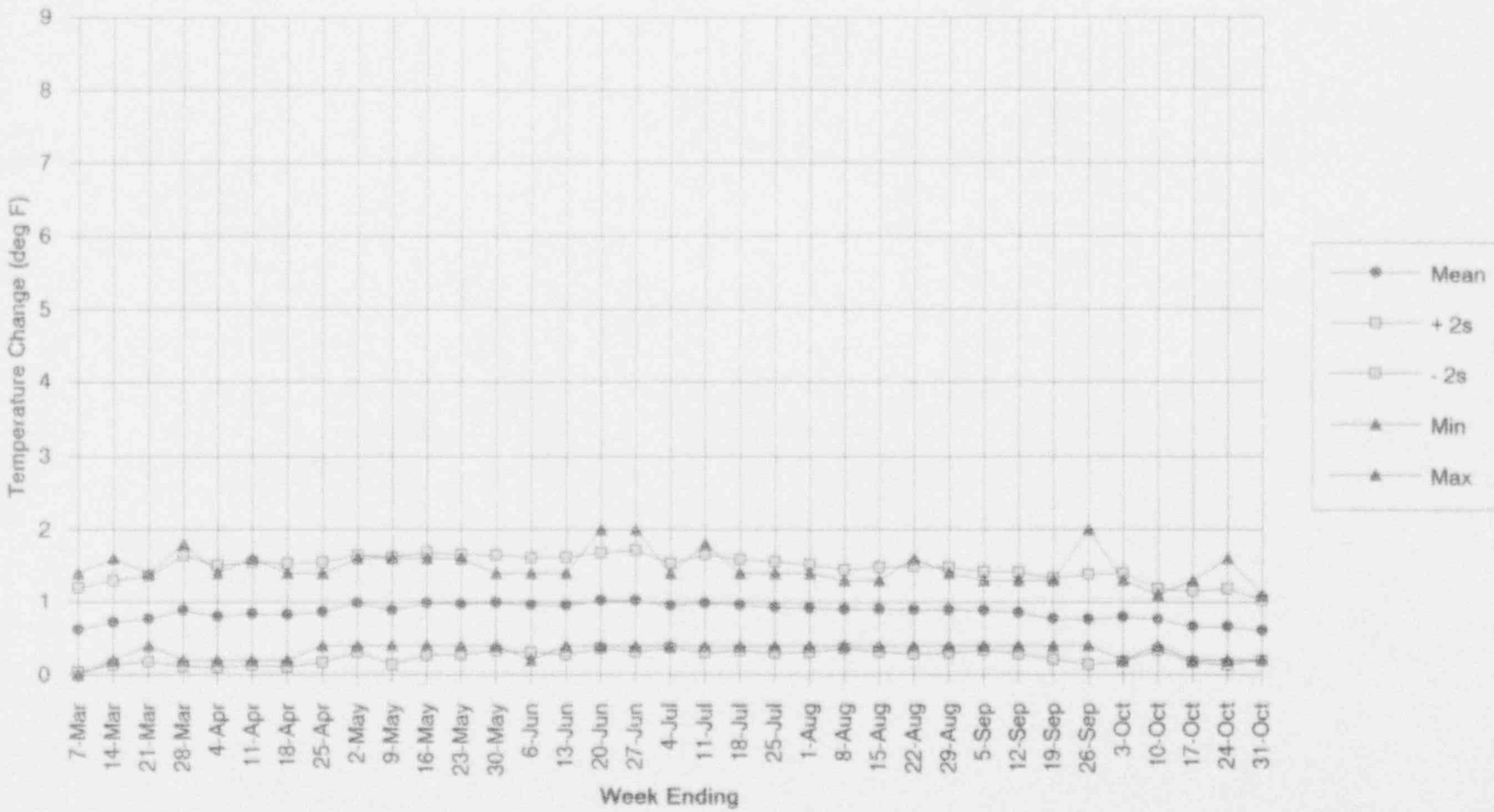


Figure 7.2-52

Segment 02

Comparison Among Weekly Means of Predicted Hourly Maximum Rate of Temperature Change at Four Diversion Rates

For the Period Oct 1983 - Sept 1992

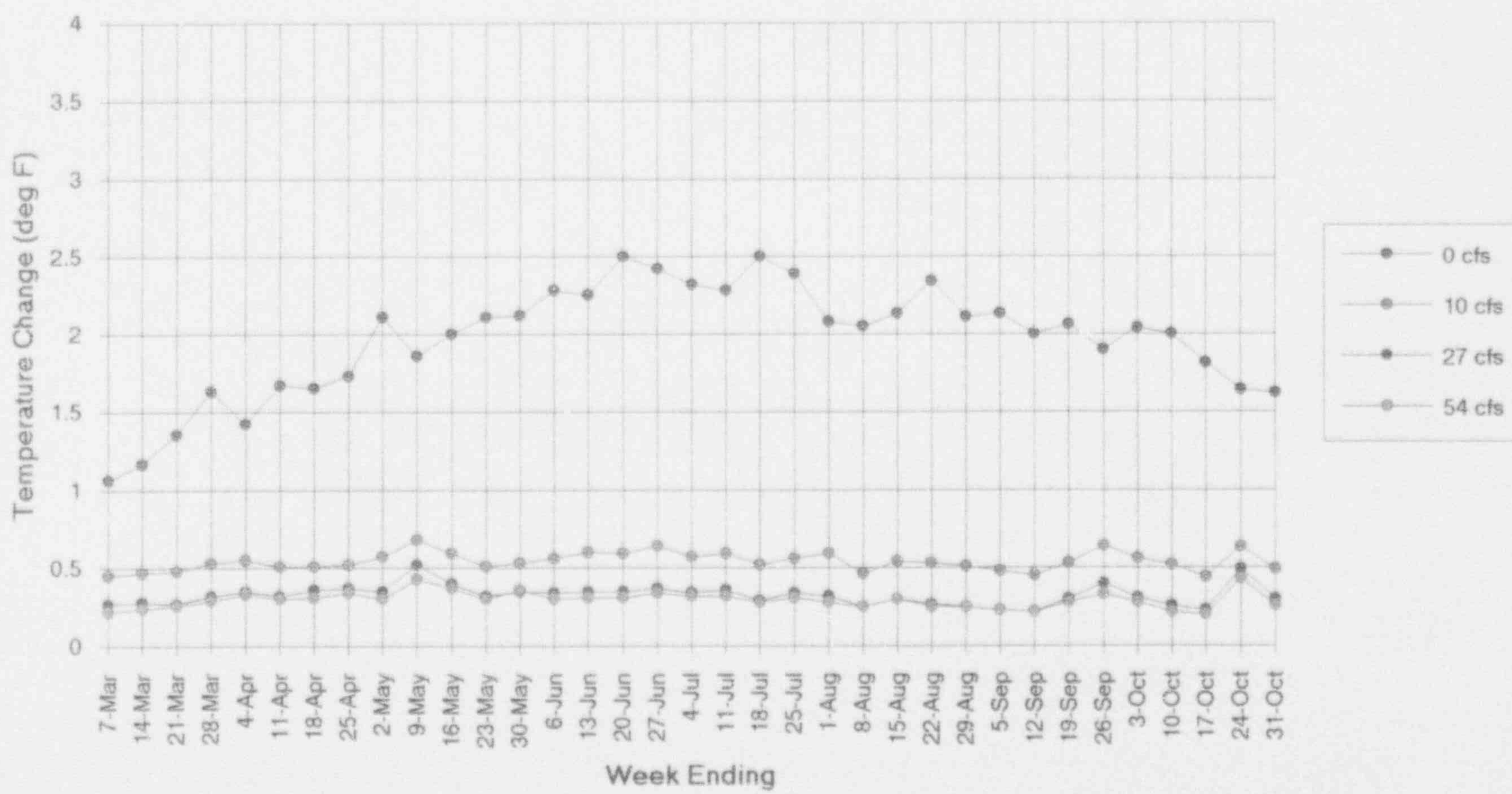


Figure 7.2-53
Segment 10
Comparison Among Weekly Means of Predicted Hourly Maximum Rate of Temperature Change
at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

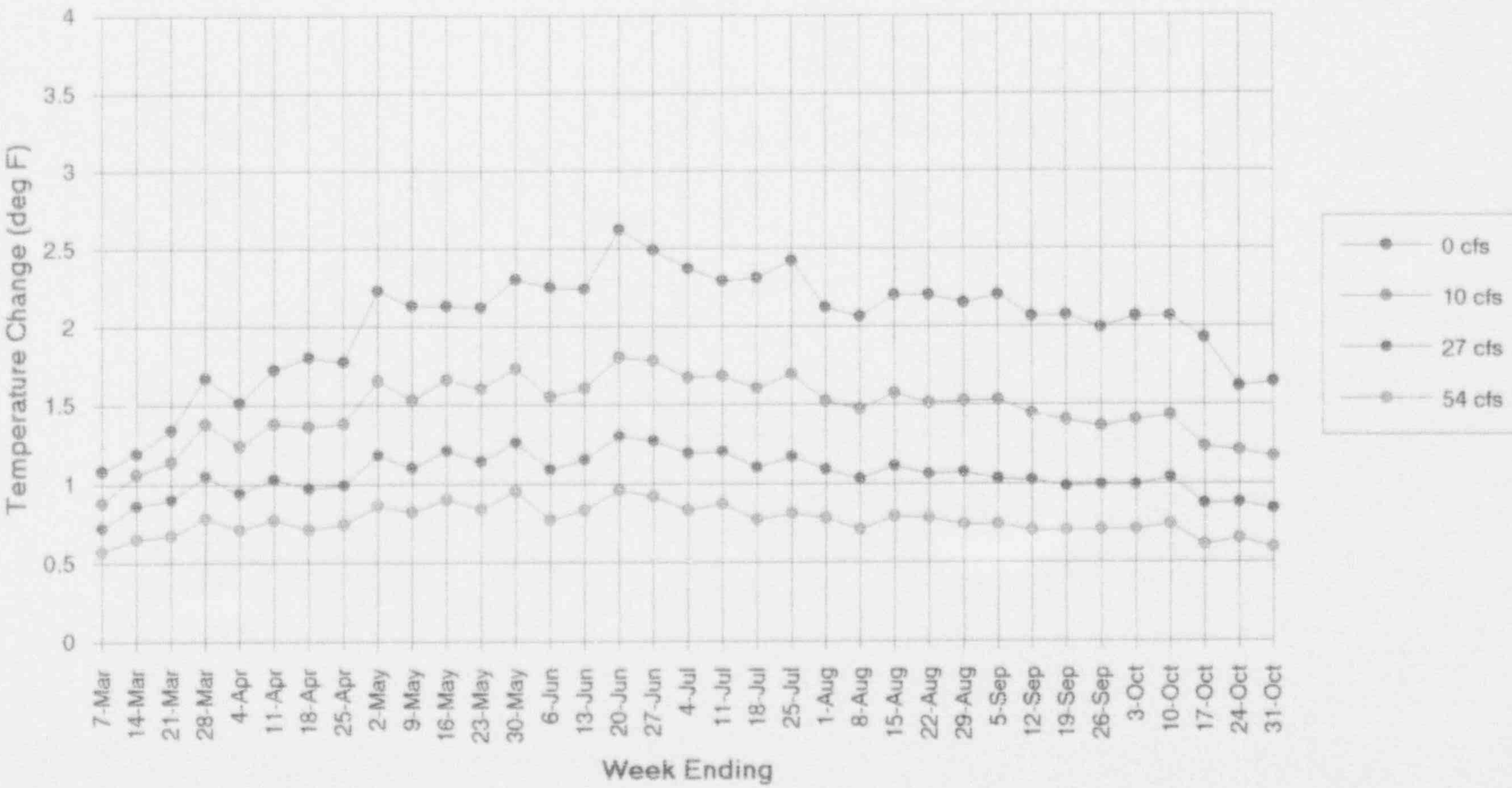


Figure 7.2-54
Segment 19
Comparison Among Weekly Means of Predicted Hourly Maximum Rate of Temperature Change
at Four Diversion Rates
For the Period Oct 1983 - Sept 1992

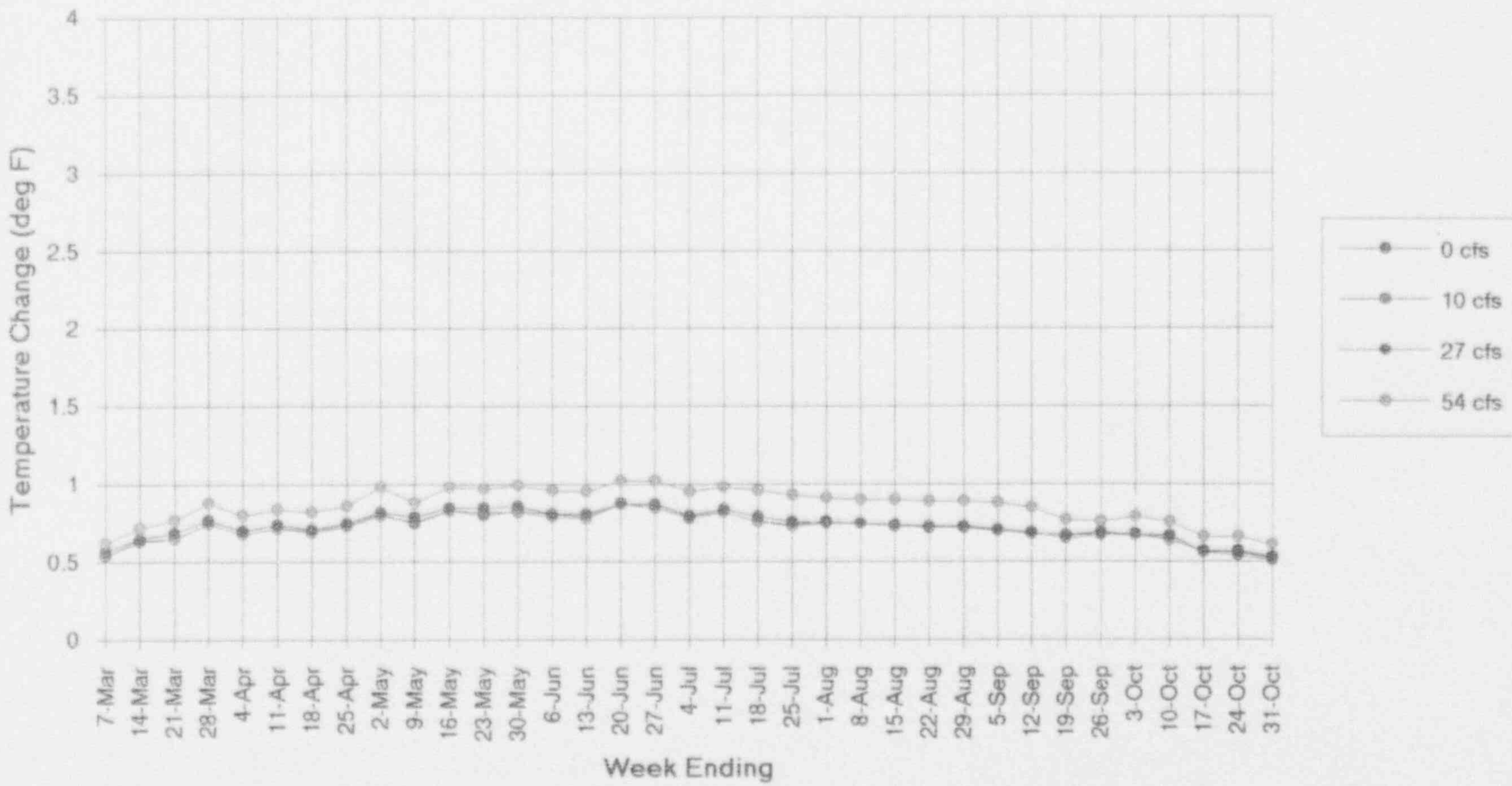
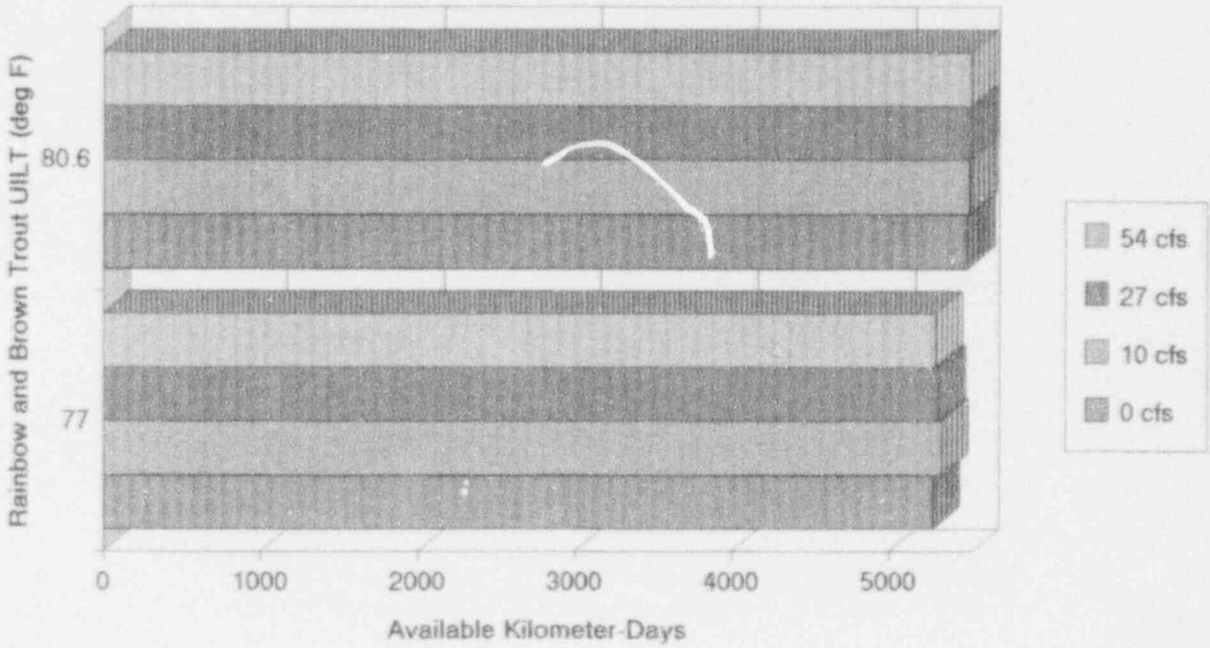


Figure 7.5-1

Area Available to Rainbow and Brown Trout at Four Diversion Rates
Based On Predicted Daily Mean Temperature in Segments 10-20
For the period 15-Mar to 1-Jul; 1984 to 1992
(Total Potentially Available Kilometer-Days = 5,533)



Area Available to Rainbow and Brown Trout at Four Diversion Rates
Based On Predicted Daily Mean Temperature in Segments 10-20
For the period 15-Feb to 1-Aug; 1984 to 1992
(Total Potentially Available Kilometer-Days = 8,580)

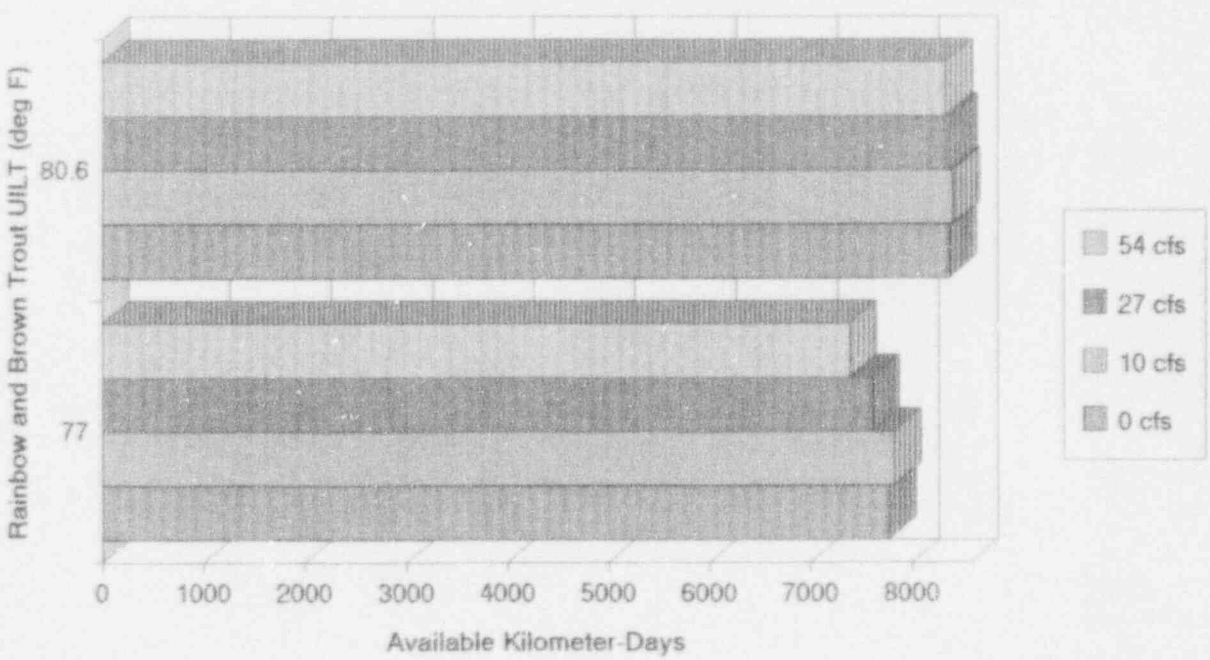
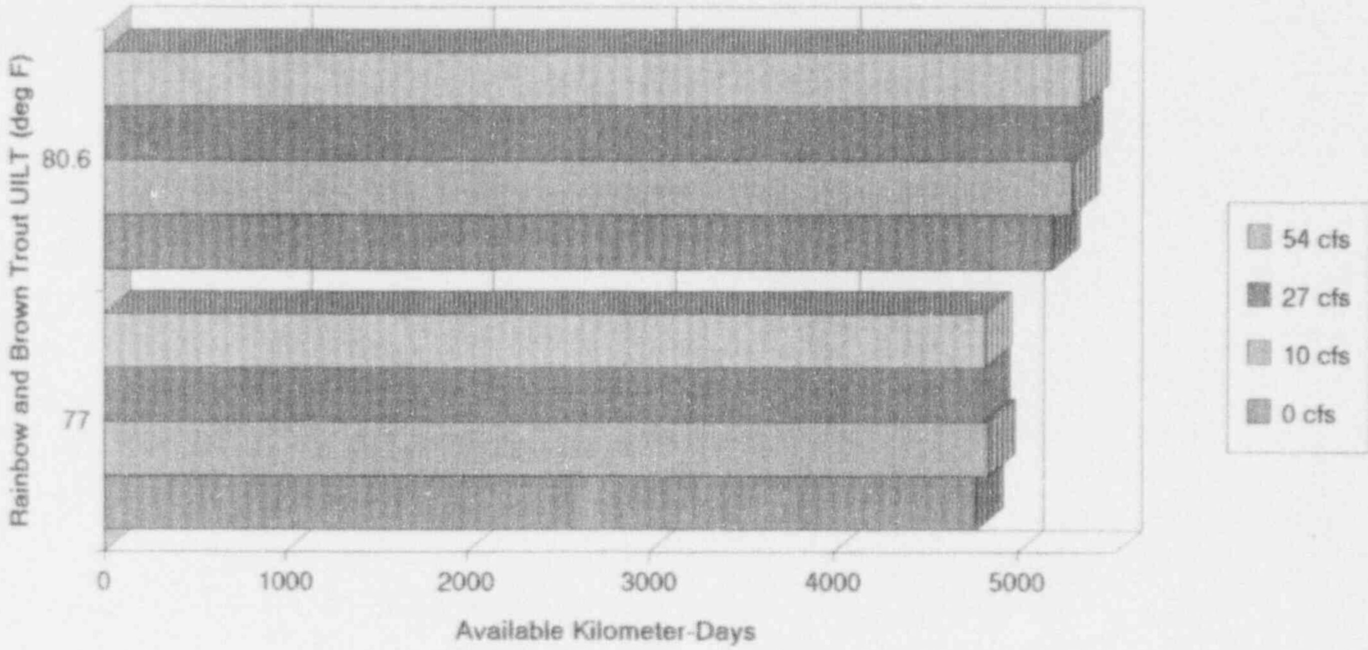
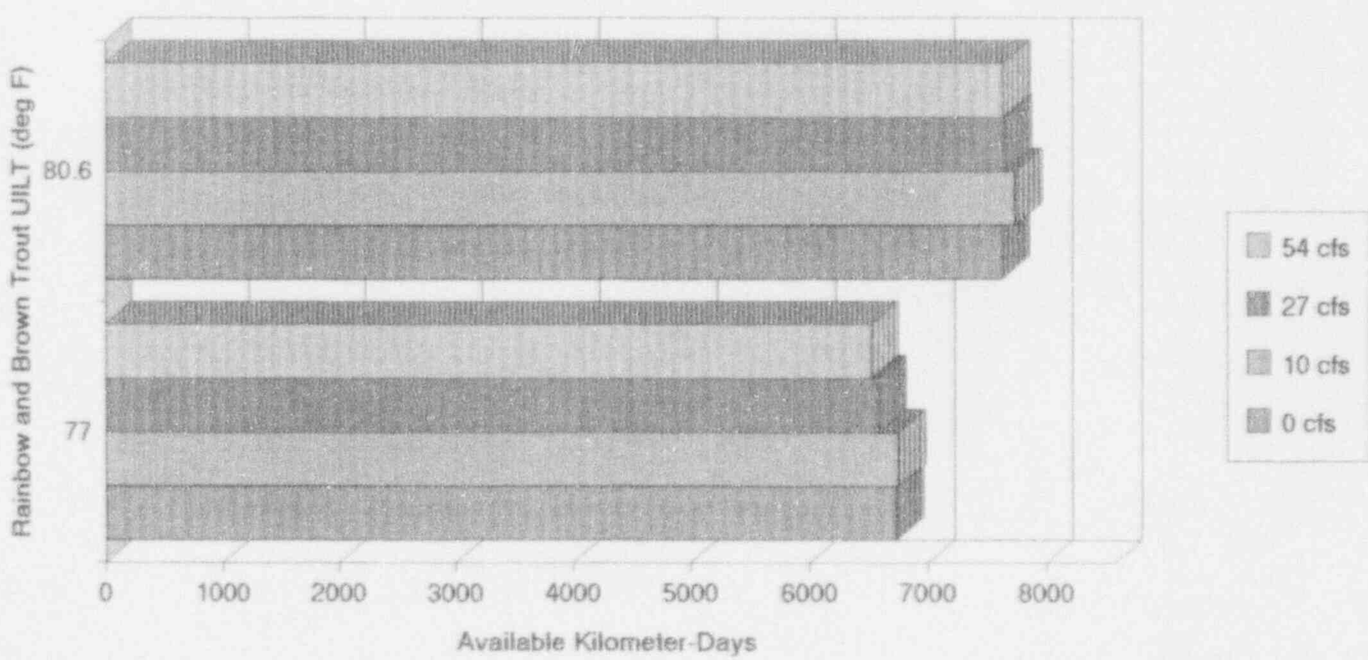


Figure 7.5-2

Area Available to Rainbow and Brown Trout at Four Diversion Rates
Based On Predicted Daily Maximum Temperature in Segments 10-20
For the period 15-Mar to 1-Jul; 1984 to 1992
(Total Potentially Available Kilometer-Days = 5,533)



Area Available to Rainbow and Brown Trout at Four Diversion Rates
Based On Predicted Daily Maximum Temperature in Segments 10-20
For the period 15-Feb to 1-Aug; 1984 to 1992
(Total Potentially Available Kilometer-Days = 8,580)



8.0 EVALUATION OF DECISION CRITERIA

8.1 Representative Important Species (RIS) - Warmwater Fish

8.1.1 Reproductive Success and Growth

This demonstration has conclusively shown that there is virtually no potential for material impairment of successful reproduction and growth of any of the three warmwater fishes identified as RIS. Each of these three fishes maintained successful reproducing populations in the East Branch Perkiomen Creek during the pre-diversion period and continued to do so in the flow augmented period. Furthermore, the existence of reproducing population of these fishes in the Delaware River is proof that the Delaware River thermal regime, as well as other habitat variables, are suitable for long term survival of warmwater RIS.

Examination of the temperature modelling results shows that prime spawning and growth periods will not be curtailed to any meaningful extent due to the altered thermal conditions inherent in Study Case II. Thermal conditions will be less stressful due to moderation of extreme diurnal and weekly temperature excursions. Temperatures at the upper range of tolerance for life stages of these fishes are not approached without diversion operation (Study Case I) and will not be of concern during diversion pumpage (Study Case II). There is no thermal enhancement of the receiving stream such that Upper Incipient Lethal Temperatures are experienced.

8.2 Representative Important Species (RIS) - Trout

8.2.1 Preclusion of Trout Stocked Fishery

None of the temperature changes predicted due to operation of the diversion will curtail the continued success of the spring trout stocked fishery for rainbow and brown trout. Thermal conditions, as reflected by stream temperatures which meet or exceed 74 F, with and without diversion, are so similar that during diversion operation trout can continue to be stocked in the same locations and at the same times as in the pre-diversion period. The stream habitat will be somewhat enhanced for the trout stocked fishery with the diversion in operation due to beneficial effects of increased stream flow.

8.2.2 Exclusion from Unacceptably Large Area

None of the diversion flow and predicted temperature conditions will exclude trout from significant portions of the TSF area during the period when trout are stocked and have a high probability of actually being in the stream in sufficient numbers to sustain a successful fishery. Some potential theoretical exclusion, in addition to that attributable to natural, non-flow-enhanced conditions, is predicted. However, the time of occurrence is substantially after the prime fishing period and the minimal areas involved support the conclusion that trout are not excluded from unacceptably large areas such that the successful TSF would be threatened.

8.2.3 Survival and Harvest

The survival of stocked trout in the stocked fishing area will not be materially affected by the thermal changes experienced at any of the diversion flows. The Study Case II thermal regime will, on average, delay the onset of temperatures lethal to rainbow trout. Theoretically, rainbow trout survival in the stream would be enhanced by the delay. However, the timing of trout stocking and very high harvest rates imply few trout would remain in the stream by these dates anyway. Similarly, days gained or lost for brown trout survival occur well after substantially all trout have been harvested from the stream. Furthermore, observations of trout harvest in years of actual diversion operation (1990-1992) have shown that virtually all trout had been harvested by anglers prior to or coincident with initiation of chiller operation.

8.3 Summary

In summary, this demonstration has shown that there will be substantially similar reproductive success and growth of the warmwater RIS for Study Case II (diversion without cooling) as was observed in Study Case I (no diversion). The demonstration has proven that the trout stocked fishery will be equally feasible under both Study Cases and that the length of stream with a thermal regime acceptable for stocked trout survival and harvest under Study Case II is not materially smaller than the area of acceptable habitat under the Study Case I thermal regime. It has also shown that the timing and duration of the trout stocked fishery is essentially the same under both Study Cases and that similar numbers of trout will be available for harvest under both Study Cases, assuming the PFBC stocks similar numbers of trout. Therefore, since all of the decision criteria agreed to in the Study Plan have been met successfully, elimination of all thermal limits on the discharge of diversion water to the East Branch is warranted.

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PENNSYLVANIA DER

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
Post Office Box 2063
Harrisburg, Pennsylvania 17105
January 26, 1993

Bureau of Water Quality Management (717) 787-9633

G. J. BECK
LICENSING SECTION

JAN 2 7 19[illegible]

NOTED: ______
REFERRED TO: GMK

Mr. G. J. Beck
Philadelphia Electric Company
Nuclear Group Headquarters
Licensing Section
955-65 Chesterbrook Blvd.
Wayne, PA. 19087-5691

DER File No. 18-10

Dear Mr. Beck:

This is to confirm that Philadelphia Electric Company's proposed study plan outline in support of an alternate thermal effluent limitation for the Point Pleasant water diversion to the East Branch of Perkiomen Creek, as amended based on comments developed by the Pennsylvania Fish Commission and our agency, and submitted by you on October 5, 1992 is acceptable.

Sincerely,

James T. Ulanoski

James T. Ulanoski, Chief
Ground Water Quality Section
Division of Assessment and Standards

COPY

PHILADELPHIA ELECTRIC COMPANY

NUCLEAR GROUP HEADQUARTERS

955-65 CHESTERBROOK BLVD.

WAYNE, PA 19087-5691

(215) 640-6000

October 5, 1992

NUCLEAR SERVICES DEPARTMENT

Mr. James T. Ulanoski
PA Department of Environmental Resources
Bureau of Water Quality Management
11th Floor, Fulton Building
Third and Locust Streets
P. O. Box 2063
Harrisburg, PA

Subject: Philadelphia Electric Company
Proposed Study Plan in Support of Thermal Variance
Request for the Point Pleasant Diversion Project

Reference: National Pollutant Discharge Elimination System
(NPDES) Permit No. PA-0052221

Dear Mr. Ulanoski:

Enclosed please find the amended Study Plan for Thermal Variance Request in Regards to the Point Pleasant Diversion NPDES Permit PA-0052221. The amended study plan incorporates your comments sent to me in a letter dated August 28, 1992.

With respect to your letter of August 31, 1992, concerning the Pennsylvania Fish and Boat Commission comment regarding Pleasant Spring Creek, please be informed that the Walnut Street monitoring instrumentation is attached to the Walnut Street Bridge. As such, the instrumentation is upstream of any influence of Pleasant Spring Creek.

If you have any questions or need additional information, please contact Mr. Robert J. Scholz at (215) 640-6853.

Very truly yours,

G. J. Beck
Licensing Section

Enclosure

cc: Martha E. Blasberg, Esquire, PA DER (w/enclosure)
John A. Arway, PA Fish and Boat Commission (w/enclosure)
Jeffrey S. Saltz, Esquire, PECo (w/enclosure)

bcc:	G. R. Rainey - 63C-1	w/o enclosure
	R. N. Charles - 51A-1	"
	R. J. Scholz - 51A-3	"
	J. W. Ballantine - 51A-3	"
	R. M. Krich - 52A-5	w/ enclosure
	R. W. Blye, RMC Environmental Services	"
	Correspondence Control Desk - 61B-3	"
	DAC	"

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ENCLOSURE

Amended
11 September 1992

Study Plan for Thermal Variance Request in
Regards to the Point Pleasant Diversion
NPDES Permit PA-0052221

I. Introduction/Overview

A. Description of Point Pleasant Diversion Project

B. Permit History - Permit Temperature Limits

C. Alternate Temperature Limit Requested

D. Data Availability (see Table 1)

E. Data Limitations - Modeling Study

1. Length of Continuous Temperature Record

2. Length of Continuous Meteorologic Record

F. Demonstration Type

1. Combination Type I and Type II (as per Meeting with PA DER and PA Fish and Boat Commission, Conshohocken on 15 April 1992).

a. Type I - Absence of Prior Appreciable Harm - Appreciable Harm defined as:

i. Substantial increase in abundance or distribution of any nuisance species.
ii. Substantial decrease of formerly indigenous species, other than nuisance species.
iii. Changes in community structure to resemble a simpler successional stage.
iv. Unaesthetic appearance or odor.
v. Elimination of an established or potential economic or recreational use.
vi. Reduction of the successful completion of life cycles of indigenous species.
vii. Substantial reduction of community heterogeneity.

b. Type II - Representative Important Species (RIS) are defined as:

i. Commercially or recreationally valuable.
ii. Threatened or Endangered.
iii. Critical to the structure and function of the ecologic system.
iv. Potentially capable of becoming localized nuisance species.
v. Necessary for the well being of species determined in *i.* through *iv.*
vi. Representative of the thermal requirements of important species.

Table 1. Ecological and water quality studies conducted in relation to Limerick Generating Station by RMC Environmental Services, Inc.

Program	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Delaware River													
Water Quality	X	X	X	X	X	X	X	X	X	X	X	X	X
East Branch													
Perkiomen Creek													
Water Quality				X	X	X	X	X	X	X	X	X	X
Benthic Macroinvertebrates				X	X	X	X	X	X	X	X	X	X
Seine		X	X	X	X	X	X	X	X	X	X	X	X
Electrofishing		X	X	X	X	X	X	X	X	X	X	X	X
Age and Growth		X		X	X	X	X		X	X	X	X	X
Creel Survey	X	X		X		X	X	X	X	X	X	X	X
Bucks Road Gage					X	X	X	X	X	X	X	X	X

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RMC ENVIRONMENTAL SERVICES

G. Major References

1. Thermal Discharges. 39 FR 36176. 8 October 1974.

2. Draft 316a Guidance Manual. 11 December 1975.

II. Scope of Work

A. Conditions to be Evaluated

1. Study Case I = No Diversion, No Chilling

2. Study Case II = Diversion without chilling

B. Data to be Obtained and Evaluated

1. Ongoing - Historical vs New Data Needs

a. Continuation of existing water quality, fish, and benthos studies

b. 1992 Temperature Monitoring Program

c. Meteorologic Station Data

2. Meteorologic Station at East Branch Transmission Main Discharge and Pennridge STP (see Figure 1)

a. Precipitation Record

b. Wind Speed

c. Wind Direction

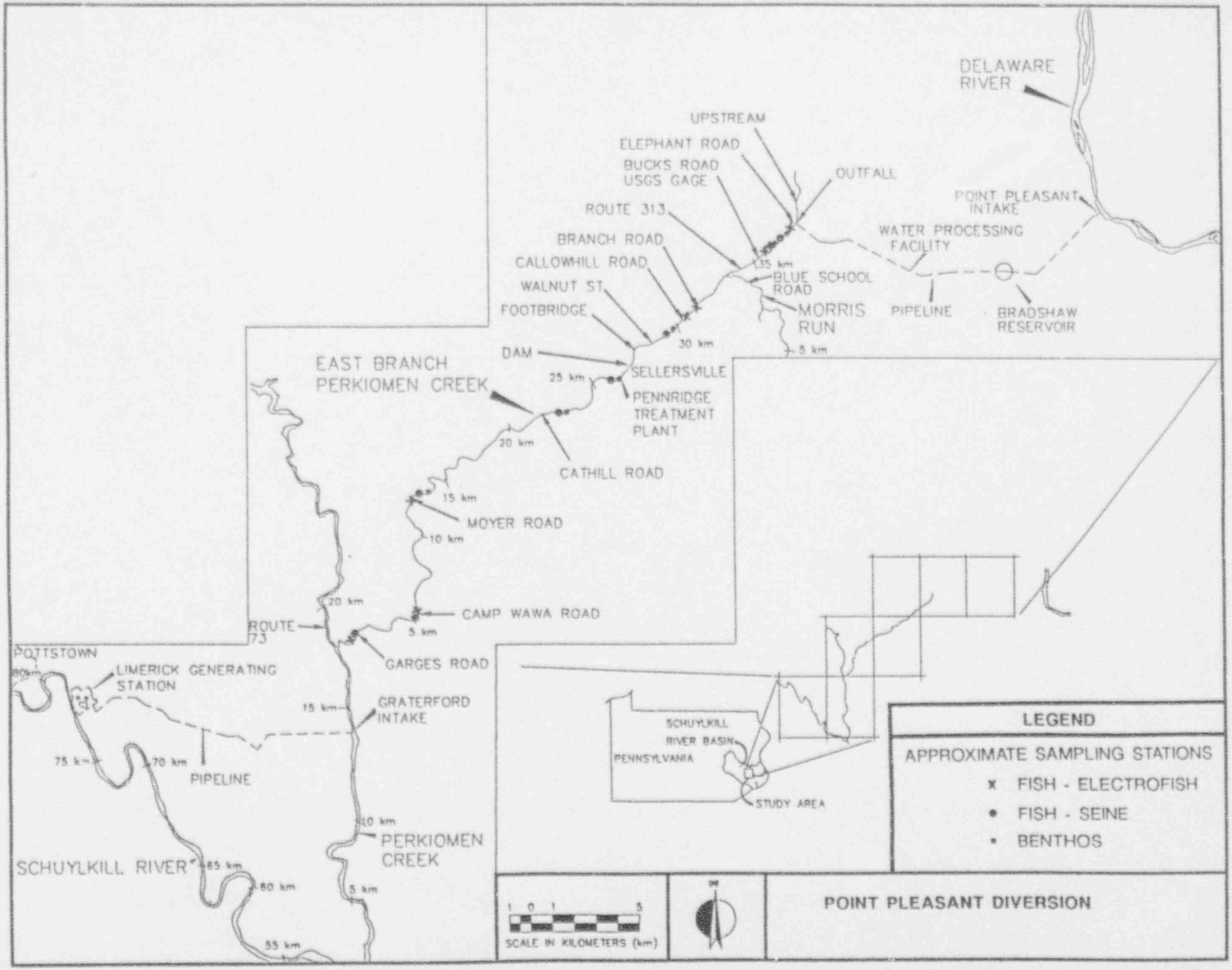
d. Solar Insolation

e. Air Temperature

f. Relative Humidity

3. Water Temperature - New Detailed Thermograph Data

Delaware River at Point Pleasant
EBTM Discharge
Bucks Road
Route 313
Branch Road
Head of Sellersville Pool (below Walnut Street Bridge)
Tail (Downstream) of Sellersville Dam
Morris Run - Blue School Road



POINT PLEASANT DIVERSION

4. Mixing Zone Discussion/Overview

5. Shutdown Record (from Limerick Generating Station (LGS))

6. QA/QC

    a. Laboratory QA/QC Manual

    b. Field Services QA Procedures

7. Continued Sampling Programs

    a. Water Quality

        1. NPDES Sampling - Outfall (see Table 2)

        2. Biweekly Water Quality Sampling Program at (see Table 3):

Point Pleasant	Cathill Road
Branch Road	Garges Road

    b. Benthos Sampling on Alternate Months at East Branch Meter Locations (see Figure 1)

36985	26700
36725	23000
29910	12500

    c. Fisheries Sampling at East Branch Meter Locations:

        1. Seine - Bimonthly

36690	12440
29810	5475
26630	1890
22980	

        2. Electrofishing - Spring and Fall

37750	32400
36300	12111
36235	5650
30700	1637

8. Pump Logs (from LGS)

9. Bucks Road Gage Record (from USGS)

Table 2. NPDES Permit PA-0052221 limits for Bradshaw Reservoir Outfall 001.

Parameter	Average monthly mg/l	Maximum daily mg/l	Instantaneous maximum
Aluminum, Total	0.4	2.0	
Cadmium	0.00076	0.0022	
Dissolved Iron	–	0.3	
Iron, Total	1.5	7.5	
Mercury	Non-detectable	Non-detectable	
Nickel, Total	0.052	0.26	
Phenolics, Total	0.005	0.01	
Zinc, Total	0.1	0.5	
Temperature			
(Feb 15 to Jul 31)			74 F 23.3 C
(Aug 1 to Feb 14)			87 F 30.6 C
Fecal Coliforms			
(May 1 to Sep 30)	Geometric average of 200 colonies/100 ml		
(Oct 1 to Apr 30)	Geometric average of 2,000 colonies/100 ml		
Dissolved Oxygen			
(Feb 15 to Jul 31)	Minimum daily average of 6.0 mg/l No value less than 5.0 mg/l		
(Aug 1 to Feb 14)	Minimum daily average of 5.0 mg/l No value less than 4.0 mg/l		
pH	Within 6.0 and 9.0 Standard Units at all times		

Table 3. Analytic parameters and methods for water quality monitoring - Delaware River and East Branch Perkiomen Creek at Point Pleasant.

Parameter	Detection limit (mg/l)	EPA method[a]	NPDES parameter
Aluminum[d]	0.07	202.1	X
Cadmium[d]	0.0002	213.2	X
Calcium[e]	1.5	215.1	
Chromium[c]	0.002	218.2	
Copper[c]	0.002	220.2	
Iron[d]	0.002	236.1	X
Lead[c]	0.002	239.2	
Magnesium[e]	0.3	242.1	
Manganese[c]	0.1	243.1	
Mercury[d]	0.0002	245.1	X
Nickel[d]	0.003	249.2	X
Potassium[e]	0.05	258.1	
Sodium[e]	0.36	273.1	
Zinc[d]	0.02	289.1	X
Alkalinity, Total as $CaCO_3$[e]	2.8	310.2	
Ammonia, Nitrogen[e]	0.011	350.1	
Chemical Oxygen Demand[c]	7.4	410.4	
Chloride[e]	2.2	325.2	
Cyanide, Total (water)[c]	0.009	335.3	
Hardness as $CaCO_3$[c]	10	130.1	
Nitrate, Nitrogen[e]	0.2	353.2	
Nitrite, Nitrogen[c]	0.01	353.2	
Ortho Phosphate Phosphorus[e]	0.03	365.1	
Phenolics (water)[d]	0.002	420.2	X
Sulfate[e]	3.4	375.2	
Fecal Coliform (MF)[d]	1 colony/100 ml	[b]	X
Biochemical Oxygen Demand[c]	0.1	405.1	
Carbon, Total Organic[c]	1	415.1	
Dissolved Oxygen[d]	NA	360.1	X
pH[d]	NA	150.0	X
Specific Conductance[e]	NA	120.1	
Temperature[d]	NA	170.1	X
Total Dissolved Solids[c]	10	160.1	
Total Phosphate Phosphorus[c]	0.03	365.1	
Total Suspended Solids[e]	4	160.2	
Turbidity[c]	0.2	180.1	

[a]U.S. EPA. 1983. Methods for Chemical Analysis of Water and Waste.
[b]U.S. EPA. 1978. Microbiological Methods for Monitoring the Environment.
[c]After November 1991 - Once annually at Point Pleasant.
[d]After November 1991 - Bi-weekly at Point Pleasant and Cathill Road.
[e]After November 1991 - Once per month at Point Pleasant, Branch Road, Cathill Road, and Garges Road.

10. Erosion Cross-sections (on file at RMC)

11. NPDES Violations (from DMR)

12. Economic and Recreation Value

    a. Creel Survey

    b. Water Contact Sport Observation

13. Rare, Threatened, and Endangered Species in Study Area

14. Pre-Post Operational Lack of Harm to Balanced Stream Community

    a. Benthos

    b. Fish

    A balanced indigenous stream community consists of the following:

    A group of populations occupying a common area which consists of desirable species of fish and shellfish, including the biota of other trophic levels which are necessary as part of the food chain or otherwise ecologically important to the maintenance of these populations.

15. Representative Important Species (Selected by PA DER)

    a. Smallmouth Bass

    b. Brown and Rainbow Trout

    c. White Sucker

    d. Spotfin Shiner

    For Trout - Adult Survival and Growth

    All Others - Life Cycle Thermal Tolerance

16. Literature Studies - Life History Thermal Requirements

III. Methodology

A. Continue Ongoing Programs: Flow - Water Quality - Benthos

B. New Temperature Data via Thermographs to Demonstrate Lack of Impact due to Alternate Thermal Effluent Limitations

C. Meteorologic Data for Modeling

D. Modeling (See Attachment A)

1. Estimate discharge temperature of diversion water without chilling at the end of the Bradshaw Transmission Main using Delaware River at Point Pleasant temperature, time of year, and time of day.

2. Describe thermal regime of both study cases including spatial, diurnal, and seasonal variation.

a. Study case I - Expand the empirical data to include diurnal variation with emphasis on thermal maxima for pre-diversion period. Predict Study Case I temperatures for comparison with Study Case II.

b. Study case II - Predict temperatures for 1980 - through present assuming 10, 27, 54 cfs diversion without chilling for stream reach from East Branch Perkiomen Creek discharge point downstream to the tail of Sellersville Pool.

c. Predict Study Case I and II temperature for future years.

IV. Selection and Development of Decision Criteria (See Attachment B)

A. Representative Important Species (RIS) - Warmwater Species

1. Reproductive Success and Growth

B. RIS - Trout

1. Preclusion of Trout Stock Fishery

2. Exclusion from Unacceptably Large Area

3. Survival and Harvest

V. Conclusion and Summary of Findings Related to 316(a) Criteria.

A. Statement Proposing Elimination of Thermal Discharge Limits

B. Evaluation of Elimination of Thermal Discharge Limits against decision criteria (See Attachment B)

ATTACHMENT A

PREDICTIVE THERMAL MODELING PLAN FOR BRADSHAW 316(a) DEMONSTRATION

Modeling efforts will result in the development of two data sets regarding temperature of the Delaware River water routed through Bradshaw Reservoir and discharged to East Branch Perkiomen Creek. The first effort of the modelers will be to predict water temperature at the discharge point from the Bradshaw Reservoir pipeline to the East Branch Perkiomen Creek with the modeling inputs being the ambient temperature of the Delaware River, time of year, and time of day.

The second effort required will be to fully develop the thermal regime for both study cases: Study Case I which is no diversion/no chilling and Study Case II which is diversion without chilling. Predicted temperatures will be required where empirical observations of temperature for either study case are not available. Thermal modeling, based on existing data, the current temperature monitoring program, and scientific or engineering principles, will be used to develop the annual thermal regime for each study case, including diurnal variation, with an emphasis on the time period 15 February through 31 July. The area of interest will be from Elephant Road to the downstream end of Sellersville Pool for three flow cases of 10 cfs, 27 cfs, and 54 cfs. In addition to predicting Study Case I and II temperatures for the period that the diversion did operate after August 1989 and for future years, the modeling effort will predict temperatures for Study Case II (diversion without chilling) for the pre-diversion time period (January 1980 through August 1989) to the extent permitted by the data because significant information on the biology, species composition, reproductive success, and growth history of both warmwater fish and stocked trout are available for the pre-diversion period. The Study Case II predicted thermal regime will be used to evaluate decision criteria described in Attachment B for RIS warmwater fish and stocked trout as they may change due to thermal differences between Study Case I and Study Case II.

It will also be necessary to estimate Study Case I (no diversion/no chilling) temperature values (especially thermal maxima and spatial variation) where empirical values do not exist for that same time period (1980 through present).

The data sources for the models will be observations of temperature made during pre- and post-diversion aquatic biological assessments; temperature logs and discharge monitoring reports for Point Pleasant Pumphouse, Bradshaw Reservoir, the Bradshaw Water Processing Facility, the Bradshaw Transmission Main Discharge Point, and the East Branch Perkiomen Creek at the discharge point above Elephant Road; and the 1992 ongoing water temperature and meteorological monitoring program described in detail at II.B of the Study Plan. A continuous temperature monitoring record for North Branch Neshaminy Creek is also available to calibrate and compare models developed for the East Branch Perkiomen Creek. Morris Run temperatures will be used as a predictor for East Branch Perkiomen Creek above its confluence with Morris Run based on empirical relationships between Morris Run, East Branch Perkiomen Creek, and meteorological and hydrological data collected in 1992.

ATTACHMENT B

SELECTION AND DEVELOPMENT OF STUDY PLAN DECISION CRITERIA FOR THERMAL VARIANCE REQUEST IN REGARD TO THE POINT PLEASANT DIVERSION NPDES PERMIT PA0052221

NPDES Permit PA0052221 was issued with preset limits on the temperature of the discharge from the Bradshaw Reservoir to East Branch Perkiomen Creek. Philadelphia Electric Company and PA DER reached a consent agreement which, in part, stipulated that Philadelphia Electric Company would apply for a variance from the NPDES thermal limits as stated in the permit based on a 316(a) demonstration. The present document specifies the decision criteria to be applied by PADER in acting on the application for a variance.

The thermal variance demonstration will be a combination Type I, Type II demonstration: Type I defined as the absence of prior appreciable harm and Type II defined as Protection of Representative Important Species. As a result of ongoing discussions with PADER, the Pennsylvania Fish and Boat Commission, and Philadelphia Electric Company and their consultant RMC Environmental Services, Inc. (RMC), the following list of decision criteria was developed as applicable to the Bradshaw Reservoir 316(a) thermal variance request.

- Warmwater RIS (smallmouth bass, white sucker, spotfin sucker)
    1. reproductive success and growth
- Coldwater RIS (trout)
    1. preclusion of trout stock fishery
    2. exclusion from unacceptably large area
    3. survival and harvest

Each of these decision criteria will be more fully developed below.

Warmwater RIS Reproductive Success and Growth

It will be the intent of the thermal variance request to demonstrate, through comparisons of the thermal regime in Study Case I (no diversion/no chilling) and Study Case II (diversion without chilling), that the deletion of thermal limits will not eliminate or impair existing use of the stream for successful reproduction or growth of the following warmwater RIS fishes: smallmouth bass, white sucker, and spotfin shiner. The decision criterion will be the quantitative and qualitative demonstration of similar reproductive success and growth history when comparing Study Case I versus Study Case II. The comparisons will be made using the observed and predicted thermal regimes for each study case, pre-diversion (Study Case I) observations of RIS fish reproductive success and growth history, a comparison of Study Case II thermal regime with the observed reproductive success and growth history of Delaware River fish (which exist in a thermal regime similar or identical to Study Case II), and lastly a comparison of published observations of reproductive success and growth history of smallmouth bass, white sucker, and spotfin shiner compared to the predicted and observed study case II thermal regime. A successful demonstration of the criterion will be the continued, substantially similar reproductive success and growth for Study Case II as was observed and described in Study Case I. An unsuccessful demonstration of the criterion will be a significant reduction of or elimination of RIS species due to Study Case II thermal regime or an observation of significantly lower reproductive success or growth history attributable to Study Case II thermal regime.

Trout RIS

Three decision criteria apply to the representative important species brown trout and rainbow trout, which are the fish released by the Pennsylvania Fish and Boat Commission (PFBC) for the trout stock fishery in the East Branch Perkiomen Creek.

1. Preclusion of Trout Stock Fishery

This decision criterion relates to the preclusion of a trout stock fishery (TSF) when comparing the thermal regimes of Study Case I versus Study Case II. The study will evaluate Study Case II for feasibility of a TSF against PFBC guidelines for an acceptable stream reach for trout stocking. A successful demonstration of the criterion will result if a trout stock fishery is feasible (i.e. not excluded or absent) as a resuit of thermal modification attributable to Study Case II to the same extent as it was feasible under Study Case I.

2. Exclusion from Unacceptably Large Area

This criterion deals with exclusion from an unacceptably large area as a result of thermal modification of the study area when comparing Study Case II versus I. The study will evaluate the quantity of acceptable TSF habitat available for Study Case I and Study Case II based on PFBC guidelines and other published criteria. A successful demonstration of the decision criterion will result if the length of stream reach with a thermal regime acceptable for stocked trout survival and harvest under Study Case II is not materially smaller than the area acceptable habitat under the Study Case I thermal regime.

3. Survival and Harvest

Decision criterion 3 for trout is concerned with the survival and harvest of stocked trout during the period 1 March through 31 July. Extensive observations of trout survival and harvest exist for Study Case I. The study will estimate trout survival and harvest for Study Case II based on Study Case I creel surveys and thermal modifications to stream reach expected for Study Case II. A successful demonstration will result if Study Case II trout survival and availability for harvest is similar both in duration and quantity to that of Study Case I. More specifically, when evaluating this criterion for a successful demonstration: (1) in terms of time, no material detrimental effect will be

observable on the timing and duration of trout stock fishery survival and harvest under Study Case II as compared with Study Case I, (2) in terms of quantity, similar numbers of trout will be available in Study Case II as were available in Study Case I assuming the PFBC makes similar numbers available for stocking.

FINAL EVALUATION OF DECISION CRITERIA

If a successful result is obtained for the Warmwater RIS and Trout RIS Decision Criteria as presented above, then the permit will be modified to eliminate all thermal limits for discharge of Bradshaw Diversion water to the East Branch Perkiomen Creek.

PHILADELPHIA ELECTRIC COMPANY

316a DEMONSTRATION

THERMAL MONITORING AND DATABASE DEVELOPMENT

Volume 1 - Final Report of Monitoring and Database Development Project

Prepared by
ADVANCEDAQUATICTECHNOLOGY ASSOCIATES, INC.
Fort Collins, CO

OCTOBER 1992

1.0 INTRODUCTION

A thermal monitoring study was initiated by Philadelphia Electric Co. (PECo) on the East Branch of Perkiomen Creek (EBPC) in April, 1992. The EBPC is used by PECo to deliver water which is diverted from the Delaware River at Point Pleasant, Pennsylvania to the nuclear power generating plant near Limerick, Pennsylvania. Upstream of Sellersville, the EBPC is classified as a trout stocked fishery and is stocked with trout. To meet the thermal requirements for a trout stocked fishery for the discharge of Delaware River water to the EBPC, PECo operates a chilling unit during the summer months. The purpose of this study was to gather data which would be used to model the natural thermal regime of the EBPC and to analyze the utility of the chilling unit in meeting the trout stocked fishery designation through the summer months.

Advanced Aquatic Technology Associates, Inc. (AATA) was contracted by PECo to purchase, calibrate, program, and install monitoring equipment and to collect data for this project. High standards of data capture and accuracy were set because of the need for highly accurate data for input to thermal models.

1.1 Thermal Monitoring Equipment

The monitoring equipment chosen was the Campbell Scientific CR10 datalogger, which supports submersible thermistors capable of achieving ± 0.1°C accuracy for continuous data collection. However, the Campbell Scientific equipment was not available for installation until the last week of May, 1992 due to restrictions in availability of equipment. In order to begin data collection as soon as possible, Ryan TempMentors (RTM) were purchased and installed April 28 through May 1, 1992. The TempMentors are accurate to ± 0.3°C; once the CR10 units were installed, these units provided the necessary redundancy required for 100% data capture.

1.2 Monitoring Locations

Monitoring locations were selected to provide comprehensive, representative data for the East Branch Perkiomen Creek between the point of discharge of the diverted water to the system and

the downstream outfall of the Sellersville pool. Monitoring stations were located above the discharge on the East Branch and on Morris Run to provide background data for comparison. Based upon these considerations of scope and the constraints of cost and access, eleven monitoring locations were selected (See Figure 1). In addition, meteorologic data are to be collected at the discharge (upstream limit of the study area) and at the PennRidge Waste Water Treatment Plant (downstream limit of the study area). The following table lists the monitoring locations and sensors installed along the East Branch Perkiomen Creek and Morris Run.

Ryan TempMentors were installed from April 28 through May 1, 1992. These units were designed to serve as temporary monitoring devices until the Campbell Scientific equipment was available. After the installation of the Campbell Scientific equipment, the Ryan TempMentors served as a back-up system to ensure that 100% data capture was achieved. The RTM units were factory calibrated before shipment and were field checked at AATA headquarters. Before the RTM units were installed they were calibrated with each other and with a NIST-traceable thermometer.

Figure 1: Site Map

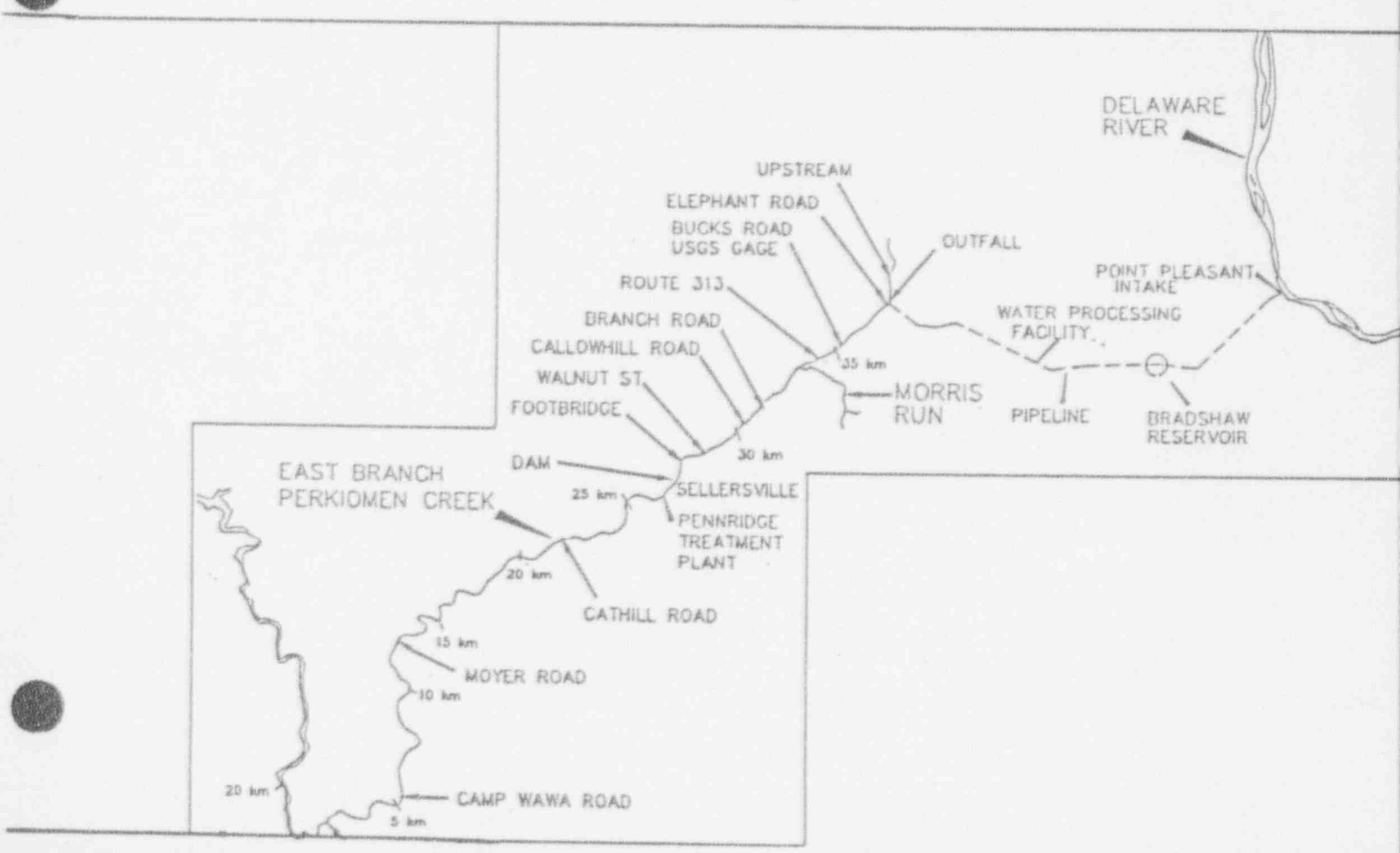


TABLE 1: STATIONS AND SENSORS INSTALLED

STATION LOCATION	EQUIPMENT INSTALLED
T-1, UPSTREAM OF DISCHARGE	C, W, A, R, B, E
T-2, AT OUTFALL STRUCTURE	C, W, A, R, RH, WS, WD, P, S, E
T-3, BUCKS ROAD GAGE	C, W, A, R, B, E
T-4, ROUTE 313 BRIDGE	C, W, A, R, B, E
T-5, BRANCH ROAD BRIDGE	C, W, A, R, B, E
T-6, CALLOWHILL ROAD BRIDGE	C, W, A, R, B, E
T-7, WALNUT STREET BRIDGE	C, W, A, R, B, E
T-8, SELLERSVILLE POOL	C, W, A, R, B, E
T-9, MAIN STREET BRIDGE	C, W, A, R, B, E
T-10, PENN RIDGE WWTP	C, A, RH, WS, WD, P, S, E
T-11 MORRIS RUN-QUARRY ROAD	C, W, A, R, B, E
T-12 MORRIS RUN-BLUE SCHOOL ROAD	C, W, A, R, B, D, E

C = CAMPBELL SCIENTIFIC DATALOGGER
WS = 014A WIND SPEED SENSOR
A = CAMPBELL 107 AIR TEMPERATURE PROBE
WD = 024A WIND DIRECTION SENSOR
W = CAMPBELL 107B WATER TEMPERATURE PROBE
R = RYAN TEMPMENTOR
S = MSX10R SOLAR PANEL
B = BATTERY PACK
P = LI200S PYRANOMETER
E = CR10 ENCLOSURE
D = DRUCK PRESSURE TRANSDUCER

Installation of the RTMs consisted of two general steps: calibration and deployment of the RTM and physical installation of the shelter and the RTM. Using a portable computer, the RTM dataloggers were tested for proper operation and battery voltage. The RTMs were allowed to equilibrate to stream temperature before final deployment. When the RTM reading was within the tolerance band for temperature measured on a NIST-traceable thermometer (0.1°C), and the time was at an even ten-minute interval, the RTM was deployed. Physical installation included placement of the RTM inside the PVC shelter; attachment of cables to the shelter and to trees, bridge abutments, cinder blocks, or other anchors; securing the shelter with a padlock to deter theft or vandalism; and protection of the padlock against corrosion. Once the shelters were placed in the stream, appropriate attempts were made to make it look unobtrusive. Camouflage painting on the shelters and the use of common materials made this possible. Brass plaques were attached to the PVC shelters. Each plaque read as follows:

PLEASE DO NOT DISTURB
Continuously recording temperature sensor
for trout-stocked fishery
enhancement study

The sites and a general description of each RTM installation is given below.

Station	RTM Serial No.	Time	Comments
T1	903945	9:20 EST	Upstream of discharge, approximately 410 feet at base of large tree. Water temp: 9.5°C
T2	903946	9:50 EST	Discharge to East Branch Perkiomen Creek. Water temp: 12.5°C
T2	901971	17:30 EST	Discharge, Air Temperature. RTM hung from fence in white PVC shelter to shield direct radiation. Air temp: 26.1°C

T3	903947	10:50 EST	Bucks Road Gage. Telemarks system reports 30.8 cfs. Water temp: 14°C. RTM installed 35.3 feet down stream of benchmark on weir.
T4	903948	11:20 EST	Route 313 Bridge. Water temp: 14.5°C. RTM installed downstream, west side of bridge in 13" water.
T5	903949	4:50 EST	Branch Road (Iron Bridge). Water temp: 10.3°C. Unit installed on upstream side of bridge, south (east) bank, in deep channel along bank.
T6	903951	5:20 EST	Callowhill Road. Water temp: 9.3°C. RTM is cabled to east pier at the downstream end.
T7	903950	6:10 EST	Walnut Street Bridge. Water temp: 12.3°C. Installed on left side below bridge.
T8	903969	5:50 EST	Sellersville Pool. Water temp: 12.2°C. RTM is cabled to the tree which was designated for CR10 installation and deployed midstream. Water depth is approximately 45".
T9	903970	15:50 EST	Main St. in Sellersville, downstream limit of study area. Water temp: 14.2°C. RTM installed upstream of NW bridge pier.
T11			Morris Run at Quarry Road. Water temp: 20°C. RTM installed in deepest part of flow, can cabled cinderblocks with a bolt anchor to the bridge.

T12	903971	6:30 EST	Morris Run at Blue School Road. Water temp: 9.8°C. RTM installed at north bridge abutment on downstream side in deep (36") water.

At the time of the RTM installation on Morris Run at Blue School Road, the stream was gaged to develop stream flow rating curves for the stream. The stream was gaged using a standard wading rod and a Marsh-McBirney flow meter.

The installation of CR10 equipment began on 28 May. Installation occurred in two stages: 1) installation of the steel shelters 2) installation of the CR10 datalogger and probes. Since different tools would be needed for each stage, steel shelters were installed one day and CR10s were installed on the next day.

The steel shelters used for housing the CR10 dataloggers were designed to deter vandalism, theft, or other damage to the CR10s. They were constructed of 1/4" steel and were 1' x 2' x 2' in dimensions. A hinged door with double hasps for padlocks provided access to the shelters. The actual CR10 enclosures were mounted on a 1 1/4" diameter pipe welded inside the shelter. Chain links were welded to the outside of the shelters for attaching them to trees or bridges. Each shelter bore a brass plaque identical to those attached to the RTM shelters.

Installation of the steel shelters involved determining the exact location and cabling arrangement for each site; placing the shelters in the desired location and temporarily fastening them at the desired height, connection of cables and leveling of the shelters. The shelters weighed approximately 100 pounds.

Installation of the CR10 equipment consisted of cutting, installing, and securing conduit for protection of the thermistor cables; pushing the thermistor cables through the conduit; mounting the CR10 and the radiation shield on the steel shelter; and the actual wiring of the CR10 datalogger. The datalogger control program was then complied and the datalogger was

calibrated to eastern standard time. All excess cable was secured and desiccant placed inside the CR10 enclosure. In cases where orthogonal cable routing was possible or desired, standard thin-walled conduit was used. In other cases where a more circuitous cable routing was needed, flexible conduit was used. Notes were taken regarding thermistor readings, datalogger functions, and temperature as measured by the NIST-traceable thermometer for QA/QC purposes. Installations at T2 and T10 were somewhat more complex due to additional sensors for meteorologic monitoring. A listing of the QA/QC reading at each station is given below.

QA/QC Measurements for CR10 Installations

Site	Time/Date*	Batt.	Sign.	Air	Water 1	Water 2	NIST
T1	1545 149	12.37	2257.9	19.265	16.527	16.547	16.5
T2	1910 149	12.68	3671.1	19.42	16.714	16.720	16.8
T8	1235 150	12.35	327.20	20.426	15.276	15.289	15.3
T7	1855 150	12.35	5944.7	21.677	19.749	19.891	19.9
T6	2030 150	12.35	5090.3	17.477	19.285	19.307	19.2
T3	2100 150	13.36	2630.3	18.049	16.821	16.584	N.A.
T9	0726 151	12.29	2189.2	12.697	17.046	17.093	17.0
T5	0853 151	12.33	780.70	15.615	16.818	16.846	16.9
T4	0952 151	12.35	2912.9	15.64	17.909	17.894	17.9
T12	1055 151	12.25	3812.6	17.078	14.963	14.965	14.9
T11	1146 151	12.33	4727.1	17.035	16.249	16.286	16.3

*Julian Day (149 = May 28).

2.0 Data Collection and Quality Assurance

2.1 Data Collection Procedures

Data collection procedures for the Ryan TempMentors (RTMs) were as follows. The RTM was removed from the stream and taken from its protective shelter. Data were then transferred from the RTM to a data diskette using a portable computer equipped with specialized software. The computer was also used to re-deploy the RTM dataloggers. Deployments were made on ten-minute intervals (measured to the NIST atomic clock in Fort Collins, Colorado) to assure consistency between sites. Data quality assurance/quality control functions were performed, including measurement of the stream temperature with a NIST-traceable thermometer, recording time of retrieval and deployment, recording last and first readings, and checking functions of the RTM (including battery voltage). Finally, the RTM was placed in the protective shelter and re-deployed in the stream. (All dataloggers were set using eastern standard time in order to avoid discrepancies resulting from time changes). Field notes documenting the operating condition of the RTM and ambient stream temperature at the time of collection were collected.

Data collection procedures for the CR10 dataloggers consisted of the following. In general terms, data collected by the CR10 and stored on the storage modules were retrieved by "swapping" storage modules. When one storage module had collected data and was ready to be retrieved (that is, the storage module was "full"), the station operator traveled to the station site and replaced the "full" storage module with an "empty" storage module for the same station. This process is described below.

The appropriate "empty" storage module was brought to the monitoring station and the keypad device was connected to the CR10. The CR10 time was checked and when the time is not within 2 minutes of the hour the flat blue communication cable was disconnected from the "full" storage module. The switch did not take place at the hour because the CR10 was transferring data to the storage module at those times. The flat cable was then quickly connected to the "empty" storage module.

After field collection of the storage modules, the data were downloaded as follows. The SC532 communications interface was attached the to the comm port of the computer and the SMCOM program activated. All data files were downloaded using the proper commands as comma delineated ASCII files and a root file name entered. The data files were then renamed to indicate the time and place of data collection.

After data downloading, the data files were examined for anomalies in the data. Missing or incomplete data or values such as -9999 or -6999 were noted. All data were then copied to floppy disk and mailed to AATA headquarters.

2.2 Data Quality Assurance Procedures

After data were collected, they were reviewed to ensure 100% data capture and compared to data quality assurance criteria. In order to ensure proper sensor operation and data reliability, all data were compared using the differences between water temperature values collected by the two Campbell 107 sensors. The average, minimum, and maximum differences between the two observed water temperature values were calculated for each station and used to assess data quality and reliability.

Data quality criteria of no difference greater than 0.4 degrees Celsius between individual sensor readings and no average difference greater than 0.25 degrees Celsius for the entire data record were used to evaluate the data. Values calculated from the data sets were compared to these data quality assurance guidelines. When CR10 temperature values did not meet these quality assurance criteria, the data were analyzed using the following procedures.

- Determine if one or both sensors were recording data in an erratic manner inconsistent with the physical behavior of the stream (i.e. oscillating values or rapid changes in stream temperature).

- Analyze the temperature data for systematic differences in the observed values from the two sensors such as consistently higher values for the maximum daily temperature from one sensor.

- Compare the CR10 temperature values to the Ryan TempMentor temperature readings to determine if one sensor consistently deviated from the RTM data.

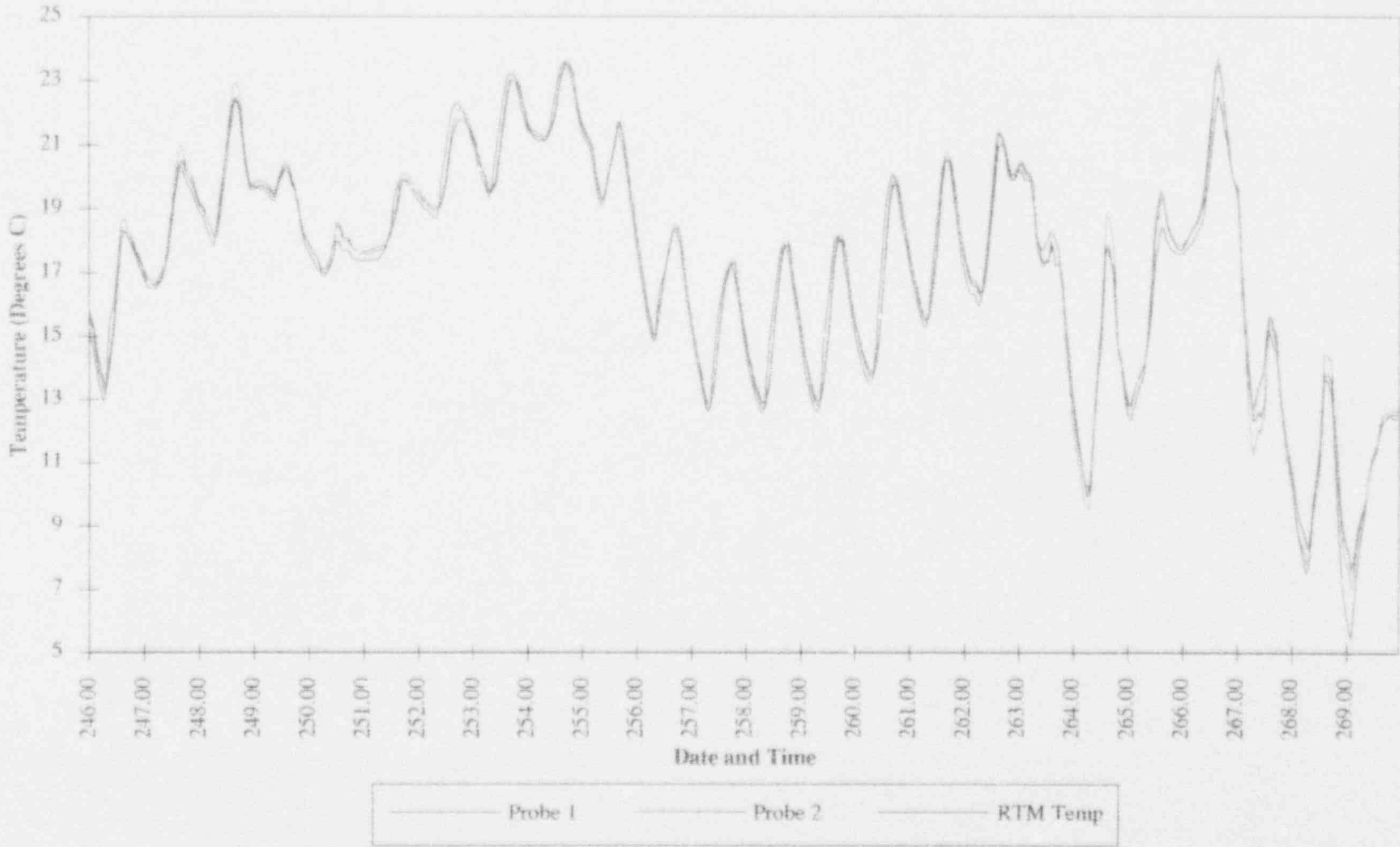
Based upon the above procedures, a decision was made either to substitute one CR10 sensor reading for the average, use the average of the CR10 sensor readings, or use the RTM temperature in the final database. These procedures were documented in the database notes and data were flagged to denote the type of QA/QC adjustment. A summary of all QA/QC outliers and the action taken are given in Appendix 1. The graphical representation of all data outside the QA/QC are shown in Appendix 2 and an example is given in Figure 2.

2.3 Database Design and Structure

The ORACLE relational database management system was used to create a database from the data collected by the CR10 and RTM dataloggers. Within the ORACLE database, separate tables were created to store the CR10 and RTM data; these were named CR10DATA and RTMDATA, respectively.

The ORACLE LOADER utility was used to automatically load the CR10 and RTM data files into the ORACLE database. This method entirely eliminated the extensive time requirements and introduction of errors that are inherent with manual data entry methods. The CR10 data files were directly loaded as created by the CR10 dataloggers. The RTM data files, however, consisted of 10 minute temperature averages with no integrated date or time information and therefore required pre-processing before they could be loaded into the ORACLE database. The pre-processing was accomplished by (*1*) loading the RTM data files into an Excel spreadsheet containing the appropriate dates and times, (*2*) averaging the data on each hour, (*3*) reducing the data to include only the date, time, and hourly average values for each station, and (*4*) exporting the values as an ASCII comma-separated text file. The pre-processed RTM data files were then

Station T1, September 2 - September 25



loaded into the ORACLE database using the ORACLE LOADER utility. The following sections describe the format of the data fields within the database.

Included as attachments to this report are a complete hard copy printout of the database, and a 3.5" floppy disk containing a soft copy of the database. The soft copy of the database is a single space-separated ASCII file in PKZIP compressed format. It is identical to the printed hard copy, with the exception that in the soft copy null values are represented by the value -6999 whereas in the hard copy null values are represented by blank spaces.

CR10 Data Table Format

The CR10 data table includes 16 separate fields and approximately 37,000 individual records. Each record in the CR10 data table represents the unique set of hydrologic and/or meteorologic data collected from a particular station at a particular time and date. All null values in the database are represented by the value -6999.

The names, content, and characteristics of the fields in the CR10 data table are presented in Table 2. All of the records for stations T1 through T9, and T11, and T12 have data in the fields ARRAYID, JDAY, TIME, AHWT1, AHWT2, USECODE, AHWT, BATVOLT, and SIG, and null values in the fields AISR, AWS, AWD, ARH, TPPT, and WSSD. Station T12 also includes pressure transducer data in the PRESS field.

Stations T2 and T10 additionally contain meteorologic data in the fields AISR, AWS, AWD, ARH, TPPT, and WSSD. The records for Station T10 have null data in the AHWT1, AHWT2, and AHWT fields because Station T10 is strictly a meteorologic station.

The CR10 data table includes the field USECODE that identifies which of four stream water temperature values should be used as the rectified stream temperature value. The value in the USECODE field identifies whether the rectified value is equal to the value recorded by probe 1 (USECODE=10), the value recorded by probe 2 (USECODE=20), the average of the values recorded by probes 1 & 2 (USECODE=30), or the value recorded by the Ryan TempMentor

(USECODE=40). The value placed in the USECODE field was determined through the QA/QC procedure and is described in Section 2.2.

RTM Data Table

The RTM data table contains the hourly averaged stream temperature data collected from the Ryan TempMentors. The RTM data were collected solely as a secondary data source to be used for QA/QC purposes and as a back-up in the event that the CR10 was unavailable, and were not intended to serve as the primary data source.

The RTM data table contains 13 fields which contain the temperature values collected from the 11 hydrologic stations and the date and time each value was collected. Station T10, which is solely a meteorologic station, does not include a Ryan TempMentor and is therefore not included in the RTM data table.

Table 2: Data Fields in CR10 Database

Field Name	Field Contents	Field Characteristics
ARRAYID	Station number	Expressed in tens (ie. T1=10, T2=20, ..., T12=120)
JDAY	Annual Julian day	Days numbered between 149 and 276 accounting for leap year
TIME	Time of the day	Expressed on a 24 hour clock
AHWT1	Average hourly water temperature measured by CR10 probe 1	Temperature in degrees C measured to the hundredths of a degree
AHWT2	Average hourly water temperature measured by CR10 probe 2	Temperature in degrees C measured to the hundredths of a degree
AHWT	Average hourly water temperature recommended by QA/QC procedure	Temperature in degrees C measured to the hundredths of a degree

AISR	Average incoming solar radiation	Solar radiation in cal/cm² with 3% accuracy
AWS	Average hourly wind speed	Wind speed in m/s with 1.5% accuracy
AWD	Average hourly wind direction	Wind direction from 0 to 360 degrees with 5 degree accuracy
WSSD	Wind speed standard deviation	Wind speed in m/s with 1.5% accuracy
ARH	Average hourly relative humidity	Percentage measured to a tenth of a percent
TPPT	Total hourly precipitation	Precipitation measured in 0.01 inch increments
PRESS	Average hourly water pressure	Pressure measured to a hundredth of a foot of water
USECODE	Code to identify water temperature value to place in AHWT field	2 digit number - 10 = CR10 probe 1 (P1) 20 = CR10 probe 2 (P2) 30 = Average of P1 & P2 40 = RTM temperature
BATVOLT	Average hourly battery voltage	Voltage measured to the hundredths of a volt
SIG	Sample signature	Four digit number identifying station location

2.4 Flow Measurement and Rating Curve Development

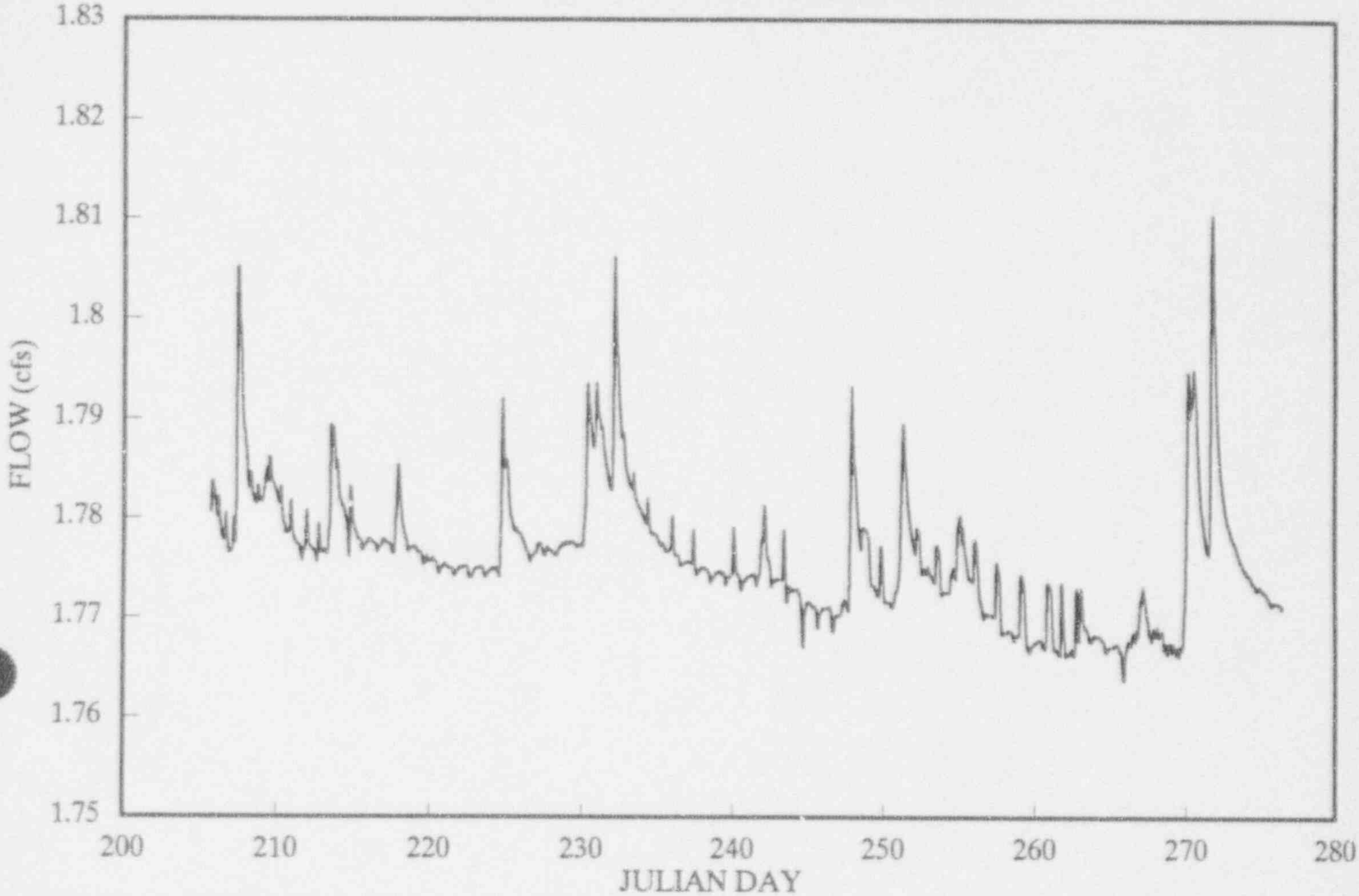
A pressure transducer was installed on Morris Run at Blue School Road to monitor river height (stage). A program of regular streamgaging was then initiated so that the relationship between stage and flow could be quantified. In this manner a flow record for Morris Run at Blue School Road was developed.

The initial Keller pressure transducer was calibrated by AATA personnel in Fort Collins and sent to RMC for installation on Morris Run. During installation, the transducer malfunctioned and a second pressure transducer was ordered from Druck, Inc. The original pressure transducer was sent back to Keller for repair by RMC personnel. The Keller pressure transducer may have malfunctioned due to damage during shipment.

The Druck pressure transducer was installed on 23 July by RMC personnel. RMC personnel performed streamgaging on approximately a biweekly basis. These data were used to develop the hydrograph which is shown in Figure 3. The complete hourly flow summary is given in Appendix 3. The mean, maximum, and minimum flows recorded were 1.78, 1.81, and 1.76 cfs respectively.

FIGURE 3: HYDROGRAPH

MORRIS RUN AT BLUE SCHOOL ROAD



JULY 23 – OCTOBER 2, 1992

3.0 RESULTS

Data collection was conducted from 1 May through 31 September with 100% thermal data capture for all stations. The complete hourly CR10 data record is provided in Volumes 2 and 3 of this report. The hourly RTM data are provided in Volume 4. Summary data for each station for the periods during the 74°F compliance restriction and after chiller operations were completed on 31 July are given in Tables 3 and 4.

During the period prior to chiller shutdown on 31 July, the maximum temperature recorded on the EBPC was 29.9°C at T8 at the Sellersville Pool on 14 July at 1900. The maximum temperature at T7 occurred the same day at 1600 hours and was 26.72°C. Upstream of T7, the maximum temperatures for sites T3, T4, and T6 for the period prior to chiller shutdown, also occurred on 14 July. At these sites, the maximum temperatures occurred at 1600, 1700, and 1600 hours respectively. Below the Sellersville pool at T9, the maximum temperatures occurred much latter the same day at 2300 hours. The maximum temperature at T9 was 26.46°C. This shows that the deep pool at Sellersville heats up much more slowly and releases its heat later in the day than sites upstream of the Sellersville pool. The sites located on Morris Run had the highest maximum temperatures in the period before chiller shutdown throughout the monitoring network. The maximum temperature at T11 on Morris Run at Quarry Road was 30.80°C and at T12 at Blue School Road on Morris Run was 30.68°C. The station located below the Sellersville pool (T9) and T12 on Morris Run had the highest average temperatures of 21.61 and 21.40°C respectively. It is interesting to note that T11 on Morris Run at the second lowest minimum temperature (11.5°C) and the highest maximum temperature (30.80°C). This indicates that the small streams in this area naturally have a wide range of temperatures due to the low thermodynamic mass of these streams. T1 upstream of the discharge outfall had the lowest minimum temperature (10.24°C) and the third highest maximum temperature (26.62°C) on the EBPC.

For the period following chiller operation, the maximum recorded temperature on the EBPC occurred at T7 on 28 August at 1600 hours (27.55°C) followed by T6 on the same day and time (27.49°C). The maximum temperature at T8 and T9 at and below the Sellersville pool occurred

much later on the same day at 1800 and 2000 hours with values of 27.41 and 26.89°C respectively. In the lower portion of the EBPC, at sites T7, T8, and T9 the difference in maximum temperatures before and after chiller shutdown were 0.83, 0.51, and 0.43°C respectively. In general, the greatest difference in maximum temperatures for the periods before and after chiller shutdown occurred at the sites directly downstream of the chiller outfall. At T3, the difference in maximum temperatures was 2.38°C and at T4 the difference in maximum temperatures before and after chiller shutdown was 2.06°C. These data indicate that the effect of the chiller is lost by the time that the water reaches the trout stocked portions of the lower EBPC.

The sites on Morris Run had maximum temperature for the period after chiller shutdown were 28.18°C for T11 and 28.03°C for T12. These values are less than those recorded for the maximum temperatures prior to 31 July. The minimum temperatures recorded after chiller shutdown were 6.55°C at T1 and 8.02°C at T12. All minimum temperatures on the EBPC occurred in the early morning hours except at T2 were the minimum temperature occurred at 1100 hours. This is probably due to a twelve hour phase shift in temperatures caused by the transient time between diversion and outfall on the EBPC.

During the period after chiller shutdown, the average temperature recorded at stations below the outfall at T2 showed a consistent downward trend. The average temperature at T2 for the period following chiller operation was 22.26°C. The average temperature at the sites below T2 decreased to 22.10°C at T3, 22.09°C at T4, 22.00°C at T5, 21.69°C at T6, and 21.47°C at T7. The trend is then reversed at T7 with a maximum temperature of 21.58°C. At T8 the maximum temperature was 21.61°C.

Table 3 Summary statistics prior to July 31

Average temperatures prior to July 31				
	Station No.	Temperature		
	10	19.35		
	20	20.82		
	30	20.84		
	40	20.96		
	50	20.95		
	60	21.14		
	70	21.09		
	80	21.23		
	90	21.61		
	110	21.23		
	120	21.40		
	Minimum temperatures prior to July 31			
	Station No.	Julian Day	Time	Minimum
	10	150	700	10.24
	20	154	1200	16.01
	30	155	300	15.92
	40	155	400	15.81
	50	155	600	15.26
	60	151	600	14.57
	70	151	600	14.28
	80	151	1000	14.75
	90	151	1600	15.43
	110	175	600	11.50
	120	175	700	12.02
	Maximum temperatures prior to July 31			
	Station No.	Julian Day	Time	Maximum
	10	196	1500	26.62
	20	195	1000	23.03
	30	196	1600	24.10
	40	196	1700	24.57
	50	192	1700	25.34
	60	196	1600	26.37
	70	196	1600	26.72
	80	196	1900	26.90
	90	196	2300	26.46
	110	196	1500	30.80
	120	196	1600	30.68

Table 4 Summary statistics after July 31

Average temperatures after July 31	
Station No.	Temperature
10	17.80
20	22.26
30	22.10
40	22.10
50	22.00
60	21.69
70	21.47
80	21.58
90	21.61
110	20.10
120	19.93

Minimum temperatures after July 31			
Station No.	Julian Day	Time	Minimum
10	275	800	6.55
20	275	1100	15.13
30	276	700	14.86
40	276	700	14.74
50	276	700	14.25
60	276	700	13.35
70	276	700	12.94
80	276	600	12.85
90	276	800	12.65
110	275	700	8.15
120	275	800	8.02

Maximum temperatures after July 31			
Station No.	Julian Day	Time	Maximum
10	240	1600	24.65
20	241	2200	26.76
30	241	1400	26.48
40	241	1500	26.63
50	241	1500	27.24
60	241	1600	27.49
70	241	1600	27.55
80	241	1800	27.41
90	241	2000	26.89
110	239	1600	28.18
120	240	1600	28.03

PHILADELPHIA ELECTRIC COMPANY

316a DEMONSTRATION

THERMAL MONITORING AND DATABASE DEVELOPMENT

Appendix 1 - QA/QC Summaries

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	169	1100	19.78	19.18	20.35	Use probe 1
T1	169	1200	21	20.46	21.43	Use probe 1
T1	169	1300	21.99	21.43	22.25	Use probe 1
T1	169	1400	22.87	22.09	22.98	Use probe 1
T1	169	1500	23.48	22.89	23.3	Use probe 1
T1	169	1600	23.49	23.07	23	Use probe 1
T1	170	1300	18.73	18.3	18.98	Use probe 1
T1	170	1400	19.5	18.91	19.53	Use probe 1
T1	170	1500	19.97	19.48	19.97	Use probe 1
T1	170	1600	20.28	19.86	20.18	Use probe 1
T1	173	1300	18.76	18.36	18.72	Use probe 1
T1	175	1200	14.44	13.5	15.93	Use probe 1
T1	175	1300	16.19	14.41	17.77	Use probe 1
T1	175	1400	18.39	15.9	19.62	Use probe 1
T1	175	1500	19.85	17.64	19.88	Use probe 1
T1	175	1600	19.82	18.27	19.97	Use probe 1
T1	175	1700	19.93	18.54	19.97	Use probe 1
T1	175	1800	19.84	18.59	19.73	Use probe 1
T1	175	1900	19.65	18.58	19.43	Use probe 1
T1	175	2000	19.47	18.51	19.07	Use probe 1
T1	175	2100	19.06	18.46	18.62	Use probe 1
T1	177	1100	18.01	17.34	18.62	Use probe 1
T1	177	1200	18.92	17.71	19.78	Use probe 1
T1	177	1300	20.18	18.44	20.82	Use probe 1
T1	177	1400	21.17	19.6	21.32	Use probe 1
T1	177	1500	21.78	20.69	21.65	Use probe 1
T1	177	1600	21.79	20.74	21.52	Use probe 1
T1	177	1700	21.62	20.55	21.4	Use probe 1
T1	177	1800	21.46	20.47	21.13	Use probe 1
T1	177	1900	21.18	20.32	21	Use probe 1
T1	177	2000	21.08	20.24	20.75	Use probe 1
T1	177	2100	20.84	20.18	20.43	Use probe 1
T1	178	1100	17.95	17.26	19.52	Use probe 1
T1	178	1200	19.35	17.9	20.92	Use probe 1
T1	178	1300	20.77	18.71	21.8	Use probe 1
T1	178	1400	21.79	19.61	22.37	Use probe 1
T1	178	1500	22.34	20.37	22.45	Use probe 1
T1	178	1600	22.34	20.67	22.32	Use probe 1
T1	178	1700	22.26	20.82	22.25	Use probe 1
T1	178	1800	22.15	20.92	22.08	Use probe 1
T1	178	1900	22.02	20.96	21.8	Use probe 1
T1	178	2000	21.81	20.91	21.47	Use probe 1
T1	178	2100	21.49	20.81	21.02	Use probe 1
T1	178	2200	21.09	20.64	20.65	Use probe 1
T1	179	1300	20.18	19.45	20.52	Use probe 1
T1	179	1400	21.04	20.37	21.48	Use probe 1
T1	179	1500	21.95	21.32	21.77	Use probe 1
T1	179	1600	21.89	21.38	21.7	Use probe 1
T1	179	1700	21.82	21.36	21.57	Use probe 1
T1	179	1800	21.6	21.2	21.33	Use probe 1
T1	180	1200	19	18.3	20.07	Use probe 1
T1	180	1300	20.39	18.99	21.45	Use probe 1
T1	180	1400	22.13	20.19	22.65	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	180	1500	23.07	21.39	22.7	Use probe 1
T1	180	1600	22.79	21.69	22.43	Use probe 1
T1	180	1700	22.51	21.69	22.12	Use probe 1
T1	180	1800	22.14	21.54	21.9	Use probe 1
T1	180	1900	22	21.38	21.57	Use probe 1
T1	180	2000	21.63	21.2	21.05	Use probe 1
T1	181	1100	18.77	17.9	19.68	Use probe 1
T1	181	1200	20.23	18.62	21.32	Use probe 1
T1	181	1300	21.96	19.72	22.65	Use probe 1
T1	181	1400	23.52	20.95	23.88	Use probe 1
T1	181	1500	24.48	22.13	24.05	Use probe 1
T1	181	1600	24.2	22.42	23.77	Use probe 1
T1	181	1700	23.96	22.5	23.5	Use probe 1
T1	181	1800	23.66	22.45	23.17	Use probe 1
T1	181	1900	23.31	22.32	22.75	Use probe 1
T1	181	2000	22.87	22.14	22.25	Use probe 1
T1	181	2100	22.3	21.88	21.75	Use probe 1
T1	182	1000	20.44	19.89	20.85	Use probe 1
T1	182	1100	21.22	20.36	21.32	Use probe 1
T1	182	1200	21.73	20.71	22.3	Use probe 1
T1	182	1300	22.98	21.43	23.42	Use probe 1
T1	182	1400	24.08	22.19	24.03	Use probe 1
T1	182	1500	24.41	22.66	24.15	Use probe 1
T1	182	1600	24.49	22.9	24.2	Use probe 1
T1	182	1700	24.56	23.06	24.2	Use probe 1
T1	182	1800	24.44	23.1	24.03	Use probe 1
T1	182	1900	24.29	23.1	23.72	Use probe 1
T1	182	2000	23.94	23.03	23.33	Use probe 1
T1	182	2100	23.52	22.85	22.88	Use probe 1
T1	183	1000	21.75	21.17	21.82	Use probe 1
T1	183	1100	22.12	21.39	22.35	Use probe 1
T1	183	1200	22.68	21.74	22.95	Use probe 1
T1	183	1300	23.31	22.21	23.5	Use probe 1
T1	183	1400	23.87	22.7	24.05	Use probe 1
T1	183	1500	24.31	23.2[illegible]	24.25	Use probe 1
T1	183	1600	24.41	[illegible]	24.28	Use probe 1
T1	183	1700	[illegible]	23.54	24.28	Use probe 1
T1	183	1800	24.51	23.57	24.22	Use probe 1
T1	183	1900	24.27	23.55	23.87	Use probe 1
T1	183	2000	23.81	23.36	23.22	Use probe 1
T1	184	1000	18.98	18.52	18.72	Use probe 1
T1	184	1100	19.76	18.8	19.27	Use probe 1
T1	184	1200	20.43	19.25	19.87	Use probe 1
T1	184	1300	21.01	19.78	20.68	Use probe 1
T1	184	1400	22.28	20.71	22.07	Use probe 1
T1	184	1500	23.84	21.89	22.53	Use probe 1
T1	184	1600	22.65	22.06	22.13	Use probe 1
T1	184	1700	22.13	21.73	21.9	Use probe 1
T1	185	100	18.28	18.72	17.9	Use probe 1
T1	185	200	17.74	18.27	17.37	Use probe 1
T1	185	300	17.23	17.81	16.9	Use probe 1
T1	185	400	16.79	17.43	16.48	Use probe 1
T1	185	500	16.35	17.04	16.07	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	186	1200	18.38	17.89	18.22	Use probe 1
T1	186	1300	18.68	18.12	18.78	Use probe 1
T1	186	1400	19.29	18.52	19.78	Use probe 1
T1	186	1500	20.34	19.44	20.38	Use probe 1
T1	186	1600	20.63	19.79	20.48	Use probe 1
T1	186	1700	20.78	20.02	20.5	Use probe 1
T1	186	1800	20.71	19.96	20.38	Use probe 1
T1	186	1900	20.63	19.91	20.27	Use probe 1
T1	186	2000	20.53	19.84	20.08	Use probe 1
T1	186	2100	20.27	19.8	19.68	Use probe 1
T1	187	1000	17.64	17.23	18.4	Use probe 1
T1	187	1100	18.7	17.69	19.5	Use probe 1
T1	187	1200	19.85	18.31	20.57	Use probe 1
T1	187	1300	21.06	19.06	21.68	Use probe 1
T1	187	1400	22.69	20.14	22.82	Use probe 1
T1	187	1500	23.69	21.33	22.98	Use probe 1
T1	187	1600	23.38	21.7	22.65	Use probe 1
T1	187	1700	22.95	21.74	22.32	Use probe 1
T1	187	1800	22.53	21.65	21.92	Use probe 1
T1	187	1900	22.1	21.43	21.55	Use probe 1
T1	187	2000	21.69	21.2	21.18	Use probe 1
T1	188	1200	20.83	20.35	21.03	Use probe 1
T1	188	1300	21.67	21.08	22.13	Use probe 1
T1	188	1400	22.87	21.89	23.27	Use probe 1
T1	188	1500	23.85	22.89	23.58	Use probe 1
T1	188	1600	23.86	23.12	23.3	Use probe 1
T1	188	1700	23.4	22.98	22.9	Use probe 1
T1	189	1100	19.67	19.08	20.17	Use probe 1
T1	189	1200	20.44	19.46	20.88	Use probe 1
T1	189	1300	21.43	20.05	21.88	Use probe 1
T1	189	1400	22.63	21.49	22.73	Use probe 1
T1	189	1500	23.32	22.56	22.98	Use probe 1
T1	189	1600	23.25	22.54	22.9	Use probe 1
T1	189	1700	23.12	22.37	22.75	Use probe 1
T1	189	1800	22.99	22.27	22.58	Use probe 1
T1	189	1900	22.81	22.16	22.42	Use probe 1
T1	189	2000	22.63	22.05	22.13	Use probe 1
T1	190	1100	19.06	18.65	20.3	Use probe 1
T1	190	1200	20.43	19.28	21.62	Use probe 1
T1	190	1300	21.84	20.17	22.42	Use probe 1
T1	190	1400	22.68	21.01	22.6	Use probe 1
T1	190	1500	22.86	21.45	22.55	Use probe 1
T1	190	1600	22.71	21.61	22.3	Use probe 1
T1	190	1700	22.61	21.7	22.23	Use probe 1
T1	190	1800	22.42	21.66	21.93	Use probe 1
T1	190	1900	22.14	21.56	21.6	Use probe 1
T1	191	1300	23.94	23.43	24.47	Use probe 1
T1	191	1400	25.02	24.45	25.22	Use probe 1
T1	191	1500	25.52	25.03	25.38	Use probe 1
T1	192	1200	21.82	21.14	22.73	Use probe 1
T1	192	1300	22.8	21.78	23.6	Use probe 1
T1	192	1400	23.77	22.64	24.55	Use probe 1
T1	192	1500	24.75	23.68	24.97	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	192	1600	24.8	23.86	25.05	Use probe 1
T1	192	1700	24.92	23.93	25.18	Use probe 1
T1	192	1800	25.01	24.01	25.1	Use probe 1
T1	192	1900	24.87	23.99	24.9	Use probe 1
T1	192	2000	24.79	23.97	24.58	Use probe 1
T1	192	2100	24.57	23.99	24.22	Use probe 1
T1	193	1200	23.39	22.89	23.73	Use probe 1
T1	193	1300	23.99	23.3	24.5	Use probe 1
T1	193	1400	25.09	24.5	25.03	Use probe 1
T1	193	1500	25.33	24.87	24.88	Use probe 1
T1	194	1800	21.98	21.58	21.98	Use probe 1
T1	195	1300	23.96	23.51	24.23	Use probe 1
T1	195	1400	24.74	24.26	24.98	Use probe 1
T1	195	1500	25.22	24.79	25.12	Use probe 1
T1	195	1600	25.24	24.79	25.2	Use probe 1
T1	196	1100	22.5	21.9	23.22	Use probe 1
T1	196	1200	23.31	22.37	24.02	Use probe 1
T1	196	1300	24.18	23.02	25.07	Use probe 1
T1	196	1400	25.69	24.32	26.15	Use probe 1
T1	196	1500	26.62	25.38	26.42	Use probe 1
T1	196	1600	26.43	25.44	26.23	Use probe 1
T1	196	1700	26.3	25.4	26.08	Use probe 1
T1	196	1800	26.17	25.33	25.92	Use probe 1
T1	196	1900	26.04	25.25	25.67	Use probe 1
T1	196	2000	25.78	25.16	25.3	Use probe 1
T1	197	1300	24.5	23.94	24.72	Use probe 1
T1	197	1400	25.03	24.31	25.58	Use probe 1
T1	197	1500	26.1	25.19	26.18	Use probe 1
T1	197	1600	26.13	25.4	25.8	Use probe 1
T1	197	1700	25.84	25.34	24.85	Use probe 1
T1	202	1200	21.47	21.05	22.48	Use probe 1
T1	202	1300	22.14	21.48	23.45	Use probe 1
T1	202	1400	23.49	22.4	24.67	Use probe 1
T1	202	1500	24.8	23.58	25.13	Use probe 1
T1	202	1600	24.67	23.88	25.28	Use probe 1
T1	202	1700	24.81	24.02	25.15	Use probe 1
T1	202	1800	24.84	24.13	24.95	Use probe 1
T1	202	1900	24.71	24.17	24.63	Use probe 1
T1	203	1300	22.71	22.26	23.18	Use probe 1
T1	203	1400	23.55	22.98	23.85	Use probe 1
T1	203	1500	24.07	23.53	24.13	Use probe 1
T1	203	1600	24.09	23.61	24.07	Use probe 1
T1	203	1700	24.05	23.61	23.98	Use probe 1
T1	204	1300	21.52	21.05	22.1	Use probe 1
T1	204	1400	22.45	21.77	22.8	Use probe 1
T1	204	1500	23.24	22.44	23.12	Use probe 1
T1	204	1600	23.19	22.68	23.02	Use probe 1
T1	204	1700	23.09	22.68	22.88	Use probe 1
T1	211	1200	19.3	18.83	20.32	Use probe 1
T1	211	1300	19.93	19.32	21.43	Use probe 1
T1	211	1400	20.98	20.58	22.73	Use probe 1
T1	211	1600	22.48	21.97	23.22	Use probe 1
T1	211	1700	22.65	22.06	23.2	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	211	1800	22.8	22.4	22.98	Use probe 1
T1	212	1600	23.5	23.03	23.35	Use probe 1
T1	212	1700	23.67	23.11	23.4	Use probe 1
T1	212	1800	23.75	23.14	23.27	Use probe 1
T1	212	1900	23.68	23.1	23.13	Use probe 1
T1	213	1500	22.79	22.36	22.88	Use probe 1
T1	218	1600	23.05	22.62	22.5	Use probe 1
T1	219	1200	18.74	18.18	19	Use probe 1
T1	219	1300	19.82	19.14	20.13	Use probe 1
T1	219	1400	21.13	20.48	21.48	Use probe 1
T1	219	1500	22.24	21.76	21.97	Use probe 1
T1	219	1600	22.61	22.03	22.17	Use probe 1
T1	219	1700	22.82	22.14	22.27	Use probe 1
T1	219	1800	22.89	22.22	22.22	Use probe 1
T1	219	1900	22.69	22.23	22	Use probe 1
T1	220	1100	18.85	18.3	19.08	Use probe 1
T1	220	1200	20.36	19.44	20.08	Use probe 1
T1	220	1300	21.44	20.49	21.07	Use probe 1
T1	220	1400	22.36	21.63	22.22	Use probe 1
T1	220	1500	23.12	22.64	22.5	Use probe 1
T1	220	1600	23.19	22.69	22.3	Use probe 1
T1	221	1300	18.87	18.47	18.77	Use probe 1
T1	221	1400	19.69	19.18	19.43	Use probe 1
T1	221	1500	20.25	19.72	19.7	Use probe 1
T1	221	1600	20.42	19.91	19.83	Use probe 1
T1	221	1700	20.5	20.03	19.9	Use probe 1
T1	221	1800	20.5	20.09	19.88	Use probe 1
T1	222	1300	22.22	21.75	22.33	Use probe 1
T1	222	1400	23.46	23.06	23.58	Use probe 1
T1	224	1100	21.46	21.04	21.45	Use probe 1
T1	224	1200	22.37	21.84	22.07	Use probe 1
T1	224	1300	23.32	22.66	22.72	Use probe 1
T1	235	1400	18.5	17.98	19.03	Use probe 1
T1	235	1500	19.17	18.71	19.53	Use probe 1
T1	235	1600	19.58	19.13	19.85	Use probe 1
T1	235	1700	19.84	19.4	19.9	Use probe 1
T1	236	1100	17.36	16.9	18.33	Use probe 1
T1	236	1200	18.01	17.4	19.02	Use probe 1
T1	236	1300	18.61	17.94	19.85	Use probe 1
T1	236	1400	19.25	18.73	20.7	Use probe 1
T1	236	1500	20	19.44	21.17	Use probe 1
T1	236	1600	20.65	19.98	21.4	Use probe 1
T1	236	1700	21.09	20.38	21.4	Use probe 1
T1	236	1800	21.4	20.61	21.35	Use probe 1
T1	236	1900	21.43	20.82	21.1	Use probe 1
T1	237	1300	19.21	18.77	20	Use probe 1
T1	237	1400	20.01	19.54	20.72	Use probe 1
T1	237	1500	20.76	20.29	21.27	Use probe 1
T1	237	1600	21.29	20.77	21.45	Use probe 1
T1	237	1700	21.51	21.02	21.57	Use probe 1
T1	237	1800	21.53	21.18	21.52	Use probe 1
T1	237	1900	21.59	21.17	21.35	Use probe 1
T1	238	1300	20.53	20.04	21.07	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	238	1400	21.44	20.89	21.77	Use probe 1
T1	238	1500	22.08	21.44	22.15	Use probe 1
T1	238	1600	22.52	21.87	22.28	Use probe 1
T1	238	1700	22.64	22.01	22.37	Use probe 1
T1	238	1800	22.71	22.13	22.4	Use probe 1
T1	238	1900	22.69	22.19	22.32	Use probe 1
T1	238	2000	22.59	22.19	22.1	Use probe 1
T1	239	1200	21.71	21.27	22	Use probe 1
T1	239	1300	22.44	21.92	22.57	Use probe 1
T1	239	1400	23.15	22.61	23.22	Use probe 1
T1	239	1500	23.82	23.21	23.7	Use probe 1
T1	239	1600	24.27	23.55	23.82	Use probe 1
T1	239	1700	24.33	23.75	24	Use probe 1
T1	239	1800	24.43	23.95	23.88	Use probe 1
T1	239	1900	24.28	23.84	23.63	Use probe 1
T1	240	1200	22.35	21.87	22.87	Use probe 1
T1	240	1300	23.16	22.63	23.45	Use probe 1
T1	240	1400	23.82	23.23	23.92	Use probe 1
T1	240	1500	24.25	23.69	24.27	Use probe 1
T1	240	1600	24.65	24.07	24.2	Use probe 1
T1	240	1700	24.49	24.05	23.97	Use probe 1
T1	241	1100	22.46	22.03	22.9	Use probe 1
T1	241	1200	23.08	22.68	23.22	Use probe 1
T1	241	1300	23.51	23.06	23.53	Use probe 1
T1	241	1400	23.93	23.49	23.95	Use probe 1
T1	241	1500	24.34	23.92	24.25	Use probe 1
T1	243	1300	17.58	17.18	18	Use probe 1
T1	243	1400	18.42	17.99	19.03	Use probe 1
T1	243	1500	19.36	18.95	19.58	Use probe 1
T1	243	1600	19.84	19.44	19.58	Use probe 1
T1	246	1200	16.15	16.62	0.47	Use probe 1
T1	246	1300	17.08	17.63	0.55	Use probe 1
T1	246	1400	17.95	18.5	0.55	Use probe 1
T1	246	1500	18.29	18.72	0.43	Use probe 1
T1	247	1100	17.89	18.34	0.45	Use probe 1
T1	247	1200	18.56	19.14	0.58	Use probe 1
T1	247	1300	19.21	19.82	0.61	Use probe 1
T1	247	1400	19.69	20.24	0.55	Use probe 1
T1	247	1500	20.11	20.71	0.6	Use probe 1
T1	247	1600	20.51	20.98	0.47	Use probe 1
T1	248	900	18.74	19.14	0.4	Use probe 1
T1	248	1000	19.33	19.81	0.48	Use probe 1
T1	248	1100	19.92	20.43	0.51	Use probe 1
T1	248	1200	20.48	21	0.52	Use probe 1
T1	248	1300	21.06	21.69	0.63	Use probe 1
T1	248	1400	21.68	22.34	0.66	Use probe 1
T1	248	1500	22.24	22.86	0.62	Use probe 1
T1	248	1600	22.46	22.96	0.5	Use probe 1
T1	262	1400	20.54	20.95	0.41	Use Average
T1	263	700	18.71	18.25	0.46	Use probe 1
T1	263	2000	15.89	15.[illegible]5	0.64	Use probe 1
T1	263	2100	15.06	14.21	0.85	Use probe 1
T1	263	2200	14.52	13.71	0.81	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	263	2300	13.58	12.68	0.9	Use probe 1
T1	264	0	12.9	11.97	0.93	Use probe 1
T1	264	100	12.32	11.41	0.91	Use probe 1
T1	264	200	11.78	11.02	0.76	Use probe 1
T1	264	300	11.15	10.5	0.65	Use probe 1
T1	264	400	10.61	10.07	0.54	Use probe 1
T1	264	500	10.23	9.71	0.52	Use probe 1
T1	264	600	10.33	9.68	0.65	Use probe 1
T1	264	700	10.04	9.48	0.56	Use probe 1
T1	264	1400	17.74	18.75	1.01	Use probe 1
T1	264	1500	17.62	18.73	1.11	Use probe 1
T1	264	1600	17.4	18.39	0.99	Use probe 1
T1	264	1700	17.19	18.03	0.84	Use probe 1
T1	264	1800	16.58	17.01	0.43	Use probe 1
T1	265	1100	16.61	17.28	0.67	Use Probe 2
T1	265	1200	17.47	18.4	0.93	Use Probe 2
T1	265	1300	17.79	18.71	0.92	Use Probe 2
T1	265	1400	18.31	19.31	1	Use Probe 2
T1	265	1500	18.41	19.32	0.91	Use Probe 2
T1	265	1600	18.12	18.81	0.69	Use Probe 2
T1	265	1700	17.93	18.42	0.49	Use Probe 2
T1	265	1800	17.77	18.19	0.42	Use Probe 2
T1	266	800	18.53	18.93	0.4	Use Probe 2
T1	266	900	18.82	19.25	0.43	Use Probe 2
T1	266	1000	19.38	19.92	0.54	Use Probe 2
T1	266	1100	19.87	20.5	0.63	Use Probe 2
T1	266	1200	20.6	21.42	0.82	Use Probe 2
T1	266	1300	21.32	22.3	0.98	Use Probe 2
T1	266	1400	21.94	23.05	1.11	Use Probe 2
T1	266	1500	22.54	23.78	1.24	Use Probe 2
T1	266	1600	22.27	23.25	0.98	Use Probe 2
T1	266	1700	21.99	22.8	0.81	Use Probe 2
T1	266	1800	21.5	22.05	0.55	Use Probe 2
T1	266	1900	21.14	21.56	0.42	Use Probe 2
T1	267	100	18.4	18	0.4	Use probe 1
T1	267	200	16.69	15.86	0.83	Use probe 1
T1	267	300	15.9	15.09	0.81	Use probe 1
T1	267	400	14.76	13.72	1.04	Use probe 1
T1	267	500	13.52	12.34	1.18	Use probe 1
T1	267	600	12.97	11.86	1.11	Use probe 1
T1	267	700	12.31	11.22	1.09	Use probe 1
T1	267	800	12.35	11.58	0.77	Use probe 1
T1	267	900	12.59	12.05	0.54	Use probe 1
T1	267	1000	12.46	11.92	0.54	Use probe 1
T1	267	1500	14.8	15.22	0.42	Use Probe 2
T1	267	1600	14.68	15.23	0.55	Use Probe 2
T1	267	1700	14.46	15.02	0.56	Use Probe 2
T1	267	2200	11.33	10.9	0.43	Use Probe 2
T1	267	2300	10.98	10.55	0.43	Use Probe 2
T1	268	0	10.63	10.16	0.47	Use Probe 2
T1	268	100	10.15	9.62	0.53	Use Probe 2
T1	268	200	9.54	8.95	0.59	Use Probe 2
T1	268	300	9.2	8.61	0.59	Use Probe 2

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T1	268	400	8.97	8.38	0.59	Use Probe 2
T1	268	500	8.83	8.29	0.54	Use Probe 2
T1	268	600	8.49	7.88	0.61	Use Probe 2
T1	268	700	8.27	7.68	0.59	Use Probe 2
T1	268	1400	13.8	14.45	0.65	Use probe 1
T1	268	1500	13.81	14.41	0.6	Use probe 1
T1	268	1600	13.73	14.28	0.55	Use probe 1
T1	268	1700	13.63	14.23	0.6	Use probe 1
T1	268	2000	10.69	10.29	0.4	Use Average
T1	268	2100	9.76	9.25	0.51	Use Average
T1	268	2200	9.11	8.56	0.55	Use Average
T1	268	2300	8.62	8.08	0.54	Use Average
T1	269	0	8.28	7.74	0.54	Use Average
T1	269	100	8.03	7.52	0.51	Use Average
T1	269	200	7.6	7.01	0.59	Use Average
T1	269	300	7.86	7.38	0.48	Use Average

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T4	270	500	16.45	15.97	0.48	Use Average
T4	270	600	16.32	15.85	0.47	Use Average

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T5	157	1800	17.25	16.17	16.8	Use probe 1
T5	157	1900	17.16	15.41	16.7	Use probe 1
T5	157	2000	17.05	15.53	16.55	Use probe 1
T5	157	2100	16.93	16.38	16.5	Use probe 1
T5	157	2200	16.89	15.91	16.5	Use probe 1
T5	157	2300	16.89	16.49	16.47	Use probe 1
T5	164	500	18.14	16.85	17.72	Use probe 1
T5	167	2000	22.3	21.08	21.62	Use probe 1
T5	167	2100	21.81	20.31	21.25	Use probe 1
T5	167	2200	21.46	20.77	20.92	Use probe 1
T5	167	2300	21.19	20.76	20.8	Use probe 1
T5	168	100	21.01	20.57	20.73	Use probe 1
T5	168	200	20.99	19.97	20.73	Use probe 1
T5	168	1500	24.5	23.16	24.18	Use probe 1
T5	168	1600	24.33	23.62	23.63	Use probe 1
T5	168	1700	23.81	22.63	23.07	Use probe 1
T5	168	1800	23.23	22.5	22.43	Use probe 1
T5	168	1900	22.55	20.1	21.85	Use probe 1
T5	168	2100	21.65	21.24	20.67	Use probe 1
T5	172	2000	21.32	20.05	20.68	Use probe 1
T5	172	2100	20.91	19.6	20.38	Use probe 1
T5	181	1900	22.62	22.15	22	Use probe 1
T5	183	1800	24.65	23.83	24.07	Use probe 1
T5	185	1000	21.01	20.33	20.82	Use probe 1
T5	185	1100	21.2	20.32	21.03	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T5	185	1500	21.32	20.88	21.1	Use probe 1
T5	185	1800	21.06	20.17	20.67	Use probe 1
T5	191	1100	23.51	23	23.63	Use probe 1
T5	191	1200	23.88	23.41	23.9	Use probe 1
T5	194	1800	22.96	22.08	22.7	Use probe 1
T5	194	1900	22.92	22.03	22.63	Use probe 1
T5	194	2000	22.88	22.03	22.6	Use probe 1
T5	194	2100	22.87	22.07	22.6	Use probe 1
T5	194	2200	22.87	22.15	22.58	Use probe 1
T5	194	2300	22.76	22.3	22.42	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T6	196	1300	25.09	24.62	25.43	Use probe 1
T6	196	1400	25.86	25.38	26.03	Use probe 1
T6	196	1500	26.33	25.88	26.22	Use probe 1
T6	197	1300	24.93	24.49	25.08	Use probe 1
T6	197	1400	25.4	24.98	25.52	Use probe 1
T6	197	1500	25.83	25.43	25.82	Use probe 1
T6	201	1200	23.03	22.58	23.17	Use probe 1
T6	201	1300	23.66	23.16	23.93	Use probe 1
T6	201	1400	24.45	23.82	24.55	Use probe 1
T6	201	1500	24.89	24.34	24.8	Use probe 1
T6	201	1600	25.08	24.58	25	Use probe 1
T6	202	1100	22.72	22.29	22.92	Use probe 1
T6	202	1200	23.5	22.95	23.83	Use probe 1
T6	202	1300	24.36	23.7	24.58	Use probe 1
T6	202	1400	25.04	24.37	25.08	Use probe 1
T6	202	1500	25.38	24.8	25.28	Use probe 1
T6	202	1600	25.41	24.96	25.18	Use probe 1
T6	203	1200	23.23	22.83	23.42	Use probe 1
T6	203	1300	23.98	23.46	24.12	Use probe 1
T6	203	1400	24.53	24	24.55	Use probe 1
T6	203	1500	24.93	24.43	24.83	Use probe 1
T6	203	1600	25.05	24.64	24.78	Use probe 1
T6	204	1200	22.54	22.1	22.67	Use probe 1
T6	204	1300	23.17	22.63	23.42	Use probe 1
T6	204	1400	23.85	23.22	23.87	Use probe 1
T6	204	1500	24.22	23.68	24.17	Use probe 1
T6	204	1600	24.44	23.86	24.2	Use probe 1
T6	207	1500	21.88	21.48	21.83	Use probe 1
T6	209	1200	22.76	22.34	22.8	Use probe 1
T6	209	1300	23.13	22.65	23.02	Use probe 1
T6	209	1400	23.27	22.83	23.2	Use probe 1
T6	209	1500	23.46	23.02	23.23	Use probe 1
T6	210	1200	21.99	21.59	22.13	Use probe 1
T6	210	1300	22.62	22.08	22.57	Use probe 1
T6	210	1400	22.9	22.45	22.78	Use probe 1
T6	210	1500	23.17	22.69	23.07	Use probe 1
T6	210	1600	23.28	22.86	23.07	Use probe 1
T6	211	1100	21.29	20.87	21.6	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T6	211	1200	22.2	21.62	22.55	Use probe 1
T6	211	1300	23.17	22.4	23.45	Use probe 1
T6	211	1400	23.98	23.24	24.13	Use probe 1
T6	211	1500	24.49	23.87	24.47	Use probe 1
T6	211	1600	24.66	24.11	24.42	Use probe 1
T6	211	1700	24.56	24.12	24.18	Use probe 1
T6	212	1200	22.7	22.26	22.82	Use probe 1
T6	212	1300	23.28	22.71	23.45	Use probe 1
T6	212	1400	23.94	23.26	24	Use probe 1
T6	212	1500	24.31	23.71	24.18	Use probe 1
T6	212	1600	24.41	23.91	24.18	Use probe 1
T6	213	1200	22.71	22.28	22.83	Use probe 1
T6	213	1300	23.24	22.7	23.28	Use probe 1
T6	213	1400	23.68	23.1	23.65	Use probe 1
T6	213	1500	23.97	23.41	23.9	Use probe 1
T6	213	1600	24.21	23.69	24	Use probe 1
T6	213	1700	24.2	23.8	23.9	Use probe 1
T6	214	1100	22.52	22.11	22.63	Use probe 1
T6	214	1200	23.23	22.66	23.35	Use probe 1
T6	214	1300	23.91	23.21	24.05	Use probe 1
T6	214	1400	24.58	23.85	24.67	Use probe 1
T6	214	1500	25.04	24.36	25	Use probe 1
T6	214	1600	25.22	24.6	25	Use probe 1
T6	214	1700	25.09	24.65	24.77	Use probe 1
T6	215	1100	23.12	22.58	23.32	Use probe 1
T6	215	1200	23.88	23.19	24.05	Use probe 1
T6	215	1300	24.56	23.83	24.73	Use probe 1
T6	215	1400	25.06	24.33	25.08	Use probe 1
T6	215	1500	25.33	24.67	25.23	Use probe 1
T6	215	1600	25.29	24.77	24.98	Use probe 1
T6	216	1100	23.61	23.1	23.68	Use probe 1
T6	216	1200	24.07	23.53	24.08	Use probe 1
T6	216	1300	24.48	23.9	24.52	Use probe 1
T6	216	1400	24.75	24.2	24.6	Use probe 1
T6	216	1500	24.81	24.32	24.73	Use probe 1
T6	216	1600	24.89	24.44	24.7	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T8	202	1500	24.34	24.75	24.12	Use probe 1
T8	202	1600	24.95	25.39	24.82	Use probe 1
T8	202	1700	25.52	25.92	25.52	Use probe 1
T8	211	1500	23.13	23.56	22.97	Use probe 1
T8	223	1500	24.68	25.1	24.6	Use probe 1
T8	223	1600	25.29	25.79	25.28	Use probe 1
T8	223	1700	26.06	26.49	26	Use probe 1
T8	240	1300	25.1	25.52	25.18	Use probe 2
T8	240	1400	25.58	26.03	25.75	Use probe 2
T8	240	1500	25.99	26.46	26.23	Use probe 2
T8	240	1600	26.3	26.74	26.62	Use probe 2
T8	240	1700	26.54	26.98	26.83	Use probe 2

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T8	240	1800	26.77	27.17	27.03	Use probe 2
T8	252	1600	23.2	23.62	0.42	Use Average
T8	253	1300	22.36	22.77	0.41	Use Probe 2
T8	253	1400	22.87	23.38	0.51	Use Probe 2
T8	253	1500	23.36	23.93	0.57	Use Probe 2
T8	253	1600	23.76	24.32	0.56	Use Probe 2
T8	253	1700	24.03	24.54	0.51	Use Probe 2
T8	253	1800	24.12	24.55	0.43	Use Probe 2
T8	254	1200	23.09	23.49	0.4	Use Probe 2
T8	254	1300	23.46	23.95	0.49	Use Probe 2
T8	254	1400	23.82	24.36	0.54	Use Probe 2
T8	254	1500	24.12	24.69	0.57	Use Probe 2
T8	254	1600	24.4	24.97	0.57	Use Probe 2
T8	254	1700	24.58	25.09	0.51	Use Probe 2
T8	254	1800	24.67	25.13	0.46	Use Probe 2
T8	254	1900	24.7	25.1	0.4	Use Probe 2
T8	255	1400	23.45	23.87	0.42	Use Probe 2
T8	255	1500	23.82	24.28	0.46	Use Probe 2
T8	255	1600	24.1	24.53	0.43	Use Probe 2
T8	256	1500	22.26	22.68	0.42	Use Probe 2
T8	256	1600	22.6	23.01	0.41	Use Probe 2
T8	257	1600	21.71	22.12	0.41	Use Probe 2
T8	258	1600	21.89	22.3	0.41	Use Probe 2
T8	259	1500	21.14	21.58	0.44	Use Probe 2
T8	259	1600	21.53	22.03	0.5	Use Probe 2
T8	259	1700	21.85	22.31	0.46	Use Probe 2
T8	259	1800	22.02	22.42	0.4	Use Probe 2
T8	260	1400	21.08	21.58	0.5	Use Probe 2
T8	260	1500	21.66	22.25	0.59	Use Probe 2
T8	260	1600	22.17	22.82	0.65	Use Probe 2
T8	260	1700	22.54	23.16	0.62	Use Probe 2
T8	260	1800	22.79	23.33	0.54	Use Probe 2
T8	260	1900	22.89	23.35	0.46	Use Probe 2
T8	261	1400	21.86	22.27	0.41	Use Probe 2
T8	261	1500	22.43	22.89	0.46	Use Probe 2
T8	261	1600	22.87	23.34	0.47	Use Probe 2
T8	261	1700	23.14	23.59	0.45	Use Probe 2
T8	261	1800	23.29	23.7	0.41	Use Probe 2
T8	262	1300	21.7	22.21	0.51	Use Probe 2
T8	262	1400	22.2	22.82	0.62	Use Probe 2
T8	262	1500	22.63	23.35	0.72	Use Probe 2
T8	262	1600	22.98	23.73	0.75	Use Probe 2
T8	262	1700	23.28	23.94	0.66	Use Probe 2
T8	262	1800	23.42	23.98	0.56	Use Probe 2
T8	262	1900	23.47	23.96	0.49	Use Probe 2
T8	268	200	18.72	18.31	0.41	Use Probe 2
T8	268	300	18.41	18	0.41	Use Probe 2
T8	268	400	18.14	17.73	0.41	Use Probe 2
T8	268	500	17.91	17.51	0.4	Use Probe 2
T8	276	100	14.2	13.8	0.4	Use Probe 2
T8	276	200	13.95	13.54	0.41	Use Probe 2
T8	276	300	13.73	13.32	0.41	Use Probe 2
T8	276	400	13.56	13.14	0.42	Use Probe 2

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T8	276	500	13.39	12.98	0.41	Use Probe 2
T8	276	600	13.26	12.85	0.41	Use Probe 2

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	246	1200	21.06	20.47	0.59	Use probe 1
T9	246	1300	21.36	16.58	4.78	Use probe 1
T9	246	1400	21.65	16.88	4.77	Use probe 1
T9	246	1500	21.84	17.06	4.78	Use probe 1
T9	246	1600	22.05	17.19	4.86	Use probe 1
T9	246	1700	22.28	17.4	4.88	Use probe 1
T9	246	1800	22.51	17.67	4.84	Use probe 1
T9	246	1900	22.72	17.86	4.86	Use probe 1
T9	246	2000	22.87	17.98	4.89	Use probe 1
T9	246	2100	22.96	18.06	4.9	Use probe 1
T9	246	2200	22.93	18.04	4.89	Use probe 1
T9	246	2300	22.83	17.99	4.84	Use probe 1
T9	247	0	22.65	17.85	4.8	Use probe 1
T9	247	100	22.42	17.67	4.75	Use probe 1
T9	247	200	22.19	17.47	4.72	Use probe 1
T9	247	300	21.94	17.28	4.66	Use probe 1
T9	247	400	21.7	17.09	4.61	Use probe 1
T9	247	500	21.5	16.93	4.57	Use probe 1
T9	247	600	21.33	16.8	4.53	Use probe 1
T9	247	700	21.24	16.72	4.52	Use probe 1
T9	247	800	21.19	16.68	4.51	Use probe 1
T9	247	900	21.18	16.67	4.51	Use probe 1
T9	247	1000	21.21	16.72	4.49	Use probe 1
T9	247	1100	21.33	16.81	4.52	Use probe 1
T9	247	1200	21.49	16.94	4.55	Use probe 1
T9	247	1300	21.66	17.07	4.59	Use probe 1
T9	247	1400	21.9	17.25	4.65	Use probe 1
T9	247	1500	22.1	17.42	4.68	Use probe 1
T9	247	1600	22.31	17.59	4.72	Use probe 1
T9	247	1700	22.45	17.71	4.74	Use probe 1
T9	247	1800	22.58	17.79	4.79	Use probe 1
T9	247	1900	22.68	17.84	4.84	Use probe 1
T9	247	2000	22.75	17.92	4.83	Use probe 1
T9	247	2100	22.76	17.96	4.8	Use probe 1
T9	247	2200	22.77	17.97	4.8	Use probe 1
T9	247	2300	22.77	17.97	4.8	Use probe 1
T9	248	0	22.69	17.91	4.78	Use probe 1
T9	248	100	22.6	17.85	4.75	Use probe 1
T9	248	200	22.5	17.77	4.73	Use probe 1
T9	248	300	22.35	17.64	4.71	Use probe 1
T9	248	400	22.11	17.44	4.67	Use probe 1
T9	248	500	21.88	17.27	4.61	Use probe 1
T9	248	600	21.71	17.15	4.56	Use probe 1
T9	248	700	21.61	17.06	4.55	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	248	800	21.58	17.04	4.54	Use probe 1
T9	248	900	21.63	17.08	4.55	Use probe 1
T9	248	1000	21.84	17.24	4.6	Use probe 1
T9	248	1100	22.12	17.45	4.67	Use probe 1
T9	248	1200	22.31	17.61	4.7	Use probe 1
T9	248	1300	22.4	-16.66	39.06	Use probe 1
T9	248	1400	22.73	-53.31	76.04	Use probe 1
T9	248	1500	23.05	-53.32	76.37	Use probe 1
T9	248	1600	23.27	-53.31	76.58	Use probe 1
T9	248	1700	23.45	-53.31	76.76	Use probe 1
T9	248	1800	23.56	-53.31	76.87	Use probe 1
T9	248	1900	23.61	-53.31	76.92	Use probe 1
T9	248	2000	23.67	-53.31	76.98	Use probe 1
T9	248	2100	23.75	-53.31	77.06	Use probe 1
T9	248	2200	23.85	-53.31	77.16	Use probe 1
T9	248	2300	23.87	-53.31	77.18	Use probe 1
T9	249	0	23.79	-53.31	77.1	Use probe 1
T9	249	100	23.67	-53.31	76.98	Use probe 1
T9	249	200	23.51	-53.31	76.82	Use probe 1
T9	249	300	23.3	-53.31	76.61	Use probe 1
T9	249	400	23.02	-53.31	76.33	Use probe 1
T9	249	500	22.71	-53.31	76.02	Use probe 1
T9	249	600	22.4	-53.31	75.71	Use probe 1
T9	249	700	22.17	-53.31	75.48	Use probe 1
T9	249	800	22.01	-53.32	75.33	Use probe 1
T9	249	900	21.91	-53.31	75.22	Use probe 1
T9	249	1000	21.97	-53.32	75.29	Use probe 1
T9	249	1100	22.11	-53.31	75.42	Use probe 1
T9	249	1200	22.19	-53.31	75.5	Use probe 1
T9	249	1300	22.32	-53.31	75.63	Use probe 1
T9	249	1400	22.48	-53.31	75.79	Use probe 1
T9	249	1500	22.63	-53.31	75.94	Use probe 1
T9	249	1600	22.72	-53.31	76.03	Use probe 1
T9	249	1700	22.85	-53.31	76.16	Use probe 1
T9	249	1800	22.93	-53.32	76.25	Use probe 1
T9	249	1900	22.94	-53.31	76.25	Use probe 1
T9	249	2000	22.93	-53.31	76.24	Use probe 1
T9	249	2100	22.89	-53.31	76.2	Use probe 1
T9	249	2200	22.79	-53.31	76.1	Use probe 1
T9	249	2300	22.69	-53.31	76	Use probe 1
T9	250	0	22.58	-53.31	75.89	Use probe 1
T9	250	100	22.42	-53.31	75.73	Use probe 1
T9	250	200	22.24	-53.31	75.55	Use probe 1
T9	250	300	22.07	-53.31	75.38	Use probe 1
T9	250	400	21.9	-53.31	75.21	Use probe 1
T9	250	500	21.74	-53.31	75.05	Use probe 1
T9	250	600	21.6	-53.31	74.91	Use probe 1
T9	250	700	21.49	-53.31	74.8	Use probe 1
T9	250	800	21.42	-53.31	74.73	Use probe 1
T9	250	900	21.4	-53.31	74.71	Use probe 1
T9	250	1000	21.42	-53.31	74.73	Use probe 1
T9	250	1100	21.47	-53.31	74.78	Use probe 1
T9	250	1200	21.55	-53.31	74.86	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	250	1300	21.61	-53.31	74.92	Use probe 1
T9	250	1400	21.63	-53.31	74.94	Use probe 1
T9	250	1500	21.67	-53.31	74.98	Use probe 1
T9	250	1600	21.71	-53.31	75.02	Use probe 1
T9	250	1700	21.74	-53.32	75.06	Use probe 1
T9	250	1800	21.78	-53.31	75.09	Use probe 1
T9	250	1900	21.8	-53.31	75.11	Use probe 1
T9	250	2000	21.8	-53.31	75.11	Use probe 1
T9	250	2100	21.79	-53.31	75.1	Use probe 1
T9	250	2200	21.77	-53.31	75.08	Use probe 1
T9	250	2300	21.73	-53.31	75.04	Use probe 1
T9	251	0	21.65	-53.31	74.96	Use probe 1
T9	251	100	21.5	-53.31	74.81	Use probe 1
T9	251	200	21.32	-53.31	74.63	Use probe 1
T9	251	300	21.2	-53.31	74.51	Use probe 1
T9	251	400	21.08	-53.31	74.39	Use probe 1
T9	251	500	20.84	-53.32	74.16	Use probe 1
T9	251	600	20.63	-53.31	73.94	Use probe 1
T9	251	700	20.6	-53.31	73.91	Use probe 1
T9	251	800	20.7	-53.31	74.01	Use probe 1
T9	251	900	20.75	-53.32	74.07	Use probe 1
T9	251	1000	20.81	-53.31	74.12	Use probe 1
T9	251	1100	20.9	-53.31	74.21	Use probe 1
T9	251	1200	21.04	-53.31	74.35	Use probe 1
T9	251	1300	21.3	-53.31	74.61	Use probe 1
T9	251	1400	21.46	-53.31	74.77	Use probe 1
T9	251	1500	21.61	-53.31	74.92	Use probe 1
T9	251	1600	21.69	-53.32	75.01	Use probe 1
T9	251	1700	21.77	-53.32	75.09	Use probe 1
T9	251	1800	21.86	-53.32	75.18	Use probe 1
T9	251	1900	21.93	-53.31	75.24	Use probe 1
T9	251	2000	21.96	-53.31	75.27	Use probe 1
T9	251	2100	21.99	-53.31	75.3	Use probe 1
T9	251	2200	22.01	-53.31	75.32	Use probe 1
T9	251	2300	21.99	-53.31	75.3	Use probe 1
T9	252	0	21.91	-53.31	75.22	Use probe 1
T9	252	100	21.78	-53.31	75.09	Use probe 1
T9	252	200	21.65	-53.31	74.96	Use probe 1
T9	252	300	21.52	-53.31	74.83	Use probe 1
T9	252	400	21.41	-53.31	74.72	Use probe 1
T9	252	500	21.32	-53.32	74.64	Use probe 1
T9	252	600	21.24	-53.32	74.56	Use probe 1
T9	252	700	21.19	-53.31	74.5	Use probe 1
T9	252	800	21.19	-53.31	74.5	Use probe 1
T9	252	900	21.3	-53.31	74.61	Use probe 1
T9	252	1000	21.52	-53.31	74.83	Use probe 1
T9	252	1100	21.79	-53.31	75.1	Use probe 1
T9	252	1200	22.05	-53.31	75.36	Use probe 1
T9	252	1300	22.39	-53.32	75.71	Use probe 1
T9	252	1400	22.73	-53.31	76.04	Use probe 1
T9	252	1500	23.03	-53.32	76.35	Use probe 1
T9	252	1600	23.2	-53.31	76.51	Use probe 1
T9	252	1700	23.33	-53.31	76.64	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	252	1800	23.43	-53.31	76.74	Use probe 1
T9	252	1900	23.52	-53.31	76.83	Use probe 1
T9	252	2000	23.58	-53.32	76.9	Use probe 1
T9	252	2100	23.55	-53.31	76.86	Use probe 1
T9	252	2200	23.44	-53.31	76.75	Use probe 1
T9	252	2300	23.27	-53.32	76.59	Use probe 1
T9	253	0	23	-53.31	76.31	Use probe 1
T9	253	100	22.7	-53.31	76.01	Use probe 1
T9	253	200	22.39	-53.31	75.7	Use probe 1
T9	253	300	22.08	-53.32	75.4	Use probe 1
T9	253	400	21.82	-53.31	75.13	Use probe 1
T9	253	500	21.57	-53.32	74.89	Use probe 1
T9	253	600	21.34	-53.31	74.65	Use probe 1
T9	253	700	21.18	-53.31	74.49	Use probe 1
T9	253	800	21.13	-53.31	74.44	Use probe 1
T9	253	900	21.22	-53.32	74.54	Use probe 1
T9	253	1000	21.4	-53.31	74.71	Use probe 1
T9	253	1100	21.68	-53.31	74.99	Use probe 1
T9	253	1200	22.02	-53.31	75.33	Use probe 1
T9	253	1300	22.46	-53.31	75.77	Use probe 1
T9	253	1400	22.9	-53.32	76.22	Use probe 1
T9	253	1500	23.31	-53.32	76.63	Use probe 1
T9	253	1600	23.58	-53.31	76.89	Use probe 1
T9	253	1700	23.81	-53.31	77.12	Use probe 1
T9	253	1800	23.99	-53.31	77.3	Use probe 1
T9	253	1900	24.14	-53.31	77.45	Use probe 1
T9	253	2000	24.25	-53.31	77.56	Use probe 1
T9	253	2100	24.28	-53.31	77.59	Use probe 1
T9	253	2200	24.22	-53.31	77.53	Use probe 1
T9	253	2300	24.09	-53.31	77.4	Use probe 1
T9	254	0	23.92	-53.32	77.24	Use probe 1
T9	254	100	23.72	-53.31	77.03	Use probe 1
T9	254	200	23.45	-53.31	76.76	Use probe 1
T9	254	300	23.15	-53.32	76.47	Use probe 1
T9	254	400	22.84	-53.31	76.15	Use probe 1
T9	254	500	22.55	-53.31	75.86	Use probe 1
T9	254	600	22.33	-53.32	75.65	Use probe 1
T9	254	700	22.21	-53.31	75.52	Use probe 1
T9	254	800	22.18	-53.32	75.5	Use probe 1
T9	254	900	22.24	-53.31	75.55	Use probe 1
T9	254	1000	22.43	-53.31	75.74	Use probe 1
T9	254	1[illegible]	22.77	-53.31	76.08	Use probe 1
T9	254	1200	23.09	-53.31	76.4	Use probe 1
T9	254	1300	23.51	-53.31	76.82	Use probe 1
T9	254	1400	23.85	-53.31	77.16	Use probe 1
T9	254	1500	24.13	-53.31	77.44	Use probe 1
T9	254	1600	24.4	-53.31	77.71	Use probe 1
T9	254	1700	24.57	-53.31	77.88	Use probe 1
T9	254	1800	24.67	-53.31	77.98	Use probe 1
T9	254	1900	24.75	-53.31	78.06	Use probe 1
T9	254	2000	24.78	-53.32	78.1	Use probe 1
T9	254	2100	24.76	-53.31	78.07	Use probe 1
T9	254	2200	24.69	-53.31	78	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temparature	Action Taken
T9	254	2300	24.52	-53.31	77.83	Use probe 1
T9	255	0	24.26	-53.31	77.57	Use probe 1
T9	255	100	23.98	-53.32	77.3	Use probe 1
T9	255	200	23.6	-53.31	76.91	Use probe 1
T9	255	300	23.24	-53.31	76.55	Use probe 1
T9	255	400	22.94	-53.31	76.25	Use probe 1
T9	255	500	22.7	-53.32	76.02	Use probe 1
T9	255	600	22.53	-53.32	75.85	Use probe 1
T9	255	700	22.4	-53.31	75.71	Use probe 1
T9	255	800	22.32	-53.31	75.63	Use probe 1
T9	255	900	22.33	-53.31	75.64	Use probe 1
T9	255	1000	22.49	-53.31	75.8	Use probe 1
T9	255	1100	22.72	-53.31	76.03	Use probe 1
T9	255	1200	23.04	-53.31	76.35	Use probe 1
T9	255	1300	23.31	-53.31	76.62	Use probe 1
T9	255	1400	23.64	-53.31	76.95	Use probe 1
T9	255	1500	23.87	-53.31	77.18	Use probe 1
T9	255	1600	23.99	-53.32	77.31	Use probe 1
T9	255	1700	23.99	-53.32	77.31	Use probe 1
T9	255	1800	24.01	-53.31	77.32	Use probe 1
T9	255	1900	23.98	-53.31	77.29	Use probe 1
T9	255	2000	23.97	-53.32	77.29	Use probe 1
T9	255	2100	23.9	-53.31	77.21	Use probe 1
T9	255	2200	23.72	-53.31	77.03	Use probe 1
T9	255	2300	23.42	-53.31	76.73	Use probe 1
T9	256	0	23.06	-53.32	76.38	Use probe 1
T9	256	100	22.66	-53.32	75.98	Use probe 1
T9	256	200	22.24	-53.31	75.55	Use probe 1
T9	256	300	21.82	-53.31	75.13	Use probe 1
T9	256	400	21.4	-53.31	74.71	Use probe 1
T9	256	500	21	-53.31	74.31	Use probe 1
T9	256	600	20.64	-53.31	73.95	Use probe 1
T9	256	700	20.36	-53.31	73.67	Use probe 1
T9	256	800	20.17	-53.31	73.48	Use probe 1
T9	256	900	20.14	-53.32	73.46	Use probe 1
T9	256	1000	20.26	-53.31	73.57	Use probe 1
T9	256	1100	20.52	-53.32	73.84	Use probe 1
T9	256	1200	20.92	-53.32	74.24	Use probe 1
T9	256	1300	21.32	-53.31	74.63	Use probe 1
T9	256	1400	21.73	-53.32	75.05	Use probe 1
T9	256	1500	22.05	-53.32	75.37	Use probe 1
T9	256	1600	22.25	-53.31	75.56	Use probe 1
T9	256	1700	22.34	-53.31	75.65	Use probe 1
T9	256	1800	22.42	-53.31	75.73	Use probe 1
T9	256	1900	22.48	-53.31	75.79	Use probe 1
T9	256	2000	22.55	-53.32	75.87	Use probe 1
T9	256	2100	22.56	-53.31	75.87	Use probe 1
T9	256	2200	22.45	-53.32	75.77	Use probe 1
T9	256	2300	22.24	-53.31	75.55	Use probe 1
T9	257	0	21.93	-53.32	75.25	Use probe 1
T9	257	100	21.56	-53.31	74.87	Use probe 1
T9	257	200	21.17	-53.31	74.48	Use probe 1
T9	257	300	20.75	-53.32	74.07	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	257	400	20.32	-53.31	73.63	Use probe 1
T9	257	500	19.9	-53.31	73.21	Use probe 1
T9	257	600	19.54	-53.31	72.85	Use probe 1
T9	257	700	19.25	-53.31	72.56	Use probe 1
T9	257	800	19.07	-53.32	72.39	Use probe 1
T9	257	900	19.08	-53.31	72.39	Use probe 1
T9	257	1000	19.26	-53.31	72.57	Use probe 1
T9	257	1100	19.54	-53.32	72.86	Use probe 1
T9	257	1200	19.84	-53.32	73.16	Use probe 1
T9	257	1300	20.2	-53.31	73.51	Use probe 1
T9	257	1400	20.55	-53.31	73.86	Use probe 1
T9	257	1500	20.92	-53.31	74.23	Use probe 1
T9	257	1600	21.24	-53.32	74.56	Use probe 1
T9	257	1700	21.43	-53.31	74.74	Use probe 1
T9	257	1800	21.58	-53.32	74.9	Use probe 1
T9	257	1900	21.71	-53.31	75.02	Use probe 1
T9	257	2000	21.82	-53.31	75.13	Use probe 1
T9	257	2100	21.92	-53.31	75.23	Use probe 1
T9	257	2200	21.94	-53.32	75.26	Use probe 1
T9	257	2300	21.82	-53.32	75.14	Use probe 1
T9	258	0	21.57	-53.31	74.88	Use probe 1
T9	258	100	21.26	-53.31	74.57	Use probe 1
T9	258	200	20.89	-53.31	74.2	Use probe 1
T9	258	300	20.49	-53.31	73.8	Use probe 1
T9	258	400	20.12	-53.31	73.43	Use probe 1
T9	258	500	19.75	-53.31	73.06	Use probe 1
T9	258	600	19.45	-53.31	72.76	Use probe 1
T9	258	700	19.19	-53.31	72.5	Use probe 1
T9	258	800	19.04	-53.31	72.35	Use probe 1
T9	258	900	19.06	-53.31	72.37	Use probe 1
T9	258	1000	19.25	-53.31	72.56	Use probe 1
T9	258	1100	19.55	-53.31	72.86	Use probe 1
T9	258	1200	19.83	-53.31	73.14	Use probe 1
T9	258	1300	20.23	-53.31	73.54	Use probe 1
T9	258	1400	20.62	-53.31	73.93	Use probe 1
T9	258	1500	20.98	-53.31	74.29	Use probe 1
T9	258	1600	21.29	-53.32	74.61	Use probe 1
T9	258	1700	21.49	53.3	74.79	Use probe 1
T9	258	1800	21.65	-53.31	74.96	Use probe 1
T9	258	1900	21.84	-53.31	75.15	Use probe 1
T9	258	2000	21.97	-53.31	75.28	Use probe 1
T9	258	2100	22.05	-53.31	75.36	Use probe 1
T9	258	2200	22.02	-53.31	75.33	Use probe 1
T9	258	2300	21.86	-53.31	75.17	Use probe 1
T9	259	0	21.59	-53.31	74.9	Use probe 1
T9	259	100	21.26	-53.31	74.57	Use probe 1
T9	259	200	20.87	-53.31	74.18	Use probe 1
T9	259	300	20.44	-53.32	73.76	Use probe 1
T9	259	400	19.99	-53.31	73.3	Use probe 1
T9	259	500	19.58	-53.32	72.9	Use probe 1
T9	259	600	19.22	-53.31	72.53	Use probe 1
T9	259	700	18.91	-53.32	72.23	Use probe 1
T9	259	800	18.73	-53.31	72.04	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	259	900	18.71	-53.31	72.02	Use probe 1
T9	259	1000	18.84	-53.31	72.15	Use probe 1
T9	259	1100	19.1	-53.31	72.41	Use probe 1
T9	259	1200	19.49	-53.31	72.8	Use probe 1
T9	259	1300	19.94	53.3	73.24	Use probe 1
T9	259	1400	20.42	-53.31	73.73	Use probe 1
T9	259	1500	20.86	53.3	74.16	Use probe 1
T9	259	1600	21.19	-53.31	74.5	Use probe 1
T9	259	1700	21.36	-53.31	74.67	Use probe 1
T9	259	1800	21.51	-53.31	74.82	Use probe 1
T9	259	1900	21.66	-53.31	74.97	Use probe 1
T9	259	2000	21.79	-53.31	75.1	Use probe 1
T9	259	2100	21.88	-53.31	75.19	Use probe 1
T9	259	2200	21.86	-53.32	75.18	Use probe 1
T9	259	2300	21.74	-53.32	75.06	Use probe 1
T9	260	0	21.51	-53.31	74.82	Use probe 1
T9	260	100	21.22	-53.31	74.53	Use probe 1
T9	260	200	20.87	-53.31	74.18	Use probe 1
T9	260	300	20.47	-53.31	73.78	Use probe 1
T9	260	400	20.06	-53.31	73.37	Use probe 1
T9	260	500	19.68	-53.31	72.99	Use probe 1
T9	260	600	19.34	-53.31	72.65	Use probe 1
T9	260	700	19.1	-53.31	72.41	Use probe 1
T9	260	800	19.01	-53.32	72.33	Use probe 1
T9	260	900	19.06	-53.31	72.37	Use probe 1
T9	260	1000	19.23	-53.31	72.54	Use probe 1
T9	260	1100	19.53	-53.31	72.84	Use probe 1
T9	260	1200	19.96	-53.31	73.27	Use probe 1
T9	260	1300	20.46	-53.32	73.78	Use probe 1
T9	260	1400	20.98	-53.32	74.3	Use probe 1
T9	260	1500	21.42	-53.31	74.73	Use probe 1
T9	260	1600	21.83	-53.31	75.14	Use probe 1
T9	260	1700	22.06	-53.31	75.37	Use probe 1
T9	260	1800	22.28	-53.31	75.59	Use probe 1
T9	260	1900	22.51	-53.31	75.82	Use probe 1
T9	260	2000	22.72	-53.31	76.03	Use probe 1
T9	260	2100	22.86	-53.31	76.17	Use probe 1
T9	260	2200	22.89	-53.31	76.2	Use probe 1
T9	260	2300	22.81	-53.31	76.12	Use probe 1
T9	261	0	22.61	-53.31	75.92	Use probe 1
T9	261	100	22.33	-53.32	75.65	Use probe 1
T9	261	200	21.96	-53.31	75.27	Use probe 1
T9	261	300	21.53	-53.31	74.84	Use probe 1
T9	261	400	21.1	-53.31	74.41	Use probe 1
T9	261	500	20.7	-53.31	74.01	Use probe 1
T9	261	600	20.36	-53.31	73.67	Use probe 1
T9	261	700	20.11	-53.31	73.42	Use probe 1
T9	261	800	20.02	-53.32	73.34	Use probe 1
T9	261	900	20.04	-53.31	73.35	Use probe 1
T9	261	1000	20.18	-53.31	73.49	Use probe 1
T9	261	1100	20.43	-53.32	73.75	Use probe 1
T9	261	1200	20.81	-53.32	74.13	Use probe 1
T9	261	1300	21.2	-53.31	74.51	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	261	1400	21.59	-53.31	74.9	Use probe 1
T9	261	1500	22.04	-53.31	75.35	Use probe 1
T9	261	1600	22.31	-53.32	75.63	Use probe 1
T9	261	1700	22.55	-53.31	75.86	Use probe 1
T9	261	1800	22.78	-53.31	76.09	Use probe 1
T9	261	1900	22.96	-53.32	76.28	Use probe 1
T9	261	2000	23.12	-53.31	76.43	Use probe 1
T9	261	2100	23.21	-53.31	76.52	Use probe 1
T9	261	2200	23.2	-53.31	76.51	Use probe 1
T9	261	2300	23.1	-53.31	76.41	Use probe 1
T9	262	0	22.9	-53.31	76.21	Use probe 1
T9	262	100	22.61	-53.31	75.92	Use probe 1
T9	262	200	22.23	-53.31	75.54	Use probe 1
T9	262	300	21.83	-53.32	75.15	Use probe 1
T9	262	400	21.45	-53.31	74.76	Use probe 1
T9	262	500	21.08	-53.31	74.39	Use probe 1
T9	262	600	20.76	-53.31	74.07	Use probe 1
T9	262	700	20.51	-53.31	73.82	Use probe 1
T9	262	800	20.4	-53.32	73.72	Use probe 1
T9	262	900	20.44	-53.31	73.75	Use probe 1
T9	262	1000	20.59	-53.31	73.9	Use probe 1
T9	262	1100	20.87	-53.31	74.18	Use probe 1
T9	262	1200	21.24	-53.31	74.55	Use probe 1
T9	262	1300	21.67	-53.31	74.98	Use probe 1
T9	262	1400	22.07	-53.31	75.38	Use probe 1
T9	262	1500	22.46	-53.31	75.77	Use probe 1
T9	262	1600	22.76	-53.31	76.07	Use probe 1
T9	262	1700	23.01	-53.32	76.33	Use probe 1
T9	262	1800	23.2	-53.31	76.51	Use probe 1
T9	262	1900	23.38	-53.32	76.7	Use probe 1
T9	262	2000	23.53	-53.31	76.84	Use probe 1
T9	262	2100	23.62	-53.31	76.93	Use probe 1
T9	262	2200	23.65	-53.31	76.96	Use probe 1
T9	262	2300	23.62	-53.31	76.93	Use probe 1
T9	263	0	23.51	-53.31	76.82	Use probe 1
T9	263	100	23.33	-53.31	76.64	Use probe 1
T9	263	200	23.07	-53.31	76.38	Use probe 1
T9	263	300	22.84	-53.32	76.16	Use probe 1
T9	263	400	22.6	-53.31	75.91	Use probe 1
T9	263	500	22.38	-53.32	75.7	Use probe 1
T9	263	600	22.21	-53.31	75.52	Use probe 1
T9	263	700	22.04	-53.32	75.36	Use probe 1
T9	263	800	21.94	-53.31	75.25	Use probe 1
T9	263	900	21.89	-53.31	75.2	Use probe 1
T9	263	1000	21.97	-53.32	75.29	Use probe 1
T9	263	1100	22.16	-53.31	75.47	Use probe 1
T9	263	1200	22.51	-53.31	75.82	Use probe 1
T9	263	1300	22.63	-53.31	75.94	Use probe 1
T9	263	1400	22.72	-53.31	76.03	Use probe 1
T9	263	1500	22.86	-53.31	76.17	Use probe 1
T9	263	1600	22.89	-53.31	76.2	Use probe 1
T9	263	1700	22.88	-53.31	76.19	Use probe 1
T9	263	1800	22.8	[illegible].31	76.11	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	263	1900	22.74	-53.31	76.05	Use probe 1
T9	263	2000	22.63	-53.31	75.94	Use probe 1
T9	263	2100	22.5	-53.31	75.81	Use probe 1
T9	263	2200	22.33	-53.32	75.65	Use probe 1
T9	263	2300	22.12	-53.31	75.43	Use probe 1
T9	264	0	21.85	-53.31	75.16	Use probe 1
T9	264	100	21.55	-53.31	74.86	Use probe 1
T9	264	200	21.21	-53.31	74.52	Use probe 1
T9	264	300	20.86	-53.31	74.17	Use probe 1
T9	264	400	20.5	-53.31	73.81	Use probe 1
T9	264	500	20.14	-53.32	73.46	Use probe 1
T9	264	600	19.8	-53.31	73.11	Use probe 1
T9	264	700	19.51	-53.31	72.82	Use probe 1
T9	264	800	19.32	-53.31	72.63	Use probe 1
T9	264	900	19.28	-53.32	72.6	Use probe 1
T9	264	1000	19.37	-53.31	72.68	Use probe 1
T9	264	1100	19.59	-53.32	72.91	Use probe 1
T9	264	1200	19.89	-53.31	73.2	Use probe 1
T9	264	1300	20.24	-53.31	73.55	Use probe 1
T9	264	1400	20.62	-53.31	73.93	Use probe 1
T9	264	1500	20.94	-53.31	74.25	Use probe 1
T9	264	1600	21.15	-53.31	74.46	Use probe 1
T9	264	1700	21.28	-53.32	74.6	Use probe 1
T9	264	1800	21.41	-53.31	74.72	Use probe 1
T9	264	1900	21.53	-53.31	74.84	Use probe 1
T9	264	2000	21.66	-53.31	74.97	Use probe 1
T9	264	2100	21.76	-53.31	75.07	Use probe 1
T9	264	2200	21.76	-53.31	75.07	Use probe 1
T9	264	2300	21.65	-53.32	74.97	Use probe 1
T9	265	0	21.43	-53.32	74.75	Use probe 1
T9	265	100	21.14	-53.31	74.45	Use probe 1
T9	265	200	20.84	-53.31	74.15	Use probe 1
T9	265	300	20.48	-53.31	73.79	Use probe 1
T9	265	400	20.12	-53.31	73.43	Use probe 1
T9	265	500	19.82	-53.31	73.13	Use probe 1
T9	265	600	19.55	-53.31	72.86	Use probe 1
T9	265	700	19.35	-53.32	72.67	Use probe 1
T9	265	800	19.28	-53.31	72.59	Use probe 1
T9	265	900	19.27	-53.32	72.59	Use probe 1
T9	265	1000	19.4	-53.31	72.71	Use probe 1
T9	265	1100	19.84	-53.31	73.15	Use probe 1
T9	265	1200	20.29	-53.31	73.6	Use probe 1
T9	265	1300	20.51	-53.31	73.82	Use probe 1
T9	265	1400	20.78	-53.31	74.09	Use probe 1
T9	265	1500	21.11	-53.32	74.43	Use probe 1
T9	265	1600	21.29	-53.31	74.6	Use probe 1
T9	265	1700	21.46	-53.32	74.78	Use probe 1
T9	265	1800	21.62	-53.31	74.93	Use probe 1
T9	265	1900	21.74	-53.32	75.06	Use probe 1
T9	265	2000	21.83	-53.31	75.14	Use probe 1
T9	265	2100	21.93	-53.31	75.24	Use probe 1
T9	265	2200	21.95	-53.31	75.26	Use probe 1
T9	265	2300	21.88	-53.31	75.19	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	266	0	21.8	-53.32	75.12	Use probe 1
T9	266	100	21.71	-53.31	75.02	Use probe 1
T9	266	200	21.59	-53.32	74.91	Use probe 1
T9	266	300	21.45	-53.31	74.76	Use probe 1
T9	266	400	21.34	-53.31	74.65	Use probe 1
T9	266	500	21.25	-53.31	74.56	Use probe 1
T9	266	600	21.2	-53.31	74.51	Use probe 1
T9	266	700	21.19	-53.31	74.5	Use probe 1
T9	266	800	21.22	-53.31	74.53	Use probe 1
T9	266	900	21.31	-53.31	74.62	Use probe 1
T9	266	1000	21.46	-53.31	74.77	Use probe 1
T9	266	1100	21.67	-53.31	74.98	Use probe 1
T9	266	1200	21.96	-53.31	75.27	Use probe 1
T9	266	1300	22.26	-53.31	75.57	Use probe 1
T9	266	1400	22.49	-53.31	75.8	Use probe 1
T9	266	1500	22.72	-53.32	76.04	Use probe 1
T9	266	1600	22.86	-53.31	76.17	Use probe 1
T9	266	1700	22.99	-53.31	76.3	Use probe 1
T9	266	1800	23.07	-53.32	76.39	Use probe 1
T9	266	1900	23.16	-53.31	76.47	Use probe 1
T9	266	2000	23.21	-53.31	76.52	Use probe 1
T9	266	2100	23.24	-53.31	76.55	Use probe 1
T9	266	2200	23.2	-53.31	76.51	Use probe 1
T9	266	2300	23.11	-53.31	76.42	Use probe 1
T9	267	0	22.98	-53.31	76.29	Use probe 1
T9	267	100	22.77	-53.31	76.08	Use probe 1
T9	267	200	22.46	-53.32	75.78	Use probe 1
T9	267	300	22.11	-53.31	75.42	Use probe 1
T9	267	400	21.76	-53.31	75.07	Use probe 1
T9	267	500	21.38	-53.31	74.69	Use probe 1
T9	267	600	21.04	-53.31	74.35	Use probe 1
T9	267	700	20.7	-53.31	74.01	Use probe 1
T9	267	800	20.43	-53.32	73.75	Use probe 1
T9	267	900	20.28	-53.32	73.6	Use probe 1
T9	267	1000	20.16	-53.31	73.47	Use probe 1
T9	267	1100	20.13	-53.32	73.45	Use probe 1
T9	267	1200	20.28	-53.32	73.6	Use probe 1
T9	267	1300	20.44	-53.31	73.75	Use probe 1
T9	267	1400	20.6	-53.31	73.91	Use probe 1
T9	267	1500	20.66	-53.31	73.97	Use probe 1
T9	267	1600	20.62	-53.31	73.93	Use probe 1
T9	267	1700	20.55	-53.31	73.86	Use probe 1
T9	267	1800	20.52	-53.32	73.84	Use probe 1
T9	267	1900	20.54	-53.31	73.85	Use probe 1
T9	267	2000	20.57	-53.31	73.88	Use probe 1
T9	267	2100	20.52	-53.31	73.83	Use probe 1
T9	267	2200	20.37	-53.31	73.68	Use probe 1
T9	267	2300	20.12	-53.31	73.43	Use probe 1
T9	268	0	19.[illegible]8	-53.31	73.09	Use probe 1
T9	268	100	19.43	-53.31	72.74	Use probe 1
T9	268	200	19.08	-53.32	72.4	Use probe 1
T9	268	300	18.66	-53.31	71.97	Use probe 1
T9	268	400	18.19	-53.31	71.5	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	268	500	17.77	-53.31	71.08	Use probe 1
T9	268	600	17.41	-53.31	70.72	Use probe 1
T9	268	700	17.11	-53.31	70.42	Use probe 1
T9	268	800	16.87	-53.32	70.19	Use probe 1
T9	268	900	16.81	-53.31	70.12	Use probe 1
T9	268	1000	16.96	-53.31	70.27	Use probe 1
T9	268	1100	17.23	-53.31	70.54	Use probe 1
T9	268	1200	17.57	-53.32	70.89	Use probe 1
T9	268	1300	17.91	-53.31	71.22	Use probe 1
T9	268	1400	18.24	-53.31	71.55	Use probe 1
T9	268	1500	18.46	-53.31	71.77	Use probe 1
T9	268	1600	18.53	-53.32	71.85	Use probe 1
T9	268	1700	18.59	-53.32	71.91	Use probe 1
T9	268	1800	18.67	-53.31	71.98	Use probe 1
T9	268	1900	18.75	-53.31	72.06	Use probe 1
T9	268	2000	18.84	-53.31	72.15	Use probe 1
T9	268	2100	18.88	-53.31	72.19	Use probe 1
T9	268	2200	18.82	-53.31	72.13	Use probe 1
T9	268	2300	18.64	-53.31	71.95	Use probe 1
T9	269	0	18.4	-53.31	71.71	Use probe 1
T9	269	100	18.13	-53.31	71.44	Use probe 1
T9	269	200	17.81	-53.31	71.12	Use probe 1
T9	269	300	17.47	-53.31	70.78	Use probe 1
T9	269	400	17.12	-53.31	70.43	Use probe 1
T9	269	500	16.79	-53.31	70.1	Use probe 1
T9	269	600	16.47	-53.31	69.78	Use probe 1
T9	269	700	16.24	-53.31	69.55	Use probe 1
T9	269	800	16.1	-53.31	69.41	Use probe 1
T9	269	900	16.06	-53.31	69.37	Use probe 1
T9	269	1000	16.07	-53.31	69.38	Use probe 1
T9	269	1100	16.12	-53.32	69.44	Use probe 1
T9	269	1200	16.21	-53.31	69.52	Use probe 1
T9	269	1300	16.31	-53.31	69.62	Use probe 1
T9	269	1400	16.49	-53.31	69.8	Use probe 1
T9	269	1500	16.73	-53.31	70.04	Use probe 1
T9	269	1600	16.95	-53.31	70.26	Use probe 1
T9	269	1700	17.07	-53.31	70.38	Use probe 1
T9	269	1800	17.17	-53.31	70.48	Use probe 1
T9	269	1900	17.22	-53.31	70.53	Use probe 1
T9	269	2000	17.28	-53.31	70.59	Use probe 1
T9	269	2100	17.3	-53.31	70.61	Use probe 1
T9	269	2200	17.28	-53.31	70.59	Use probe 1
T9	269	2300	17.15	-53.31	70.46	Use probe 1
T9	270	0	16.95	-53.32	70.27	Use probe 1
T9	270	100	16.7	-53.31	70.01	Use probe 1
T9	270	200	16.55	-53.31	69.86	Use probe 1
T9	270	300	16.37	-53.31	69.68	Use probe 1
T9	270	400	16.14	-53.31	69.45	Use probe 1
T9	270	500	16.07	-53.31	69.38	Use probe 1
T9	270	600	16.09	-53.32	69.41	Use probe 1
T9	270	700	16.12	-53.31	69.43	Use probe 1
T9	270	800	16.14	-53.31	69.45	Use probe 1
T9	270	900	16.19	-53.31	69.5	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	270	1000	16.22	-53.31	69.53	Use probe 1
T9	270	1100	16.23	-53.31	69.54	Use probe 1
T9	270	1200	16.23	-53.31	69.54	Use probe 1
T9	270	1300	16.22	-53.31	69.53	Use probe 1
T9	270	1400	16.17	-53.31	69.48	Use probe 1
T9	270	1500	16.19	-53.31	69.5	Use probe 1
T9	270	1600	16.27	-53.31	69.58	Use probe 1
T9	270	1700	16.38	-53.31	69.69	Use probe 1
T9	270	1800	16.41	-53.32	69.73	Use probe 1
T9	270	1900	16.32	-53.31	69.63	Use probe 1
T9	270	2000	16.26	-53.31	69.57	Use probe 1
T9	270	2100	16.3	-53.31	69.61	Use probe 1
T9	270	2200	16.43	-53.31	69.74	Use probe 1
T9	270	2300	16.63	-53.31	69.94	Use probe 1
T9	271	0	16.76	-53.31	70.07	Use probe 1
T9	271	100	16.77	-53.31	70.08	Use probe 1
T9	271	200	16.76	-53.31	70.07	Use probe 1
T9	271	300	16.77	-53.31	70.08	Use probe 1
T9	271	400	16.74	-53.32	70.06	Use probe 1
T9	271	500	16.73	-53.32	70.05	Use probe 1
T9	271	600	16.76	-53.31	70.07	Use probe 1
T9	271	700	16.8	-53.31	70.11	Use probe 1
T9	271	800	16.86	-53.32	70.18	Use probe 1
T9	271	900	16.92	-53.32	70.24	Use probe 1
T9	271	1000	16.98	-53.31	70.29	Use probe 1
T9	271	1100	17.07	-53.32	70.39	Use probe 1
T9	271	1200	17.16	-53.32	70.48	Use probe 1
T9	271	1300	17.24	-53.31	70.55	Use probe 1
T9	271	1400	17.42	-53.32	70.74	Use probe 1
T9	271	1500	17.64	-53.31	70.95	Use probe 1
T9	271	1600	17.87	-53.31	71.18	Use probe 1
T9	271	1700	18.12	-53.32	71.44	Use probe 1
T9	271	1800	18.18	-53.31	71.49	Use probe 1
T9	271	1900	18.15	-53.31	71.46	Use probe 1
T9	271	2000	18.16	-53.31	71.47	Use probe 1
T9	271	2100	18.11	-53.32	71.43	Use probe 1
T9	271	2200	18.04	-53.31	71.35	Use probe 1
T9	271	2300	17.94	53.3	71.24	Use probe 1
T9	272	0	17.83	-53.31	71.14	Use probe 1
T9	272	100	17.7	-53.32	71.02	Use probe 1
T9	272	200	17.6	-53.32	70.92	Use probe 1
T9	272	300	17.49	-53.32	70.81	Use probe 1
T9	272	400	17.38	-53.31	70.69	Use probe 1
T9	272	500	17.28	-53.31	70.59	Use probe 1
T9	272	600	17.16	-53.31	70.47	Use probe 1
T9	272	700	17.02	-53.31	70.33	Use probe 1
T9	272	800	16.95	-53.31	70.26	Use probe 1
T9	272	900	16.97	-53.32	70.29	Use probe 1
T9	272	1000	16.99	-53.31	70.3	Use probe 1
T9	272	1100	17.08	-53.31	70.39	Use probe 1
T9	272	1200	17.17	-53.31	70.48	Use probe 1
T9	272	1300	17.33	-53.31	70.64	Use probe 1
T9	272	1400	17.48	-53.31	70.79	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	272	1500	17.69	-53.32	71.01	Use probe 1
T9	272	1600	17.84	-53.32	71.16	Use probe 1
T9	272	1700	17.95	-53.31	71.26	Use probe 1
T9	272	1800	18.03	-53.31	71.34	Use probe 1
T9	272	1900	18.1	-53.31	71.41	Use probe 1
T9	272	2000	18.15	-53.31	71.46	Use probe 1
T9	272	2100	18.13	-53.31	71.44	Use probe 1
T9	272	2200	18.04	-53.31	71.35	Use probe 1
T9	272	2300	17.91	-53.31	71.22	Use probe 1
T9	273	0	17.78	-53.31	71.09	Use probe 1
T9	273	100	17.61	-53.31	70.92	Use probe 1
T9	273	200	17.42	-53.32	70.74	Use probe 1
T9	273	300	17.22	-53.31	70.53	Use probe 1
T9	273	400	16.98	-53.31	70.29	Use probe 1
T9	273	500	16.77	-53.31	70.08	Use probe 1
T9	273	600	16.58	-53.31	69.89	Use probe 1
T9	273	700	16.41	-53.31	69.72	Use probe 1
T9	273	800	16.29	-53.32	69.61	Use probe 1
T9	273	900	16.25	-53.32	69.57	Use probe 1
T9	273	1000	16.33	-53.32	69.65	Use probe 1
T9	273	1100	16.53	-53.31	69.84	Use probe 1
T9	273	1200	16.78	-53.31	70.09	Use probe 1
T9	273	1300	17.07	-53.31	70.38	Use probe 1
T9	273	1400	17.31	-53.31	70.62	Use probe 1
T9	273	1500	17.45	-53.31	70.76	Use probe 1
T9	273	1600	17.45	-53.32	70.77	Use probe 1
T9	273	1700	17.43	-53.31	70.74	Use probe 1
T9	273	1800	17.36	-53.31	70.67	Use probe 1
T9	273	1900	17.32	-53.32	70.64	Use probe 1
T9	273	2000	17.28	-53.31	70.59	Use probe 1
T9	273	2100	17.2	-53.31	70.51	Use probe 1
T9	273	2200	17.02	-53.32	70.34	Use probe 1
T9	273	2300	16.75	-53.31	70.06	Use probe 1
T9	274	0	16.45	-53.31	69.76	Use probe 1
T9	274	100	16.1	-53.31	69.41	Use probe 1
T9	274	200	15.74	-53.31	69.05	Use probe 1
T9	274	300	15.36	-53.31	68.67	Use probe 1
T9	274	400	15	-53.32	68.32	Use probe 1
T9	274	500	14.7	-53.32	68.02	Use probe 1
T9	274	600	14.45	-53.31	67.76	Use probe 1
T9	274	700	14.27	-53.32	67.59	Use probe 1
T9	274	800	14.2	-53.31	67.51	Use probe 1
T9	274	900	14.21	-53.31	67.52	Use probe 1
T9	274	1000	14.38	-53.31	67.69	Use probe 1
T9	274	1100	14.6	-53.31	67.91	Use probe 1
T9	274	1200	14.71	-53.31	68.02	Use probe 1
T9	274	1300	14.8	-53.31	68.11	Use probe 1
T9	274	1400	15	-53.31	68.31	Use probe 1
T9	274	1500	15.14	-53.31	68.45	Use probe 1
T9	274	1600	15.25	-53.31	68.56	Use probe 1
T9	274	1700	15.31	-53.32	68.63	Use probe 1
T9	274	1800	15.38	-53.31	68.69	Use probe 1
T9	274	1900	15.33	-53.31	68.64	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T9	274	2000	15.21	-53.31	68.52	Use probe 1
T9	274	2100	15.07	-53.32	68.39	Use probe 1
T9	274	2200	14.91	-53.32	68.23	Use probe 1
T9	274	2300	14.71	-53.32	68.03	Use probe 1
T9	275	0	14.46	-53.31	67.77	Use probe 1
T9	275	100	14.2	-53.31	67.51	Use probe 1
T9	275	200	13.96	-53.31	67.27	Use probe 1
T9	275	300	13.76	-53.32	67.08	Use probe 1
T9	275	400	13.54	-53.31	66.85	Use probe 1
T9	275	500	13.34	-53.32	66.66	Use probe 1
T9	275	600	13.13	-53.31	66.44	Use probe 1
T9	275	700	12.95	-53.31	66.26	Use probe 1
T9	275	800	12.87	-53.31	66.18	Use probe 1
T9	275	900	12.91	-53.31	66.22	Use probe 1
T9	275	1000	13.09	-53.31	66.4	Use probe 1
T9	275	1100	13.32	-53.31	66.63	Use probe 1
T9	275	1200	13.56	-53.32	66.88	Use probe 1
T9	275	1300	13.82	-53.32	67.14	Use probe 1
T9	275	1400	14.05	-53.31	67.36	Use probe 1
T9	275	1500	14.27	-53.31	67.58	Use probe 1
T9	275	1600	14.47	-53.31	67.78	Use probe 1
T9	275	1700	14.61	-53.31	67.92	Use probe 1
T9	275	1800	14.7	-53.32	68.02	Use probe 1
T9	275	1900	14.8	-53.31	68.11	Use probe 1
T9	275	2000	14.88	-53.31	68.19	Use probe 1
T9	275	2100	14.92	-53.31	68.23	Use probe 1
T9	275	2200	14.9	-53.31	68.21	Use probe 1
T9	275	2300	14.78	-53.31	68.09	Use probe 1
T9	276	0	14.58	-53.31	67.89	Use probe 1
T9	276	100	14.33	-53.31	67.64	Use probe 1
T9	276	200	14.03	-53.32	67.35	Use probe 1
T9	276	300	13.73	-53.32	67.05	Use probe 1
T9	276	400	13.44	-53.31	66.75	Use probe 1
T9	276	500	13.18	-53.32	66.5	Use probe 1
T9	276	600	12.95	-53.31	66.26	Use probe 1
T9	276	700	12.76	-53.32	66.08	Use probe 1
T9	276	800	12.65	-53.31	65.96	Use probe 1
T9	276	900	12.7	-53.31	66.01	Use probe 1

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T11	218	1300	23.51	23.92	25.2	Use Average
T11	219	1200	22.19	22.61	24.23	Use Average

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T12	217	1400	25.08	24.42	20.48	Use Average
T12	217	1500	25.78	25.02	20.5	Use Average
T12	217	1600	26.16	25.53	20.5	Use Average
T12	219	1300	22.19	22.61	17.37	Use Average
T12	231	1400	21.52	21.06	19.1	Use Average

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T12	231	1500	22.47	21.94	19.17	Use Average
T12	231	1600	23.01	22.52	19.25	Use Average
T12	231	1700	23.27	22.84	19.3	Use Average
T12	238	1200	22.72	22.28	18.68	Use Average
T12	238	1300	23.99	23.32	18.82	Use Average
T12	238	1400	25.54	24.61	18.93	Use Average
T12	238	1500	26.27	25.45	19	Use Average
T12	238	1600	26.58	25.92	19	Use Average
T12	238	1700	26.41	25.93	19.08	Use Average
T12	239	1300	25.82	25.25	20.33	Use Average
T12	239	1400	26.89	26.32	20.48	Use Average
T12	239	1500	27.61	27.08	20.5	Use Average
T12	239	1600	27.99	27.49	20.62	Use Average
T12	240	1200	24.9	24.27	21.1	Use Average
T12	240	1300	26.12	25.39	21.15	Use Average
T12	240	1400	27.39	26.47	21.27	Use Average
T12	240	1500	28.26	27.35	21.33	Use Average
T12	240	1600	28.36	27.69	21.35	Use Average
T12	240	1700	27.88	27.46	21.33	Use Average
T12	241	1200	25.01	24.54	21.7	Use Average
T12	241	1300	25.62	25.07	21.7	Use Average
T12	241	1400	26.29	25.63	21.72	Use Average
T12	241	1500	26.9	26.16	21.8	Use Average
T12	241	1600	27.1	26.51	21.88	Use Average
T12	242	700	20.36	20.76	20.3	Use Average
T12	242	800	20	20.41	19.98	Use Average
T12	242	2300	19.42	19.84	19.75	Use Average
T12	243	0	18.87	19.4	19.27	Use Average
T12	243	100	18.34	18.96	18.77	Use Average
T12	243	200	17.84	18.5	18.27	Use Average
T12	243	300	17.34	18.06	17.78	Use Average
T12	243	400	16.89	17.62	17.32	Use Average
T12	243	500	16.42	17.19	16.88	Use Average
T12	243	600	15.96	16.78	16.43	Use Average
T12	243	700	15.69	16.47	16.08	Use Average
T12	243	800	15.51	16.25	15.72	Use Average
T12	243	900	15.88	16.43	15.58	Use Average
T12	243	1000	16.55	17.05	15.62	Use Average
T12	243	1300	20.59	19.7	15.85	Use Average
T12	243	1400	21.76	20.85	15.98	Use Average
T12	243	1500	21.91	21.32	16.17	Use Average
T12	243	1600	22.9	22.04	16.25	Use Average
T12	243	1700	23.04	22.37	16.37	Use Average
T12	243	1800	22.78	22.32	16.38	Use Average
T12	244	1200	21.04	20.61	17.7	Use Average
T12	244	1300	22.07	21.34	17.87	Use Average
T12	244	1400	23	22.16	18.07	Use Average
T12	244	1500	23.57	22.9	18.28	Use Average
T12	244	1600	23.49	22.98	18.3	Use Average
T12	244	1700	23.83	23.2	18.33	Use Average
T12	244	1800	24.37	23.66	18.4	Use Average
T12	245	0	20.39	20.82	18.6	Use Average
T12	245	100	19.75	20.26	18.67	Use Average

Station No.	Julian Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T12	245	200	19.17	19.75	18.75	Use Average
T12	245	300	18.63	19.25	18.65	Use Average
T12	245	400	18.17	18.74	18.4	Use Average
T12	245	500	17.55	18.25	18	Use Average
T12	245	600	17.03	17.79	17.57	Use Average
T12	245	700	16.62	17.4	17.15	Use Average
T12	245	800	16.43	17.11	16.78	Use Average
T12	245	900	16.69	17.12	16.57	Use Average
T12	245	1300	20.16	19.47	16.73	Use Average
T12	245	1400	21.52	20.56	16.83	Use Average
T12	245	1500	22.22	21.31	17.05	Use Average
T12	245	1600	22.4	21.63	17.1	Use Average
T12	245	1700	22.82	22.01	17.1	Use Average
T12	245	1800	22.73	22.15	17.1	Use Average
T12	246	0	19.37	19.77	17.3	Use Average
T12	246	100	18.9	19.33	17.3	Use Average
T12	246	200	18.5	18.92	17.4	Use Average
T12	246	300	18.05	18.49	17.4	Use Average
T12	246	400	17.55	18.08	17.4	Use Average
T12	246	500	17.02	17.68	17.22	Use Average
T12	246	600	16.57	17.32	16.95	Use Average
T12	246	700	16.22	17	16.62	Use Average
T12	246	800	16.05	16.61	16.38	Use Average
T12	246	1200	19.02	18.6	0.42	Use Average
T12	246	1300	20.18	19.56	0.62	Use Average
T12	246	1400	21.03	20.38	0.65	Use Average
T12	246	1500	21.58	20.96	0.62	Use Average
T12	246	1600	21.69	21.2	0.49	Use Average
T12	247	1600	21.51	21.07	0.44	Use Average
T12	247	1700	21.68	21.28	0.4	Use Average
T12	248	1100	21.15	20.67	0.48	Use Average
T12	248	1200	21.98	21.46	0.52	Use Average
T12	248	1300	22.58	22.04	0.54	Use Average
T12	248	1400	23.44	22.74	0.7	Use Average
T12	248	1500	24.31	23.52	0.79	Use Average
T12	248	1600	24.67	23.95	0.72	Use Average
T12	248	1700	24.67	24.09	0.58	Use Average
T12	248	1800	24.39	23.98	0.41	Use Average
T12	251	1300	20.69	20.28	0.41	Use Average
T12	251	1400	21.24	20.83	0.41	Use Average
T12	252	1100	21.8	21.36	0.44	Use Average
T12	252	1200	22.94	22.26	0.68	Use Average
T12	252	1300	24	23.21	0.79	Use Average
T12	252	1400	24.74	23.95	0.79	Use Average
T12	252	1500	25.39	24.57	0.82	Use Average
T12	252	1600	25.5	24.83	0.67	Use Average
T12	252	1700	25.38	24.82	0.56	Use Average
T12	252	1800	25.12	24.67	0.45	Use Average
T12	253	1200	23.46	22.8	0.66	Use Average
T12	253	1300	24.57	23.77	0.8	Use Average
T12	253	1400	25.65	24.75	0.9	Use Average
T12	253	1500	26.2	25.37	0.83	Use Average
T12	253	1600	26.36	25.65	0.71	Use Average

Station No.	Julien Day	Time	CR10 - Probe 1	CR10 - Probe 2	RTM Temperature	Action Taken
T12	253	1700	26.25	25.64	0.61	Use Average
T12	253	1800	26.06	25.55	0.51	Use Average
T12	255	1300	23.14	22.73	0.41	Use Average
T12	255	1400	24.06	23.54	0.52	Use Average
T12	255	1500	24.55	24.09	0.46	Use Average
T12	256	500	16.[illegible]9	17.3	0.41	Use Average
T12	256	600	16.45	16.96	0.51	Use Average
T12	256	700	16.05	16.6	0.55	Use Average
T12	256	800	15.79	16.3	0.51	Use Average
T12	256	1400	20.83	20.25	0.58	Use Average
T12	256	1500	21.71	21.18	0.53	Use Average
T12	256	1600	21.84	21.44	0.4	Use Average
T12	257	0	17.44	17.85	0.41	Use Average
T12	257	100	16.88	17.33	0.45	Use Average
T12	257	200	16.36	16.85	0.49	Use Average
T12	257	300	15.88	16.39	0.51	Use Average
T12	257	400	15.39	15.92	0.53	Use Average
T12	257	500	14.92	15.47	0.55	Use Average
T12	257	600	14.46	15.04	0.58	Use Average
T12	257	700	14.04	14.66	0.62	Use Average
T12	257	800	13.84	14.4	0.56	Use Average
T12	257	1500	19.67	19.25	0.42	Use Average
T12	258	0	16.92	17.32	0.4	Use Average
T12	258	100	16.42	16.87	0.45	Use Average
T12	258	200	15.98	16.49	0.51	Use Average
T12	258	300	15.52	16.06	0.54	Use Average
T12	258	400	15.11	15.69	0.58	Use Average
T12	258	500	14.76	15.32	0.56	Use Average
T12	258	600	14.48	14.92	0.44	Use Average
T12	258	700	14.24	14.69	0.45	Use Average
T12	258	800	14.13	14.56	0.43	Use Average
T12	258	1300	18.66	18.1	0.56	Use Average
T12	258	1400	19.91	19.2	0.71	Use Average
T12	258	1500	20.5	19.86	0.64	Use Average
T12	258	1600	21.02	20.36	0.66	Use Average
T12	258	1700	21.04	20.51	0.53	Use Average
T12	259	600	14.99	15.43	0.44	Use Average
T'2	259	700	14.8	15.25	0.45	Use Average
T12	259	800	14.67	15.17	0.5	Use Average
T12	268	200	15.11	15.51	0.4	Use Average
T12	268	300	14.63	15.06	0.43	Use Average
T12	268	400	14.22	14.62	0.4	Use Average
T12	268	500	13.77	14.23	0.46	Use Average
T12	268	600	13.37	13.8	0.43	Use Average
T12	268	700	13.03	13.44	0.41	Use Average
T12	268	800	12.55	13.06	0.51	Use Average
T12	268	900	12.41	12.88	0.47	Use Average
T12	268	1000	12.49	12.9	0.41	Use Average
T12	269	0	13.87	14.27	0.4	Use Average

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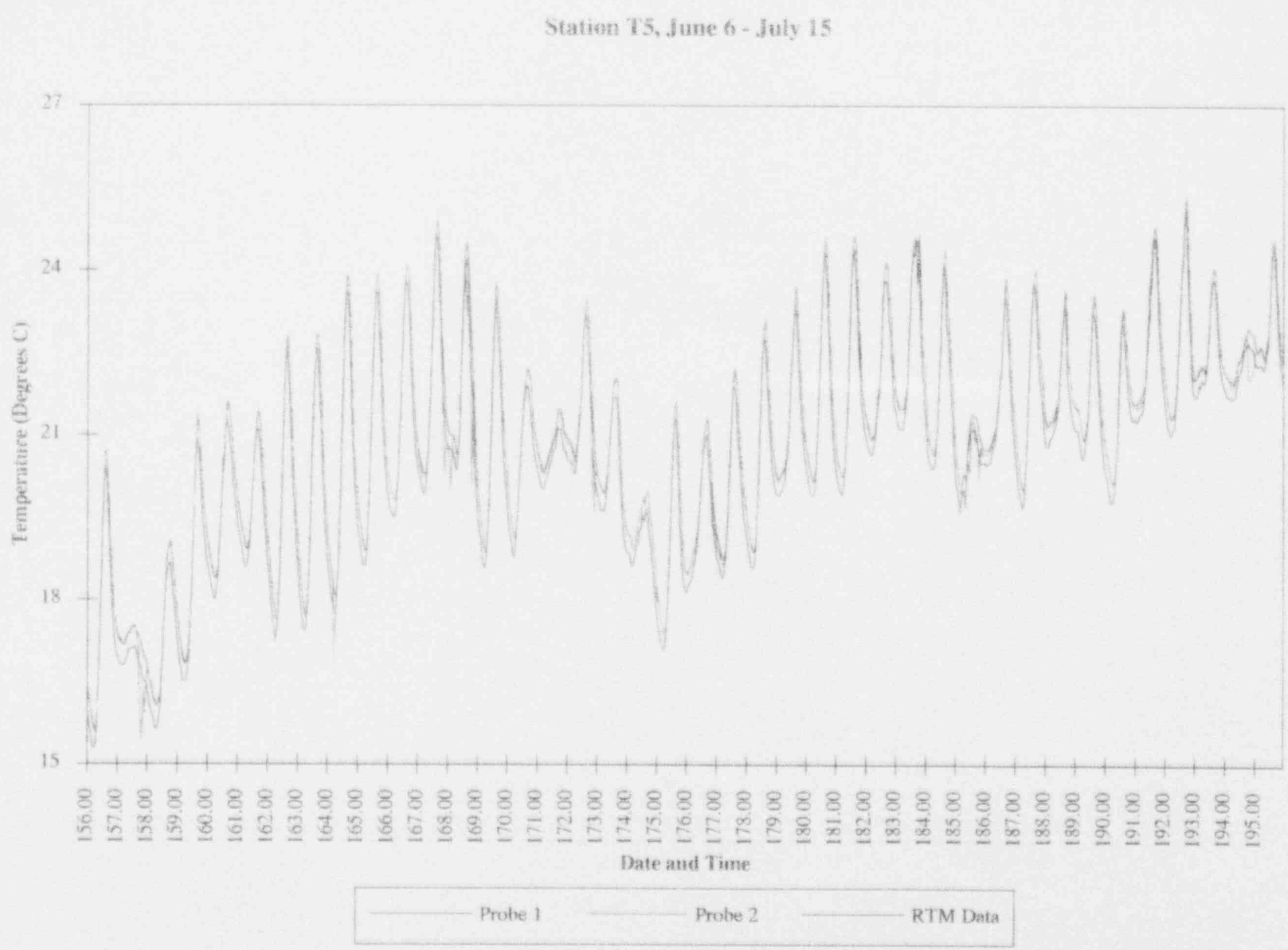
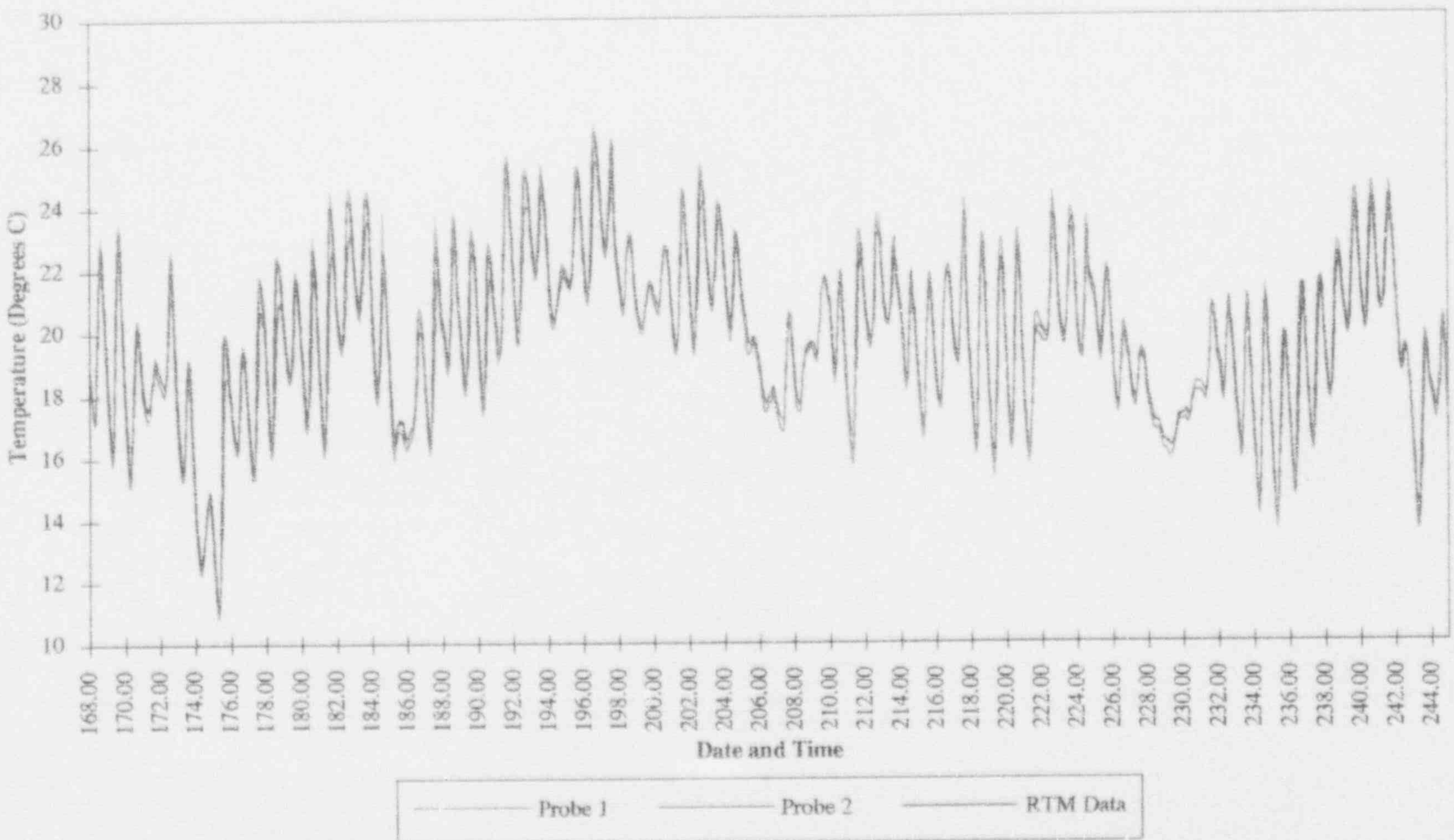
THERMAL MONITORING AND DATABASE DEVELOPMENT

Appendix 2 - QA/QC Graphs

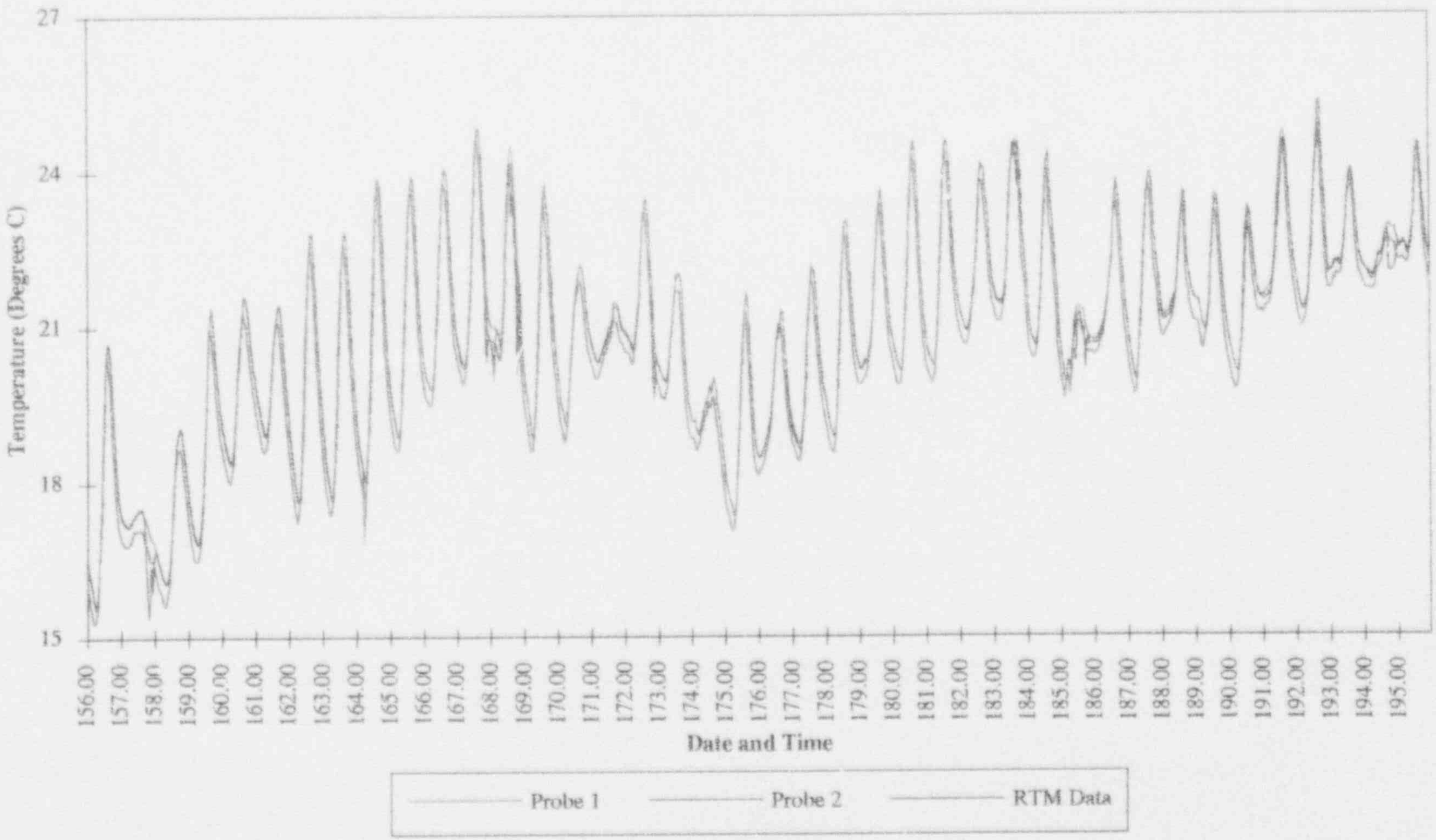
Figure 2 Example graph showing data comparison for QA/QC



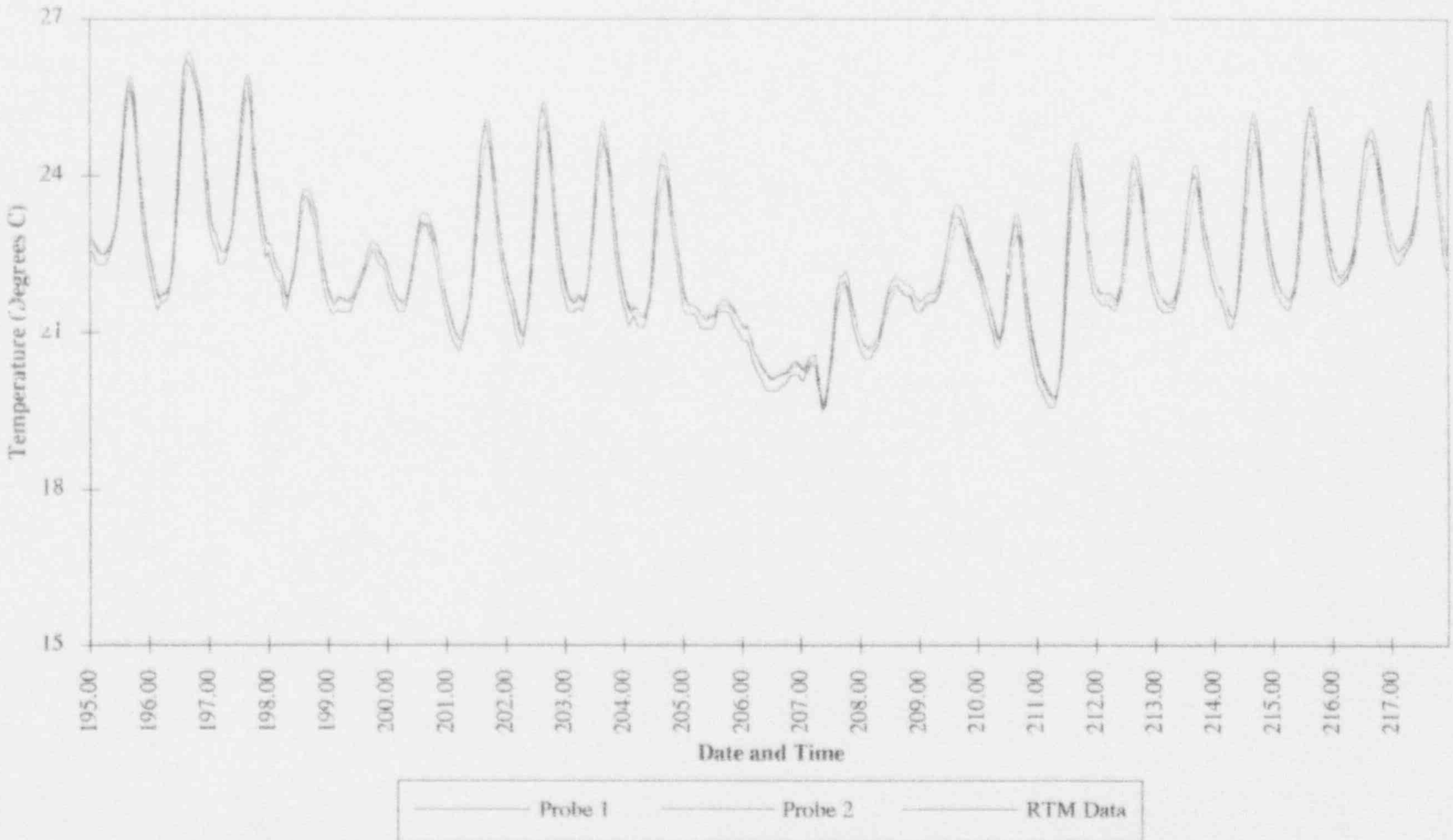
Station T1, June 18 - September 2



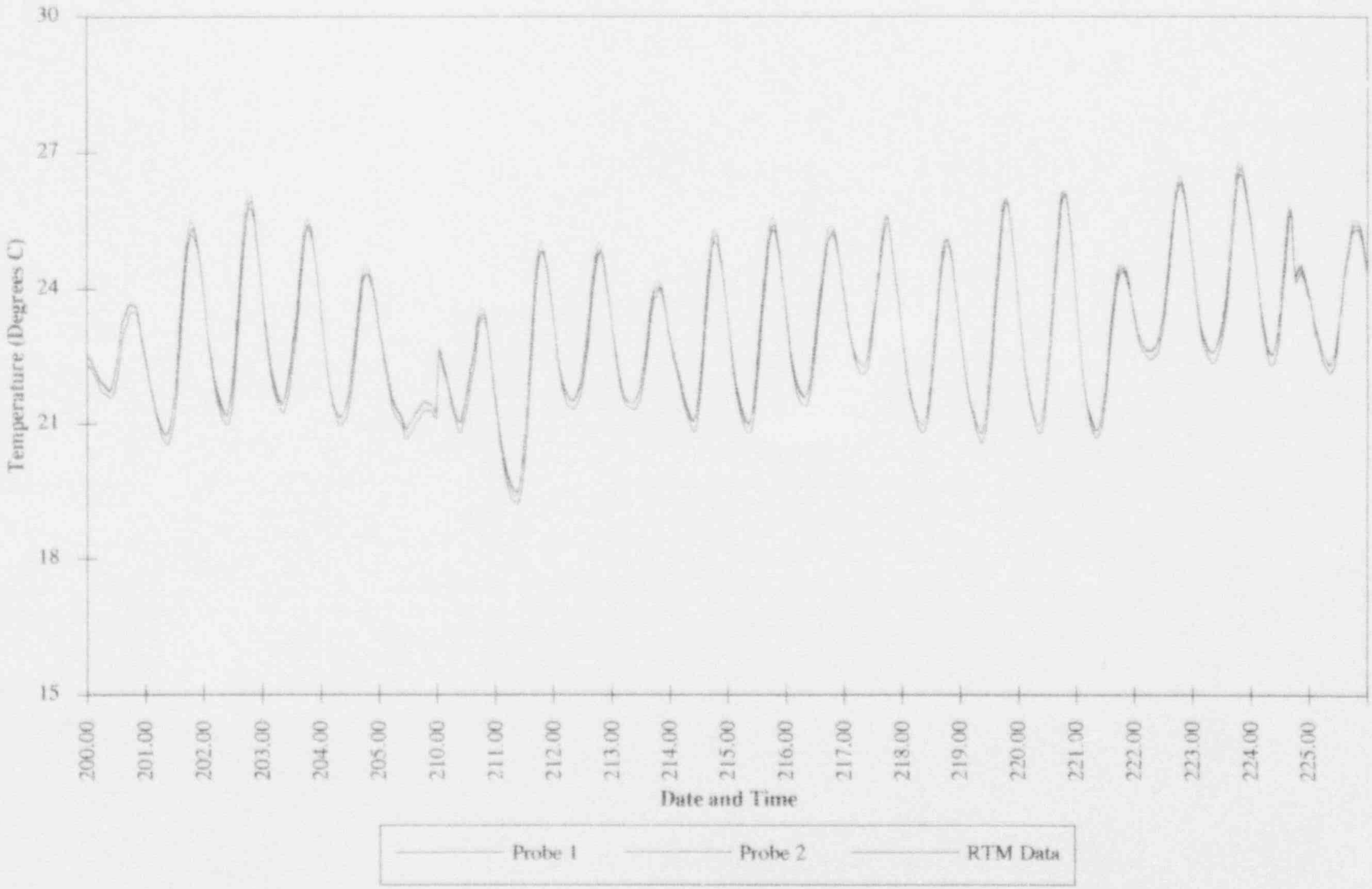
Station T5, June 6 - July 15



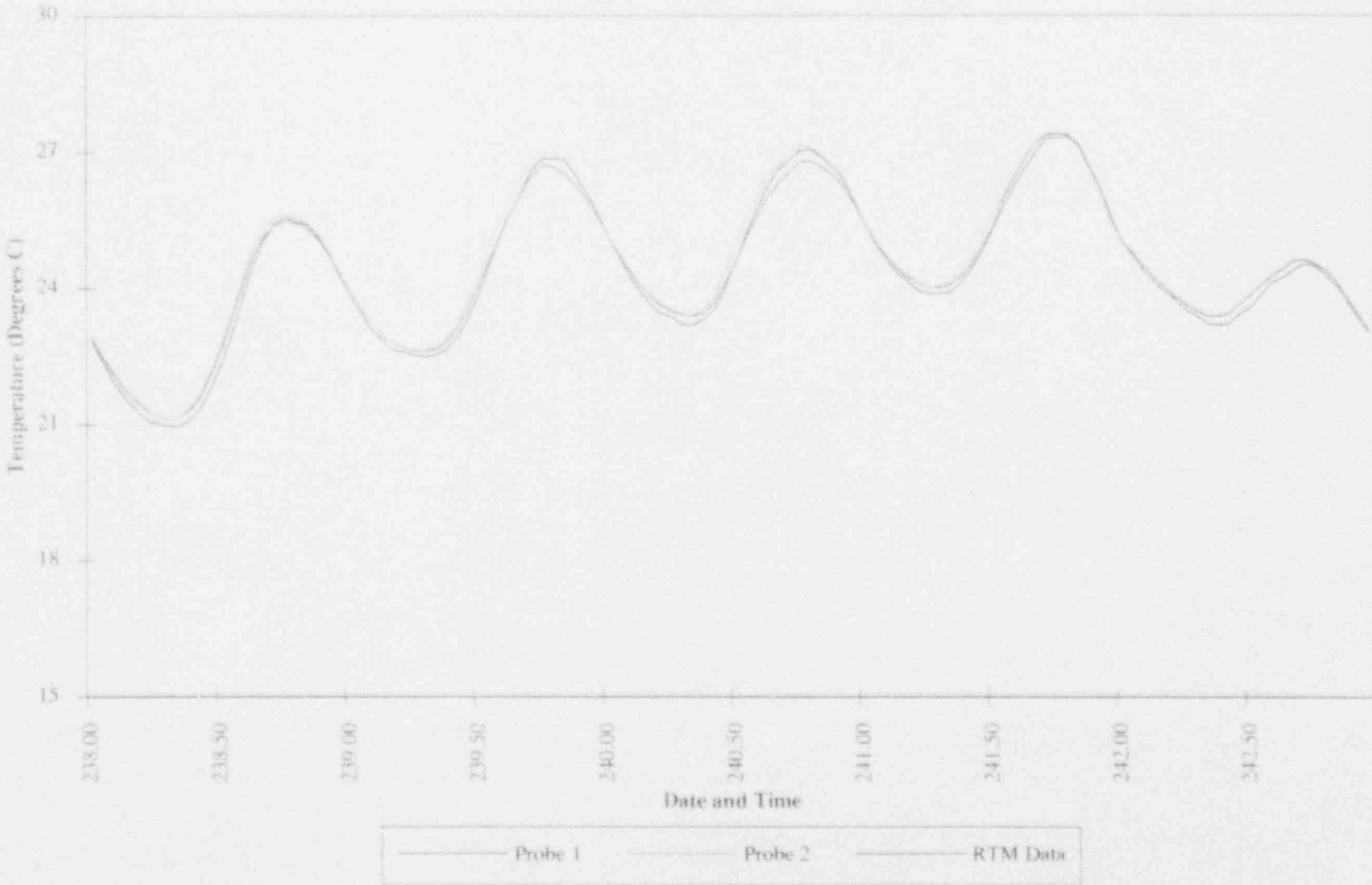
Station T6, July 15 - August 6



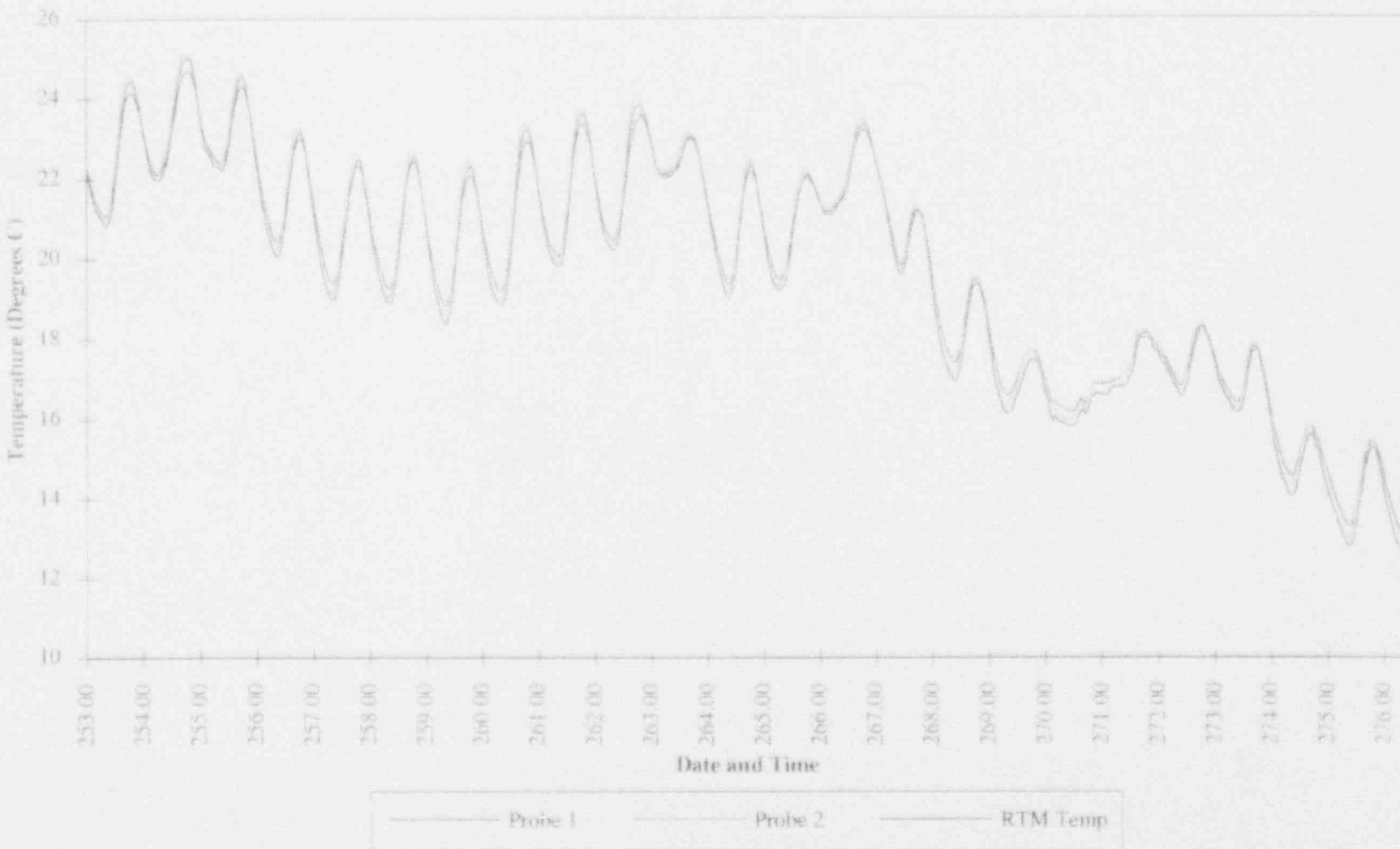
Station T8, July 20 - August 14



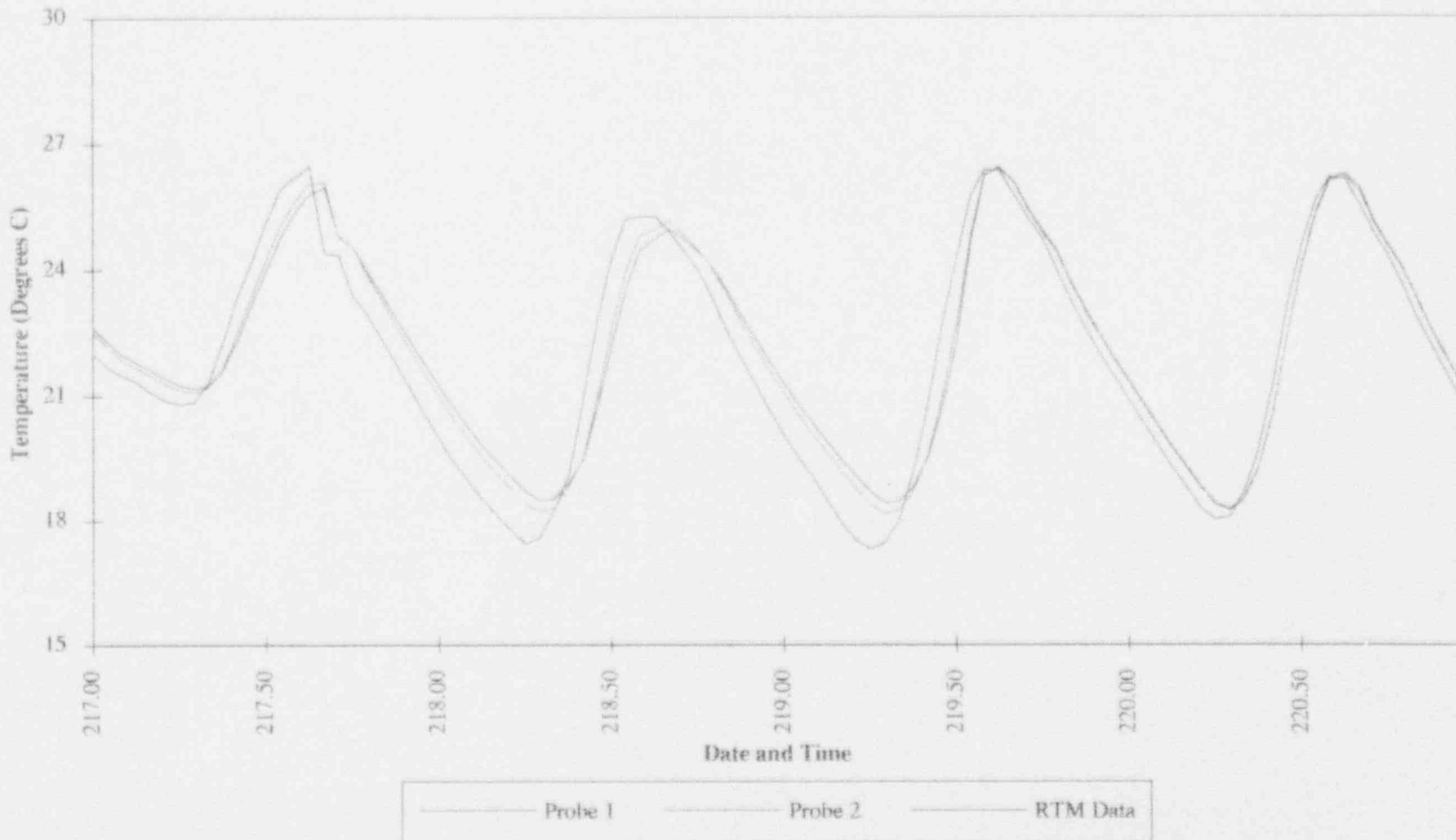
Station 18, August 27 - August 31



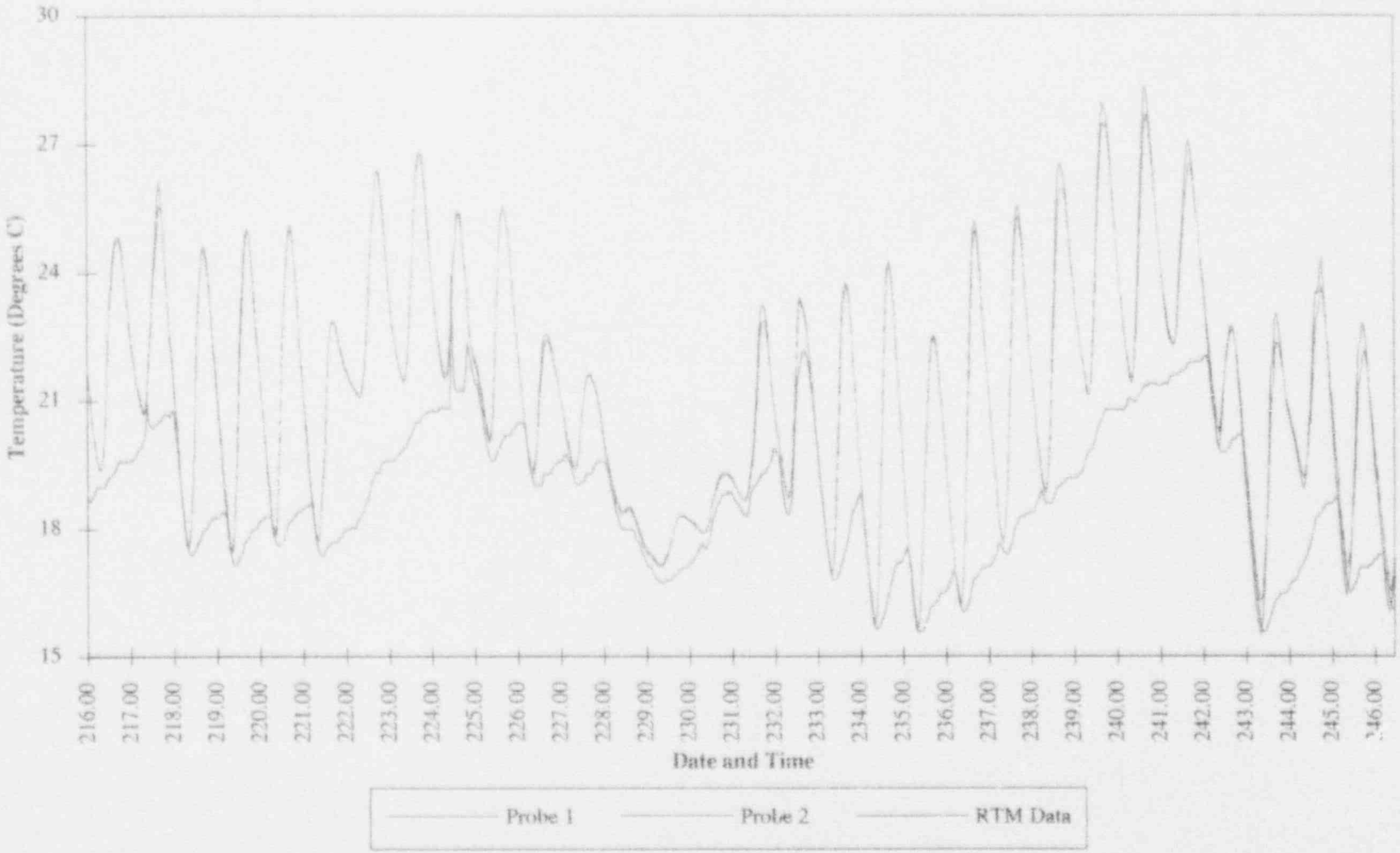
Station 18, September 9 - October 2



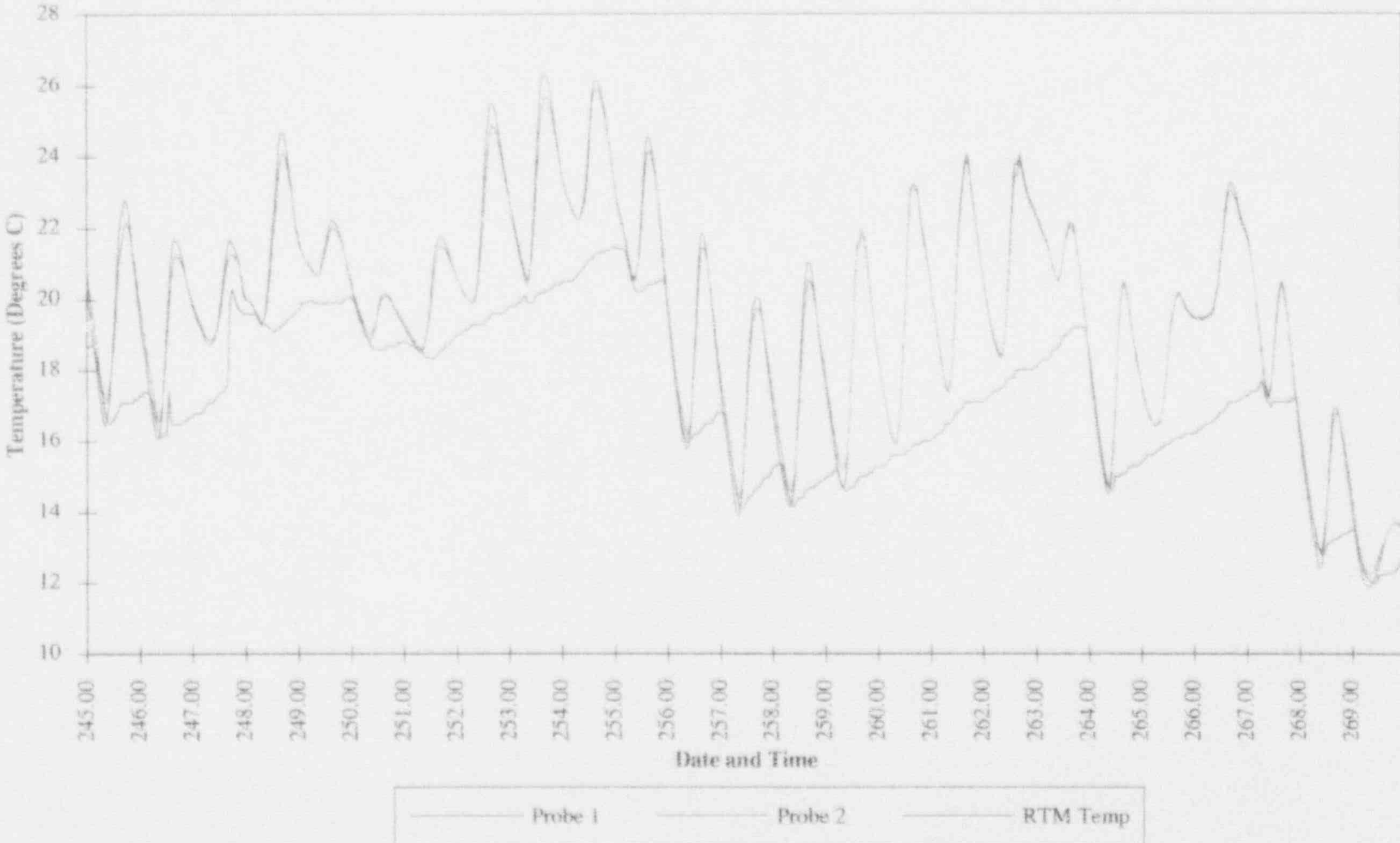
Station T11 , August 6 - August 9



Station T 12, August 5 - September 6



Station T12, September 1 - September 25



PHILADELPHIA ELECTRIC COMPANY

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THERMAL MONITORING AND DATABASE DEVELOPMENT

Appendix 3 - Flow Data
Morris Run at Blue School Road

Appendix 3: Flow Summary for Morriss Run at Blue School Road

Date	Time	Flow (cfs)
205	1500	1.781
205	1600	1.781
205	1700	1.784
205	1800	1.784
205	1900	1.784
205	2000	1.783
205	2100	1.783
205	2200	1.782
205	2300	1.781
206	0	1.781
206	100	1.780
206	200	1.780
206	300	1.782
206	400	1.782
206	500	1.781
206	600	1.780
206	700	1.779
206	800	1.778
206	900	1.778
206	1000	1.778
206	1100	1.778
206	1200	1.778
206	1300	1.778
206	1400	1.780
206	1500	1.781
206	1600	1.780
206	1700	1.778
206	1800	1.777
206	1900	1.777
206	2000	1.777
206	2100	1.777
206	2200	1.777
206	2300	1.777
207	0	1.777
207	100	1.777
07	200	1.777
207	300	1.779
207	400	1.780
207	500	1.779
207	600	1.777
207	700	1.778
207	800	1.785
207	900	1.801
207	1000	1.805
207	1100	1.803
207	1200	1.805
207	1300	1.800
207	1400	1.799
207	1500	1.798
207	1600	1.796
207	1700	1.793
207	1800	1.791
207	1900	1.790
207	2000	1.789
207	2100	1.789
207	2200	1.788
207	2300	1.788
208	0	1.787
208	100	1.785
208	200	1.784
208	300	1.784
208	400	1.783
208	500	1.783
208	600	1.784
208	700	1.785
208	800	1.784
208	900	1.783
208	1000	1.782
208	1100	1.782
208	1200	1.782
08	1300	1.782
8	1400	1.782
208	1500	1.782

Julian Date	Time	Flow (cfs)
208	1600	1.782
208	1700	1.783
208	1800	1.783
208	1900	1.783
208	2000	1.782
208	2100	1.782
208	2200	1.782
208	2300	1.782
209	0	1.782
209	100	1.782
209	200	1.782
209	300	1.783
209	400	1.783
209	500	1.783
209	600	1.784
209	700	1.784
209	800	1.785
209	900	1.785
209	1000	1.784
209	1100	1.784
209	1200	1.786
209	1300	1.786
209	1400	1.786
209	1500	1.785
209	1600	1.784
209	1700	1.784
209	1800	1.784
209	1900	1.783
209	2000	1.783
209	2100	1.783
209	2200	1.783
209	2300	1.783
210	0	1.782
210	100	1.782
210	200	1.782
210	300	1.782
210	400	1.782
210	500	1.783
210	600	1.783
210	700	1.781
210	800	1.780
210	900	1.780
210	1000	1.780
210	1100	1.780
210	1200	1.779
210	1300	1.779
210	1400	1.778
210	1500	1.779
210	1600	1.779
210	1700	1.779
210	1800	1.779
210	1900	1.779
210	2000	1.779
210	2100	1.782
210	2200	1.782
210	2300	1.780
211	0	1.779
211	100	1.778
211	200	1.778
211	300	1.778
211	400	1.778
211	500	1.778
211	600	1.778
211	700	1.777
211	800	1.777
211	900	1.777
211	1000	1.777
211	1100	1.777
211	1200	1.777
211	1300	1.776
211	1400	1.776
211	1500	1.776
211	1600	1.777

Julian Date	Time	Flow (cfs
211	1700	1.777
211	1800	1.777
211	1900	1.777
211	2000	1.777
211	2100	1.778
211	2200	1.781
211	2300	1.780
212	0	1.779
212	100	1.778
212	200	1.777
212	300	1.777
212	400	1.777
212	500	1.777
212	600	1.777
212	700	1.777
212	800	1.777
212	900	1.777
212	1000	1.777
212	1100	1.777
212	1200	1.776
212	1300	1.776
212	1400	1.776
212	1500	1.776
212	1600	1.777
212	1700	1.779
212	1800	1.779
212	1900	1.778
212	2000	1.777
212	2100	1.777
212	2200	1.777
212	2300	1.777
213	0	1.777
213	100	1.777
213	200	1.777
213	300	1.777
213	400	1.777
213	500	1.777
213	600	1.776
213	700	1.776
213	800	1.777
213	900	1.779
213	1000	1.779
213	1100	1.780
213	1200	1.782
213	1300	1.789
213	1400	1.789
213	1500	1.789
213	1600	1.789
213	1700	1.789
213	1800	1.788
213	1900	1.787
213	2000	1.786
213	2100	1.785
213	2200	1.785
213	2300	1.786
214	0	1.785
214	100	1.783
214	200	1.782
214	300	1.782
214	400	1.782
214	500	1.781
214	600	1.781
214	700	1.781
214	800	1.781
214	900	1.781
214	1000	1.781
214	1100	1.781
214	1200	1.780
214	1300	1.780
214	1400	1.779
214	1500	1.778
214	1600	1.777
214	1700	1.776

Julian Date	Time	Flow (cfs)
214	1800	1.780
214	1900	1.783
214	2000	1.783
214	2100	1.783
214	2200	1.782
214	2300	1.780
215	0	1.779
215	100	1.779
215	200	1.779
215	300	1.779
215	400	1.779
215	500	1.778
215	600	1.778
215	700	1.778
215	800	1.778
215	900	1.778
215	1000	1.778
215	1100	1.778
215	1200	1.777
215	1300	1.777
215	1400	1.777
215	1500	1.777
215	1600	1.777
215	1700	1.777
215	1800	1.777
215	1900	1.777
215	2000	1.777
215	2100	1.778
215	2200	1.778
215	2300	1.778
216	0	1.778
216	100	1.778
216	200	1.778
216	300	1.778
216	400	1.778
216	500	1.778
216	600	1.778
216	700	1.777
216	800	1.777
216	900	1.777
216	1000	1.777
216	1100	1.777
216	1200	1.777
216	1300	1.777
216	1400	1.777
216	1500	1.777
216	1600	1.777
216	1700	1.777
216	1800	1.777
216	1900	1.777
216	2000	1.777
216	2100	1.778
216	2200	1.778
216	2300	1.778
217	0	1.778
217	100	1.778
217	200	1.778
217	300	1.778
217	400	1.778
217	500	1.778
217	600	1.777
217	700	1.777
217	800	1.777
217	900	1.777
217	1000	1.777
217	1100	1.777
217	1200	1.777
217	1300	1.777
217	1400	1.776
217	1500	1.776
217	1600	1.777
217	1700	1.779
217	1800	1.780
217	1900	1.780
217	2000	1.782

Julian Date	Time	Flow (cfs)
217	2100	1.783
217	2200	1.785
217	2300	1.785
218	0	1.784
218	100	1.782
218	200	1.781
218	300	1.780
218	400	1.780
218	500	1.779
218	600	1.779
218	700	1.779
218	800	1.778
218	900	1.778
218	1000	1.778
218	1100	1.778
218	1200	1.777
218	1300	1.777
218	1400	1.777
218	1500	1.777
218	1600	1.777
218	1700	1.777
218	1800	1.777
218	1900	1.777
218	2000	1.777
218	2100	1.777
218	2200	1.777
218	2300	1.777
219	0	1.777
219	100	1.777
219	200	1.777
219	300	1.777
219	400	1.777
219	500	1.777
219	600	1.777
219	700	1.777
219	800	1.777
219	900	1.777
219	1000	1.776
219	1100	1.776
219	1200	1.776
219	1300	1.776
219	1400	1.775
219	1500	1.775
219	1600	1.775
219	1700	1.776
219	1800	1.776
219	1900	1.776
219	2000	1.776
219	2100	1.776
219	2200	1.776
219	2300	1.776
220	0	1.776
220	100	1.776
220	200	1.776
220	300	1.776
220	400	1.776
220	500	1.776
220	600	1.776
220	700	1.776
220	800	1.776
220	900	1.775
220	1000	1.775
220	1100	1.776
220	1200	1.775
220	1300	1.775
220	1400	1.775
220	1500	1.774
220	1600	1.775
220	1700	1.775
220	1800	1.775
220	1900	1.775
220	2000	1.775
220	2100	1.775
220	2200	1.775
220	2300	1.775

Julian Date	Time	Flow (cfs)
221	0	1.775
221	100	1.775
221	200	1.775
221	300	1.775
221	400	1.775
221	500	1.775
221	600	1.775
221	700	1.775
221	800	1.775
221	900	1.775
221	1000	1.775
221	1100	1.775
221	1200	1.775
221	1300	1.775
221	1400	1.774
221	1500	1.774
221	1600	1.774
221	1700	1.774
221	1800	1.774
221	1900	1.775
221	2000	1.775
221	2100	1.775
221	2200	1.775
221	2300	1.775
222	0	1.775
222	100	1.775
222	200	1.775
222	300	1.775
222	400	1.775
222	500	1.775
222	600	1.775
222	700	1.775
222	800	1.775
222	900	1.775
222	1000	1.775
222	1100	1.775
222	1200	1.775
222	1300	1.775
222	1400	1.774
222	1500	1.774
222	1600	1.774
222	1700	1.774
222	1800	1.774
222	1900	1.774
222	2000	1.774
222	2100	1.775
222	2200	1.775
222	2300	1.775
223	0	1.775
223	100	1.775
223	200	1.775
223	300	1.775
223	400	1.775
223	500	1.775
223	600	1.775
223	700	1.775
223	800	1.775
223	900	1.775
223	1000	1.775
223	1100	1.775
223	1200	1.775
223	1300	1.775
223	1400	1.775
223	1500	1.774
223	1600	1.774
223	1700	1.774
223	1800	1.774
223	1900	1.774
223	2000	1.774
223	2100	1.775
223	2200	1.775
223	2300	1.775
224	0	1.775
224	100	1.775
224	200	1.775

Julian Date	Time	Flow (cfs)
224	300	1.775
224	400	1.775
224	500	1.775
224	600	1.775
224	700	1.775
224	800	1.775
224	900	1.775
224	1000	1.775
224	1100	1.775
224	1200	1.775
224	1300	1.774
224	1400	1.774
224	1500	1.776
224	1600	1.779
224	1700	1.780
224	1800	1.786
224	1900	1.790
224	2000	1.792
224	2100	1.789
224	2200	1.787
224	2300	1.785
225	0	1.785
225	100	1.785
225	200	1.786
225	300	1.786
225	400	1.785
225	500	1.783
225	600	1.782
225	700	1.781
225	800	1.780
225	900	1.780
225	1000	1.780
225	1100	1.779
225	1200	1.779
225	1300	1.779
225	1400	1.779
225	1500	1.779
225	1600	1.779
225	1700	1.779
225	1800	1.779
225	1900	1.779
225	2000	1.779
225	2100	1.779
225	2200	1.778
225	2300	1.778
226	0	1.778
226	100	1.778
226	200	1.778
226	300	1.778
226	400	1.778
226	500	1.778
226	600	1.777
226	700	1.777
226	800	1.777
226	900	1.777
226	1000	1.777
226	1100	1.777
226	1200	1.776
226	1300	1.776
226	1400	1.776
226	1500	1.776
226	1600	1.776
226	1700	1.776
226	1800	1.776
226	1900	1.776
226	2000	1.776
226	2100	1.776
226	2200	1.776
226	2300	1.777
227	0	1.776
227	100	1.777
227	200	1.777
227	300	1.777
227	400	1.777
227	500	1.777

Julian Date	Time	Flow (cfs)
227	600	1.777
227	700	1.777
227	800	1.777
227	900	1.777
227	1000	1.777
227	1100	1.777
227	1200	1.776
227	1300	1.776
227	1400	1.776
227	1500	1.776
227	1600	1.777
227	1700	1.777
227	1800	1.777
227	1900	1.777
227	2000	1.777
227	2100	1.777
227	2200	1.777
227	2300	1.777
228	0	1.777
228	100	1.777
228	200	1.777
228	300	1.777
228	400	1.777
228	500	1.776
228	600	1.776
228	700	1.776
228	800	1.776
228	900	1.776
228	1000	1.776
228	1100	1.777
228	1200	1.777
228	1300	1.777
228	1400	1.777
228	1500	1.777
228	1600	1.777
228	1700	1.777
228	1800	1.777
228	1900	1.777
228	2000	1.777
228	2100	1.777
228	2200	1.777
228	2300	1.778
229	0	1.778
229	100	1.777
229	200	1.777
229	300	1.777
229	400	1.777
229	500	1.778
229	600	1.777
229	700	1.777
229	800	1.777
229	900	1.778
229	1000	1.778
229	1100	1.777
229	1200	1.777
229	1300	1.777
229	1400	1.777
229	1500	1.777
229	1600	1.777
229	1700	1.777
229	1800	1.777
229	1900	1.777
229	2000	1.777
229	2100	1.777
229	2200	1.777
229	2300	1.777
230	0	1.777
230	100	1.777
230	200	1.777
230	300	1.778
230	400	1.780
230	500	1.780
230	600	1.782
230	700	1.784
230	800	1.788

Julian Date	Time	Flow (cfs)
230	900	1.792
230	1000	1.793
230	1100	1.792
230	1200	1.791
230	1300	1.791
230	1400	1.790
230	1500	1.789
230	1600	1.788
230	1700	1.788
230	1800	1.787
230	1900	1.787
230	2000	1.787
230	2100	1.787
230	2200	1.789
230	2300	1.791
231	0	1.793
231	100	1.792
231	200	1.791
231	300	1.790
231	400	1.790
231	500	1.790
231	600	1.789
231	700	1.789
231	800	1.789
231	900	1.789
231	1000	1.789
231	1100	1.787
231	1200	1.786
231	1300	1.786
231	1400	1.786
231	1500	1.785
231	1600	1.785
231	1700	1.785
231	1800	1.784
231	1900	1.784
231	2000	1.784
231	2100	1.783
231	2200	1.783
231	2300	1.783
232	0	1.783
232	100	1.785
232	200	1.788
232	300	1.798
232	400	1.803
232	500	1.806
232	600	1.802
232	700	1.800
232	800	1.798
232	900	1.796
232	1000	1.794
232	1100	1.793
232	1200	1.792
232	1300	1.791
232	1400	1.790
232	1500	1.789
232	1600	1.788
232	1700	1.788
232	1800	1.789
232	1900	1.788
232	2000	1.787
232	2100	1.786
232	2200	1.785
232	2300	1.785
233	0	1.785
233	100	1.784
233	200	1.784
233	300	1.784
233	400	1.784
233	500	1.783
233	600	1.783
233	700	1.783
233	800	1.783
233	900	1.783
233	1000	1.784
233	1100	1.784

Julian Date	Time	Flow (cfs)	Julian Date	Time	Flow (cfs)	Julian Date	Time	Flow (cfs)
233	1200	1.783	236	1500	1.775	239	1800	1.774
233	1300	1.782	236	1600	1.775	239	1900	1.774
233	1400	1.782	236	1700	1.775	239	2000	1.774
233	1500	1.782	236	1800	1.775	239	2100	1.774
233	1600	1.782	236	1900	1.775	239	2200	1.774
233	1700	1.781	236	2000	1.775	239	2300	1.774
233	1800	1.781	236	2100	1.776	240	0	1.774
233	1900	1.781	236	2200	1.776	240	100	1.777
233	2000	1.781	236	2300	1.776	240	200	1.779
233	2100	1.781	237	0	1.776	240	300	1.778
233	2200	1.781	237	100	1.776	240	400	1.776
233	2300	1.781	237	200	1.776	240	500	1.775
234	0	1.780	237	300	1.776	240	600	1.774
234	100	1.780	237	400	1.776	240	700	1.774
234	200	1.780	237	500	1.776	240	800	1.774
234	300	1.780	237	600	1.776	240	900	1.774
234	400	1.780	237	700	1.775	240	1000	1.774
234	500	1.780	237	800	1.775	240	1100	1.774
234	600	1.780	237	900	1.776	240	1200	1.773
234	700	1.779	237	1000	1.778	240	1300	1.773
234	800	1.779	237	1100	1.779	240	1400	1.773
234	900	1.781	237	1200	1.777	240	1500	1.773
234	1000	1.782	237	1300	1.775	240	1600	1.774
234	1100	1.781	237	1400	1.774	240	1700	1.774
234	1200	1.779	237	1500	1.774	240	1800	1.774
234	1300	1.779	237	1600	1.774	240	1900	1.774
234	1400	1.779	237	1700	1.774	240	2000	1.774
234	1500	1.778	237	1800	1.775	240	2100	1.774
234	1600	1.779	237	1900	1.775	240	2200	1.774
234	1700	1.778	237	2000	1.775	240	2300	1.774
234	1800	1.778	237	2100	1.775	241	0	1.774
234	1900	1.778	237	2200	1.775	241	100	1.774
234	2000	1.778	237	2300	1.775	241	200	1.774
234	2100	1.778	238	0	1.775	241	300	1.774
234	2200	1.778	238	100	1.775	241	400	1.774
234	2300	1.778	238	200	1.775	241	500	1.774
235	0	1.778	238	300	1.775	241	600	1.774
235	100	1.778	238	400	1.775	241	700	1.774
235	200	1.778	238	500	1.775	241	800	1.774
235	300	1.778	238	600	1.775	241	900	1.774
235	400	1.777	238	700	1.775	241	1000	1.774
235	500	1.777	238	800	1.775	241	1100	1.774
235	600	1.777	238	900	1.775	241	1200	1.774
235	700	1.777	238	1000	1.775	241	1300	1.773
235	800	1.777	238	1100	1.774	241	1400	1.773
235	900	1.777	238	1200	1.774	241	1500	1.774
235	1000	1.777	238	1300	1.774	241	1600	1.774
235	1100	1.777	238	1400	1.773	241	1700	1.774
235	1200	1.777	238	1500	1.774	241	1800	1.774
235	1300	1.777	238	1600	1.774	241	1900	1.774
235	1400	1.777	238	1700	1.774	241	2000	1.775
235	1500	1.777	238	1800	1.774	241	2100	1.777
235	1600	1.777	238	1900	1.774	241	2200	1.778
235	1700	1.777	238	2000	1.774	241	2300	1.778
235	1800	1.777	238	2100	1.774	242	0	1.778
235	1900	1.777	238	2200	1.775	242	100	1.779
235	2000	1.777	238	2300	1.775	242	200	1.781
235	2100	1.777	239	0	1.775	242	300	1.781
235	2200	1.777	239	100	1.775	242	400	1.780
235	2300	1.777	239	200	1.775	242	500	1.778
236	0	1.780	239	300	1.775	242	600	1.777
236	100	1.780	239	400	1.775	242	700	1.776
236	200	1.779	239	500	1.775	242	800	1.776
236	300	1.777	239	600	1.775	242	900	1.776
236	400	1.777	239	700	1.774	242	1000	1.775
236	500	1.776	239	800	1.774	242	1100	1.775
236	600	1.776	239	900	1.774	242	1200	1.774
236	700	1.776	239	1000	1.775	242	1300	1.773
236	800	1.776	239	1100	1.774	242	1400	1.773
236	900	1.776	239	1200	1.774	242	1500	1.773
236	1000	1.776	239	1300	1.773	242	1600	1.774
236	1100	1.776	239	1400	1.773	242	1700	1.774
236	1200	1.776	239	1500	1.774	242	1800	1.774
236	1300	1.775	239	1600	1.774	242	1900	1.774
236	1400	1.775	239	1700	1.774	242	2000	1.774

Julian Date	Time	Flow (cfs)
242	2100	1.774
242	2200	1.774
242	2300	1.774
243	0	1.774
243	100	1.774
243	200	1.774
243	300	1.774
243	400	1.774
243	500	1.774
243	600	1.774
243	700	1.774
243	800	1.777
243	900	1.779
243	1000	1.778
243	1100	1.776
243	1200	1.774
243	1300	1.773
243	1400	1.772
243	1500	1.772
243	1600	1.772
243	1700	1.773
243	1800	1.773
243	1900	1.773
243	2000	1.773
243	2100	1.773
243	2200	1.773
243	2300	1.773
244	0	1.773
244	100	1.773
244	200	1.773
244	300	1.773
244	400	1.773
244	500	1.773
244	600	1.773
244	700	1.773
244	800	1.773
244	900	1.773
244	1000	1.773
244	1100	1.772
244	1200	1.772
244	1300	1.771
244	1400	1.769
244	1500	1.768
244	1600	1.767
244	1700	1.769
244	1800	1.770
244	1900	1.771
244	2000	1.771
244	2100	1.771
244	2200	1.771
244	2300	1.772
245	0	1.772
245	100	1.772
245	200	1.772
245	300	1.771
245	400	1.771
245	500	1.771
245	600	1.771
245	700	1.771
245	800	1.771
245	900	1.771
245	1000	1.771
245	1100	1.771
245	1200	1.771
245	1300	1.771
245	1400	1.770
245	1500	1.769
245	1600	1.769
245	1700	1.770
245	1800	1.770
245	1900	1.770
245	2000	1.771
245	2100	1.771
245	2200	1.771
245	2300	1.771

Julian Date	Time	Flow (cfs)
246	0	1.771
246	100	1.771
246	200	1.771
246	300	1.771
246	400	1.771
246	500	1.771
246	600	1.771
246	700	1.771
246	800	1.771
246	900	1.771
246	1000	1.771
246	1100	1.771
246	1200	1.771
246	1300	1.770
246	1400	1.770
246	1500	1.769
246	1600	1.769
246	1700	1.769
246	1800	1.770
246	1900	1.770
246	2000	1.770
246	2100	1.770
246	2200	1.770
246	2300	1.770
247	0	1.770
247	100	1.770
247	200	1.770
247	300	1.770
247	400	1.770
247	500	1.770
247	600	1.771
247	700	1.771
247	800	1.771
247	900	1.771
247	1000	1.772
247	1100	1.772
247	1200	1.771
247	1300	1.771
247	1400	1.771
247	1500	1.771
247	1600	1.771
247	1700	1.771
247	1800	1.776
247	1900	1.779
247	2000	1.785
247	2100	1.788
247	2200	1.793
247	2300	1.790
248	0	1.786
248	100	1.785
248	200	1.785
248	300	1.785
248	400	1.783
248	500	1.782
248	600	1.781
248	700	1.780
248	800	1.780
248	900	1.779
248	1000	1.778
248	1100	1.777
248	1200	1.777
248	1300	1.777
248	1400	1.779
248	1500	1.779
248	1600	1.779
248	1700	1.779
248	1800	1.779
248	1900	1.779
248	2000	1.779
248	2100	1.779
248	2200	1.779
248	2300	1.778
249	0	1.778
249	100	1.778
249	200	1.776

Julian Date	Time	Flow (cfs)
249	300	1.775
249	400	1.774
249	500	1.773
249	[illegible]	1.773
249	[illegible]	[illegible]
249	[illegible]	[illegible]
249	[illegible]	[illegible]
249	1000	1.773
249	1100	1.773
249	1200	1.773
249	1300	1.773
249	1400	1.772
249	1500	1.772
249	1600	1.772
249	1700	1.772
249	1800	1.774
249	1900	1.777
249	2000	1.777
249	2100	1.777
249	2200	1.776
249	2300	1.774
250	0	1.773
250	100	1.772
250	200	1.772
250	300	1.772
250	400	1.772
250	500	1.772
250	600	1.772
250	700	1.772
250	800	1.772
250	900	1.772
250	1000	1.771
250	1100	1.771
250	1200	1.771
250	1300	1.771
250	1400	1.771
250	1500	1.771
250	1600	1.771
250	1700	1.772
250	1800	1.772
250	1900	1.773
250	2000	1.773
250	2100	1.773
250	2200	1.773
250	2300	1.773
251	0	1.774
251	100	1.775
251	200	1.777
251	300	1.780
251	400	1.783
251	500	1.785
251	600	1.786
251	700	1.789
251	800	1.789
251	900	1.788
251	1000	1.786
251	1100	1.785
251	1200	1.784
251	1300	1.782
251	1400	1.782
251	1500	1.781
251	1600	1.781
251	1700	1.780
251	1800	1.780
251	1900	1.779
251	2000	1.778
251	2100	1.778
251	2200	1.778
251	2300	1.777
252	0	1.777
252	100	1.777
252	200	1.776
252	300	1.777
252	400	1.779
252	500	1.779

Julian Date	Time	Flow (cfs)
252	600	1.779
252	700	1.779
252	800	1.778
252	900	1.778
252	1000	1.776
252	1100	1.775
252	1200	1.775
252	1300	1.774
252	1400	1.774
252	1500	1.775
252	1600	1.775
252	1700	1.775
252	1800	1.775
252	1900	1.775
252	2000	1.774
252	2100	1.775
252	2200	1.775
252	2300	1.775
253	0	1.775
253	100	1.775
253	200	1.775
253	300	1.774
253	400	1.774
253	500	1.774
253	600	1.774
253	700	1.774
253	800	1.774
253	900	1.773
253	1000	1.774
253	1100	1.777
253	1200	1.777
253	1300	1.777
253	1400	1.777
253	1500	1.777
253	1600	1.777
253	1700	1.775
253	1800	1.774
253	1900	1.773
253	2000	1.772
253	2100	1.772
253	2200	1.772
253	2300	1.773
254	0	1.773
254	100	1.773
254	200	1.773
254	300	1.773
254	400	1.773
254	500	1.773
254	600	1.772
254	700	1.772
254	800	1.773
254	900	1.773
254	1000	1.773
254	1100	1.774
254	1200	1.774
254	1300	1.775
254	1400	1.775
254	1500	1.775
254	1600	1.774
254	1700	1.774
254	1800	1.774
254	1900	1.774
254	2000	1.776
254	2100	1.778
254	2200	1.779
254	2300	1.780
255	0	1.780
255	100	1.780
255	200	1.780
255	300	1.779
255	400	1.777
255	500	1.779
255	600	1.779
255	700	1.778
255	800	1.777

Julian Date	Time	Flow (cfs)
255	900	1.777
255	1000	1.776
255	1100	1.775
255	1200	1.775
255	1300	1.775
255	1400	1.774
255	1500	1.774
255	1600	1.774
255	1700	1.774
255	1800	1.774
255	1900	1.774
255	2000	1.774
255	2100	1.774
255	2200	1.774
255	2300	1.777
256	0	1.778
256	100	1.778
256	200	1.777
256	300	1.777
256	400	1.777
256	500	1.775
256	600	1.774
256	700	1.772
256	800	1.772
256	900	1.772
256	1000	1.772
256	1100	1.771
256	1200	1.771
256	1300	1.771
256	1400	1.770
256	1500	1.770
256	1600	1.770
256	1700	1.770
256	1800	1.770
256	1900	1.770
256	2000	1.770
256	2100	1.770
256	2200	1.770
256	2300	1.770
257	0	1.770
257	100	1.770
257	200	1.770
257	300	1.770
257	400	1.770
257	500	1.770
257	600	1.770
257	700	1.770
257	800	1.770
257	900	1.770
257	1000	1.774
257	1100	1.775
257	1200	1.775
257	1300	1.775
257	1400	1.775
257	1500	1.774
257	1600	1.773
257	1700	1.772
257	1800	1.770
257	1900	1.769
257	2000	1.768
257	2100	1.768
257	2200	1.768
257	2300	1.768
258	0	1.769
258	100	1.769
258	200	1.768
258	300	1.769
258	400	1.769
258	500	1.769
258	600	1.769
258	700	1.769
258	800	1.769
258	900	1.769
258	1000	1.769
258	1100	1.769

Julian Date	Time	Flow (cfs)
258	1200	1.768
258	1300	1.768
258	1400	1.768
258	1500	1.768
258	1600	1.768
258	1700	1.768
258	1800	1.768
258	1900	1.768
258	2000	1.768
258	2100	1.768
258	2200	1.766
258	2300	1.768
259	0	1.771
259	100	1.774
259	200	1.774
259	300	1.774
259	400	1.774
259	500	1.774
259	600	1.774
259	700	1.773
259	800	1.771
259	900	1.769
259	1000	1.768
259	1100	1.767
259	1200	1.767
259	1300	1.767
259	1400	1.767
259	1500	1.767
259	1600	1.767
259	1700	1.767
259	1800	1.767
259	1900	1.767
259	2000	1.767
259	2100	1.767
259	2200	1.767
259	2300	1.767
260	0	1.767
260	100	1.768
260	200	1.768
260	300	1.768
260	400	1.768
260	500	1.768
260	600	1.768
260	700	1.768
260	800	1.768
260	900	1.768
260	1000	1.768
260	1100	1.768
260	1200	1.767
260	1300	1.767
260	1400	1.767
260	1500	1.767
260	1600	1.767
260	1700	1.767
260	1800	1.769
260	1900	1.773
260	2000	1.773
260	2100	1.773
260	2200	1.773
260	2300	1.773
261	0	1.773
261	100	1.773
261	200	1.772
261	300	1.770
261	400	1.768
261	500	1.767
261	600	1.767
261	700	1.767
261	800	1.767
261	900	1.767
261	1000	1.767
261	1100	1.767
261	1200	1.766
261	1300	1.767
261	1400	1.766

Julian Date	Time	Flow (cfs)
261	1500	1.766
261	1600	1.766
261	1700	1.769
261	1800	1.773
261	1900	1.773
261	2000	1.773
261	2100	1.771
261	2200	1.769
261	2300	1.767
262	0	1.766
262	100	1.766
262	200	1.766
262	300	1.766
262	400	1.766
262	500	1.766
262	600	1.766
262	700	1.766
262	800	1.767
262	900	1.767
262	1000	1.767
262	1100	1.767
262	1200	1.766
262	1300	1.766
262	1400	1.766
262	1500	1.766
262	1600	1.767
262	1700	1.772
262	1800	1.773
262	1900	1.772
262	2000	1.770
262	2100	1.768
262	2200	1.768
262	2300	1.772
263	0	1.773
263	100	1.773
263	200	1.773
263	300	1.772
263	400	1.770
263	500	1.769
263	600	1.769
263	700	1.769
263	800	1.769
263	900	1.769
263	1000	1.769
263	1100	1.769
263	1200	1.768
263	1300	1.768
263	1400	1.768
263	1500	1.768
263	1600	1.768
263	1700	1.768
263	1800	1.768
263	1900	1.768
263	2000	1.768
263	2100	1.768
263	2200	1.768
263	2300	1.768
264	0	1.768
264	100	1.768
264	200	1.768
264	300	1.768
264	400	1.768
264	500	1.768
264	600	1.768
264	700	1.768
264	800	1.768
264	900	1.768
264	1000	1.768
264	1100	1.768
264	1200	1.768
264	1300	1.767
264	1400	1.767
264	1500	1.767
264	1600	1.767
264	1700	1.767
264	1800	1.767
264	1900	1.767
264	2000	1.767
264	2100	1.767
264	2200	1.767
264	2300	1.767
265	0	1.767
265	100	1.767
265	200	1.767
265	300	1.767
265	400	1.767
265	500	1.767
265	600	1.767
265	700	1.767
265	800	1.767
265	900	1.767
265	1000	1.767
265	1100	1.767
265	1200	1.767
265	1300	1.767
265	1400	1.767
265	1500	1.767
265	1600	1.767
265	1700	1.766
265	1800	1.766
265	1900	1.765
265	2000	1.764
265	2100	1.764
265	2200	1.765
265	2300	1.766
266	0	1.767
266	100	1.767
266	200	1.767
266	300	1.768
266	400	1.768
266	500	1.767
266	600	1.768
266	700	1.768
266	800	1.767
266	900	1.768
266	1000	1.768
266	1100	1.768
266	1200	1.768
266	1300	1.768
266	1400	1.768
266	1500	1.768
266	1600	1.768
266	1700	1.769
266	1800	1.769
266	1900	1.768
266	2000	1.769
266	2100	1.770
266	2200	1.771
266	2300	1.772
267	0	1.771
267	100	1.772
267	200	1.772
267	300	1.773
267	400	1.773
267	500	1.772
267	600	1.772
267	700	1.771
267	800	1.771
267	900	1.770
267	1000	1.770
267	1100	1.770
267	1200	1.769
267	1300	1.769
267	1400	1.768
267	1500	1.768
267	1600	1.768
267	1700	1.768
267	1800	1.768
267	1900	1.769
267	2000	1.769
267	2100	1.769
267	2200	1.768
267	2300	1.768
268	0	1.768
268	100	1.769
268	200	1.769
268	300	1.769
268	400	1.768
268	500	1.768
268	600	1.768
268	700	1.768
268	800	1.768
268	900	1.769
268	1000	1.769
268	1100	1.768
268	1200	1.767
268	1300	1.767
268	1400	1.767
268	1500	1.767
268	1600	1.767
268	1700	1.767
268	1800	1.766
268	1900	1.766
268	2000	1.767
268	2100	1.767
268	2200	1.768
268	2300	1.767
269	0	1.767
269	100	1.767
269	200	1.767
269	300	1.767
269	400	1.767
269	500	1.767
269	600	1.767
269	700	1.767
269	800	1.766
269	900	1.766
269	1000	1.767
269	1100	1.767
269	1200	1.766
269	1300	1.766
269	1400	1.766
269	1500	1.767
269	1600	1.767
269	1700	1.767
269	1800	1.767
269	1900	1.768
269	2000	1.770
269	2100	1.770
269	2200	1.771
269	2300	1.774
270	0	1.778
270	100	1.782
270	200	1.790
270	300	1.795
270	400	1.793
270	500	1.790
270	600	1.791
270	700	1.792
270	800	1.791
270	900	1.791
270	1000	1.792
270	1100	1.794
270	1200	1.795
270	1300	1.794
270	1400	1.793
270	1500	1.792
270	1600	1.790
270	1700	1.788
270	1800	1.787
270	1900	1.786
270	2000	1.784
270	2100	1.783
270	2200	1.782
270	2300	1.782

Julian Date	Time	Flow (cfs)
271	0	1.781
271	100	1.780
271	200	1.780
271	300	1.779
271	400	1.779
271	500	1.778
271	600	1.778
271	700	1.777
271	800	1.777
271	900	1.777
271	1000	1.777
271	1100	1.777
271	1200	1.776
271	1300	1.778
271	1400	1.782
271	1500	1.793
271	1600	1.805
271	1700	1.808
271	1800	1.810
271	1900	1.809
271	2000	1.804
271	2100	1.800
271	2200	1.797
271	2300	1.795
272	0	1.792
272	100	1.791
272	200	1.789
272	300	1.788
272	400	1.787
272	500	1.786
272	600	1.785
272	700	1.784
272	800	1.783
272	900	1.783
272	1000	1.783
272	1100	1.782
272	1200	1.782
272	1300	1.781
272	1400	1.781
272	1500	1.780
272	1600	1.780
272	1700	1.780
272	1800	1.780
272	1900	1.779
272	2000	1.779
272	2100	1.779
272	2200	1.779
272	2300	1.779
273	0	1.778
273	100	1.778
273	200	1.778
273	300	1.778
273	400	1.778
273	500	1.778
273	600	1.777
273	700	1.777
273	800	1.777
273	900	1.777
273	1000	1.777
273	1100	1.776
273	1200	1.776
273	1300	1.776
273	1400	1.776
273	1500	1.776
273	1600	1.776
273	1700	1.775
273	1800	1.775
273	1900	1.775
273	2000	1.775
273	2100	1.775
273	2200	1.775
273	2300	1.775
274	0	1.775
274	100	1.774
274	200	1.775
274	300	1.774
274	400	1.774
274	500	1.774
274	600	1.774
274	700	1.774
274	800	1.774
274	900	1.774
274	1000	1.774
274	1100	1.773
274	1200	1.774
274	1300	1.773
274	1400	1.773
274	1500	1.773
274	1600	1.773
274	1700	1.773
274	1800	1.773
274	1900	1.773
274	2000	1.773
274	2100	1.773
274	2200	1.773
274	2300	1.773
275	0	1.773
275	100	1.773
275	200	1.773
275	300	1.773
275	400	1.773
275	500	1.773
275	600	1.773
275	700	1.773
275	800	1.773
275	900	1.772
275	1000	1.772
275	1100	1.772
275	1200	1.772
275	1300	1.772
275	1400	1.772
275	1500	1.772
275	1600	1.771
275	1700	1.771
275	1800	1.771
275	1900	1.771
275	2000	1.772
275	2100	1.772
275	2200	1.772
275	2300	1.772
276	0	1.772
276	100	1.771
276	200	1.772
276	300	1.772
276	400	1.771
276	500	1.771
276	600	1.771
276	700	1.771
276	800	1.771
276	900	1.771
276	1000	1.771