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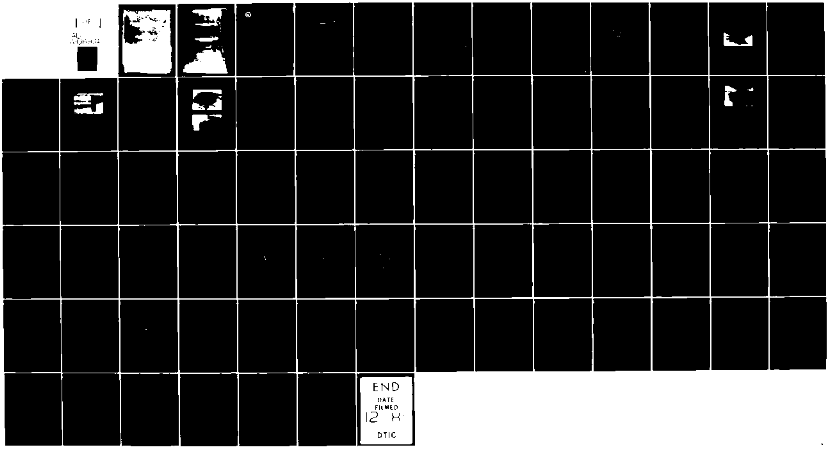

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No. 1

INVESTIGATION OF RELEASE TEMPERATURES
FOR KINZUA DAM, ALLEGHENY RIVER
PENNSYLVANIA

Hydraulic Model Investigation

Technical Report HL-81-9

September 1981

On the cover of the report, first line under the title: Change Hydraulic Model Investigation to Hybrid Model Investigation.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Kinzua Dam, which impounds the Allegheny Reservoir, is a multipurpose project that includes pumped-storage hydropower and flood control. Prior to the construction of Kinzua Dam, the Allegheny River in the vicinity of Kinzua Dam was considered primarily a warmwater stream and supported an important smallmouth bass sport fishery. Since the construction of the dam and power station, stream temperatures below the dam have been colder than expected. To address this

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20. ABSTRACT (Continued).

problem, a hybrid modeling study was initiated to determine the causes of colder-than-expected releases and to identify and evaluate measures that could be taken to increase the release temperatures.

The existing data base alone was insufficient to determine the causes of colder-than-expected releases. Additional temperature data were collected, and the enlarged data base was used to better understand the physical processes to be simulated in a pumped-storage reservoir thermal simulation numerical model. A physical model, scale 1:100, of the inlet-outlet structure and the surrounding Allegheny Reservoir near-field topography was used during the study to determine the selective withdrawal and pumped-storage mixing characteristics. Mathematical thermal model simulations were used to determine the major factors contributing to the release characteristics. Subsequently, the model was used to evaluate various structural and operational modifications to increase release temperatures.

The study determined that the pumped-storage operations have not been the cause of the colder-than-desired releases. Pumped-storage actually causes the hypolimnion to warm faster without significant cooling of the epilimnion. Structural modification of the sluices was determined to be the most effective and practical means of releasing warmer water.

PREFACE

The study reported herein was authorized by the Office, Chief of Engineers, U. S. Army, on 7 July 1977, at the request of the U. S. Army Engineer District, Pittsburgh.

The investigation was conducted during the period September 1977 to August 1979, in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and D. G. Fontane, Acting Chief of the Reservoir Water Quality Branch (RWQB). The study was conducted by Mr. M. S. Dortch. This report was written by Mr. Dortch and reviewed by Mr. Grace and Dr. D. R. Smith, Chief of RWQB.

Commanders and Directors of WES during the conduct of this study and the preparation and publication of this report were COL John L. Cannon, CE, COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acre-feet	1233.482	cubic metres
acres	4.046	square kilometres
British thermal unit	1055.056	joules
cubic feet per second	0.02832	cubic metres per second
degrees Fahrenheit	5/9	degrees Celsius or Kelvins*
feet	0.3048	metres
inches	25.4	millimetres
miles (U. S. statute)	1.609	kilometres
square feet	0.092903	square metres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

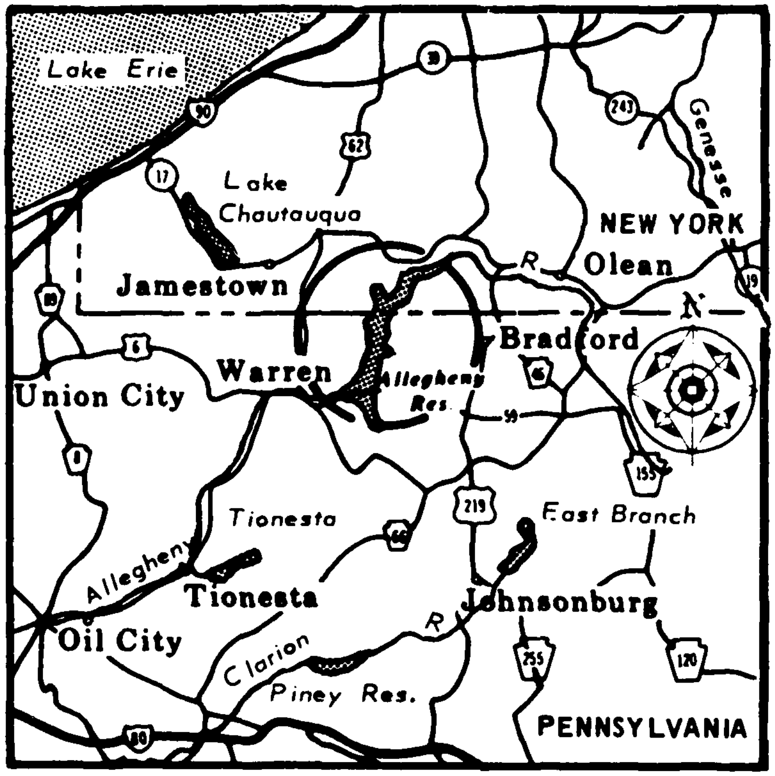

Figure 1. Vicinity map

INVESTIGATION OF RELEASE TEMPERATURES FOR KINZUA DAM
ALLEGHENY RIVER, PENNSYLVANIA
Hybrid Model Investigation

PART I: INTRODUCTION

Purpose of Investigation

1. Prior to the construction of Kinzua Dam, the Allegheny River in that vicinity was considered primarily a warmwater stream and supported an important smallmouth bass sport fishery. Since the construction of the dam and power station, colder-than-expected stream temperatures with phototropic periods out-of-phase have been experienced below the dam. The complexity of the reservoir dynamics, affected by general configuration, sluice outlet elevations, and unique pumped-storage features, thwarted efforts to reproduce preimpoundment temperatures downstream. This caused concern for the warmwater fishery; and many sportsmen and the Federal and State fishery agencies expressed repeated desire to restore or approximate pre-dam conditions to stabilize the river environment.

2. To address these concerns, the U. S. Army Engineer District, Pittsburgh (ORP), initiated an effort to determine the impact of Kinzua Dam on the Allegheny stream temperatures. ORP requested the U. S. Army Engineer Waterways Experiment Station (WES) to investigate the causes of colder-than-expected releases and to identify and evaluate potential remedial measures to increase the release temperatures.

Project Description

3. Kinzua Dam, completed in 1965 and operated by ORP, is a multipurpose project, which includes pumped-storage hydropower (380-MW capacity), located on the Allegheny River in northern Pennsylvania (Figure 1). The project consists of an upper and lower reservoir. The lower

reservoir, Allegheny Reservoir, has a capacity of about 572,000 acre-ft,* a surface area of 12,080 acres, a depth of 128 ft at normal summer pool el** 1328, and thermally stratifies. The upper reservoir, a much smaller impoundment that does not stratify, is located on top of a ridge 800 ft above and adjacent to Allegheny Reservoir. The asphalt-lined upper reservoir has a capacity of about 7,100 acre-ft and a surface area of 110 acres at a maximum depth of about 73 ft. Figure 2 shows Allegheny Reservoir in the vicinity of the dam; project features are identified in Figure 3.

Figure 2. Overall view of reservoir and dam

4. The Seneca pumped-storage power plant, which consists of two reversible pump-turbines (175 MW each) and one conventional turbine (30 MW), is owned and operated by Cleveland Electric Illuminating Company and Pennsylvania Electric Company. The various pumping and generating modes possible with the three turbines are shown in Figure 4. Generation and pumpback flows to and from Allegheny Reservoir pass through an

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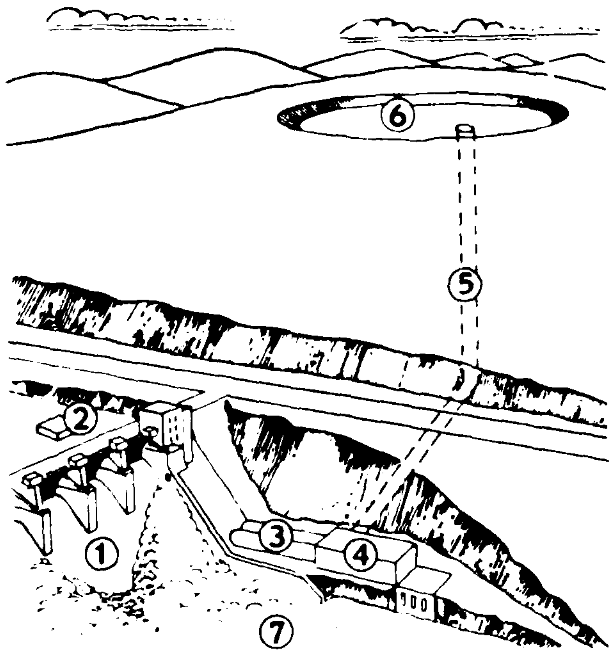
* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

** All elevations (el) cited herein are in feet referred to mean sea level (msl).

Figure 3. Project features



1. Kinzua Dam
2. Inlet-Outlet Structure
3. Main Reservoir Supply and Return - Two 15' Diameter Tunnels
4. Seneca Power Plant
5. Supply and Discharge Tunnel - 22' in Diameter, 1/2 Mi. Long
6. Upper Reservoir - 800' above Plant
7. Allegheny River

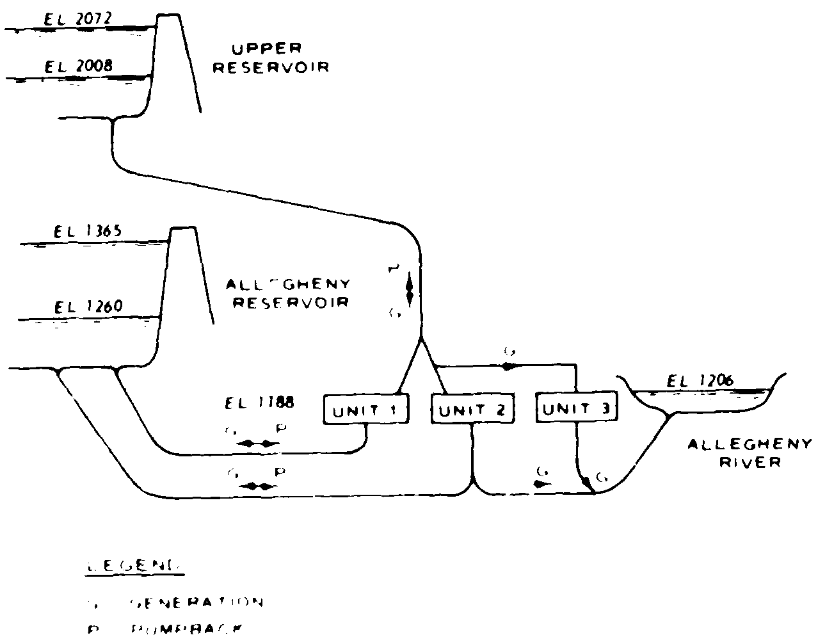


Figure 4. Power operation schemes for Kinzua Dam

inlet-outlet tower adjacent to the dam. The penstocks for units 1 and 2 are connected to separate wet wells within the tower. Selective withdrawal is provided for each well through two port openings at invert el 1226 (center-line el 1241.5) and invert el 1289.5 (center-line el 1310.25). The selective withdrawal intakes are equipped with slide gates and are operated fully open or closed. When the pool is stratified, water is withdrawn through the upper ports. When the pool is not stratified, the lower ports are used. A schematic of the inlet-outlet structure is shown in Figure 5. Figure 6 shows the inlet-outlet structure during a generation cycle.

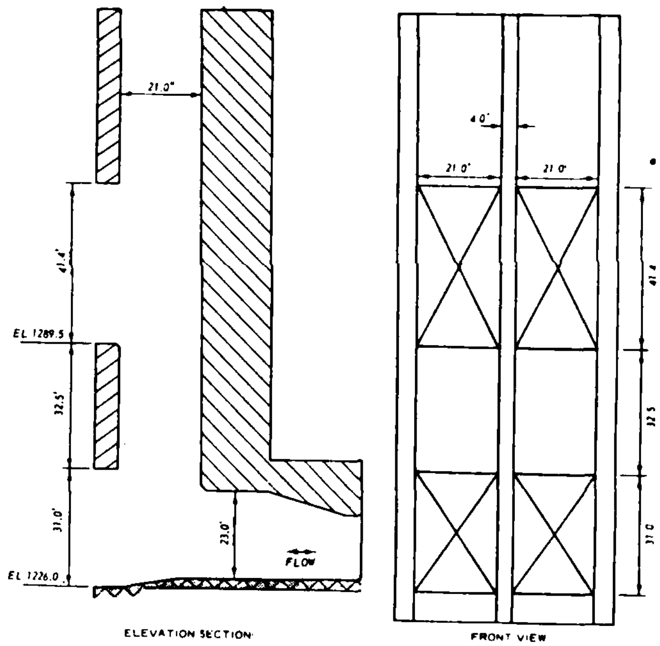


Figure 5. Inlet-outlet structure

5. In addition to power releases, flood control is augmented by sluice withdrawal at Kinzua Dam. Two upper sluices are located at invert el 1300 (center-line el 1305), and six low-level sluices are located at invert el 1205 (center-line el 1210), Figure 7. All sluice intake openings are 5 ft 8 in. wide by 10 ft high.

6. The generation and pumpback discharge capacities for units 1

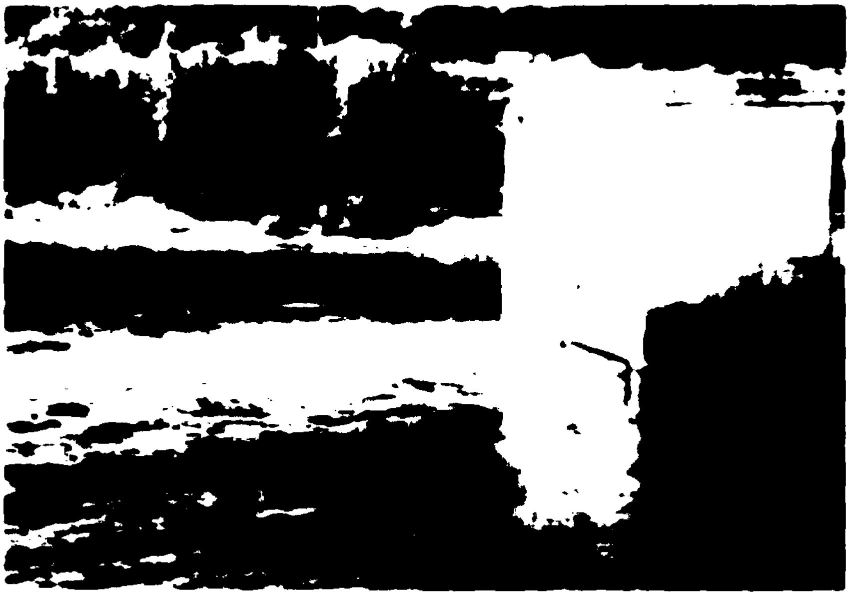


Figure 6. Inlet-out structure during power generation

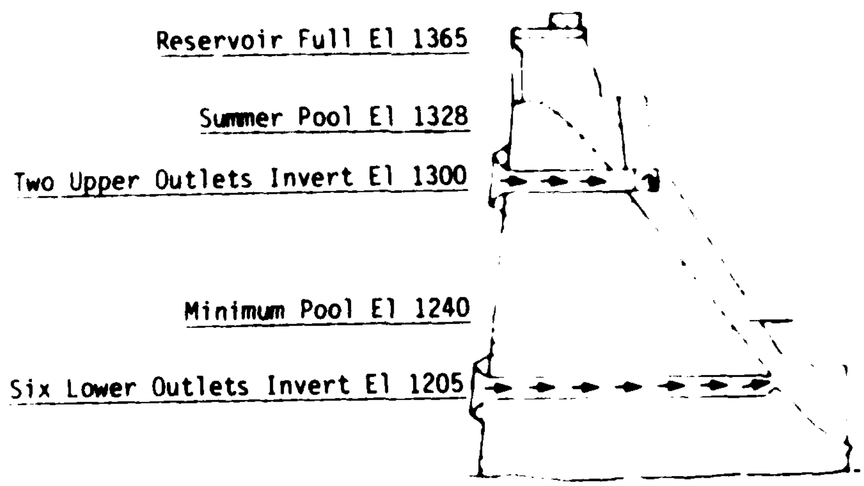


Figure 7. Section through dam

and 2 at normal pool levels are respectively about 4000 and 3500 cfs each. The generation discharge capacity for unit 3 is about 500 cfs. At full gate opening and normal pool el 1328, the capacities of each of the upper and lower sluices are 1760 and 4200 cfs, respectively.

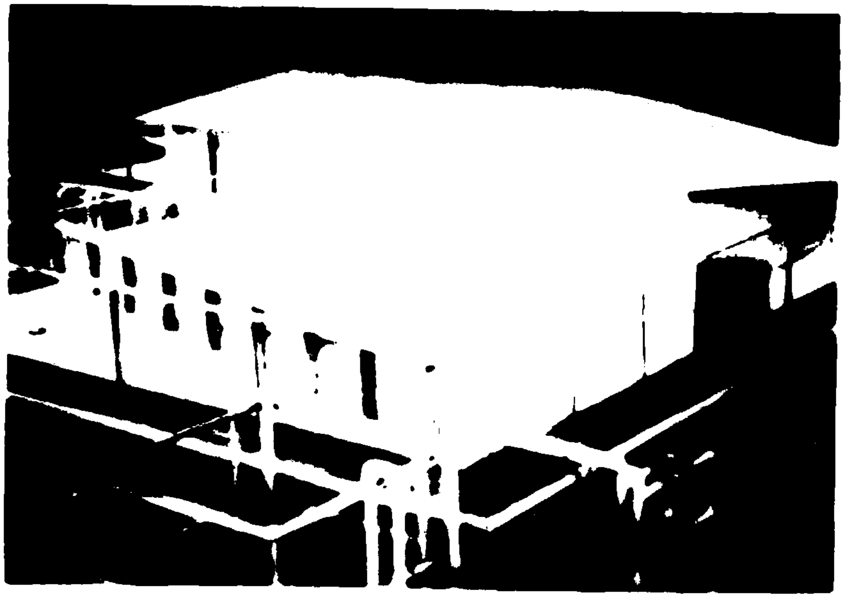
Approach

7. The existing data base was insufficient to determine the causes of the colder-than-expected releases. Additional temperature data were collected, and the enlarged data base was coupled to a hybrid modeling approach, which combines the use of both physical and mathematical models. A physical model, scale 1:100 (Figure 8), of the inlet-outlet structure and the surrounding near-field topography of the Allegheny Reservoir was used during the study to determine the selective withdrawal and pumped-storage mixing characteristics. These results were used to improve the predictive capability of the mathematical model used for simulation of the thermal structure of the reservoir.

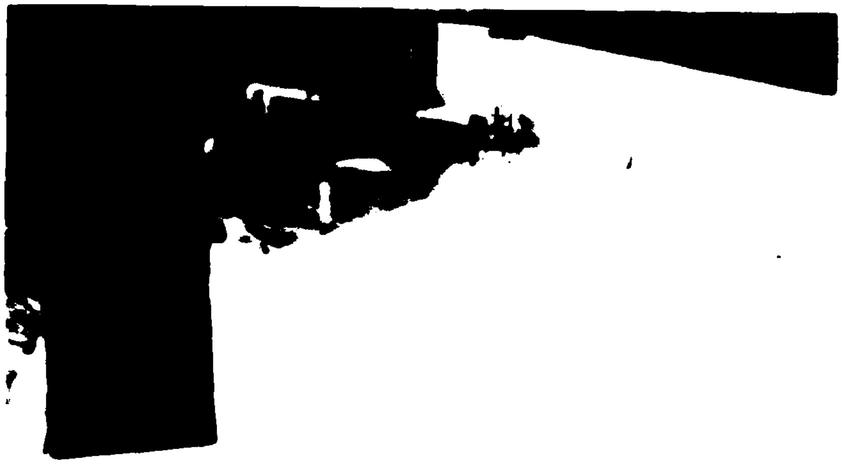
8. Mathematical thermal model simulations were used to determine the major factors contributing to the release characteristics. Subsequently, the model was used to evaluate various structural and operational modifications to increase release temperatures. The recommended modifications are presented herein.

9. To evaluate the effect of power operations on release temperatures, it was necessary to study a year without and a year with power operation. Although Kinzua Dam has been in operation since 1966, release temperatures and in-lake temperature profiles have been collected on a regular basis only since 1970. Between 1970 and the initiation of this study (1977), 1970 was the only year without power operation. Fortunately, a fairly good data base existed for 1970, and it was used for the without power study year. Between 1971 and 1977, 1977 exhibited the best data base; consequently, it was selected for the with power study year.

10. It was necessary to use a synthetic average natural stream temperature curve during the investigation for comparision and evaluation of various operational conditions and geometrical alternatives.



a. Looking upstream



b. Looking downstream

Figure 8. Physical model (scale 1:100)

The average or expected seasonal variation of natural stream temperature for the Allegheny River near Kinzua was synthesized by Drummond and Robey (1975) and is referred to in this report as expected or average natural stream temperatures. Although efforts were not made to determine if release temperatures were actually colder than the natural variation, it was evident during the course of the study that the releases are colder than the synthesized average natural variation. This can be recognized from several of the data plots that are presented for other purposes later in this report.

PART II: SIMULATION MODEL

Description

11. The mathematical simulation model used in this study was developed during previous studies (Fontane and Bohan 1974, Dortch et al. 1976, and Fontane et al. 1977) to evaluate the effects of pumped-storage operations on temperature regimes within and downstream of impoundments. A flow chart for the model is shown in Figure 9. The model includes methods for simulating heat transfer at the air-water interface, advective heat due to inflow, outflow, and pumpback processes, and internal dispersion of thermal energy. The one-dimensional model is based on the division of the impoundment into discrete horizontal layers of uniform thickness. Each discrete layer is assumed isotropic and physically homogeneous. Isotherms are assumed parallel to the water surface both laterally and longitudinally.

12. All of the surface heat exchange processes, with the exception of shortwave radiation, affect approximately only the top 2 ft of the lake. The mechanism in the model for evaluating surface heat transfer was developed by Edinger and Geyer (1965) and can be expresses as

$$H = K(T_E - \theta) \qquad (1)$$

where

H = net rate of surface heat transfer, $Btu/ft^2/day$

K = coefficient of surface heat exchange, $Btu/ft^2/day°F$

T_E = equilibrium temperature, °F

θ = surface temperature, °F

The computation of equilibrium temperature and heat exchange coefficient is based solely on meteorological data as outlined by Edinger, Duttweiler, and Geyer (1968). Shortwave radiation penetrates the water surface and increases the temperature at greater depths. Based on laboratory investigations, Dake and Harleman (1966) have suggested an exponential decay with depth for describing the heat flux due to

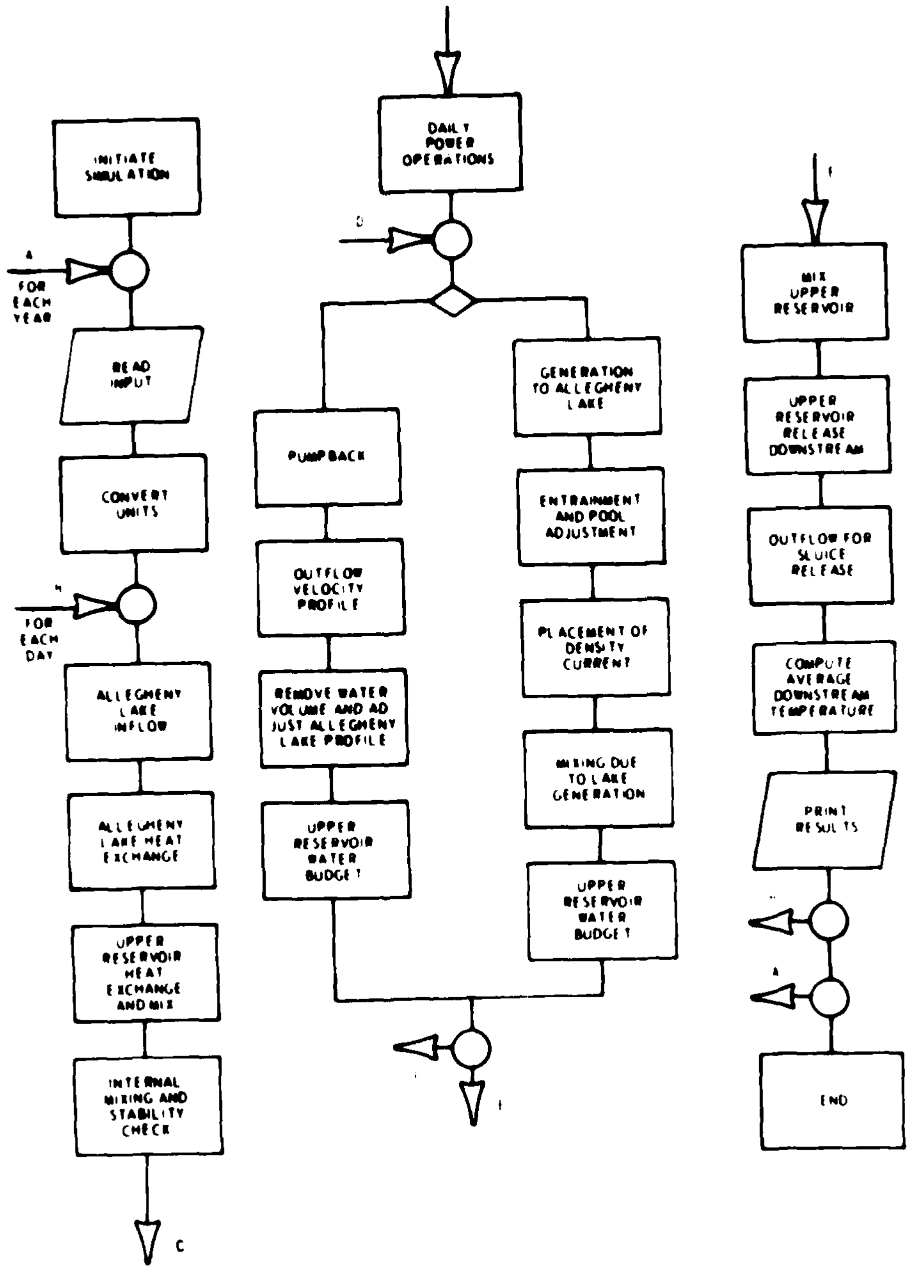


Figure 9. Simulation model flow chart

shortwave penetration. The surface heat exchange concepts are implemented in the model by an exponential decay of the incoming shortwave radiation and the placement of the effect of all other sources of surface heat exchange into the surface layer. This procedure can be expressed mathematically by the following two equations:

$$H_s = K(T_E - \theta) - (1 - \beta)S \tag{2}$$

$$H_i = (1 - \beta)Se^{-\lambda z_i} \tag{3}$$

where

H_s = heat transfer rate into or out of surface layer, Btu/ft^2/day

β = shortwave radiation absorbed in the surface layer, percent

S = total incoming shortwave radiation rate, Btu/ft^2/day

H_i = rate of heat absorbed in layer i, Btu/ft^2/day

e = natural logarithmic base (2.7183)

λ = heat absorption coefficient, ft^{-1}

z_i = depth below surface, ft

Equations 2 and 3 are applied to Allegheny Reservoir once during each one-day time-step. The net heat exchange into each layer is computed and converted to a temperature change. Since the upper reservoir is fully mixed, Equation 1 is used to apply heat exchange to the upper reservoir. In this case, θ is the temperature of the water in the upper reservoir.

13. The process of inflow is simulated by the placement of inflow quantity and temperature at that layer in which the density of the lake corresponds nearest to the density of the inflow. The inflow displaces upward a volume equal to the total inflow quantity. The internal dispersion process is represented by an internal mixing scheme based on a simple diffusion analogy. The magnitude of the mass transfer between two layers is a percentage of the total transfer required to completely mix the two layers. This percentage is a mixing coefficient which is defined for every layer. Data input includes values of the mixing

coefficient at the top and at the bottom of the lake. An exponential fit between the two extreme values is used to determine the appropriate coefficient for each layer. For this study, however, a value of 0.10 was used for the dispersion coefficient in all layers. This is equivalent to about ten times molecular diffusion. Inflow and internal dispersion occur once over a daily time-step.

14. The model uses the WES selective withdrawal technique (Bohan and Grace 1973) to determine the release temperature and the withdrawal distribution in the reservoir for outflows due to both sluice and pumpback operations. The technique computes the limits of withdrawal and the withdrawal velocity profile. A flow-weighted average is applied to the temperature profile to determine the average release temperature. The limits of withdrawal are functionally related to the withdrawal discharge rate. Because of the large variation of flows that occur with peaking power operations, it was necessary to use the average flow rate occurring during each period of pumpback withdrawal rather than a daily average pumpback flow rate. Daily average flows were used for sluice withdrawals. Additionally, the combined outflow of the two upper sluices and the combined outflow of the six lower sluices were modeled as releases from a single upper-level and lower-level outlet, respectively.

15. Mixing within Allegheny Reservoir is enhanced during periods of power generation when the discharge is directed into the reservoir. The generation flow enters the lake as a free turbulent shear flow (jet) which caused entrainment of ambient water. As the jet spreads, the energy flux decreases and the volume flux increases until the flow collapses into a density current that spreads horizontally within the density stratified impoundment. The entrainment coefficient, E , is the ratio of the volume of reservoir water entrained relative to the volume of water released from the powerhouse during a generation cycle. The entrained water of the Allegheny pool is numerically withdrawn and mixed with the generation water volume at its temperature. The mixed volume is placed into the layer of the lake that most closely corresponds to the mixed temperature, and layers above the entrance layer are displaced

upward. The model computes the thickness, D , of the generation flow density current from the expression:

$$D = 4.1 \left(\frac{Q_c}{W \sqrt{\frac{\Delta\rho}{\rho_c} g}} \right)^{2/3} \tag{4}$$

where

Q_c = volumetric flow rate of the generation density current (includes entrainment), cfs

W = average reservoir width at the elevation of the current in the vicinity of the dam, ft

$\Delta\rho$ = density difference of the epilimnion and hypolimnion, g/mℓ

ρ_c = average density of the current, g/mℓ

and

$$Q_c = (1 + E)Q_o$$

where Q_o (cfs) is the discharge rate of hydropower releases directed into Allegheny Reservoir. Hydropower discharges into Allegheny Reservoir, Q_o , were computed as the average flow rate during each generation period rather than daily average generation flow rate.

16. To simulate mixing within the zone of the generation current, a sequential mixing algorithm is utilized. A fraction of each layer in the density current zone is removed and mixed. The fraction of water removed from each layer is computed by an equation developed from previous laboratory studies (Dortch et al. 1976 and Fontane et al. 1977). The quantity withdrawn from the respective layers is then replaced from the mixed volume and subsequently mixed within each layer. The mixing coefficient for each layer is calculated as a function of the distance between the layer and the current inflow layer

$$\eta_i = A\, e^{-B \chi_i} \tag{5}$$

where

η_i = mixing coefficient

A = 0.16

B = 0.035

χ_i = distance from the current inflow layer to layer i

This mixing scheme is applied only to layers within the current zone, D , for each period of generation.

Calibration

17. To simplify the calibration process, observed data for a year (1970) without power and pumped-storage operations were used. Releases from Kinzua Dam were controlled by the sluices. Observed temperature data, sluice operations, and daily average inflow rates were furnished by ORP. Meteorological data from the Bradford, Pa., weather station were obtained through the National Climatic Center of NOAA. Inflow temperatures were generated from streamflow and air temperature data with the regression equations developed by Drummond and Robey (1975). The most appropriate coefficients resulting from the calibration simulations were $\beta = 0.50$, $\lambda = 0.20$, $\alpha_1 = 0.10$, and $\alpha_2 = 0.10$ where α_1 and α_2 are diffusion coefficients at the top and bottom of the lake, respectively. A comparison of the computed and observed temperature profiles is presented in Plate 1. The observed profiles were obtained immediately upstream of the dam.

18. The deviation between predicted and observed release temperatures is shown in Plate 2. The 1970 release temperatures were observed once daily and are not daily averages as are the computed temperatures. This may account for some of the larger deviations between the predicted and observed values. The average absolute deviation between the predicted and observed release temperature is 0.75°C.

Model Refinement

19. To maximize the predictive capability of the mathematical

model under pumped-storage (power) conditions, it was necessary to describe properly the selective withdrawal and jet entrainment processes unique to the project.

20. A 1:100-scale physical model was used to evaluate the selective withdrawal and pumpback characteristics of the inlet-outlet structure. Since the structure has separate intakes (and wet wells) for units 1 and 2, it was necessary to determine whether the outlets should be mathematically modeled as a single or individual outlet(s). Also the Allegheny pool surface elevation is normally below the top of the upper intake of the inlet-outlet structure during the stratification season; thus it was not known if the selective withdrawal characteristics of the intake should be modeled as a submerged weir or an orifice (port). Physical model tests indicated that the two outlets should be addressed in the simulation model as a single port with the center-line elevation placed midway between the water-surface and the invert elevation.

21. During 27-28 June 1978, field data at Kinzua Dam were collected by WES and ORP personnel. Temperature profiles obtained during the site visit are displayed in Plate 3. The profile taken halfway between the trash boom and the dam was within the turbulent mixing region of the generation jet. The effect of mixing on the temperature distribution during generation into the lake is evident in profile C (Plate 3). The trash boom is approximately 2000 ft upstream of the inlet-outlet structure. The jet dissipates and collapses into an interflow density current before reaching the trash boom as indicated by profile A and Figure 10. Variations in stratification demonstrated by profile B probably resulted from internal seiches rather than local mixing. Peaking operations can create internal waves and oscillations accompanied by fluctuations in the thickness of the hypolimnion and epilimnion and longitudinal density gradients. The temperature of generation and pumpback flow during the two-day test period varied from 14.5 to 15.5°C. During the site visit, it was discovered that considerable upwelling of cold water occurred in the Allegheny pool near the dam during generation into Allegheny Reservoir. This observation had an important impact on the refinement of the entrainment description.

Figure 10. Generation flow into Allegheny Reservoir

22. An estimate of the quantity and source (location in the water column) of entrained water was needed to adequately simulate the jet entrainment that occurs during generation. The upwelling of cold water in the Allegheny pool observed during the site visit was a result of the entrainment of hypolimnetic water into the power generation discharge. The physical model was used to estimate the total entrainment caused by the generation jet and the relative contribution from the hypolimnion and epilimnion. Two fluorescent dyes, sulpha rhodamine B and fluorescent disodium salt, were used for estimating the amount of entrainment and dilution. One fluorescent dye was added to the water representing generation flow into Allegheny Reservoir and the other dye was added to the hypolimnion of the model Allegheny pool. The pool was density stratified with saline and fresh waters. A typical generation flow condition of 7000 cfs was simulated and water samples were collected from the generation flow beyond the point where the jet collapsed into a density current. From these data the dilution (total entrainment) of the dye and the amounts of entrained flow from the ambient sources (epilimnion and hypolimnion) were estimated.

23. The physical model results indicated a total entrainment coefficient, E , of approximately 2.5 and thus the total flow of the generation density current, Q_c , was

$$Q_c = 3.5Q_o$$

Physical model results also indicated that about 30 percent of the entrained water came from the hypolimnion. The mathematical model was coded to allow a two-step uniform distribution of entrainment with 70 percent from the epilimnion and 30 percent from the hypolimnion.

Model Verification

24. The mathematical model was tested to determine how well the thermal characteristics for existing (as operated) conditions could be simulated. The 1977 simulation established baseline conditions for the mathematical model and provided a basis for evaluating alternatives to increase release temperatures. As discussed in paragraph 9, 1977 was selected as a study year for pumped-storage operations. Observed temperature data, power operations, sluice flows, and inflows were furnished by ORP for 1977 and the meteorological data were obtained from the Bradford Weather Station. The simulation was started on calendar day 129 (9 May) with an observed profile.

25. The computed and observed (at the trash boom) temperature profiles for 1977 are plotted for comparison in Plate 4. The model produced reasonably good predictions for most of the days of observed data. However, during the spring months, it was not possible to compute as much heat in the pool as was observed. It is possible that the meteorological input from Bradford may not have been representative of that experienced at the project during the spring since the project and the weather station are separated by a ridge of the Allegheny Mountains and the project is closer to Lake Erie. There was also some discrepancy in the observed and predicted profiles for 26 July. Profiles observed at the trash boom were compared (Plate 5) with those measured 3 miles

upstream at the mouth of Kinzua Creek for the same dates. Profiles at the two locations compared closely except for 26 July. The profile at the mouth of Kinzua Creek for 26 July is very similar to the profile predicted for the same date, thus indicating that the predicted profile is not unreasonable.

26. A plot of the deviation of computed from the observed (computed minus observed) daily average release temperatures is shown in Plate 6. The greatest deviation occurred in the spring when the computed release temperature was colder than observed which is consistent with the temperature profile discrepancies in the spring discussed above. In general, the computed release temperatures were also colder than those observed during the summer. The cause of this was not determined. However, the continuous temperature monitor was located near the left bank downstream of Kinzua Dam, and the power discharges are directed from the left bank toward the right bank. It is possible that the temperatures near the left bank may be slightly warmer than those near the right bank. The average absolute deviation in release temperature was 1.14°C for the entire simulation period. Regardless of these discrepancies, the simulated base year (1977) was considered accurate enough to compare and evaluate the simulated project revisions.

PART III: ANALYSES

Existing Conditions

27. Efforts were made to determine the causes of the colder-than-expected releases with the "existing" (as-built and -operated) conditions. An understanding of the causes facilitates a solution.

28. Comparisons were made of observed temperature data for 1970 (a year without power) and 1977 (a year with power). Deviation plots (the observed release temperatures minus the expected natural stream temperatures) for 1970 and 1977 are shown in Plates 7 and 8. Plate 7 shows that the 1970 release temperatures were much colder (as much as 6°C) than the expected natural stream temperature in the early spring, but by June the releases had warmed to within approximately 1°C of the expected. The releases were colder than natural during the early spring, in part, because all releases were made through the lower sluices until the end of April at which time the upper sluices were brought into use. During 1977 the release temperatures were about 1 to 2°C colder than the expected natural stream temperatures and were as much as 6°C warmer than 1970 releases during March through May (Plates 8 and 9). During this period, the meteorological conditions for 1977 were in general warmer than those for 1970 as shown by the equilibrium temperature deviations in Plate 10. Also, the upper level sluice releases were initiated during mid-April 1977 compared with the end of April in 1970 and thus contributed to the warmer spring 1977 releases. The June through August 1977 releases are considerably colder than both the expected natural stream temperatures and the 1970 release temperatures for the same period. An examination of the temperature profiles for 1970 and 1977 (Plate 11) revealed that although the epilimnion of Allegheny Reservoir was slightly warmer (at times) during 1970 than in 1977, the hypolimnion was significantly warmer in 1977 than in 1970. From this comparison of profiles, one would expect the release temperatures for 1977 to have been about as warm as the releases for 1970 in the summer. Several factors were found to contribute to the discrepancy actually observed. The

major factor is the frequent occurrence of lower sluice withdrawals during July and August 1977 as exhibited in Plates 8 and 9. Use of the lower sluices during the summer resulted in a direct and substantial drop in release temperature as is evident by the dips in the temperature deviations in Plates 8 and 9. Even though there is no lower sluice withdrawal during June 1977, the releases were still substantially colder than both the expected and 1970 releases. A discussion of the probable cause of this is provided in the following two paragraphs.

29. During part of April and May of several years including 1977, the power operations were stopped and the upper reservoir was drained so that inspection and maintenance could be performed. During this shutdown period, the lower reservoir's thermal stratification resembles the stratification that would exist for the reservoir without pumped-storage operations (strongly stratified with cold hypolimnion). Power operations were resumed in late May. The observed data for 1977 indicated a period of about 30 days (during June) after power restart in which the release temperatures were about 3°C colder than the expected stream temperatures. If the power shutdowns had been postponed until fall, warmer releases might have occurred during June. The explanation for this is that mixing during pumped-storage operations causes the lake to warm up faster and the epilimnion to extend deeper than without pumped-storage operations. This is supported by the profiles in Plate 11. During power shutdown, less mixing occurred so the hypolimnion was not as warm and the epilimnion was not as deep as would have been the case if power operations had not been interrupted. When power operations were resumed, large withdrawal flow rates during pumpback resulted in a deep withdrawal zone thus contributing to a colder-than-desired release temperature. Eventually pumped-storage operations warmed the hypolimnion and the pumpback withdrawal water was not as cold. Potentially, continuous (uninterrupted) power operations through the spring and summer could result in warmer releases.

30. Observed release temperature data for 1975-1978 were analyzed to determine if prototype data supported the above hypothesis. During 1975 and 1976, there was continuous power operation, whereas during 1977

and 1978, power was interrupted or shut down in the spring for inspection and maintenance purposes. The deviation of the observed daily average release temperature from the average natural stream temperature (observed minus natural) is plotted versus calendar day for each of the four study years in Plates 8, 12, 13, and 14. The mean and variance of the deviation below "natural" were computed for each of the four study years for the days of June and July when the low-level sluices were not used. The mean deviations and the corresponding computational periods are shown in the tabulation below.

Mean Deviations of Observed Release Temperature Below the Average Natural Stream Temperature

	Continuous Power in the Spring (Condition A)				Power Shutdown in the Spring (Condition B)			
Year	1975		1976		1977		1978	
Mean deviation °C	0.63	1.58	2.93	3.02	3.71	2.96	3.10	3.26
Period of analysis, calendar days	179-190	179-212	152-190	152-212	179-190	152-190	179-212	152-212

Note: Periods of analysis were limited to days in June and July without low-level sluice releases. These periods were matched such that conditions A and B could be compared.

Statistical test for two means was used to determine that condition A (continuous power in the spring) was warmer than condition B (power shutdown in the spring). Results of this statistical analysis indicate that condition A was warmer than condition B with a probability that this conclusion is erroneous of less than 1 percent for 1975 compared with 1977 and 1978, 44 percent for 1976 compared with 1977, and 4 percent for 1976 compared with 1978. It should be recognized that the average natural stream temperature, which was used in this analysis, can differ from the natural stream temperature for a given year with a particular hydrology and meteorology and that the hydrology and meteorology influence the release temperature. For these reasons results of the statistical analysis, which are summarized below, cannot be considered conclusive concerning the continous power hypothesis. However, the results do not contradict the hypothesis that continuous power in the spring can increase the release temperature.

Summary of Statistical Analysis

Conclusion	Probability of Erroneous Conclusion
1975 was warmer than 1977 for days 179-190	Less than 1 percent
1975 was warmer than 1978 for days 179-212	Less than 1 percent
1976 was warmer than 1977 for days 152-190	Less than 44 percent
1976 was warmer than 1978 for days 152-212	Less than 4 percent

31. Simulations were conducted to determine what effect continuous power operations could have had during the spring. Conditions for 1977 were simulated for continuous power operations and were compared with the base simulation of existing or "as-operated" 1977 conditions which involved a power shutdown in the spring. The historical power operations just prior to shutdown were used to simulate the condition of continuous power during the historical shutdown period. Temperature profiles for the two simulated conditions can be compared in Plate 15. The profiles indicate that the hypolimnion warms faster for the continuous power condition. A comparison of the computed release temperatures for the two conditions is shown in Plate 16 in the form of temperature deviation versus time. The temperature deviation was calculated by subtracting the computed release temperature for the "as-operated" condition from the computed release temperature for the condition of no power shutdown. As shown by the plot, continuing power through the spring could have allowed almost 1°C warmer releases during June and July.

32. Simulations were made for 1977 with the power generation operations artificially removed to determine if the pumped-storage hydropower operations were a direct cause of the colder-than-expected releases. To keep the total downstream release quantity consistent with

historical routings, the power releases downstream were treated as additional sluice flows. Therefore, for the simulations of 1977 without power generation, the inflow, total outflow, water budget, and heat exchange were identical to historical conditions with power generation. While this type of operation may not represent exactly the way the project would actually have been operated if there had been no power generation, the simulated conditions were in general realistic. For periods when the outflows exceeded the capacity of the upper sluices, the mathematical model forced the use of the low-level sluices. During those periods, the simulation for 1977 (without power) released cold water while the base simulation for 1977 (with power generation) released warmer water from the upper level of the inlet-outlet tower. Except for those periods, the comparison of the simulated release temperatures should be meaningful. The computed profiles with and without power generation are compared in Plate 17. In general, the water-surface temperatures are about the same, but there is stronger stratification and the bottom waters are colder for conditions without power generation. Pumped-storage operations decreased stratification, transferred heat from the epilimnion to the hypolimnion, and increased the total heat content of the lake. The deviation in predicted release temperature between operation without power generation and the base simulation with power generation is plotted in Plate 18. It is noted that the only significant deviations occurred when the outflows exceeded the capacity of the upper sluices and cold water was released through the low-level sluices as previously discussed. It is, therefore, concluded that pumped-storage hydropower operations have not been detrimental to the release temperature objective.

33. From the analyses of the existing conditions, three basic conclusions can be drawn: (a) releases through the lower sluices can have a significant impact on release temperature; (b) there is not evidence to indicate that continuous pumped-storage operations cause release temperatures to be any colder than without pumped-storage; (c) postponement of power shutdown for inspection and maintenance until fall should result in slightly warmer releases during late spring and

early summer. The effects of the existing selective withdrawal intakes design on release temperature will be addressed in the next section through the evaluation of various intake modifications.

Modifications

34. Operational and structural modifications to the sluices and the power inlet-outlet structure of the lower reservoir were investigated with the reservoir thermal simulation model for 1977 with power. The results are discussed in the following sections.

Operational modification of the power inlet-outlet structure

35. An operational change of passing generation flows into Allegheny Reservoir through the lower openings of the lower power inlet-outlet structure was simulated. For this simulation, E was assumed to by 2.5 and all the entrained flow was assumed to be uniformly withdrawn from the hypolimnion. Power withdrawals (pumped flows) were still taken through the upper openings. The deviation of the computed release temperatures with this modification from the 1977 computed release temperatures for historical conditions is shown in Plate 19. These results indicate that this modification would result in slightly colder release temperatures during most of the stratification season. This operational change would result in faster warming of the hypolimnion because of the increased mixing associated with this type of operation; but the rate of mixing was not nearly rapid enough to benefit (increase) the release temperature during the period of interest. Additionally, this type of operation is not desirable because of the difficulty of switching from the upper to the lower power intake opening during each pumped-storage cycle.

Structural modification of the power inlet-outlet structure

36. Various structural modifications were evaluated through simulations with the mathematical model. One modification considered raising the invert elevation of the upper ports of the lower reservoir

power inlet-outlet structure to 10.0 ft below the water surface rather than at el 1289.5 (existing condition), which is approximately 40 ft below the normal summer pool. This modification had very little effect on warming the releases as shown in Plate 20. This minor influence was partly due to the relatively low quantity of downstream release contributed by power discharges in the summer. During the summer, most power generation discharges are directed into the lower reservoir, rather than downstream, as demonstrated below. Therefore, this modification would not be worthwhile.

Year	Percent of Time for Release of Generation Flow Downstream Through No. 2 Turbine, for Period Mid-May Through September
1975	25
1976	16
1977	37
1978	13

Note: No. 2 and No. 3 turbines will discharge downstream, but No. 3 is much smaller than No. 2.

Operational modifications of the sluices

37. Because lower sluice releases during the stratification season decrease the release temperatures, two operational modifications of the lower sluices were evaluated. One modification consisted of switching from low-level to upper-level sluice operation one month later than actually occurred in 1977. Conceptually, releasing more cold water in the spring could decrease the cold water volume and result in warmer releases during the summer. A plot (Plate 21) of temperature deviation for the simulated modified operation versus the simulated existing (as-operated) condition indicates that this modification would result in significantly colder releases in the early spring with only moderately warmer (0.5°C) releases in the late spring and early summer. Such a modification is inadvisable since warmer releases are desired in the early spring.

38. Another modification of the low-level sluice operation that was evaluated consisted of prohibiting low-level sluice releases between 1 June and 21 September (the period of major thermal stratification). The temperature deviation plot of Plate 22 shows that this modification could result in significantly warmer releases during the period that the low-level sluices were actually used. However, the pool rose 12.5 ft higher than the existing condition thus causing the upper-level sluice intakes to be deeper in the pool and to withdraw colder water during other parts of the summer. This operational modification is also inadvisable and could infringe on other project purposes.

Structural modifications of the sluices

39. Simulations were made to evaluate the effect of raising various sluice intake elevations. Such modifications are feasible and can be done by attaching vertical risers (collection wells) on the upstream face of the dam so that water is drawn from the upper pool levels over the top of the riser. This type of modification was provided at Sutton Dam, West Virginia (Huntington District), and is described in George, Dortch, and Tate (1980).

40. The two upper sluices are located at center-line el 1305, and the six lower sluices are located at center-line el 1210. Normal summer pool is el 1328. It is apparent that even the upper sluices are located fairly deep within the pool (23.0 ft); therefore, structural modifications to both the upper and lower sluices were evaluated. The following modifications were simulated.

Sluice Structural Modification No.	Modification
1	Intake inverts of upper sluices raised to 10.0 ft below water surface
2	Intake inverts of upper and lower sluices raised to 10.0 ft below water surface
3	Intake inverts of lower sluices raised to 10.0 ft below water surface
4	Lower sluices center line raised to el 1305

Each modification was simulated with 1977 conditions to obtain computed daily average release temperatures. The deviations of these computed release temperatures (with the modification) from those computed for existing conditions are plotted in Plates 23-26 for each of the four sluice modifications. From the plots it is evident that modifications 1 and 2 had the greatest effect of increasing the release temperature. Raising only the upper sluices (modification 1) had considerably more impact on release temperature than raising only the lower sluices (modifications 3 and 4). Raising both the upper and lower sluices (modification 2) had the greatest impact. It is pointed out that 1977 had a wet spring and summer; normally the lower sluices are not used too often during May through September. Based on the above results, structural modifications 1 and 2 would be the most effective means of increasing release temperatures. It is also expected that continuous power operation would contribute to warmer releases.

41. Mathematical simulations of 1977 conditions were conducted with sluice modifications 1 and 2 and for continuous power operation in the spring to determine the combined effect. These simulated release temperatures were compared with the average natural stream temperature and are shown as temperature deviations in Plates 27 and 28. Plates 27 and 28 should be compared with Plate 8. The predicted release temperatures for each of the two simulations are also plotted (Plates 29 and 30) with the natural stream temperature to allow comparison of absolute values rather than temperature deviations. These two plots should be compared with Plate 31 (1977 observed release temperatures) to evaluate the benefits of the modified conditions. It can be concluded (from the results presented in Plates 27-30) that for the conditions of continuous power in the spring and sluice modification 1 or 2, the releases for 1977 could have been warmed within 2.0°C of the average natural stream temperature for a majority of the time.

PART IV: RECOMMENDATIONS

42. This study has determined that the pumped-storage operations have not been the cause of the colder-than-desired releases. Pumped-storage actually causes the hypolimnion to warm faster without significant cooling of the epilimnion. To achieve a release temperature approximately equal to the average natural stream temperature during the stratification season, water from the top levels of the pool would have to be released. If this is desired, structural modification of the sluices is the most effective and practical means of releasing warmer water.

43. There are several options available for modifying the sluices. However, the most practical modification is to attach risers to two of the lower sluices and operate these sluices throughout the stratification period using the upper-level sluices (as existing) only when the discharge capacities of the two modified low-level sluices are exceeded. Only two low-level sluices were used during the 1977 stratification season, and the combined discharges of the upper and lower sluices did not exceed the capacity of two lower sluices. In other words, by attaching risers to two low-level sluices, surface releases for even a wet year like 1977 could be made between 1 April and 20 September without using the upper-level sluices or any additional low-level sluices. Because of the way the sluice releases were handled in the numerical model (see last sentence of paragraph 14), the simulated results of this type of modification would be identical to the simulated results of modification 2, paragraph 41 (Plates 24, 28, and 30), for 1977 conditions with the exception of differences caused by continuous power versus power shutdown in the spring. Modification 2 of paragraphs 40 and 41 was the most effective means tested for increasing release temperatures. Adding risers to two of the lower sluices would require that an opening be provided in the lower portion of each riser so that these sluices can make releases when the pool is below the risers' crest elevation. The riser crests should be located at approximately el 1318 to provide conditions similar to those shown in Plates 24, 28, and 30. In addition to this

recommendation, it is again emphasized that power shutdowns for inspection and maintenance should be avoided (if possible) between April and August if warmer releases are desired.

44. After completion of this study, the results were presented on 18 December 1979 to the Fish and Wildlife Service, the Pennsylvania Fish Commission, and representatives from a variety of local groups. Subsequent official replies from these groups recommended no structural modifications to Kinzua Dam. They indicated concern that elevating the release temperature might not restore the previous smallmouth bass fishery and could, in fact, jeopardize the fine coldwater and coolwater fisheries that currently exist. As a result, no additional consideration (as indicated in Appendix A) will be given to structural modifications as an alternative for elevating release temperatures.

REFERENCES

Bohan, J. P., and Grace, J. L., Jr. 1973 (Mar). "Selective Withdrawal from Man-Made Lakes; Hydraulic Laboratory Investigation," Technical Report H-73-4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Dake, J. M. K., and Harleman, D. R. F. 1966 (Sep). "An Analytical and Experimental Investigation of Thermal Stratification in Lakes and Ponds," Technical Report No. 99, Massachusetts Institute of Technology, Hydrodynamics Laboratory, Cambridge, Mass.

Dortch, M. S., et al. 1976 (Dec). "Dickey-Lincoln School Lakes Hydrothermal Study; Hydraulic Laboratory Investigation," Technical Report H-76-22, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Drummond, G. R., and Robey, D. L. 1975 (Feb). "Natural Stream Temperature Analysis, Allegheny River near Kinzua, Pennsylvania," Special Report No. 8, U. S. Army Engineer Division, Ohio River, Cincinnati, Ohio.

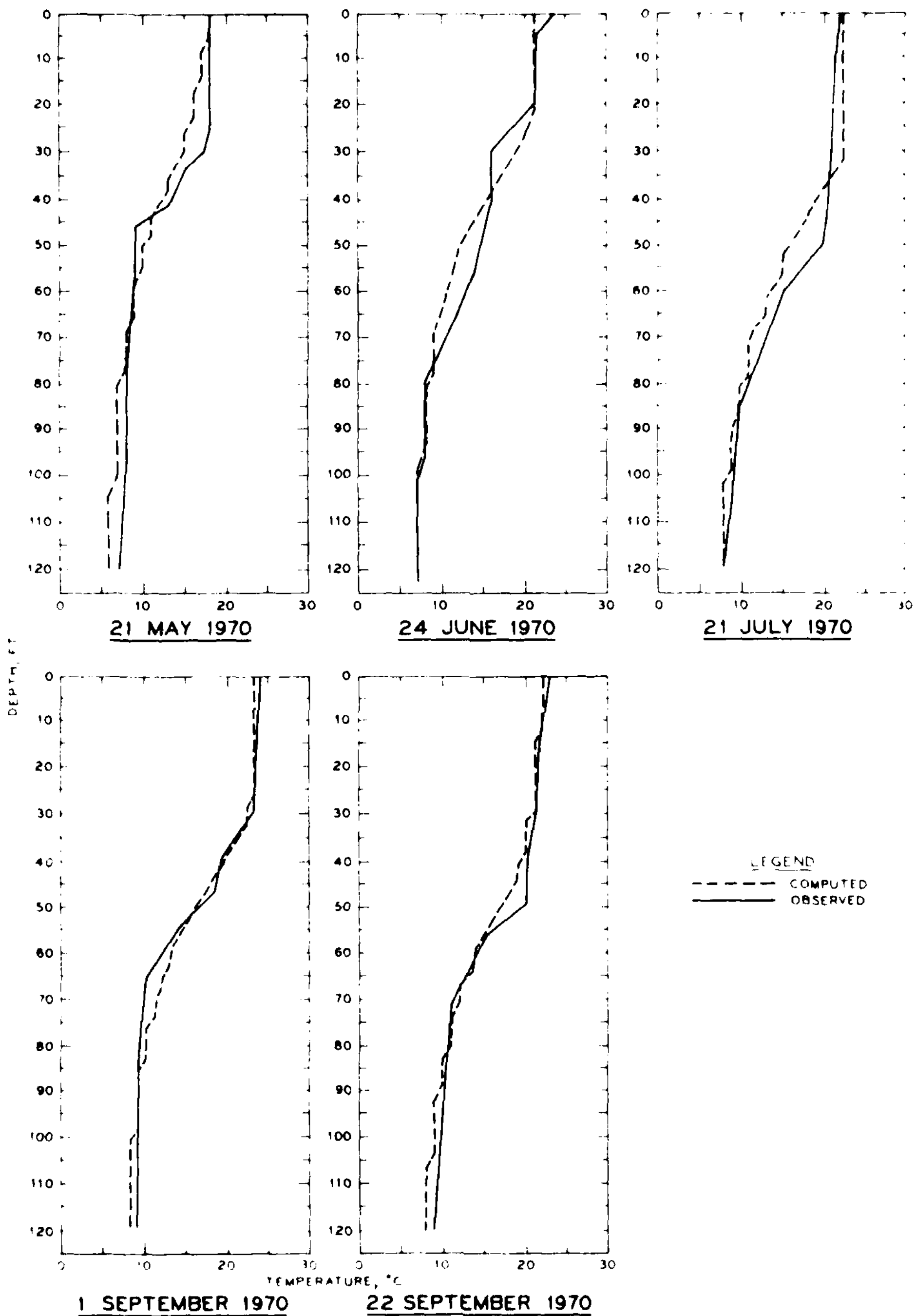
Edinger, J. E., and Geyer, J. C. 1965 (Jun). "Heat Exchange in the Environment," Publication No. 65-902, Edison Electric Institute, New York, N. Y.

Edinger, J. E., Duttweiler, D. W., and Geyer, J. C. 1968 (Oct). "The Response of Water Temperature to Meteorological Conditions," Water Resources Research, Vol 4, No. 5, pp 1137-1143.

Fontane, D. G., and Bohan, J. P. 1974 (Dec). "Richard B. Russell Lake Water Quality Investigation; Hydraulic Laboratory Investigation," Technical Report H-74-14, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

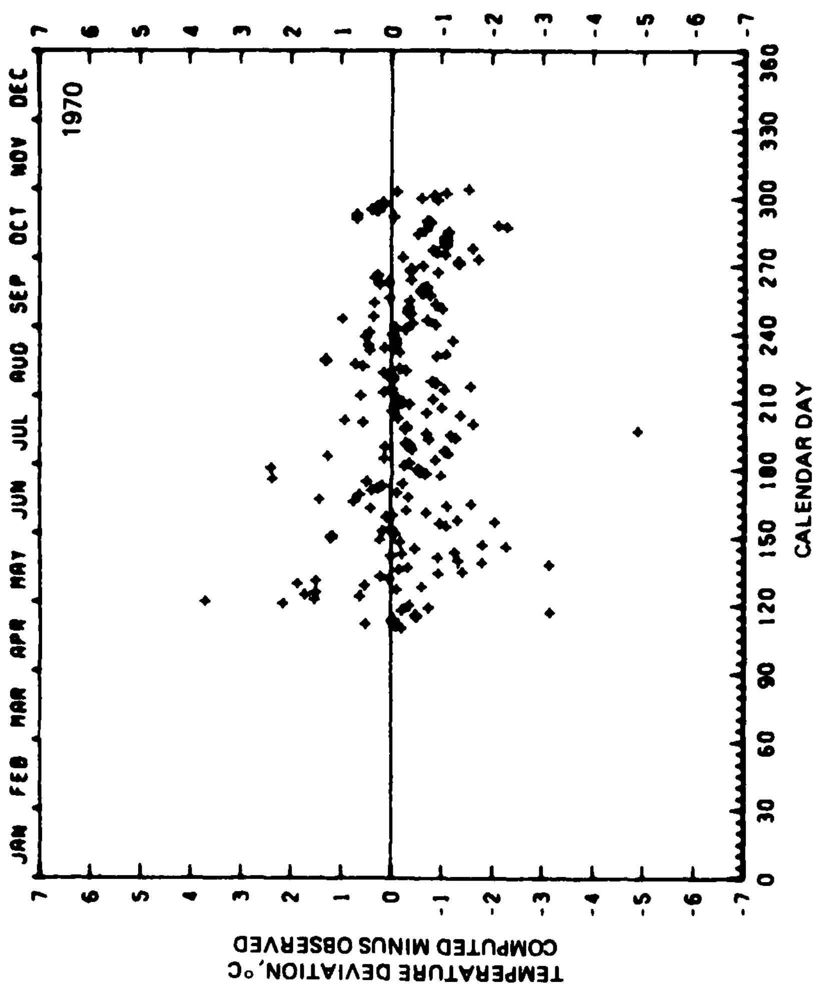
Fontane, D. G., et al. 1977 (May). "Marysville Lake Hydrothermal Study; 900-mw Project; Hydraulic and Mathematical Model Investigation," Technical Report H-77-5, Report 1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

George, J. F., Dortch, M. S., and Tate, C. H., Jr. 1980 (Mar). "Selective Withdrawal Riser for Sutton Dam, West Virginia; Hydraulic Model Investigation," Technical Report HL-80-4, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.



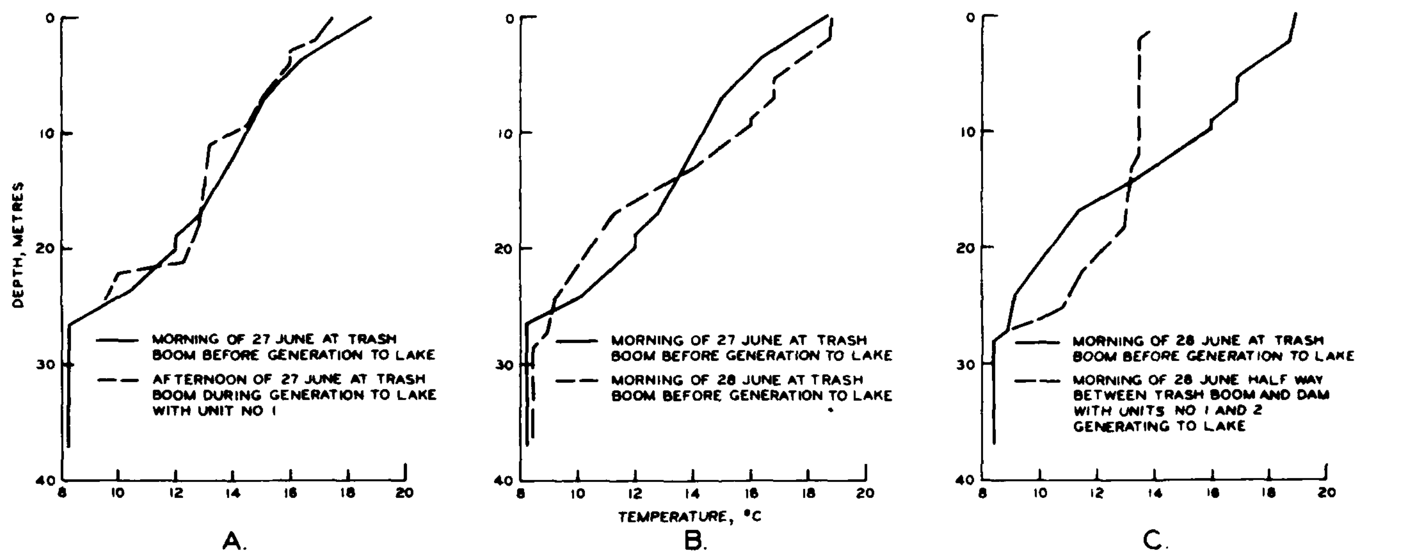
COMPUTED AND OBSERVED TEMPERATURE PROFILES
1970 NO POWER

PLATE 1



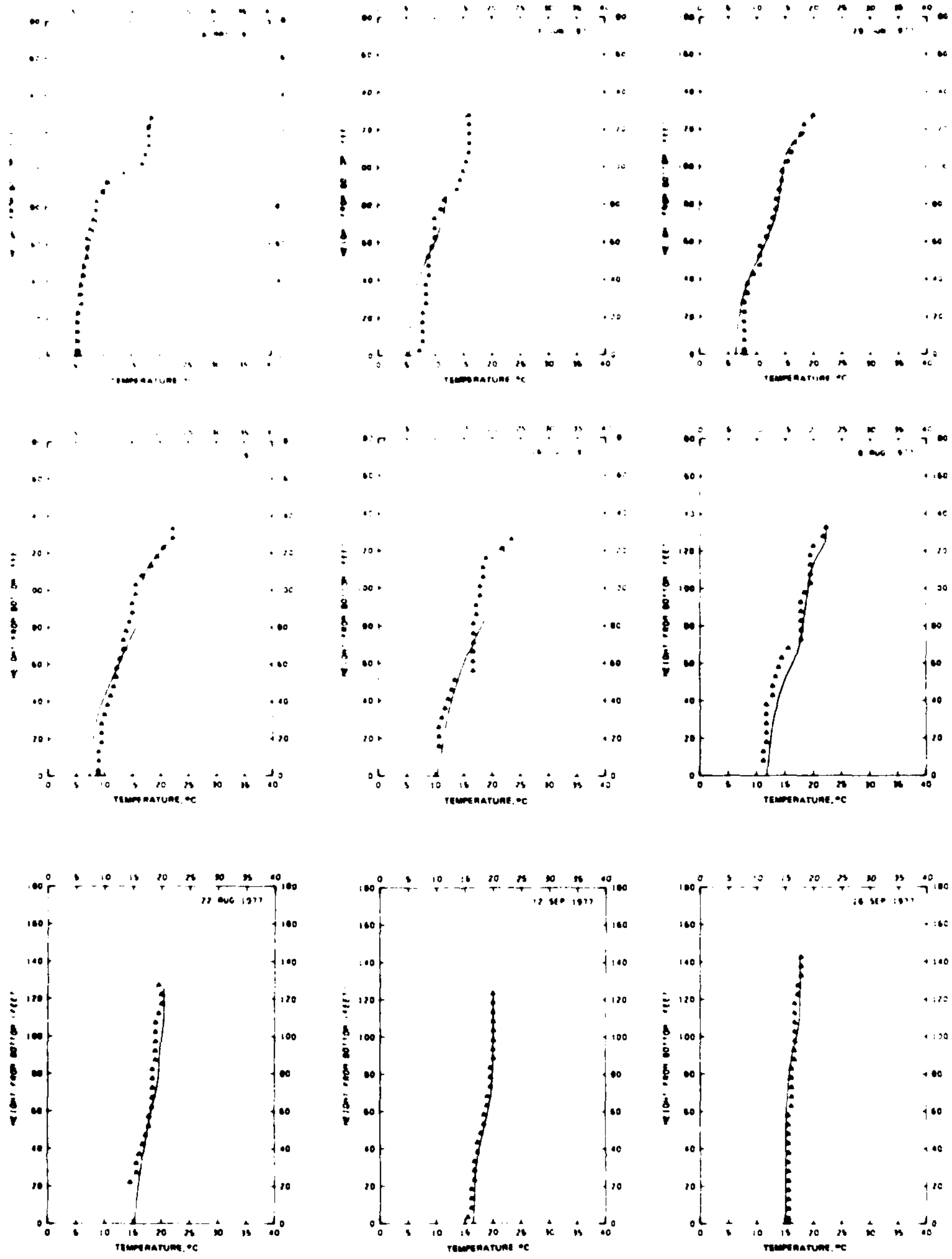
DEVIATION OF COMPUTED FROM OBSERVED RELEASE TEMPERATURES
1970

PLATE 2



OBSERVED TEMPERATURE PROFILES

PLATE 3



LEGEND

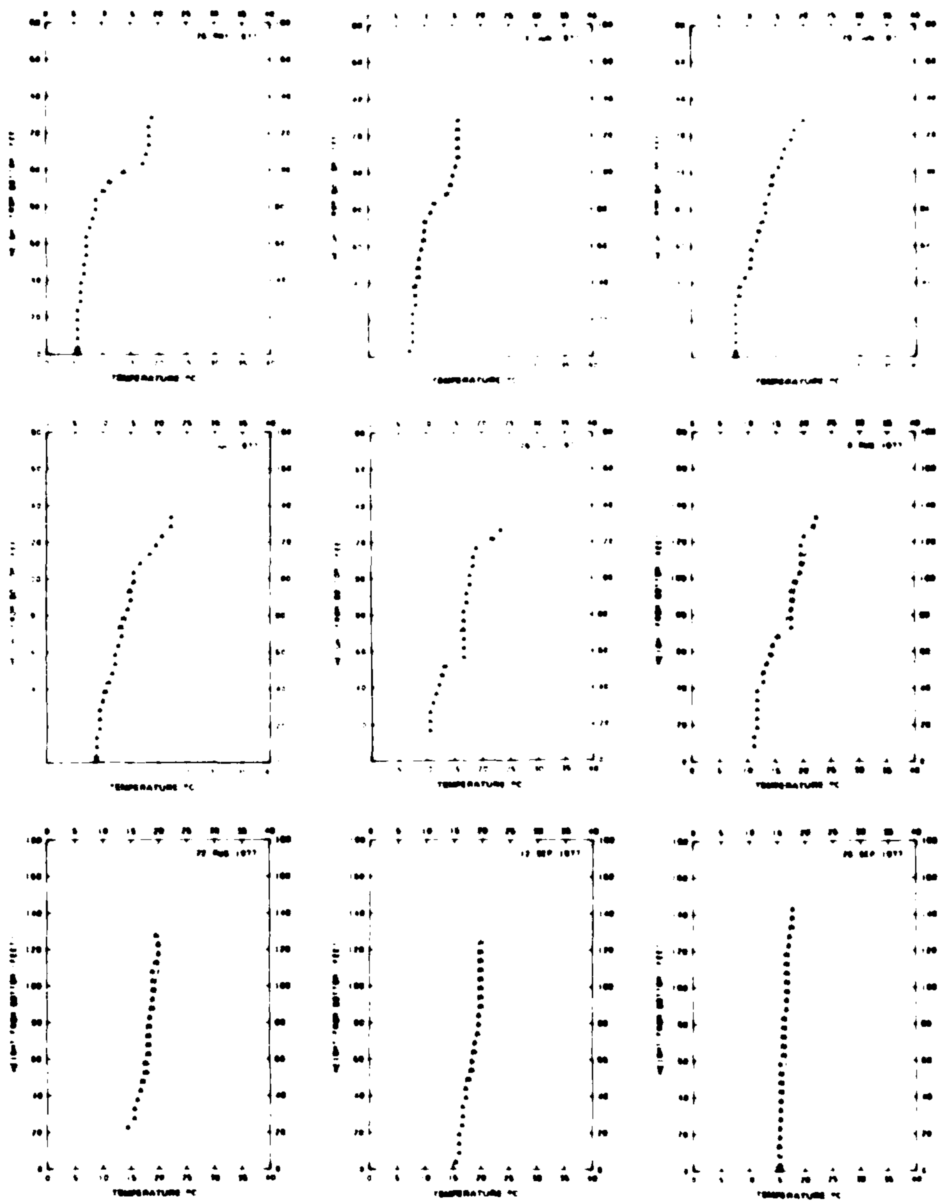
——— COMPUTED

▲ OBSERVED

COMPUTED AND OBSERVED TEMPERATURE PROFILES

1977 WITH POWER

PLATE 4



LEGEND

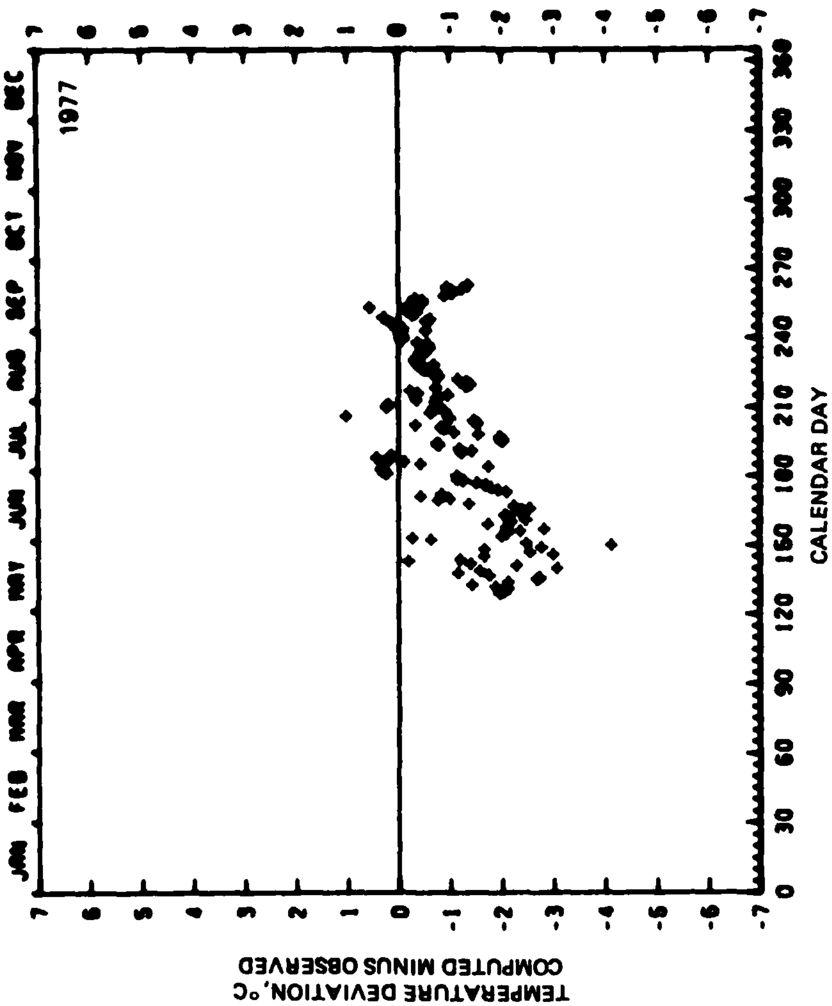
▲ MEASURED AT TRASH BOOM

MEASURED AT MOUTH OF KINZUA CREEK

OBSERVED TEMPERATURE PROFILES

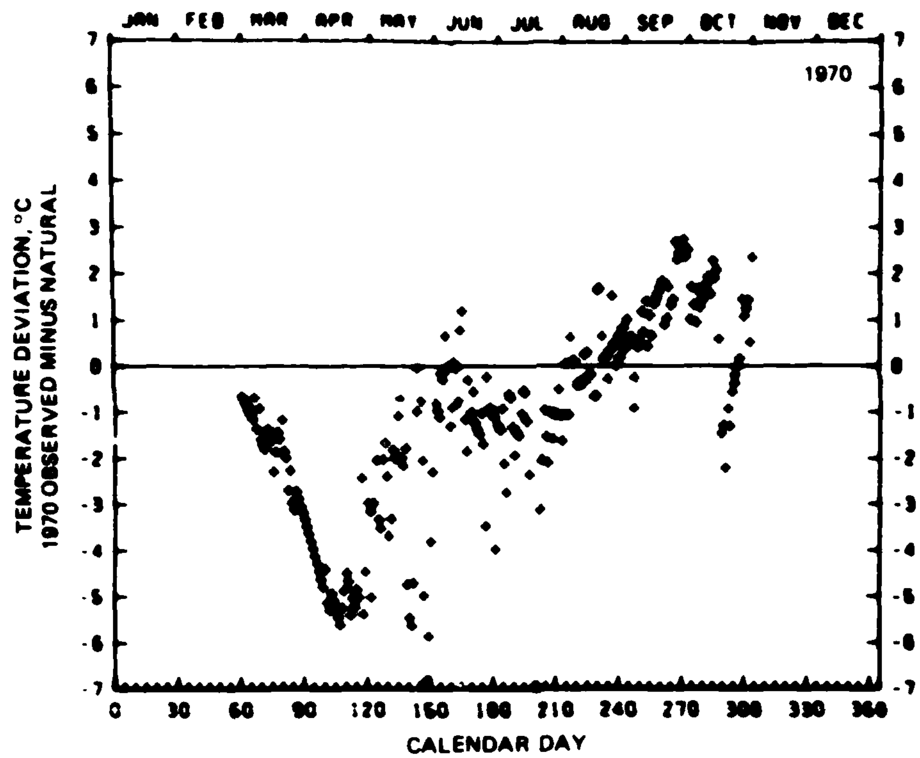
1977

PLATE 5



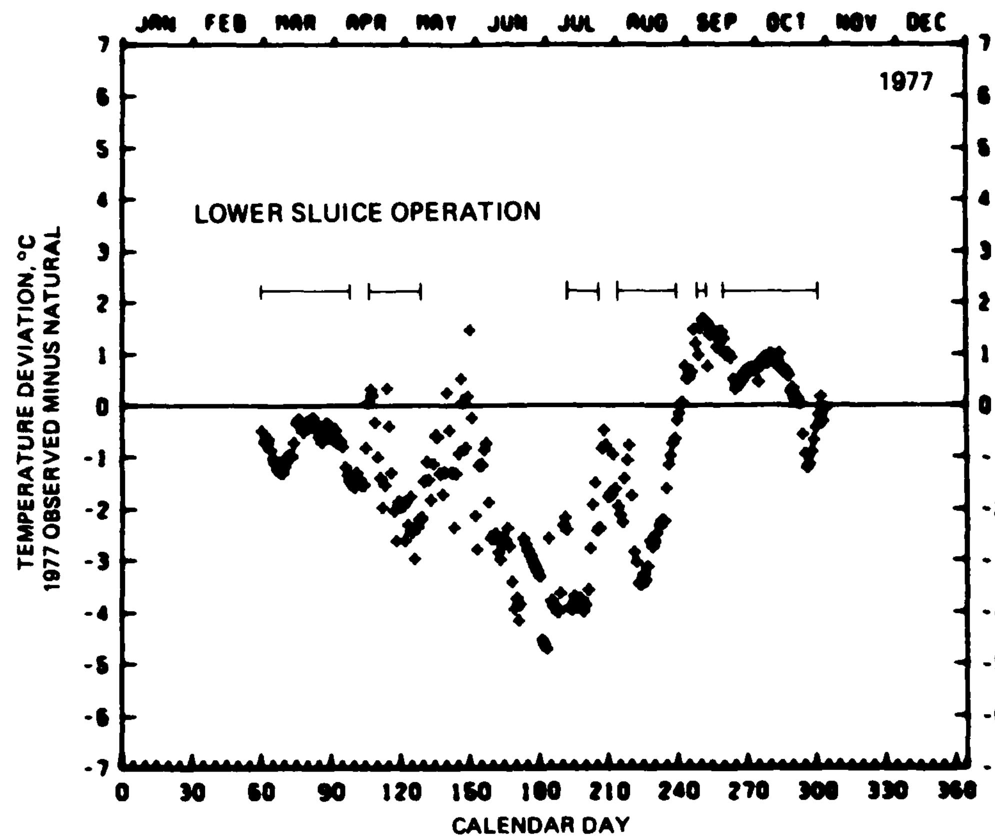
DEVIATION OF COMPUTED FROM
OBSERVED RELEASE TEMPERATURES
1977 AS OPERATED

PLATE 6



DEVIATION OF OBSERVED RELEASE TEMPERATURE
FROM AVERAGE NATURAL STREAM TEMPERATURE
1970

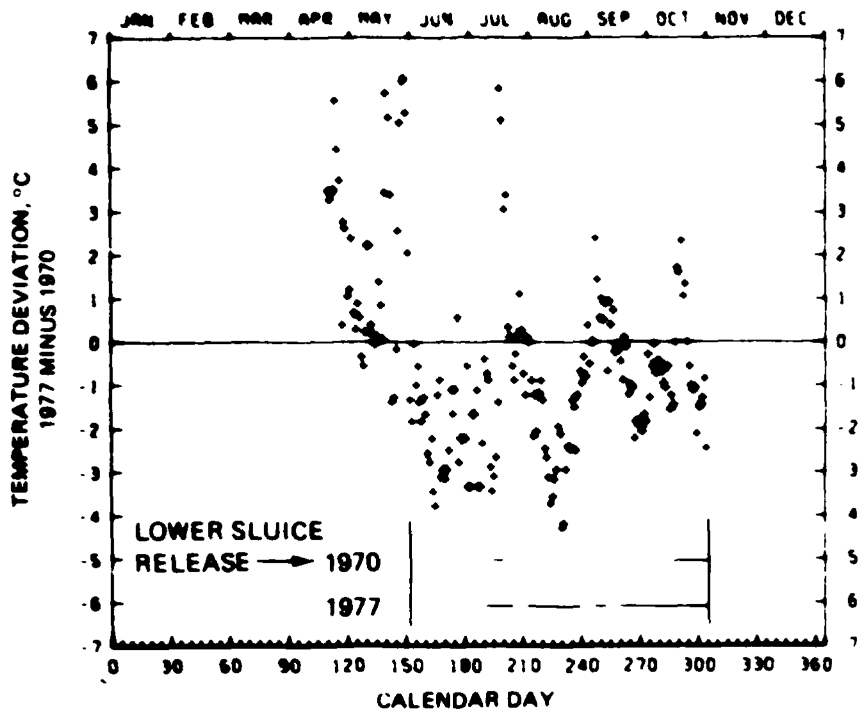
PLATE 7



DEVIATION OF OBSERVED RELEASE TEMPERATURE
FROM AVERAGE NATURAL STREAM TEMPERATURE
1977

NOTE: POWER SHUTDOWN IN SPRING

PLATE 8



DEVIATION OF OBSERVED RELEASE TEMPERATURES
1977 VS 1970

PLATE 9

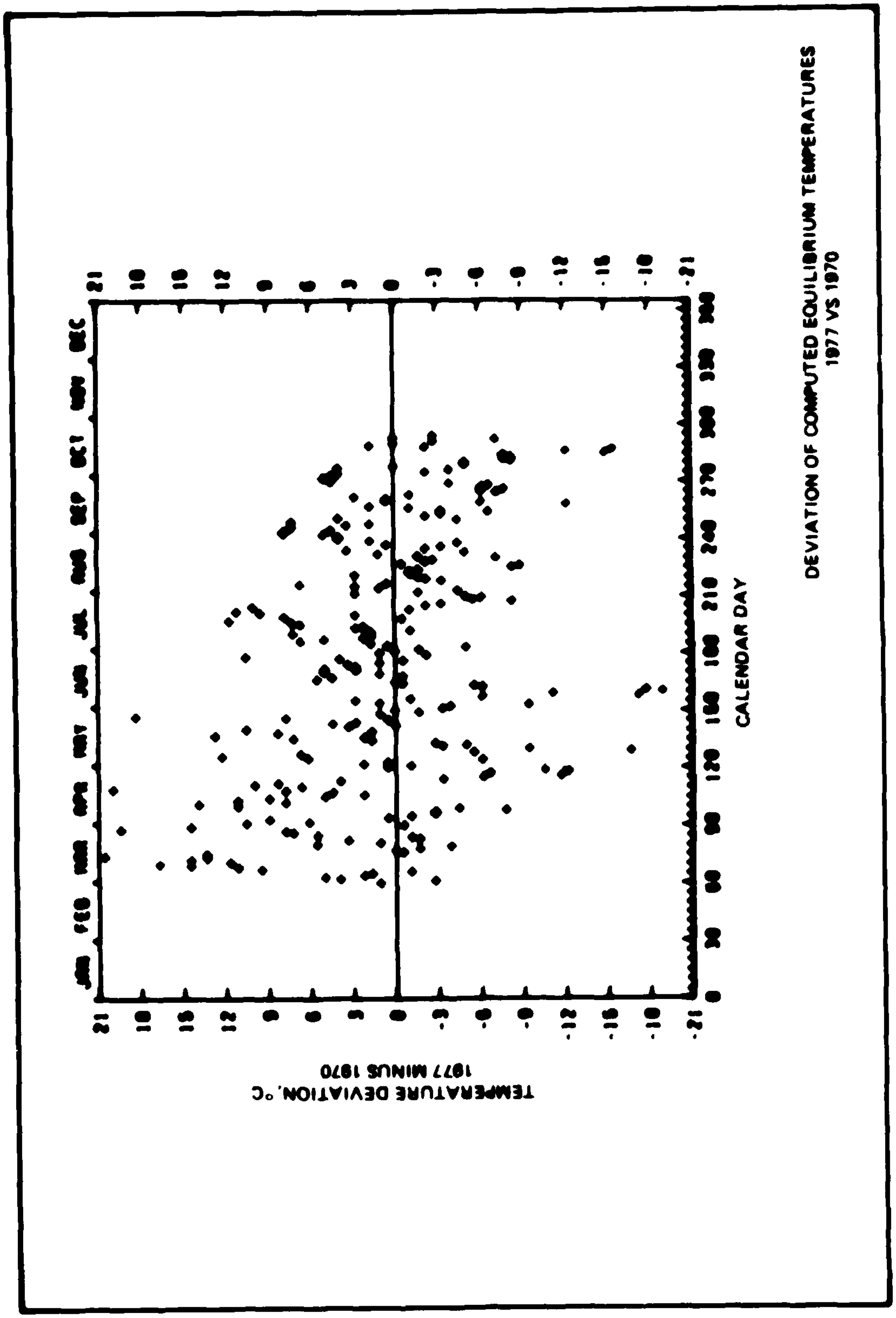
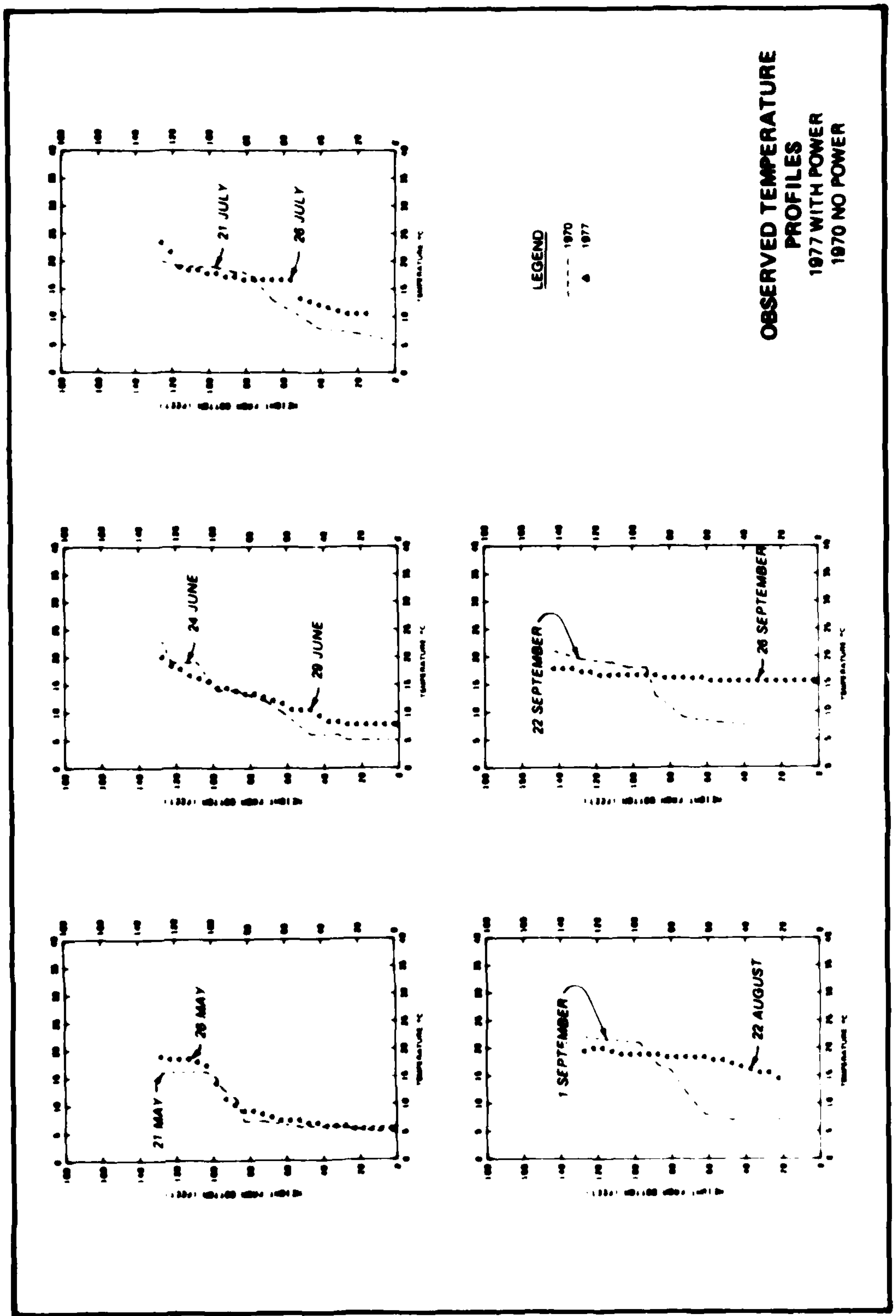
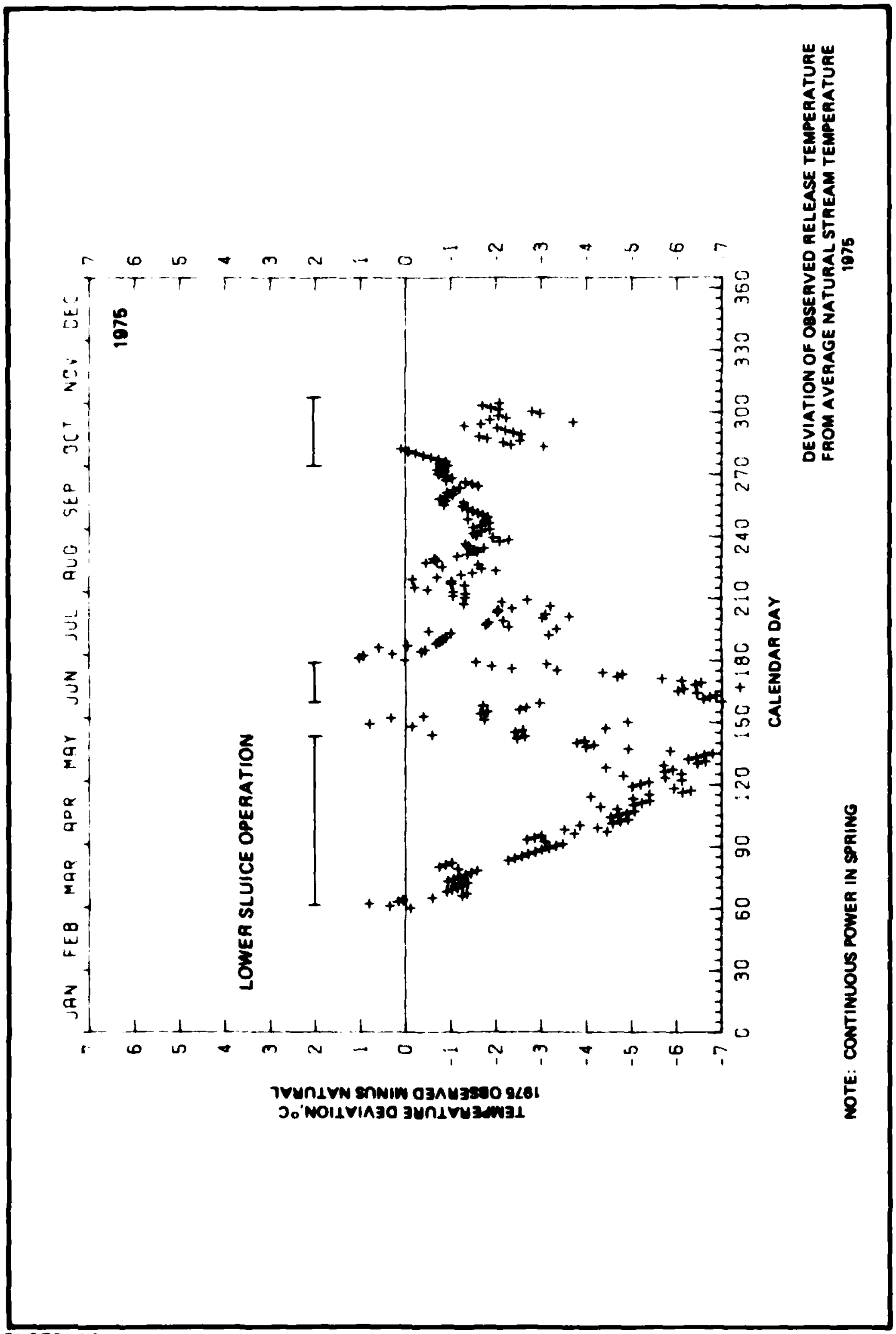

DEVIATION OF COMPUTED EQUILIBRIUM TEMPERATURES
1977 VS 1970
CALENDAR DAY
TEMPERATURE DEVIATION, °C
1977 MINUS 1970

PLATE 10



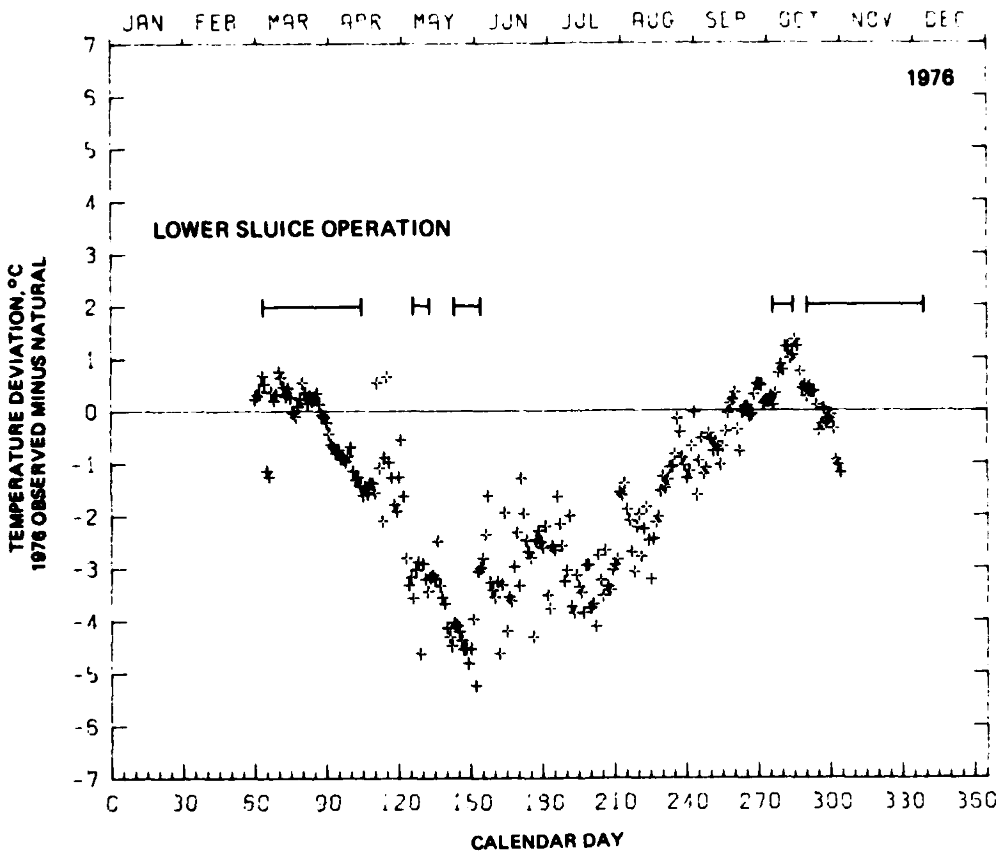
OBSERVED TEMPERATURE PROFILES
1977 WITH POWER
1970 NO POWER
LEGEND
1970
1977
21 JULY
26 JULY
24 JUNE
20 JUNE
21 MAY
26 MAY
22 SEPTEMBER
26 SEPTEMBER
1 SEPTEMBER
22 AUGUST

PLATE 11



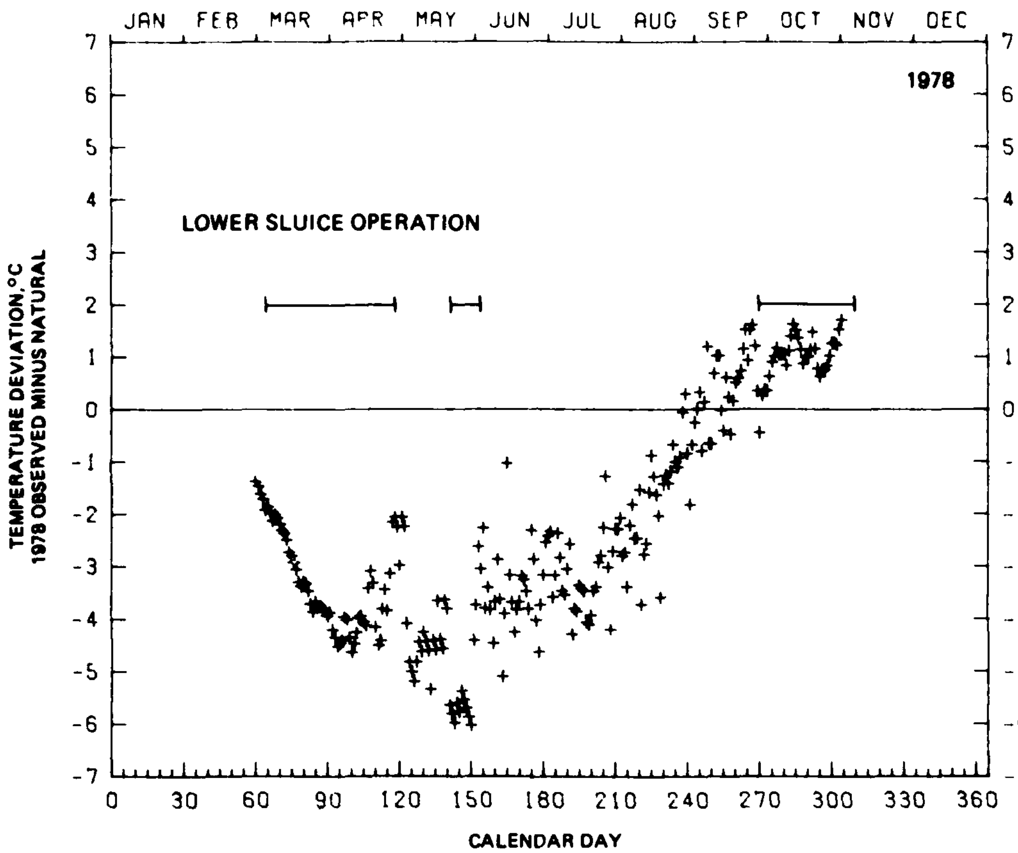
DEVIATION OF OBSERVED RELEASE TEMPERATURE FROM AVERAGE NATURAL STREAM TEMPERATURE 1975

PLATE 12



NOTE: CONTINUOUS POWER IN SPRING

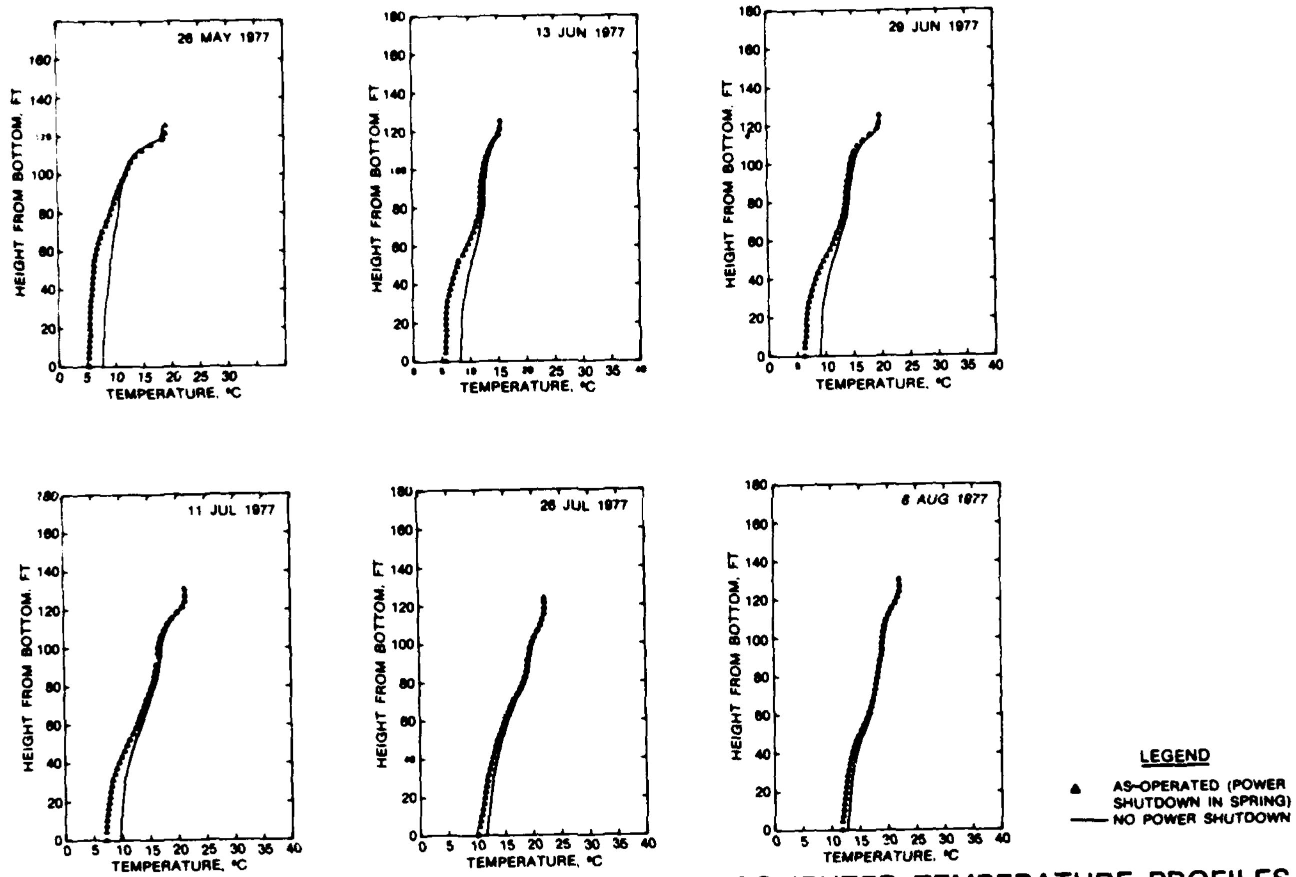
DEVIATION OF OBSERVED RELEASE TEMPERATURE
FROM AVERAGE NATURAL STREAM TEMPERATURE
1976



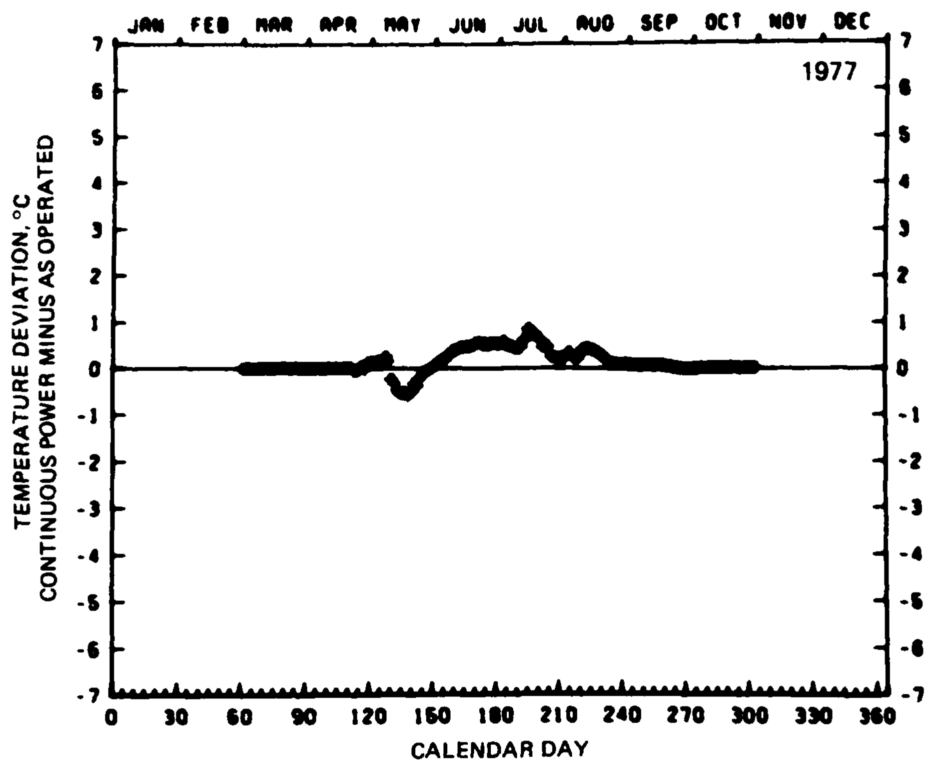
NOTE: POWER SHUTDOWN IN SPRING

DEVIATION OF OBSERVED RELEASE TEMPERATURE
FROM AVERAGE NATURAL STREAM TEMPERATURE
1978

PLATE 14

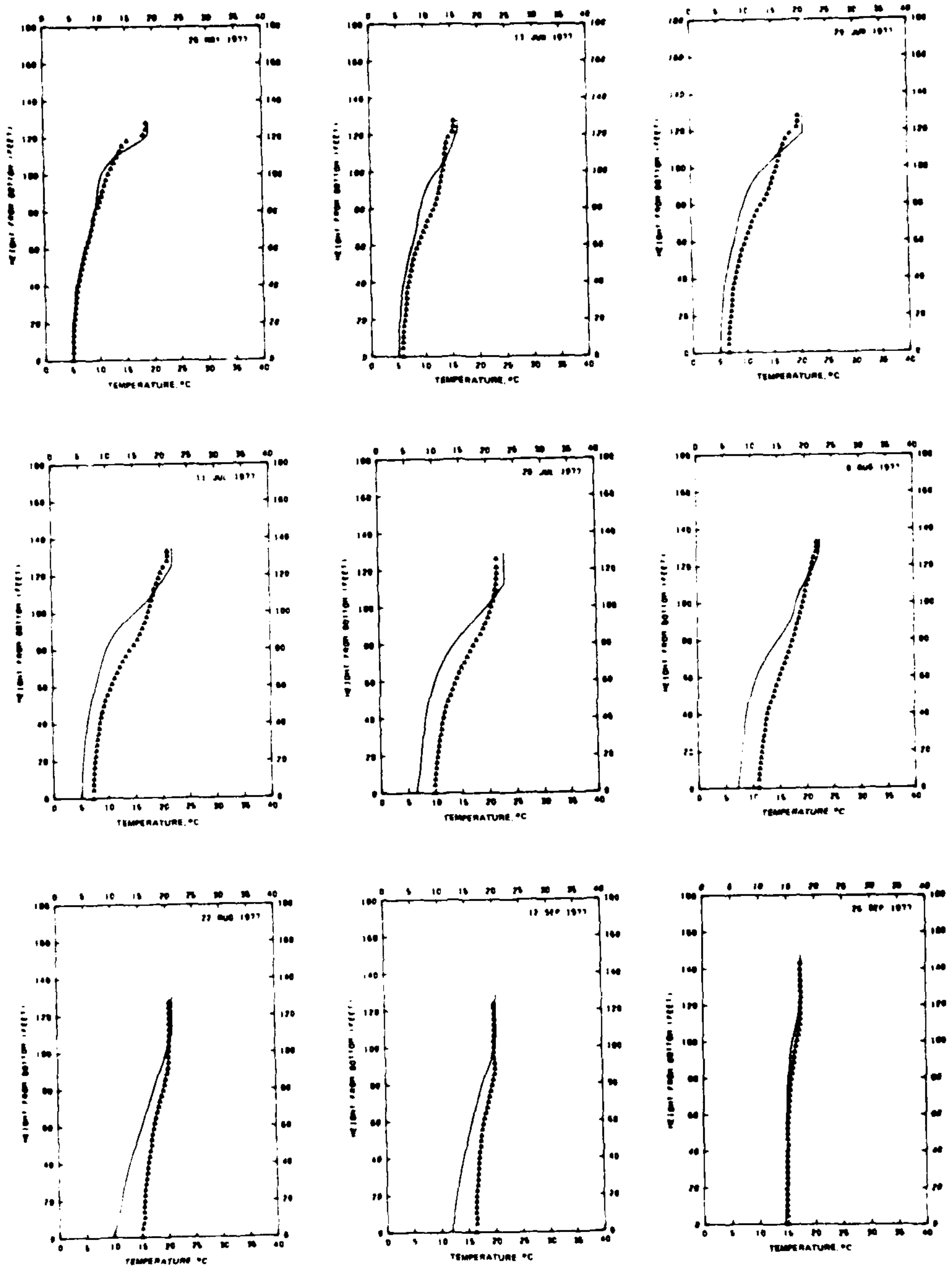


COMPUTED TEMPERATURE PROFILES
1977 WITH POWER



DEVIATION OF COMPUTED RELEASE TEMPERATURES
CONTINUOUS POWER IN SPRING VS AS-OPERATED CONDITION OF
POWER SHUTDOWN IN SPRING
1977

PLATE 16



LEGEND

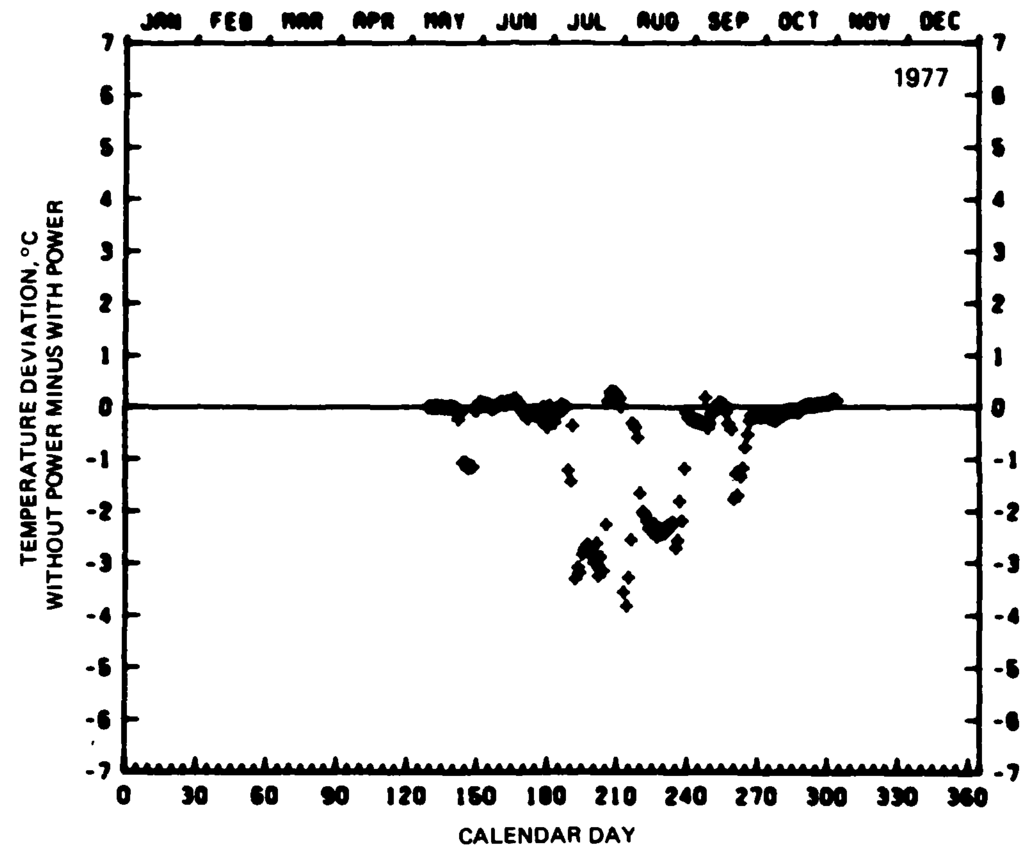
——— WITHOUT POWER

▲ WITH POWER

COMPUTED TEMPERATURE PROFILES

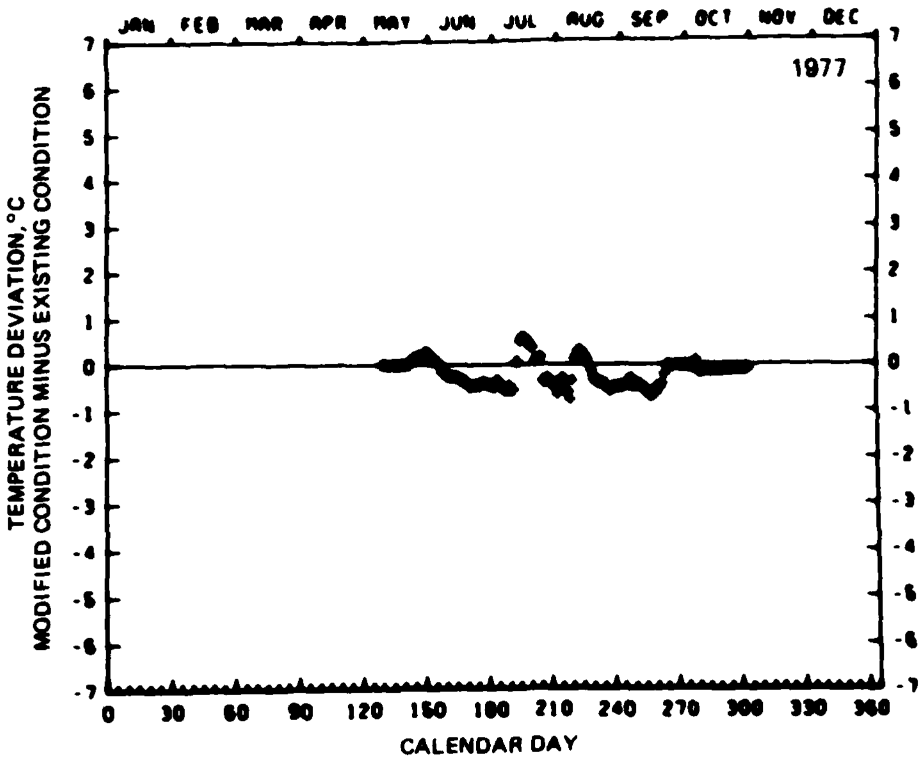
1977

PLATE 17

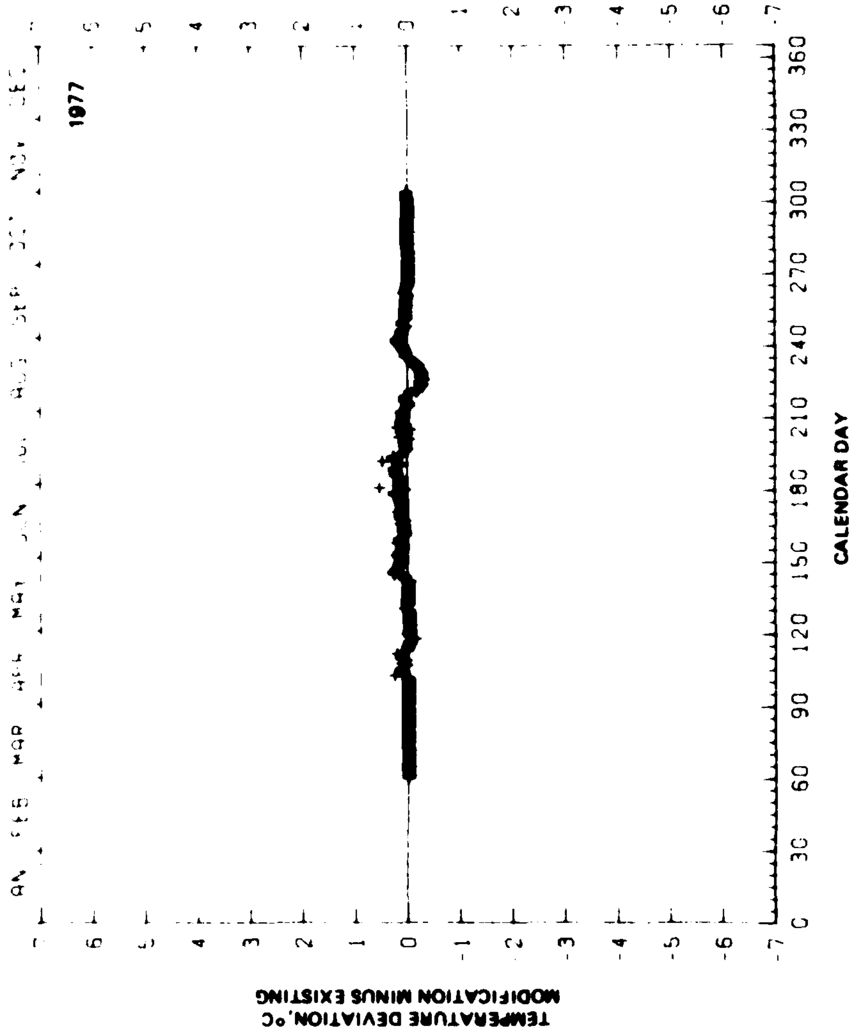


DEVIATION OF COMPUTED RELEASE TEMPERATURES
WITHOUT POWER VS WITH POWER (EXISTING CONDITIONS)
1977

PLATE 18

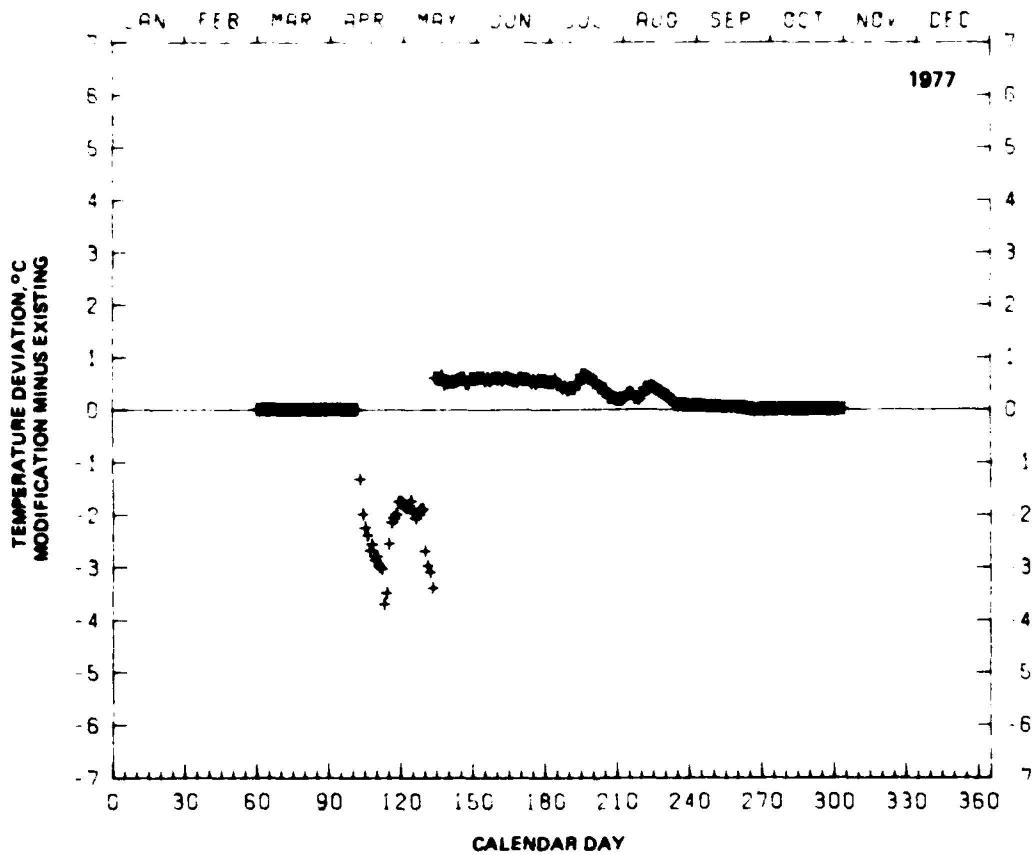


DEVIATION OF COMPUTED RELEASE TEMPERATURES
POWER INTAKE OPERATIONAL MODIFICATION VS EXISTING CONDITIONS
1977



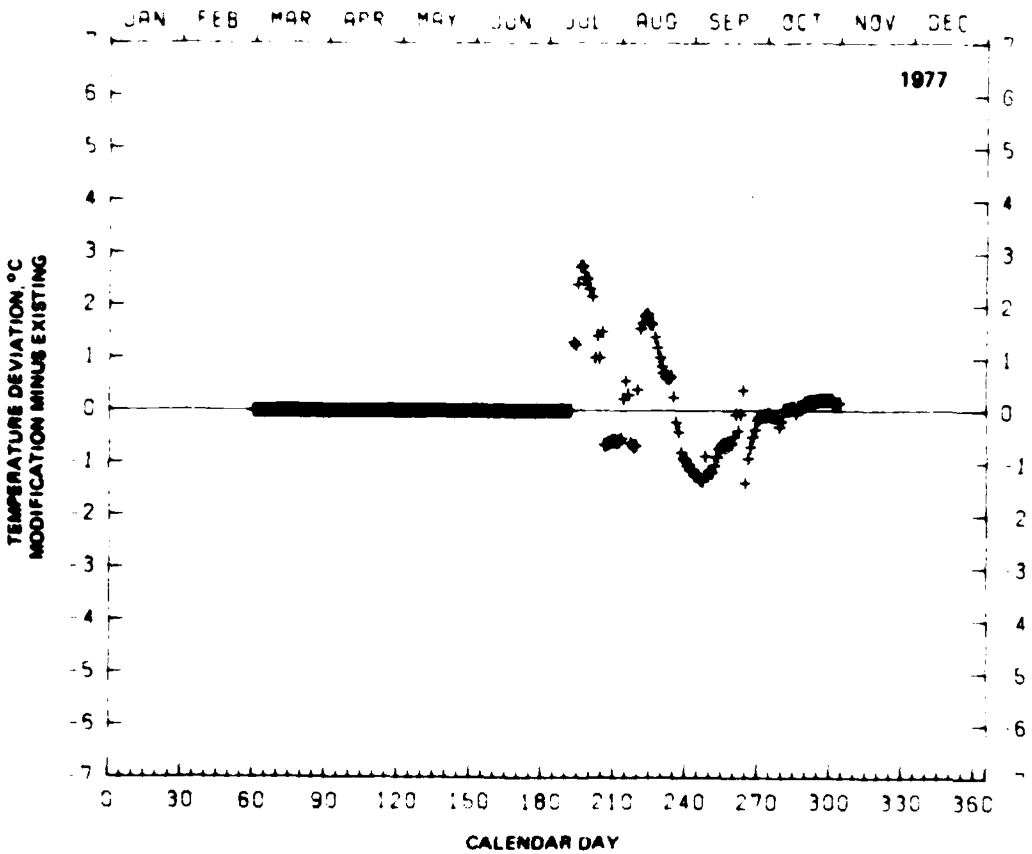
DEVIATION OF COMPUTED RELEASE TEMPERATURES
POWER INTAKE INVERT 10.0 FT BELOW SURFACE VS EXISTING CONDITIONS
1977

PLATE 20



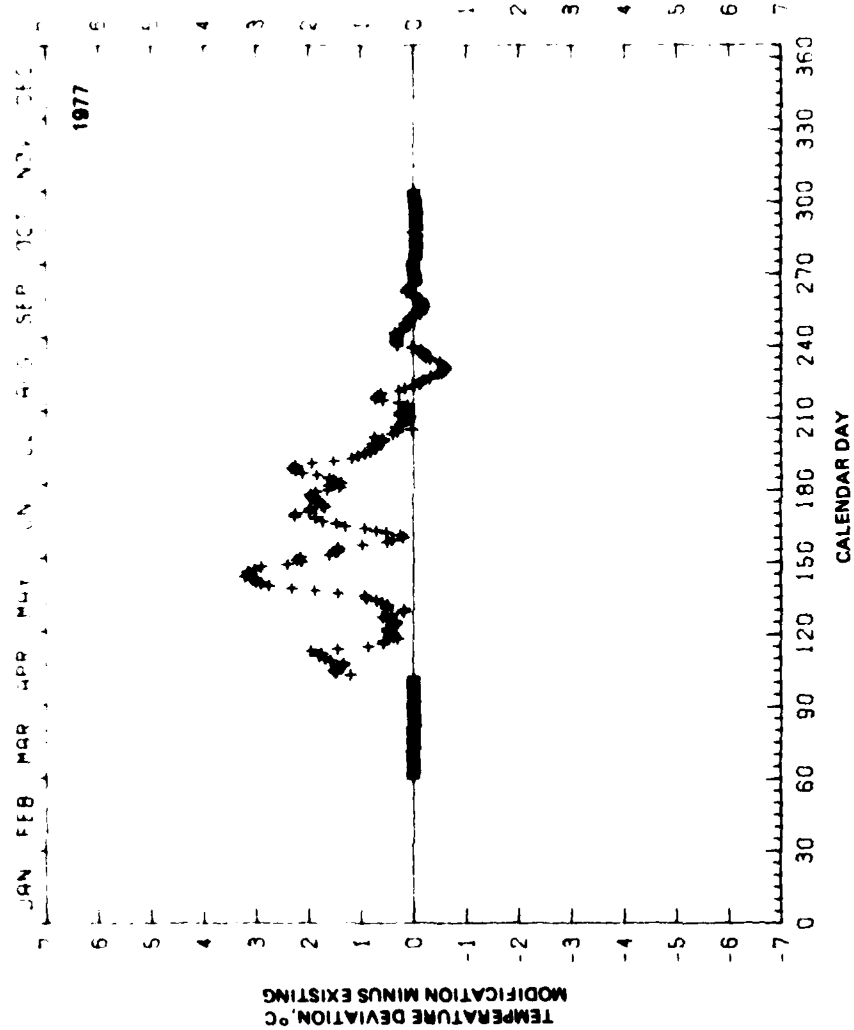
NOTE: OPERATED LOWER SLUICES UNTIL DAY 133 RATHER THAN DAY 103

DEVIATION OF COMPUTED RELEASE TEMPERATURES
OPERATE LOWER SLUICES ONE MONTH LONGER VS EXISTING CONDITIONS
1977

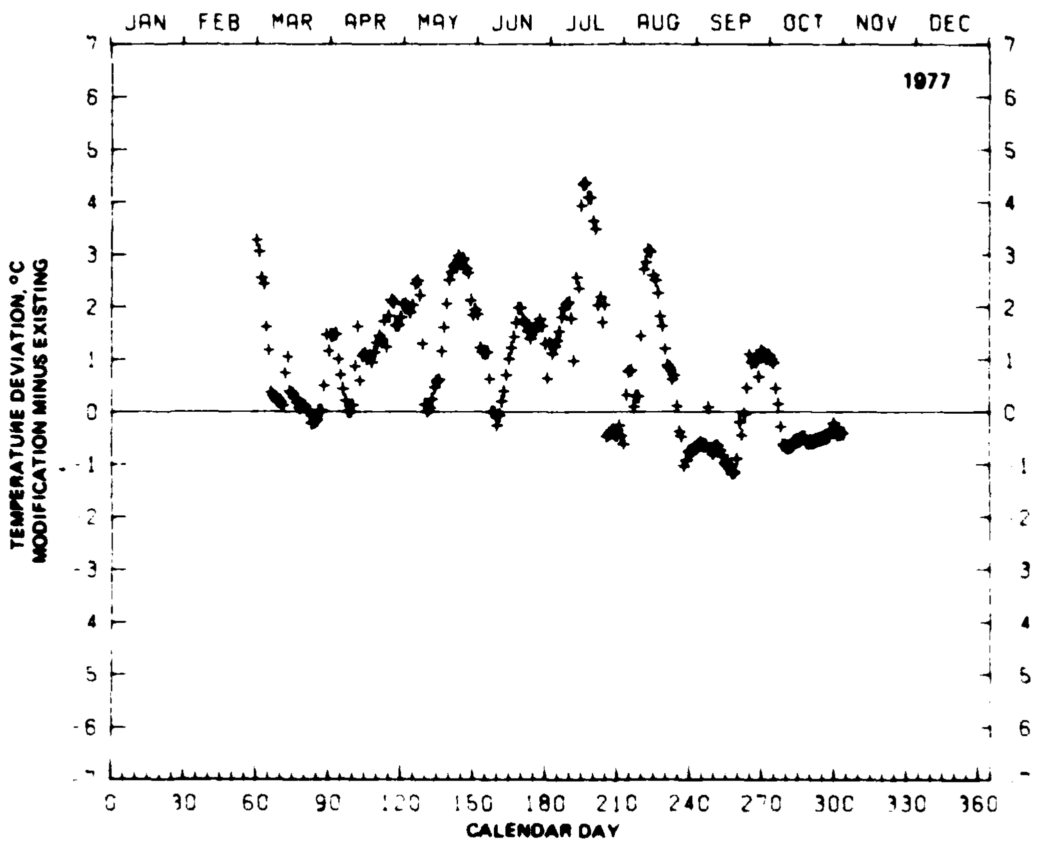


DEVIATION OF COMPUTED RELEASE TEMPERATURES
NO LOWER SLUICE FLOW FOR DAYS 152-264 VS EXISTING CONDITIONS
1977

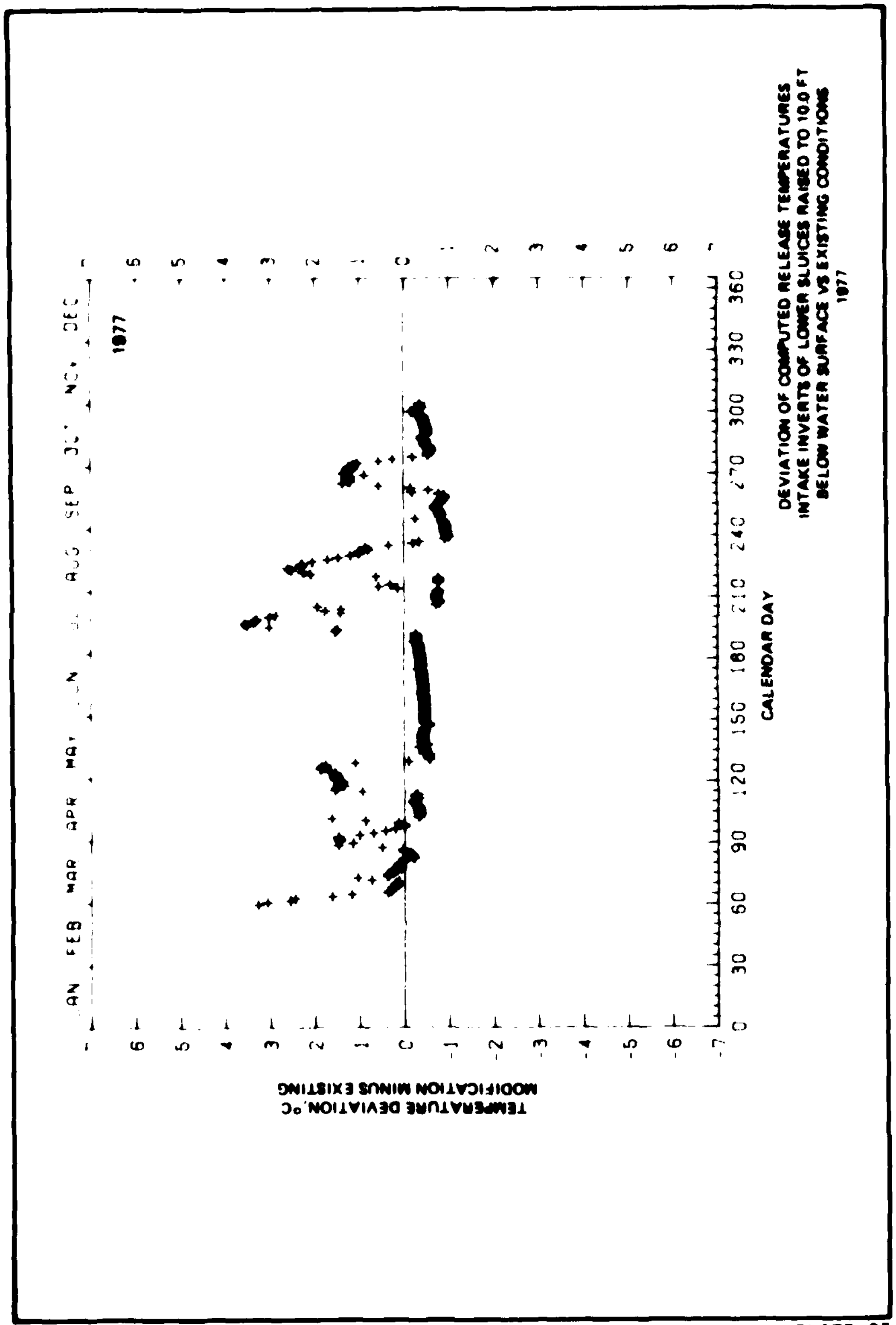
PLATE 22

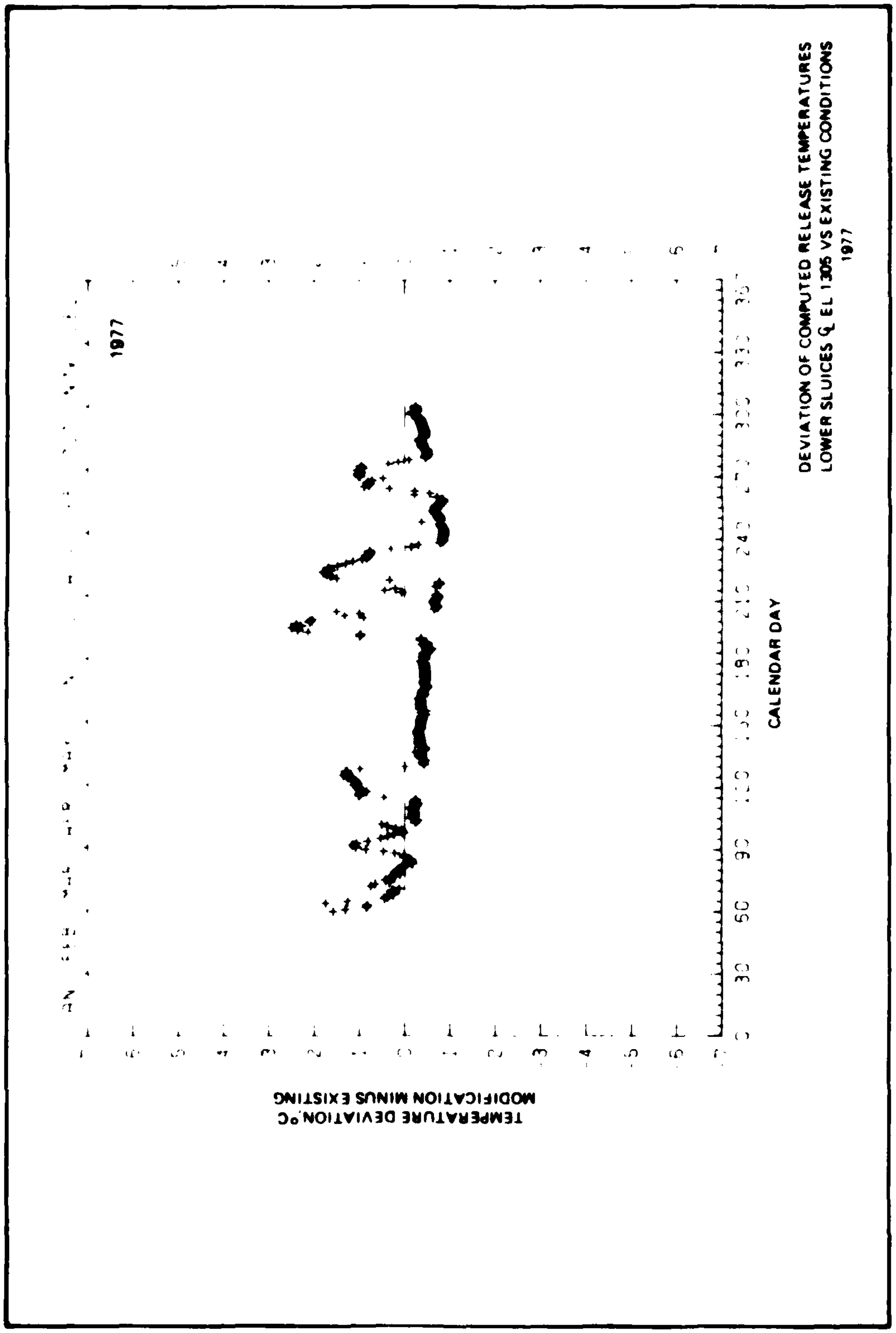


DEVIATION OF COMPUTED RELEASE TEMPERATURES
INTAKE INVERTS OF UPPER SLUICES RAISED TO 10.0 FT BELOW
WATER SURFACE VS EXISTING CONDITIONS
1977



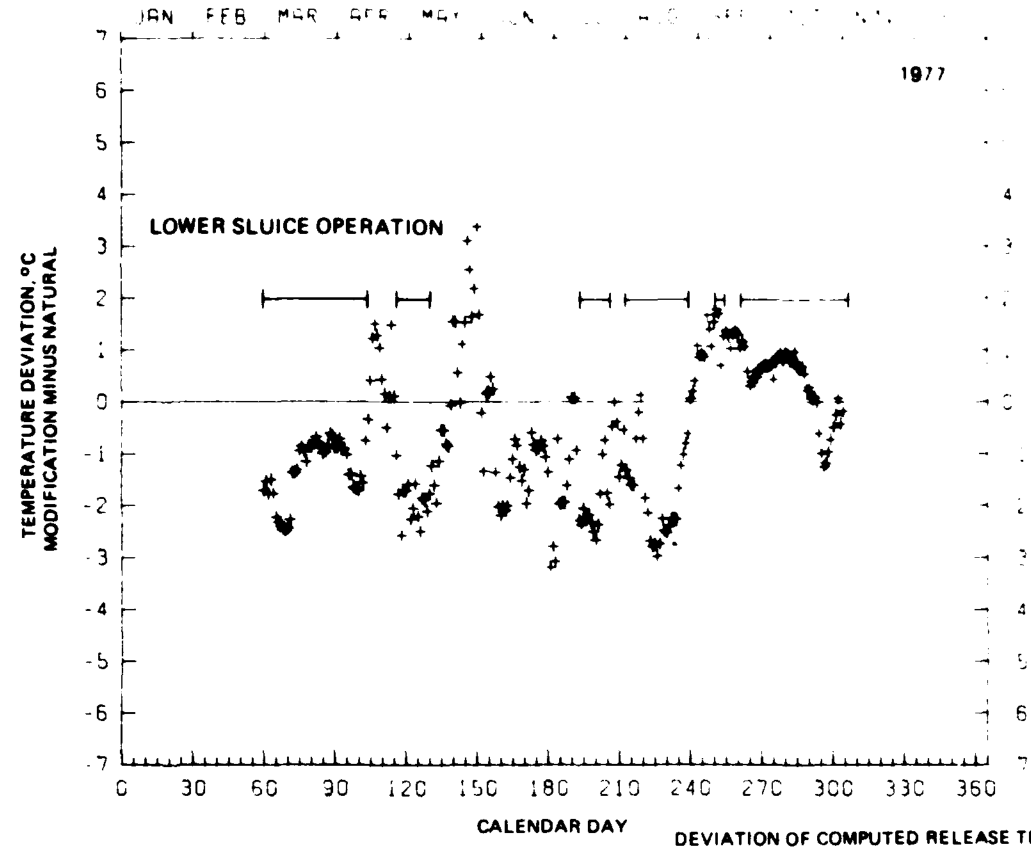
DEVIATION OF COMPUTED RELEASE TEMPERATURES
INTAKE INVERTS OF UPPER AND LOWER SLUICES RAISED TO 10.0 FT
BELOW WATER SURFACE VS EXISTING CONDITIONS
1977


DEVIATION OF COMPUTED RELEASE TEMPERATURES
INTAKE INVERTS OF LOWER SLUICES RAISED TO 10.0 FT
BELOW WATER SURFACE VS EXISTING CONDITIONS
1977
TEMPERATURE DEVIATION, °C
MODIFICATION MINUS EXISTING
CALENDAR DAY
1977
FEB
MAR
APR
MAY
SEP
DEC



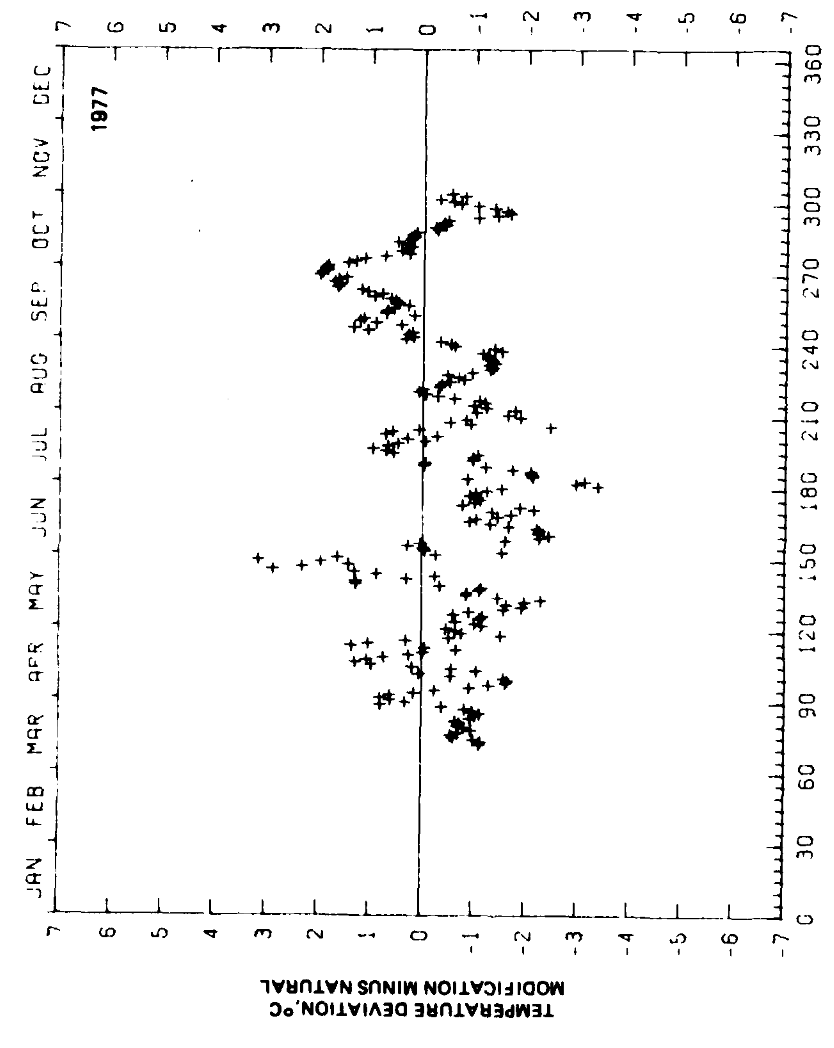
DEVIATION OF COMPUTED RELEASE TEMPERATURES
LOWER SLUICES ℄ EL 1305 VS EXISTING CONDITIONS
1977
1977
CALENDAR DAY
TEMPERATURE DEVIATION,°C
MODIFICATION MINUS EXISTING

PLATE 26



NOTE: FOR CONTINUOUS POWER IN SPRING

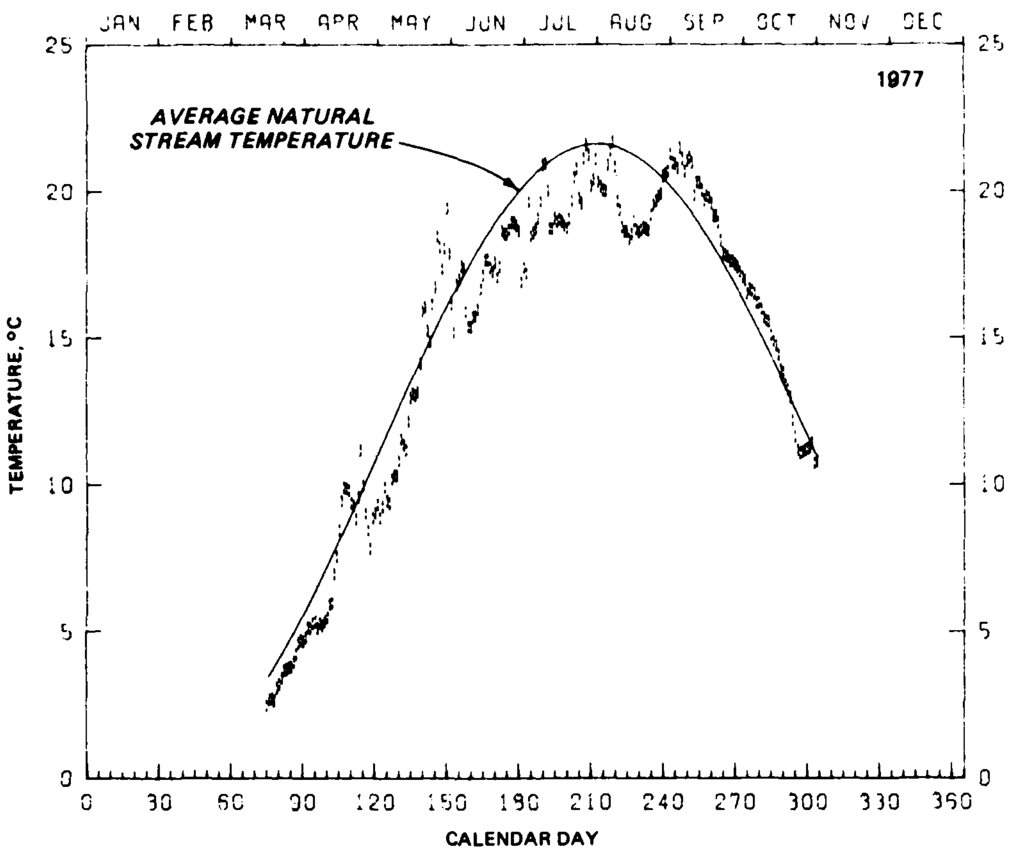
DEVIATION OF COMPUTED RELEASE TEMPERATURES
INTAKE INVERTS OF UPPER SLUICES RAISED TO 10.0 FT
BELOW WATER SURFACE VS AVERAGE NATURAL STREAM TEMPERATURE
1977



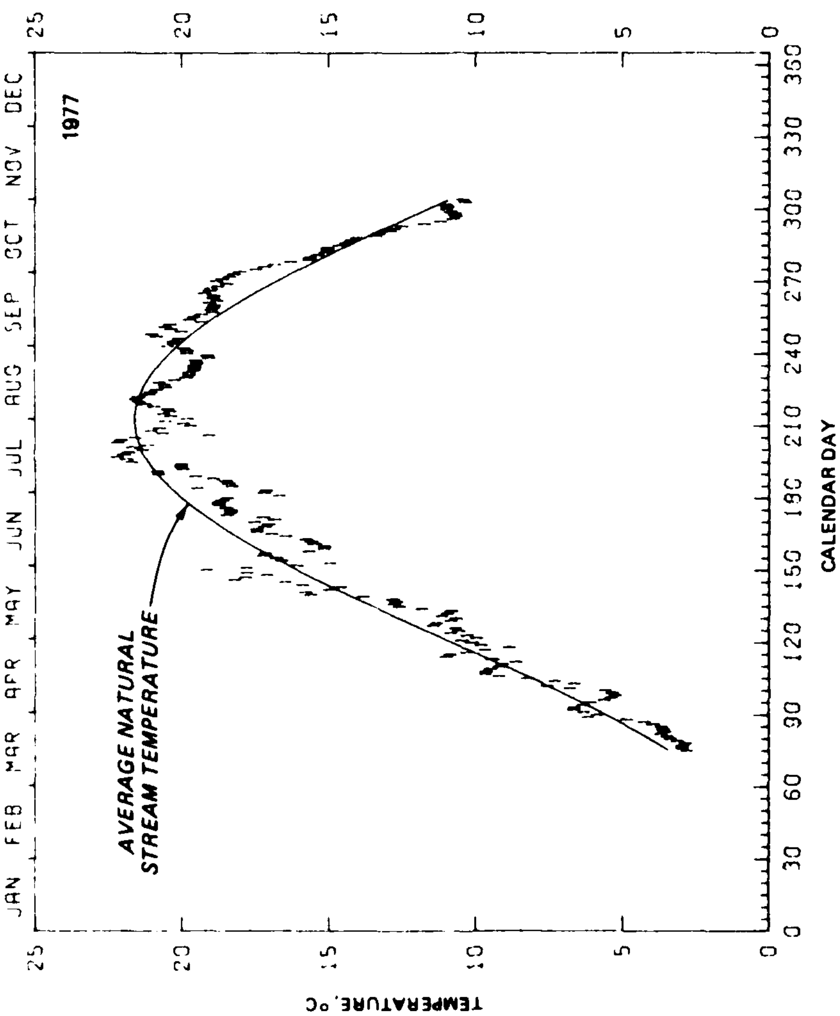
DEVIATION OF COMPUTED RELEASE TEMPERATURES
INTAKE INVERTS OF UPPER AND LOWER SLUICES RAISED TO 10.0 FT
BELOW WATER SURFACE VS AVERAGE NATURAL STREAM TEMPERATURE
1977

NOTE: FOR CONTINUOUS
POWER IN SPRING

PLATE 28

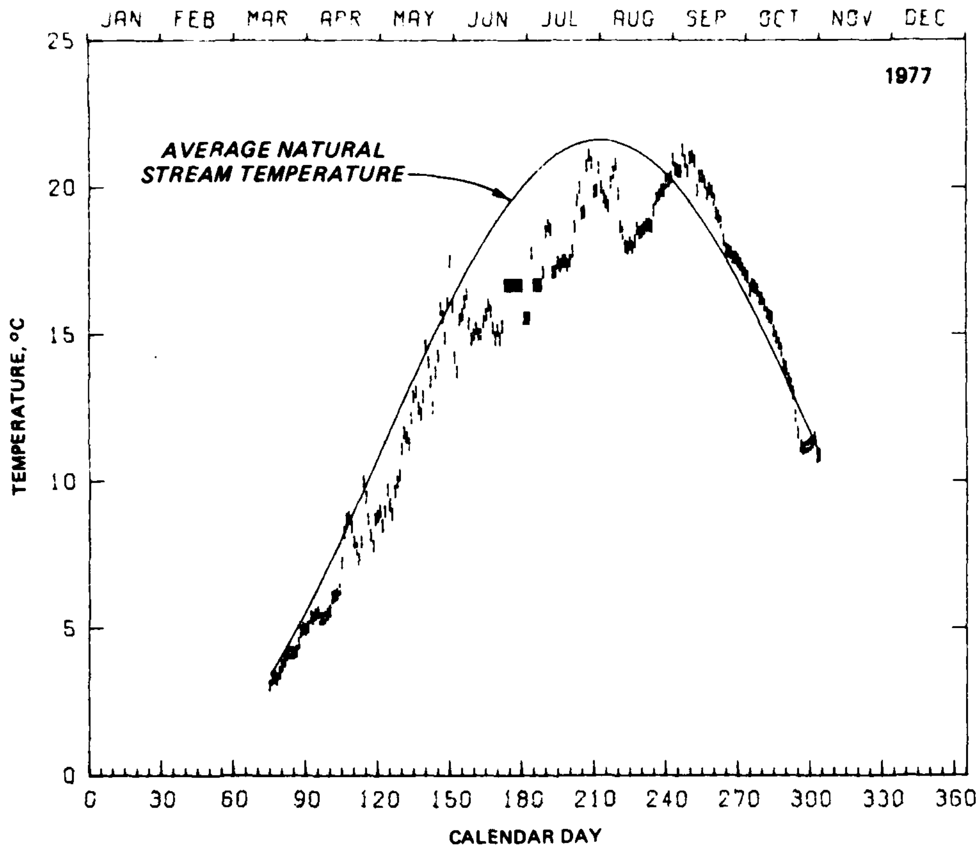


COMPUTED RELEASE TEMPERATURE
CONTINUOUS POWER AND INTAKE INVERTS OF UPPER SLUICES
RAISED TO 10.0 FT BELOW WATER SURFACE
1977



COMPUTED RELEASE TEMPERATURE
CONTINUOUS POWER AND INTAKE INVERTS OF UPPER AND LOWER SLUICES
RAISED TO 10.0 FT BELOW WATER SURFACE
1977

PLATE 30



OBSERVED RELEASE TEMPERATURE
1977

PLATE 31

APPENDIX A: CORRESPONDENCE CONCERNING FINAL RECOMMENDATIONS

DEPARTMENT OF THE ARMY
PITTSBURGH DISTRICT, CORPS OF ENGINEERS
FEDERAL BUILDING, 1000 LIBERTY AVENUE
PITTSBURGH, PENNSYLVANIA 15222

ORPED-HR 19 December 1980

SUBJECT: Kinzua Water Temperature Model, Kinzua Dam, Pennsylvania

Commander and Director
U.S. Army Engineer Waterways Experiment Station
ATTN: WESHS
P.O. Box 631
Vicksburg, MS 39180

1. This will confirm oral permission given on 6 August 1980 by our Mr. Robert W. Schmitt to your Mr. John L. Grace, Jr. to dismantle the Kinzua Dam Water Temperature Model and publish the final report.

2. On 18 December 1979, a meeting was held at the U.S. Fish and Wildlife Hatchery just downstream from Kinzua Dam. Twenty-four attendees from State, Federal, sportsmen, and power company organizations were briefed by Mr. Grace on the studies made at the Waterways Experiment Station to determine ways of increasing the temperature of the outflow water. The Waterways Experiment Station's recommendation consisted of adding risers to two low-level sluices if the District determined the need and cost could be justified by expected benefits.

3. Subsequent written replies were received from the Butler County Sportsman Council, the U.S. Fish and Wildlife Service, and the Pennsylvania Fish Commission. The opinions were unanimous that expensive risers should not be installed. There is a real concern that the risers might not restore the smallmouth bass fishery and could, in fact, jeopardize the fine coldwater and coolwater fisheries that have since developed below the dam.

4. No further consideration will be given to structural alteration in the interest of raising outflow water temperatures. Although it will not be necessary for the District to implement the study recommendations, it is acknowledged that the decision could not have been made, to the satisfaction of all concerned, without the valuable study.

FOR THE DISTRICT ENGINEER:

J. S. MINNOTTE
Chief, Engineering Service

ORPED-HR 19 December 1980
SUBJECT: Kinzua Water Temperature Model, Kinzua Dam, Pennsylvania

CF:
Div. Engr., Ohio River
ATTN: ORDED-T

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Dortch, Mark S.
Investigation of release temperatures for Kinzua Dam, Allegheny River, Pennsylvania : hybrid model investigation / by Mark S. Dortch (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. ; available from NTIS, 1981.
37 p. in various pagings, 31 p. of plates : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; HL-81-9)
Cover title.
"September 1981."
Final report.
"Prepared for U.S. Army Engineer District, Pittsburgh."
Bibliography: p. 34.

1. Hydraulic models. 2. Kinzua Dam (Pa.) 3. Pumped storage power plants. 4. Reservoirs. 5. Simulation methods. 6. Thermal pollution of rivers, lakes, etc. I. United States. Army. Corps of Engineers.

Dortch, Mark S.
Investigation of release temperatures for Kinzua : ... 1981.
(Card 2)

Pittsburgh District. II. U.S. Army Engineer Waterways Experiment Station. Hydraulics Laboratory. III. Title IV. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; HL-81-9.
TA7.W34 no.HL-81-9

END

DATE FILMED

12-81

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