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A TWO DIMENSIONAL DEPTH AVERAGED NUMERICAL TEMPERATURE MODEL OF NARRAGANSETT BAY

BY

JOHN J. ALFANO

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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MASTER OF SCIENCE THESIS

OF

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1973

ABSTRACT

The numerical temperature model proposed in this thesis approximates the temperature distributions produced by natural or man made conditions in Narragansett Bay. The model approximates the temperature distribution by averaging the vertical structure over depth. A two dimensional, planar coordinate system continuously specifies the temperatures within the bay. A hydrodynamic model calculates the necessary velocities and depths required by the thermal model. The combined thermal-hydraulic model calculates bottom roughness, Coriolis acceleration, non-linear convective terms, astronomical tidal series for Rhode Island Sound, and air-water heat exchange. Known river flow inputs are used as boundary conditions. To simplify the model geometry the Mount Hope Bay structure is replaced by a boundary flow rate at the Mount Hope Bridge grids.

Narragansett Bay has an average depth of 32 feet and a length of approximately 24 nautical miles with a maximum width of six nautical miles. By specifing a total of 325 square grids with eleven boundary grids 1/2 nautical mile in length the model approximates the features of the estuary.

Verification of the model is achieved through conservation of mass analysis and comparison of predicted temperatures for given meteorological and water temperature data. The model is used to predict the thermal fields from a proposed power plant near Rome Point in the West Passage of Narragansett Bay. By specifying plant flow rates and dispersion coefficients characteristic temperature field conditions are observed. Under specified plant operating conditions, a maximum temperature rise of 5.5°C above ambient in the discharge grid is predicted. For a temperature rise of 5.5°C the area encompassed by the 1°C excess isotherm is approximately two square miles while the 0.5°C isotherm area is about four square miles. Temperature isotherms over a tidal cycle retain the same general shape, especially in the far field where temperatures fall below 0.4°C excess.

This model can simulate salinity or other non-decaying constituents if appropriate boundary condition changes are made.

In summary, the thermal model gives valuable insight into natural and man-made temperature distributions that will aid the marine scientist in preserving and understanding the dynamics of Narragansett Bay.

ACKNOWLEDGEMENT

Although computer modeling is primarily a struggle between the modeler and the model it would be a grave injustice not to mention the support I received from my committee. In particular Dr. Frank White's encouraging words on the model, this thesis and other related matters deserve commendation. During the darkest days Dr. George Brown's help proved invaluable as well as Professor Warren Hagist's encouraging support.

It is unfortunate that certain ultimate goals were not achieved but the confidence and love of my wife clarified my perspective and stimulated this work. We weathered the storm together.

Mr. Kurt Hess's constant support and patience went beyond the normal bounds of friendship.

Miss Linda Weinreich, showing profitable enthusiam with the many drafts made the manuscript into a thesis.

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I. INTRODUCTION

A. GENERAL

A model tries to represent the salient characteristics of a system so that the user can gain insight into the governing features of the particular site. This thesis explains the implementation of a model that will predict vertically-averaged temperature distribution in Narragansett Bay. The thermal model, as it is called, uses a tidal model (Hess, 4) to provide the necessary hydrodynamic structure in the bay. The hydrodynamic inputs are velocity, tidal elevation, and bottom friction. The thermal model then predicts the effect of thermal convection and diffusion as well as the heat exchange that takes place at the air-water interface for specified locations or grids. Pertinent meterological data must be read in for periods of simulation. In essence, the model predicts the movement or mixing of heat subject to eleven known boundary conditions around the bay.

The model is a digital computer program, written in Fortran language, that uses over three hundred 1/2 by 1/2 nautical mile cells to represent the characteristic features of the bay. The model is two dimensional in that it determines a temperature value for each cell volume in both a general north-south and east-west direction.

With this model, marine life behavior and electric generating plant thermal discharges can be studied. Other applications, such as salinity prediction, are possible with minor model modifications.

To begin this study, a breakdown of main model components is shown in Figure 1.1. It can be seen that to understand the convective, diffusive and time varying quantities we must rely on a hydrodynamic model that will simulate the transporting medium accurately. The grouping of these terms, in block diagram form, indicates no interaction of constituent on flow behavior. If the model had a vertical structure, one would couple the hydrodynamic model with constituent model through the vertical buoyancy flux term, creating a much more difficult problem and many more cells.

B. HISTORICAL DATA

General historical information consists of data obtained from various cruises and buoy measurements taken in and around the bay area during the last 100 years. Tables 1.1, 1.2, and 1.3 present a summary of temperature informa-

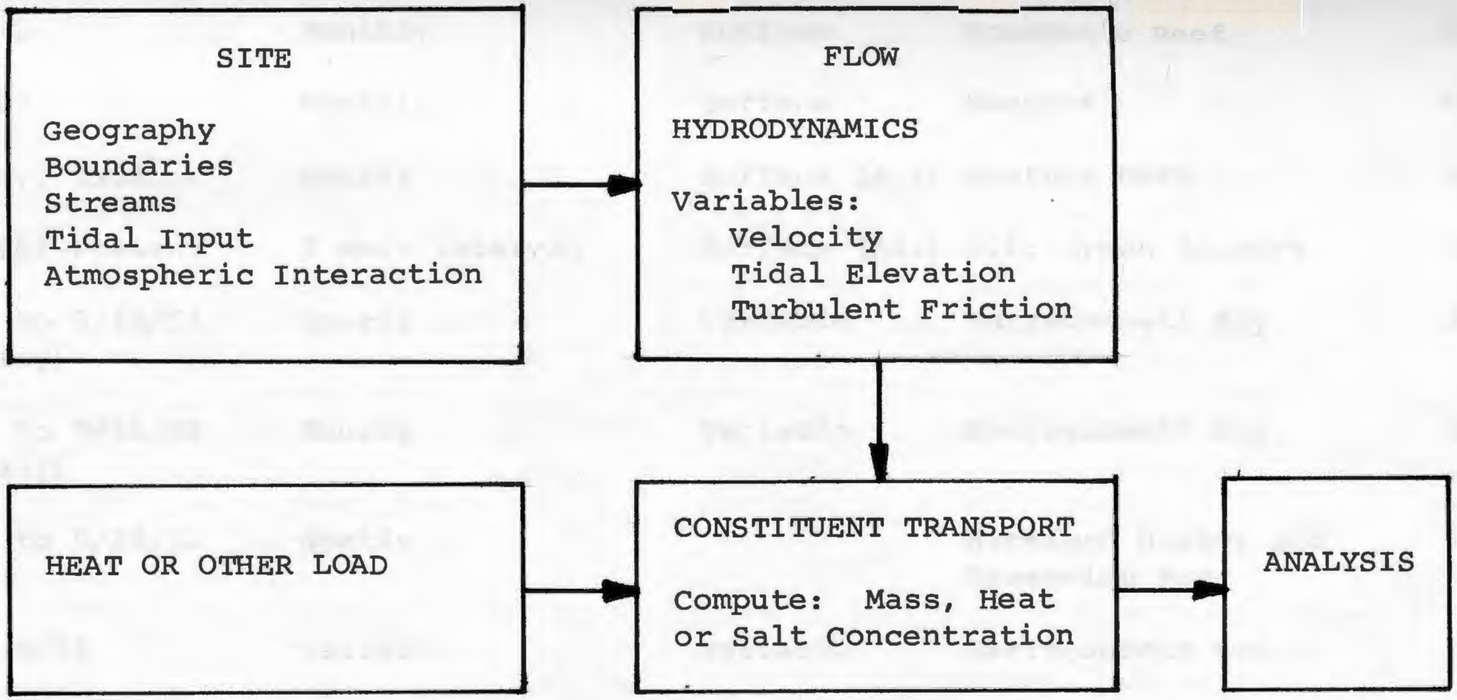


FIGURE 1.1. MODEL COMPONENTS

PERIOD	TIME	PROBE	LOCATION	REFERENCE
1879-1942	Monthly	Surface	Brenton's Reef	31
1881-1883	Monthly	Surface	Newport	31
1905-Dec., 1966	Hourly	Surface (Air)	Weather Data	56
Jan., 1967-Present	3 Hour Interval	Surface (Air)	T.F. Green Airport	56
8/24/51 to 9/18/51 (Not Daily)	Hourly	Variable	Narragansett Bay	32
2/19/52 to 9/16/52 (Not Daily)	Hourly	Variable	Narragansett Bay	32
4/16/50 to 9/28/52	Weekly		Wickford Harbor and Greenwich Bay	33
6/51 to 9/52	Variable	Variable	Narragansett Bay	58
2/1-21/56 (Cr. 14)	Hourly	Variable	Narragansett Bay	34 (mostly isotherms)
4/2-20/56 (CR. 15)	Hourly	Variable	Narragansett Bay	34

TABLE 1.1. TEMPERATURE DATA, 1879-1956

PERIOD	TIME	PROBE	LOCATION	REFERENCE
6/11-28/56 (Cr. 18)	Hourly	Variable	Narragansett Bay	35
8/6-10/56 (CR.19)	Hourly	Variable	Narragansett Bay	35
9/1/56 to 12/31/56	Daily (Max., Min.)	Surface	Narragansett Marine Lab Pier	36
1/22 to 2/6/57 (Cr.1)	Hourly	Variable	Narragansett Bay	37
4/10 to 4/18/57 (Cr.2)	Hourly	Variable	Narragansett Bay	37
7/15 to 7/19/57 (Cr.3)	Hourly	Variable	Narragansett Bay	37
11/11 to 11/16/57 (Cr. 4)	Hourly	Variable	Narragansett Bay	37
2/7 to 1/29/58	Weekly	Sfc., Bot.	Narragansett Marine Lab	37
1/1 to 12/31/57	Daily (Max., Min.)	Surface	Narragansett Marine Lab	38
5/18/57 to 3/18/58	Weekly	Surface	Mt. Hope Bay, Fox Island	39

TABLE 1.2. TEMPERATURE DATA, 1956-1958

PERIOD	TIME	PROBE	LOCATION	REFERENCE
8/55 to 12/58	Monthly Daily (Available)	Surface	Newport, R.I.	41
1959	Daily (Average)	Surface	Narragansett Marine Lab	40
Summer 1959	Hourly	Surface-Bottom	Upper Narragansett Bay	42
1960	Daily (Average)	Surface	Narragansett Marine Lab	43
7/19/63 to 7/64	Period	Variable	R.I. Sound (Isotherms)	44
1960 to 1966	Monthly Daily (Available)	Surface	Newport, R.I.	45
1967 to Present	Weekly	Surface	Fox Island, Whale Rock	46
3/71 to 10/71	Continuous Daily (Max., Min.)	Near Bottom	East of Saunderstown (71°25', 41°30'30")	47
6/72 to 8/72	Hourly	Variable	Narragansett Bay	48

TABLE 1.3. TEMPERATURE DATA, 1958-PRESENT

tion for the Narragansett Bay. This compilation of data provides some understanding of boundary conditions and very general spacial variations throughout the bay.

First, the Brenton's Reef Data (31) provides an estimate for the monthly surface temperature for the lower bay boundary condition. The averaged monthly temperature for Brenton's Reef is shown in Figure 1.2. For the thermal model, the average value during the prediction period is read off Figure 1.2 and specified as the Rhode Island Sound boundary condition. Included in reference 31 is a brief temperature record for Newport during the period May, 1881 to March, 1883 and the average values are also seen in Figure 1.2.

The data collected by Wehe (32) is given in chart form with longitude and latitude, date, time in minutes, various depths, temperature of water (^{o}F), salinity, oxygen, sound velocity, Secchi Disk measurements, sea state, wind direction and magnitude, and weather conditions. The report has 91 pages of data with measurements taken on August 24, 27-31, September 5, 10-12, 14, 17, 18 in 1951, and February 2, 19-22, March 25-27, August 13, 27-29, September 4, 9, 11, 15, 16 in 1952.

The weekly temperature variations of surface water in

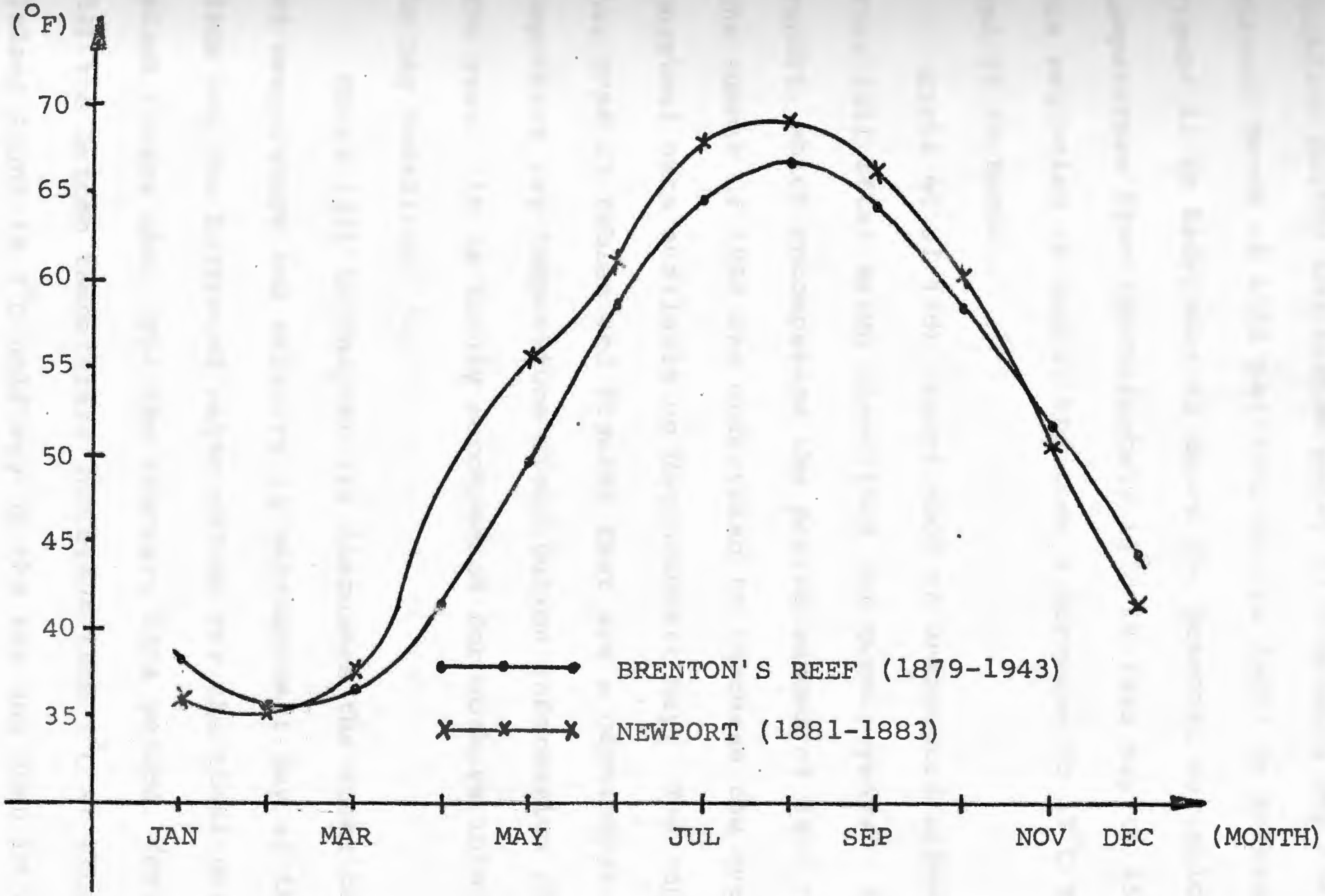


FIGURE 1.2. MONTHLY SURFACE WATER TEMPERATURE FOR NEWPORT, RHODE ISLAND AND BRENTON'S REEF (31)

Wickford Harbor and bottom water in Greenwich Bay for May through March of 1951 and 1952 can be found in Reference 33. Figure 11 in Reference 33 shows the seasonal variation of temperature from approximately 16°C in late May to 25°C at the beginning of August and then a decrease to 17°C for the end of September.

Hicks et al (58) report made an unexpected appearance this fall after being classified for twenty years. This report, which encompasses the period summer of 1951 through the summer of 1952 was undertaken to increase the overall physical data available on Narragansett Bay. The report has over 25 tables and figures that are a cornucopia of important bay temperature distribution information throughout the year. It is highly recommended for workers interested in Bay modeling.

Hicks (34) in Chapter III discusses the distribution of temperature and salinity in Narragansett Bay at the surface and the bottom of water column for the tidal period, slack before ebb. For the February 1956 period, (Cruise, 14) the bottom temperature increases from 1°C at Rhode Island Sound to 3°C half way up the bay and down to 2°C in Providence River area. Surface temperatures for Cruise 14 remain at 2°C for the entire bay. The isothermal pattern for the April 1956 period (Cruise 15) is very irregular, with variations in bottom water from 1°C to 7°C while the surface water is 3°C in Rhode Island Sound and increases to 10°C in the Providence River.

Hicks (34) undertook two more cruises one in June (Cruise 18) and another in August, 1956 (Cruise 19). The isothermal pattern for the June cruise shows a surface temperature variation of 19°C at Rhode Island Sound to 20°C in the Providence River while the bottom water changes from 11°C to 17°C respectively. For the second cruise, the temperature variation in the surface water was about 4°C or the difference between 23°C in the Providence River compared with 19°C in the lowest portions of the bay. The bottom water varied from 20°C in the upper portion of the bay to about 17°C in the Rhode Island Sound.

Continuous temperature readings were taken at the Narragansett Marine Laboratory on a Bristol Recorder. These temperature readings were reduced into maximum and minimum values (36, 38) and then to just a daily average (40, 43). The average values for each month are listed and these are plotted against the Brenton's Reef data (31) to estimate how weather conditions affect general bay behavior.

Hicks (37), in a comprehensive report, presents temperature data in four quarterly cruises. In this report are tables estimating seasonal temperature trends and ranges as well as vertical distribution of temperature during the various cruises. In addition, his Figure 14 (37) shows the surface and bottom temperature variation at Narragansett Marine Lab Pier for the period February, 1957 through June, 1958. The information for this figure is contained in Appendix Table 5 (37) for which temperature data is taken about once a week.

Weekly surface water temperatures for Mt. Hope Bay and Fox Island for the interval May 18, 1957 to March 18, 1958 were taken by Herman (39). The general temperature pattern can be seen in Figure 1.3.

Since August, 1955, surface water temperature data (41, 45) has been gathered at Newport, Rhode Island. The surface water temperatures are measured several times a week and these data sheets (available) are compiled into monthly maximum, mean maximum, mean, mean minimum, and minimum temperatures. The temperature variations for Narragansett Marine Lab Pier and Newport are shown in Figure 1.4.

The Corps of Engineer Survey (42) did extensive measurements during the summer of 1959 in the portion of Narragansett

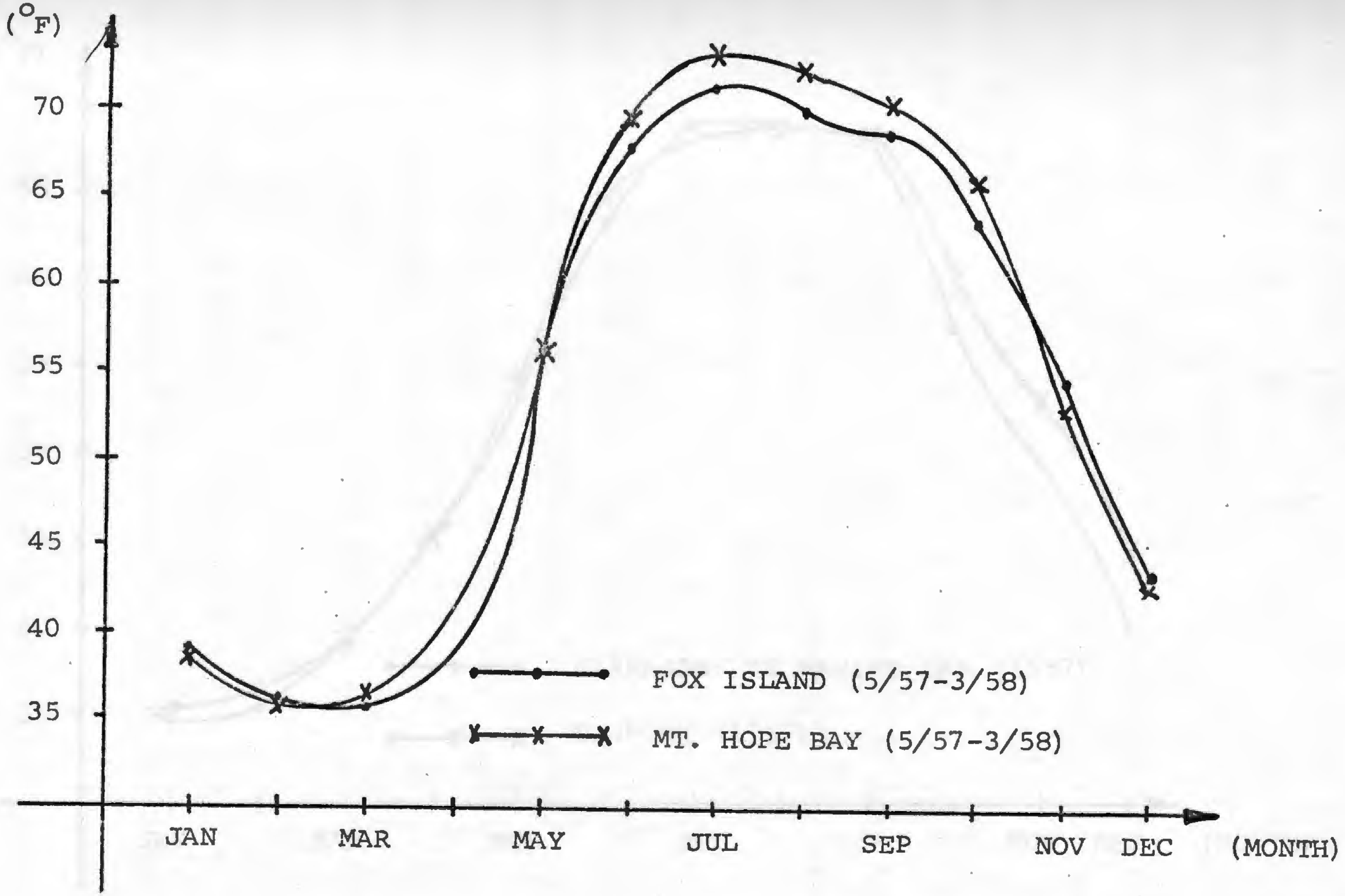


FIGURE 1.3. SURFACE WATER TEMPERATURE, MT. HOPE BAY AREA AND FOX ISLAND (39)

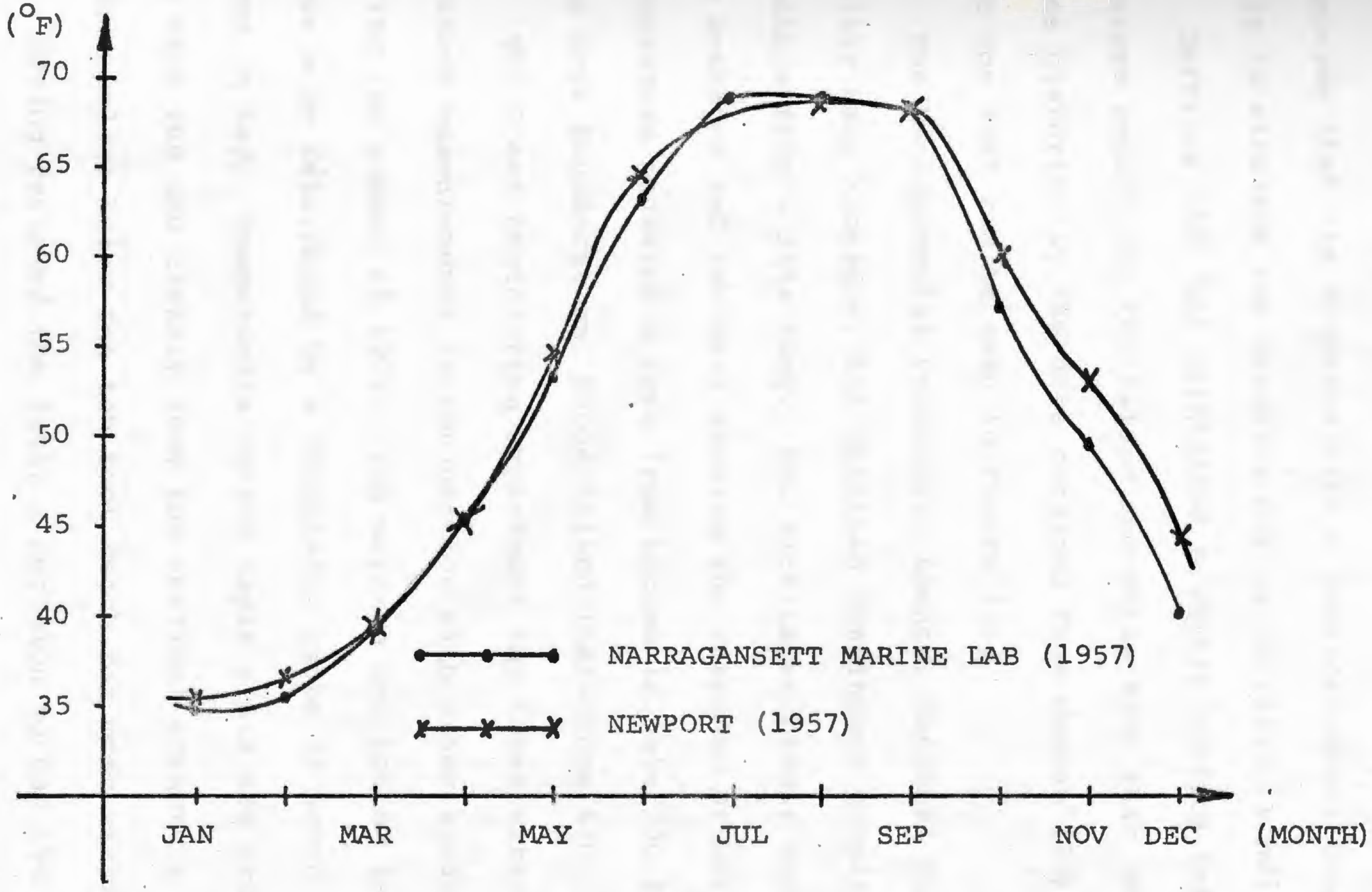


FIGURE 1.4. MONTHLY WATER SURFACE TEMPERATURE AVERAGES FOR NEWPORT AND NARRAGANSETT MARINE LAB PIER (41, 38)

Bay north of Prudence Island. The report includes average isotherms that are compared with a physical model that was built to simulate bay dynamics during hurricane conditions.

Jeffries (46) has maintained a weekly surface temperature record for Fox Island and Whale Rock that complements historically the data obtained from Herman (39). This data for 1967 can be seen in Figure 1.5.

The Environmental Protection Agency, National Water Quality Lab, Kingston, has obtained continuous temperature readings from a data buoy. Mr. Rick Lapan kindly supplied the averaged and raw data showing the response of water temperature measured 8 feet from bottom in water 30 feet deep near Saunderstown, Rhode Island (Reference 47).

The Ocean Engineering Department has taken water temperature measurements in conjunction with other studies during the summer of 1972. The surface and bottom temperatures were determined by a thermistor probe at seven stations in bay. Temperature versus depth plots are provided for each run and clearly show the vertical structure with a thermocline below the ten foot depth for most stations.

Having reviewed the data, a decision to use the period, Summer 1957, was made because it represents the best collection of published data in the bay for use in

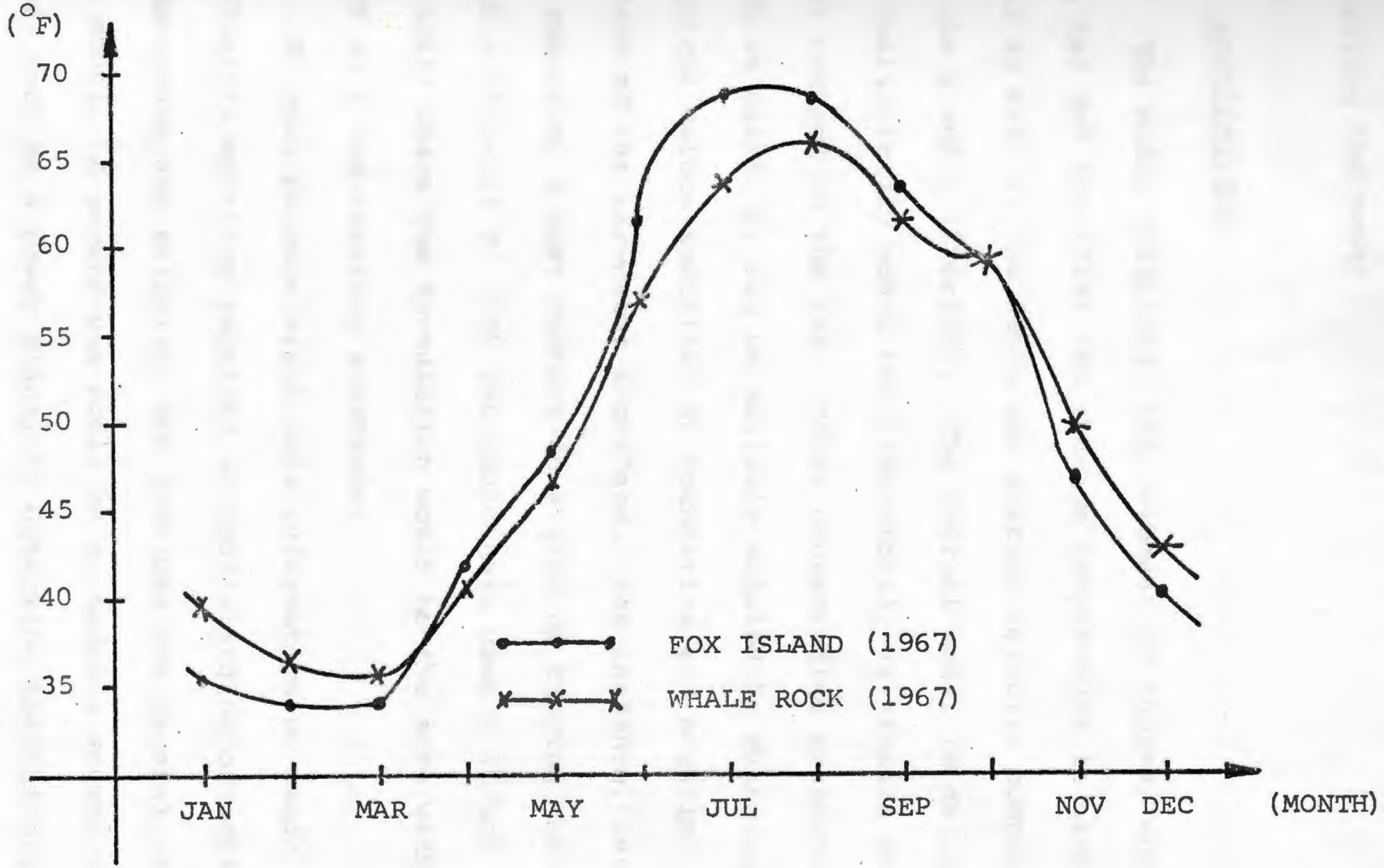


FIGURE 1.5. SURFACE WATER TEMPERATURES AT FOX ISLAND AND WHALE ROCK, 1967, (46)

verifying the model.

C. APPLICATIONS

The model calculates the movement of thermal energy in the bay and specifies the average temperature in each grid as well as the depth and average velocity components in the x and y direction. The thermal model is designed to realistically model two dimensional, vertically averaged heat content in the bay. Other conservative properties, such as salinity, can be suitably modeled by changing physical values specified at boundaries and negating the effect of the air-water interface. For instance, instead of specifing a heat content in a grid by tagging the grid with a value of T, (^{o}C) you could have used S (^{o}/oo) for salinity where the formulation would be the same with regard to a non-reacting substance.

To what purpose might this information be used? Biological modeling requires an understanding of ambient temperature and salinity, and provides one general use of the model. A second use would be to model a source of heat, such as a power plant, to determine thermal structure around an outfall area. An analysis of re-entrainment of heated effluent would be a valuable aid in determining desirable site locations from both a power plant operation and biological viewpoint.

One of the important physical parameters of the bay that determines the mixing of heat is the dispersive term. This dispersive term has a dispersion coefficient that can be varied to simulate various bay conditions. Since most biologists are interested in mixing patterns in the aquatic environment the thermal model and its dispersion coefficient effects would be enlightening for large scale effects.

D. APPROACH

Kurt Hess (4) has adapted Leendertse's (1) [pronounced: lee an der' see] two-dimensional, depth averaged model to simulate hydrodynamics of bay. The hydrodynamic model is a computer program that formulates the fluid equations of linear momentum and continuity into a usable finite difference scheme applicable for use on a high speed computer.

The fundamental equations of motion and energy can be formulated into a general finite difference scheme. The specific technique for arranging spatial and time variables are many in number. Anyone is free to choose a method that he feels will work satisfactorily, but the burden of proof is on him. Grimsrud (6) conducted an investigation of various methods as well as this author to see if better methods were available for modeling Narragansett Bay. A general summary for hydrodynamic, non-reacting concentration models is presented in Table 1.4.

Masch et al (57) have followed an approach similar to Leendertse (3) with a slightly different spatial arrangement for grid depth specification. The governing equations are explicitly formulated using forward difference substitutions for the partial derivatives in the time varying concentration-salinity model.

Pritchard (5, Chapter II) develops the equations for a three dimensional dynamic concentration model for an estuary, which includes isobaric slope for the pressure force term. The equations of linear momentum, continuity, salt and energy when applied with phenomenological relations can only be solved by an interative numerical approach given reasonable spatial distributions of velocity, energy and salt. Hess (59) is developing a three dimensional time averaged model that uses tidally averaged values from the two dimensional vertically averaged hydraulic model. This model has six levels that are equally spaced for all grid depth specifications to determine vertical structure.

MODEL CHARACTERISTICS	MASCH ET AL (57)	PRITCHARD (5)	LEENDERTSE (3)
Assumptions	Uniformly vertically mixed water conditions	Vertically averaged with relative pressure surface slope and cross product of turbulent velocity fluctuation	Vertically averaged components using distribution functions for vertical column
Application	Estuary-fresh and tidal inlets	Estuary-fresh and tidal inlets	Estuary-fresh and tidal inlets
Influence	Wind included	Wind included	Wind included
Time Scale	Long Term Lasting Effect	Short or Long Term	Short or Long Term
Comments	Steady state and time varying salinity capability, 300 grid, prototype available for verification	No application presented	Jamaica Bay, 2000 Grids

TABLE 1.4.a. HYDRODYNAMIC CONCENTRATION MODELS

MODEL CHARACTERISTICS	MASCH ET AL (57)	PRITCHARD (5)	LEENDERTSE (3)
Boundary Condition	Reflective boundary condition for zero concentration gradient at fixed boundary	Not Applicable	Computational scheme formulates grids next to land as boundary value for row or column
Computer Time	2 min./tidal cycle	Not Applicable	30 min./tidal cycle
Dispersion Coefficient	2,500 ft^2/sec (Very High)	Realistic (5-40 ft^2/sec)	Realistic (5-40 ft^2/sec)
Verification Error Magnitude	2-3 ppt, 10-20% tidal estimation	Not Applicable	1-2°C, 10% tidal estimation

TABLE 1.4.b. HYDRODYNAMIC CONCENTRATION MODELS

Taking a more conservative approach, Pritchard, reduced the three dimensional problem to a two dimensional vertically averaged model that calculates the horizontal velocity components and a time varying slope.

The conservation of dissolved constituent equation is presented and interfaced in development of a solution technique.

The two dimensional formulations are similar to equations used by Leendertse (3) and by Masch et al (57) with two significant differences. The first variance is the inclusion of the slope term for the pressure surfaces due to horizontal variation in density (salinity). The second is the ensemble average of the turbulent velocity fluctuations time averaged for the squared velocity components, $(u')^2$ in x and $(v')^2$ in y direction, and also their cross product (u'v'). According to Pritchard, the inclusion of these terms will improve model accuracy for a velocity field with a predominant sign.

Since Leedertse (3) had proven workability of a two-dimensional, depth averaged water quality model with realistic dispersion, it was decided to convert this into a thermal model that required the hydrodynamic input currently available. This coordination between hydrodynamic and thermal models greatly facilitated implementation and eventually led to improvements in boundary condition formulation for the hydrodynamic model.

If a pioneering effort had been undertaken in the development of a different hydrodynamic-thermal model formulations it would have taken considerably more time and effort just to prove feasibility, not to mention prediction ability. One of the major problems in model development is turn around time of one day and slow computational speed of the present computer system at the University of Rhode Island.

It should be made quite clear that the depth averaged model does have limitations if one is very concerned with near field buoyant plumes. The physical dimensions of the bay necessitated a large grid size of about 1000 yards which, in general, makes the input box the entire near field. Yet, with temperature rises of several degrees around the source one would expect stratification in the surrounding grids. This stratification is mixed into the entire depth and the grid displays the average temperature required by the total heat content in the box for any tidal condition.

E. VERIFICATION

As previously mentioned, the year 1957 was chosen for verification purposes. The model will be run under identical meterological and boundary conditions for an initial constant temperature field of 21°C during the period of verification. In most instances, the data was taken at isolated points either at or near surface water at various times during the day. Keeping this in mind, grid temperature discrepancies between the data points are to be expected, but spatial agreements should be reasonable.

Ideally, a dozen continuous temperature recorders could be dispersed around the bay to measure both vertical and horizontal temperature distributions to verify validity of model beyond question.

F. CONCLUDING REMARKS

The lengthy discourse on the temperature data for Narragansett Bay provides information for future development of model predictive ability.

The work presented in the following sections will elaborate on the various inputs of model development and implementation. The power plant site was chosen at Rome Point because it appears to be a reasonable first choice even though the proposed atomic plant seems doubtful at this time. The experimental runs for the various boundary conditions and siting variables are an outline of the procedure to be followed in making an environmental impact judgement. A comprehensive investigation of power plant siting throughout the bay is beyond the scope of this work. Other applications of the model, such as the salt modeling or biological studies are discussed, but no computer modeling was attempted.

In summary, the thermal model is a very valuable tool that allows the engineer to graphically display natural, natural plus man made and man made temperature fields to serve some useful estuarine requirement. The thermal model, in essence, provides the spatial arrangement of water temperatures subject to boundary conditions and source inputs.

II. MODEL DEVELOPMENT

A. INTRODUCTION

Any modeling procedure is derived from the fundamental equations of nature combined with the pertinent phenomenological relations. The basic differential equations (Bird, 27) to be considered for a Newtonain fluid are as follows:

Momentum x:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{ox} + fv + \frac{1}{\rho}\left(\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right) \qquad (2.1)$$

Momentum y:

$$\frac{\partial v}{ot} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - fu + \frac{1}{\rho}\left(\frac{\partial \tau_{yx}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{yz}}{\partial x}\right) \qquad (2.2)$$

Momentum z:

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial W}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z} - g + \frac{1}{\rho}\left(\frac{\partial \tau_{zx}}{\partial x} + \frac{\partial \tau_{zy}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right) \qquad (2.3)$$

where

f - Coriolis parameter, $2\Omega\sin\phi$

τ_{ij} - shear stress tensor,

g - gravitational acceleration, ft^2/sec

ρ - density of fluid, lb_m/ft^3

Conservation of mass (ρ = constant):

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \qquad (2.4)$$

where

$u(x,y,z,t)$ = velocity in the x direction

$v(x,y,z,t)$ = velocity in the y direction

$w(x,y,z,t)$ = velocity in the z direction

$p(x,y,z,t)$ = pressure

Concentration or energy equation:

$$\rho c_p \left(\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} + w\frac{\partial c}{\partial z}\right) - \frac{\partial}{\partial x}\left(e_x \frac{\partial c}{\partial x}\right)$$

$$- \frac{\partial}{\partial y}\left(e_y \frac{\partial c}{\partial y}\right) - \frac{\partial}{\partial z}\left(e_z \frac{\partial c}{\partial z}\right) = S(x,y,z,t) + \text{Dissipation Terms} \qquad (2.5)$$

where

c_p - specific heat of water in Btu/lb_m-°F

e_i - the diffusion tensor - molecular and viscous

$S(x,y,z,t)$ - source term in Btu/ft^3-sec

c - non-reacting substance

In this thesis, the dissipation terms are neglected.

At present (2) computational techniques are inadequate to deal with three dimensional fluid flow problems. The approach here is to reduce the equations to a two dimensional system by vertically averaging the u, v, and c components of the fundamental equations. This is shown in Equation 2.6, in symbolic form

$$\left\langle \begin{matrix} U \\ V \\ C \end{matrix} \right\rangle = \frac{1}{h + \eta} \int_{-h}^{\eta} \left\langle \begin{matrix} u \\ v \\ c \end{matrix} \right\rangle dz \qquad (2.6)$$

where η, surface elevation, and h, bottom depth, are shown in Figure 2.1. In general, these variables have a distinct vertical distribution. For example,

$$u = U\,[1 + E_u(z)] \qquad (2.7a)$$

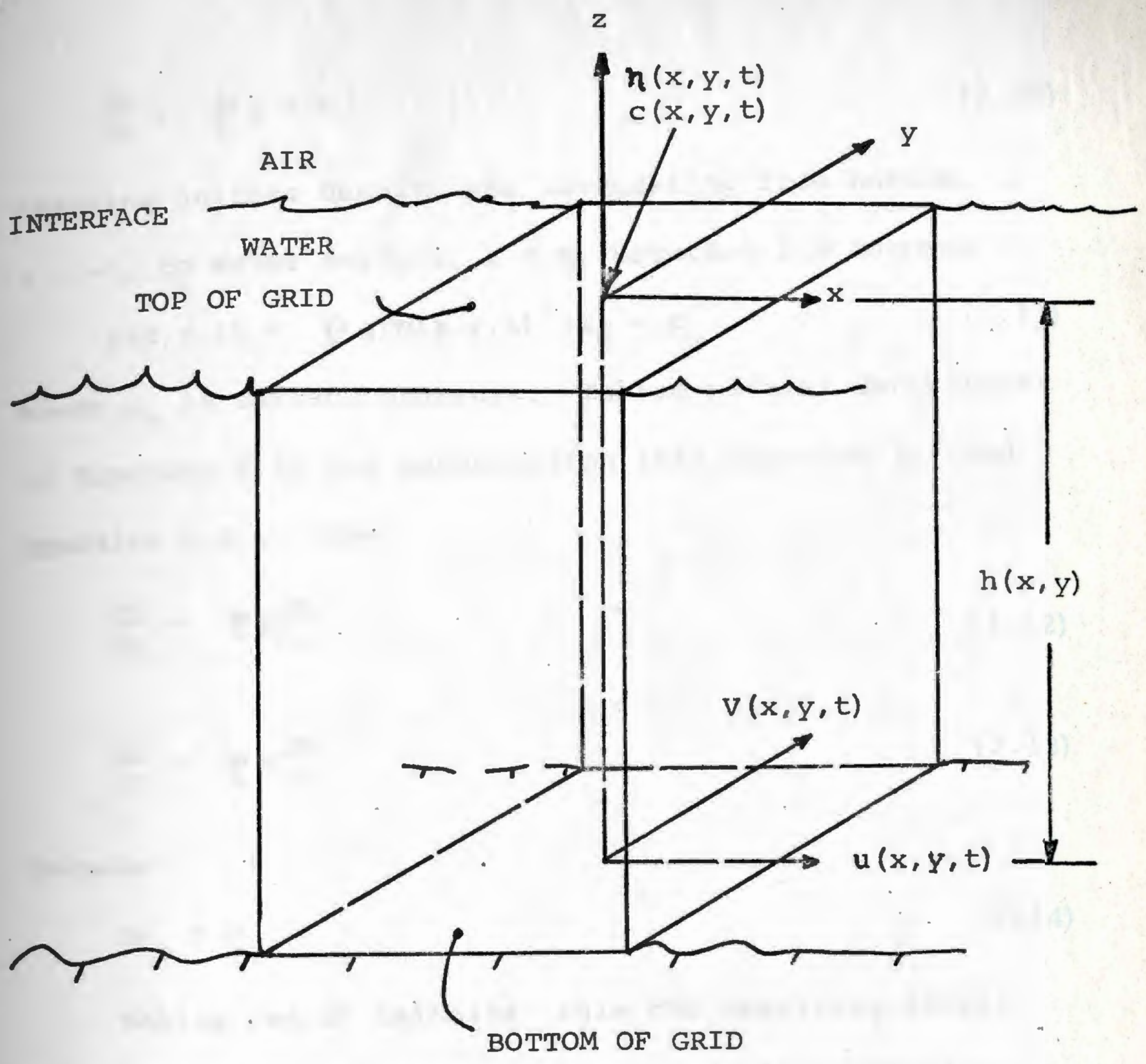
$$v = V\,[1 + E_v(z)] \qquad (2.7b)$$

where E_u and E_v are distribution coefficients.

In order to simplify equations 2.1 to 2.3, we make two general assumptions. First, that the magnitude of the vertical velocity is much less than the magnitude of horizontal velocity components. Secondly, that the partial derivatives, $\partial/\partial x$ and $\partial/\partial y$ are much less than the vertical term, $\partial/\partial z$. These assumptions reduce equations 2.1 to 2.3 as follows:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + fv + \frac{1}{\rho}\frac{\partial \tau_{xz}}{\partial z} \qquad (2.8)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} - fu + \frac{1}{\rho}\frac{\partial \tau_{yz}}{\partial z} \qquad (2.9)$$



$h(x,y)$ - Average grid depth

$\eta(x,y,t)$ - Tidal variation in grid (plus or minus)

FIGURE 2.1. COORDINATE AND VARIABLE SCHEME FOR THE MODEL

$$\frac{\partial p}{\partial z} + \rho g = 0 \tag{2.10}$$

Assuming uniform density and integrating from bottom, $z = -h$, to water surface, $z = \eta$, Equation 2.9 becomes

$$p(x,y,t) = \rho g[\eta(x,y,t) - z] + p_o \tag{2.11}$$

where p_o is surface pressure. Taking partial derivatives of Equation 2.10 for substitution into Equation 2.7 and Equation 2.8 we have

$$\frac{\partial p}{\partial x} = \rho g \frac{\partial \eta}{\partial x} \tag{2.12}$$

$$\frac{\partial p}{\partial y} = \rho g \frac{\partial \eta}{\partial y} \tag{2.13}$$

because

$$Dp_o = 0 \tag{2.14}$$

Making use of Leibnitz' rule the resulting simplification shown by Grimsrud (6) gives us the hydraulic equations in the following form

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} = -g\frac{\partial \eta}{\partial x} + fV + \frac{1}{\rho\,(h+\eta)}\,(\tau_{sx} - \tau_{bx}) \tag{2.15}$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} = -g\frac{\partial \eta}{\partial y} - fU + \frac{1}{\rho\,(h+\eta)}\,(\tau_{sy} - \tau_{by}) \tag{2.16}$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial (HU)}{\partial x} + \frac{\partial (HV)}{\partial x} = 0 \qquad (2.17)$$

where

τ_{bi} - bottom shear stress

τ_{si} - surface shear stress

$H = h + \eta$

with boundary condition

$$w(\eta) = u(\eta)\frac{\partial \eta}{\partial x} + v(\eta)\frac{\partial \eta}{\partial y} + \frac{\partial \eta}{\partial t} = \frac{D\eta}{Dt}$$

The bottom stresses in the x and y directions are approximated by the Chezy relationship of the form

$$\tau_{bx} = \rho g U \frac{(U^2 + V^2)^{1/2}}{C_z^{\;2}} \qquad (2.18)$$

$$\tau_{by} = \rho g V \frac{(U^2 + V^2)^{1/2}}{C_z^{\;2}} \qquad (2.19)$$

where C_z = Chezy coefficient $[(8g/\text{friction factor})^{1/2}]$ and is a function of bottom roughness and depth and calculated from

$$C_z = \frac{1.49}{N}(h + \eta)^{1/6} \qquad (2.20)$$

with N - Manning's formula, $(\text{len})^{1/6}$

The basic model equations now contain all the phenomenological relationships necessary for conversion to a finite difference scheme. Equation 2.5, as yet unmodified, is now time averaged to eleminate the turbulent fluctuations associated with the flow. We introduce, for a vertically averaged substance

$$C = \frac{1}{h} \int_{-h}^{h} c_a dz \qquad (2.21)$$

where

$$c_a(z) = C\,[1 + E_a(z)] \qquad (2.22)$$

and E_a is the density distribution function.

Bearing definitions 2.21 and 2.22 in mind we have

$$\int_{-h}^{h} E_a(z)\,ds = 0 \qquad (2.23)$$

which actually defines the density distribution function.

Vertical integration of Equation 2.5 and use of Leibnitz' rule in conjunction with Equations 2.21 and 2.22 we have:

$$\frac{\partial HC}{\partial t} + \frac{\partial [\left\langle 1+E_u(z)\,E_a(z)\right\rangle\ UC]}{\partial x} + \frac{\partial [\left\langle 1+E_v(z)\,E_a(z)\right\rangle\ VC]}{\partial y}$$

$$= \frac{\partial \left\langle e_x \frac{\partial c_a}{\partial x}\right\rangle}{\partial x} + \frac{\partial \left\langle e_y \frac{\partial c_a}{\partial y}\right\rangle}{\partial y} + \frac{\partial \left\langle e_z \frac{\partial c_a}{\partial z}\right\rangle}{\partial z} + HS \qquad (2.24)$$

Assuming that Narragansett Bay is well mixed imposes the condition that no differences in mass concentrations exist over vertical structure.

$$E_a \cong 0 \tag{2.25}$$

Applying the above considerations to the model, Equation 2.24 reduces to

$$\frac{\partial HC}{\partial t} + \frac{\partial (HUC)}{\partial x} + \frac{\partial (HVC)}{\partial y} = \frac{\partial}{\partial x} (HD_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y} (HD_y \frac{\partial C}{\partial y}) + HS \tag{2.26}$$

where D_x and D_y are dispersion coefficients.

In order to develop relations to express adequately these dispersive terms a brief attempt will be made to investigate the mechanisms of dispersion.

B. DISPERSION

Dispersion of substances is caused by the mean flow velocity differences that occur in all directions. These variations of velocity, greater in the deeper portions and smaller in the shallow areas, cause stretching and spreading of substances in a non-homogenous fluid. Turbulent diffusion is primarily responsible for the cross-sectional spreading that tends to transfer constituents from the areas of higher concentration to those of lower concentration.

Considering one-dimensional steady flow the longitudinal dispersion coefficient found by Elder (28) is

$$D_l = 5.93\ Hu^* \qquad (2.27)$$

where u* - friction velocity (shear stress velocity)

The friction velocity is related to the mean velocity by the relation:

$$u^* = \left(\frac{{}_{bx}}{\rho}\right)^{1/2} = ug^{1/2}C_z^{-1} \qquad (2.28)$$

where τ_{bx} - bed shear due to u, the uniform flow velocity

Now combining Equations 2.27 and 2.28 results in

$$D_l = 5.93\ Hug^{1/2}C_z^{-1} \qquad (2.29)$$

For the lateral turbulent dispersion, perpendicular to the mean flow, Elder (28) obtained:

$$D_y = 0.23\ Hu^* \qquad (2.30)$$

Oddly enough, this formulation, designed specifically for river flow, underestimated the longitudnal dispersion for river flow. For the slowly time varying flow conditions such as Narragansett Bay it is considered in better agreement. In addition, the longitudinal dispersion is influenced by wind generated local circulation and wave action (Wilson & Masch, 29). Rather naturally, the lateral turbulent diffusion is affected by the same wind and wave processes.

Since the longitudinal dispersion coefficient is generally larger, except around a source term than the lateral coefficient, the dispersion is anisotropic. To make the model suitable for arbitrary direction and the influence of large scale substance variations from grid to grid, the general expression for dispersive transport becomes

$$\frac{\partial[(E_{xx}\frac{\partial c}{\partial x} + E_{xy}\frac{\partial c}{\partial y})H]}{\partial x} + \frac{\partial[(E_{yx}\frac{\partial c}{\partial y} + E_{yy}\frac{\partial c}{\partial x})H]}{\partial y} \qquad (2.31)$$

where the dispersion coefficients E_{xx}, E_{xy}, E_{yx} and E_{yy} are dependent on the current magnitude and direction. The relationship 2.31 more closely models the physical bay situation but requires four dispersion coefficients which are at least as difficult to determine as the two included in Equation 2.26. In addition the coupling of the longitudinal and lateral diffusion coefficient makes the computation cumbersome because it would couple the x and y conservation equations requiring at least twice the effort to solve substance distribution. Realizing the computational limitations of available computer this approach was deemed unacceptable.

A possible alternate approach by Holley (30) is to compare magnitudes of mass transport by longitudinal dispersion versus advective transport. Since the ratio of dispersion over advection is generally very small, except around outfall areas where steep gradients do exist, the general procedure is to assume that variations in the longitudinal dispersion will not affect the solution. The net result of the above discussion is to assume that the process is isentropic in the sense that there is uncoupled lateral and longitudinal dispersion which are independent functions of velocity, Chezy coefficient and depth in one coordinate direction.

Finally, after all various alternatives were evaluated, the formulation in Equation 2.29 was considered the best choice and is currently being used in the model.

This concludes the introduction of basic differential equations with phenomenological relations as shown below, as the basic equation set for the forthcoming finite difference formulation.

$$\frac{\partial U}{\partial t} + u\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV + g\frac{\partial \eta}{\partial x} + g\frac{U(U^2 + V^2)^{1/2}}{C_z^{\,2} H} = 0 \qquad (2.32)$$

$$\frac{\partial V}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial V}{\partial y} + fU + g\frac{\partial \eta}{\partial x} + g\frac{V(U^2 + V^2)^{1/2}}{C_z^{\,2} H} = 0 \qquad (2.33)$$

$$\frac{\partial \eta}{\partial t} + \frac{\partial HU}{\partial x} + \frac{\partial (HV)}{\partial y} = 0 \qquad (2.34)$$

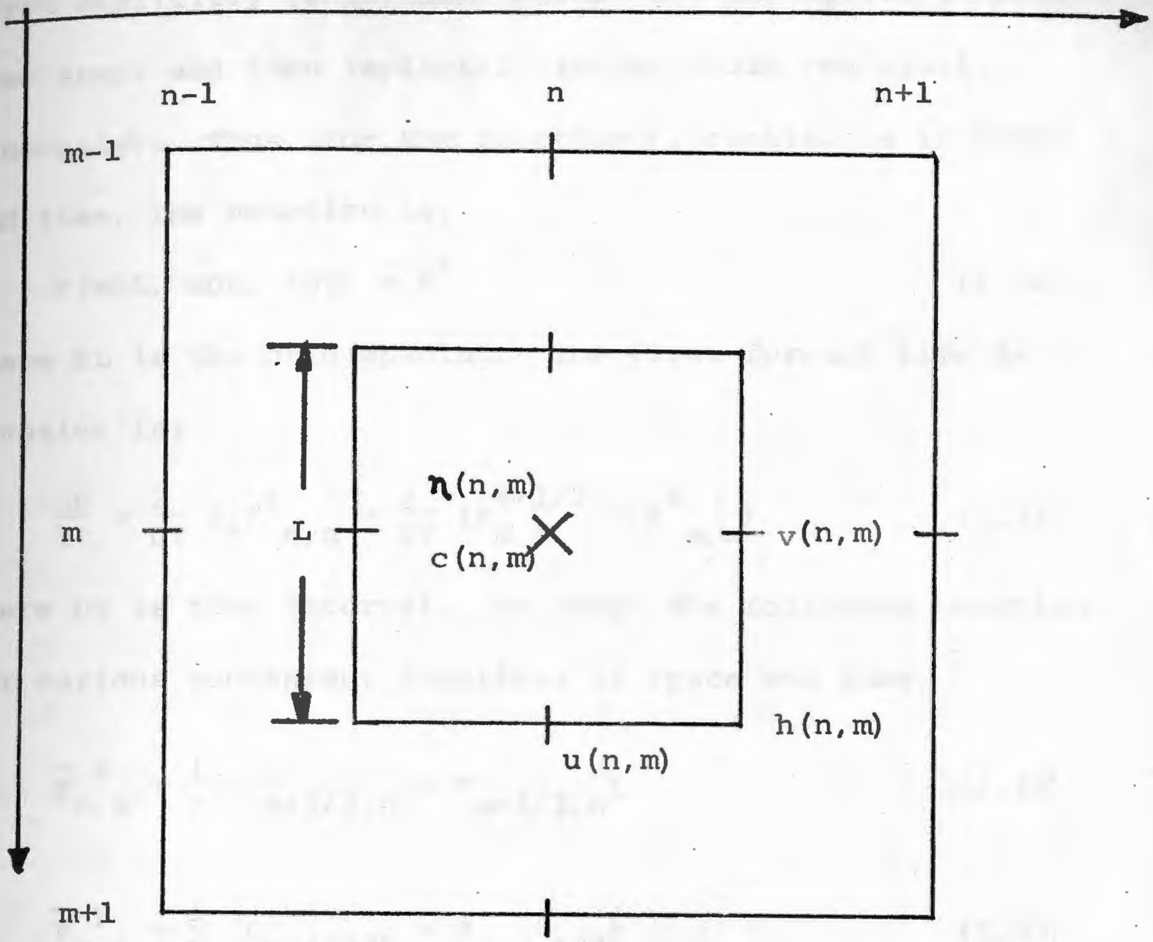
$$\frac{\partial (HC)}{\partial t} + \frac{\partial (HUC)}{\partial x} + \frac{\partial (HVC)}{\partial y} = \frac{\partial}{\partial x}\left(5.93\ HUg^{1/2}C_z^{\,-1}\right) + \frac{\partial}{\partial y}\left(5.93\ HUg^{1/2}C_z^{\,-1}\right) + S \qquad (2.35)$$

C. FINITE DIFFERENCE APPROXIMATIONS

For the solution of the Equations 2.32 to 2.35 the approach of Leendertse (1) will be followed. In this scheme, the variables η, c, v, u, h are arranged, with general coordinate system explanation, as shown in Figure 2.2.

This scheme has the advantage that for the variable operated upon in time there is a centrally located spatial derivative for the linear term. In the x-momentum Equation 2.32, the time-derivative of water level ($g \frac{\partial \eta}{\partial x}$) is an example of this.

In accordance with the semi-implicit method the time-step is split into two halves, and the time-derivative taken over the half time-step. Semi-implicit means solving



$$x_c = (m-\tfrac{1}{2})\,L/2$$

$$y_c = (n-\tfrac{1}{2})\,L/2$$

$$\eta_{m,n} = \eta(x_c,\ y_c)$$

$$U_{m,n} = u(x_c + L/2,\ y_c)$$

$$V_{m,n} = v(x_c,\ y_c + L/2)$$

$$h_{m,n} = h(x_c + L/2,\ y_c + L/2)$$

$$c_{m,n} = c(x_c,\ y_c)$$

FIGURE 2.2. SPACE STAGGERED GRID SYSTEM

first explicitly (individual values are calculated at next time step) and then implicitly (solve whole row simultaneously). Thus, for the function F, continuous in space and time, the notation is:

$$F(mDL,\ nDL,\ tDT) = F^{t} \qquad (2.36)$$

where DL is the grid spacing. The first forward time derivative is:

$$\frac{\partial F}{\partial t} = \frac{2}{DT}\,\delta_t F^{t}_{m,n} = \frac{2}{DT}\left(F^{t+1/2}_{m,n} - F^{t}_{m,n}\right) \qquad (2.37)$$

where DT is time interval. We adopt the following notation for various convenient functions of space and time:

$$\bar{F}^{x}_{m,n} = \frac{1}{2}\left(F_{m+1/2,n} + F_{m-1/2,n}\right) \qquad (2.38)$$

$$\bar{F}^{y}_{m,n} = \frac{1}{2}\left(F_{m,n+1/2} + F_{m,n-1/2}\right) \qquad (2.39)$$

$$\delta_x F_{m,n} = \left(F_{m+1/2,n} - F_{m-1/2,n}\right) \qquad (2.40)$$

$$\delta_y F_{m,n} = \left(F_{m,n+1/2} - F_{m,n-1/2}\right) \qquad (2.41)$$

$$\delta_x {}^{*}F_{m,n} = \frac{1}{2}\left(F_{m+1,n} - F_{m,n-1}\right) \qquad (2.42)$$

$$\delta_y {}^{*}F_{m,n} = \frac{1}{2}\left(F_{m,n+1} - F_{m,n-1}\right) \qquad (2.43)$$

$$\bar{\bar{F}}_{m,n} = \frac{1}{4}\left(F_{m+1/2,n+1/2} + F_{m-1/2,n+1/2} + F_{m+1/2,n-1/2} + F_{m-1/2,n-1/2}\right) \qquad (2.44)$$

The momentum and conservation of mass equations may then be transformed into finite-difference equations and solved for the new value in time for a total of eight equations, four for each time step. The equations are given in Appendix B and D.

The solution of Equations B.1 to B.6 (Appendix B and D) is called by Leendertse a "multi-operation" method, which is a modification of the "leap-frog" method. In the first half time-step, values of U and η are computed implicitly along a grid row in the x-direction at the time (t+1/2) DT. Then V is computed at the same time level explicitly. In the second half time-step, V and n are computed implicitly at (t+1) DT along grid rows in the y-direction, after which U is calculated explicitly at (t+1) DT.

In the first half of the time-step, the time derivative of U in the x-momentum equation is approximated by a backward difference:

$$\frac{\partial}{\partial t}(U^{t+1/2}) = \frac{2}{DT}(U^{t+1/2}-U^{t}) = \text{fcn }(\eta^{t+1/2}) \qquad (2.45)$$

In the second half time-step, a forward difference is used:

$$\frac{\partial}{\partial t}(U^{t+1}) = \frac{2}{DT}(U^{t+1} - U^{t+1/2}) = \text{fcn }(\eta^{t+1/2}) \qquad (2.46)$$

Thus, over a full time-step, the time derivative is a central difference with respect to the water level:

$$\frac{\partial U}{\partial t} = \frac{U^{t+1} - U^{t}}{DT} = \text{fcn } (\eta^{t+1/2}) \qquad (2.47)$$

This composite relation defines the leap-frog method.

The set of difference equations for the implicit time-step on U and η may be written as

$$[A] \; (U^{t+1/2} \text{ or } \eta^{t+1/2}) = (b) \qquad (2.48)$$

where [A] is a tridiagonal matrix and (b) is a column vector of known terms. Equation 2.48 may then be solved by Gaussian elimination (see Mitchell (24) for example) for the new values of U and η at (t+1/2). A similar procedure is used for the second implicit operation involving V and η at time (t+1). The details are given in (Hess (4), Appendix B and C).

D. DIFFERENCING COMMENTS

D.1. Stability

An extensive analytical treatment of stability has been given by Leendertse (1, 2) with further comments by Grimsrud (6), Hess (4), and Spaulding (16). Whenever a problem in the physical values produced by a computational scheme occurs by a model user the word 'stability' is generally used. Instability may be defined as the unlimited amplifications of errors. This can occur because of the dissimilar nature of upstream or central differencing or the simplified unidimensional dispersion coefficient used with a source with significant temperature gradients.

D.2. Boundary Conditions

In Figure 2.3, the general boundary conditions format is outlined for the model. Hess (4) summarized the difficulty encountered by Leendertse (1) when handling the spatial derivaties, Equations 2.41 and 2.42. Briefly stated, the convective terms encountered at land boundaries are dropped in the solution of the momentum equation. This effect causes an inaccuracy in the hydraulic model and will create computational problems for a source term with a low dispersion coefficient if the substance varies significantly from grid to grid. Some model users adhere to the policy that the upstream differencing technique (Appendix E), which enhances the dispersion coefficient a thousand fold in the model, should be used. In essence, the model creates far field conditions for a dispersed substance in what is considered the intermediate zone.

A technique that might be used (Spaulding, 16) is an upstream differencing technique around a source and conver-

LOCATION	VARIABLE	MODEL INPUT
Source (Power Plant)	Flow Rate (Fixed) * Temperature Difference Through Plant	Velocity*Concentration
	YDS^3/SEC	(YDS/SEC) - °C
Rivers	Flow Rate (Fixed)	Velocity*Concentration at Boundary
	YDS^3/SEC	(YDS/SEC) - °C
Mt. Hope Bay	Tidal Flow Rate (Variable)	Velocity*Concentration at Boundary
	YDS^3/SEC	(YDS/SEC) - °C
Rhode Island Sound	Tidal Height (Variable)	Velocity*Concentration at Boundary
	YDS	(YDS/SEC) - °C

FIGURE 2.3. BOUNDARY CONDITIONS

sion to a central differencing scheme (see Appendix E) at some specified distance from source discontinuity. This author prefers, if necessary, to use a formulation suggested by Kurt Hess that would naturally enhance dispersion coefficient for large discontinuities of concentration in the model near a source. This is then an alternative to arbitrarily increasing the dispersion coefficient in the upstream differencing technique, for the entire bay, as shown below.

$$D_{m+1/2} = D[1 + \frac{(C_{m+1} - C_m)^2}{(C_{m+1} + C_m)^2} E] \qquad (2.49)$$

$$D_{m-1/2} = D[1 + \frac{(C_m - C_{m-1})^2}{(C_m + C_{m-1})^2} E] \qquad (2.50)$$

where

D - is the normal model dispersion coefficient

E - arbitrary constant of order one.

This means that the centered spacial derivative can be used when the adjacent concentrations are different without having computational problems for suitable values of E. This technique was not used here.

D.3. Computational Differences for Central and Upstream Differencing

An explanation of the computational problems with regard to upstream and central differencing is now necessary. According to Leendertse (2), certain difficulties are encountered upstream from sources with respect to the convective term. Consider Figure 2.4, and the case of a centered spatial derivative ($A = B = 1/2$). Suppose the concentration at $m+1$ is unity, and zero elsewhere. Applying the finite-difference equation at M leads to a decrease

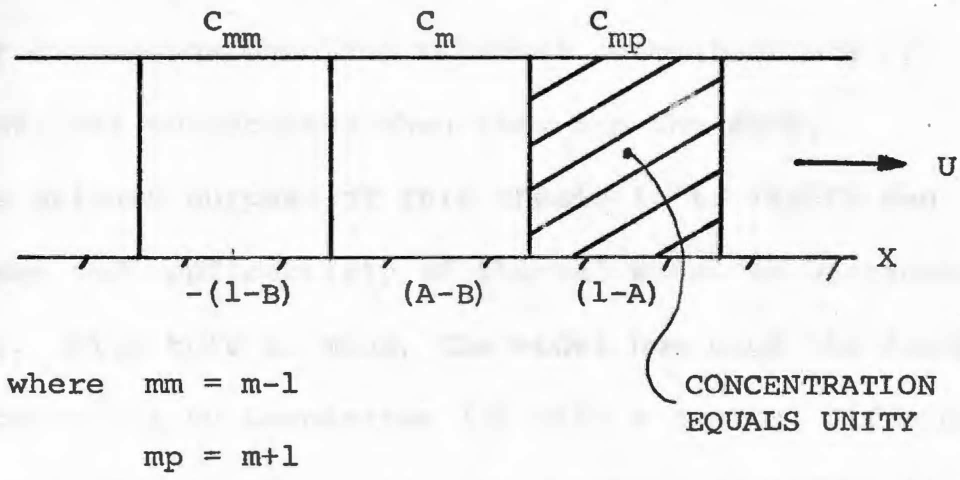


FIGURE 2.4. ONE DIMENSIONAL CONCENTRATION SCHEME

in concentration C_m. The remedy is to use upstream differencing (B = 0, A = 1) at grid m (or B = 1, A = 0 if $u <$ 0) so that concentration at m will then remain zero.

A few calculations will show that if upstream differencing is used only at m, mass will not be conserved elsewhere. Therefore, for consistency, upstream differencing would have to be used everywhere. However, as shown by Leendertse (1, p. 34), this approximation results in an effective increase in the dispersion coefficient.

One possible alternative is to use the centered spatial derivative, and increase the dispersion coefficient artificially as shown before in Equation 2.49, which allows a higher dispersion when the adjacent concentrations are different, but no increase when they are the same.

The primary purpose of this thesis is to verify the techniques and applicability of thermal model to Narragansett Bay. With this in mind, the model now uses the formulation conceived by Leendertse (3) with a central differencing scheme. The final decision on whether adjustment in the present dispersion coefficient, using for instance Equation 2.49, will occur after an evaluation of the results.

III. TEMPERATURE AND AIR WATER INTERFACE BOUNDARY CONDITIONS AND VERIFICATION DATA RELATIONSHIPS

A. AIR WATER INTERFACE-SURFACE HEAT TRANSFER PROCESSES

The literature, (5, 9, 11, 12, 15, 17, 25), has treated the heat transfer rate at air-water interface as a formulation of a net heat flux equation which is composed of specific transfer terms by distinguishing air, water and air-water terms.

Figure 3.1 shows the term by term formulation of the heat transfer processes which control the water temperature at the air-water interface. Figure 3.2 shows general temperature, pressure and velocity profiles expected at the interface.

The general continuity equation for the interface is:

$$\frac{\partial}{\partial t}(m_{cv}) = \int dw_{in} - \int dw_{out} \tag{3.1}$$

where

t - time

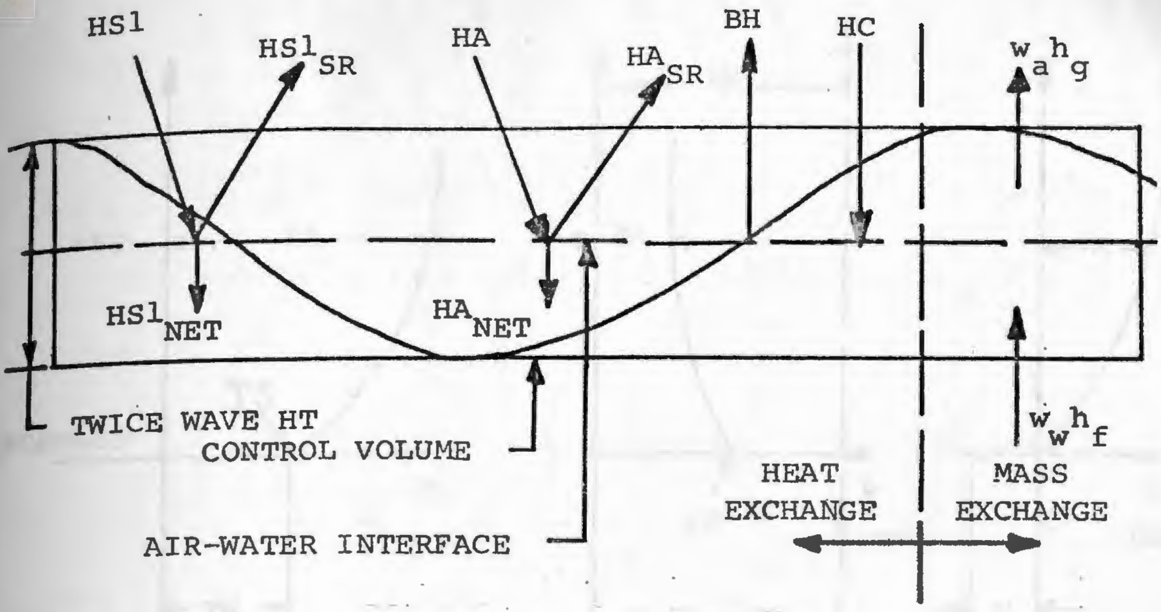
cv - refers to the control volume in Figure 3.1

Since the volume of the control volume is assumed small

$$m_{cv} \cong 0 \tag{3.2}$$

Equation (3.1) becomes (see Figure 3.1)

$$0 = w_w - w_a \tag{3.3}$$



HS1 - incident solar radiation heat transfer rate (HTR)

$HS1_{SR}$ - reflected solar radiation HTR

$HS1_{NET} = HS1 - HS1_{SR}$

HA - incident atmospheric radiation HTR

HA_{SR} - reflected atmospheric radiation HTR

$HA_{NET} = HA - HA_{SR}$

BH - back radiation HTR from surface

HC - conduction heat transfer rate from atmosphere side of interface conversion

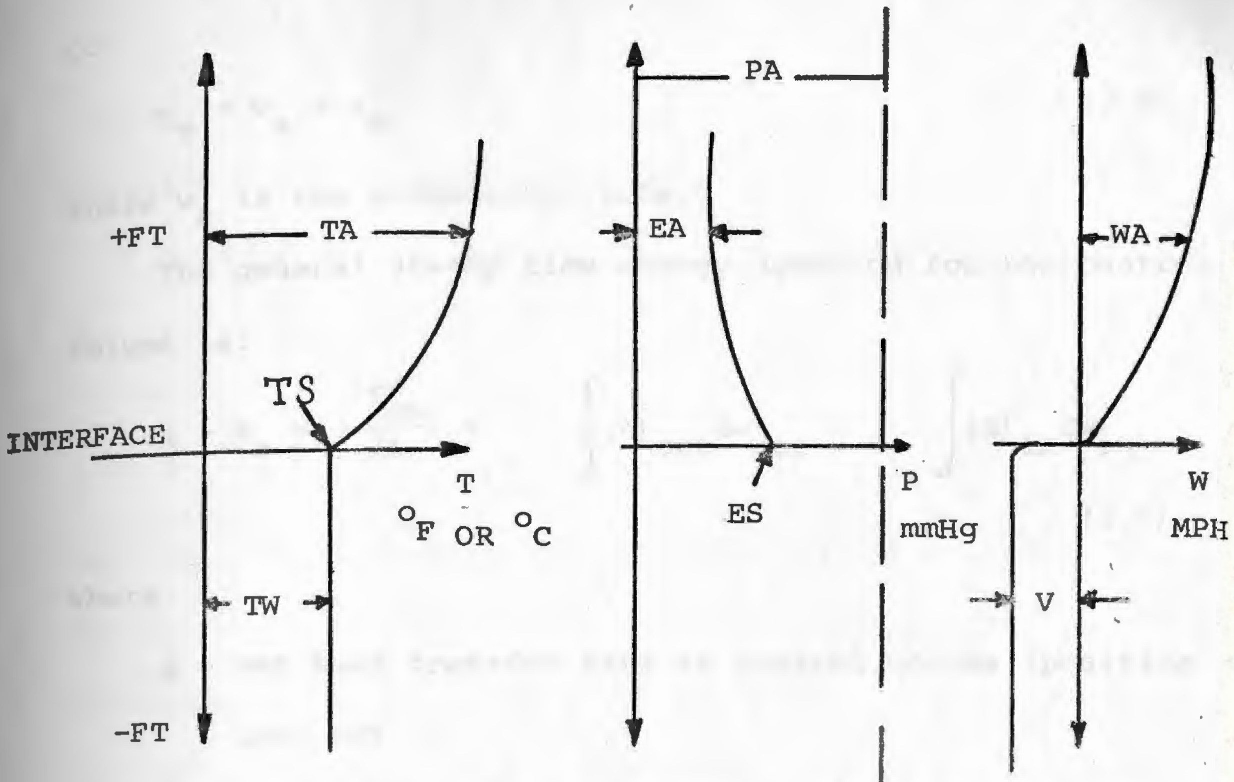
w_a - evaporation mass flow rate, atmosphere side of interface

w_w - evaporation mass flow rate, water side of interface

h_f - enthalpy, saturated liquid state

h_g - enthalpy, saturated vapor state

FIGURE 3.1. SCHEMATIC, SURFACE HEAT TRANSFER PROCESS PER UNIT AREA



TA - temperature of air

TS - temperature surface water

TW = TS - water temperature, constant for depth of grid

EA - air vapor pressure, function relative humidity, TA

ES - saturated vapor pressure, function of TW

PA-atmospheric pressure

WA - wind velocity in MPH

V - water velocity constant for depth of grid, assumed independent of wind velocity

FIGURE 3.2. TEMPERATURE, PRESSURE AND VELOCITY PROFILES NEAR INTERFACE

or

$$w_w = w_a = w_e \tag{3.4}$$

where w_e is the evaporation rate.

The general steady flow energy equation for the control volume is:

$$q - P_x = \left(\frac{\partial E_{cv}}{\partial t}\right) + \int (A)_{out} dw_{out} - \int (A)_{in} dw_{in} \tag{3.5}$$

where

q - net heat transfer rate to control volume (positive into cv)

P_x - net shaft power to control volume (power to external elements from cv positive)

E - energy inside control volume

$A = (h + \frac{V^2}{g} + gz)$

h - enthalpy

V - velocity

g - acceleration of gravity

z - height in gravitational field above arbitrary level

Since mass in conserved, as shown in Equation 3.2,

$$E_{cv} \cong 0 \tag{3.6}$$

Also for conditions in Figure 3.1

$$P_x = 0 \tag{3.7a}$$

$$V = 0 \tag{3.7b}$$

$$z = 0 \tag{3.7c}$$

Equation 3.5 with substitution of 3.6, 3.7a, 3.7b, and 3.7c reduces to

$$q = w_e(h_g - h_f) \tag{3.8}$$

or

$$q = w_e\ h_{fg} \tag{3.9}$$

where h_{fg} is the latent heat of vaporization evaluated at the surface temperature, TS. Summing heat transfer rates for control volume in Figure 3.1, Equation 3.9 becomes:

$$HS1_{NET} + HA_{NET} - BH + HC + HTOT = w_e\ h_{fg} \tag{3.10}$$

where, by definition

$$HE = w_e h_{fg} \tag{3.11}$$

Equation 3.10 becomes

$$HS1_{NET} + HA_{NET} - BH + HC + HTOT - HE = 0 \tag{3.13}$$

or

$$-HTOT = HS1_{NET} + HA_{NET} - BH + HC - HE \tag{3.13}$$

Note that HE is considered an enthalpy flux and not a heat transfer rate. Reviewing sign convention, we see that if the right hand side (RHS) of Equation 3.13 is positive, HTOT is <u>negative</u> and the heat transfer across the interface is <u>to</u> the water below the interface. If the RHS of

Equation 3.13 is negative, HTOT is positive and the heat transfer across the interface is <u>from</u> the water below the interface.

A common formulation found in the literature (Edinger and Geyer, 12) is the grouping of water independent heat exchange rates for solar and atmospheric radiation as shown

$$HR = HS1_{NET} + HA_{NET} \tag{3.14}$$

In order to be consistent with current usage of HC and HE having the same signs in the heat balance, the following change is made:

$$HC = -(-HC) \tag{3.15}$$

Finally, the equation used in the model is:

$$HTOT = HR - (BH + HC + HE) \tag{3.16}$$

In summary, the specific formulation of some of these quantified heat exchange rates into functions of model variables that are both physically complex and interrelated poses a challenge. Each net heat transfer rate, as described in the model, will be discussed with regard to literature formulations and current thinking.

B. INCIDENT SOLAR RADIATION HEAT TRANSFER RATE

When no solar radiation data is available, a common approach (Harleman, 15, 24) is to formulate the solar radiation heat transfer rate as a function of a solar constant, solar altitude, normalized radius of earth's orbit, atmospheric transmission coefficient, optical air mass and cloudiness. In Wonderlich (19) and List (20) equations for calculating these values can be found.

Fortunately for the Narragansett Bay area, Eppley Laboratory in Newport, Rhode Island have been taking continuous readings of net solar energy since the early 1950's. If no data is read in on an hourly basis the model requires the total solar input for that day or HS1. One can determine what hourly variations, HS2, there would be for clear sky conditions by using the following empirical equations derived from actual solar radiation plots throughout the year:

$$D = HS1(IDY)\ /(1.7+(HS1(IDY)-100.)/350.) \qquad (3.17a)$$

$$G = 2.\ PI\ (TIMEX-6.\ (1.\ +.2\ EXP(-3.\ (182.-ABS(DAY -182.))/182.))) \qquad (3.17b)$$

$$T = 24.\ (1.-.2\ COS(2.\ PI\ DAY/365)) \qquad (3.17c)$$

$$HS2(IDY)=D\ SIN(G/T) \qquad (3.17d)$$

$$HS1(IDY)=17.85\ HS2(IDY) \qquad (3.17e)$$

where

HS1(IDY) - total solar input for day IDY

TIMEX = initial starting time = 0 at 7 a.m.

DAY = IDY = Day of year, e.g., 14 July is DAY 195

PI = 3.1416

$17.85 = 0.2*24\frac{\text{hours}}{\text{day}}/0.27$

0.2 = Eppley Laboratory scale factor (can also be .1)

0.27 = conversion factor from Grm-Cal/cm^2 to Btu/ft^2

Since hourly solar data is read in, the final step of determining the affects of cloudiness on above formulation was not pursued. A simple procedure of taking total solar radiation for input day and determining hourly values on this basis and adding or subtracting a certain amount depending on the cloudiness factor for an hour versus average cloudiness factor for a day should bring results within 10-20% of the true value.

C. REFLECTED SOLAR RADIATION HEAT-TRANSFER RATE

The reflected solar radiation heat-transfer rate is usually calculated from the incident solar rate and a solar reflectivity, R_{sr}, defined as:

$$R_{sr} = \frac{HS1_{sr}}{HS1} \tag{3.18}$$

Typical data can be found in Anderson (21). R_{sr} can be estimated from the following empirical formula:

$$R_{sr} = a_1 \alpha^{b_1} \tag{3.19}$$

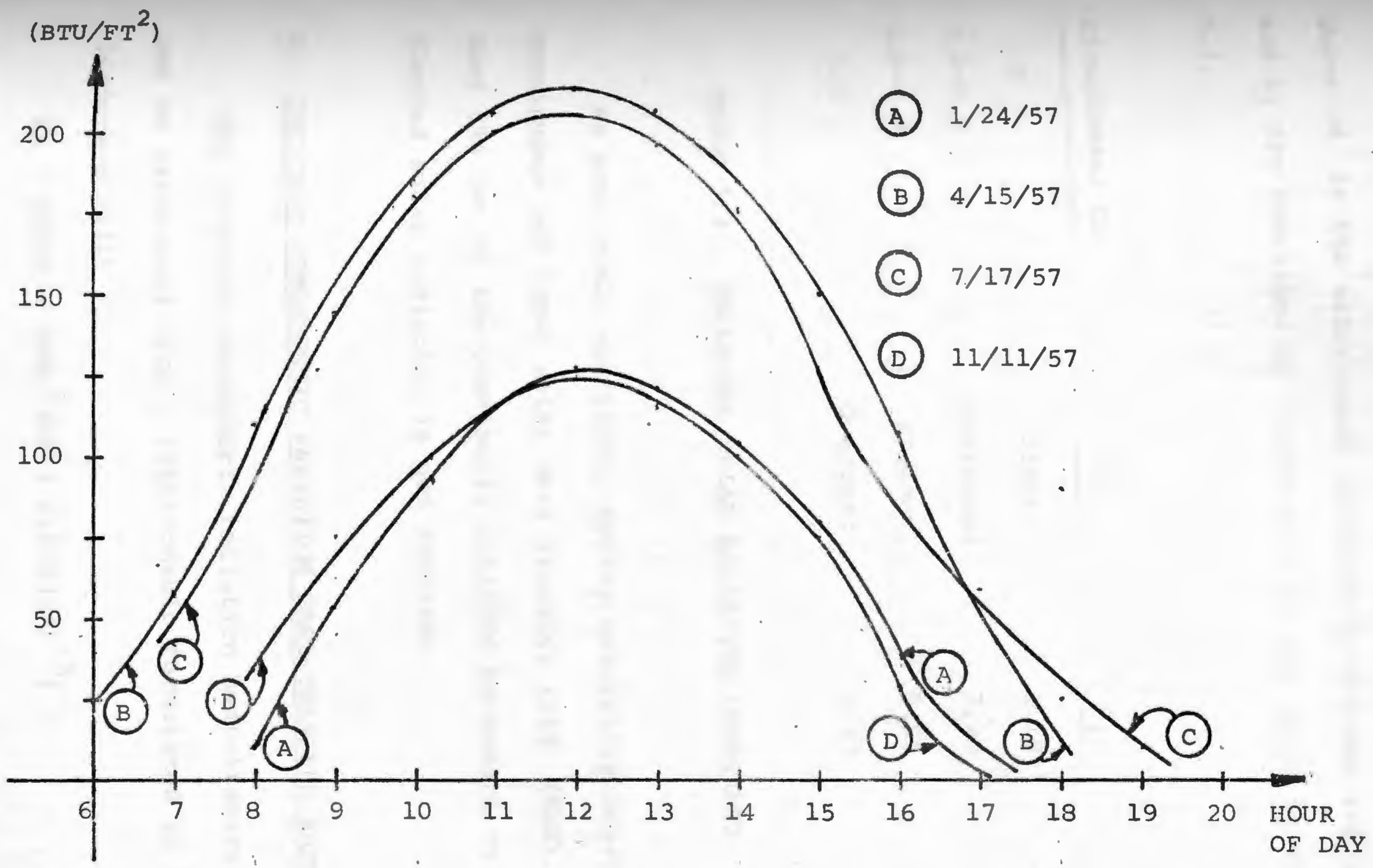


FIGURE 3.3. TYPICAL NET SOLAR RADIATION DATA FOR NARRAGANSETT BAY

where α is the solar (sun) altitude in degrees and a_1 and b_1 are functions of cloudiness, CL, and given in Table 3.1.

Cloudiness, CL	Sky	a_1	b_1
0	Clear	1.18	-0.77
0.1-0.5	Scattered	2.20	-0.97
0.6-0.9	Broken	0.95	-0.75
1.0	Overcast	0.35	-1.45

TABLE 3.1. REFLECTED SOLAR RADIATION CONSTANTS

As previously mentioned, Eppley Laboratory measures continuous net input solar heat transfer rate, (HS2), so that the use of the previously outlined procedure on reflected solar radiation is not required.

D. INCIDENT ATMOSPHERIC RADIATION HEAT-TRANSFER RATE

The incident atmospheric radiation heat-transfer rate may be calculated from a relationship formulated by Brunt (Anderson (21))

$$HA = SB(TA + 460)^4(CB + 0.031(EA)^{.5}) \qquad (3.20)$$

where

HA - $\mathrm{Btu/ft^2}$ - day

SB - Stefan-Boltzman constant, $4.15 * 10^{-8} \dfrac{\mathrm{Btu}}{\mathrm{ft^2\,day\,{}^oR^4}}$

TA - air temperature, ^{o}F, (measured six feet above surface)

EA - atmospheric vapor pressure, mmHg (measured six feet above surface)

CB - coefficient determined by air temperature and C' the ratio of the measured solar radiation to the clear sky solar radiation

CL is determined from the total daily solar radiation by integrating the solar radiation curve for a particular day from the pyreheliometer reading and dividing this value by the clear sky solar radiation. The values of TA and CL then determine CB as shown in Reference 12, Figure 2.5, page 26. The effect on HA can be seen in Reference 12, Figure 2.4, page 25.

The Brunt coefficient may be estimated from the following equation:

$$CB = .74 - \frac{3.5(96 - TA)^{1.67}}{10^{(4 + 3CL)}} \tag{3.21}$$

where

TA - temperature of air in ^{o}F

CL - cloudiness ratio

An alternate method, not used in the model for determining HA, from Swinbank (22) is:

$$HA = 1.2 * 10^{-13} (TA + 460)^{6} (1 + 0.17CL^{2}) \qquad (3.22)$$

If less accuracy is desired assume black body radiation in Equation 3.20 and let the second bracket equal 0.87 or emissivity constant.

E. REFLECTED ATMOSPHERIC RADIATION HEAT-TRANSFER RATE

The reflected atmospheric radiation heat-transfer rate is usually calculated from the incident atmospheric rate and an atmospheric reflectivity, R_{ar}, defined as:

$$R_{ar} = \frac{HA_{ar}}{HA} \qquad (3.23)$$

The value of R_{ar} is usually taken as 0.03 (Edinger and Geyer (12)). The result is:

$$HA_{NET} = HA - HA_{ar} = 0.97HA \qquad (3.24)$$

F. BACK RADIATION HEAT-TRANSFER RATE FROM WATER SURFACE

The back radiation heat-transfer from the water surface is calculated from black-body radiation with an emissivity of 0.97:

$$BH = EW \times SB(TW + 460)^{4} \qquad (3.25)$$

where

BH - Btu/ft^2 - day

EW - emissivity of water surface = 0.97

SB - Stefan-Boltzmann constant = $4.2 * 10^{-8} \frac{\text{Btu}}{\text{ft}^2 \text{day} {}^{\circ}\text{R}^4}$

TW - °F water temperature

G. AIR VAPOR PRESSURE, EA

EA is empirically determined by first finding partial pressure, PMM as follows:

$$PMM = A - B \cos (PI \ (((TA-30.)/70.)C+D)/180.) \quad (3.26)$$

and A, B, C, and D in mmHg are found in Table 3.2

TA(°F)	A	B	C	D
30.00-59.99	94.5	90.	54.5	2.5
60.00-79.99	94.5	90.	51.	14.
80.00-89.99	94.5	90.	61.	-3.0
90.00-100.00	99.5	100.	59.5	0.

TABLE 3.2. AIR VAPOR PRESSURE CONSTANTS

$$EA = (PMM - (((TA-30)/70.)3.5 + 1.))(RH-10.)/90.+((TA-30.)/70.)3.5+1. \quad (3.27)$$

where RH is relative humidity in percent.

H. SATURATED VAPOR PRESSURE (DUE POINT TEMPERATURE)

The vapor pressure, ES, is found from the simple empirical formula

$$ES = 99.0-96.0\cos(3.14(((TW-30.)/50.)33.+7.)/180.) \qquad (3.28)$$

I. EVAPORATION HEAT-TRANSFER RATE

The evaporation heat-transfer rate is calculated from:

$$HE = f(V)(ES - EA) \qquad (3.29)$$

where

$HE = \text{Btu/ft}^2 - \text{DAY}$

V - wind velocity measured at specific elevation above the water surface, MPH

f(V) - wind velocity function, energy/time-area-pressure

ES - vapor pressure at water surface temperature, TW

EA - vapor pressure measured at specific elevation above the water surface at air temperature TA

The wind velocity function f(V) is usually expressed as

$$f(V) = a_2 + b_2 V \qquad (3.30)$$

Table 3.3 presents typical values of a_2 and b_2.

Source	a_2 (Btu/day-ft^2-mmHg)	b_2 (Btu/day-ft^2-mmHg-mph)
Lake Hefner	0	11.4
Lake Colorado City	0	16.8
Meyer	73	7.3

TABLE 3.3. WIND VELOCITY FUNCTION PARAMETERS

Note that Table 3.3 implies the following set of units on Equations 3.29 and 3.30.

HE - Btu/ft^2- day

V - mph

[EA, ES - mmHg]

It should also be noted that certain quantities in Equations 3.29 and 3.30 are time averages and are measured at specified elevations above the water surface. Table 3.4 summarizes these details.

	V		EA, ES	
Source	Averaging Period	Elevation (Ft.)	Averaging Period	Elevation (Ft.)
Lake Hefner	3 hours	24	3 hours	24
Lake Colorado City	24 hours	24	24 hours	24
Meyer	Monthly	?	?	?

TABLE 3.4. EVAPORATION FORMULA MEASUREMENT PARAMETERS

The Lake Hefner values are more widely used because of the extensive investigative work that went into their formulation but the equation, at best, is a rough approximation of a physical process that is not well defined. When a calculation of the net heat transfer rate is performed the result is of the order of the evaporation rate. Thus, long computer runs and a massive data gathering effort to precisely measure air and water temperature at several elevations in conjunction with wind speed, humidity and wave height measurements are necessary to justify the application of the Lake Hefner values on Narragansett Bay. In summary, improvement on the present formula is very necessary and a plausible research area.

J. EVAPORATION MASS FLOW RATE

The evaporation mass flow rate can be estimated from the evaporation heat-transfer rate by:

$$\frac{w_e}{A} = HE/h_{fg} \qquad (3.31)$$

where

w_e/A - evaporation mass flow rate, mass/time-area

HE - energy/time-area

h_{fg} - latent heat of vaporization at TW, energy/mass

with h_{fg} estimated from

$$h_{fg} = 1087 - 0.54\ TW \qquad (3.32)$$

for TW - ^{o}F and h_{fg} in Btu/lb_m. Use of Equations 3.29 through 3.32 with values from Table 3.3 will yield evaporation mass flow rates in lb_m/ft^2- day.

K. CONDUCTION HEAT-TRANSFER RATE

The conduction heat-transfer rate is approximated as a fraction of the evaporation heat-transfer rate through the Bowen ratio, B:

$$-HC = HE * B \qquad (3.33)$$

and

$$B = C_3 \frac{(TS - TA)}{(ES - EA)} * \frac{P}{760} \qquad (3.34)$$

where

TS - surface temperature (^{o}F) = TW

TA - air temperature, ^{o}F

ES - saturated vapor pressure at water surface temperature, TS

EA - air vapor pressure calculated from air temperature, TA, and relative humidity, RH

P - barametric pressure, mmHG

C_3 - an experimental constant usually taken as 0.26 (0.24 for smooth water surfaces and 0.28 for rough water surfaces).

Note that a minus sign has been introduced into Equation 3.33 due to the sign convention in Figure 3.1. If TS is less than TA then from Equations 3.33 and 3.34, HTOT will be positive and the heat transfer will be from the air to the water surface in agreement with the sign convention of Figure 3.1.

Combining Equations 3.29, 3.30, 3.33, and 3.34 yields

$$HC = -C_3 f(V)(TS - TA)\frac{P}{760} \qquad (3.35)$$

or for P = 760 mmHg we have

$$HC = -C_3(a_2 + b_2 V)(TS - TA) \qquad (3.36)$$

Again, emphasis must be placed on the empirical nature of conduction heat rate formulation with regard to the Bowen ratio and the wind factor.

L. MODEL FORMULATION

Substitution of Equations 3.20, 3.25, 3.29, and 3.36 into 3.14 and 3.16 results in the model formula 3.37, shown below.

$$\begin{aligned} HTOT = HS2 &+ SB\ (TA + 460)^{4}(CB + .031(EA)^{0.5}) \\ &- EW * SB * (TW + 460)^{4} - (a_{2} + b_{2}\ V)(ES-EA) \\ &- C_{3}\ (a_{2} + b_{2}\ V)(TW - TA) \qquad (3.37) \end{aligned}$$

Since ES is a function of water temperature only, we assume that for the time increment used in the model there is no significant error introduced by using the calculated water temperature value from the previous time step. In addition, the previous water temperature values are used to predict current heat exchange rates as shown in Equation 3.37. The other variables, air temperature, wind speed, relative humidity, solar radiation, and cloudiness are given, so one can now determine HTOT directly from Equation 3.37.

The model vertically averages (no buoyant effects) temperature structure so the energy equation is considered linear if the net heat exchange is linear for the temperature range considered. The net heat exchange rate for man made conditions requires only the water temperature excess, assuming that the air and natural water temperature remain unchanged as formulated in the following way:

$$\text{Forced Water Temperature Rise} = \text{Man Made Rise} - \text{Natural Condition} \tag{3.38}$$

or

$$FTR = HS2_{MM} + HA_{MM} - BH_{MM} - HE_{MM} - HC_{MM} - HS2_{N} + HA_{N} - BH_{N} - HE_{N} - HC_{N} \tag{3.39}$$

where MM index means man made condition, N is natural condition, and FTR equals forced water temperature rise (DELTAT in model). The following assumptions are made with regard to Equation 3.39:

1) $HS2_{MM} = HS2_{N}$ (net solar input)
2) $HA_{MM} = f(TA, \text{cloudiness}) = HA_{N}$ (incoming radiation)
3) $BH_{MM} = BH_{N} + BH_{FTR}$ (back radiation)
4) $HE_{MM} = HE_{N} + HE_{FTR}$ (evaporation)
5) $HC_{MM} = HC_{N} + HC_{FTR}$ (conduction)

Noting that we must know approximate temperature range of water for linearized saturated vapor pressure, ES, we now rewrite 3.39 into the following form:

$$(\text{Net Heat Exchange})_{FTR} = BH_{FTR} + HE_{FTR} + HC_{FTR} \quad (3.40)$$

where

$BH_{FTR} = EW * SB * (TW_{FTR} + 460)^4$

$HE_{FTR} = (a_2 + b_2V)ES*TW_{FTR}$

$a_2 + b_2V$ - wind evaporation function

ES - saturated vapor pressure for water temperature (mmHg)

TW_{FTR} - calculated forced water temperature rise from model (^oC)

$HC = 0.26(a_2 + b_2V)TW_{FTR}$

Linearization of BH_{FTR} is done by using the following binomial expansion:

$$(Y + G)^m = G^m + mG^{m-1}Y + \frac{m(m-1)}{2!}G^{(m-2)}Y^2 + \frac{m(m-1)(m-2)}{3!}G^{m-3}Y^3 \quad (3.41)$$

for

$Y = TW$

$G = 460^oF$

$m = 4$

Equation 3.41 becomes

$$(TW + 460)^4 = (460)^4(1 + 4 * TW/460 + 6 * (TW/460)^2$$

$$+ 4 * (TW/460)^3 + (TW/460)^4 \qquad (3.42)$$

and neglecting the last three terms as small we have

$$BH_{FTR} = EW(460)^3 4TW_{FTR} \qquad (3.43)$$

The use of the forced temperature rise for a heated effluent is ideal because it allows predictions that are much less sensitive to inaccuracies in the meterological data being used. This method improves predictive confidence for intelligent "worst case" analysis by separately considering maximum temperature rise during tidal cycle coupled and the maximum natural rise, say, during a hot summer day. As an add to understanding the tidal excursions of isotherms and the maximum value and location they attain, the forced temperature rise calculations are very valuable especially if one is concerned with small temperature differences of the order of 0.1°C in the far field.

M. EQUILIBRIUM TEMPERATURE

If the net heat transfer rate, HTOT, to the water, as given in Equation 3.37 is zero the grid point water temperature is then said to be at its equilibrium temperature, TE. Therefore, Equation 3.37 becomes:

$$0 = HS2 + SB(TA + 460)^4 (CB + .031\ (EA)^{1/2})$$

$$- EW*SB(TE + 460)^4 - (a_2 + b_2V)(ES - EA)$$

$$- C_3\ (a_2 + b_2V)(TE - TA) \qquad (3.44)$$

Solving Equation 3.44 in terms of TE requires at worst an iterative procedure because the saturated vapor pressure function, ES is calculated from the equilibrium temperature. In actuality, the solution of Equation 3.43 requires about six iterations in the computer model for five place accuracy. In the next section, the heat exchange coefficient approach will be used to actually calculate the equilibrium coefficient.

N. EXCHANGE COEFFICIENT

The use of Newton's law of cooling, Equation 3.45, is essential for making an engineering estimate of the equilibrium temperature.

$$Q = K * DT \qquad (3.45)$$

where

Q - heat transfer rate (HTOT in model) normal to grid surface area (Btu/ft^2- day)

K - idealized heat transfer coefficient (Btu/ft^2-day-^{o}F)

DT - temperature difference (TE - TW) (^{o}F)

By subtracting Equation 3.44 from 3.37 it follows that

$$HTOT = -[EW * SB[(TW + 460)^{4} - (TE + 460)^{4}]$$

$$+ (a_2 + b_2V)(ES - EE) + C_3 \; (a_2 + b_2V)(TW - TE)] \qquad (3.46)$$

where EE is saturated vapor pressure evaluated at TE. Now by combining 3.45 and 3.46 and solving for K we have the relationship

$$K = EW * SB \; [(TW + 460)^{4} - (TE + 460)^{4}]$$

$$+ (a_2 + b_2V)(ES - EE) + C_3 \; (a_2 + b_2V)(TW-TE) \; /(TW-TE) \qquad (3.47)$$

By using the bionomial expansion and neglecting second and higher order terms in Equation 3.41 and Equation 3.48 the linear vapor pressure approximation, BETA, shown below

$$ES - EE = BETA(TW-TE) \qquad (3.48)$$

where BETA is found in Table 3.5, we have, from Equations 3.46 to 3.48,

$$K = 4EW * SB \; 460^{3} + (a_2 + b_2V)(C_3 + BETA) \qquad (3.49)$$

After substitution of

$$EW = 0.97 \text{ and } SB = 4.2 \times 10^{-8} \frac{Btu}{ft^{2}\text{-day } ^{o}R}$$

Temperature Range $^{\circ}F$	BETA (mmHg $^{\circ}F^{-1}$)
40-50	0.291
50-60	0.405
60-70	0.553
70-80	0.774
80-90	0.990
90-100	1.289

TABLE 3.5. LINEARIZED VAPOR PRESSURE CONSTANT, BETA
(REFERENCE 12)

The final result is:

$$K = 15.7 + (a_2 + b_2V)(C_3 + BETA) \tag{3.50}$$

where K has units of Btu/ft^2- day $^{\circ}F$ and a_2, b_2, V, C_3, BETA are all constants. Finally, we substitute 3.37 and 3.50 into Fourier's law, Equation 3.45, and the result is:

$$TE = \frac{HTOT}{K} + TW \tag{3.51}$$

Equation 3.51 now is used to calculate the equilibrium temperature in the model.

IV. COMPUTER MODEL SUMMARY

A. PRELIMINARY MODEL DETAILS

A.1. General

The computational scheme is controlled from the main section of the computer program by calling subprograms in order with suitable comments inserted to guide user through model operation. Pertinent hydrodynamic information for Narragansett Bay can be found in Kurt Hess's, Numerical Tidal Model of Narragansett Bay (4). Following the general computational procedure in the main section of the thermal model we encounter the following input control parameters:

IPRIND - Number of 4-minute intervals after which temperature displays are read into storage. If IPRIND equals 15, it does this once an hour.

HS1(IDY) - Total daily solar radiation for day-IDY (not used if hourly values are available)

RDCNP - Logical variable, if true, one should specify temperature field. If false program defaults to a constant bay temperature field of arbitrary specification, TBNB.

A.2. Computation Parameters

DELTAT - Logical variable, if true, model will calculate temperature above ambient (forced temperature rise, FTR) where we now define boundary temperature to be nearly zero:

TMHOPE = .00001°C

TRIVER = .00001°C

TSOUND = .00001°C

- If false, the model calculates ambient plus forced temperature rise

TBNB - Arbitrary temperature field specification

UPCON - Variable that increases dispersion coefficient, same for x and y direction with a range of values from 2 to 500 yd^2/sec. (Dived by 5.93 from Equation 2.27)

TIN - Temperature increase in condenser (°C)

QIN - Condenser flow rate (cfs)

SITE - Various location choices for surface or submerged discharge from heat source

NPRINT(I) - Print out of velocity and temperature field, first index must be 1 and all numbers thereafter must be

in increments of 15 or 30, e.g., 1
15, 30, 60, 75, 105 . . .

A.3. Main Body of Program

Subroutine HEATIN - Specifies source term and indices for power plant siting

Subroutine INVAL - Reads and writes all initial values for program

Subroutine OPENED - Specifies all hydrodynamic and thermal boundary conditions

Subroutine UPNFHT - Claculates VP and SEP on column n (north-south) for first half timestep

where

$UP = u^{t+1/2}$ $U = u^t$

$SEP = n^{t+1/2}$ $SE = n^t$

$VP = v^{t+1/2}$ $V = v^t$

so "P" means higher time level in notation seen above

Subroutine VPMFHT - Calculates VP on row m (east-west) for first half timestep

Contained within subroutine VPMFHT are the following:

a. Subroutine WATDEP - Heat exchange values that are a function of water temperature

b. Subroutine WATIND - Heat exchange values that are independent of water temperature

c. Subroutine AZ - Calculates the average bay temperature from a total of six arbitrary subdivisions

d. Subroutine PRINT - Controls all print punch operations as well as time-step reallocation for variables

Subroutine VPMSHT - Computes VP and SEP on column m second half timestep

Subroutine UPNSHT - Computes SEP on row n second half timestep

Subroutine DISPLY - Graphical output of thermal model at end of the computational run. Calls IBM subroutine PLOT at the end of the computer run

Subroutine ANALYZE - Tidal pattern real vs. actual

A.4. Data

YR - Year, e.g., 57 for 1957

DAY - Day of Year, e.g., 194 for July 17

THR - Hour in Day, e.g., 17

TMIN - Minute, e.g., 48

TMHOPE - Mt. Hope temperature condition

TRIVER - River temperature conditions around bay

TSOUND - Rhode Island Sound temperature condition.

A.5. Execution Parameters

IMODES = 2, for central and, 1 for upstream differencing

IPUNCH - timestep at which model will punch out data

AT - half timestep = 120 sec

MAXST - computational length, MAXST/15 = number of hours real time

B. MODEL APPLICATION FOR NARRAGANSETT BAY, HYDRODYNAMICS SECTION

B.1. Introduction

Now that the fundamentals of the computer scheme have been discussed, the model may be applied to the specific case of Narragansett Bay. This requires the selection of the grid net which describes the Bay geography, with physical data on grid depths and bottom friction read in. The hydrodynamic boundary conditions are given as time varying functions at Mt. Hope Bay and Rhode Island Sound. The following sections outline the application procedure.

B.2. Grid Net Selection

Few, if any, guidelines exist for the selection of an optimum grid system for a water body, especially one like Narragansett Bay with its complicated geography. The first step taken, however, was the choice of the water boundaries. The area of the Bay to be modeled is bounded on the south by Rhode Island Sound, on the east by the entrance of Mt. Hope Bay, and the north at the narrowing of the Seekonk River. This area represents about two-thirds of the entire Bay. The portion excluded, Mt. Hope Bay and the Sakonnet River, comprises another estuarine system, and is connected to the main part of the Bay by a narrow passage.

Secondly, the computation scheme imposes a minimum of two grids per row or columns in the field. Thus, the narrowest channel must be at least two grids wide. These critical areas occur in the lower Bay, in the East and West passages, and in the upper Bay in the Providence River (Figure 4.1). Therefore, a grid length of one-half nautical mile (1012.7 yds.) was chosen. The resulting grid net consists of 314 water and 11 water-boundary grids within the rectangular (19 by 48) field for a total of 325 grids. The model axis has been rotated 10.1 degrees clockwise from the true north-south direction for more accurate representation of the shore geometry.

B.3. Model Time Step Selection

One important property of the implicit solution method is its unconditional numerical stability, (values need only be bounded) regardless of time step. However, the size of the time step has an effect on the accuracy of the solution.

Leendertse (1) has shown that the solution is accurate when Equation 4.1, shown below, is less than 5.

$$\frac{AT}{L} (gh_{max})^{1/2} \leq 5 \qquad (4.1)$$

where

AT - time step

L - grid length

g - acceleration of gravity

h_{max} = maximum bay depth

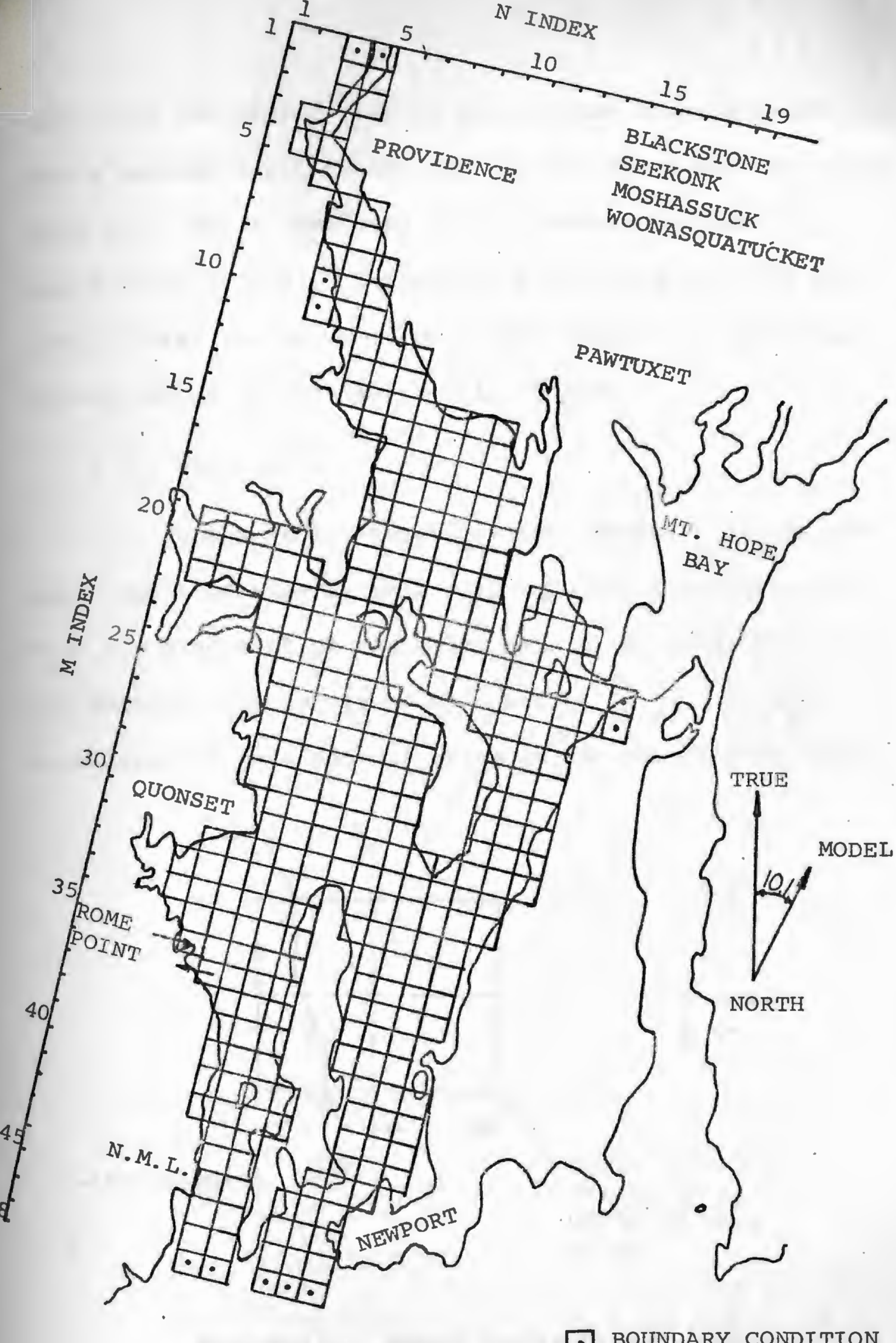


FIGURE 4.1. GRID SYSTEM FOR NARRAGANSETT BAY

Note that the factor $\sqrt{gh}$ is the maximum long-wave celerity. For a maximum depth of 152 feet in the bay a grid length of 3038 feet, and a time step of 220 seconds Equation 4.1 has a value of 4.91. Therefore, a time step, AT, of this size or less insures good accuracy, especially since the average depth of the Bay is only 30 feet.

B.4. Bay Depths

Bathymetric variations are accounted for in the depth specification at each grid square. In accordance with the placement of variables within the grid, Figure 4.2, the depth in the corner of the grid at $(x_c + 1/2, y_c + 1/2)$ is entered as data for all grids in the computation field.

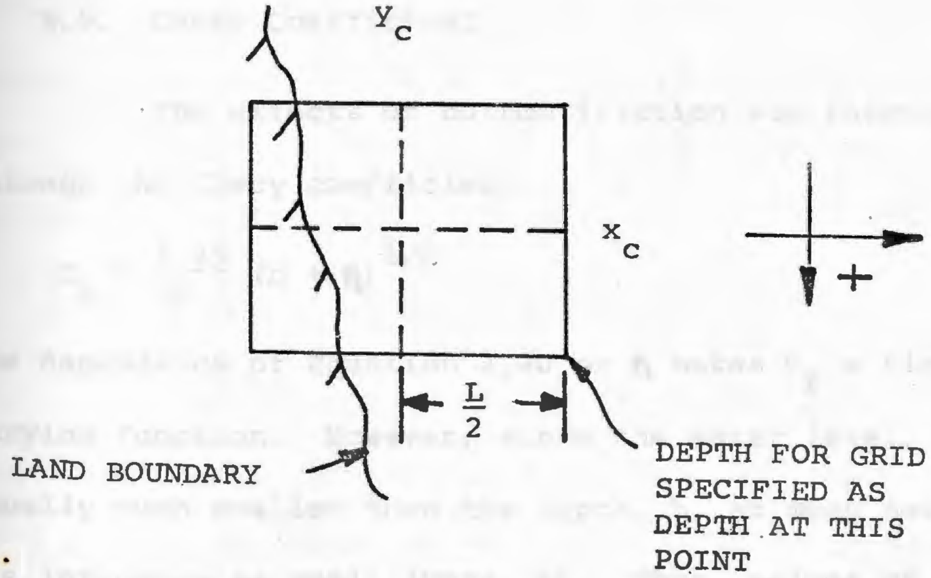


FIGURE 4.2. DEPTH SPECIFICATION

The number entered is the actual depth at mean sea level at that point on the grid, and not the average depth over the grid square as shown in Figure 4.2. Depths may also be entered without harm at grid squares outside the computation field, such as those adjacent to water grids.

General information on the bathymetry was obtained from the U.S. Coast and Geodetic Survey chart No. 353, which gives depths at mean low water. It should be noted that while such charts are useful, certain small-scale features may not be evident from them. For certain critical locations, therefore, depth surveys would be quite useful. These were carried out in the West Passage at the Jamestown Bridge, and at the Mt. Hope Bridge.

B.5. Chezy Coefficient

The effects of bottom friction are introduced through the Chezy coefficient

$$C_z = \frac{1.49}{N} (h + \eta)^{1/6} \tag{2.20}$$

The dependence of Equation 2.20 on η makes C_z a time-varying function. However, since the water level, η, is usually much smaller than the depth, h, at mean sea level, its influence is small (Hess, 4). Thus, values of C_z are computed at the start of each run (for $\eta = 0$), and are not changed afterward.

The selection of the Manning factor (N in ft$^{1/6}$) poses a somewhat more difficult problem, due to the lack of extensive studies for rivers and bays. Masch and Brandes (49), for example, use values between 0.018 and 0.054, which corresponds to "rubble set in cement" and "natural river channels: winding, with pools and shoals", respectively, in a table given by Henderson (50). The essential concept is bottom roughness, which varies considerably in an area as large as Narragansett Bay. For approximation, then, the Manning factor was taken as a linear function of m, the north-south section number:

$$N(m) = N_{avg}\,(1.3 - 0.6m/max) \qquad (4.2)$$

which varies from 1.3 Navg in the Providence River to 0.7 Navg at the mouth of the Bay. The average value, Navg, was determined from comparisons of predicted and observed velocities, and was taken as 0.020.

B.6. Rhode Island Sound Boundary

The primary driving force at the mouth of Narragansett Bay is the astronomical tide, and thus is entered as a water level boundary condition at that location, grids m = 48, n = 8, 9, 11, 12, 13. The coast and Geodetic Survey regularly collects and analyzes tidal elevations at several locations around the Bay. The primary stations are at Newport, Bristol, and Providence, and the data obtained is used to calculate the amplitude and phase angle of the twenty or so largest tidal constituents (51). A number of secondary stations have been occupied, and the times of high and low water relative to Newport are given for them in reference 51.

The tidal forcing function may be represented by the sum of several sinusoidally varying terms, each with a specified amplitude, angular speed, and phase angle (52). The phase angle is taken relative to Greenwich, England; the amplitude is modified by a function of lunar position, $f_{\bar{\eta}}$. The equation for the water level, η, is

$$\eta(t) = H_o + \sum^{\bar{n}} f_{\bar{\eta}}(t)\ H_{\bar{\eta}} \cos\left[w_{\bar{\eta}} t + (V_o + u)_{\bar{\eta}} - k_{\bar{\eta}}\right] \tag{4.3}$$

where

H_o - the height of the mean sea level above the datum (mean low water)

and for each constituent, $\bar{\eta}$,

$f_{\bar{\eta}}(t)$ - amplitude factor depending on the position of the moon's line of nodes

$H_{\bar{\eta}}$ - amplitude of the constituent

$w_{\bar{\eta}}$ - angular speed (degrees per hour) of the constituent

$(V_o + u)_\pi$ - value of the equilibrium agrument when

$t = 0$

k_π - epoch (angular phase difference from Greenwich)

t - time (hours) from reference time

The values of H_o, H_π, and k_π are calculated for each tide station. The angular speed (w), lunar node function f_π and equilibrium agrument $(V_o + u)_\pi$ can be calculated from knowledge of astronomical motions, and are tabulated in reference 52. (See Hess (4), Subroutine KURIH).

The tide at the lower boundary is calculated at each of the end grids (m = 48, n = 8, 9, 11-13) by an equation of the form 4.3. The tide at the intermediate grids is obtained by linear interpolation. The amplitude and epoch of each constituent used at the boundary is derived from the analysis of tidal data taken at three previously mentioned stations. The tidal values will be improved by data obtained from the Ocean Engineering Department's, Whale Rock tide gauge.

Several other types of boundary conditions are included in the model, and can be used in various hydrodynamic experiments. (See Hess (4), Chapter II).

B.7. Providence River Boundaries

The boundaries located in the northern part of the Bay represents river flows and are velocity boundary conditions in the model. The Providence Harbor is the sum of several rivers, while the Pawtuxet River joins the Providence River further down the Bay. Several smaller river flows into the Bay are neglected because their discharge flow rates would have no noticeable affect on local fluid motions.

The total volumetric flow rate from the Blackstone-Seekonk, Moshassuck, and Woonasquatucket Rivers is entered at boundary grid m = 1, n = 3 and 4 to simplify the model grid system in that region. The mean annual flow rate, about 890 cfs including discharge from the City of Providence, is fairly small compared to tidal flowrate so that local velocities do not differ significantly in the area as a result. The daily average flowrate may either be obtained from surface water records (53) or estimated from the ratio of monthly to yearly mean discharges.

The Pawtuxet River boundary (m = 10 and 11, n = 4) is handled in the same manner as the Providence Harbor boundary.

B.8. The Mt. Hope Boundary

The boundary at the entrance to Mt. Hope Bay probably is the most difficult to model accurately. The local geography does not permit the use of the Bristol Harbor tide as a water level boundary condition, so a tidal velocity, based upon the volumetric flowrate, is used.

The total flow under the Mt. Hope Bridge is determined by tidal differences, river discharges, and wind effects. The tidal flow results from water level variations between the Narragansett and Mt. Hope Bays where the Mt. Hope Bay is also connected to the Rhode Island Sound by the Sakonnet River. Also, a certain fraction of the fresh water discharge into the Mt. Hope Bay, primarily from the Taunton River (mean annual flowrate of 660 cfs), passes under the bridge. Local winds may contribute to daily variations in the flow, but they are neglected since no data on wind currents is available.

The earliest available measurement of the flow under the bridge were reported by Haight (54), who used a 7 foot pole and three current meters on August 7 and 8, 1930. Recent measurements, Binkerd (55), (August 5 and 18, 1971) were taken by using several poles spaced across the section under the bridge. The general approach of analyzing the data used by Haight was applied to the newer observations.

Due to the nature of the bay geometry, Haight (54) showed that the currents due to the lunar (M_2, M_4, and M_6) constituents of the tide accounted for most of the obtained current. The flowrate can then be approximated by

$$q = \sum_{k=1}^{3} q_k \cos \left[\frac{2xPIxk}{12.42} (t - tau_k)\right] \qquad (4.4)$$

where q is the flowrate, and tau the time to first flood after high water. The flowrate was deduced from the 1930 data by integrating the velocity over the depth, and multiplying by a weighted area under the bridge (90,600 ft^2). The flowrates for the other observations were calculated by summing the products of the pole velocity and the incremental area; the resultant values were adjusted for the tidal range and smoothed. A weighted average was then analyzed, by a least squares technique, using an equation similar to 4.4. The results are shown in Table 4.1.

k	Lunar Constituent	Period (hr.) T	Time to First Flood (hrs)	Current (kts)	q_k (10^3 cfs)
1	M_2	12.42	9.87	1.12	150.5
2	M_4	6.21	6.29	0.29	33.2
3	M_6	4.14	3.32	0.15	35.4

TABLE 4.1. LUNAR CONSTITUENT ANALYSIS OF FLOW UNDER MT. HOPE BRIDGE

The tidal velocity is obtained by dividing the flowrate, q, by the area at the boundary.

The portion of the Taunton River discharge passing under the bridge is obtained from Hicks, (57), who estimated the river outflow from the ebb flowrates through each Bay passage. The value used here is 72% of the annual mean flow or 475 cfs.

C. MODEL APPLICATIONS FOR NARRAGANSETT BAY - THERMAL SECTION

C.1. Boundary Conditions

As previously mentioned in the hydrodynamic section, the river flow rates are small compared to tidal flow and as a consequence the river temperature boundary conditions around the bay have no noticeable affect on spatial heat variations. Nevertheless, a constant value of 22.20°C was chosen to represent mid-summer conditions at all river outfall areas. The Mt. Hope boundary condition is important because the flow under the bridge is of the order of 10-20% of the tidal flow. From data available at this time (37) a constant value of 21.75°C was chosen. Finally, at the Rhode Island Sound boundary condition, a constant value of 18.5°C is used (31). It is quite obvious that the fixed Rhode Island Sound boundary condition will represent the greatest source of inaccuracy in the model. A proposed improvement would be to vary the boundary condition as a function of tidal velocity across lower east and west passage as shown in Equation 4.5

$$\begin{matrix}\text{Rhode Island temperature} \\ \text{boundary condition}\end{matrix} = 18.65 + \frac{\text{Ampl} * \text{Vel}}{\text{Vel}_{\text{max}}} \qquad (4.5)$$

where

18.65 is now the average value of the boundary condition

Ampl = .15°C - half temperature tidal excursion

Vel - tidal velocity (yds/sec)

Vel_{max} - maximum tidal velocity - taken as .125 yds/sec

Temperature excursion was determined by plotting at a typical North-South temperature profile shown in Figure 4.3.

The use of Equation 4.5 would help model boundary condition by taking into account, in an approximate way, the flow of warm water back into the bay.

C.2. Thermal Model Modes

The model can operate under various schemes that are shown in Table 4.2. These were formulated to help isolate the various heat transfer processes involved in simulating both natural and man-made conditions. Mode I is most commonly used.

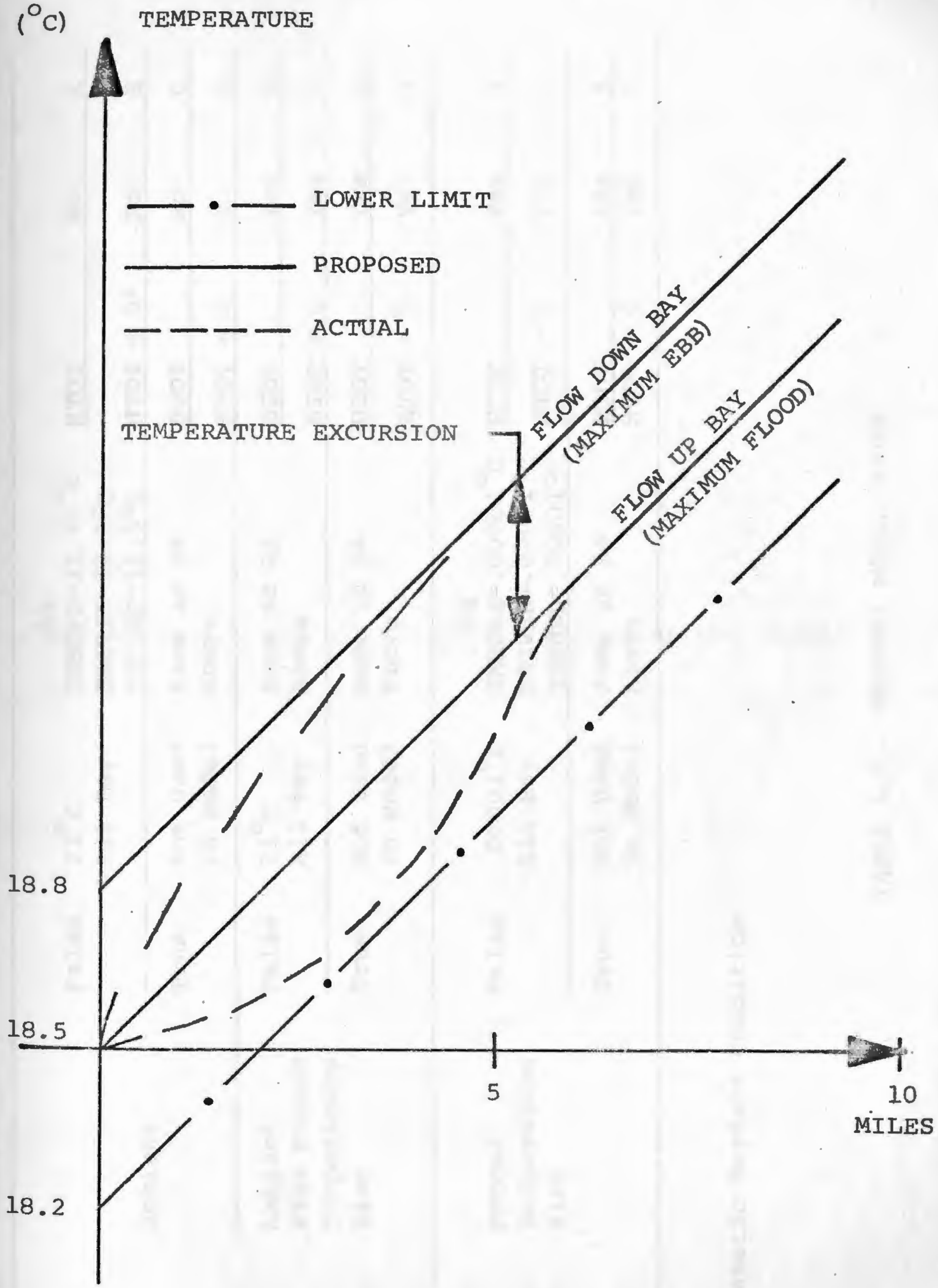


FIGURE 4.3. NORTH-SOUTH TEMPERATURE PROFILE

DELTAT	CONDITIONS	RDCNP	TBNB	BOUNDARY CONDITIONS	NET HEAT EXCHANGE	POWER PLANT	MODE
False	Ambient	False	21°C All Bay	AA TMHOPE=21.75°C TRIVER=22.2°C TSOUND=18.5°C	HTOT	No	A
					HTOT = 0*	No	B
		True	Not Used in Model	Same as AA Above	HTOT	No	C
					HTOT = 0	No	D
	Ambient Plus Forced Temperature Rise	False	21°C All Bay	Same as AA Above	HTOT	Yes	E
					HTOT = 0	Yes	F
		True	Not Used in Model	Same as AA Above	HTOT	Yes	G
					HTOT = 0	Yes	H
True	Forced Temperature Rise	False	.00001°C All Bay	BB TMHOPE=.00001°C TRIVER=.00001°C TSOUND=.00001°C	HTOT	Yes	I
					HTOT = 0	Yes	J
		True	Not Used in Model	Same as BB Above	HTOT	Yes	K
					HTOT = 0	Yes	L

* Adiabatic Surface Condition

TABLE 4.2. THERMAL MODEL MODES

C.3. Net Heat Exchange

The value of HTOT, the net heat exchange transfer rate, is obtained from Equation 3.37. This is read into the model by the following formulation:

$$\text{HTOT x AREA} = \frac{\text{Btu}}{\text{ft}^2\text{-day}} \text{ x GSA x } \frac{\text{yd}^2 \text{ x } 9 \text{ ft}^2/\text{yd}^2}{(24 \text{ hr/day})(3600 \text{ sec/hr})} \tag{4.6}$$

$$\text{Heat into box} = \frac{9 \text{ x GSA}}{24 \text{ x } 3600} \quad \frac{\text{Btu}}{\text{sec}} = Q \tag{4.7}$$

where GSA - grid surface area

$$\text{but } Q = mc_p \text{ DT} \tag{4.8}$$

and

Q - heat transfer rate per unit time

c_p - specific heat of water at constant pressure

DT = temperature change in box per unit time

Combining 4.7 and 4.8 and solving for DT we have:

$$\text{DT} = \frac{Q}{mc_p} = \frac{9 \text{ x GSA}}{24 \text{ x } 3600} \text{ x}$$

$$64 \frac{\text{lb}_m}{\text{ft}^3} [\text{GSA yd}^2 * \frac{9 \text{ ft}^2}{\text{yd}^2}] * \text{Depth (yd)} * \frac{3 \text{ ft}}{\text{yd}} \tag{4.9}$$

Consolidating, the result is

$$\text{DT} = \frac{\text{HTOT}}{24 * 3600 * 64 * 3 * \text{Depth}} = {}^{\text{o}}\text{F/sec} \tag{4.10}$$

for a depth of 30 feet the final result is

$$T = \frac{HTOT}{1.66 * 10^7} \; {}^{o}F/sec \qquad (4.11)$$

For a value of HTOT = 10 Btu/ft^2-day, the net heat flux, we have

$$DT = \frac{10 * 86,400}{1.66 * 10^7} \qquad (4.12)$$

$$= \frac{8.6 * 10^5}{1.66 * 10^7} = .052 \; {}^{o}F/day \qquad (4.13)$$

For one year we would have

$$T = .052 * 365 = 19^{o}F \qquad (4.14)$$

which is of the order of the annual variation in the Narragansett Bay area.

The read in variables required for computing Equation 3.37 are the following:

TA - temperature of the air, ^{o}F (T.F. Green Airport, (56))

RH - Relative humidity, percent (T.F. Green Airport, (56))

HS2(1) - Hourly solar radiation parameter (grm-cal/cm^2) (scale factor of .2 from Eppley Laboratory, Unpublished)

WA - Wind speed, miles per hour (T.F. Green Airport, (56))

ANG - Direction that wind blows from, degrees (T.F.

Green Airport, (56))

CLDCVR - Percent of sky covered with clouds (T.F. Green Airport, (56))

C.4. Power Plant

To determine power plant requirements, the cooling water rate per unit power must be known (see Figure 4.4).

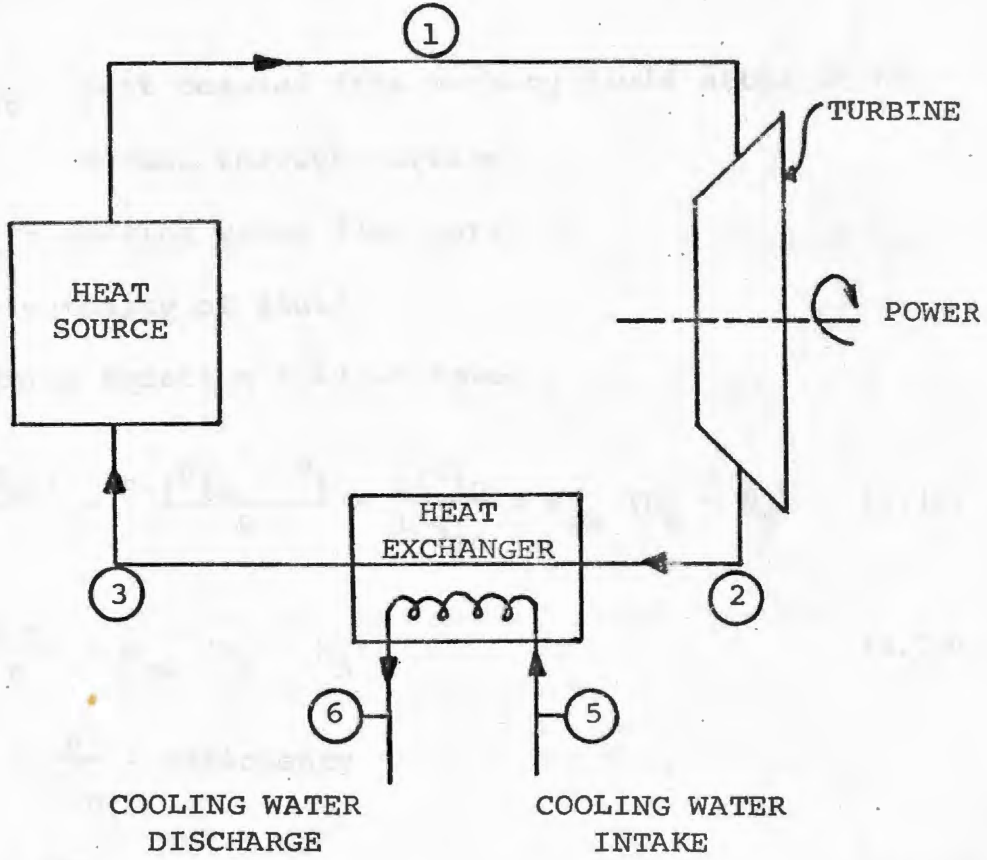


FIGURE 4.4. POWER PLANT SCHEMATIC

A straightforward calculation is presented using the steady flow energy equation

$$q - P_x = W_{cw} \left[\left(h_6 + \frac{V_6^2}{2} + z_6\right) - \left(h_5 + \frac{V_5^2}{2} + z_5\right) \right] \tag{4.15}$$

$$q_{out} - 0 = W_{cw} [h_6 + 0 + 0] - (h_5 + 0 + 0)] \tag{4.16}$$

$$q_{out} = W_{cw} (h_6 - h_5) \tag{4.17}$$

where

q_{out} - heat removed from working fluid after it has passed through turbine

W_{cw} - cooling water flow rate

h - enthalpy of fluid

Transforming Equation 4.17 we have

$$\frac{P \cdot q_{out}}{P} = \frac{P \cdot [q_{in} - P]}{P} * \frac{1/q_{in}}{1/q_{in}} = W_{cw} (h_6 - h_5) \tag{4.18}$$

$$\frac{P(1-E)}{E} = W_{cw} (h_6 - h_5) \tag{4.19}$$

where $E = \frac{P}{q_{in}}$ - efficiency

for $h = c_p DT_{cw}$

and DT_{cw} - temperature increase, °F, in cooling water through heat exchanger

Equation 4.19 becomes, after a little rearranging

$$\frac{W_{cw}}{P} = \frac{1-E}{E}\ \frac{1}{c_p DT_{cw}} \qquad (4.20)$$

Assuming

E = plant efficiency = 40%

$c_p = 1\ \text{Btu/lb}_m{}^{o}\text{F}$

$DT_{cw} = 20^{o}\text{F}$

Equation 4.20 is now

$$\frac{W_{cw}}{P} = \frac{1-.4/.4}{\text{Btu/hr}} * \frac{\text{lb}_m{}^{o}\text{F}}{1\ \text{Btu x } 20^{o}\text{F}} * \frac{3413\ \text{Btu/hr}}{\text{Kw}} * \frac{10^3\text{kw}}{\text{Mw}} \qquad (4.21)$$

which results in

$$\frac{W_{cw}}{P} = 255.97 * 10^3\ \frac{\text{lb}_m}{\text{hr Mw}} * \frac{\text{ft}^3}{64\ \text{lb}_m} + \frac{\text{hr}}{3600\ \text{sec}} \qquad (4.22)$$

$$= 1.1\ \frac{\text{cfs}}{\text{Mw}} \qquad (4.23)$$

For a plant with an 1800 megawatt capacity we would need approximately 2000 cfs for a rated efficiency of 40%. The data used in the model is summarized as follows:

$$W_{cw} = 2000 \text{ cfs} = \text{QIN}$$
$$DT_{cw} = 12^{o}\text{C} = \text{TIN} \qquad (4.24)$$

These two values represent reasonable values but certain engineers might prefer to use a cooling water rate based on 1500 cfs/1,000 megawatts or a $DT_{cw} = 25^{o}F$. There are so many possible choices of flow rates, temperature increases and site locations that the model is structured to handle these many personal preferences in user production runs.

Also, it should be kept in mind, that a power plant generally has an average power production rate below the 95% maximum output rate under peak load conditions to further complicate environmental studies.

C.5. Bay Zonal Divisions

The bay was divided into six major geographically similar sections each with various subsections that comprise the main hydrodynamic elements of the model. This is seen in Figure 4.5. The Rome Point area will affect primarily zone 1.

C.6. Rome Point Area

An enlarged section of Narragansett Bay map Figure 4.10 for the Rome Point area is seen in Figure 4.6. In the prediction portion of this report, isotherms will be drawn in, with average temperature values included in each box.

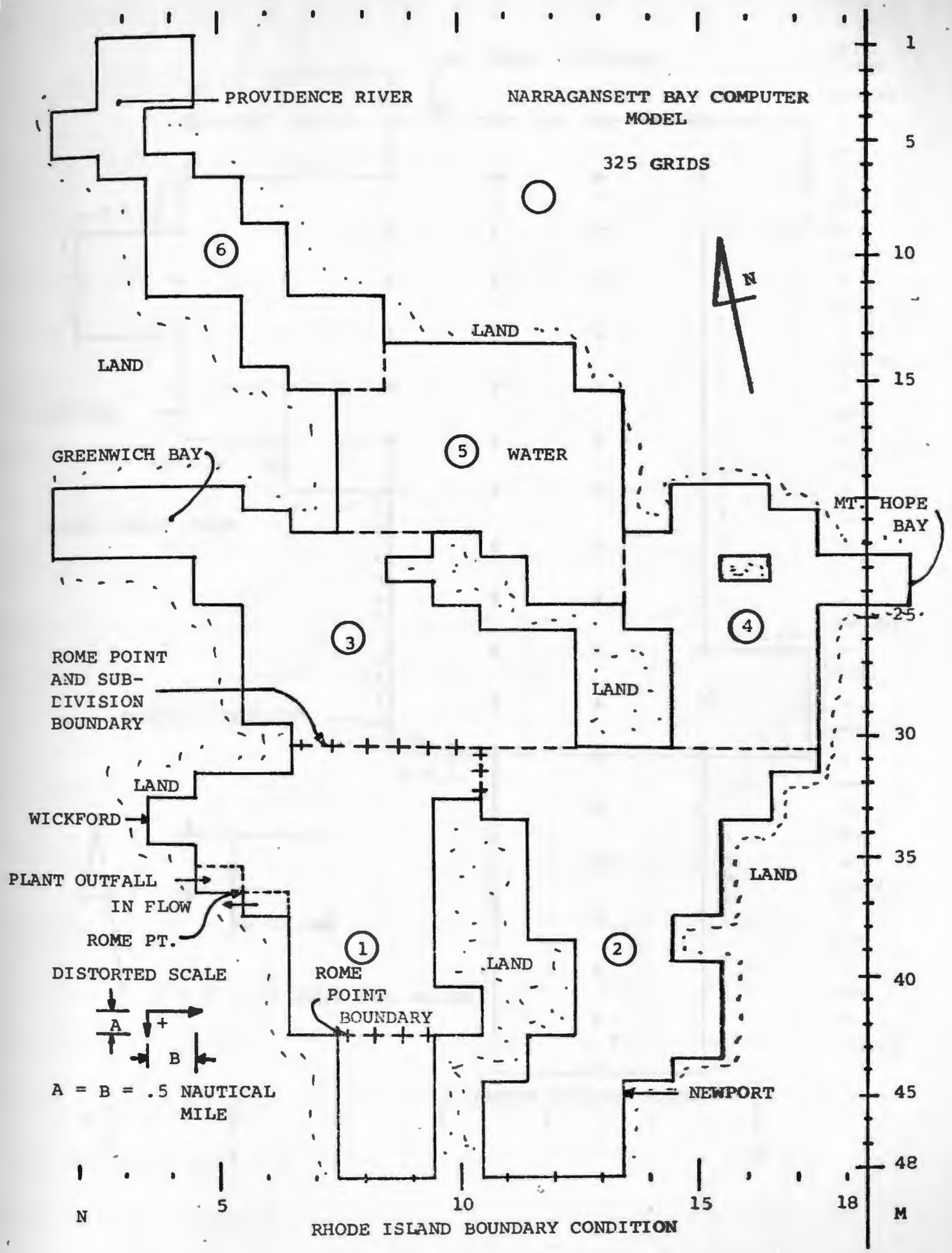


FIGURE 4.5. NARRAGANSETT BAY ZONAL DIVISIONS

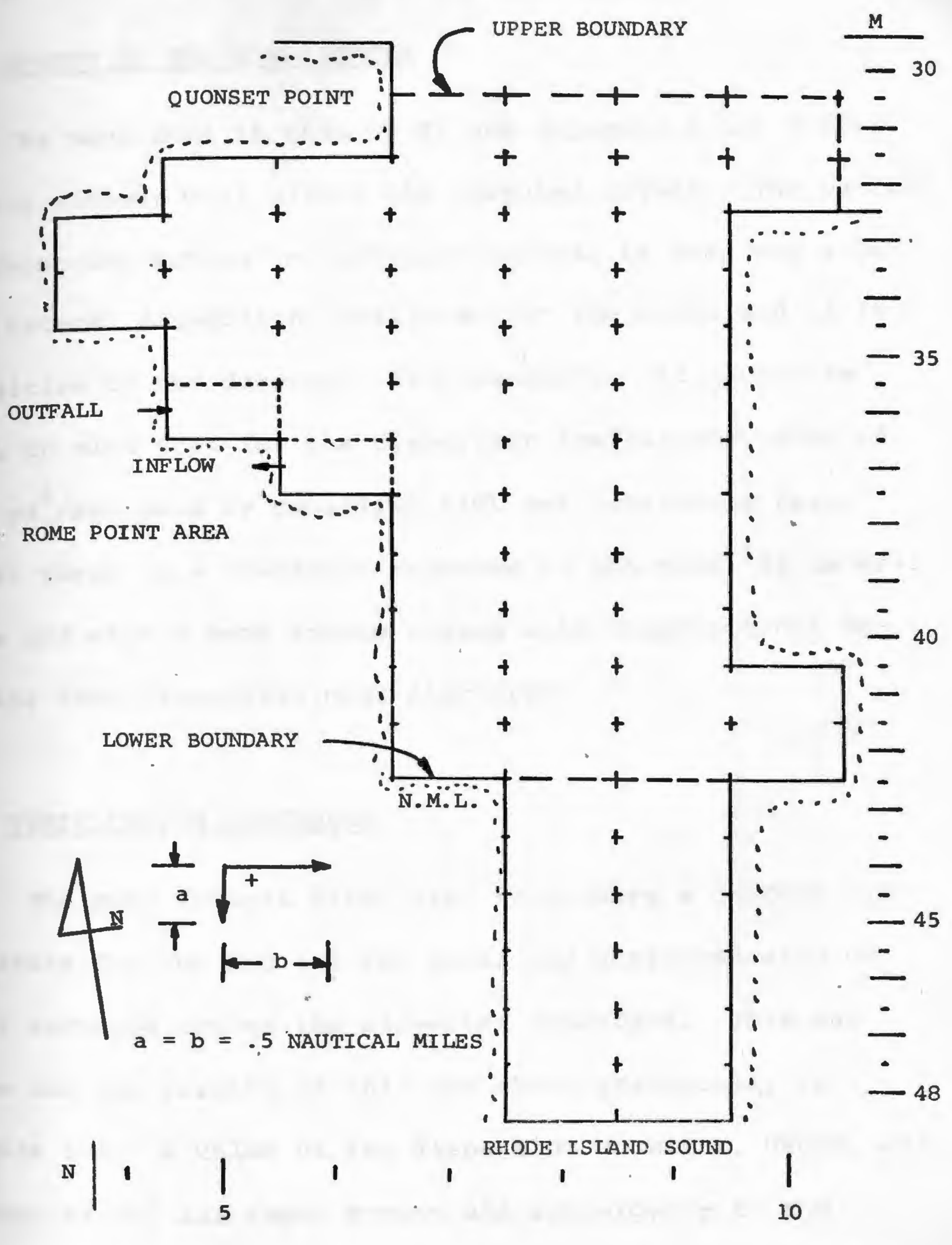


FIGURE 4.6 . ROME POINT AREA

V. GENERAL STUDIES OF TEMPERATURE MODEL BEHAVIOR

A. EFFECT OF THE DIFFERENCES

As mentioned in Chapter II and Appendix D the differencing schemes will affect the computed values. The central differencing scheme is preferred because it does not alter the natural dispersion coefficient in the model and is insensitive to the divergent flow patterns. It should be kept in mind that for the dispersion coefficient value of 5.0 yd^2/sec used by Sapulding (16) and considered realistic there is a transient response in the model of several days and with a heat source causes wild computational behavior that propagates near discharge.

B. VERIFICATION PROCEDURE

The most logical first step is to have a uniform temperature for the Bay and its exits and entrances with no heat exchange across the air-water interface. This was done and the results of this are shown graphically in Figure 5.1. A value of the dispersion constant, UPCON, was chosen as 500 for rapid mixing and convergence to the steady state bay temperature. This procedure required two hours of computer time.

The energy loss is only 0.03/21.00 or 0.14 percent drop

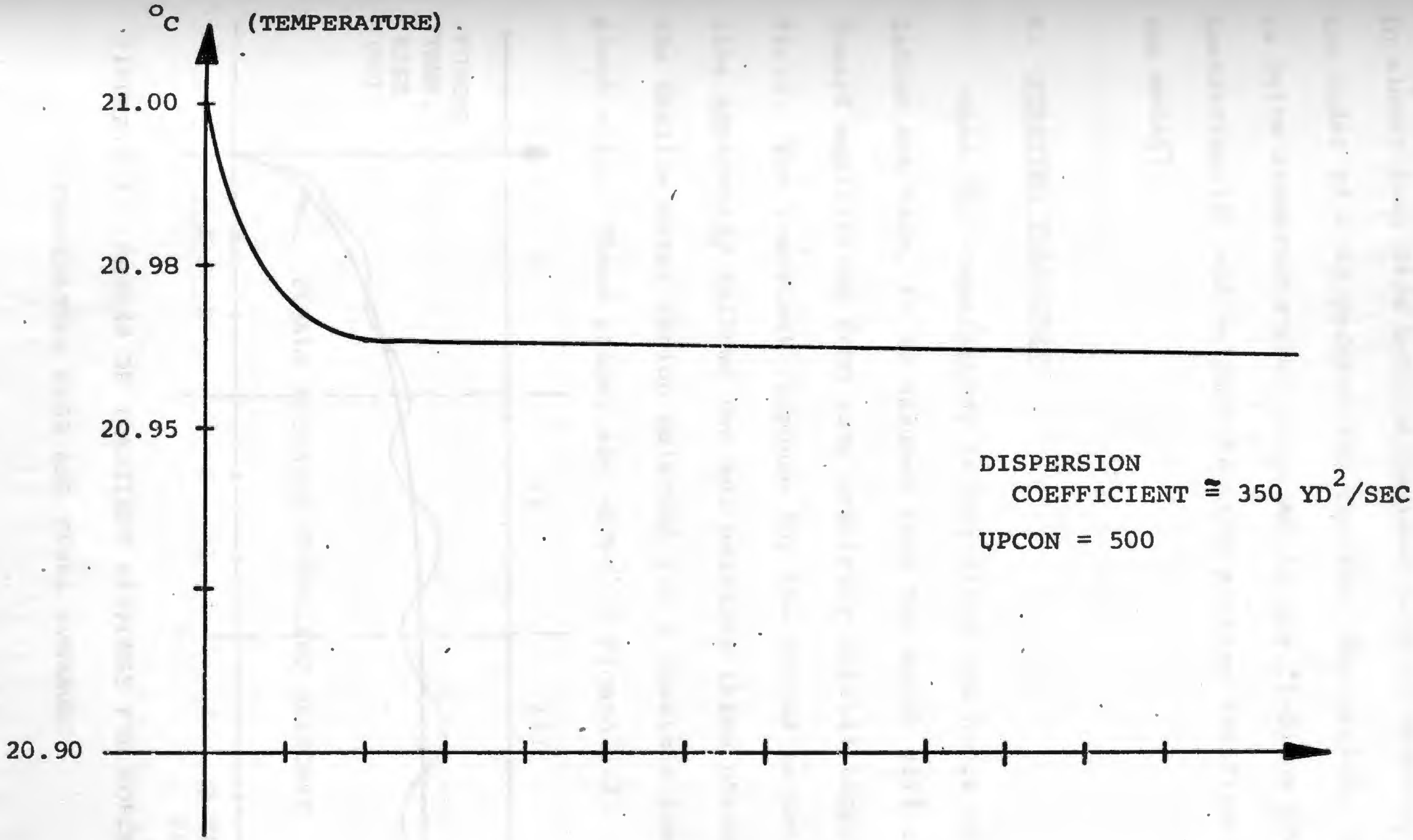


FIGURE 5.1. ENERGY BALANCE FOR BAY, UNIFORM TEMPERATURE CASE

in almost four days but the maximum rate of decrease is of the order of 0.05 percent for the four day period. This is quite acceptable when compared to the findings of Leendertse (2) and establishes the primary verification of the model.

C. STARTING TRANSIENT

When the computations during first few hours of simulation are made, it is assumed that the model will tend toward equilibrium from some arbitrary initial temperature field. The transient response for the forced temperature rise apparently follows two and possibly three phases for the shallow water region selected for a possible power plant site. These phases are shown in Figure 5.2.

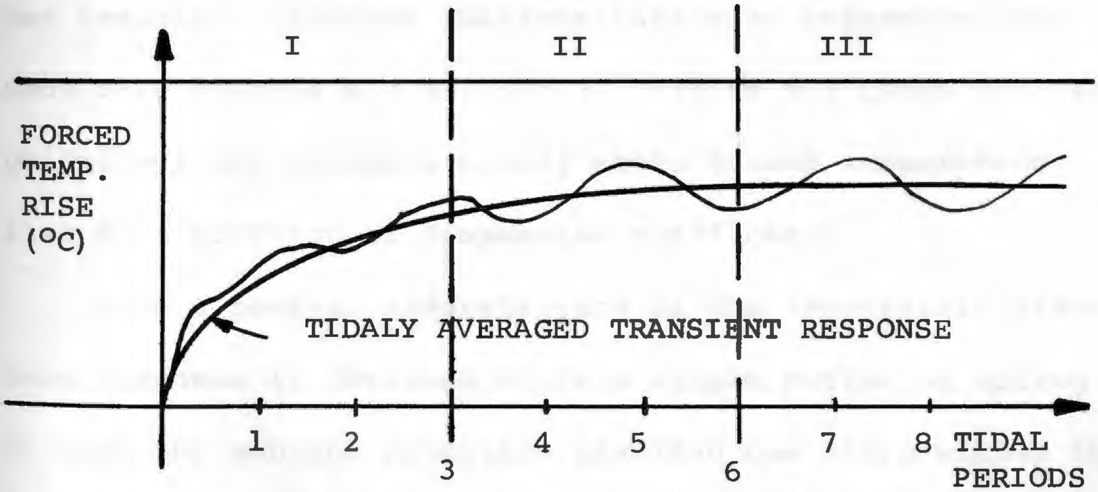


FIGURE 5.2. PHASES OF TRANSIENT RESPONSE FOR FORCED TEMPERATURE RISE AND TIDAL AVERAGES

Phase I is primarily the rapid increase in the temperature to within 80-90 percent of the steady state value. Steady state means that the apparent temperature average from tidal cycle to tidal cycle is at most a gradual but regular change. Phase II will consist of the alignment of the temperature peaks and dips with some sort of tidal regularity. Finally, Phase III, not always distinct from II, will represent the level at which we have established some steady state value for the forced temperature rise. Further investigation is necessary to determine how steady state values vary over an average monthly variation of tidal cycles. The steady state is emphasized as the apparent average of the temperature oscillation that may itself have a much larger period of oscillation. Each grid has its own transient response characteristics so reference here is made only to grid m = 35, n = 5. Figure 5.3 gives general guidelines for reaching steady state forced temperature rise as a function of dispersion coefficient.

Once a general understanding of the temperature transient response is obtained it is a simple matter of adding it onto the ambient condition provided one stays within the bounds of the linearization assumptions explained in Chapter III, Section L.

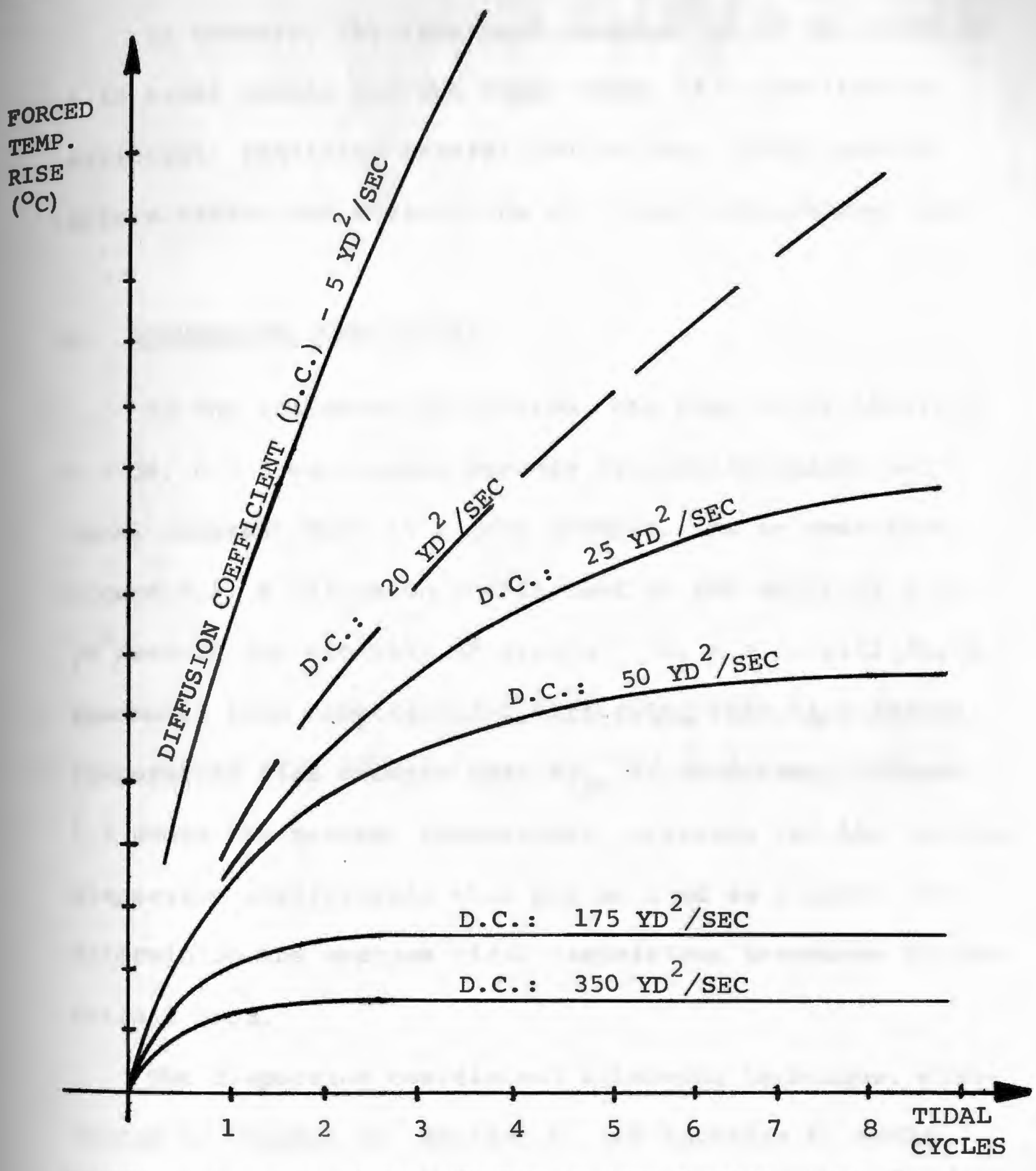


FIGURE 5.3. THE ESTABLISHMENT OF THE STEADY STATE TIDALY AVERAGED VALUES OF FORCED TEMPERATURE RISE AS A FUNCTION OF DIFFUSION COEFFICIENT FOR GRID m = 35, n = 5

In summary, the transient response is of the order of 5-10 tidal cycles for the lower range of dispersion coefficient; requiring careful preliminary investigation before making any evaluations of forced temperature rise.

D. DISPERSION COEFFICIENT

In the following discussion, the Rome Point location m = 36, n = 5 was chosen because its shallow depth and local interest make it a good example. As is seen from Figure 5.3, a diffusion coefficient of the order of 5-20 yd^2/sec in the vicinity of grid m = 36, n = 5, will force the model into computational difficulty, that is, a forced temperature rise greater than DT_{cw} of condenser. Figure 5.3 shows the general temperature increases for the various dispersion coefficients that may be used as a guide for determining the average tidal temperature increases in the outfall area.

The dispersion coefficient enhancing technique, elaborated in Chapter II, Section D, and Appendix D, would enable one to use a value of 5-20 yd^2/sec in the model and would be as close to the real conditions as possible. At this stage in the development of the model, it was decided to use the value of 50 yd^2/sec throughout the bay as a

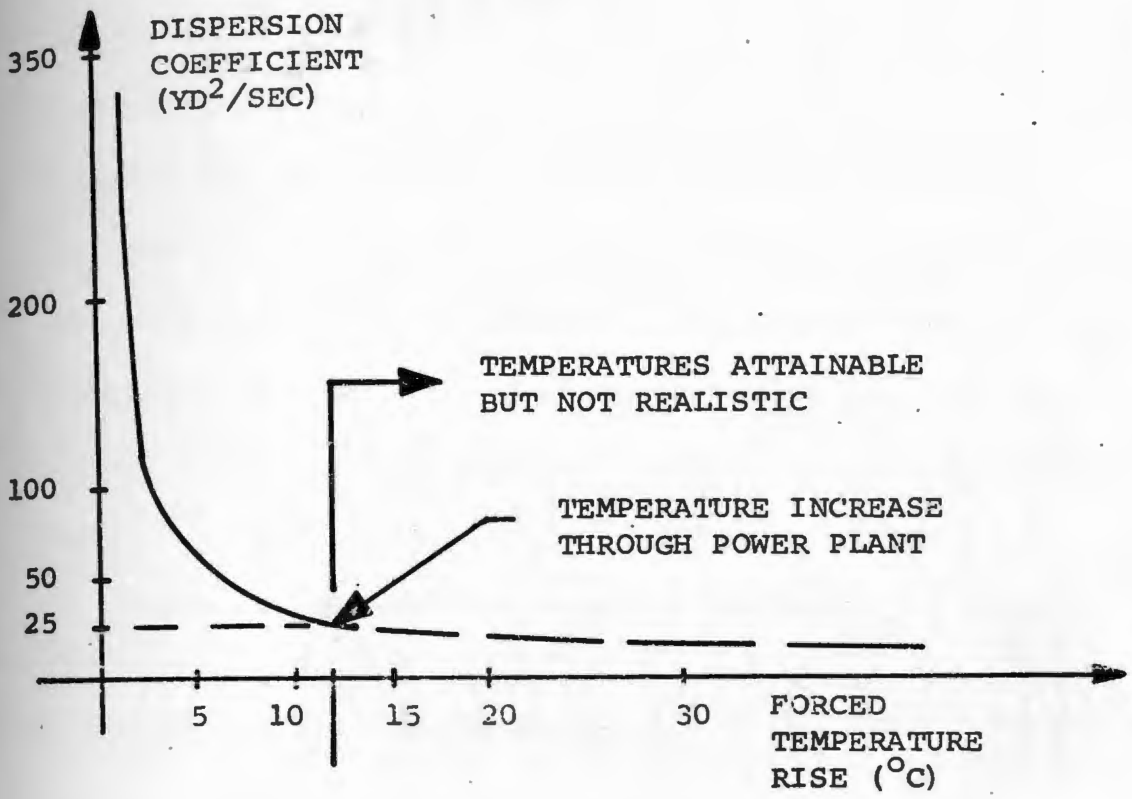


FIGURE 5.4. GRAPHICAL REPRESENTATION OF MINIMUM VALUE OF DISPERSION COEFFICIENT FOR ROME POINT, m = 36, n = 5

first estimate in determining the general isotherm pattern around the discharge. With a grid size of about 1000 yards and the model interest in the far field it is felt that the results for a dispersion coefficient of the order of 50

yd^2/sec (UPCON = 100) would be satisfactory.

VI. COMPARISON OF CALCULATED RESULTS AND HISTORICAL DATA

A. BACKGROUND

Given the necessary meterological data, solar inputs, and boundary conditions it is feasible to predict the bay temperature field through thermal model calculations. In any model verification procedure, the comparison between measured and computed values is difficult because of the small area encompassed by measurements versus the larger 1/2 by 1/2 nautical mile area of the model grids. Since model averages vertical water temperature column, surface to bottom temperature measurements continuously taken on area wide basis, are required to achieve more realistic verification criterion. Being realistic, the reference period July, 1957 was chosen to give insight on where the model and measurements are most divergent because of the dissimilar nature of the model and the historical measurements.

This does not mean that the model has little value, which it does have for large scale simulation, but rather that measurements should be taken on a length and time scale comparable to the model. The summer of 1957 was chosen for comparison because it contains the heaviest concentration of temperature data taken in Narragansett Bay.

B. MODEL SIMULATION CONDITIONS

The following conditions were adopted for comparison procedure (see next page).

C. NARRAGANSETT BAY DATA

C.1. Narragansett Marine Lab Pier

The data obtained from Hicks (37) and Day (38) is plotted in Figure 6.1 along with the computer results. In addition, the lower boundary condition derived from the average of July measurements at Brenton's Reef (31) was changed arbitrarily from 18.5 to 19.5°C and this result is also shown in Figure 6.1.

It is quite clear that the model grid predictions are between 1.0°C and 2°C too low.

C.2. Newport, Rhode Island

The Newport Data (41) as presented in Table 6.1 shows reasonable agreement with data.

DATE	TIME	MEASURED	MODEL
July 16	11:30	20.0°C	19.85°C
July 17	11:30	20.0°C	19.90°C
July 18	14:10	21.67°C	20.20°C

(Table Continued)

DATE	TIME	MEASURED	MODEL
Monthly Average	Morning	20.1°C	20.0°C

TABLE 6.1. NEWPORT TEMPERATURE DATA, (41) GRID LOCATION n = 15, m = 40

C.3. Bay Data

Hicks (37) undertook Cruise III between July 15 to July 19, 1957 with a total of 19 stations around the bay. In most cases at least four depth measurements were taken at each station and the average of these was used as a comparison with the model as shown in Table 6.2.

The agreement is good for stations where the temperature in the water column is rather uniform. For the Rhode Island Sound station, where the bottom temperatures go as low as 15.3°C, 3.2°C cooler than any temperature in the bay thermal field, the average of measured values are about 0.5°C too low.

C.4. Meterological Data

The air temperature measurements taken at T.F. Green Airport (56) can be seen in Figure 6.2 and they show no extreme activity for this period. Although the monthly

VARIABLE NUMBER	CONDITIONS	VALUE
1	YEAR (YR)	57.
2	DAY	195.
3	THR (HOUR)	17.
4	TMIN (MINUTE)	48.
5	TMHOPE (Temperature Mt. Hope Bay)	21.75°C
6	TRIVER (Temperature of Rivers)	22.2°C
7	TSOUND (Temperature of R.I. Sound)	18.50°C
8	TBNB (Temperature Field)	21.0°C
9	IMODES (1-Upstream; 2-Central Differencing)	2
10	RDCNP (Temperature Read In, °C)	False
11	UPCON (Dispersion Coefficient Constant)	500 x Elder's Value/5.93
12	QIN (Source Flow Rate CFS, i.e. Power Plant)	0.0
13	TIN (Cooling Water Temperature Increase)	12°C
14	SITE (Power Plant Output and Input)	100 (Flow Out: n=5, m=36. Flow In: n=6, m=37)
15	Plotting Time	96 Hours
16	Program No.	12271
17	Date of Run	1/26/73

EXPERIMENTAL RUN 1 (NATURAL CONDITIONS FOR MODEL-MEASUREMENT COMPARISON WITH NO POWER PLANT EFFECTS)

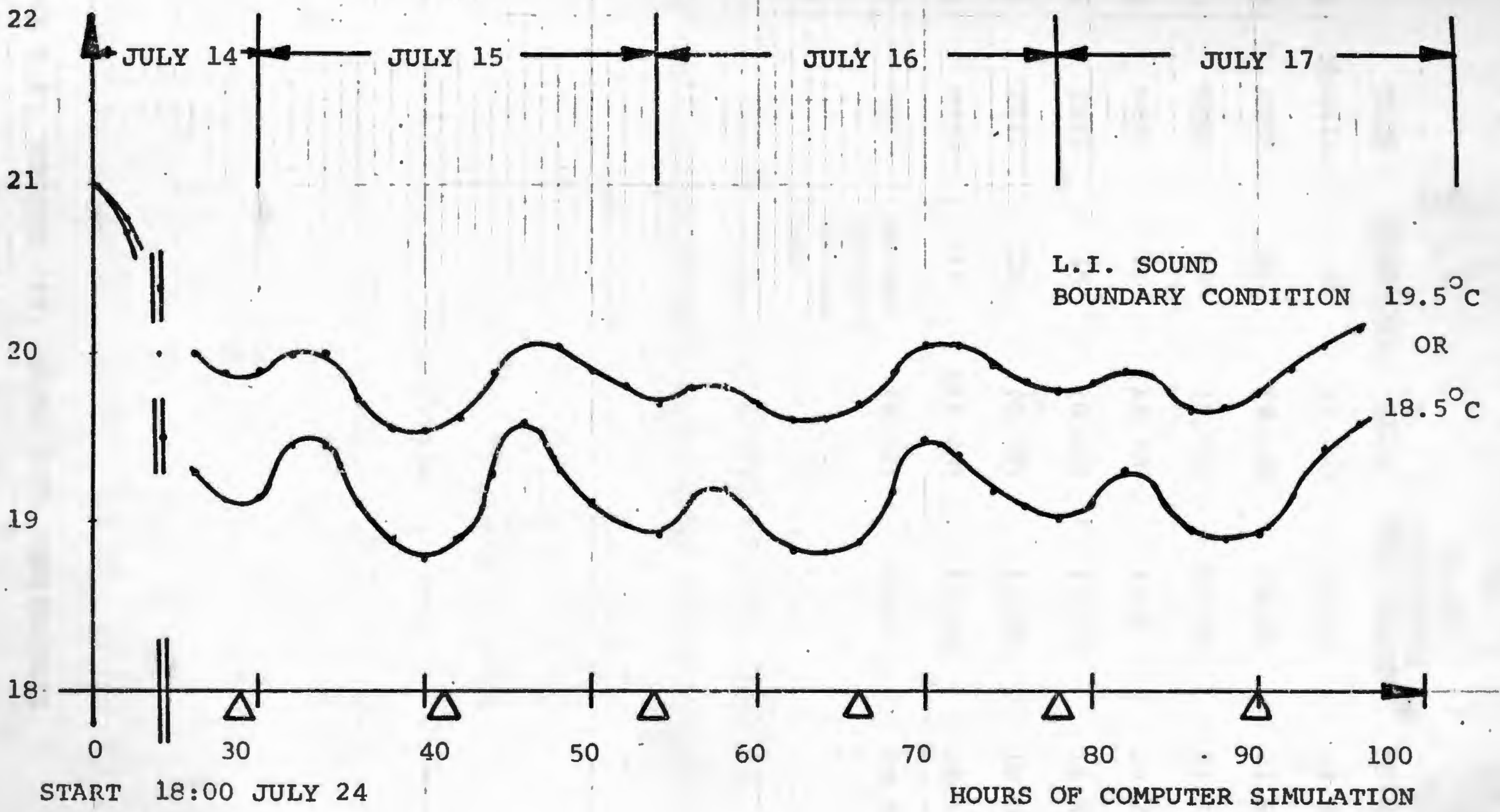


FIGURE 6.1. NARRAGANSETT MARINE LAB PIER LOCATION (8, 43)

DATE	TIME	STATION	GRID	°C DEPTH AVERAGED MEASUREMENT	°C MODEL
July 15	Morning	5	(3,21)	23.00	22.9
July 15	0855	10	(9,28)	21.40	21.8
July 15	0810	13	(8,33)	20.60	21.7
July 16	0850	14	(13,38)	18.5	20.2
July 16	1058	15	(8,41)	18.75	18.50
July 16	1012	16	(8,48)	17.90	18.50
July 16	0950	17	(12,48)	17.10	18.50
July 17	1445	Narragansett Marine Lab	(8,43)	21.0	19.50

TABLE 6.2. CRUISE III, HICKS (37) TEMPERATURE MEASUREMENTS

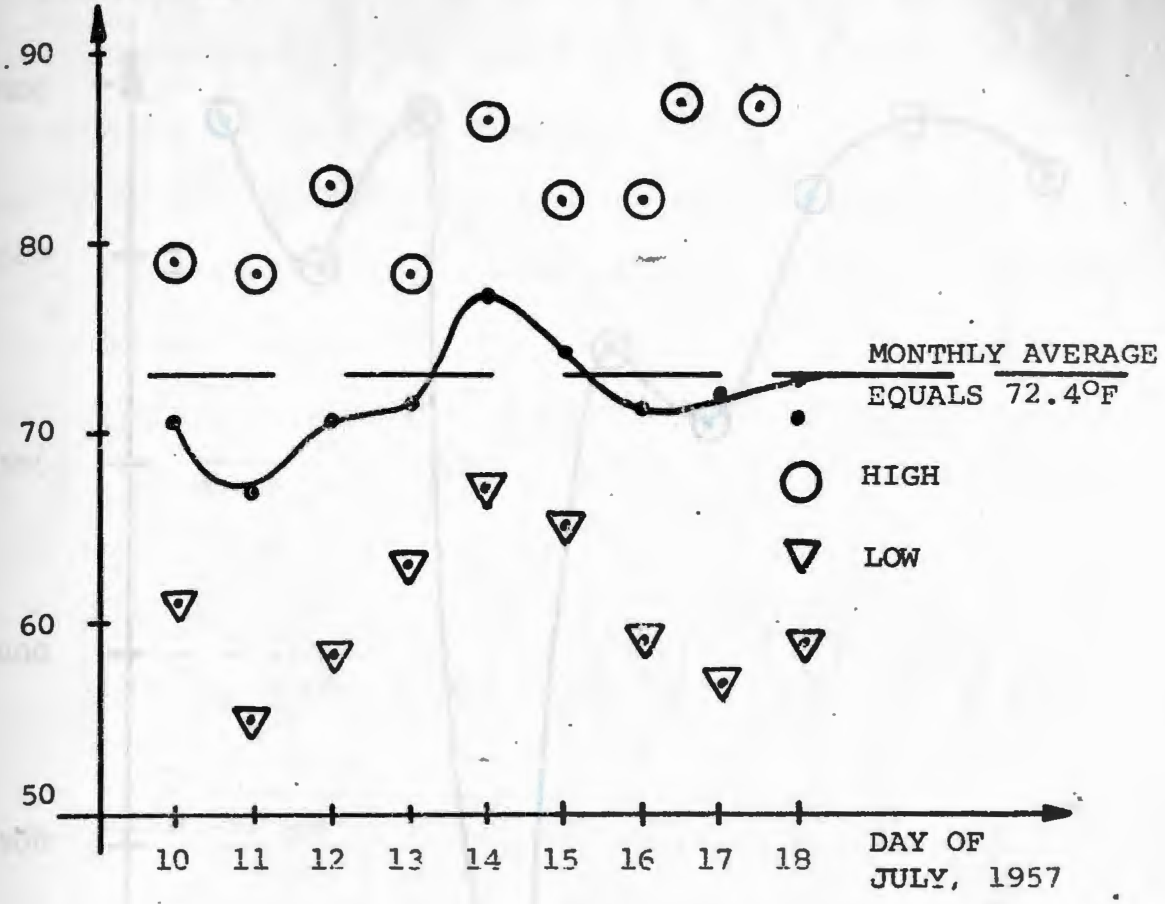


FIGURE 6.2. DAILY TEMPERATURE PATTERN AT T.F. GREEN AIRPORT (56)

average was 1.0°C above normal, wind speeds were in the 10-12 M.P.H. normal range and relative humidity was about 67 percent or within normal range for this measurement period.

Solar input, as recorded at the Eppley Laboratory, Newport, Rhode Island can be seen in Figure 6.3.

The solar input for this period is about 25 percent

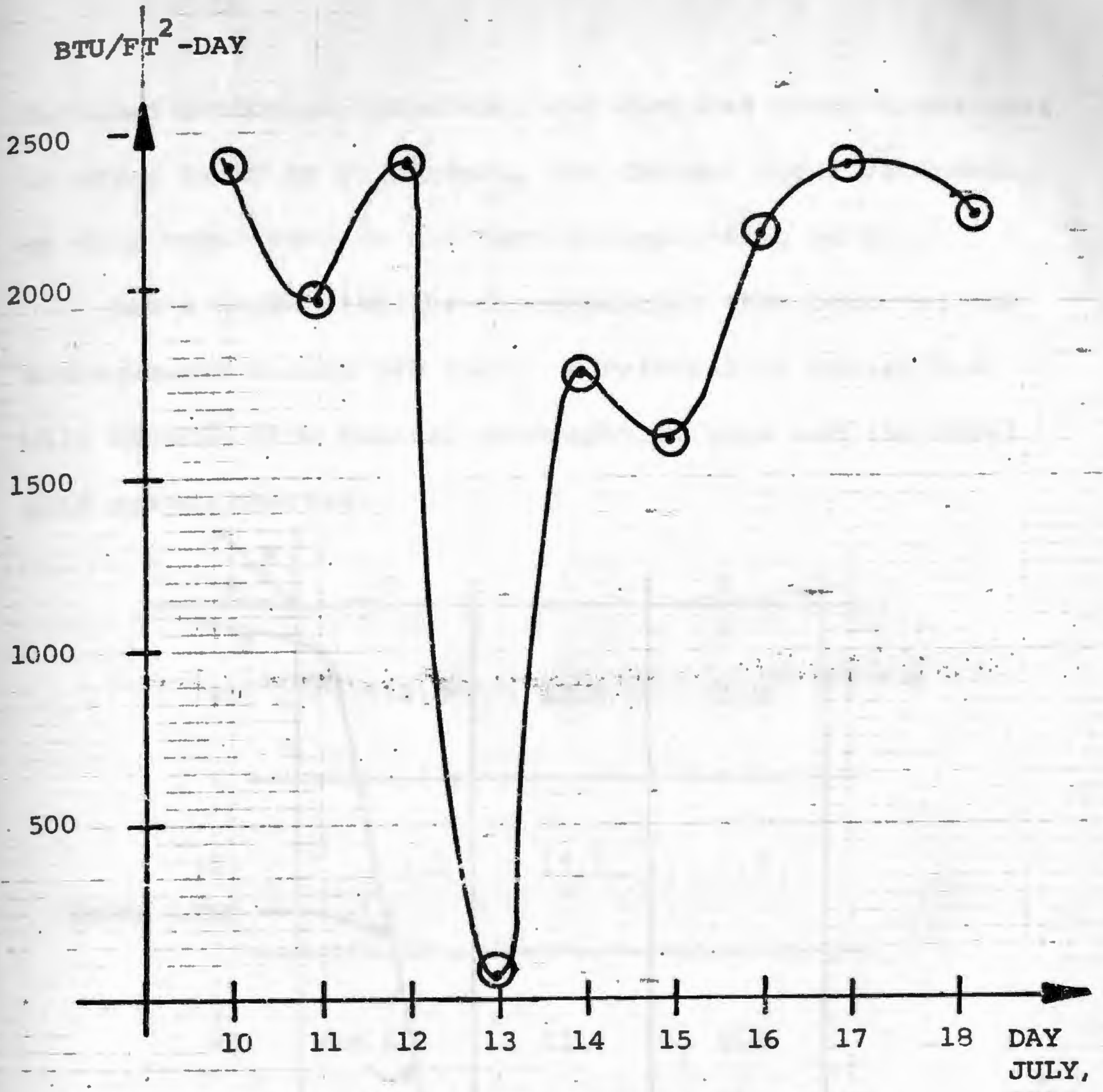


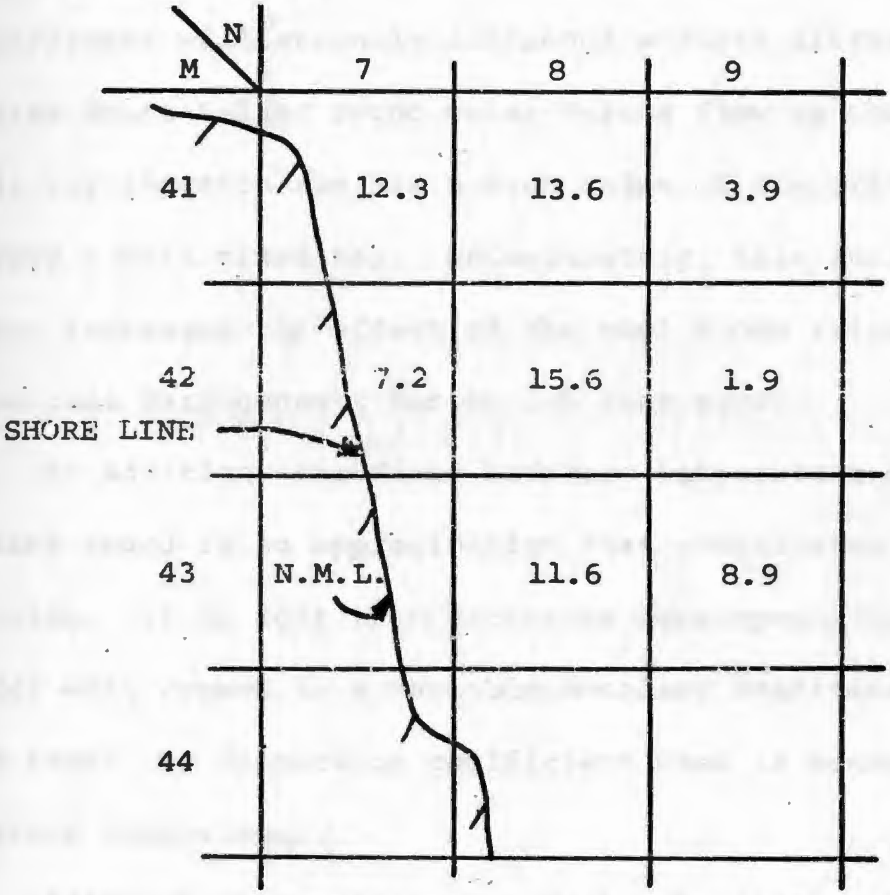
FIGURE 6.3. SOLAR INPUT, EPPLEY LABORATORY, NEWPORT, RHODE ISLAND

above the average monthly value of 1920 Btu/ft^2-day.

D. EVALUATIONS

With the discrepancies in the predicted versus actual values of water temperature, it is certainly not clear that this form of verification is realistic or profitable. With regard to Masch et al (57), where comparisons between detailed prototype, physical, and computer predictions were in error by 10 to 25 percent, the thermal model variances, of this magnitude, do not seem disappointing at all.

Let's begin with the discrepancies that occur at the Narragansett Marine Lab Pier. A referral to Figure 6.4 will clearly show general geographical area and the model grid system overlay.



ALL DEPTHS IN YARDS

FIGURE 6.4. NARRAGANSETT MARINE LAB PIER, GENERAL LOCATION AND DEPTHS

The model can include grid (7,43) with a depth of 7.2 yards which would be a much better representation for the Narragansett Marine Lab than the originally chosen grid (8,43), with a depth of 15.6 yards. The temperatures in grid (7,42), directly north of a more desirable grid (7,43), averaged 0.5°C above those in grid (8,43). Since the proposed box would also be a corner box, the dispersion coefficient will strongly influence western diffusion of cooler Rhode Island Sound water during flow up the bay. This verification run has a high value of dispersion to insure a well mixed bay. Unfortunately, this inflated value increases the effect of the cool Rhode Island Sound flow past Narragansett Marine Lab Pier area.

In addition, the fixed boundary temperature for Rhode Island Sound is an approximation that complicates the prediction. It is felt that extensive development of the model with regard to a variable boundary condition for one tenth the dispersion coefficient used is necessary to improve comparison.

Although not certain, Dr. Hicks, by letter, has expressed a belief that the water temperature data at Marine Lab (38) was taken by a Bristol Recorder from a source at an unspecified depth below the surface and possibly flushed through a holding tank with a capacity of several hundred gallons. It is interesting to note that the temperature data obtained by Hicks (37) shows that temperature differences at Narragansett Marine Lab Pier between top and bottom water for the period February 1952 to January 1958 averages 0.2°C. Referring back to Day (38) we also observe that temperature variations of a 4°C during the day at Narragansett Marine Lab Pier appear to be larger than common sense tidal flushing estimates. In Figure 6.5, it is seen for July 9 and 13 that with low solar input, temperature maximum decreases about 0.5°C while minimum temperature is unaffected. It appears that with this low solar input, we should be able to estimate depth of the water column if the solar energy is considered evenly distributed. We have,

$$\text{Solar Input} = 2000\ \text{Btu/ft}^2\,\text{(half day)} \tag{6.1}$$

$$= \text{Mass} * C_p * DT \tag{6.2}$$

where $DT = .5^{\circ}\text{C}$

$$1000\ \frac{\text{Btu}}{\text{ft}^2\,\text{(full day)}} = \text{Depth} \times \text{Unit Area} \times 64\ \frac{\text{lb}_m}{\text{ft}^3} \times \frac{1\ \text{Btu}}{\text{lb}_m\,{}^{\circ}\text{F}} \times \frac{.9^{\circ}\text{F}}{\text{Day}} \tag{6.3}$$

after rearranging

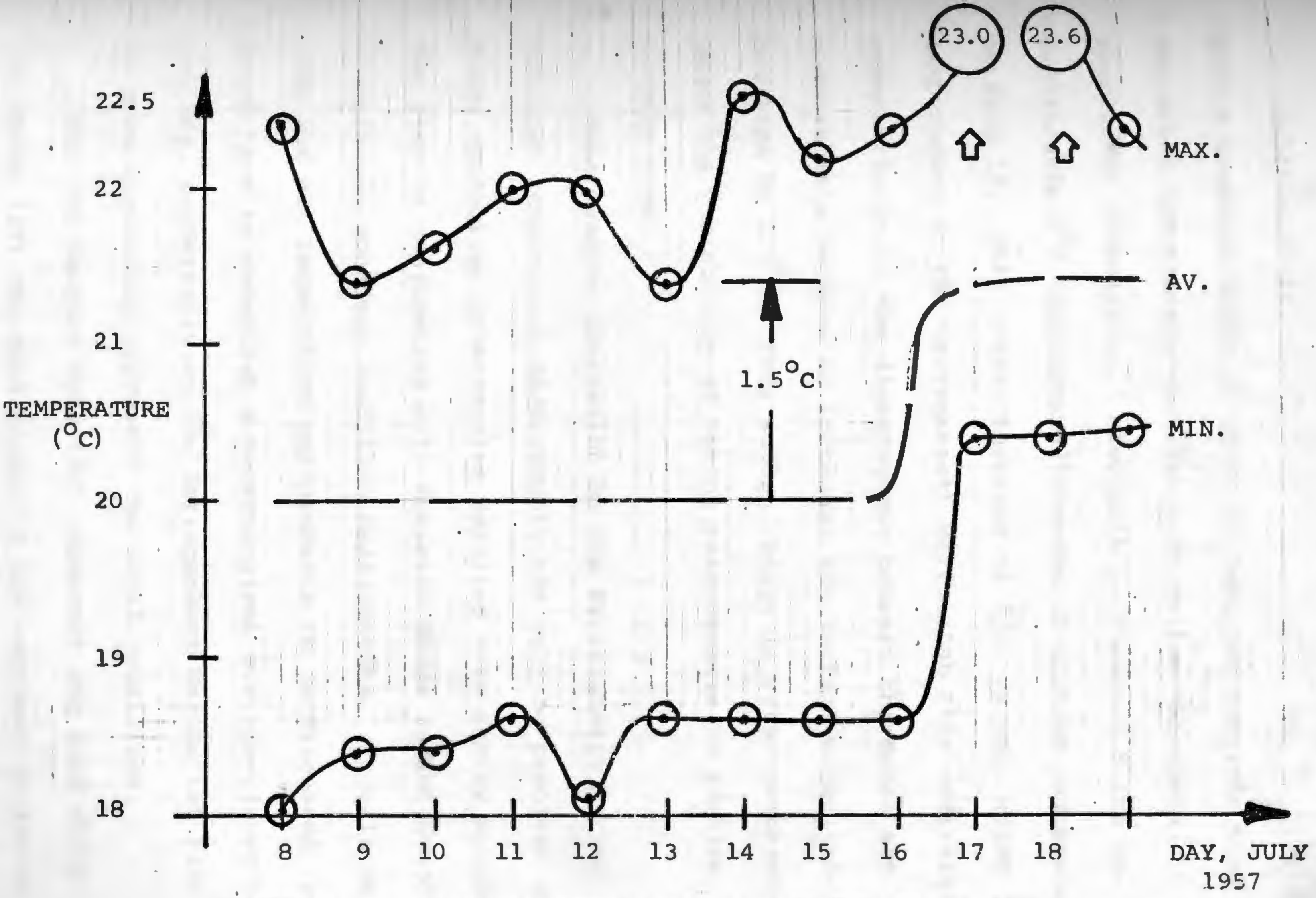


FIGURE 6.5. NARRAGANSETT MARINE LAB TEMPERATURES (38)

Depth = 20 ft (6.4)

With a measured depth of about 20 feet, we conclude that the water temperature variations do follow the above simplistic formulation. Also note in Figure 6.5 the unexplainable 2°C temperature increase of minimum temperature on July 17. This sudden increase of 2°C, in mean water temperature at the Narragansett Marine Lab Pier contributes substantially to the disagreement between the model and measurements because it increases the average water temperature by 1.5°C. This sudden change in water temperature shows the variability of taking measurements in shallow, inshore water.

This lengthy discussion on the Narragansett Marine Lab Pier temperature measurements can only be resolved by first conducting an extensive detailed area survey around the pier in conjunction with accurate Rhode Island Sound temperature boundary condition measurements. As will be true for all temperature measurements to be discussed, we would have to establish a meterological station closer to the bay, preferrably on the Narragansett Marine Lab Pier to more accurately represent the input conditions.

For the Newport Data (41) agreement was good while for Hicks (37) the data agreed if the vertical structure was homogenous. It should be noted that if the 15-16°C bottom water temperatures for Rhode Island Sound stations were not included in vertical average the agreement between predicted and actual values would be closer.

E. CONCLUSION

This attempt at thermal model verification with field measurements while enlightening for general temperature variation shows quite clearly how formidable a task it is to have grid locations agree with temperature measurements to a ±5 percent. Since the desired type of measurements for improved verification work would entail about 10 continuously operating data stations which are beyond the scope of department capability no further verification attempts were initiated. Dr. Eidinger (5) discusses the seemingly impossible task of the model verification with field measurements, an undertaking that no one has yet done successfully.

The lack of detailed model spatial agreement with measured temperature data should not detract from the information the model does predict of a more general nature.

VII. THERMAL MODEL PREDICTIONS

A. POWER PLANT LOCATION

The thermal model can place a heat source simulating an electric generating plant in any of the 314 non-boundary grids. The selection of the Rome Point area was made because the area is of local interest and the relative shallow water depth of 10 feet provides a good indication of the computational effectiveness of the model for a specific value of the dispersion coefficient. From a utility viewpoint, the surface discharge in the Rome Point grid, n = 5, m = 36, is inexpensive to construct and the land boundary at n = 6, m = 36 affords reentrainment protection from the intake grid located at n = 6, m = 37 or southeast of the intake.

The general geometry at the Rome Point site can be seen in Figure 7.1. The shaded area covers the most likely intake and discharge locations.

B. INTRODUCTION TO EXPERIMENTAL RUNS

The following experimental sections will contain various results that clearly show the effectiveness of the thermal model in predicting isothermal patterns around

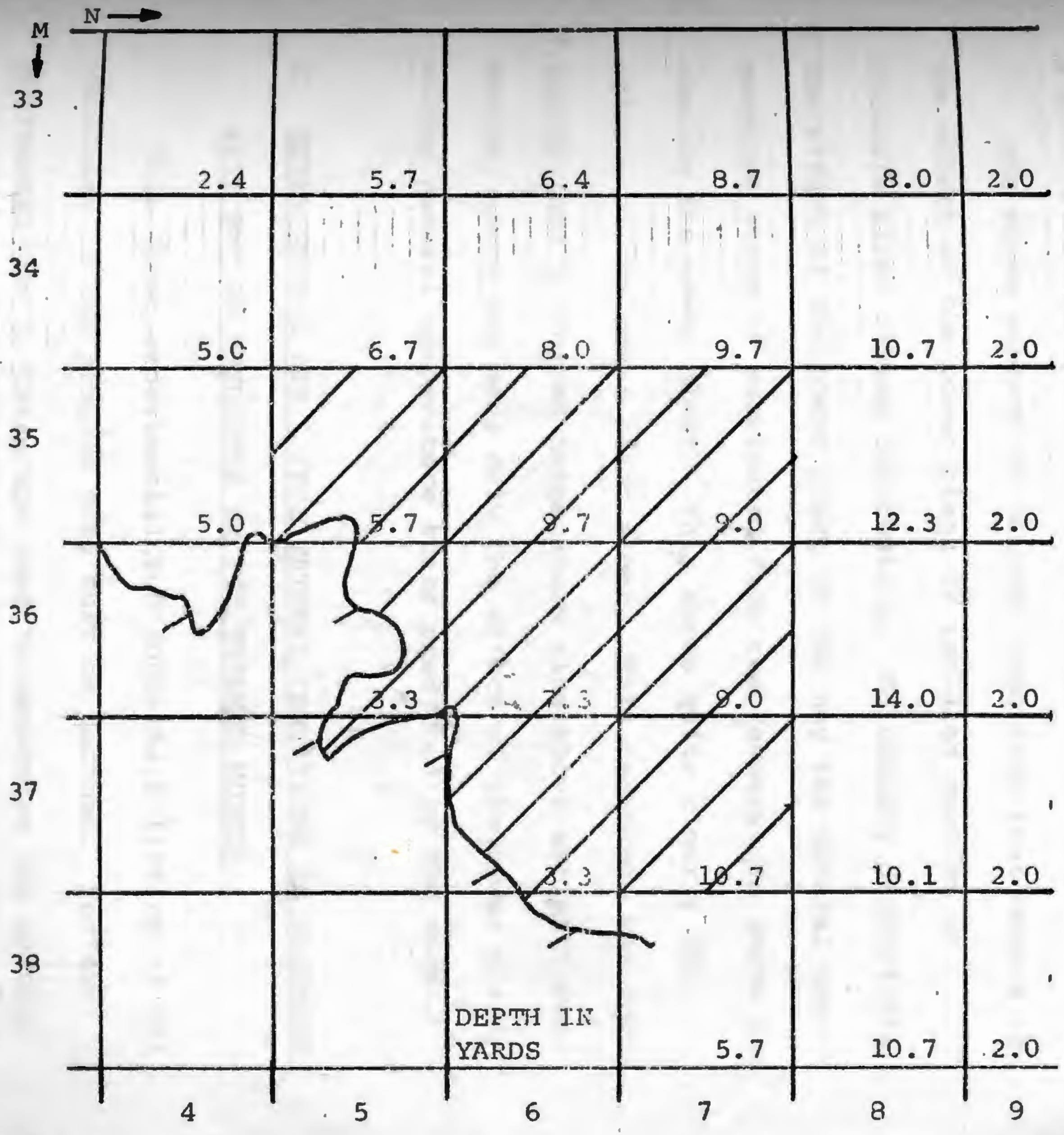


FIGURE 7.1. ROME POINT AREA WITH MODEL GRIDS, DISCHARGE LOCATIONS AND DEPTHS

a particular heat source. The natural or non-power plant predictions show the thermal patterns that can be measured in the bay. The natural plus power plant predictions are an indication of the thermal pattern that would occur with a power plant in operation for the specified data.

The above ambient or natural condition that occurs if the effect of the power plant is isolated results in valuable plant siting information. To clearly demonstrate the effect of the power plant on the bay the natural temperature state is subtracted from the temperature state including the power plant. This shows quite clearly the effects of the power plant alone. This technique was formulated into a 'forced temperature rise above ambient' condition, where one sees only the effect of the power plant on the natural temperature state predicted by the model.

C. EXPERIMENTAL RUN 1 (THE NATURAL CONDITIONS IN NARRAGANSETT BAY AS PREDICTED BY THE THERMAL MODEL)

This first experimental run contains a listing of all variables in the program that must be defined. For experimental run 1, these are used to determine the natural temperature condition that occurs from July 14 to July 18, 1957 with no heat source included. In an effort to simplify the discussion of the following experimental runs only the variables that are different from run 1 are listed.

TABLE 7.1. PROGRAM VARIABLES

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
1	YEAR	57.
2	DAY	195.
3	THR (HOUR)	17.
4	TMIN (MINUTE)	48.
5	TMHOPE (Temperature for the Mt. Hope Bay Boundary Condition, (B.C.))	21.75°C
6	TRIVER (Temperature for the River B.C.)	22.2°C
7	TSOUND (Temperature for the Rhode Island Sound B.C.)	18.50°C
8	TBNB (Temperature Field in the Bay)	21.0°C
9	IMODES (1-Upstream; 2-Central Differencing)	2
10	RDCNP (Temperature field read in, °C)	False

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
11	UPCON (Dispersion Coefficient Constant Times Elder's Value)	500
12	QIN (Source Flow Rate, cfs)	0.0
13	TIN (Cooling Water Temperature Increase Through Plant)	12.0°C
14	SITE (Power Plant Output and Input Grids Specified)	100 (Flow Out: n=5, m=36. Flow In: n=6, m=37)
15	DELTAT (Logical Variable. If true the model calculates forced temperature rise, if false it calculates natural condition with or without power plant	True
16	Plotting Time	68 Hours
17	Program Number	12271
18	Date of Run	1/26/73

C.1. Comments

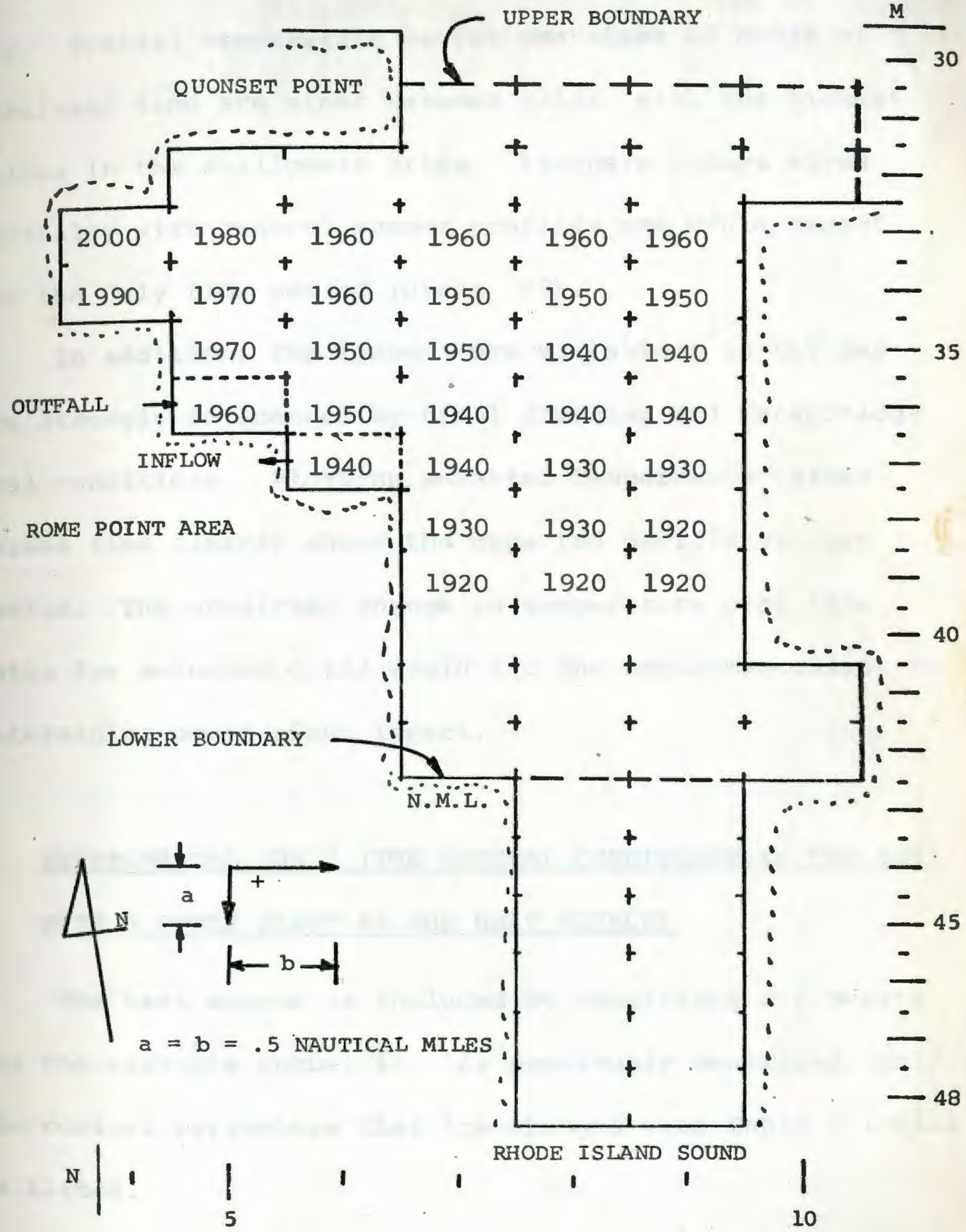
The temperature fields, as shown in Figure 7. and Figure 7.3, represent a typical display pattern. The relative similarity of isotherms with regard to shape and

```
AVERAGED TEMP. (DEGREES C TIMES 1000)  FOR TIMESTEP  1020 AT TIME =  68.00 HRS

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19
  1       0     0 22199 22199     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  2       0     0 22633 22412     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  3       0     0 22468 22421     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  4       0 22057 22054     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  5       0 22036 21998     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  6       0     0 21936 21862     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  7       0     0     0 21806 21758     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  8       0     0     0 21781 21718     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  9       0     0     0 21793 21677 21609     0     0     0     0     0     0     0     0     0     0     0     0     0
 10       0     0     0 22199 21649 21602     0     0     0     0     0     0     0     0     0     0     0     0     0
 11       0     0     0 22199 21623 21592     0     0     0     0     0     0     0     0     0     0     0     0     0
 12       0     0     0     0     0 21548 21526 21616     0     0     0     0     0     0     0     0     0     0     0
 13       0     0     0     0     0 21521 21488 21465     0     0     0     0     0     0     0     0     0     0     0
 14       0     0     0     0     0 21493 21445 21410 21373 21354 21381 21465     0     0     0     0     0     0     0
 15       0     0     0     0     0     0 21424 21376 21321 21279 21282 21302     0     0     0     0     0     0     0
 16       0     0     0     0     0     0     0 21346 21242 21195 21206 21238 21209     0     0     0     0     0     0
 17       0     0     0     0     0     0     0 21231 21089 21062 21157 21180 21164     0     0     0     0     0     0
 18       0     0     0     0     0     0     0 21064 20934 20925 21082 21136 21137     0     0     0     0     0     0
 19       0     0     0     0     0     0     0 20912 20889 20915 21002 21100 21109     0     0     0     0     0     0
 20       0 21612 21500 21495 21481     0     0 20805 20831 20874 20975 21071 21048     0 21722 21448     0     0     0
 21       0 21421 21288 21218 21118 20775     0 20696 20769 20828 20995 21057 21016     0 21201 21262 21308     0     0
 22       0 21471 21318 21167 21023 20701 20570 20627 20710     0 21045 21028 20982 20938 20972 21187 21322     0     0
 23       0     0     0     0 20902 20588 20540 20569     0     0     0 21009 20944 20878 20842     0 21390 21576 21750
 24       0     0     0     0 20750 20554 20459 20447 20292     0     0 20980 20891 20816 20751 20784 21105 21307 21750
 25       0     0     0     0     0 20473 20387 20342 20235 20136     0     0     0 20750 20658 20605 20930     0     0
 26       0     0     0     0     0 20406 20304 20242 20160 20075 20001 19955     0     0 20460 20499 20686     0     0
 27       0     0     0     0     0 20312 20212 20161 20088 20004 19941 19883     0     0 20261 20327 20509     0     0
 28       0     0     0     0     0 20186 20115 20066 20018 19920 19859 19808     0     0 20131 20209 20342     0     0
 29       0     0     0     0     0 20094 20022 19962 19919 19852 19805 19739     0     0 20014 20079 20176     0     0
 30       0     0     0     0     0     0 19910 19872 19832 19780 19732 19678     0     0 19899 19940 19954     0     0
 31       0     0     0     0     0     0 19778 19756 19752 19715 19676 19616 19548 19600 19741 19815 19884     0     0
 32       0     0     0     0 19949 19671 19701 19674 19661 19671 19605 19548 19509 19573 19640 19713     0     0     0
 33       0     0     0 19936 19802 19585 19605 19582 19595     0 19544 19478 19444 19500 19553 19608     0     0     0
 34       0     0     0 19832 19727 19543 19533 19495 19504     0 19465 19411 19382 19422 19461     0     0     0     0
 35       0     0     0     0 19668 19511 19466 19424 19426     0     0 19324 19292 19350 19409     0     0     0     0
 36       0     0     0     0 19602 19488 19418 19365 19349     0     0 19252 19217 19276 19335     0     0     0     0
 37       0     0     0     0     0 19434 19364 19304 19279     0     0 19177 19177 19208 19262     0     0     0     0
 38       0     0     0     0     0     0 19309 19242 19214     0     0 19130 19126 19108     0     0     0     0     0
 39       0     0     0     0     0     0 19220 19182 19157     0     0 19091 19069 19042     0     0     0     0     0
 40       0     0     0     0     0     0 19128 19135 19108     0     0     0 19008 18997 18941     0     0     0     0
 41       0     0     0     0     0     0 19076 19084 19065 19057     0     0 18960 18926 18915     0     0     0     0
 42       0     0     0     0     0     0 19029 18999 18959 19025     0     0 18864 18886 18897     0     0     0     0
 43       0     0     0     0     0     0     0 18941 18895     0     0     0 18806 18850 18864     0     0     0     0
 44       0     0     0     0     0     0     0 18877 18824     0     0 18721 18760 18799     0     0     0     0     0
 45       0     0     0     0     0     0     0 18756 18738     0 18648 18663 18715     0     0     0     0     0     0
 46       0     0     0     0     0     0     0 18660 18650     0 18625 18623 18624     0     0     0     0     0     0
 47       0     0     0     0     0     0     0 18572 18573     0 18545 18568 18565     0     0     0     0     0     0
 48       0     0     0     0     0     0     0 18500 18500     0 18500 18500 18500     0     0     0     0     0     0
```

FIGURE 7.2. RUN 1 BAY TEMPERATURE AT 68 HOURS

Given: Q = 2000 cfs, TIN = 0.0°C



ALL TEMPERATURES °C x 100

FIGURE 7.3. RUN 1, NATURAL THERMAL FIELD AT 68 HOURS NEAR OUTFALL

position reveal important thermal characteristics of the bay. Spatial temperature variations after 68 hours of simulated time are minor between grids, with the highest values in the shallowest grids. Isotherm values agree spatially with general summer profiles one would expect for the July time period (Hicks, 58).

In addition, the temperature variations in the bay are strongly influenced by tidal flushing and meteorological conditions. Plotting selected temperature values versus time clearly shows the expected oscillatory behavior. The predicted change in temperature over time ratio for selected grids would aid the environmentalist in determining power plant impact.

D. EXPERIMENTAL RUN 2 (THE NATURAL CONDITIONS IN THE BAY WITH A POWER PLANT AS THE HEAT SOURCE)

The heat source is included by specifying a flowrate for the variable number 12. As previously mentioned, only the control parameters that are changed from Table 7.1 will be listed.

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
12	QIN (Source Flow Rate cfs)	2000

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
17	Program Number	11770
18	Date of Run	1/25/73

D.1. Comments

A typical model predicted heat source distribution in the natural environment can be seen in Figure 7.4. If one subtracts the natural conditions shown in Figure 7.3 from the power plant condition in Figure 7.4 one then obtains Figure 7.5 which shows the forced temperature rise resulting from the heat source in the model.

E. EXPERIMENTAL RUN 3 (THIS PREDICTS ONLY THE TEMPERATURE INCREASE DUE TO HEAT LOAD FROM A POWER PLANT OR FORCED TEMPERATURE RISE)

This run calculates only temperature excess above natural conditions by the variable changes listed below. If the formulation is correct, the thermal field prediction for run 3 should equal the difference in thermal fields between runs 2 and 1.

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
5	TMHOPE (Temperature Mt. Hope Bay)	0.00°C
6	TRIVER (Temperature of all Rivers)	0.00°C
7	TSOUND (Temperature for the Rhode Island Sound)	0.00°C
8	TBNB (Temperature Field in the Bay)	0.00°C
12	QIN (Source Flow Rate, cfs)	2000
15	DELTAT (Logical Variable. If true the model calculates forced temperature rise, if false it calculates natural conditions with or without power plant)	True

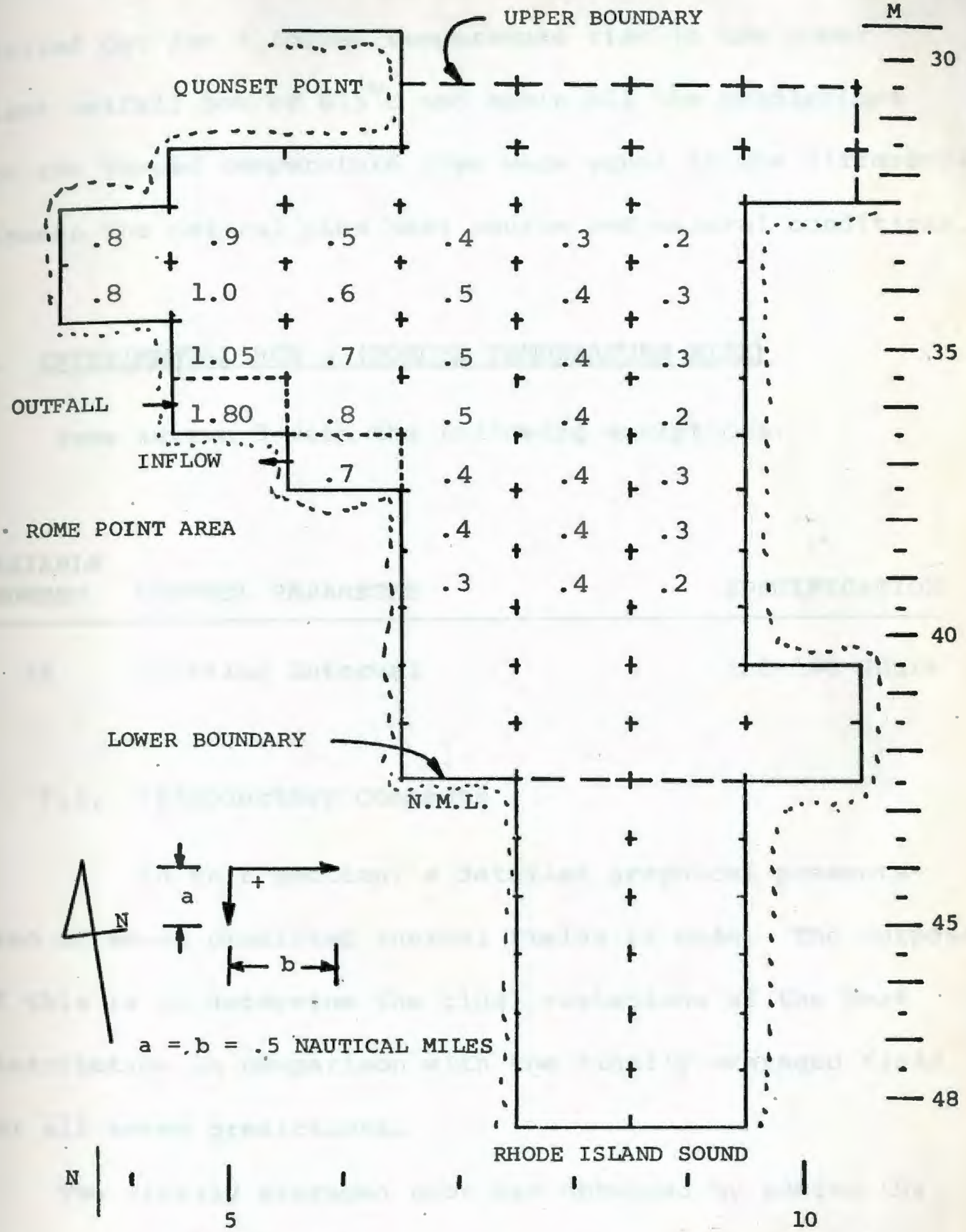
E.1. Comments

Figure 7.6 shows the result of the forced temperature rise without the natural conditions included. These values are nearly identical to Figure 7.5 and serve to prove the correctness of the forced temperature rise formulation in run 3.

```
AVERAGED TEMP. (DEGREES C TIMES 1000)  FOR TIMESTEP  1020 AT TIME =  68.00 HRS
        1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19
  1     0     0 22199 22199     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  2     0     0 22586 22362     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  3     0     0 22426 22375     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  4     0 22027 22324     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  5     0 22007 21970     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  6     0     0 21911 21840     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  7     0     0     0 21787 21742     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  8     0     0     0 21764 21705     0     0     0     0     0     0     0     0     0     0     0     0     0     0
  9     0     0     0 21760 21667 21602     0     0     0     0     0     0     0     0     0     0     0     0     0
 10     0     0     0 22199 21642 21598     0     0     0     0     0     0     0     0     0     0     0     0     0
 11     0     0     0 22199 21618 21590     0     0     0     0     0     0     0     0     0     0     0     0     0
 12     0     0     0     0     0 21550 21530 21625     0     0     0     0     0     0     0     0     0     0     0
 13     0     0     0     0     0 21526 21496 21478     0     0     0     0     0     0     0     0     0     0     0
 14     0     0     0     0     0 21502 21458 21427 21393 21377 21406 21486     0     0     0     0     0     0     0
 15     0     0     0     0     0     0 21440 21395 21345 21306 21309 21327     0     0     0     0     0     0     0
 16     0     0     0     0     0     0     0 21372 21273 21229 21233 21264 21232     0     0     0     0     0     0
 17     0     0     0     0     0     0     0 21271 21133 21106 21191 21207 21189     0     0     0     0     0     0
 18     0     0     0     0     0     0     0 21119 20988 20980 21122 21164 21162     0     0     0     0     0     0
 19     0     0     0     0     0     0     0 20981 20947 20971 21049 21129 21132     0     0     0     0     0     0
 20     0 21644 21545 21553 21555     0     0 20884 20901 20937 21025 21097 21070     0 21720 21448     0     0     0
 21     0 21460 21342 21286 21203 20884     0 20789 20850 20899 21039 21081 21036     0 21206 21265 21311     0     0
 22     0 21514 21376 21243 21115 20815 20682 20729 20800     0 21076 21050 21000 20953 20981 21191 21325     0     0
 23     0     0     0     0 21010 20714 20658 20680     0     0     0 21027 20959 20892 20853     0 21394 21578 21750
 24     0     0     0     0 20872 20683 20595 20574 20433     0     0 20794 20905 20829 20764 20794 21112 21313 21750
 25     0     0     0     0     0 20618 20535 20435 20383 20282     0     0     0 20762 20671 20617 20939     0     0
 26     0     0     0     0     0 20562 20466 20400 20314 20223 20129 20074     0     0 20474 20513 20697     0     0
 27     0     0     0     0     0 20495 20393 20331 20249 20151 20076 19999     0     0 20276 20341 20522     0     0
 28     0     0     0     0     0 20398 20321 20253 20190 20065 19987 19915     0     0 20147 20225 20356     0     0
 29     0     0     0     0     0 20320 20251 20174 20109 19992 19928 19838     0     0 20031 20096 20192     0     0
 30     0     0     0     0     0     0 20174 20102 20023 19922 19850 19767     0     0 19917 19958 19971     0     0
 31     0     0     0     0     0     0 20083 20014 19945 19863 19784 19696 19587 19624 19761 19834 19902     0     0
 32     0     0     0     0 20615 20066 20036 19949 19867 19813 19701 19618 19549 19596 19661 19733     0     0     0
 33     0     0     0 20768 20661 20100 19993 19684 19329     0 19623 19535 19474 19523 19580 19629     0     0     0
 34     0     0     0 20727 20726 20164 19970 19615 19768     0 19524 19456 19410 19444 19482     0     0     0     0
 35     0     0     0     0 20816 20244 19951 19767 19710     0     0 19359 19315 19371 19430     0     0     0     0
 36     0     0     0     0 21360 20315 19911 19731 19547     0     0 19279 19233 19296 19355     0     0     0     0
 37     0     0     0     0     0 20106 19837 19674 19584     0     0 19197 19195 19225 19231     0     0     0     0
 38     0     0     0     0     0     0 19731 19579 19496     0     0 19146 19142 19123     0     0     0     0     0
 39     0     0     0     0     0     0 19552 19479 19412     0     0 19106 19083 19056     0     0     0     0     0
 40     0     0     0     0     0     0 19393 19402 19336     0     0     0 19020 19008 18951     0     0     0     0
 41     0     0     0     0     0     0 19330 19317 19272 19221     0     0 18971 18936 18924     0     0     0     0
 42     0     0     0     0     0     0 19227 19184 19114 19169     0     0 18872 18895 18906     0     0     0     0
 43     0     0     0     0     0     0     0 19101 19027     0     0     0 18813 18857 18871     0     0     0     0
 44     0     0     0     0     0     0     0 19010 18929     0     0 18726 18766 18806     0     0     0     0     0
 45     0     0     0     0     0     0     0 18839 18815     0 18651 18667 18720     0     0     0     0     0     0
 46     0     0     0     0     0     0     0 18709 18693     0 18627 18625 18627     0     0     0     0     0     0
 47     0     0     0     0     0     0     0 18596 18596     0 18545 18569 18566     0     0     0     0     0     0
 48     0     0     0     0     0     0     0 18500 18500     0 18500 18500 18500     0     0     0     0     0     0
```

FIGURE 7.4. RUN 2 THERMAL FIELD WITH HEAT SOURCE AT 68 HOURS FOR NARRAGANSETT BAY

Given: $Q = 2000$ cfs, $TIN = 12.0^{\circ}C$



ALL TEMPERATURES °C

FIGURE 7.5. FORCED TEMPERATURE RISE FROM RUNS 1 AND 2

The same procedure indicated for runs 1 through 3 was carried out for a forced temperature rise in the power plant outfall box of 6.5°C and again all the predictions for the forced temperature rise were equal to the difference between the natural plus heat source and natural conditions.

F. EXPERIMENTAL RUN 4 (FORCED TEMPERATURE RISE)

Same as run 3 with the following exceptions:

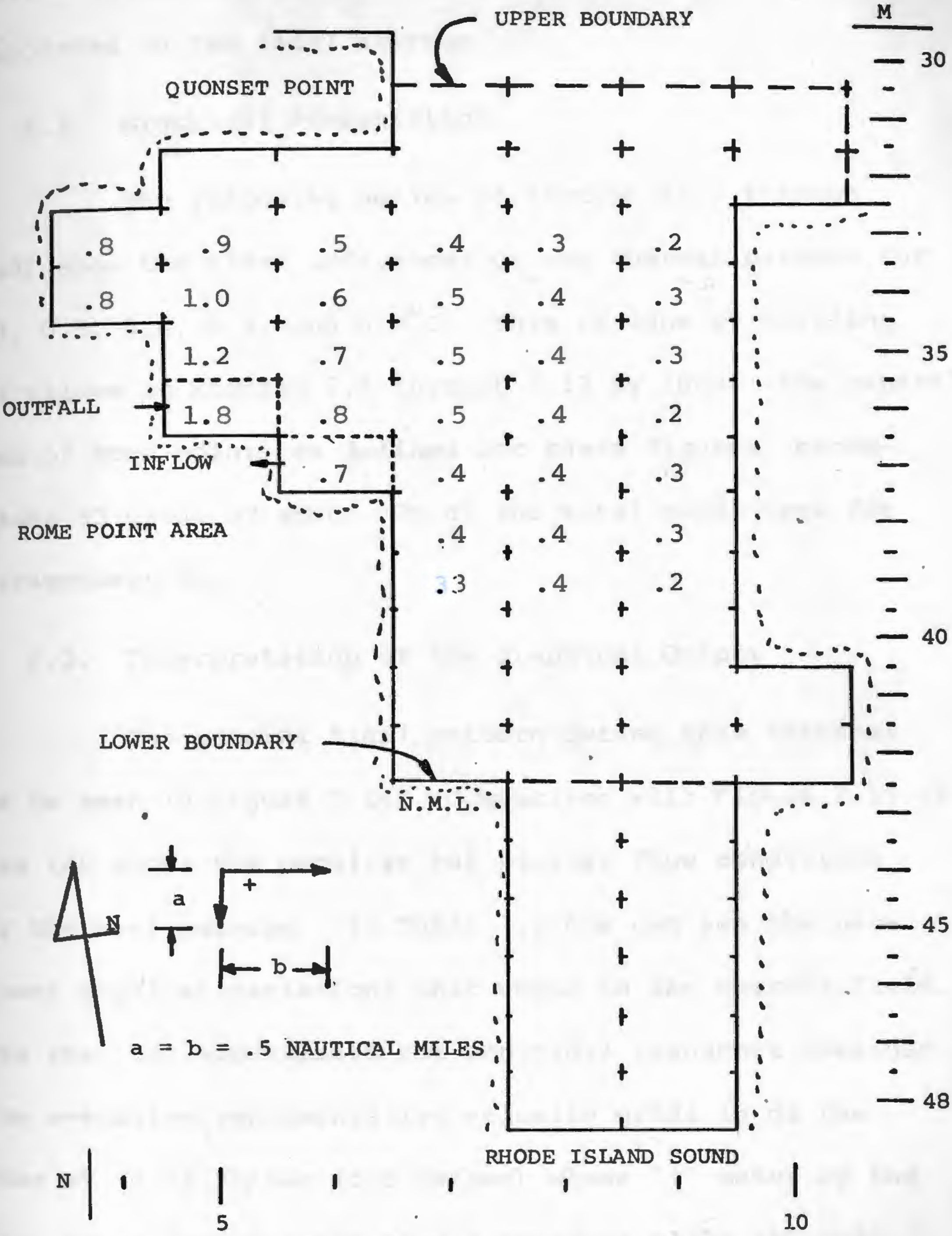
VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
16	Plotting Interval	128-140 Hours

F.1. Introductory Comments

In this section, a detailed graphical presentation of seven predicted thermal fields is made. The purpose of this is to determine the tidal variations of the heat distribution in comparison with the tidally averaged field for all seven predictions.

The tidally averaged plot was obtained by adding the values at 130, 132, 134, 136, and 138 hours to one half the values at 128 and 140 hours and dividing by six. This weighting procedure was chosen because it allowed the

Given: QIN = 2000 cfs, TIN = 12°C



ALL TEMPERATURES °C

FIGURE 7.6. FORCED TEMPERATURE RISE FROM RUN 3

desired velocity profile, shown in Figure 7.15, to be incorporated in the tidal average.

F.2. Graphical Presentation

The following series of figures (7.7 through 7.14) show the tidal influences on the thermal pattern for 1.0, 0.5, 0.4, 0.3, and 0.2°C. This is done by dividing all values in Figures 7.6 through 7.13 by 1000. The general area of Rome Point, as defined for these figures, encompasses 53 grids or about 17% of the total model area for Narragansett Bay.

F.3. Interpretation of the Graphical Output

The general tidal pattern during this interval can be seen in Figure 7.14. Comparison with Figure 7.15 of Hess (4) shows the peculiar but similar flow conditions for the west passage. In Table 7.1 one can see the pertinent physical variations that occur in the thermal field. Note that the approximate net non-tidal transport obtained from averaging representative velocity grids is of the order of +0.02 ft/sec (o.6 cm/sec) where "+" means up the bay. For a length scale of 3.5 nautical miles it would take a heated particle from Rome Point roughly two weeks to pass out of the Rome Point area if we assumed a net

Given: QIN = 2000 cfs, TIN = 12°C

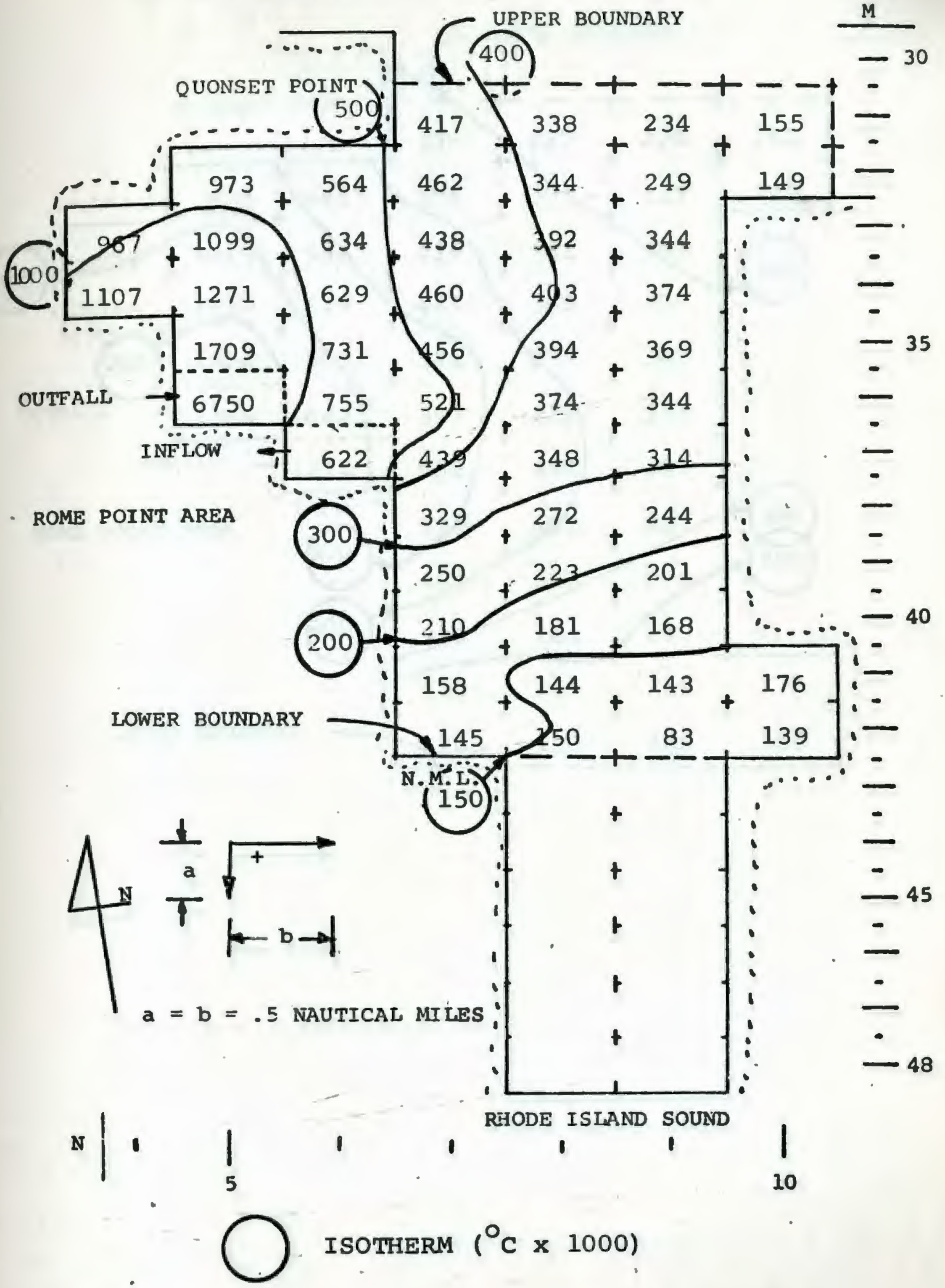


FIGURE 7.7. RUN 4, THERMAL FIELD AT 128 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

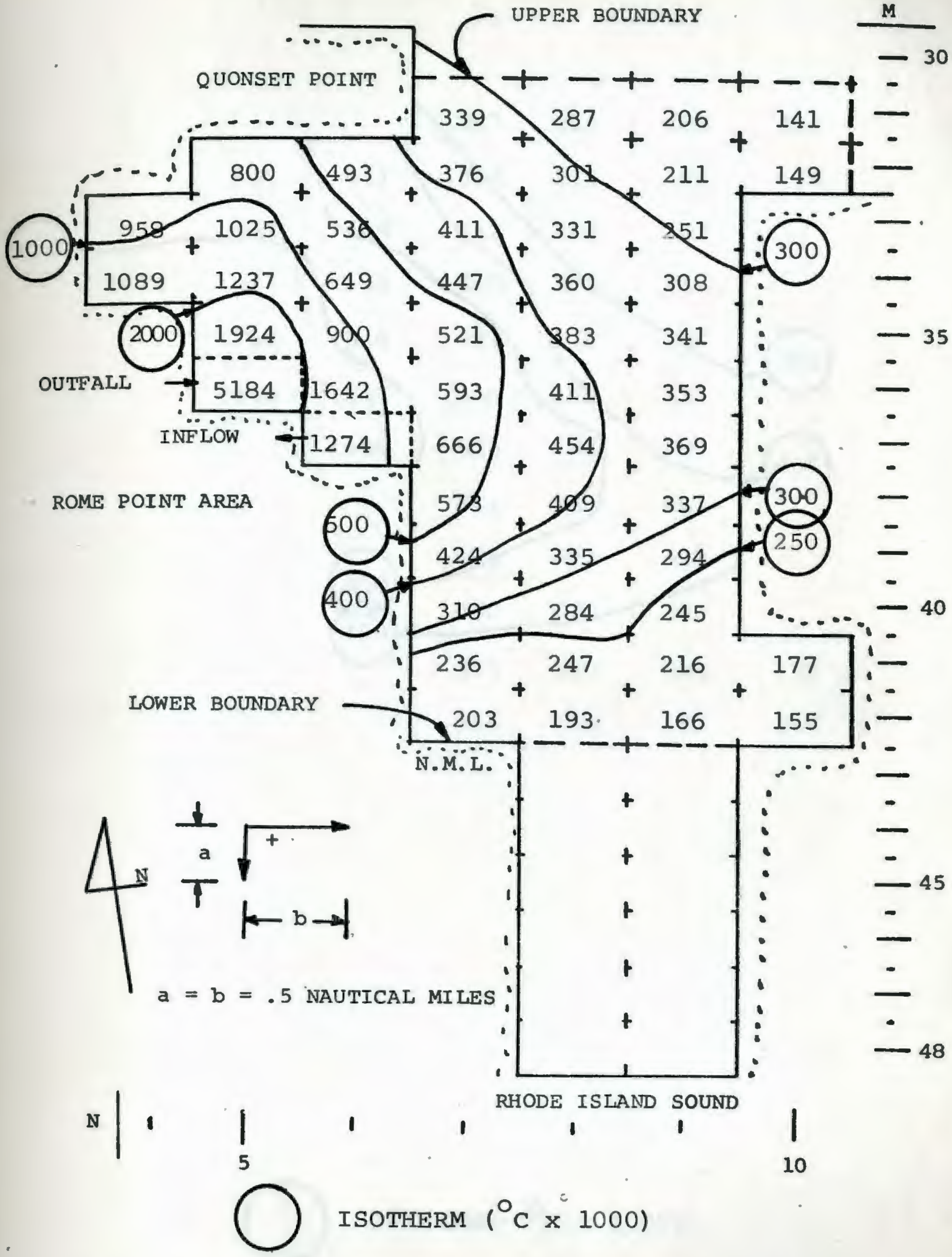


FIGURE 7.8. RUN 4, THERMAL FIELD AT 130 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

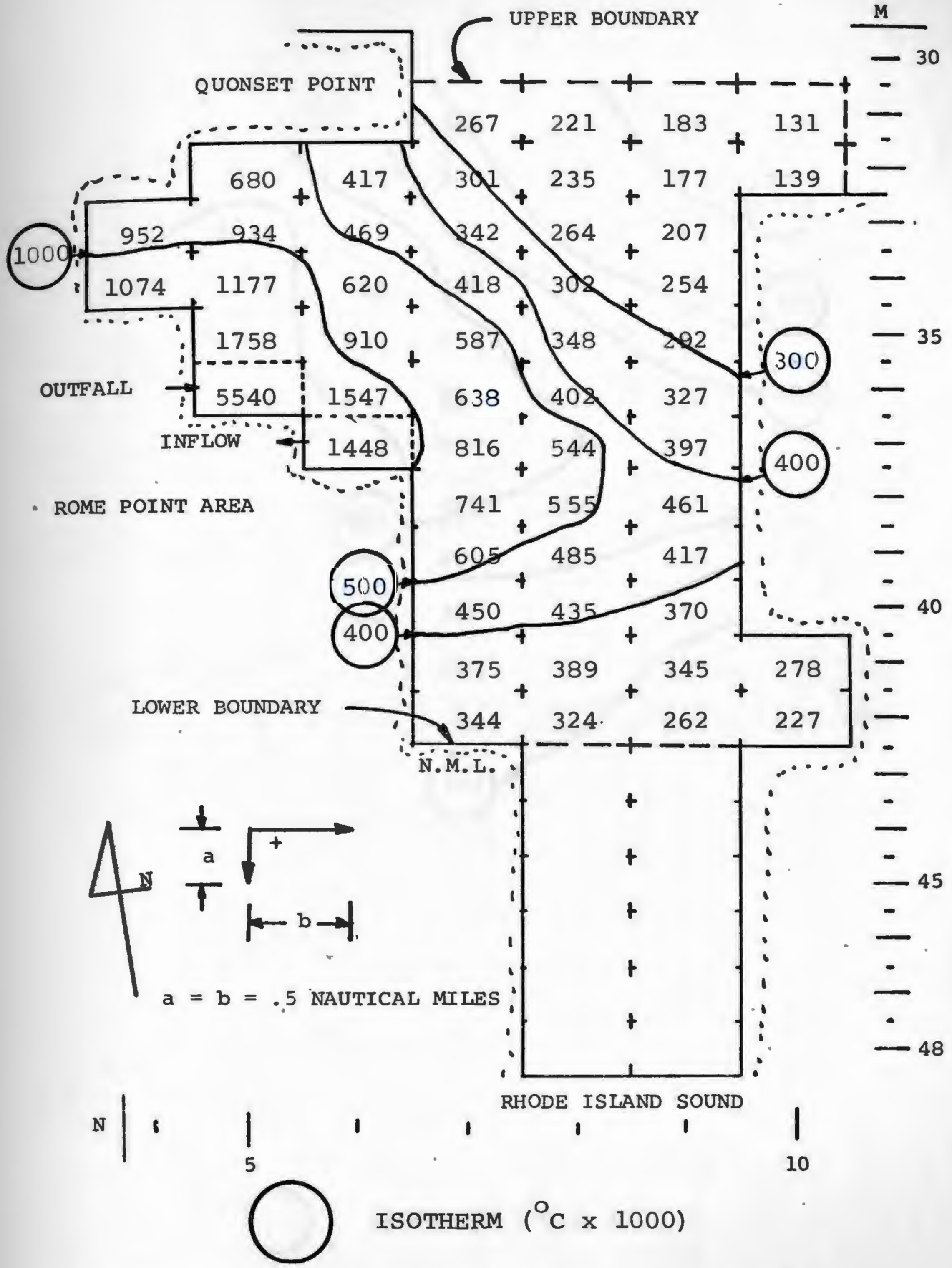


FIGURE 7.9. RUN 4, THERMAL FIELD AT 132 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

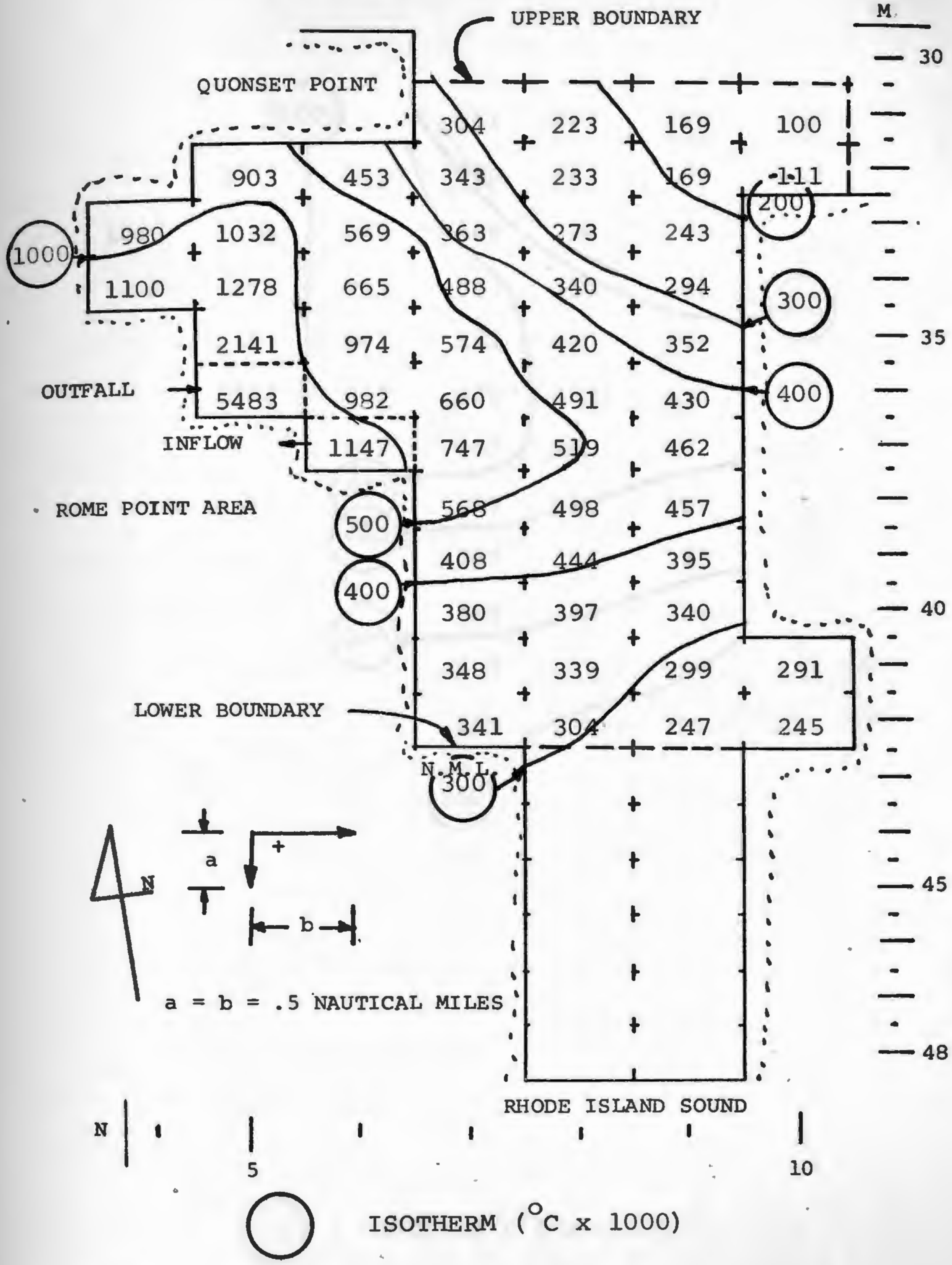


FIGURE 7.10. RUN 4, THERMAL FIELD AT 134 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

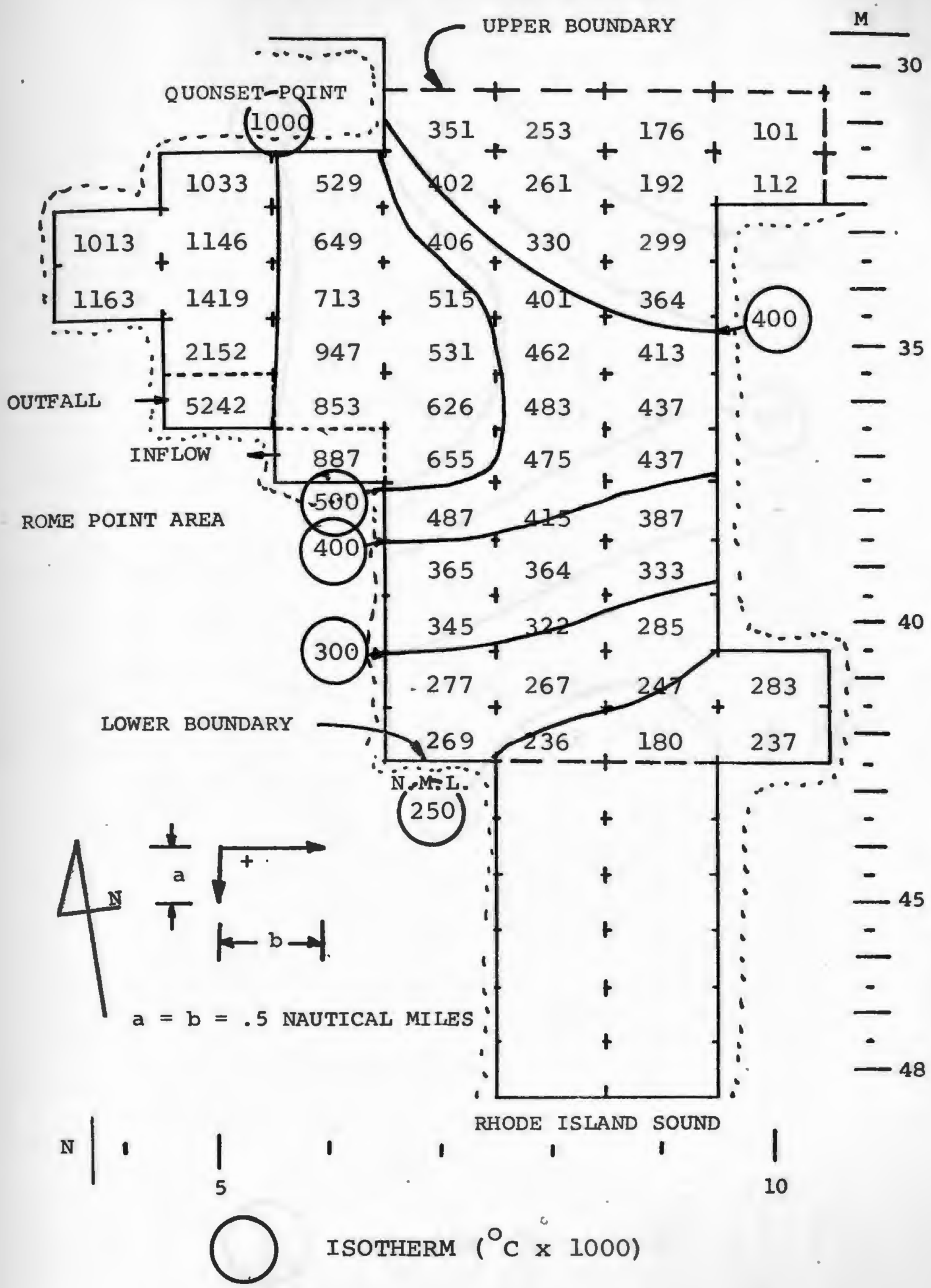


FIGURE 7.11. RUN 4, THERMAL FIELD AT 136 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

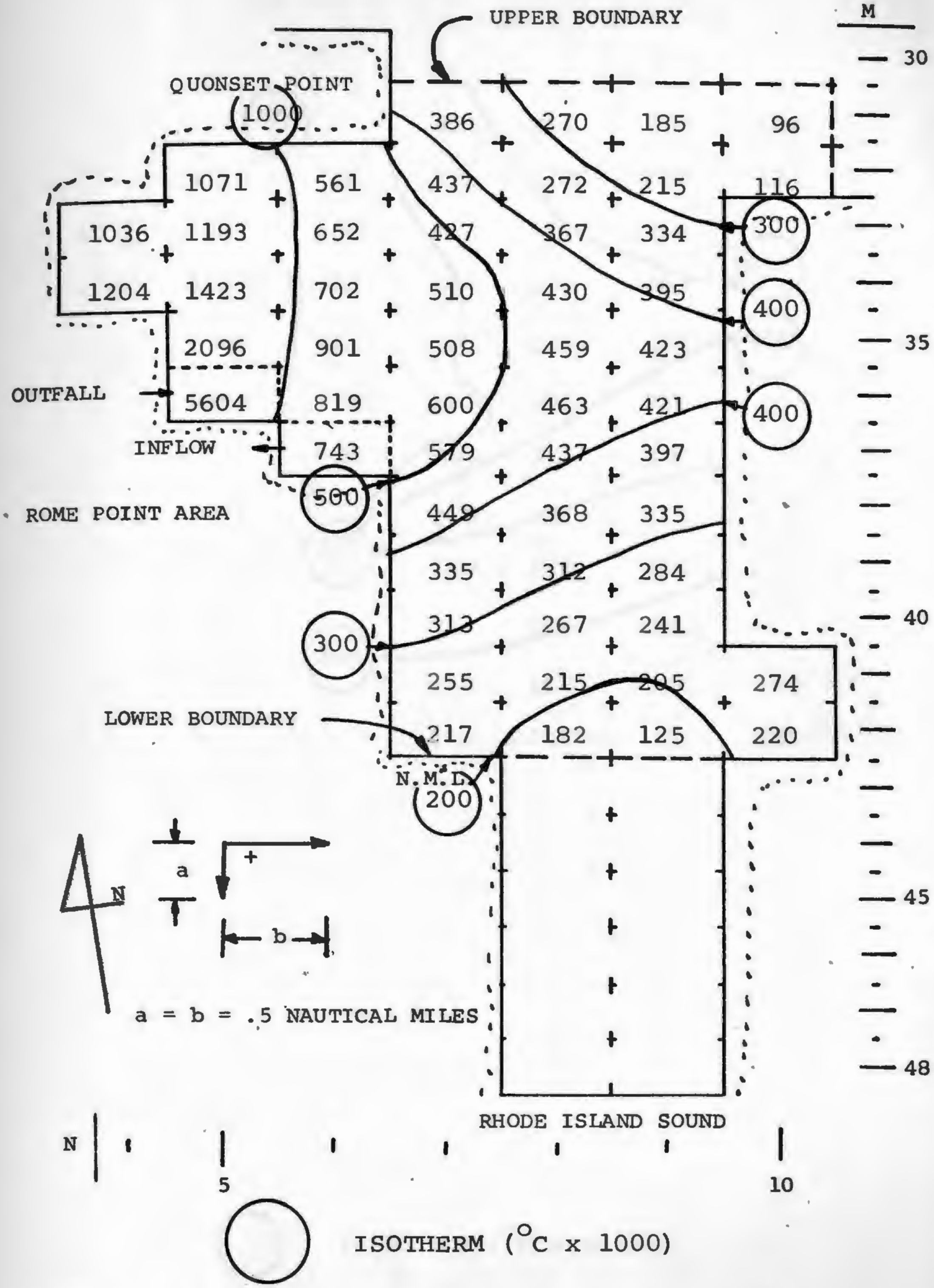


FIGURE 7.12. RUN 4, THERMAL FIELD AT 138 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

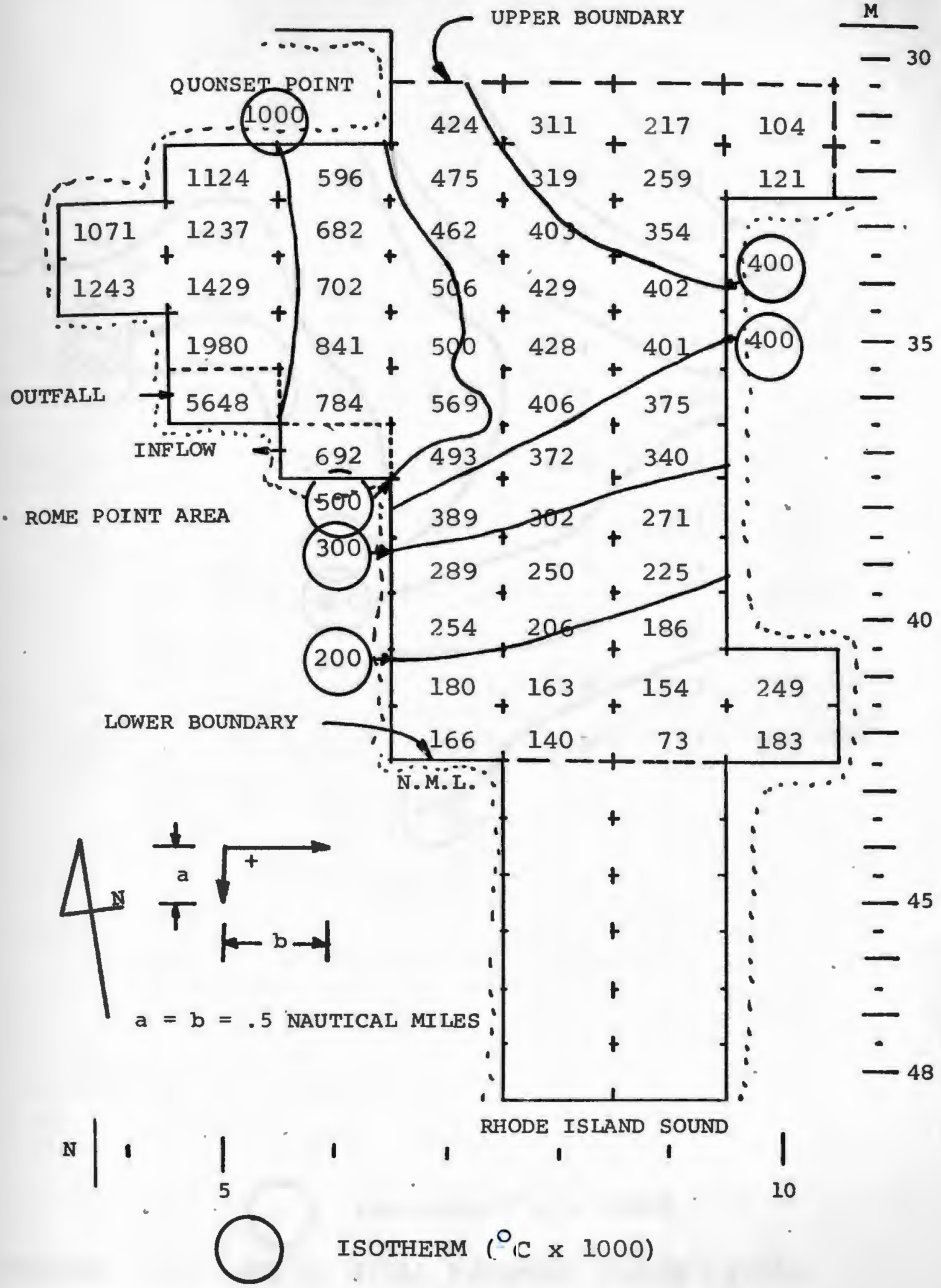


FIGURE 7.13. RUN 4, THERMAL FIELD AT 140 HOURS

ALL TEMPERATURES °C x 1000

Given: QIN = 2000 cfs, TIN = 12°C

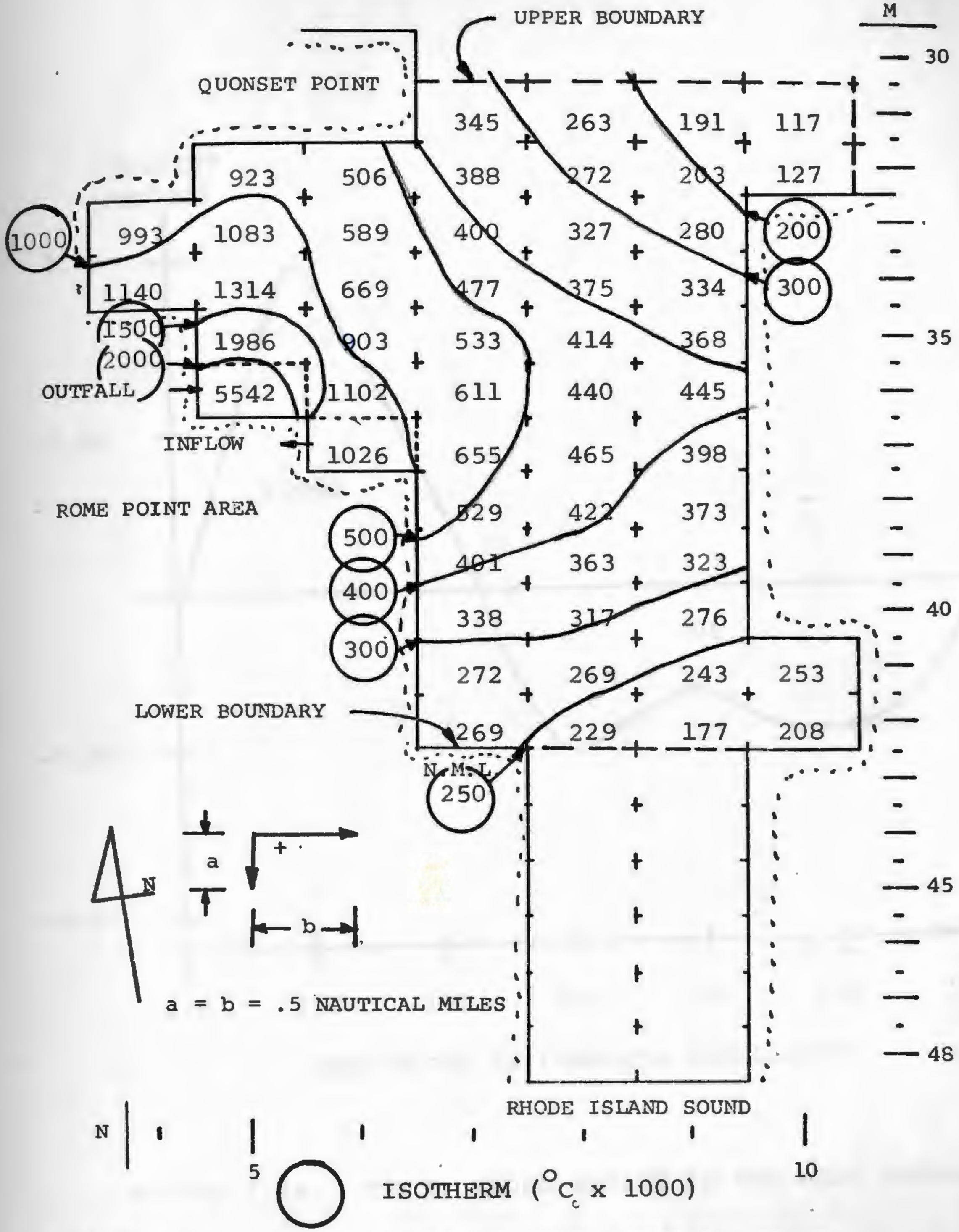


FIGURE 7.14. RUN 4, TIDAL AVERAGED THERMAL FIELD, 128-140 HOURS

ALL TEMPERATURES °C x 1000

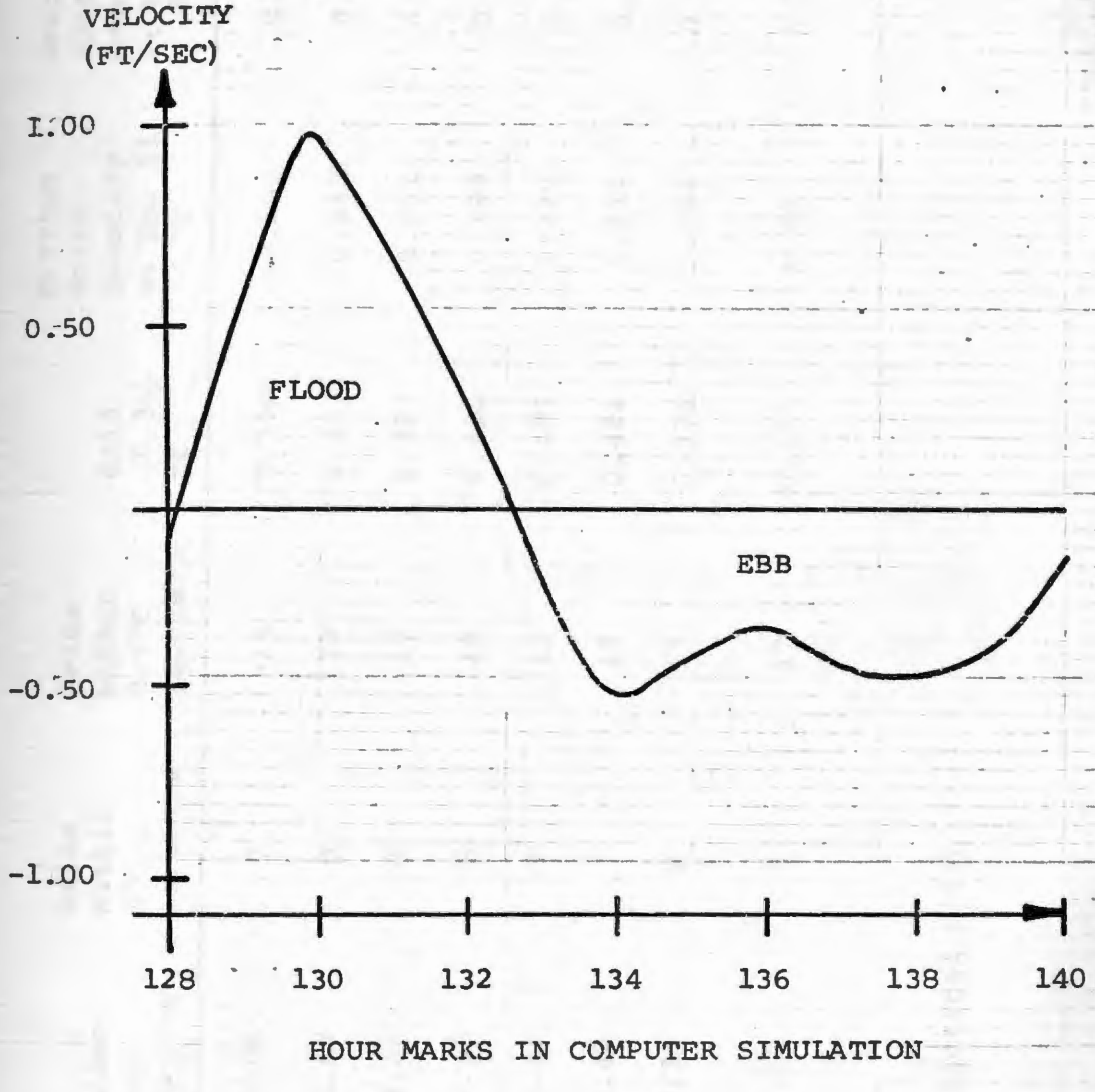


FIGURE 7.15. RUN 4, TIDAL MOTION IN THE WEST PASSAGE

TABLE 7.2. RUN 4, GENERAL TIDAL AND THERMAL RESULTS FOR RUN 4

Length of Simulation (Hours)	Ft/Sec Tidal Velocity	Grids Within 1°C Isotherm	Grids Within 0.5°C Isotherm	Grid (9,36) °C	Average North Boundary at Row 31 °C	Average South Boundary at Row 42 °C
128	-0.065	7	14	0.344	0.286	0.129
130	+1.12	8	17	0.353	0.243	0.179
132	+0.36	9	19	0.327	0.201	0.289
134	-0.55	8	19	0.430	0.199	0.284
136	-0.31	7	17	0.437	0.220	0.231
138	-0.44	7	17	0.421	0.234	0.186
140	-0.24	8	17	0.375	0.264	0.141
Tidal Average 128-140	+0.02	8	17	0.445	0.23	0.220

Grid Area = 1/4 (nautical mile)^2

average transport north of 0.02 ft/sec. In Rose (10) Figures 7a, 7b, and 7c, pages 13-15, one can see that net transport is variable and of the order of ±0.14 ft/sec (4 cm/sec) depending on wind direction and magnitude. A net transport of 4 cm/sec would reduce particle residence time in Rome Point area to one or two days.

Evaluation of Table 7.2 leads to the following conclusions:

1. 1°C isotherm encompasses an area of 2 square nautical miles (S.N.M.).
2. 0.5°C isotherm encompasses an area of 4.25 S.N.M.
3. Average temperature for entire Rome Point area (13.25 S.N.M.) is 0.6°C above natural condition.
4. The average value of the upper and lower Rome Point area boundaries is 0.23°C.
5. Tidal variations cause minor variations in locations of isotherms (See Figure 7.16) below 1.0°C.

G. LONG TERM VARIATIONS IN SURFACE DISCHARGE BOX FOR A HIGH DISPERSION COEFFICIENT

The complexity of the flow pattern around the Rome Point area causes very interesting tidal variations in heat content for box n = 5, m = 36. Referring to Figure 7.17

one can appreciate the value of computer modeling especially when with large variations in temperature of the grid due to sudden high velocity conditions at the 78 hour mark.

H. EXPERIMENTAL RUN 5 (FORCED TEMPERATURE RISE WITH 50% INCREASE IN FLOWRATE)

Run 5 is the same as run 3 with the following exceptions:

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
12	QIN (Source Flow Rate, cfs)	3000
15	Plotting Interval (Hours)	36
16	Program Number	33225
17	Date of Run	6/2/73

H.1. Discussion

The thermal pattern for grid n = 5, m = 36, run 4, is compared with run 5 (Figure 7.18) to see what effect there will be in temperature field for a 50 percent increase in flowrate, from 2000 to 3000 cfs, for the same temperature increase through the condenser.

One can see from Figure 7.18 that the estimated steady state value is +9.0°C or an 80 percent increase in forced temperature rise for grid n = 5, m = 36. Surrounding grid locations show a similar increase in heat content to balance the warmer input grid.

I. EXPERIMENTAL RUN 6, (FORCED TEMPERATURE RISE UPCON EQUALS 50)

Run 6 is the same as run 1 with the following exceptions:

VARIABLE NUMBER	CONTROL PARAMETER	SPECIFICATION
11	UPCON (Dispersion Coefficient Constant Times Elders' Value)	50/ 93
16	Plotting Interval (Hours)	36
17	Program Number	33374
18	Date of Run	6/5/73

I.1. Discussion

The dispersion coefficient constant (control parameter) was lowered by 50 percent to see what effect this would have on the temperature field. The results have been plotted in Figure 7.18 and are of the same

Given: QIN = 2000 cfs, TIN = 12°C

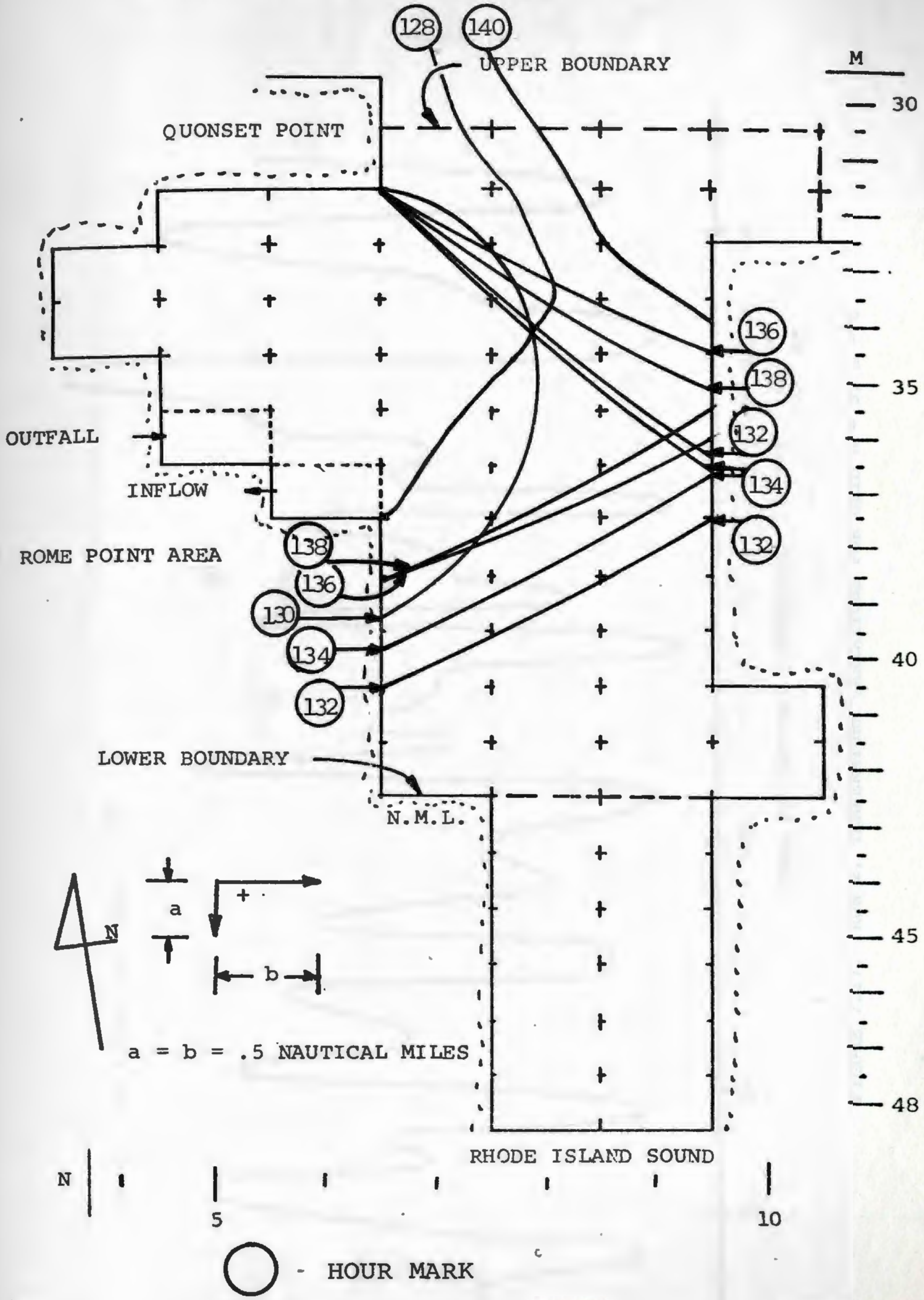


FIGURE 7.16. TIDAL EFFECTS ON THE 0.4°C ISOTHERM

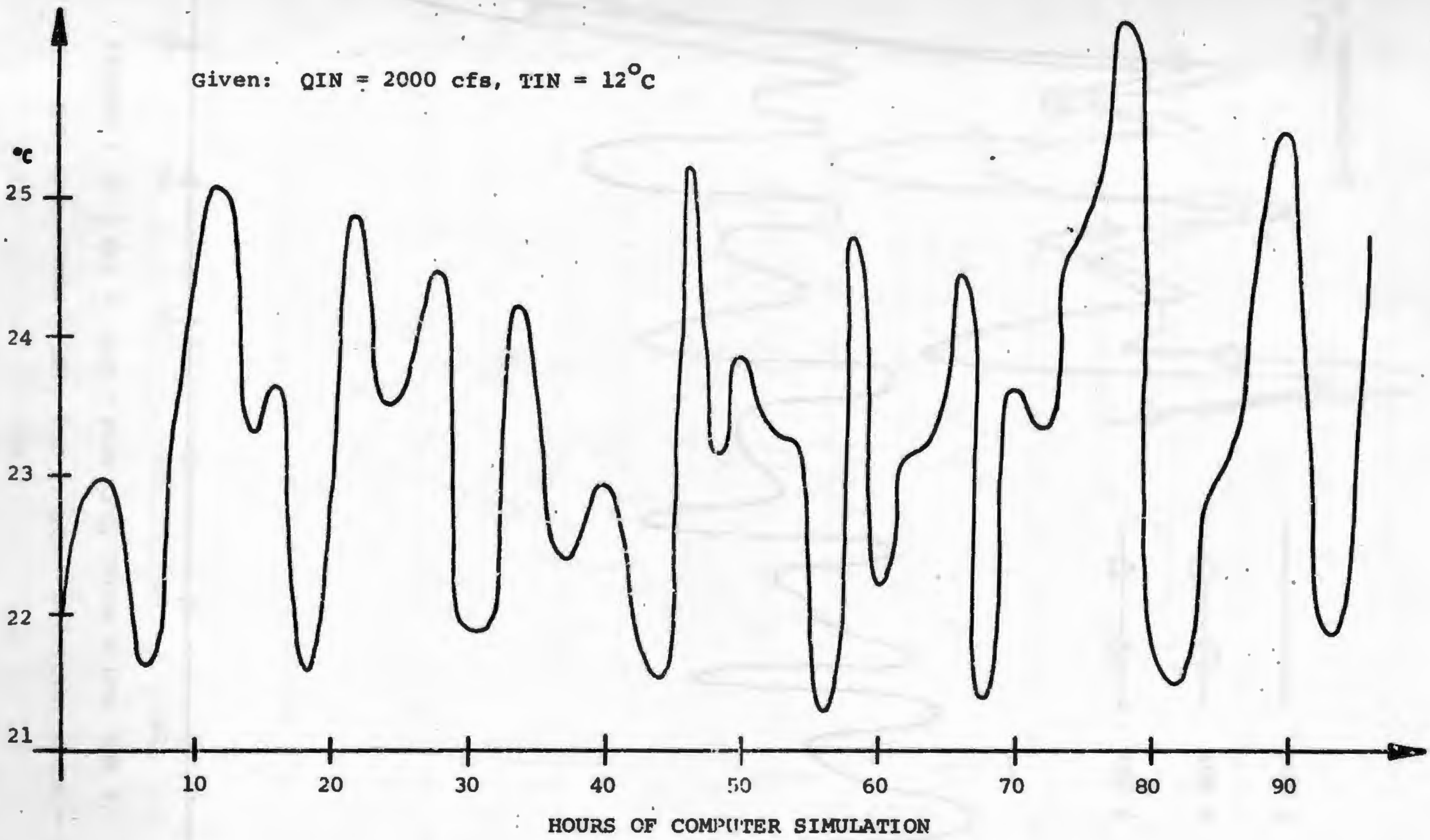


FIGURE 7.17. RUN 2, TEMPERATURE VARIATIONS FOR GRID n = 5, m = 6

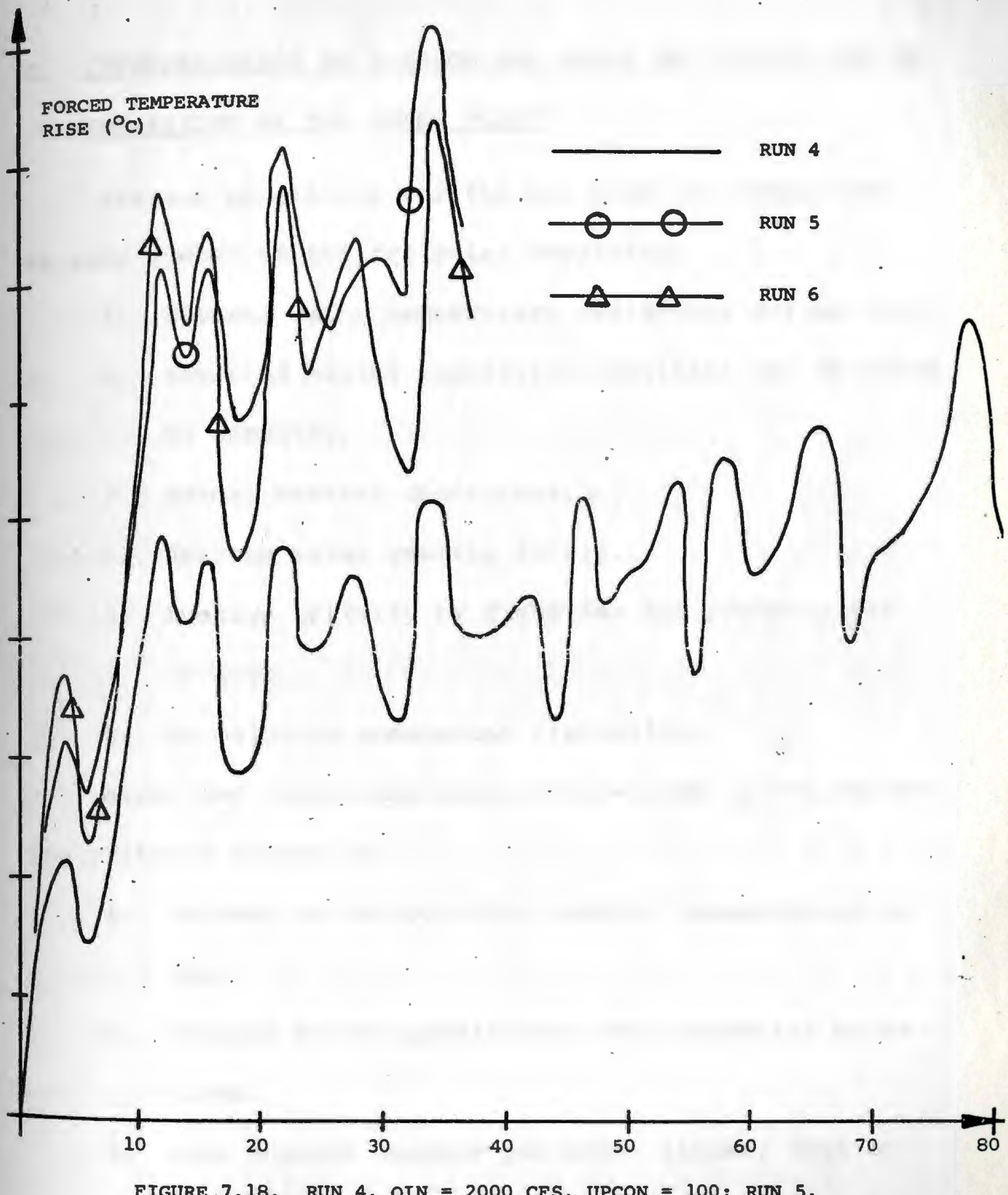


FIGURE 7.18. RUN 4, QIN = 2000 CFS, UPCON = 100; RUN 5, QIN = 3000 CFS, UPCON = 100; RUN 6, QIN = 2000 CFS, UPCON = 50

magnitude as run 5.

J. INTERPRETATION OF AVERAGE AND WORST BAY CONDITIONS ON THE SITING OF THE POWER PLANT

Average conditions for the bay might be summarized as some number of the following occurring:

1. Natural water temperature variations during year.
2. Expected marine population densities can be found by sampling.
3. Normal weather conditions.
4. Average water quality levels.
5. Average activity by fisheries and pleasure interests.
6. No major or unexpected fish kills.

Worst bay conditions would follow some of the following criteria occurring:

1. Extreme or biologically harmful temperatures in bay.
2. Unusual marine populations and unexpected migrations.
3. Very unusual weather patterns, storms, heat or cold spells, etc.
4. Very poor water quality levels.

5. Unusual activity of bay users.

6. Unexpected major fish kills.

K. GENERAL COMMENTS

In the presentation of the computational results this report has stressed the forced temperature rise method because it would be applicable for any period of the year. The warm water temperatures during mid summer coupled with peak power production by utility would create the highest temperatures in the outfall area. Whether the highest temperature and the worst temperature are synononous remains a judgment for the biologist who must evaluate the thermal affects of the power plant on marine life throughout the year. The point here is to determine the need, if any, for temperature limitations that would be imposed on power plant operations for various air and water temperature values. Once the operating specifications have been determined, the environmental engineer can utilize his options to meet these criteria. Some engineering options available are:

1. Reduce plant output.
2. Increase flow rate through the plant.
3. Increase dilution in the discharge channel.

4. Change the outfall location by moving discharge into deeper water.
5. Dissipating heat near power plant through cooling towers or ponds.

Except for 1, these techniques do not reduce or "dissolve" the heat load on the bay environment but rather soften the impact by increasing the total area affected.

The upper temperature limit in the discharge grid would be the total temperature increase of condenser flow water for the entire grid. This value is somewhat fictitious, because with dilution in the normal tidal environment this value is not attainable. As a "worst case" it would be used in conjunction with the forced temperature rise analysis for any part of the year. With the 1800 megawatt sample plant at maximum output, the tidally averaged value for the discharge grid is approximately half the condenser temperature rise. This prediction was made with a value of the dispersion constant coefficient, UPCON, set at 50.

VIII. CONCLUSIONS

A. GENERAL

The thermal model can predict the general spatial temperature distribution in Narragansett Bay for either natural or man made conditions. When isotherms are sketched in by interpolation between grid temperatures, the effect of tidal flushing and heat sources are quite evident. The isotherms drawn for the forced temperature rise above ambient case serve as a valuable guide for environmental impact statements, because they dramatically display the effect of the heated effluent from a power plant. The heat content in a grid is vertically averaged but the Rome Point area is shallow enough to assume a high degree of vertical mixing for good model simulation. This mixing is further added by the variable current direction and magnitude during most of the tidal cycle.

Another challenging area comes from thermal field prediction or the attempt of the model to simulate bay boundary conditions in the form of a boundary value problem for temperature field calculation. The results obtained for the period of simulation, July 14-18, 1957, were of the same order of accuracy as those obtained by MASCH (57).

Long computer simulation runs of the order of a month would be required to pursue this verification procedure for the empirical heat exchange formulas and the variable boundary conditions. Verification improvements could be made by adjusting the empirical heat exchange formulas and the necessary variable boundary conditions.

When the Rome Point discharge grid temperature is plotted against time, one can observe the characteristic peaks and valleys of tidal flushing but the variations within a tidal cycle are most irregular. The sudden changes in temperature of the discharge grid, as seen in Figure 7.17, are important for physical impact studies. Knowing the general isothermal patterns around the discharge grid, the oceanographer now can make biological observations and recommendations.

The basic model can predict the spatial distribution of any dissolved constituent. For instance, the salinity distribution in the bay would be very valuable for biological models now being developed.

In general summary, the thermal model produces valuable temperature distribution information for both natural and man made conditions. The ability to predict thermal plume patterns for various input and output sites is of great value to both the ecologist and the electric utility.

B. SPECIFIC

The verification of the model indicates no gross or unreasonable values are produced when the approximations used to formulate the model are evaluated. This model has been used to predict Jamaica Bay flushing characteristics and verification accuracy is comparable.

To limit this study, only one specific site at m = 36, n = 5 was chosen. This site enabled a verification of the forced temperature rise criterion. It is felt that this technique produces the most usable output for thermal impact studies.

In Chapter VII, the tidally averaged thermal field shown in Figure 7.14 clearly shows the scale of the spreading of the heat. The 0.5°C isotherm encompasses about eight to nine square nautical miles of bay. The tidally varying patterns appear to have surprising similarity beyond the 0.5°C isotherm mark. As discussed in earlier chapters, the higher the diffusion coefficient the less variation in heat content from box to box especially near the outfall area. In conclusion, the ground work has been laid for extensive development. Various physical testing must be undertaken to pinpoint near field dispersion. This must of course be done in conuunction with computer runs that vary dispersion coefficient and site location.

IX. RECOMMENDATIONS

This thesis has established the value of the thermal model to make realistic spatial temperature distribution predictions. Before attempting to develop a better model that would more closely represent the three dimensional structure of Narragansett Bay, one should make salinity predictions. This would establish the ability of the difference scheme to predict the concentration of salinity without the use of the semi-empirical heat balance that occurs at the air-water interface.

As a prelude to a more sophisticated model, one should perform dye dispersion studies in conjunction with model predictions. These studies would indicate the importance of vertical structure on overall bay mixing. Finally, one could develop a two-dimensional width averaged vertically layered model. This would then reveal the importance of the vertical bay structure, especially in the deeper water grids.

It should be noted that Hess (59) is developing a three dimensional tidally averaged model for Narragansett Bay that shows considerable promise for understanding non-reacting constituent distribution of salt.

Research should be planned to bridge the gap between the non-reacting concentration models to determine the differences predicted by vertical averaging, width averaging and time averaging on, for example, spatial distribution of salinity.

APPENDIX A

A. INTRODUCTION

The physical limitations on the amount of computer core and time available on the present operating computer required a reworking of the computer model into more manageable segments. This reworking enabled one to use a special storage unit, called a disk pack, to facilitate handling. In addition, the introduction of H level Fortran during the development stage offered a reduction of at least 50 percent in execution time, if the current batch processing mode was upgraded. That is to say, the program in its entirety exceeded the core requirement for Fortran H, optimization level 2, for the long runs, making segmentation and disk pack utilization a necessity.

B. TERMINOLOGY

To understand the workings of the disc pack a review of the technical language (I.B.M., (1) and Clayton, (3)) is presented.

Data Sets: A data set is a named, organized, logical collection of records. Generally, this consists of the main control segment, subroutines, and the input data for starting model. A disk pack is used for the storage of data set records.

Sequential: Means an organized data set that is arranged in a logical, physical order of computational need. This is done to facilitate debugging by the user.

Direct: Each record in the model has independent address.

Partitioned: Combination of the sequential and direct organization. The grouping of these records is sequentially arranged into collections called "members".

OCEPAK: Name of the disk pack used for all computation.

Library: Sum of all the sets of partitioned data sets available in the disk pack that facilitate job execution.

OCESMODS: Name of all the partitioned data sets containing many members which are the source input.

OCECOMP: Name of all partitioned data sets containing compiled modules from OCESMODS.

OCEDATAS: Name of all the partitioned data sets that contain initialization and data information required for execution of the program. You do not compile this information. It is just read by the model.

C. DISK PACK USE

The job control language (JCL) for the library creation (IBM, la, lb) is as follows:

```
//LIBRARY   JOB   (INO100, 256,5,5,500),'J.J.A.',
        MSGLEVEL=1                                         (A-1)
//BLDSTEP   EXEC   PGM=IEBFBR14                            (A-2)
//NEWSRCE   DD   DS=OCESMODS                               (A-3)
//    DISP=(NEW,CATLG),VOL=SER=OCEPAK                      (A-4)
//    UNIT=2314,SPACE=(CYL,(15,5,20)),                     (A-5)
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=3440)                 (A-6)
//ADDSTEP   EXEC   PGM=IEBUPDTE                            (A-7)
//SYSPRINT   DD   SYSOUT=A                                 (A-8)
//SYSUT1   DD   DSN=OCESMODS,DISP=OLD,UNIT
        =2314,VOL=SER=OCEPAK                               (A-9)
//SYSUT2   DD   DSN=OCESMODS,DISP=OLD,UNIT
        =2314,VOL=SER=OCEPAK                               (A-10)
//SYSIN   DD   *                                           (A-11)
```

The following data cards for execution appear after the input program JCL:

```
./   ADD    NAME=AMAIN,LIST=ALL                        (A-12)
./   NUMBER    INCR=100,NEW1=100                       (A-13)
     DIMENSION.....
     .             AMAIN
     .             FORTRAN CARDS
     END
./   ADD    NAME=AINVAL,LIST=ALL                       (A-14)
./   NUMBER    INCR=100,NEW1-1000                      (A-15)
     SUBROUTINE AINVAL(.....
     .             AINVAL
     .             FORTRAN CARDS
     END
```

One repeats the above procedure for the remaining modules: APRINT, AHEATN, AOPBD, AUPNFH, AVPMFH, AVPMSH, AUPNSH, AWTDEP, AWTIND, AAZ, AKURIH, ADIVE, AFIND, ADEPTH, ACHEZY, AANLZE, ACHECK, APLOT and ADISPLY. This makes a total of 21 model modules.

To enter data for initilization of the model a partitioned data set, called OCEDATAS was created and filled in the same manner as OCESMODS with the following specific changes:

on line A-3, OCESMODS to OCEDATAS
A-5, SPACE=(CYL,(15,5,20))
A-9, OCESMODS to OCEDATAS (A-16)
A-10, OCESMODS to OCEDATAS

OCEDATAS module names are: ADATA1, ADATA2, ADATA3, ADATA4, AD191, AD192, AD193, for a total of seven.

To change or update the library the following is done:

on line A-7, ADDSTEP to CHNGSTEP
A-12, ADD replaced by CHANGE
A-13, Fortran statement(s) on IBM card(s) with module line number is columns 73 to 80, for the specified change in module. It is important to list the line numbers in ascending order. (A-17)

For obvious ease in handling changes it is desirable to stay in the CHNSTEP mode once modules have been added to the library. For any data change or update one should do the following:

on line A-9, OCESMODS to OCEDATAS
A-10, OCESMODS to OCEDATAS (A-18)
A-17, Specific changes desired

As an example, a typical deck layout for updating the library would be as follows:

```
    lines A-1, LIBRARY   JOB(.....
          A-7, //CHNGSTEP   .....
          A-8, //SYSPRINT   ....
          A-9, //SYSUT1   ..   OCESMODS   ..
         A-10, //SYSUT2   ..   OCESMODS   ..
         A-11, //    SYSIN    DD   *
               ./   CHANGE   ..   AMAIN
               COL:    7GO TO    10    ..   7300046000
                        10 CONTINUE             00046900
                        etc.
          A-7, //CHNGSTEP    ....
          A-8, //SYSPRINT    ....
          A-9, //SYSUT1,     ..   OCEDATAS   ..
         A-10, //SYSUT2,     ..   OCEDATAS   ..
         A-11, //    SYSIN   DD    *
               ./    CHANGE   ..   ADATA1   ..
               COL:    1000010   ..   2000020   ...   7300007700
                          .
                          .
                        etc.
            JCL FOR REMAINING PROGRAM
```

After creation of the input partitioned data sets, the next step is to create a third partitioned data set called OCECOMP. This is done by making the following changes:

on line A-3, OCESMODS to OCECOMP
A-5, SPACE=(CYL,(2,2,2))   (A-19)
A-6, final line

The primary function of this data set is to store all the compiled modules after they have been updated. Once a program has been compiled it need not be recompiled unless a change is made in the structure of the module. This results in a great saving in compilation time for each run. The necessary JCL is:

```
//    EXEC   FORTHOL,PARM.FORT-'OPT=2',PARM.LKED
      ='LET,LIST,NCAL,XREF'           (A-20)
//FORT.SYSIN    DD    DSN=OCESMODS(AMAIN),DISP    (A-23)
      =SHR                            (A-21)
//LKED.SYSLMOD    DD    DSN=OCECOMP(MAIN),DISP
      =OLD                            (A-22)
```

Repeat set A-23 for as many modules as needed in OCESMODS that have just been updated for a maximum of 21 compilations. Note here that AMAIN is the uncompiled module in OCESMODS while MAIN is the same module compiled and stored in OCECOMP.

Now that after all the modules are compiled they must be included in the object (functional) library through the LINK Editor as follows:

```
//LKED   EXEC   PGM=IEWL,PARM=(MAP,LET,LIST,OVLY,XREF)
                                          (A-24)
//SYSLIB   DD   DSN=SYS1.FORTLIB,DISP=SHR
                                          (A-25)
//   DD   DSN=URI.SSPLIB,DISP=SHR         (A-26)
//   DD   DSN=URI.OPOTLIB,DISP=SHR        (A-27)
//SYSPRINT   DD   SYSOUT=A                (A-28)
//SYSLIN   DD   DDNAME=SYSIN              (A-29)
//SYSLMOD   DD   DSN=&GOSET(MAIN),UNIT=SYSDA,DISP   (A-35)
     =(,PASS),                            (A-30)
//   SPACE=(3072,(30,10,1))               (A-31)
//SYSUT1   DD   DSN=&SYSUT1,UNIT=SYSDA,SPACE
     =(1024,(200,20)),SEP=SYSLMOD         (A-32)
//LKED.OBJLIB   DD   DSN=OCECOMP,DISP=SHR,VOL=SER
     =OCEPAK,UNIT-2314                    (A-33)
//LKED.SYSIN   DD   *                     (A-34)
```

Since the core restriction of 256 K is imposed on the fastest turn-around class it is necessary to follow up with the Overlay feature (IBM, (2)) that is specified in A-24. The modules in the program must be organized into usable groups that minimize the core demand for any one executing group. See Figure A-1, Overlay Flow Chart, for details. Directly after A-34 are the instructions.

```
COL:    7ENTRY    MAIN                                      (A-36)
          INCLUDE    OBJLIB(MAIN)                           (A-37)
          OVERLAY    ONE                                    (A-38)
          INCLUDE OBJLIB(KURIH,HEATIN,DIVE,FIND,DEPTH,
                 CHEZY,CHECK,INVAL)                         (A-39)
          OVERLAY    ONE                                    (A-40)
          INCLUDE    OBJLIB(OPENBD,UPNFHT,VPMFHT,VPMSHT,
                 UPNSHT,WATDEP,WATIND)                      (A-41)
          INCLUDE    OBJLIB(AZ,PRINT,DISPL,PLOT)            (A-42)
          OVERLAY    ONE                                    (A-43)
          INCLUDE    OBJLIB(ANLYZE)                         (A-44)
```

The final JCL required for reading in the initialization values is:

```
//GO    EXEC    PGM=*.LKED.SYSLMOD                          (A-45)
//FT06F001    DD    SYSOUT=A                                (A-46)
//FT07F001    DD    SYSOUT=B                                (A-47)
//FT05F001    DD    DSN=OCEDATAS(ADATA2),DISP=SHR,VOL
        =SER=OCEPAK                                         (A-48)
//    UNIT=2314,LABEL=(,,,IN)                               (A-49)
```

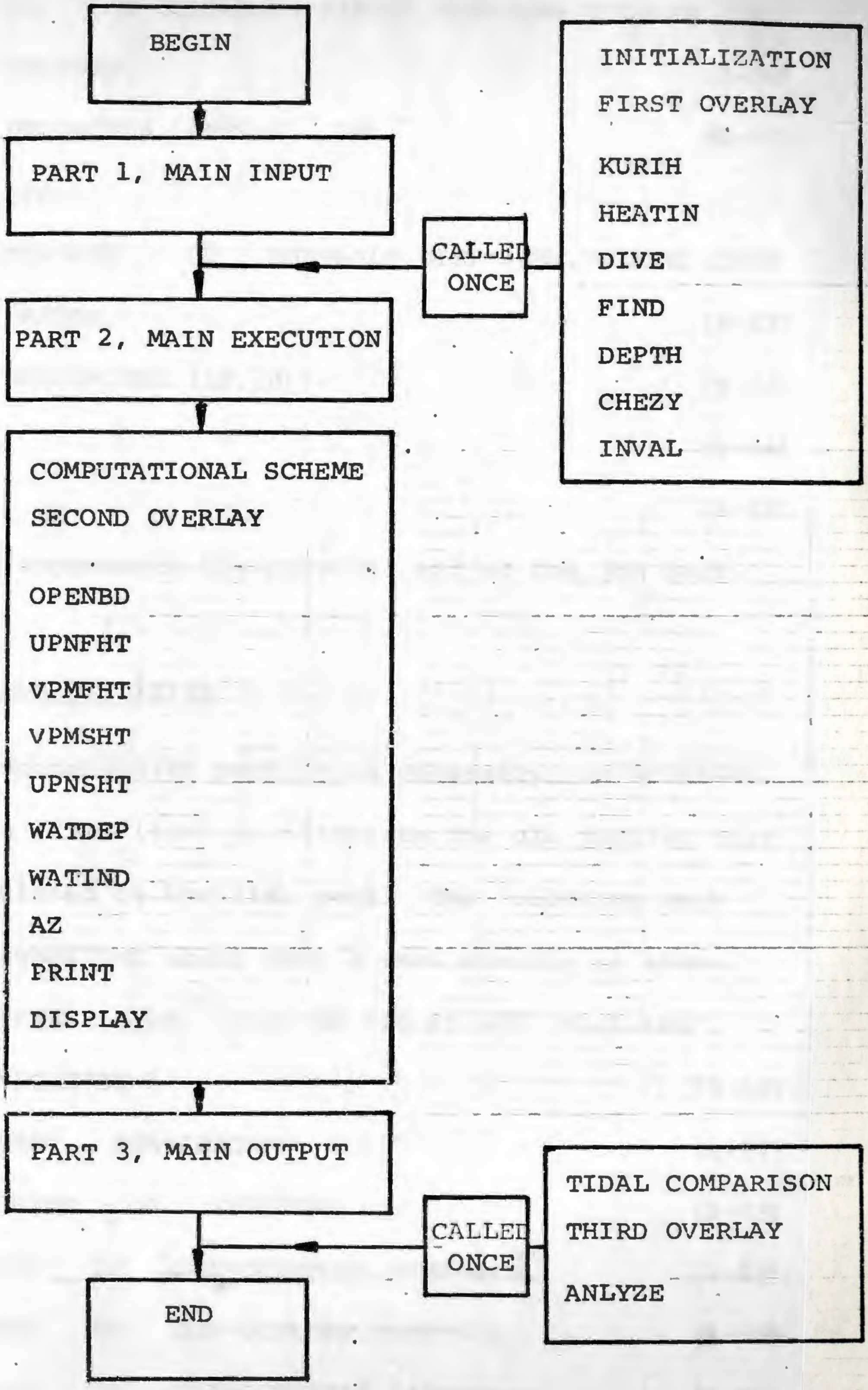


FIGURE A.1. OVERLAY FLOW CHART

```
//     DD    DSN=OCEDATAS(ADATA3),DISP=SHR,VOL=SER
       =OCEPAK.                                         (A-50)
//     UNIT=2314,LABEL=(,,,IN)                          (A-51)
       etc.
//GO.FT13F001    DD    DSN=&ALF,DISP=(NEW,DELETE),UNIT
       =SYSDA,                                          (A-52)
//     SPACE=(TRK,(10,10))                              (A-53)
//                                                      (A-54)
/*                                                      (A-55)
```

where A-55 represents the physical end of the job deck.

D. DISK PACK UTILITIES

When using a disk pack it is necessary, on occasion, to compress (IBM, (1c)) or eliminate the old modules that have accumulated on the disk pack. The following deck should be submitted about once a week exactly as shown.

```
//COMPRESS    JOB    (IN0100,256,05,10),'USERNAME',
       MSGLEVEL=1                                       (A-56)
//     EXEC    PGM=IEBCOPY                              (A-57)
//SYSPRINT    DD    SYSOUT=A                            (A-58)
//INOUT1    DD    DSN=OCESMODS,DISP=OLD                 (A-59)
//INOUT2    DD    DSN=OCECOMP,DISP=OLD                  (A-60)
//INOUT3    DD    DSN=OCEDATAS,DISP=OLD                 (A-61)
```

```
//SYSIN   DD   *                                   (A-62)
//                                                 (A-63)
/*                                                 (A-64)
```

From time to time it is convenient to have a total print and punch (IBM, (1d)) of the disk pack. The programs that will perform this function are described below.

```
//PTWOH   JOB   (INO100,128,01,10,3500),'USERNAME',
     MSGLEVEL=1                                    (A-65)
//   EXEC   PGM=IEBPTPCH                           (A-66)
//SYSPRINT   DD   SYSOUT=A                         (A-67)
//SYSUT1   DD   DSN=OCESMODS,DISP=(OLD,KEEP),VOL
     =SER=OCEPAK,UNIT=2314                         (A-68)
                     A Gives Printed Output
//SYSUT2   DD   SYSOUT= [                     -Choose One]
                     B Gives Punched Output
                                                   (A-69)
//SYSIN   DD   *
     COL:   7
                 PRINT
[Choose One -         ]   TYPORG=PO,MAXFLDS=1      (A-70)
                 PUNCH
                 TITLE   ITEM=('   PRINT AND PUNCH ALL
                      MEMBERS',10)                 (A-71)
                 RECORD FIELD=(80,,,5)             (A-72)
//                                                 (A-73)
/*                                                 (A-74)
```

Note that one can obtain either punched or printed output (but not both) by picking the "A PRINT", or "B PUNCH" options.

E. ACKNOWLEDGMENT

Now that the model is fully operational in all modes it would be a great injustice not to cite the very valuable and timely assistance given to me by the entire computer center staff. Specifically, Dave "I can solve your problem" Clayton was undoubtedly the individual in the staff I must cite as instrumental in bringing the computer hardware into line. In addition to his daily assistance, he formalized all the above information into a special class especially for the Ocean Engineering Bay Model group.

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e.	IEBCOPY	59-89

2. IBM Systems Reference Library, Linkage Editor & Loader, File No. 5360-3, Order No. GC28-6538-9, 10th Ed., Jan., 1972, 63-88, Overlay.

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APPENDIX B

HYDRODYNAMIC FINITE DIFFERENCE EQUATIONS

A. HYDRODYNAMIC MODEL

The three basic equations, 2-32 through 2-35, may be expressed in finite difference form, using the notation outlined in Equations 2-36 through 2-44. The results are:

A.1 First Half Timestep

X - Momentum:

$$\begin{aligned} U^{t+1/2} = {} & U^t + \tfrac{1}{2}\,DT\,f\,\bar{\bar{V}}^t - \tfrac{1}{2}\,\frac{DT}{DL}\,U^{t+1/2}\delta^*_x\,U^t \\ & - \tfrac{1}{2}\,\frac{DT}{DL}\,U^{t+1/2}\,\bar{\bar{V}}^t\,\delta^*_y\,U^t - \tfrac{1}{2}\,\frac{DT}{DL}\,g\,\delta_x\,\eta^{t+1/2} \\ & - \tfrac{1}{2}\,DT\,R^t_{(x)} - \tfrac{1}{2}\,T\,F^{t+1/2}_{(x)}, \end{aligned} \qquad (B.1)$$

at $X_c + \tfrac{1}{2}\,DL,\ Y_c$.

Conservation of Mass:

$$\begin{aligned} \eta^{t+1/2} = {} & \eta^t - \tfrac{1}{2}\,\frac{DT}{DL}\,\delta_x\,\left[(\bar{h}^y + \bar{\eta}^x)^{t+1/2}\,U^{t+1/2}\right] \\ & - \tfrac{1}{2}\,\frac{DT}{DL}\,\delta_y\,\left[(\bar{h}^x + \bar{\eta}^y)^t\,V^t\right], \end{aligned} \qquad (B.2)$$

at $X_c,\ Y_c$.

Y-Momentum:

$$V^{T + 1/2} = V^{t} - \tfrac{1}{2} \frac{DT}{DL} \delta_x^* V^{t} \bar{\bar{U}}^{t + 1/2} - \tfrac{1}{2} \frac{DT}{DL} \delta_y^* V^{t} V^{t + 1/2}$$

$$- \tfrac{1}{2} \frac{DT}{DL} g \delta_y \eta^{t} - \tfrac{1}{2} DT R_{(y)}^{t + 1/2} - \tfrac{1}{2} DT F_{(y)}^{t} \qquad (B.3)$$

at X_c, $Y_c + \tfrac{1}{2}$ DL.

A.2 Second Half Timestep

X - Momentum:

$$U^{t + 1} = U^{t + 1/2} + \tfrac{1}{2} DT f \bar{\bar{V}}^{t + 1/2} - \tfrac{1}{2} \frac{DT}{DL} U^{t + 1/2} \delta_x^* U^{t + 1/2}$$

$$- \tfrac{1}{2} \frac{DT}{DL} \bar{\bar{V}}^{t + 1} \delta_y^* U^{t + 1/2} - \tfrac{1}{2} \frac{DT}{DL} g \delta_x \eta^{t + 1/2}$$

$$- \frac{DT}{DL} R_x^{t + 1} - F_y^{t + 1/2} \qquad (B.4)$$

at $X_c + \tfrac{1}{2}$ DL, Y_c.

Conservation of Mass:

$$\eta^{t + 1} = \eta^{t + 1/2} - \frac{DT}{DL} \delta_x \left[(\bar{h}^y + \bar{\eta}^x)^{t + 1/2} \right] U^{t + 1/2}$$

$$- \tfrac{1}{2} \frac{DT}{DL} \delta_y \left[(\bar{h}^x + \bar{\eta}^y)^{t + 1} \right] V^{t + 1} \qquad (B.5)$$

at X_c, Y_c.

Y - Momentum:

$$V^{t+1} = V^{t+1/2} - \tfrac{1}{2}\frac{DT}{DL} f\, \bar{\bar{U}}^{t+1/2} - \tfrac{1}{2}\frac{T}{L}\, \bar{\bar{U}}^{t+1/2}\, \delta^{*}_{x} V^{t+1/2}$$

$$- \tfrac{1}{2}\frac{DT}{DL} V^{t+1} \delta^{*}_{y} V^{t+1} - \tfrac{1}{2}\frac{DT}{DL} g\, \delta_{y}\, \eta^{t+1}$$

$$- \tfrac{1}{2}\frac{DT}{DL} R_{y}^{t+1/2} - \tfrac{1}{2}\frac{DT}{DL} F_{y}^{t+1} \qquad \text{(B.6)}$$

at X_c, $Y_c + \tfrac{1}{2} L$

where the bottom stress term, R, is defined as:

$$R_{x}^{t} = g\, U^{t}\, \frac{\left[(U^{t})^{2} + (\bar{\bar{V}}^{t})^{2}\right]^{\frac{1}{2}}}{(\bar{h}^{y} + \bar{\eta}^{x})^{t}\, (\bar{g}^{x})^{2}} \qquad \text{(B.7)}$$

$$R_{y}^{t+1/2} = g\, V^{t+1/2}\, \frac{\left[(\bar{\bar{U}}^{t+1/2})^{2} + (V^{t})^{2}\right]^{\frac{1}{2}}}{(\bar{h}^{x} + \bar{\eta}^{y})^{t+1/2}\, (\bar{C}^{y})^{2}} \qquad \text{(B.8)}$$

$$R_{x}^{t+1} = g\, U^{t+1}\, \frac{\left[(U^{t+1/2})^{2} + (\bar{\bar{V}}^{t+1})^{2}\right]^{\frac{1}{2}}}{(\bar{h}^{y} + \bar{\eta}^{x})^{t+1/2}\, (\bar{C}^{x})^{2}} \qquad \text{(B.9)}$$

$$R_{y}^{t+1/2} = g\, V^{t+1/2}\, \frac{\left[(\bar{\bar{U}}^{t+1/2})^{2} + (V^{t+1/2})^{2}\right]^{\frac{1}{2}}}{(\bar{h}^{x} + \bar{\eta}^{y})^{t+1/2}\, (\bar{U}^{y})^{2}} \qquad \text{(B.10)}$$

and the surface stress terms, f, are defined as

$$F_x^{t+1/2} = \frac{K\,(\omega_x^{t+1/2})^2}{(\bar{h}^y + \bar{\eta}^x)^t} \tag{B.11}$$

$$F_y^{t} = \frac{K\,(\omega_y^{t})^2}{(\underset{h}{\bar{\eta}}^x + \bar{\eta}^y)^t} \tag{B.12}$$

$$F_x^{t+1/2} = \frac{K\,(\omega_x^{t+1/2})^2}{(\bar{h}^y + \bar{\eta}^x)^{t+1/2}} \tag{B.13}$$

$$F_y^{t+1} = \frac{K\,(\omega_y^{t+1})^2}{(\bar{h}^x + \bar{\eta}^y)^{t+1/2}} \tag{B.14}$$

where

$$K = \frac{k\,\rho_{air}}{\rho_{water}}$$

The conservation of mass equations, B.2 and B.6, contain the non-linearihes $(\bar{\eta}^x)$ $t + 1/2$ and $(\bar{\eta}^y)$ $t + 1$, respectively, which are at the same time level as η on the left-hand side of the equations. In the solution, these terms are taken at the lower time level in the first approximation and at the same time level in succeeding iterations. The hydraulic portion of model does contain iterative procedure but is not used because the improvement in accuracy was negligible.

APPENDIX C

METHOD OF SOLUTION

The implicit method of solution for η and u in the first half of the time step is first presented. The solution of η and v in the second is analogous. Starting with equations B.2 and B.1 (in Appendix B), and writing out the finite-difference approximations, we have

$$-r_{m-1/2}\, u_{m-1/2} + \eta_m + r_{m+1/2}\, u_{m+1/2} = A_m \qquad (C.1)$$

$$-r_m\, \eta_m + u_{m+1/2} + r_{m+1}\, \eta_{m+1} = B_{m+1/2} \qquad (C.2)$$

where the coefficients r are

$$r_{m \pm 1/2} = \frac{1}{2}\frac{DT}{DL}\left(\bar{h}^{y} + \bar{\eta}^{x}\right)_{m \pm 1/2} \qquad (C.3)$$

$$r_m = \frac{1}{2}\frac{DT}{DL}\, g \qquad (C.4)$$

and A_m, B_m are the remaining terms in equations C.2 and C.1, respectively. Both η and u are at the t + 1/2 time level (except for $\bar{\eta}^{x}$ in C.3, which is at time t).

Suppose the first computational grid is at m = 2, and the last is m = J. Then the values of η occur with subscripts m = 2, 3, ...J, while u values have subscripts of m = 1½, 2½, ... J+ ½ (see Figure C.1).

Solving eq. C.1 for η_m at $m = 2$, gives

$$\eta_2 = A_2 + r_{1\frac{1}{2}} u^*_{1\frac{1}{2}} - r_{2\frac{1}{2}} u_{2\frac{1}{2}} \qquad (C.5)$$

where $u^*_{1\frac{1}{2}}$ is the velocity at the boundary. For the case of a land boundary, $u^*_{1\frac{1}{2}}$ is zero. Equation C.5 may be rewritten as

$$\eta_2 = -\rho_2 u_{2\frac{1}{2}} + u_2 \qquad (C.6)$$

where $$\rho_2 = r_{2\frac{1}{2}} \qquad (C.7)$$

and $$\eta_2 = A_2 + r_{1\frac{1}{2}} u^*_{1\frac{1}{2}} \qquad (C.8)$$

Equation C.2 at $m = 2$ is

$$u_{2\frac{1}{2}} = B_{2\frac{1}{2}} + r_2 \eta_2 - r_3 \eta_3 \qquad (C.9)$$

Taking the expression for η_2 from eq. C.6, and substituting into the above,

$$u_{2\frac{1}{2}} = B_{2\frac{1}{2}} + r_2 (-\rho_2 u_{2\frac{1}{2}} + u_2) - r_3 \eta_3 \qquad (C.10)$$

or $$u_{2\frac{1}{2}} = -R_2 \eta_3 + S_2 \qquad (C.10a)$$

where $$R_2 = \frac{r_3}{1 + r_2 \rho_2} \qquad (C.11)$$

$$S_2 = \frac{B_{2\frac{1}{2}} + r_2 u_2}{1 + r_2 \rho_2} \qquad (C.12)$$

The next water level, η_3, is (from eq. C.1 at m = 3)

$$\eta_3 = A_3 + r_{2\frac{1}{2}} u_{2\frac{1}{2}} - r_{3\frac{1}{2}} u_{3\frac{1}{2}} \qquad \text{(C.13)}$$

and substituting the expression for $u_{2\frac{1}{2}}$ from eq. C.10a,

$$\eta_3 = A_3 + r_{2\frac{1}{2}} (-R_2 \eta_3 + S_2) - r_{3\frac{1}{2}} u_{3\frac{1}{2}}$$

or $$\eta_3 = -\rho_3 u_{3\frac{1}{2}} + \eta_3 \qquad \text{(C.14)}$$

where $$\rho_3 = \frac{r_{3\frac{1}{2}}}{1 + r_{2\frac{1}{2}} H_2} \qquad \text{(C.15)}$$

and $$u_3 = \frac{A_3 + r_{2\frac{1}{2}} S_2}{1 + r_{2\frac{1}{2}} R_2} \qquad \text{(C.16)}$$

The velocity $u_{3\frac{1}{2}}$ is obtained from eq. C.2 at m = 3:

$$u_{3\frac{1}{2}} = B_{3\frac{1}{2}} + r_3 \eta_3 - r_4 \eta_4 \qquad \text{(C.17)}$$

Or $$u_{3\frac{1}{2}} = -R_3 \eta_4 + S_3 \qquad \text{(C.18)}$$

where $$R_3 = \frac{r_4}{1 + r_3 \rho_3} \qquad \text{(C.19)}$$

$$S_3 = \frac{B_{3\frac{1}{2}} + r_3 Q_3}{1 + r_3 \rho_3} \qquad \text{(C.20)}$$

This procedure (calculation of p_m, Q_m, R_m, and S_m) is repeated for all m up to m = J, where, for a land boundary at J + ½,

$$\eta_J = - p_J \overset{*}{u}_{J+\frac{1}{2}} + Q_J \tag{C.21}$$

and η_j is easily computed since $\overset{*}{u}_{J+\frac{1}{2}}$ is zero.

Suppose, however, that instead of land boundaries, the first (m = 1) and last (m = J + 1) are water boundaries, with either velocity or water level values given. For a first grid water level value, $\overset{*}{\eta}_1$, eq. C.2 gives

$$u_{1\frac{1}{2}} = B_{1\frac{1}{2}} + r_1 \overset{*}{\eta}_1 - r_2 \eta_2 = - R_1 \eta_2 + S_1 \tag{C.22}$$

$$\text{where} \quad R_1 = r_2 \tag{C.23}$$

$$\text{and} \quad S_2 = B_{1\frac{1}{2}} + r_1 \overset{*}{\eta}_1 \tag{C.24}$$

For a first gird velocity, $\overset{*}{u}_{1\frac{1}{2}}$, eq. B.5 will suffice. For the case of a last grid water level value, $\overset{*}{\eta}_{J+1}$, eq. C.2 leads to

$$\begin{aligned} u_{J+\frac{1}{2}} &= B_{J+\frac{1}{2}} + r_J \eta_J - r_{J+1} \overset{*}{\eta}_{J+1} \\ &= - R_J \overset{*}{\eta}_{J+1} + S_J \end{aligned} \tag{C.25}$$

There are three methods of specifying the last grid (m = J + 1) velocity. The first is to specify the value $\overset{*}{u}_{J+1+\frac{1}{2}}$, and

$$\eta_{J+1} = - p_{J+1} \overset{*}{u}_{J+1+\frac{1}{2}} + \overset{Q}{\cancel{u}}_{J+1} \tag{C.26}$$

which involves the calculation of η at the boundary grid (□ = J).

Secondly, it is possible to calculate $u_{J+\frac{1}{2}}$, from $u^{*}_{J+1+\frac{1}{2}}$ using a flowrate conservation law. Finally, the velocity at $J + \frac{1}{2}$ could be specified and eq. C.21 used directly. This last method is the most efficient, and is the one used in the present model calculations.

In general, the coefficients can be written as:

$$P_m = \frac{r_{m+\frac{1}{2}}}{1 + r_{m-1} R_{m-1}} \tag{C.27}$$

$$u_m = \frac{A_m + r_{m+\frac{1}{2}} S_{m-1}}{1 + r_{m-\frac{1}{2}} R_{m-1}} \tag{C.28}$$

$$R_m = \frac{r_m}{1 + r_{m-1} P_m} \tag{C.29}$$

$$S_m = \frac{B_{m+\frac{1}{2}} + r_m u_m}{1 + r_{m-1} P_m} \tag{C.30}$$

Starting at the lower boundary ($m = 1$), R_m and S_m are calculated, (from C.23 and C.24 for a water level boundary; $R_1 = S_1 = 0$ for a land boundary; $R_1 = 0$, $S_1 = u^{*}_{1+\frac{1}{2}}$ for a velocity boundary). Then at the computational levds ($m = 2$ to $m = J$) A_m, P_m, u_m, B_m, R_m, and S_m are calculated in that order for each m. At $m = J$, $u_{J+\frac{1}{2}}$ assumes its appropriate value (zero for a land boundary; the specified value for a velocity boundary; or computed from eq. C.25 for a water level boundary). The remaining values of η and u are then obtained from the recursive relations

$$\eta_m = - P_m u_{m+\frac{1}{2}} + Q_m \tag{C.31}$$

$$u_{m-\frac{1}{2}} = -R_m \eta_m + S_{m-1} \qquad \text{(C.32)}$$

for m decreasing from m = J to m = 2.

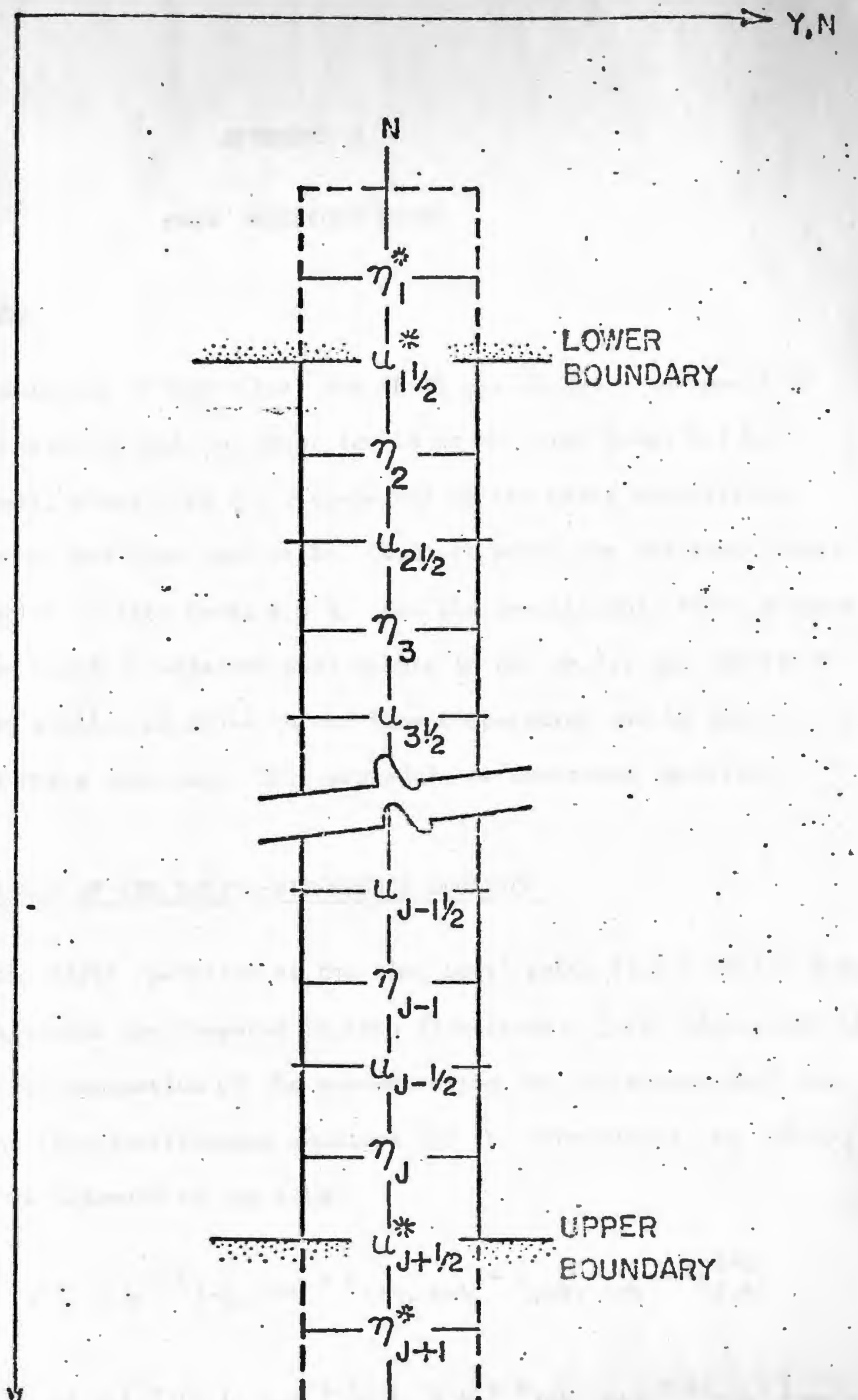


FIGURE C-1: SPATIAL ARRANGEMENT OF VARIABLES ON GRIDS

APPENDIX D

MASS TRANSPORT MODEL

A. GENERAL

The solution of Eqs. (B.1) and (B.2) yields the x component of the water velocity and the water levels at the time level $\eta + \frac{1}{2}$. These values, along with the y component of the water velocity at time level η, are then used in Eq. (B.3) to solve for the constituent concentration at time level $\eta + \frac{1}{2}$. For the constituent, three unknown values are found at adjacent grid points in Eq. (B.3), and numerical procedures similar to those in the flow computation can be used to solve for these unknowns. This procedure is described in detail below.

B. EXPANSION OF THE FINITE-DIFFERENCE EQUATION

In the first operation at the time level going from t to t + ½ Dt, the constituents are computed in both directions. This information is used in the computation of the concentration for the second half time step. The finite-difference equation for the constituent, Eq. (B.3), can then be expanded in the form:

$$\left[C^{t+\frac{1}{2}}_{j,k}\,(h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}} + 4\eta^{t+\frac{1}{2}}_{j,k})\right.$$

$$\left. - C^{t}_{j,k}\,(h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}} + 4\eta_{j,k})\right]\frac{1}{2Dt}$$

$$- [\eta^{t}_{j-1,\,k} + \eta^{t}_{j,\,k} + h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}})\;u^{t+\frac{1}{2}}_{j-\frac{1}{2},\,k}\,(C^{t+\frac{1}{2}}_{j-1,\,k;\,i} + C^{t+\frac{1}{2}}_{j,\,k})$$

$$- (\eta^{t}_{j,k} + \eta^{t}_{j+1,k} + h_{j+\frac{1}{2},k-\frac{1}{2}} + h_{j+\frac{1}{2},k+\frac{1}{2}})\, u^{t+\frac{1}{2}}_{j+\frac{1}{2},k}\, (C^{t+\frac{1}{2}}_{j,k} + C^{t+\frac{1}{2}}_{j+1,k})] \left(\frac{1}{4Dx}\right)$$

$$- [\eta^{t}_{j,k-1} + \eta^{t}_{j,k} + h_{j-\frac{1}{2},k-\frac{1}{2}} + h_{j+\frac{1}{2},k-\frac{1}{2}})\, v^{t}_{j,k-\frac{1}{2}}\, (C^{t}_{j,k-1} + C^{t}_{j,k})$$

$$- (\eta^{t}_{j,k} + \eta^{t}_{j,k+1} + h_{j-\frac{1}{2},k+\frac{1}{2}} + h_{j+\frac{1}{2},k+\frac{1}{2}})\, v^{t}_{j,k+\frac{1}{2}}\, (C^{t}_{j,k+1} + C^{t}_{j,k})] \left(\frac{1}{4Dx}\right)$$

$$+ [\eta^{t+\frac{1}{2}}_{j-1,k} + \eta^{t+\frac{1}{2}}_{j,k} + h_{j-\frac{1}{2},k-\frac{1}{2}} + h_{j-\frac{1}{2},k+\frac{1}{2}})\, D^{t+\frac{1}{2}}_{x_{j-\frac{1}{2},k}}\, (C^{t+\frac{1}{2}}_{j,k} - C^{t+\frac{1}{2}}_{j-1,k})$$

$$- (\eta^{t+\frac{1}{2}}_{j,k} + \eta^{t+\frac{1}{2}}_{j+1,k} + h_{j+\frac{1}{2},k-\frac{1}{2}} + h_{j+\frac{1}{2},k+\frac{1}{2}})\, D^{t+\frac{1}{2}}_{x_{j+\frac{1}{2},k}}\, (C^{t+\frac{1}{2}}_{j+1,k} - C^{t+\frac{1}{2}}_{j,k})] \left[\frac{1}{2\,(Dx)^{2}}\right] \tag{D.1}$$

$$+ [(\eta^{t}_{j,k-1} + \eta^{t}_{j,k} + h_{j-\frac{1}{2},k-\frac{1}{2}} + h_{j+\frac{1}{2},k-\frac{1}{2}})\, D^{t}_{y_{j,k-\frac{1}{2}}}\, (C^{t}_{j,k} - C^{t}_{j,k-1})$$

$$- (\eta^{t}_{j,k} + \eta^{t}_{j,k+1} + h_{j-\frac{1}{2},k+\frac{1}{2}} + h_{j+\frac{1}{2},k+\frac{1}{2}})\, D^{t}_{y_{j,k+\frac{1}{2}}}\, (C^{t}_{j,k+1} - C^{t}_{j,k})] \left[\frac{1}{2\,(Dx)^{2}}\right]$$

$$+ (h_{j+\frac{1}{2},k+\frac{1}{2}} + h_{j+\frac{1}{2},k-\frac{1}{2}} + h_{j-\frac{1}{2},k+\frac{1}{2}} + h_{j-\frac{1}{2},k-\frac{1}{2}} + 4\eta_{j,k})\, \frac{S^{t}_{j,k}}{4} = 0$$

where $C^{t+\frac{1}{2}}_{j,k}$ is the concentration of constituent at the grid point j, k for time level $t + \frac{1}{2}$. The dispersion coefficients D_x, D_y and the source of constituent S can be both space- and time-varying functions in this formulation. Point sources of constituents, such as occur at a power plant outfall, can be included. These procedures used for this part of the computation are described in Leendertse(2).

There are only three unknown variables in Eq. (D.1). They are:

$$C^{t+\frac{1}{2}}_{j,k} \quad ; \quad C^{t+\frac{1}{2}}_{j-1,k} \quad ; \quad \text{and} \quad C^{t+\frac{1}{2}}_{j+1,k} \tag{D.2}$$

Thus, rewriting Eq. (D.1) after multiplying through by $t_{an} = t/2$ yields

$$a_j \, C^{t+\frac{1}{2}}_{j-1,\,k} + b_j \, C^{t+\frac{1}{2}}_{j,\,k} + c_j \, C^{t+\frac{1}{2}}_{j+1,\,k} = D_j \qquad \text{(D.3)}$$

where:

$$a_j = -(\eta^{t}_{j-1,\,k} + \eta^{t}_{j,\,k} + h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}}) \, u^{t}_{j-\frac{1}{2},\,k} \left(\frac{t_{an}}{4\ Dx}\right)$$

$$- (\eta^{t+\frac{1}{2}}_{j-1,\,k} + \eta^{t+\frac{1}{2}}_{j,\,k} + h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}}) \, D^{t+\frac{1}{2}}_{x_{j-\frac{1}{2},\,k}} \left[\frac{t_{an}}{2\ (Dx)^2}\right] \qquad \text{(D.4)}$$

$$c_j = - \Big[(\eta^{t}_{j,\,k} + \eta^{t}_{j+1,\,k} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}}) \, (-u^{t+\frac{1}{2}}_{j+\frac{1}{2},\,k})$$

$$+ (\eta^{t+\frac{1}{2}}_{j,\,k} + \eta^{t+\frac{1}{2}}_{j+1,\,k} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}}) \, D^{t+\frac{1}{2}}_{x_{j+\frac{1}{2},\,k}} \ \frac{2}{Dx}\Big] \left(\frac{t_{an}}{4\ Dx}\right) \qquad \text{(D.5)}$$

$$b_j = \tfrac{1}{4} (h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}}) + \eta^{t+\frac{1}{2}}_{j,\,k}$$

$$- (\eta^{t}_{j-1,\,k} + \eta^{t}_{j,\,k} + h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}}) \, u^{t+\frac{1}{2}}_{j-\frac{1}{2},\,k} \left(\frac{t_{an}}{4\ Dx}\right)$$

$$+ (\eta^{t}_{j,\,k} + \eta^{t}_{j+1,\,k} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}}) \, u^{t+\frac{1}{2}}_{j+\frac{1}{2},\,k} \left(\frac{t_{an}}{4\ Dx}\right)$$

$$+ (\eta^{t+\frac{1}{2}}_{j-1,\,k} + \eta^{t+\frac{1}{2}}_{j,\,k} + h_{j-\frac{1}{2},\,k-\frac{1}{2}} + h_{j-\frac{1}{2},\,k+\frac{1}{2}}) \, D^{t+\frac{1}{2}}_{x_{j-\frac{1}{2},\,k}} \left[\frac{t_{an}}{2\ (Dx)^2}\right] \qquad \text{(D.6)}$$

$$+ (\eta^{t+\frac{1}{2}}_{j,\,k} + \eta^{t+\frac{1}{2}}_{j+1,\,k} + h_{j+\frac{1}{2},\,k-\frac{1}{2}} + h_{j+\frac{1}{2},\,k+\frac{1}{2}}) \, D^{t+\frac{1}{2}}_{x_{j+\frac{1}{2},\,k}} \left[\frac{t_{an}}{2\ (Dx)^2}\right]$$

$$D_j = C^t_{j,\,k}\left[\tfrac{1}{4}\,(h_{j-\frac12,\,k-\frac12} + h_{j-\frac12,\,k+\frac12} + h_{j+\frac12,\,k-\frac12} + h_{j+\frac12,\,k+\frac12} + \eta^t_{j,\,k}\right]$$

$$+\Big[\left(\eta^t_{j,\,k-1} + \eta^t_{j,\,k} + h_{j-\frac12,\,k-\frac12} + h_{j+\frac12,\,k-\frac12}\right) v^t_{j,\,k-\frac12}\,(C^t_{j,\,k-1} + C^t_{j,\,k})$$

$$- (\eta^t_{j,\,k} + \eta^t_{j,\,k+1} + h_{j-\frac12,\,k+\frac12} + h_{j+\frac12,\,k+\frac12})\, v^t_{j,\,k+\frac12}\,(C^t_{j,\,k+1} + C^t_{j,\,k})\Big]\left(\frac{t_{an}}{4\ Dx}\right)$$

(D.7)

$$- \Big[(\eta^t_{j,\,k-1} + \eta^t_{j,\,k} + h_{j-\frac12,\,k-\frac12} + h_{j+\frac12,\,k-\frac12})\, D^t_{y_{j,\,k-\frac12}}\,(C^t_{j,\,k} - C^t_{j,\,k-1})$$

$$- (\eta^t_{j,\,k} + \eta^t_{j,\,k+1} + h_{j-\frac12,\,k+\frac12} + h_{j+\frac12,\,k+\frac12})\, D^t_{y_{j,\,k+\frac12}}\,(C^t_{j,\,k+1} - C^t_{j,\,k})\Big]\left(\frac{t_{an}}{2\ (Dx)^2}\right)$$

$$-\left[\tfrac{1}{4}\ (h_{j+\frac12,\,k+\frac12} + h_{j+\frac12,\,k-\frac12} + h_{j-\frac12,\,k+\frac12} + h_{j-\frac12,\,k-\frac12}) + \eta^t_{j,\,k}\right] S^t_{j,\,k}$$

For each row k, Eq. (D.7) can be written as:

$$a_j C_{j-1} + b_j C_j + e_j C_{j+1} = D_j \qquad \text{(D.8)}$$

where the subscripts k and superscript t + ½ are dropped for convenience. Equation (D.8) can be solved for the concentration of constituent at each grid point along row k by a process of elimination of unknowns. To illustrate the method, a closed left-hand boundary is assumed at some value of j = J-1, k = K, as shown in Figure D-1.

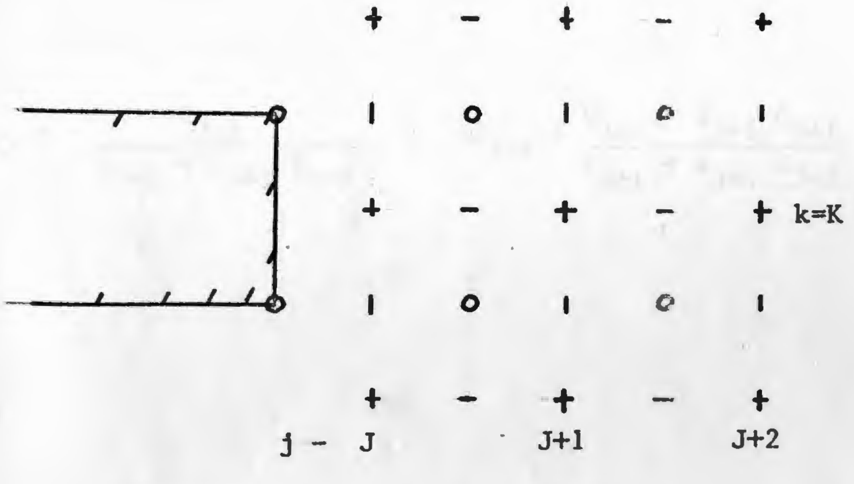


FIGURE D-1: LEFT CLOSED BOUNDARY

For this case, both the advective and dispersive transport of constituent through the cross section between grid points J-1 and J is zero. Thus $a_j = 0$, and Eq. (D.8) can be written as:

$$b_J C_J + e_J C_{J+1} = D_J \tag{D.9}$$

For the next point, $j = J+1$, along row $k = K$, Eq. (D.8) is written as:

$$a_{J+1} C_J + b_{J+1} C_{J+1} + e_{J+1} C_{J+2} = D_{J+1} \tag{D.10}$$

Solving Eq. (D.9) for C_J yields

$$C_J = E_{J+1}\, C_{J+1} + Q_{J+1} \tag{D.11}$$

where

$$E_{J+1} = - \frac{e_J}{b_J} \quad ; \quad Q_{J+1} = \frac{D_J}{b_J} \tag{D.12}$$

Substituting Eq. (D.9) for C_J into Eq. (D.10) gives

$$a_{J+1}\, (E_{J+1}\, C_{J+1} + Q_{J+1}) + b_{J+1}\, C_{J+1} + e_{J+1}\, C_{J+2} = D_{J+1} \tag{D.13}$$

Solving for C_{J+1} yields

$$C_{J+1} = E_{J+2}\, C_{J+2} + Q_{J+2} \tag{D.14}$$

where

$$E_{J+2} = - \frac{e_{J+1}}{b_{J+1} + a_{J+1}\, E_{J+1}} \quad ; \quad Q_{J+2} = \frac{D_{J+1} - a_{J+1}\, Q_{J+1}}{b_{J+1} + a_{J+1}\, E_{J+1}} \tag{D.15}$$

In general, the following recursion formulas are valid:

$$P_j = E_{j+1} C_{j+1} + Q_{j+1} \tag{D.16}$$

where

$$E_{j+1} = - \frac{e_j}{b_j + a_j E_j} \tag{D.17}$$

$$Q_{j+1} = \frac{D_j - a_j Q_j}{b_j + a_j E_j} \tag{D.18}$$

It is assumed that the right-hand boundary at j = M, k = K is also a closed boundary, as shown in Figure D-2.

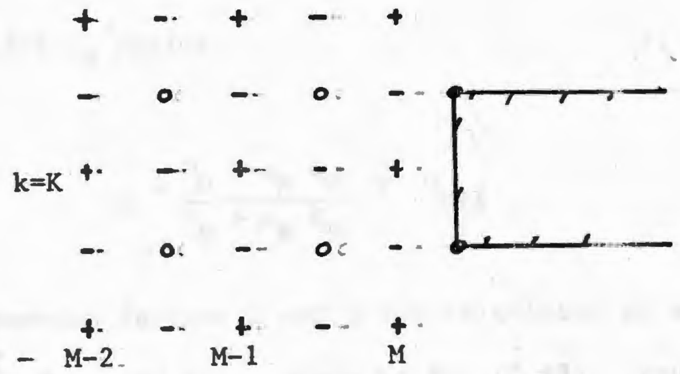


FIGURE D-2: RIGHT CLOSED BOUNDARY

The advective and diffusive transport of constituent through the cross section between j = M and j = M + 1 is zero for this case, and therefore $e_M \equiv 0$. Equation (D.8) for j = M then becomes

$$a_M C_{M-1} + b_M C_M = D_M \tag{D.19}$$

and solving for C_{M-1} yields

$$ {}_{M-1} = -\frac{b_M}{a_M} C_M + \frac{D_M}{a_M} \tag{D.20} $$

Writing the general recursion formula given by Eq. (D.17) for j = M-1 leads to

$$ C_{M-1} = E_M P_M + Q_M \tag{D.21} $$

Using Eq. (D.21) in Eq. (D.22) gives

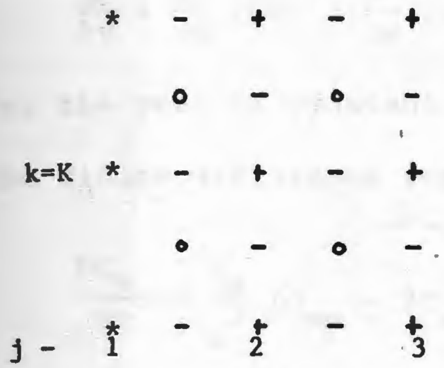
$$ E_M C_M + Q_M = -\frac{b_M}{a_M} C_M + \frac{D_M}{a_M} \tag{D.22} $$

and solving for C_M yields

$$ {}_{M} = \frac{D_M - a_M Q_M}{b_M + a_M E_M} \equiv Q_{M+1} \tag{D.23} $$

The recursion factors E and Q are calculated in ascending order, starting with E_{J+1} and Q_{J+1}, given by Eq. (D.13). Equations (D.17) and (D.18) are used to calculate the remaining recursion factors to j = M, noting that $E_{M+1} \equiv 0$ since $e_M = 0$. The concentrations are then computed in descending order, starting with j = M, using Eq. (D.16).

If instead of a closed boundary at either end of the computational field, the geography of the region to be modeled requires an open boundary, then the above procedure must be modified slightly. As in the example given for the flow model, it is assumed that part of the left-hand boundary, j = 1, of the computational field contains an open boundary, as shown in Figure D-3. For this case, E_2 is set equal to zero and Q_2 is set equal to the concentration of constituent i at the open boundary, C_1. This concentration is a given input variable and is usually a function of time. The methods used to obtain C_1 for the sample calculations are explained in the next section.



* Concentration of constituent at open boundary (function of time)

FIGURE D-3: LEFT OPEN BOUNDARY

The rest of the recursion factors and concentrations are then calculated in the same way as for a closed boundary.

APPENDIX E

DIFFERENCING SCHEMES AND THEIR EFFECTS

Consider the one-dimensional convective-dispersion equation

$$\frac{\partial c}{\partial t} + \frac{\partial}{\partial x} (UC) = \frac{\partial}{\partial x} (D_x \frac{\partial c}{\partial x}) = 0 \qquad \text{(E-1)}$$

For the case of constant velocity and dispersion coefficient, the finite difference formulation is

$$\frac{DC_m}{Dt} = \frac{D_x}{L^2} [C_{mp} - 2C_m + C_{mm}] - \frac{U}{L} [C_{mp} (1-A) + (A-B) C_m$$

$$-C_{mm} (1 - B)] \qquad \text{(E-2)}$$

where L is the grid length, A and B are parameters with possible values of 0, 1/2, or 1, mm = m-1 and mp = m+1.

Let us suppose a constant depth and width channel with unit concentration at grid M, and zero elsewhere in Figure E.1.

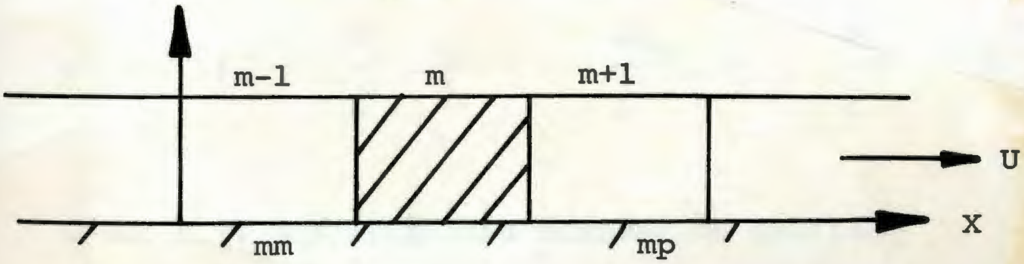


FIGURE E.1. ONE DIMENSIONAL DIFFERENCING SCHEME

Using a central spatial derivative in the convective term (A = B = 1/2), the rate of change of concentration, DC/Dt, may be computed as follows:

$$\text{at M } \frac{DC_m}{Dt} = \frac{D_x}{L^2} [C_{mp} - 2C_m + C_{mm}] - \frac{u}{2L} [C_{mp} - C_{mm}] \tag{E-3}$$

which becomes, upon substitution of values of C from Figure E-1,

$$\frac{DC_m}{Dt} = \frac{D_x}{L^2} [-2C_m] = -\frac{2D_x}{L^2} \tag{E-4}$$

A	B	$\frac{DC_{mm}}{Dt}$	$\frac{DC_m}{Dt}$	$\frac{DC_{mp}}{Dt}$
1/2	1/2	$\frac{D_x}{L^2} - \frac{u}{2L}$	$-\frac{2D_x}{L^2}$	$\frac{D_x}{L^2} + \frac{u}{2L}$
1	0	$\frac{D_x}{L^2}$	$-\frac{2D_x}{L^2} - \frac{u}{L}$	$\frac{D_x}{L^2} + \frac{u}{L}$
0	1	$\frac{D_x}{L^2} - \frac{u}{L}$	$-\frac{2D_x}{L^2} - \frac{u}{L}$	$\frac{D_x}{L^2}$

TABLE E.1. DIFFERENCING SCHEMES ON SPATIAL CONCENTRATION GRID

The results for grids M, MM, and MP are given in the table. If the dispersion coefficient, D_x, is small (less than 25 yd^2), this scheme results in a negative concentration at the grid immediately upstream from the grid with unit concentration.

To overcome this, the upstream differencing technique may be used to advantage. That is, instead of using a central difference in the spacial term, a backward difference is used (with velocity in (+) - x direction), which is obtained by setting A = 1, and B = 0. Applying this at M, we have

$$\frac{DC_m}{Dt} = \frac{D}{L^2} [-2C_m] - \frac{u}{L} [C_m - C_{mm}] \tag{E-5}$$

$$= - \frac{2D}{L^2} - \frac{u}{L} \tag{E-6}$$

The results for M, MM, and MP are shown in Table E.1. The upstream concentration is now positive. However, this scheme results in an increase in effective dispersion. This may be seen by making the substitution for A = 1, B = 0 into Equation E-1.

Consider the consequences of using a mixture of the two schemes. By adding the rates of increase of concentration for the three grids M, MM, MP for the upstream scheme

(A = 1, B = 0), the sum is zero, indicating that mass is conserved. However, if a central derivative is used at grid MP, its increase is

$$\frac{DC_{mp}}{Dt} = \frac{D_x}{L^2} + \frac{u}{2L} \tag{E-7}$$

The sum for the three grids is then

$$- 1/2 \frac{U}{L} \tag{E-8}$$

indicating that mass is lost. Thus a mixture of the two schemes is to be avoided. For the velocity conditions below

$$\begin{array}{lll} \text{Case} & u \text{ greater than } 0; & A = 1,\ B = 0 \\ \text{A} & & \\ & v \text{ greater than } 0; & A = 1,\ B = 0 \end{array} \tag{E-9}$$

$$\begin{array}{lll} \text{Case} & u \text{ less than } 0; & A = 0,\ B = 1 \\ \text{B} & & \\ & v \text{ less than } 0; & A = 0,\ B = 1 \end{array} \tag{E-10}$$

the upstream differencing would be

$$\text{Case A} \qquad \frac{\partial C}{\partial x} = \frac{1}{2L}[2C_m - 2C_{m-1}] \tag{E-11}$$

$$\text{Case B} \qquad \frac{\partial C}{\partial x} = \frac{1}{2L}[2C_{m+1} - 2C_m] \tag{E-12}$$

where L = is length of grid

The second term in Equation E-4, $\frac{\partial}{\partial x}$ (UC) is now analyzed for $U\frac{\partial C}{\partial x}$ according to Figure E.2

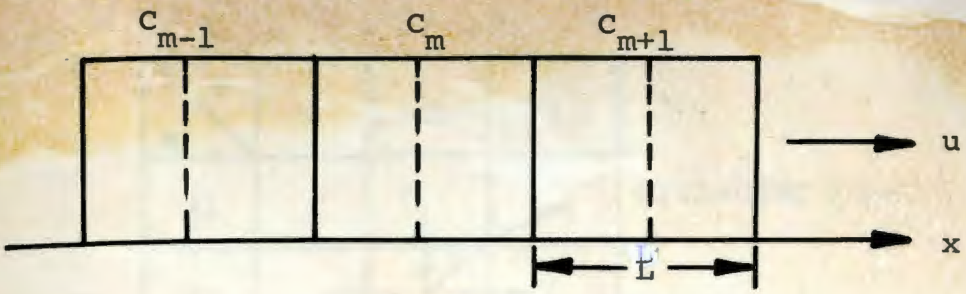


FIGURE E.2. ONE DIMENSIONAL CONCENTRATION SCHEME

and we have

$$U\frac{\partial C}{\partial x} = u[(1 + A)\ C_{m+1} - 2(A-B)\ C_m - (1 - B)\ C_{m-1}]\ \frac{1}{2L} \tag{E-13}$$

for centered derivative A = 1/2 and B = 1/2, we have

$$= (C_{m+1} - C_{m-1})\ \frac{u}{2L} \tag{E-14}$$

A. UPSTREAM DIFFERENCING IN A CONSISTENT DIVERGENT FLOW PATTERN

It was discovered that for the grid point N = 10, M = 32 the upstream differencing scheme is unstable. This is shown by first referring to Figure E.3., and noting the general divergent flow condition that exists especially with regard to their velocity component.

Since we have Case A, Equation E.1 is supposed to be applicable which it normally would be if the component was

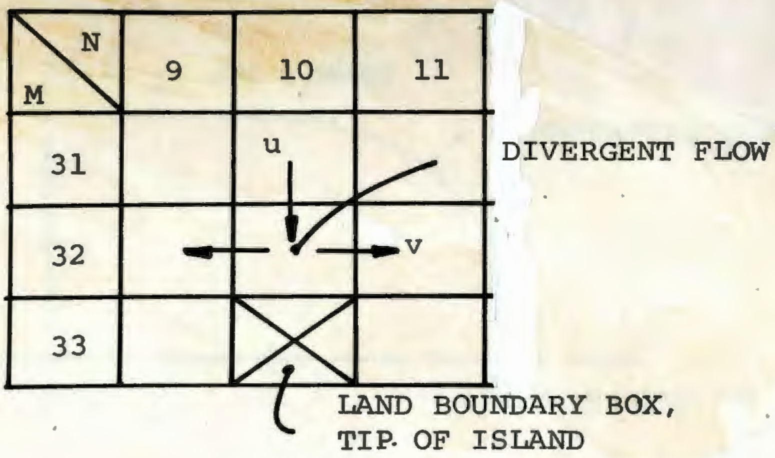


FIGURE E.3. DIVERGENT FLOW AROUND THE NORTH TIP OF CONANICUT ISLAND, JAMESTOWN, RHODE ISLAND

not plus (easterly) over 90% of the time. The result is that the C_{m-1} term is forced to change sign by the differencing scheme, which means that the $\frac{\partial C}{\partial x}$ term is larger than it should be, which in turn increases the net advective transport out of the box, giving the response shown in Figure E.4.

Considering the divergent flow and artificial diffusion enhancing properties of the upstream differencing scheme, it was decided to make initial prediction runs using the central differencing scheme.

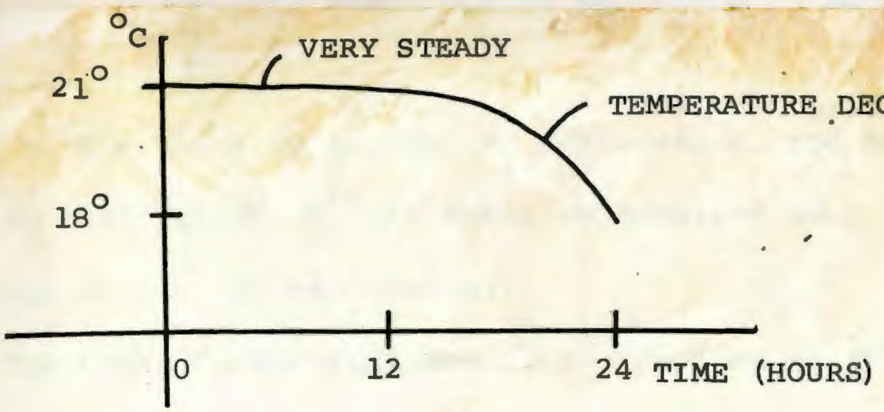


FIGURE E.4. DIVERGENT FLOW INSTABILITY

B. CONSERVATION OF MASS

An attempt was made to check on the mass-conserving properties of several approximations to the convective-dispersion concentration equation

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} - D_x \frac{\partial C^2}{\partial x^2} = 0 \qquad \text{(E-1.a)}$$

which have been used in mathematical models. The approximations involve the use of various differencing schemes on the convective term, and modifications of the dispersion coefficient, D_x, if applicable.

In finite-difference form, the above equation may be written as

$$\frac{C^+_m - C^0_m}{t} + \frac{U}{2L}\left[2(1 - A)\ C^+_{mp} + 2(A - B)\ C^+_m\right.$$

$$- 2(1 - B)\ C^{+}_{mm}] - \frac{D_x}{L^2}\ [C^{+}_{mp} - 2C^{+}_{m} + C_{mm}^{+}] = 0 \qquad \text{(E-16)}$$

where U, the velocity in the (+) x-direction, and the dispersion coefficient, D, are taken as constant over x (as they are in the uniform channel).

The terms C represent the concentrations at the center of each grid, with the superscript (+) denoting the upper time level, and the (0) the lower time level. The subscripts denote the grid number in the x-direction, with MP = M+1, MM = M-1. The above finite-difference equation is written for grid M.

The dispersion coefficient, (refer to Figure E.4), D, is calculated from the velocity, u, the depth, H, and the Chezy coefficient, C_z, in the general form

$$\frac{\partial C}{\partial t} = - u\frac{\partial C}{\partial x} = - u\ [(1 - A)\ C_{mp} + (A - B)\ C_m$$

$$- (1 - B)\ C_{mm}]\ \frac{1}{L} \qquad \text{(E-9)}$$

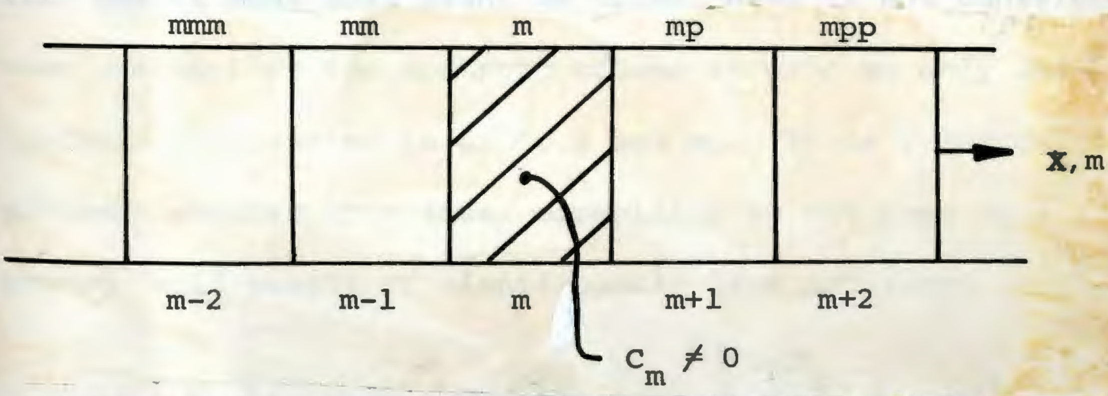


FIGURE E.5. ONE DIMENSIONAL FIVE GRID SCHEME for $C_m \neq 0.0$, and $E = u/L$

$C_{mp} = C_{mm} = 0 = C_{mpp} = C_{mmm}$

Case I upstream: all M $A = 1,\ B = 0$

$m = m \qquad DC_m = -E(C_m - C_{mm}) = EC_m$ (E-17)

$m = mp \qquad DC_{mp} = -E(C_{mp} - C_m) = +EC_m$ (E-18)

$m = mm \qquad DC_{mm} = -E(C_{mmm} - C_{mm}) = 0$ (E-19)

Case II no upstream $A = B = 1/2$

$mm \qquad DC_{mm} = -(E/2)\ (C_m - C_{mmm}) = -EC_m/2$ (E-20)

$m \qquad DC_m = -(E/2)\ (C_{mp} - C_{mm}) = 0$ (E-21)

$mp \qquad DC_{mp} = -(E/2)\ (C_{mpp} - C_m) = +EC_m/2$ (E-22)

Case III upstream at mm only

$mm \qquad DC_{mm} = -E\ (C_{mm} - C_{mmm}) = 0$ (E-23)

$m \qquad DC_m = -(E/2)\ (C_{mp} - C_{mm}) = 0$ (E-24)

$mp \qquad DC_{mp} = -(E/2)\ (C_{mpp} - C_m) = +EC_m/2$ (E-25)

For Cases I and II mass is conserved if schemes are consistent, that is either upstream of central differencing is used exclusively in computational procedure. In Case III, one of many that might be tried, mass is not conserved when one applies the upstream scheme at grid mm only and central differencing in grids m and mp. It is a matter of judgment whether this loss, especially in the area of a source, will result in significantly less accuracy.

Appendix F

Sample Program For Thermal Model Segments

```
//LIBRARY JOB (IN0100,060.15,500),'JOHN ALFANO',MSGLEVEL=1,CLASS=E           JOB 146
//CHNGSTEP EXEC PGM=IEBUPDTE
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=OCESMODS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUT2 DD DSN=OCESMODS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSIN DD *
IEF236I ALLOC. FOR LIBRARY  CHNGSTEP
IEF237I 631    ALLOCATED TO SYSPRINT
IEF237I 241    ALLOCATED TO SYSUT1
IEF237I 241    ALLOCATED TO SYSUT2
IEF237I 601    ALLOCATED TO SYSIN
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000055         DELETED
IEF285I    VOL SER NOS=         .
IEF285I    OCESMODS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IFF285I    OCESMODS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000056         DELETED
IEF285I    VOL SER NOS=         .
UR1001I    STEP EXECUTION TIME       .22 MINS.
// EXEC FORTHCL,PARM.FORT='OPT=2',PARM.LKED='LET,LIST,NCAL,XREF'
XXDEFAULT  PROC LIB1=SSP,LIB2=OPLOT                                     00000100
XXFORT   EXEC  PGM=IEKAA00,REGION=228K                                  00000200
XXSYSPRINT DD  SYSOUT=A                                                 00000300
XXSYSPUNCH DD  SYSOUT=B                                                 00000400
XXSYSLIN   DD  DSNAME=&LOADSET,UNIT=SYSSQ,DISP=(MOD,PASS),             *00000500
IFF653I SUBSTITUTION JCL - DSNAME=&LOADSET,UNIT=SYSSQ,DISP=(MOD,PASS),
XX            SPACE=(1680,(50,10)),DCB=(RECFM=FB,BLKSIZE=1680,LRECL=80) 00000600
//FORT.SYSIN DD DSN=OCESMODS(AMAIN),DISP=SHR
IEF236I ALLOC. FOR LIBRARY  FORT
IEF237I 631    ALLOCATED TO SYSPRINT
IEF237I 660    ALLOCATED TO SYSPUNCH
IEF237I 240    ALLOCATED TO SYSLIN
IEF237I 241    ALLOCATED TO SYSIN
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000057         DELETED
IEF285I    VOL SER NOS=         .
IEF285I    SYS73156.T003132.RF000.LIBRARY.LOADSET          PASSED
IFF285I    VOL SER NOS= COB101.
IEF285I    OCESMODS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
UR1001I    STEP EXECUTION TIME       .78 MINS.
XXLKED EXEC PGM=IEWL,REGION=96K,PARM=(MAP,LET,LIST),COND=(4,LT,FORT)    00000700
XXSYSLIB    DD  DSNAME=SYS1.FORTLIB,DISP=SHR                            00000800
XX          DD  DSNAME=URI.&LIB1.LIB,DISP=SHR                           000C0900
IFF653I SUBSTITUTION JCL - DSNAME=URI.SSPLIB,DISP=SHR
XX          DD  DSNAME=URI.&LIB2.LIB,DISP=SHR                           00001000
IEF653I SUBSTITUTION JCL - DSNAME=URI.OPLOTLIB,DISP=SHR
XXSYSPRINT DD  SYSOUT=A                                                 00001100
//LKED.SYSLMOD DD DSN=OCECOMP(MAIN),DISP=OLD
X/SYSLMOD  DD  DSNAME=&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),            *00001200
IEF653I SUBSTITUTION JCL - DSNAME=&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
XX             SPACE=(3072,(30,10,1))                                   00001300
XXSYSLIN   DD  DSNAME=&LOADSET,DISP=(OLD,DELETE)                        00001400
IEF653I SUBSTITUTION JCL - DSNAME=&LOADSET,DISP=(OLD,DELETE)
XX         DD  DDNAME=SYSIN                                             00001500
XXSYSUT1 DD DSNAME=&SYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD 00001600
IEF653I SUBSTITUTION JCL - DSNAME=&SYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD
IEF236I ALLOC. FOR LIBRARY  LKED
IEF237I 130    ALLOCATED TO SYSLIB
IFF237I 244    ALLOCATED TO
```

```
IEF237I 244    ALLOCATED TO
IEF237I 631    ALLOCATED TO SYSPRINT
IEF237I 241    ALLOCATED TO SYSLMOD
IEF237I 240    ALLOCATED TO SYSLIN
IEF237I 133    ALLOCATED TO SYSUT1
IEF285I    SYS1.FORTLIB                                   KEPT
IEF285I    VOL SER NOS= MFTRES.
IEF285I    URI.SSPLIB                                     KEPT
IEF285I    VOL SER NOS= MFTLB1.
IEF285I    URI.OPLOTLIB                                   KEPT
IEF285I    VOL SER NOS= MFTLB1.
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000059        DELETED
IEF285I    VOL SER NOS=        .
IEF285I    OCECOMP                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.LOADSET         DELETED
IEF285I    VOL SER NOS= COBI01.
IEF285I    SYS73156.T003132.RF000.LIBRARY.SYSUT1          DELETED
IEF285I    VOL SER NOS= CEDISK.
URI001I    STEP EXECUTION TIME       .04 MINS.
//CHNGSTEP EXEC PGM=IEBUPDTE
//SYSPRINT DD SYSOUT=A
//SYSUT1 DD DSN=OCEDATAS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUT2 DD DSN=OCEDATAS,DISP=OLD,UNIT=2314,VOL=SER=OCEPAK
//SYSUDUMP DD SYSOUT=A
//SYSIN DD *
IEF236I ALLOC. FOR LIBRARY  CHNGSTEP
IEF237I 631    ALLOCATED TO SYSPRINT
IEF237I 241    ALLOCATED TO SYSUT1
IEF237I 241    ALLOCATED TO SYSUT2
IEF237I 632    ALLOCATED TO SYSUDUMP
IEF237I 602    ALLOCATED TO SYSIN
IEF285I    SYS73156.T003132.RF000.LIBRARY.R000006D        DELETED
IEF285I    VOL SER NOS=        .
IEF285I    OCEDATAS                                       KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    OCEDATAS                                       KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000062        DELETED
IEF285I    VOL SER NOS=        .
URI001I    STEP EXECUTION TIME       .19 MINS.
//LKED EXEC PGM=IEWL,PARM=(MAP,LET,LIST,OVLY,XREF)
//SYSLIB DD DSN=SYS1.FORTLIB,DISP=SHR
//        DD DSN=URI.SSPLIB,DISP=SHR
//        DD DSN=URI.OPLOTLIB,DISP=SHR
//SYSPRINT DD SYSOUT=A
//SYSLIN DD DDNAME=SYSIN
//SYSLMOD DD DSN=&GOSET(MAIN),UNIT=SYSDA,DISP=(,PASS),
//        SPACE=(3072,(30,10,1))
//SYSUT1 DD DSN=&SYSUT1,UNIT=SYSDA,SPACE=(1024,(200,20)),SEP=SYSLMOD
//LKED.OBJLIB DD DSN=OCECOMP,DISP=SHR,VOL=SER=OCEPAK,UNIT=2314
//LKED.SYSIN DD *
IEF236I ALLOC. FOR LIBRARY  LKED
IEF237I 130    ALLOCATED TO SYSLIB
IEF237I 244    ALLOCATED TO
IEF237I 244    ALLOCATED TO
IEF237I 631    ALLOCATED TO SYSPRINT
IEF237I 603    ALLOCATED TO SYSLIN
IEF237I 242    ALLOCATED TO SYSLMOD
IEF237I 130    ALLOCATED TO SYSUT1
```

```
IEF237I 241    ALLOCATED TO OBJLIB
IEF285I    SYS1.FORTLIB                                    KEPT
IEF285I    VOL SER NOS= MFTRES.
IEF285I    URI.SSPLIB                                      KEPT
IEF285I    VOL SER NOS= MFTLB1.
IEF285I    URI.GPLOTLIB                                    KEPT
IEF285I    VOL SER NOS= MFTLB1.
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000063         DELETED
IEF285I    VOL SER NOS=           .
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000064         DELETED
IEF285I    VOL SER NOS=           .
IEF285I    SYS73156.T003132.RF000.LIBRARY.GOSET            PASSED
IEF285I    VOL SER NOS= CHMPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.SYSUT1           DELETED
IEF285I    VOL SER NOS= MFTRES.
IEF285I    OCECOMP                                         KEPT
IEF285I    VOL SER NOS= OCEPAK.
URI001I    STEP EXECUTION TIME       .15 MINS.
//GO EXEC PGM=*.LKED.SYSLMOD
//FT06F001 DD SYSOUT=A
//FT07F001 DD SYSOUT=B
//FT05F001 DD DSN=OCEDATAS(ADATA2),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
//          DD DSN=OCEDATAS(ADATA3),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
//          DD DSN=OCEDATAS(ADATA4),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
//          DD DSN=OCEDATAS(ADATA4),DISP=SHR,VOL=SER=OCEPAK,UNIT=2314,
// LABEL=(,,,IN)
//GO.FT13F001 DD DSN=&ALF,DISP=(NEW,DELETE),UNIT=SYSDA,
// SPACE=(TRK,(10,10))
//
IEF236I ALLOC. FOR LIBRARY  GO
IEF237I 242    ALLOCATED TO PGM=*.DD
IEF237I 631    ALLOCATED TO FT06F001
IEF237I 661    ALLOCATED TO FT07F001
IEF237I 241    ALLOCATED TO FT05F001
IEF237I 241    ALLOCATED TO
IEF237I 241    ALLOCATED TO
IEF237I 241    ALLOCATED TO
IEF237I 130    ALLOCATED TO FT13F001
IEF285I    SYS73156.T003132.RF000.LIBRARY.GOSET            PASSED
IEF285I    VOL SER NOS= CHMPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000065         DELETED
IEF285I    VOL SER NOS=           .
IEF285I    SYS73156.T003132.RF000.LIBRARY.R0000066         DELETED
IEF285I    VOL SER NOS=           .
IEF285I    OCEDATAS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    OCEDATAS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    OCEDATAS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    OCEDATAS                                        KEPT
IEF285I    VOL SER NOS= OCEPAK.
IEF285I    SYS73156.T003132.RF000.LIBRARY.ALF              DELETED
IEF285I    VOL SER NOS= MFTRES.
URI001I    STEP EXECUTION TIME.     49.26 MINS.
IEF285I    SYS73156.T003132.RF000.LIBRARY.GOSET            DELETED
IEF285I    VOL SER NOS= CHMPAK.
```

```
SYSIN                          NEW MASTER                          IEBUPDTE LOG PAGE 0001

./ CHANGE NAME=AMAIN,LIST=ALL
                                     DIMENSION A(048),B(48),Q(48),R(48),S(48), T(48),P(48),              00001000
                                    1KONVRT(21),NH(21),NPRINT(200),DAVG(80),         AHOLD(48),NT(30),   00001100
                                    2NS(10),MS(10),SS(10),ZIF(0175),NTP(10),ZIH(0175),ZIG(0175)          00001200
                               C                                                                         00001300
                                     COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001400
                                    1 C(21,48),NBD(85),MBD(85),MOBD(4),NOBD(4),H(21,48),                 00001500
                                    2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),              00001600
                                    3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),                 00001700
                                    4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),   00001740
                                    5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                          00001900
                                    6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)        00002000
                               C                                                                         00002100
                                     LOGICAL READIN,DOSAL,RDCNP,DELTAT                                   00002200
                               C                                                                         00002300
                                     DATA YR,DAY,THR,TMIN /57.,195.,17.,48./                             00002400
                                     DATA MSOURC,NSOURC /1,1/                                            00002500
                                     DATA AL,AG,SALRIS,TMHOPE,TRIVER,TSOUND/1012.7,10.73,32.5,21.75,     00002600
                                    122.2,18.50/                                                         00002700
                                     DATA HINV,SEINV,PI,CMANN,WX,WY,CDRAG,CRHO /0.,0.,3.1415927,         00002800
                                    1.015,0.,0.,.0025,.00114/                                            00002900
                               C                                                                         00003000
                               C                                                                         00003100
                               C     SET EXECUTION PARAMETERS                                            00003200
                               C                                                                         00003300
                               C     IMODES = 1 UPSTREAM DIIFERENCING                                    00003400
                               C     IMODES = 2 CENTRAL DIFFERENCING                                     00003500
                               C                                                                         00003600
                               C                                                                         00003650
                                     IMODES=2                                                            00003700
                                2871 IPUNCH=540                                                          00003800
                                     AT = 120.                                                           00003900
                                     EXTRA3=AT                                                           00004000
                               C     IPRIND WILL SPECIFY TIME THAT VARIABLES ARE DISPLAYED               00004100
                                     IPRIND=15                                                           00004200
                                     ILD=1                                                               00004300
                               C     SUMMING MODES REQUIRED FOR DISPLAYS                                 00004400
                                     SUMZIG=0.0                                                          00004500
                                     SUMZID=0.0                                                          00004600
                                     SUMZIF=0.0                                                          00004700
                                     SUMZIH=0.0                                                          00004800
                                     SUMAA=0.0                                                           00004900
                                     SUMBB=0.0                                                           00005000
                                     MAXST=540                                                           00005100
                                     NW=MAXST+1                                                          00005200
                                     IDY=1                                                               00005300
                                     HS1(IDY) = 2000.                                                    00005400
                                     RDCNP=.FALSE.                                                       00005500
                               C     RDCNP FOR READING IN PREVIOUS VALUES OF CNP                         00005600
                                     READIN=.TRUE.                                                       00005700
                                     DOSAL=.TRUE.                                                        00005800
                                     IRMS=1000                                                           00005900
```

```
      IMODE1 = 1
C
C     SET COMPUTATION PARAMETERS
C
C
C     IF DELTAT IS TRUE MODEL WILL CALCUALTE TEMPERATURE ABOVE AMBIENT
      DELTAT=.TRUE.
      TBNB=21.0
      IF(DELTAT) GO TO 2873
      GO TO 2875
 2873 TBNB=0.00001
      TMHOPE=.00001
      TRIVER=.00001
      TSOUND=.00001
 2875 CONTINUE
C     DIFFUSION CONSTANT IS UPCON
C     FOR UPCON =500 THE ORDER OF MAGNITUDE OF HIGHEST DIFFUSION COEF
C     IS ABOUT 350 YDSQ/SEC
C
      UPCON=050.
C
C     POWER PLANT
C     TIN =0.0 YOU WILL HAVE HYDRODYNAMICS OF POWER PLAT SITE BUT
C     NO THERMAL LOAD ON BAY
C     IF EFFECTS OF POWER PLANT ARE DESIRED SET TIN EQUAL TO 12.
      TIN=12.
      QIN=2000.
C
C     SITE SELECTION.  SEE HEATIN FOR DETAILS ON LOCATIONS
      SITE=100.
C
C
      LNL = 0
      ARHO=27.*1.940*(1.00+0.000841*SALRIS-0.000100*TSOUND)
C
C
      NMAX=19
      MMAX=48
      ANGLAT=41.6
      NI=1
      MOBD(1)=0103042
      MOBD(2)=4808091
      MOBD(3)=4811131
      NOBD(1)=1923242
      NOBD(2)=0410112
      MINDO=4
      NINDO=3
      NSECT=80
C
   87 CONTINUE
      ARG=ANGLAT*3.1415927/180.
      FF=3.1415927*SIN(ARG)/21600.
```

```
 2080 NST=0                                                             00011200
      IP=1                                                              00011300
      C1=AT*AG/AL                                                       00011400
      C2=AT/AL                                                          00011500
      C3=AT/4.                                                          00011600
      C4=8.*AT*AG                                                       00011700
      C5=2.*27.*AL                                                      00011800
C    27 IS FOR CUFT TO CUYDS CONVERSION AND 2 IS FOR DISPLAYING         00011900
C     ACTUAL CROSSECTIONAL FLOW IN FOR RIVER                            00012000
      C6=2.*CDRAG*CRHO*(1.687/3.)**2*AT                                 00012100
      C7=40.00*SURT(AG)                                                 00012200
      C8=1./AL                                                          00012300
      C9=1./(AL**2)                                                     00012400
      C10 = 0.                                                          00012500
      C11=C7                                                            00012600
      C12 = 0.                                                          00012700
      C13=1./AT                                                         00012800
      C14=1./(4.*AL)                                                    00012900
      DO 8 M=1,MMAX                                                     00013000
      DO 6 N=1,NMAX                                                     00013100
      SE(N,M)=0.0                                                       00013200
      SEP(N,M)=0.0                                                      00013300
      CN(N,M)=0.0                                                       00013400
      CNP(N,M)=0.0                                                      00013500
       UAVG(N,M)=0.0                                                    00013600
      VAVG(N,M)=0.0                                                     00013700
      VP(N,M)=0.0                                                       00013800
      UP(N,M)=0.0                                                       00013900
      V(N,M)=0.                                                         00014000
      U(N,M)=0.                                                         00014100
      C(N,M)=0.                                                         00014200
      H(N,M)=0.0                                                        00014300
    6 F(N)=FF                                                           00014400
    8 CONTINUE                                                          00014500
      RA=0.0                                                            00014600
      CALL KURIH(MAXST,AT,NTERM,FCHECK,YR,DAY,THR,TMIN,TS)              00014700
      CALL DIVE(NMAX,MMAX)                                              00014750
      CALL FIND(MIND,NIND,MMAX,NMAX,MINDO,NINDO,NSECT)                  00015000
      CALL DEPTH(NMAX,MMAX)                                             00015100
      CALL CHEZY(NMAX,MMAX,CMANN)                                       00015200
      CALL CHECK(NMAX,MMAX)                                             00015300
      DO 26 I=1,5                                                       00015400
      L=18*I                                                            00015500
      M=18*(I-1) +1                                                     00015600
      READ(5,25) (NPRINT(N),N=M,L)                                      00015700
   25 FORMAT(18I4)                                                      00015800
   26 CONTINUE                                                          00015900
      DO 62 M=1,MMAX                                                    00016000
      DAVG(M)=0.0                                                       00016100
      DEP=0.0                                                           00016200
      DO 61 N=1,NMAX                                                    00016300
      IF(H(N,M).EQ.0.0) GO TO 61                                        00016400
```

```
      DAVG(M)=DAVG(M)+H(N,M)
      DEP=DEP+1.
   61 CONTINUE
      DAVG(M)=3.*DAVG(M)/DEP
   62 CONTINUE
      NUM=1
      DEP=0.0
      DEPSQ=0.0
      GRIDN1=0.0
    7 IF(NUM.EQ.NIND) GO TO 3
      NSRCH=NBD(NUM)/1000000
      N    =NBD(NUM)/10000    -NSRCH*100
      MF   =NBD(NUM)/100-NSRCH*10000-N*100
      L    =NBD(NUM)-NSRCH*1000000-N*10000-MF*100
      NN=N-1
      K=MF
      NGRID=L-K+1
      GRIDN2=NGRID
      GRIDN1=GRIDN1+GRIDN2
C
C     USED ONLY IF NO SE VALUES ARE READ IN
C
       DO 2 M=K,L
      DEP=DEP+H(N,M)
      DEPSQ=DEPSQ+SQRT(H(N,M))
      DIM1=M
      DIM1=DIM1-1.
      CN(N,M)=TBNB
      CNP(N,M)=TBNB
      SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV
    2 SE(N,M)= SEINV*(1.-DIM1/46.)+HINV
      NUM=NUM+1
       GO TO 7
    3 CONTINUE
      CN (3,1) = TBNB
      CNP(3,1) = TBNB
      CN (4,1) = TBNB
      CNP(4,1) = TBNB
      CN (19,23)=TBNB
      CNP(19,23)=TBNB
      CN (19,24)=TBNB
      CNP(19,24)=TBNB
      CN (08,48)=TBNB
      CNP(08,48)=TBNB
      CN (09,48)=TBNB
      CNP(09,48)=TBNB
      CN (11,48)=TBNB
      CNP(11,48)=TBNB
      CN (12,48)=TBNB
      CNP(12,48)=TBNB
      CN (13,48)=TBNB
      CNP(13,48)=TBNB
```

```
      DEP=3.*DEP/GRIDN1
      DEPSQ=DEPSQ/GRIDN1
      DEPSQ=3.*(DEPSQ**2)
       NA=1
    5 IF(NA.EQ.MINDO) GO TO 31
      M=MOBD(NA)/100000
      NBOT  =MOBD(NA)/1000   -M*100
      NTOP  =MOBD(NA)/10  -M*10000  -NBOT*100
      DO 32 N=NBOT,NTOP
      DIM1=M
      DIM1=DIM1-1.
      SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV
   32 SE(N,M)= SEINV*(1.-DIM1/46.)+HINV
      NA=NA+1
      GO TO 5
   31 NA=1
   33 IF(NA.EQ.NINDO) GO TO 34
      N=NOBD(NA)/100000
      MLEF =NOBD(NA)/1000  -N*100
      MRIG =NOBD(NA)/10    -N*10000  -MLEF*100
      DO 35 M=MLEF,MRIG
      DIM1=M
      DIM1=DIM1-1.
      SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV
   35 SE(N,M)= SEINV*(1.-DIM1/46.)+HINV
      NA=NA+1
      GO TO 33
   34 CONTINUE
C***********************************************************************
C
      CALL INVAL(MMAX,NMAX,GRIDN1 ,DEP,DEPSQ,READIN,RDCNP,DAVG)
C
      CALL HEATIN(NS,MS,SS,TIN,NZ,SITE,NINPUT,QIN)
C***********************************************************************
C
      WRITE(6,2050) NS(5),MS(5)
 2050 FORMAT(//,5X,'NS(5) = ',I4   ,'MS(5) = ',I4)
   40 ISTEP=2
C
C**********************************
C
      CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,
     1HE,HC,SAVE,IPUNCH)
C
C***********************************************
C
   88 ISTEP=1
      NST=NST+1
      K=2*NST-1
 2001 IF(NST.GT.MAXST) GO TO 501
C
C***********************************************
```

```
C
C          SET OPEN BOUNDS
C
C
      CALL OPENBD(NST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,
     1INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN)
C
C***********************************************************************
C
C     COMPUTE UP AND SEP ON ROW N ( FIRST HALF TIMESTEP)
C
      CALL UPNFHT(WX,WY,C6,C1,C2,C4,AT,AG,NIND,F,NI)
C
C***********************************************************************
C
C          COMPUTE VP ON COLUMN M (FIRST HALF TIMESTEP)
C
      CALL VPMFHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,
     1C10,C7,C8,C9,C14,C1,MIND,F,NI,NST,NPRINT ,IP,TBNB,KRT,NMAX,MMAX,
     2IDY,PI,DAY,THR,TMIN,HTOT,HA,BH,HE,HC,SAVE,NS,MS,SS,
     3QIN,TIN,NZ,NW,UPCON,VAR1,DELTAT,NINPUT,ZIG)
C
C***********************************************
C
      CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,
     1HE,HC,SAVE,IPUNCH)
C
C***********************************************************************
C
      CALL OPENBD(NST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,
     1INTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN)
C
C***********************************************************************
C
      NXT=ILD
      IF(NXT.EQ.0) GO TO 2020
 2010 IF(NST.LT.90) GO TO 2040
      GO TO 2020
 2040 WRITE(6,2030) NXT,CN(5,36),CNP(5,36),QIN,TIN,NS(1),MS(1),NZ,
     1NINPUT,SS(1), ZIA(NXT),ZIB(NXT),ZIC(NXT), ZIE(NXT),ZID(NXT),
     2AA(NXT),BB(NXT),SITE,NS(5),MS(5),NST
 2030 FORMAT(5X, 'NST= ',I4, '  CN(5,36) = ', E12.4, ' CNP(5,36) =',
     1E12.4, 'QIN = ', E12.4,  ' TIN = ', E12.4, ' NS = ',I4, ' MS = ',
     2I4,/,5X,' NZ = ',I4, ' NINPUT = ',I4, ' SS(1) = ', E12.4,
     3'ZIA(NST) = ',E12.4,' ZIB(NST) = ',E12.4,'ZIC(NST=',E12.4,/,5X,
     4'ZIE(NST) = ', E12.4, ' ZID(NST) = ',E12.4, 'AA(NST) = ',E12.4,
     5'BB(NST) = ',E12.4,/,5X,' SITE = ',E12.4, '[illegible](5) = ',I4,
     6'MS(5) = ',I4,'NST = ',I4)
 2020 CONTINUE

C***********************************************************************
  299 ISTEP=2
```

```
      K=2*NST
C
C
C          COMPUTE VP AND SEP ON COLUMN M (SECOND HALF TIMESTEP)
C
      CALL VPMSHT(WX,WY,C6,C1,C2,C4,AT,AG,MIND,F,NI)
C
C***********************************************************************
C
      CALL UPNSHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,
     1C10,C7,C8,C9,C14,C1,NIND,F,NI,NST,NPRINT,IP,TBNB,KRT,NMAX,MMAX,
     2 IDY,PI,DAY,NS,MS,SS,QIN,TIN,NZ,THR,TMIN,HTOT,NW,UPCON,VAR1,
     3NINPUT)
C
      SUM1=0.
      GRIDT1 = 0.0
C
      SUM=0.0
C
C                             BAY AREA
C
      NUM=1
   17 IF(NUM.EQ.NIND) GO TO 36
      NSRCH=NBD(NUM)/1000000
      N    =NBD(NUM)/10000   -NSRCH*100
      MF   =NBD(NUM)/100-NSRCH*10000-N*100
      L    =NBD(NUM)-NSRCH*1000000-N*10000-MF*100
      NN=N-1
      NGRID = L-MF+1
      GRIDN2=NGRID
      GRIDT1=GRIDT1+GRIDN2
      DO 22 M=MF,L
      MM= M-1
      SUMTWT  =CNP(N,M)*(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))
     1*3.0
      SUM=SUM+SUMTWT
      SUM1=SUM1+CNP(N,M)
   22 CONTINUE
      NUM=NUM+1
      GO TO 17
   36 SUMZIG=SUM1/GRIDT1 + SUMZIG
C     CONSTAN SHOULO EQUAL (AL**2)*9*DENS*9/5
      CONSTA=1.00
      SUMZID=CONSTA*SUM+SUMZID
      IF(MOD(NST,IPRIND).EQ.0) GO TO 45
      GO TO 41
   45 IPRINZ=IPRIND
      IF(DELTAT) GO TO 47
      IPRINZ=IPRINZ*10**4
   47 ZID(ILD)=SUMZID/IPRINZ
      ZIG(ILD)=SUMZIG/IPRINZ
      SUMZIG=0.0
```

```
      SUMZID=0.0                                                        00035500
   41 CONTINUE                                                          00035600
      SUM=0.                                                            00035700
      SUM1=0.0                                                          00035800
      NUM=1                                                             00035900
      GRIDT3=0.0                                                        00036000
      NTP(1)= NBD(8)                                                    00036100
      NTP(2)= NBD(11)                                                   00036200
      NTP(3)= NBD(14)                                                   00036300
      NTP(4)= NBD(16)                                                   00036400
      NTP(5)= NBD(17)                                                   00036500
      NTP(6)= NBD(19)                                                   00036600
C                                                                       00036700
C                           POWER PLANT AREA                            00036800
C                                                                       00036900
  300 IF(NUM.EQ.07) GO TO 310                                           00037000
  312 NSRCH=NTP(NUM)/1000000                                            00037100
      N=NTP(NUM)/10000-NSRCH*100                                        00037200
      MF=NTP(NUM)/100-NSRCH*10000-N*100                                 00037300
      L=NTP(NUM)-NSRCH*1000000-N*10000-MF*100                           00037400
      IF(MF.LT.32) MF=32                                                00037500
      IF(L.GT.42) L=42                                                  00037600
      NN=N-1                                                            00037700
      NNGD=L-MF+1                                                       00037800
      GRT4=NNGD                                                         00037900
      GRIDT3=GRIDT3+GRT4                                                00038000
      DO 330 M=MF,L                                                     00038100
      MM=M-1                                                            00038200
      SUMIPT  =CNP(N,M)*(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))00038300
     1*3.0                                                              00038400
      SUM1=SUM1+CNP(N,M)                                                00038500
  330 SUM=SUM+SUMTPT                                                    00038600
   60 SUMZIF=CONSTA*SUM+SUMZIF                                          00038700
      SUMZIH=SUM1/GRIDT3 + SUMZIH                                       00038800
      IF(MOD(NST,IPRIND).EQ.0) GO TO 65                                 00038900
      GO TO 70                                                          00039000
   65 IPRINZ=IPRIND                                                     00039100
      IF(CELTAT) GO TO 67                                               00039200
      IPRINZ=IPRINZ*10**2                                               00039300
   67 ZIF(ILD)=SUMZIF/IPRINZ                                            00039400
      ZIH(ILD)=SUMZIH/IPRINZ                                            00039500
      SUMZIF=0.0                                                        00039600
      SUMZIH=0.0                                                        00039700
   70 CONTINUE                                                          00039800
      NUM=NUM+1                                                         00039900
      GO TO 300                                                         00040000
  310 CONTINUE                                                          00040100
C                                                                       00040200
C     VELOCITY COMPONENETS IN OUTFALL AREA                              00040300
C                                                                       00040400
      SUM=0.0                                                           00040500
      SUM1=0.0                                                          00040600
```

```
SYSIN                          NEW MASTER                                    IEBUPDTE LOG PAGE 0009

                  316 NZ=1                                                                    00040700
                      INS=NS(NZ)                                                              00040800
                      IMS=MS(NZ)                                                              00040900
                C     CHANGE 5 TO NS(2) AND 36 TO MS(I) WHEN YOU RUN POWER PLANT              00041000
                      SUM=UP(INS,IMS)+SUM                                                     00041100
                      SUM1=VP(INS,IMS)+SUM1                                                   00041200
                  375 CONTINUE                                                                00041300
                      ANZ=NZ                                                                  00041400
                      SUM=SUM/ANZ                                                             00041500
                      SUM1=SUM1/ANZ                                                           00041600
                      SUMAA=SUM  + SUMAA                                                      00041700
                      SUMBB=SUM1+SUMBB                                                        00041900
                      IF(MOD(NST,IPRIND).EQ.0) GO TO 75                                       00042000
                      GO TO 80                                                                00042100
                   75 AA(ILD)=SUMAA/IPRIND                                                    00042200
                      BB(ILD)=SUMBB/IPRIND                                                    00042300
                      SUMAA=0.0                                                               00042400
                      SUMBB=0.0                                                               00042500
                      IF(MOD(NST,IPRIND).EQ.0) ILD=ILD+1                                      00042600
                      NXT=ILD-1                                                               00042650
                   80 CONTINUE                                                                00042700
                C                                                                             00042800
                      WRITE(6,2070) ZID(NXT),ZIG(NXT),ZIF(NXT),ZIH(NXT)                       00042850
                 2070 FORMAT(//,5X,'ZID(NXT) = ', E12.4, 'ZIG(NXT) = ',E12.4,                 00042860
                     1'ZIF(NXT) = ', E12.4, 'ZIH(NST) = ',E12.4)                              00042890
                C     AVERAGE VELCCITY IN WEST PASSAGE                                        00042900
                      ZIE(ILD)=(UP(8,47)+UP(9,47))/2.                                         00043000
                      CALL DISPLY(NST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND)                          00043400
                C                                                                             00043500
                      IF(NST.LT.MAXST) GO TO 40                                               00043600
                  110 CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,               00043700
                     1HE,HC,SAVE,IPUNCH)                                                      00043800
                C                                                                             00043900
                C*****************************************************************************00044000
                C                                                                             00044100
                C                                                                             00044200
                C                                                                             00044300
                C     END OF MAIN COMPUTATIONAL SCHEME                                        00044400
                C                                                                             00044500
                C                                                                             00044600
                C*****************************************************************************00044700
                C                                                                             00044800
                  501 CONTINUE                                                                00044900
                      CALL ANLYZE(MAXST,NTERM,AT,NST,ZIF)                                     00045000
                      RETURN                                                                  00045100
                      END                                                                     00045200
IEB816I MEMBER NAME (AMAIN   ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
```

```
./ CHANGE NAME=AVPMFH,LIST=ALL
      SUBROUTINE VPMFHT(C2, C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,
     1MSOURC,C13,C10,C7,C8,C9,C14,C1,MIND,F,NI,NST,NPRINT,IP,TBNB,KRT,
     2NMAX,MMAX,IDY,PI,DAY,THR,TMIN,HTOT,HA,BH,HE,HC,SAVE,NS,MS,SS,
     3QIN,TIN,NZ,NW,UPCON,VAR1,DELTAT,NINPUT,ZIG)
      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),
     1 C(21,48),NBD(85),MBD(85),MOBD(4),NOBD(4),H(21,48),
     2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),
     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),
     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),
     5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),
     6 IFIELO(21,48),HS1(015),HS2(015),ZIO(0175),AA(0175),BB(0175)
      DIMENSION A(790),B(48),P(48),Q(48),R(48),S(48),F(48),
     1KONVRT(21),NH(21),NPRINT(200),DAVG(80),        AHOLD(48),
     2MS(10),NS(10),SS(10),ZIG(1)
      EXTRA1=1.0
      NUM=1
      NZ=1
      LOGICAL DOSAL,DELTAT
  201 IF(NUM.EQ.MIND) GO TO 202
C      * * * *******     **                            ***********
 1615 CONTINUE
C       ***  * ** *                                  *************
      MSRCH=MBD(NUM)/1000000
      M     =MBD(NUM)/10000 -MSRCH*100
      NF    =MBD(NUM)/100    -MSRCH*10000 -M*100
      L     =MBD(NUM)       -MSRCH*1000000-M*10000-NF*100
      LLL=L+1
      LL=L-1
      NFF=NF-1
      MMM=M+1
      MM=M-1
      IA=MSRCH/10
      IB=MSRCH-10*IA
 2903 CONTINUE
      DO 220 N=NF,L
      NN=N-1
      NNN=N+1
C
      ALFAC=.5
      BETAC=.5
      GAMMAC=.5
      DELTAC=.5
      IF(N.EQ.NF) GO TO 206
      IF(N.EQ.L) GO TO 210
  211 CONTINUE
      BETA=0.5
      TEMP4=C2*((1.-BETA)*(V(NNN,M)-V(N,M))+BETA*(V(N,M)-V(NN,M)))
      TEMP1=V(N,M)**2+((((UP(N,M)+UP(NNN,M)+UP(N,MM)+UP(NNN,MM))**2)/
     116.)
      TEMP2=(SEP(N,M)+SEP(NNN,M)+H(N,MM)+H(N,M))*(C(N,M)+
     1C(NNN,M))**2
```

```
      TEMP12=C6*WK**2/(SE(N,M)+SE(NNN,M)+H(N,MM)+H(N,M))                00006100
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4+TEMP12                        00006200
      TEMP3=1./TEMP3                                                    00006300
      DELTA=0.5                                                         00006400
      TEMP10=V(N,MMM)                                                   00006500
      IF(TEMP10.EQ.0.) TEMP10=  V(N,MM)                                 00006600
      TEMP11=V(N,MM)                                                    00006700
      IF(TEMP11.EQ.0.) TEMP11=  V(N,MMM)                                00006800
      TEMP1=(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(N,M))+DELTA*C2*            00006900
     1(V(N,M)-TEMP11))*.25                                              00007000
  204 VP(N,M)=TEMP3*                                                    00007100
     1(V(N,M)-TEMP1*(UP(N,M)+UP(NNN,M)+UP(N,MM)+UP(NNN,MM))             00007200
     2- C1*(SE(NNN,M)-SE(N,M)))                                         00007300
C             COMPUTE CNP ON ROW M (SECOND HALF TIMESTEP )              00007400
  212 CONTINUE                                                          00007500
      IF(DOSAL) GO TO 213                                               00007600
      GO TO 220                                                         00007700
  213 CONTINUE                                                          00007800
      IF(IMODES.EQ.1) GO TO 7096                                        00007900
      GO TO 7098                                                        00008000
 7096 ALFAC=0.0                                                         00008100
      BETAC=1.0                                                         00008200
      GAMMAC=0.0                                                        00008300
      DELTAC=1.0                                                        00008400
      IF(U(N,M).GT.0.0) ALFAC=1.0                                       00008500
      IF(U(N,M).GT.0.0) BETAC=0.0                                       00008600
      IF(V(N,M).GT.0.0) GAMMAC=1.0                                      00008700
      GO TO 7099                                                        00008800
C     NEXT TIME I WILL CHANGE A1,A2,B1,B2 TO = 1.                       00008900
 7098 A1=1.                                                             00009000
      A2=1.                                                             00009100
C     B1 = B2 = 1.02                                                    00009200
      ALFAC=.5                                                          00009300
      BETAC=.5                                                          00009400
      GAMMAC=.5                                                         00009500
      DELTAC=.5                                                         00009600
      B1 = 0.                                                           00009700
      B2 = 0.                                                           00009800
 7099 CONTINUE                                                          00009850
      IF(N.EQ.NS(NZ).OR.M.EQ.MS(NZ)) GO TO 510                          00009900
      GO TO 520                                                         00010000
  510 CONTINUE                                                          00010100
      IF(M.EQ.MS(NZ)) GO TO 512                                         00010200
      GO TO 515                                                         00010300
  512 CONTINUE                                                          00010400
      IF(NNN.EQ.NS(NZ).AND.V(N,M).GT.0.0) GAMMAC=1.0                    00010500
      IF(NN.EQ.NS(NZ).AND.V(N,M).LT.0.0) DELTAC=1.0                     00010600
      IF(N.EQ.NS(NZ)) GO TO 514                                         00010700
      GO TO 520                                                         00010800
  514 IF(U(N,M).GT.0.0) BETAC=0.0                                       00010900
      IF(U(N,M).LT.0.0) ALFAC=0.0                                       00011000
      IF(V(N,M).LT.0.0) DELTAC=0.0                                      00011100
```

```
      IF(V(N,M).LT.0.0) GAMMAC=0.0                                      00011200
      GO TO 520                                                         00011300
  515 IF(MM.EQ.MS(NZ).AND.U(N,M).LT.0.0) BETAC=1.0                      00011400
      IF(MMM.EQ.MS(NZ).AND.U(N,M).GT.0.0) ALFAC=1.0                     00011500
  520 CONTINUE                                                          00011600
  230 CONTINUE                                                          00011700
C                                                                       00011800
      TEMP1=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))+SEP(N,M))*C13        00011900
      TEMP2=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))+SE(N,M))*C13         00012000
      TEMP3=.5*(H(NN,M)+H(NN,MM)+SE(N,M)+SE(NN,M))                      00012100
      TEMP4=.5*(H(N,M)+H(N,MM)+SE(N,M)+SE(NNN,M))                       00012200
      TEMP5=.5*(H(N,MM)+H(NN,MM)+SE(N,M)+SE(N,MM))                      00012300
      TEMP6=.5*(H(N,M)+H(NN,M)+SE(N,M)+SE(N,MMM))                       00012400
      TEMPA=.5*(H(NN,M) +H(NN,MM)+SEP(N,M)+SEP(NN,M))                   00012500
      TEMPB=.5*(H(N,M)+H(N,MM)+SEP(NNN,M)+SEP(N,M))                     00012600
C                                                                       00012700
      DYNM=C7*ABS(VP(N,M))*TEMPB/(.5*(C(N,M)+C(NNN,M)))+C10             00012800
      DYNNM=C7*ABS(VP(NN,M))*TEMPA/(.5*(C(N,M)+C(NN,M)))+C10            00012900
      DXNM=C7*ABS(U(N,M))*TEMP6/(.5*(C(N,M)+C(N,MMM)))+C10              00013000
      DXNMM=C7*ABS(U(N,MM))*TEMP5/(.5*(C(N,M)+C(N,MM)))+C10             00013100
      DYNM=DYNM*UPCON                                                   00013200
      DYNNM=DYNNM*UPCON                                                 00013300
      DXNM=DXNM*UPCON                                                   00013400
      DXNMM=DXNMM*UPCON                                                 00013500
C                                                                       00013600
      TEMP20=TEMP3*A2*VP(NN,M)*C8                                       00013700
      TEMP21=TEMPA*DYNNM*C9                                             00013800
      TEMP22=TEMP4*A2*VP(N,M)*C8                                        00013900
      TEMP23=TEMPB*DYNM*C9                                              00014000
      TEMP24=TEMP5*A1*U(N,MM)*C8                                        00014100
      TEMP25=TEMP5*DXNMM*C9                                             00014200
      TEMP26=TEMP6*A1*U(N,M)*C8                                         00014300
      TEMP27=TEMP6*DXNM*C9                                              00014400
C                                                                       00014500
      TEMP30=SEP(NNN,M)                                                 00014600
      IF(TEMP30.EQ.0.) TEMP30=2.*SEP(N,M)-SEP(NN,M)                     00014700
      TEMP31=SEP(NN,M)                                                  00014800
      IF(TEMP31.EQ.0.) TEMP31=2.*SEP(N,M)-SEP(NNN,M)                    00014900
      TEMP32=SE( N,MMM)                                                 00015000
      IF(TEMP32.EQ.0.) TEMP32=2.*SE(N,M)-SE(N,MM)                       00015100
      TEMP33=SE(N,MM)                                                   00015200
      IF(TEMP33.EQ.0.) TEMP33=2.*SE(N,M)-SE(N,MMM)                      00015300
C                                                                       00015400
      P(N)=-((1.-DELTAC)*TEMP20+TEMP21)                                 00015500
      Q(N)   =TEMP1+GAMMAC*TEMP22+TEMP23-DELTAC*TEMP20+TEMP21           00015600
     1  -B2*C14*(VP(NN,M)+VP(N,M))*(TEMP30-TEMP31)                      00015700
      R(N)=(1.-GAMMAC)*TEMP22-TEMP23                                    00015800
      S(N)= -CN(N,MM)*((1.-BETAC)*TEMP24+TEMP25)                        00015900
     1+CN(N,M)*(-TEMP2+ALFAC*TEMP26-BETAC*TEMP24+TEMP27+TEMP25          00016000
     2 -B1*C14*(U(N,M)+U(N,MM))*(TEMP32-TEMP33))                        00016100
     3+CN(N,MMM)*((1.-ALFAC)*TEMP26-TEMP27 )                            00016200
 1806 CONTINUE                                                          00019900
```

```
      INS=NS(NINPUT)
      IMS=MS(NINPUT)
      IF(NS(NZ).EQ.N.AND.MS(NZ).EQ.M)   GO TO 525
      GO TO 530
  525 S(N) = S(N)-SS(NZ)*(TIN + CNP(INS,IMS))
      NPLUS=NPRINT(IP) -29
      IF(NST.EQ.NPLUS) GO TO 1903
      IF(NST.EQ.1) GO TO 1903
      GO TO 1904
 1903 ISUM=0.0
      SDXNM=0.0
      SDYNM=0.0
      SDXNMM=0.0
      SDYNNM=0.0
 1904 SDXNM=SDXNM+DXNM
      SDYNM=SDYNM+DYNM
      SDXNMM=SDXNMM+DXNMM
      SDYNNM=SDYNNM+DYNNM
      ISUM=ISUM+1
 1907 IF(NST.EQ.NPRINT(IP)) GO TO 1909
      IF(NST.EQ.MAXST) GO TO 1909
      GO TO 1908
 1909 SDYNM=SDYNM/ISUM
      SDXNMM=SDXNMM/ISUM
      SDYNNM = SDYNNM/ISUM
      SDXNM = SDXNM/ISUM
      NNS=NS(NZ)
      MMS=MS(NZ)
      WRITE(6,7121) NNS,MMS,SDXNM,SDYNM,SDXNMM,SDYNNM
 7121 FORMAT(5X, 'AV. DIFFUSION COEF IS',3X,'DXNM(',I2,',',I2,') = ',
     1E12.4,3X, 'DYNM = ',E12.4,3X,'DXNNM = ',E12.4,3X, 'DYNMM = ',
     2E12.4)
 1908 CONTINUE
  530 CONTINUE
      IF(N.EQ.INS.AND.M.EQ.IMS) GO TO 526
      GO TO 527
  526 S(N) = S(N)+SS(NZ)*CNP(INS,IMS)
      NZ=NZ+1
  527 CONTINUE
C
C     HEAT EXCHANGE CALUCLATIONS
C
      EXTRAL = EXTRAL + 1.
      IF(EXTRAL.EQ.44.) GO TO 1730
      GO TO 1732
 1730 SAVE = S(N)
 1732 IF(EXTRAL.EQ.2.) GO TO 3035
      GO TO 1508
 3035 CONTINUE
C     MORE TEMP CALCUALTIONS YEAAAAA
      IF(NST.EQ.NPRINT(IP)) GO TO 1500
      IXA = NPRINT(IP) - 15
```

```
      IF(NST.EQ.IXA) GO TO 1500                                         00025100
      GO TO 1508                                                        00025200
 1500 IF(NST.EQ.1) GO TO 15C2                                           00025300
      GO TO 1506                                                        00025400
 1502 TWBAY=TBNB                                                        00025500
      TEQ=TBNB                                                          00025600
      TEQ=1.8*TEQ +32.                                                  00025700
 1506 CONTINUE                                                          00025800
      CALL WATIND(IDY,AT,PI,DAY,TBNB,TA,WA,WB,WC,WFACT,RH,              00025900
     1CLDCVR,ANG, EXTRA1,TIME, BC,HA,EA,PMM,NST,EXTRA2,THR,TMIN)        00026000
 1515 TW=(CNP(11,17)+ CNP(9,27)+CNP(6,26)+CNP(8,37)+CNP(13,37))/5.      00026100
      CALL WATDEP(TBNB,TA,TW, EA,BH,ES,EXTRA3,SUMONE,HE,HC,S,           00026200
     1HTOT,EXTRA4,N,NST,IDY,WA,WB,WC,WFACT,HA,ANG,TEMP5,TEMP6,DELTAT)   00026300
 1508 CONTINUE                                                          00026400
C     CALL AZ(ZONE1,ZONE2,ZCNE3,ZONE4,ZONE5,ZONE6,TWBAY,NMAX,MMAX,NST,  00026500
C    1KRT)                                                              00026600
      TWBAY =1.0                                                        00026650
      WC = ABS(WA*COS(ANG/57.1))                                        00026700
      IF(TEQ.LE.70.) GO TO 25                                           00026800
      GO TO 30                                                          00026900
   25 BETA = .5553                                                      00027000
      CBETA = -20.15                                                    00027100
      GO TO 40                                                          00027200
   30 BETA = .7774                                                      00027300
      CBETA = -33.60                                                    00027400
   40 CONTINUE                                                          00027500
      SUMONE = 73. + 7.3*((WC**2+WB**2)**.5)*WFACT                      00027600
      X= 15.7 + (0.26+BETA)*SUMONE                                      00027700
      EE = ES                                                           00027800
      TA=1.8*TA + 32.                                                   00027900
      TW=TW*1.8 + 32.                                                   00028000
      SIGN1 = EE-EA                                                     00028100
      IF(SIGN1.LE.0.) SIGN1=0.0                                         00028200
      HR = 1801.*(TEQ/460.+1.)**4 + SUMONE*(SIGN1) +.26*SUMONE*(TEQ-TA) 00028300
      TEQ =(HR-1801.)/X+((X-15.7)/X)*(.26*TA/(0.26+BETA)+(EA-CBETA)/    00028400
     1(.26+BETA))                                                       00028500
      HTEQ = -(15.7 + (.26+BETA)*(SUMONE))*(TW-TEQ) - .05*(TW**2+TEQ**2)00028600
      TA=(TA-32.)*5./9.                                                 00028700
      TW=(TW-32.)*5./9.                                                 00028800
      HTQE = HTEQ/(64.*24.*3600.*3.)                                    00028900
      HTQE=HTQE*5.0/9.0                                                 00029000
      IF(NST.EQ.NPRINT(IP)) GO TO 1533                                  00029500
      IF(NST.EQ.IXA) GO TO 1533                                         00029505
      GO TO 1511                                                        00029600
 1533 CONTINUE                                                          00029700
      IF(EXTRA1.NE.2.) GO TO 1511                                       00029750
 1536 CONTINUE                                                          00029760
C     HTOT = HTOT*1.1                                                   00029800
      WRITE(6,1535) BC,PMM,EA,WC, SUMONE, X, ES,HTOT,HA,BH,HE,HC,TW     00029900
C                                                                       00029950
 1535 FORMAT(4X,' CALCUALTED VALUES',3X,'BC = ',F6.2,3X, 'PMM = ',F6.2, 00030000
     13X, 'EA = ',F6.2,3X, 'WC = ',F6.2, 3X,'SUMONE = ',F6.2,3X,'X = ',F00030100
```

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     26.2,' ES = ',F6.2,/,3X,'HEAT EX VAL',2X,'HTOT = ',E9.3,2X,'HA = ',00030200
     3E9.3,2X,'BH = ',E9.3, 2X, 'HE = ',E9.3,2X,'HC = ',E9.3, 2X,       00030300
     4'TW = ',E9.3)                                                     00030400
 1511 CONTINUE                                                          00030500
C                                                                       00030600
C          HEAT  INPUT                                                  00030700
C                                                                       00030800
C     HEAT INPUT CONVERTED INTO TEMPERATURE                             00030900
C                                                                       00031000
C     HTOT=HTOT*1.1                                                     00031200
      HTPRBX=HTOT*(CN(N,M)+.000001/NST)/(TW+.00010/NST)                 00031300
      HTPRBX=HTOT                                                       00031350
      S(N)=S(N) - HTPRBX                                                00031400
  220 CONTINUE                                                          00031500
      IF(DOSAL) GO TO 1131                                              00031600
      GO TO 214                                                         00031700
 1131 CONTINUE                                                          00031800
      A(NFF)=CNP(NFF,M)                                                 00031900
      IF(MSRCH.EQ.0) A(NFF)=0.                                          00032000
      B(NFF)=0.                                                         00032100
      DO 232 N=NF,L                                                     00032200
      NN=N-1                                                            00032300
      F1=Q(N)-P(N)*B(NN)                                                00032400
      A(N)=(-S(N)-P(N)*A(NN))/F1                                        00032500
      B(N)=R(N)/F1                                                      00032600
  232 CONTINUE                                                          00032700
      CNP(L,M)=A(L)-B(L)*CNP(LLL,M)                                     00032800
      NX=L-NF                                                           00032900
      DO 233 J=1,NX                                                     00033000
      IF(MSRCH.EQ.0) CNP(L,M)=A(L)                                      00033100
      N=L-J                                                             00033200
      NP=N+1                                                            00033300
      CNP(N,M)=A(N)-B(N)*CNP(NP,M)                                      00033400
  233 CONTINUE                                                          00033500
      GO TO 214                                                         00033600
  210 CONTINUE                                                          00033700
      IF(IB.EQ.0) TEMP1=0.                                              00033800
      IF(IB.EQ.2) TEMP1 =VP(L,M)                                        00033900
      IF(IB.EQ.1) GO TO 205                                             00034000
      GO TO 209                                                         00034100
  205 TEMP10=V(L,MMM)                                                   00034200
C     IF(V(N,M).GT.0.0) GAMMAC= 1.0                                     00034300
      IF(TEMP10.EQ.0.) TEMP10=  V(L,MM)                                 00034400
      TEMP11=  V(L,MM)                                                  00034500
      IF(TEMP11.EQ.0.) TEMP11=  V(L,MMM)                                00034600
  933 LLL=L+1                                                           00034700
      BETA  =0.                                                         00034800
      LL =L-1                                                           00034900
      TEMP4=C2*BETA*(V(L,M)-V(LL,M))                                    00035000
      TEMP1=V(L,M)**2+(((UP(L,M)+UP(L,MM))**2)/16.)                     00035100
      TEMP2=(SEP(L,M)+SEP(LLL,M)+H(L,MM)+H(L,M))*(C(L,M)+C(LLL,M))**2   00035200
      TEMP12=C6*WX**2/(SEP(NFF,M)+SEP(NF,M)+H(NFF,M)+H(NFF,MM))         00035300
```

```
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4+TEMP12
      TEMP3=1./TEMP3
      DELTA=0.5
      TEMP1=.25*(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(L,M))+DELTA*C2*
     1(V(L,M)-TEMP11))
      TEMP1  =TEMP3*(V(L,M)-TEMP1*(UP(L,M)+UP(L,MM))
     1-C1*(SE(LLL,M)-SE(L,M)))
  209 VP(L,M)=TEMP1
      GO TO 212
  206 CONTINUE
      IF(IA.EQ.0) TEMP1=0.
      IF(IA.EQ.2) TEMP1=VP(NFF,M)
      IF(IA.EQ.1) GO TO 207
      GO TO 208
  207 NFF=NF-1
C     IF(V(N,M).LT.0.0) DELTAC=1.0
      TEMP10=V(NFF,MMM)
      IF(TEMP10.EQ.0.) TEMP10=  V(NFF,MM)
  936 TEMP11=V(NFF,MM)
      IF(TEMP11.EQ.0.) TEMP11=  V(NFF,MMM)
  938 BETA=1.
      TEMP4=C2*(1.-BETA)*(V(NF,M)-V(NFF,M))
      TEMP1=V(NFF,M)**2+(((UP(NF,M)+UP(NF,MM))**2)/16.)
      TEMP2=(SEP(NFF,M)+SEP(NF,M)+H(NFF,M)+H(NFF,MM))*
     1(C(NF,M)+C(NFF,M))**2
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4
      TEMP3=1./TEMP3
      DELTA=0.5
      TEMP1=.25*(AT*F(N)+(1.-DELTA)*C2*(TEMP10-V(NFF,M))
     1  +DELTA*C2*(V(NFF,M)-TEMP11))
      TEMP1     =TEMP3*(V(NFF,M)-TEMP1*(UP(NF,M)+UP(NF,MM))
     1          -C1*(SE(NF,M)-SE(NFF,M)))
  208 VP(NFF,M)=TEMP1
      GO TO 211
  214 NUM=NUM+1
      GO TO 201
  202 CONTINUE
      RETURN
      END
IEB816I MEMBER NAME (AVPMFH  ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
```

```
./ CHANGE NAME=AUPNSH,LIST=ALL
      SUBROUTINE UPNSHT(C2, C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,
     1C13,C10,C7,C8,C9,C14,C1,NIND,F,NI,NST,NPRINT,IP,TBNB,KRT,
     2NMAX,MMAX,IDY,PI,DAY,NS,MS,SS,QIN,TIN,NZ,THR,TMIN,HTOT,NW,
     3UPCON,VAR1,NINPUT)
      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),
     1 C(21,48),NBD(85),MBD(85),MOBD(4),NOBD(4),H(21,48),
     2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),
     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),
     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),
     5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),
     6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)
      DIMENSION A(790),B(48),P(48),Q(48),R(48),S(48),F(48),
     1KUNVRT(21),NH(21),NPRINT(200),DAVG(80),         AHOLD(48),
     2NS(10),MS(10),SS(10)
      LOGICAL DOSAL
      EXTRA1=1.0
      NUM=1
      NZ=1
  340 IF(NUM.EQ.NIND) GO TO 402
 1021 NSRCH=NBD(NUM)/1000000
      N     =NBD(NUM)/10000  -NSRCH*100
      MF    =NBD(NUM)/100-NSRCH*10000-N*100
      L     =NBD(NUM)-NSRCH*1000000-N*10000-MF*100
      IA=NSRCH/10
      IB=NSRCH-10*IA
      NN=N-1
      NNN=N+1
      LL=L-1
      LLL=L+1
      MFF   =MF-1
      DO 420 M=MF,L
      MMM=M+1
      MM=M-1
C
      DELTAC=.5
      GAMMAC=.5
      BETAC=.5
      ALFAC=.5
      IF(M.EQ.MF) GO TO 406
      IF(M.EQ.L) GO TO 410
  411 CONTINUE
      ALPHA=0.5
      TEMP4=C2*((1.-ALPHA)*(U(N,MMM)-U(N,M))+ALPHA*(U(N,M)-U(N,MM)))
      TEMP1 =U(N,M)**2+(((V(N,M)+V(N,MMM)+V(NN,M)+V(NN,MMM))**2)/16.)
      TEMP2=(SEP(N,M)+SEP(N,MMM)+H(N,M)+H(NN,M))*(C(N,M)+C(N,MMM))**2
      TEMP12=C6*WY**2/(SEP(N,M)+SEP(N,MMM)+H(N,M)+H(NN,M))
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4+TEMP12
      TEMP3=1./TEMP3
      GAMMA=0.5
      TEMP10=U(NNN,M)
      IF(TEMP10.EQ.0.) TEMP10=  U(NN,M)
```

```
  978 TEMP11=U(NN,M)                                                    00006100
      IF(TEMP11.EQ.0.) TEMP11=  U(NNN,M)                                00006200
  980 TEMP1=AT*F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,M))                       00006300
     1-GAMMA*C2*(U(N,M)-TEMP11)                                         00006400
      TEMP1=.25*TEMP1                                                   00006500
  404 UP(N,M)=TEMP3*                                                    00006600
     1    (U(N,M)+TEMP1*(VP(N,M)+VP(N,MMM)+VP(NN,M)+VP(NN,MMM))         00006700
     2- C1*(SE(N,MMM)-SE(N,M)))                                         00006800
C               COMPUTE CNP ON ROW N ( FIRST HALF TIMESTEP )            00006900
  412 CONTINUE                                                          00007000
      IF(COSAL) GO TO 413                                               00007100
      GO TO 420                                                         00007200
  413 CONTINUE                                                          00007300
      IF(IMODES.EQ.1) GO TO 7196                                        00007400
      GO TO 7198                                                        00007500
 7196 ALFAC=0.0                                                         00007600
      BETAC=1.0                                                         00007700
      GAMMAC=0.0                                                        00007800
      DELTAC=1.0                                                        00007900
      IF(U(N,M).GT.0.0) ALFAC=1.0                                       00008000
      IF(U(N,M).GT.0.0) BETAC=0.0                                       00008100
      IF(V(N,M).GT.0.0) GAMMAC=1.0                                      00008200
      IF(V(N,M).GT.0.0) DELTAC=0.0                                      00008300
      GO TO 7199                                                        00008350
 7198 A1=1.0                                                            00008400
      A2=1.0                                                            00008500
C       CHANGED B1 AND B2                                               00008600
      ALFAC=.5                                                          00008700
      BETAC=.5                                                          00008800
      GAMMAC=.5                                                         00008900
      DELTAC=.5                                                         00009000
      B1 = 0.                                                           00009100
      B2 = 0.                                                           00009200
 7199 CONTINUE                                                          00009250
      IF(N.EQ.NS(NZ).OR.M.EQ.MS(NZ)) GO TO 510                          00009300
      GO TO 520                                                         00009400
  510 CONTINUE                                                          00009500
      IF(N.EQ.MS(NZ)) GO TO 512                                         00009600
      GO TO 515                                                         00009700
  512 CONTINUE                                                          00009800
      IF(NNN.EQ.NS(NZ).AND.V(N,M).GT.0.0) GAMMAC=1.0                    00009900
      IF(NN.EQ.NS(NZ).AND.V(N,M).LT.0.0) DELTAC=1.0                     00010000
      IF(N.EQ.NS(NZ)) GO TO 514                                         00010100
      GO TO 520                                                         00010200
  514 IF(U(N,M).GT.0.0) BETAC=0.0                                       00010300
      IF(U(N,M).LT.0.0) ALFAC=0.0                                       00010400
      IF(V(N,M).LT.0.0) DELTAC=0.0                                      00010500
      IF(V(N,M).LT.0.0) GAMMAC=0.0                                      00010600
      GO TO 520                                                         00010700
  515 IF(MM.EQ.MS(NZ).AND.U(N,M).LT.0.0) BETAC=1.0                      00010800
      IF(MMM.EQ.MS(NZ).AND.U(N,M).GT.0.0) ALFAC=1.0                     00010900
  520 CONTINUE                                                          00011000
```

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NEW MASTER                                                   TFRUPOTE LIN. PAGE 0019

  430 CONTINUE
C
      TEMP1=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))+SEP(N,M))*C13
      TEMP2=(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM))+SE(N,M))*C13
      TEMP3=0.5*(H(N,MM)+H(NN,MM)+SE(N,M)+SE(N,MM))
      TEMP4=.5*(H(N,M)+H(NN,M)+SE(N,M)+SE(N,MMM))
      TEMP5=.5*(H(NN,M)+H(NN,MM)+SE(N,M)+SE(NN,M))
      TEMP6=.5*(H(N,M)+H(N,MM)+SE(N,M)+SE(NNN,M))
      TEMPA=0.5*(H(N,MM)+H(NN,MM)+ SEP(N,M)+SEP(N,MM))
      TEMPB=.5*(H(N,M)+H(NN,M)+SEP(N,M) +SEP(N,MMM))
C
      DXNM=C7*ABS(UP(N,M))*TEMPB/(.5*(C(N,M)+C(N,MMM)))+C10
      DXNMM=C7*ABS(UP(N,MM))*TEMPA/(.5*(C(N,M)+C(N,MM)))+C10
      DYNM=C7*ABS(V(N,M))*TEMP6/(.5*(C(N,M)+C(NNN,M)))+C10
      DYNNM=C7*ABS(V(NN,M))*TEMP5/(.5*(C(N,M)+C(NN,M)))+C10
      DXNM=DXNM*UPCON
      DXNMM=DXNMM*UPCON
      DYNM=DYNM*UPCON
      DYNNM=DYNNM*UPCON
C
      TEMP20=TEMP3*A1*UP(N,MM)*C8
      TEMP21=TEMPA*DXNMM*C9
      TEMP22=TEMP4*A1*UP(N,M)*C8
      TEMP23=TEMPB*DXNM*C9
      TEMP24=TEMP5*A2*V(NN,M)*C8
      TEMP25=TEMP5*DYNNM*C9
      TEMP26=TEMP6*A2*V(N,M)*C8
      TEMP27=TEMP6*DYNM*C9
C
      TEMP30=SEP(N,MMM)
      IF( TEMP30.EQ.0.) TEMP30=2.*SEP(N,M)-SEP(N,MM)
       TEMP31=SEP(N,MM)
      IF(TEMP31.EQ.0.) TEMP31=2.*SEP(N,M)-SEP(N,MMM)
      TEMP32=SE(NNN,M)
      IF(TEMP32.EQ.0.) TEMP32=2.*SE(N,M)-SE(NN,M)
      TEMP33=SE(NN,M)
      IF(TEMP33.EQ.0.) TEMP33=2.*SE(N,M)-SE(NNN,M)
C
      P(M)=-((1.-BETAC)*TEMP20+TEMP21)
      Q(M)=TEMP1 +ALFAC*TEMP22 +TEMP23-BETAC*TEMP20 +TEMP21 -B1*C14*
     1 (UP(N,MM)+UP(N,M))*(TEMP30-TEMP31)
      R(M)=(1.-ALFAC)*TEMP22-TEMP23
      S(M) = -CN(NN,M)*((1.-DELTAC)*TEMP24+TEMP25)
     1+CN(N,M)*(-TEMP2+GAMMAC*TEMP26-DELTAC*TEMP24 +TEMP27+TEMP25
     2  -B2*C14*(V(N,M)+V(NN,M))*(TEMP32-TEMP33))
     3+CN(NNN,M)*((1.-GAMMAC)*TEMP26-TEMP27 )
C     NOTE DISCOVERED ON 31 JULY 72 THAT LINE 0953/3 HAD CN(N,MMM)
C     INSTEAD OF CN(NNNN,M)
      INS=NS(NINPUT)
      IMS=MS(NINPUT)
      IF(NS(NZ).EQ.N.AND.M.EQ.MS(NZ))  GO TO 525
      GO TO 530
```

```
  525 S(M) = S(M)-SS(NZ)*(TIN + CNP(INS,IMS))
  530 CONTINUE
      IF(N.EQ.INS.AND.M.EQ.IMS) GO TO 526
      GO TO 527
  526 S(M) = S(M)+SS(NZ)*CNP(INS,IMS)
      NZ=NZ+1
  527 CONTINUE
C
      TW=(CNP(11,17)+ CNP(9,27)+CNP(6,26) +CNP(8,37)+CNP(13,37))/5.
      HTPRBX=HTOT*(CN(N,M)+.000001/NST)/(TW+.00010/NST)
      HTPRBX=HTOT
      S(M)=S(M) - HTPRBX
  420 CONTINUE
      IF(DOSAL) GO TO 1115
      GO TO 414
 1115 CONTINUE
      A(MFF)=CNP(N,MFF)
       IF(NSRCH.EQ.0) A(MFF)=0.
      B(MFF)=0.
      DO 432 M=MF,L
      MM=M-1
      F1=C(M)-P(M)*B(MM)
      A(M)=-(S(M)+P(M)*A(MM))/F1
      B(M)=R(M)/F1
  432 CONTINUE
      CNP(N,L)=A(L)-B(L)*CNP(N,LLL)
      IF(NSRCH.EQ.0) CNP(N,L)=A(L)
      MX=L-MF
      DO 433 J=1,MX
      M=L-J
      MP=M+1
      CNP(N,M)=A(M)-B(M)*CNP(N,MP)
  433 CONTINUE
      GO TO 414
  410 CONTINUE
      IF(IB.EQ.2) TEMP1=UP(N,L)
      IF(IB.EQ.3) TEMP1=0.
      IF(IB.EQ.1) GO TO 405
      GO TO 409
  405 TEMP10=U(NNN,L)
C     IF(U(N,M).GT.0.0) ALFAC=1.0
      IF(TEMP10.EQ.0.) TEMP10=  U(NN,L)
 1001 TEMP11=U(NN,L)
C     INSERTED FOLLOWING TWO CARDS 24 AUG
      IF(TEMP11.EQ.0.) TEMP11=U(NNN,L)
      ALFA=0.
      TEMP4=C2*ALPHA*(U(N,L)-U(N,LL))
      TEMP1=U(N,L)**2+(((V(N,L)+V(NN,L))**2)/16.)
      TEMP2=(SEP(N,L)+SEP(N,LLL)+H(N,L)+H(NN,L))*(C(N,L)+C(N,LLL))**2
      TEMP12=SEP(N,L)+SEP(N,LLL)+H(N,L)+H(NN,L)
      TEMP12=C6*WY**2/TEMP12
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4 +TEMP12
```

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SYSIN                          NEW MASTER                          IEBUPDTE LOG PAGE 0021

      TEMP3=1./TEMP3                                                    00021400
      GAMMA=0.5                                                         00021500
      TEMP1=.25*(AT*F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,L))-GAMMA*C2*        00021600
     1(U(N,L)-TEMP11))                                                  00021700
      TEMP1  =TEMP3*(U(N,L)+TEMP1*(VP(N,L)+VP(NN,L))                    00021800
     1-C1*(SE(N,LLL)-SE(N,L)))                                          00021900
  409 UP(N,L)=TEMP1                                                     00022000
      GO TO 412                                                         00022100
  406 IF(IA.EQ.1) GO TO 407                                             00022200
      IF(IA.EQ.2) TEMP1=UP(N,MFF)                                       00022300
      IF(IA.EQ.0) TEMP1=0.                                              00022400
      GO TO 408                                                         00022500
  407 MFF=MF-1                                                          00022600
C     IF(U(N,M).LT.0.0) BETAC=1.0                                       00022700
      TEMP10=U(NNN,MFF)                                                 00022800
      IF(TEMP10.EQ.0.) TEMP10=  U(NN,MFF)                               00022900
 1006 TEMP11=U(NN,MFF)                                                  00023000
      IF(TEMP11.EQ.0.) TEMP11=  U(NNN,MFF)                              00023100
 1008 ALPHA=1.                                                          00023200
      TEMP4=C2*(1.-ALPHA)*(U(N,MF)-U(N,MFF))                            00023300
      TEMP1=U(N,MFF)**2+(((V(N,MF)+V(NN,MF))**2)/16.)                   00023400
      TEMP2=(SEP(N,MFF)+SEP(N,MF)+H(N,MFF)+H(NN,MFF))*(C(N,MF)+C(N,MFF) 00023500
     1)**2                                                              00023600
      TEMP12=SEP(N,MFF)+SEP(N,MF)+H(N,MFF)+H(NN,MFF)                    00023700
      TEMP12=C6*WY**2/TEMP12                                            00023800
      TEMP3=1.+C4*SQRT(TEMP1)/TEMP2+TEMP4 +TEMP12                       00023900
      TEMP3=1./TEMP3                                                    00024000
      GAMMA=0.5                                                         00024100
      TEMP1=.25*(AT*F(N)-(1.-GAMMA)*C2*(TEMP10-U(N,MFF))-GAMMA*C2*      00024200
     1(U(N,MFF)-TEMP11))                                                00024300
      TEMP1     = TEMP3*(U(N,MFF)+TEMP1*(VP(N,MF)+VP(NN,MF))            00024400
     1-C1*(SE(N,MF)-SE(N,MFF)))                                         00024500
  408 UP(N,MFF)=TEMP1                                                   00024600
      GO TO 411                                                         00024700
  414 NUM=NUM+1                                                         00024800
      GO TO 340                                                         00024900
  402 CONTINUE                                                          00025000
      RETURN                                                            00025100
      END                                                               00025200
IEB816I MEMBER NAME (AUPNSH  ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
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SYSIN                           NEW MASTER                                      IEBUPDTE LOG PAGE 0022

./ CHANGE NAME=AWTDEP,LIST=ALL
./ NUMBER INCR=100,NEW1=1000
                                      SUBROUTINE WATDEP(TBNB,TA,TW,EA,BH,ES,EXTRA3,SUMONE,HE,HC,S,      00001000
                                     1HTOT,EXTRA4,N,NST,ICY,WA,WB,WC,WFACT,HA,ANG,TEMP5,TEMP6,DELTAT)   00001100
                                      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001200
                                     1C(21,48),NBD(85),MBC(85),MOBD(   4),NOBD(   4),H(21,48),          00001300
                                     2      W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),       00001400
                                     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),               00001500
                                     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
                                     5 ACCSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                        00001700
                                     6 IFIFLU(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)      00001800
                                      DIMENSION S(48)                                                   00001900
                                      LOGICAL DELTAT                                                    00002000
                                C           TEMP CALCUALTIONS                                           00002100
                                C     WB = WIND FROM Y DIRECTION                                        00002200
                                C      WC = WIND FROM X DCRECTION                                       00002300
                                      WC = ABS(WA*COS(ANG/57.1))                                        00002400
                                      WB = ABS(WA*SIN(ANG/57.1))                                        00002500
                                      EXTRA4= 0.0                                                       00002600
                                 2969 TA=1.8*TA+32.                                                     00002700
                                      IF(DELTAT) GO TO 100                                              00002800
                                      GO TO 200                                                         00002900
                                  100 TW = 1.8*TW                                                       00003000
                                      BH = .97*4.2E-8*4.0*(459.7**3)*TW                                 00003100
                                      BETA = .67                                                        00003200
                                      SUMONE=11.4*WA                                                    00003300
                                      HE = SUMONE*BETA*TW                                               00003400
                                      IF(HE.LT.0.0) HE=0.0                                              00003500
                                      HC=.26*SUMONE*TW                                                  00003600
                                      HA = 0.0                                                          00003700
                                      ES=0.0                                                            00003800
                                      HS2(IDY) = 0.0                                                    00003900
                                      TW=TW*5.0/9.0                                                     00004000
                                      GO TO 300                                                         00004100
                                  200 A=457.9                                                           00004200
                                      TW= 1.8*TW+32.                                                    00004300
                                      BH=(.97*4.2E-8)*((TW+A   )**4)                                    00004400
                                C                                                                       00004500
                                      ES=99.-96.*COS(3.14*(((TW-30.)/50.)*33.+7.)/180.)                 00004600
                                      SUMONE=73.+7.3*((WC**2+WB**2)**.5)*WFACT                          00004700
                                      SUMONE=11.4*WA                                                    00004800
                                      HC=.26*SUMONE*(TW-TA)                                             00004900
                                C                                                                       00005000
                                      HE=SUMONE*(ES-EA)                                                 00005100
                                      SIGN = ES-EA                                                      00005200
                                      IF(SIGN.LT.0.0) HE=0.                                             00005300
                                      TW=(TW-32.)*5.0/9.0                                               00005400
                                  300 CONTINUE                                                          00005500
                                      HTOT = HS2(IDY) + HA - BH - HE -HC                                00005600
                                      HTOT = HTOT/(64.*24.*3600.*3.)                                    00005700
                                C     CONVERTING HTOT   INTO DEG CENT                                   00005800
                                      HTOT = HTOT*5.0/9.0                                               00005900
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SYSIN                          NEW MASTER                               IEBUPDTE LOG PAGE 0023


                               C
                                     TA =(TA - 32.)* 5.0/9.0                                   00006000
                                     RETURN                                                    00006100
                                     END                                                       00006200
IEB816I MEMBER NAME (AWTDEP  ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.                      00006300
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SYSIN                          NEW MASTER                          IEBUPDTE LOG PAGE 0024

./ CHANGE NAME=AWTIND,LIST=ALL
./ NUMBER INCR=100,NEW1=1000
      SUBROUTINE WATIND(IDY,AT,PI,DAY,TBNB,TA,WA,WB,WC,WFACT,RH,          00001000
     1CLDCVR,ANG, EXTRA1,TIME, BC,HA,EA,PMM,NST,EXTRA2,THR,TMIN)          00001100
      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001200
     1C(21,48),NBD(85),MBD(85),MOBD(   4),NOBD(   4),H(21,48),            00001300
     2       W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),        00001400
     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),                 00001500
     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
     5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                          00001700
     6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)        00001800
  725 READ(5,600) TA,RH,HS2(1),WA,ANG,CLDCVR                              00001900
  600 FORMAT(6F5.1)                                                       00002000
C     GRM-CAL/CM**2 * .2 SCALE FACTOR DIVIDED BY .27 CONVERSION FACTOR    00002100
C     HS2(01) = HS2(1)*.745                                               00002200
C     CONVERT TO BTU/FT**2 - DAY                                          00002300
C     HS2(1) = HS2(1)*24.                                                 00002400
C     FINALLY WE HAVE HS2(1) = HS2(1)*17.85                               00002500
      HS2(1) = HS2(1)*17.85                                               00002600
      WRITE(6,650) TA,RH,HS2(1),WA,ANG,CLDCVR                             00002700
  650 FORMAT( 2X, ' METEROLOGICAL DATA READ IN (WATIND)',2X,'TA = ',   F00002800
     16.2,2X,'RH = ',F6.2,2X,'HS(1) = ',F8.2,2X, 'WA = ',F6.2,2X, 'ANG =00002900
     2 ',F6.2,2X, 'CLDCVR = ',F6.2)                                       00003000
      WA= WA*1.152                                                        00003100
      WA= WA*1.152                                                        00003200
      WFACT = 1.0                                                         00003300
      KTIK = 0                                                            00003400
      EXTRA2= 0.0                                                         00003500
  100 CONTINUE                                                            00003600
      IDY=1                                                               00003700
      HS1(IDY)=100.                                                       00003800
      GO TO 5300                                                          00003900
C     REMOVE IF NO SOLAR INPUT   GO TO 5300                               00004000
 1540 KTIK = KTIK + 1                                                     00004100
C    INITIAL TIME = 7 OCLOCK                                              00004200
      IF(KTIK.GT.1) GO TO 2883                                            00004300
 2872 TIMEX= THR+TMIN/60.0                                                00004400
 2883 TIMEX= TIMEX+AT/3600.                                               00004500
 2891 XONE = TIMEX- 7.0                                                   00004600
      IF(XONE.GT.0.) GO TO 2865                                           00004700
 2865 IF(XONE.LT.12.) GO TO 2963                                          00004800
 2963 D=HS1(IDY) /(1.7+(HS1(IDY)-100.)/350.)                              00004900
      G=2.*PI*(TIMEX-6.*(1. +.2*EXP(-3.*(182.-ABS(DAY-182.))/182.)))      00005000
      T= 24.*(1.-.2*COS(2.*PI*DAY/365.))                                  00005100
      HS2(IDY)=D*SIN(G/T)                                                 00005200
      HS2(IDY)= 17.85*HS2(IDY)                                            00005300
C     FIGURE SOLAR ENERGY INPUT ON PER HOUR BASIS, MULTIPLY BY 12 SO      00005400
C     YOU AVERAGE IN ON PER DAY BASIS                                     00005500
  300 TA = TBNB + 10.*(SIN(3.14*(TIMEX-2.)/24.))**3                       00005600
 5300 CONTINUE                                                            00005700
 5214 IF(.NOT.(TA.GE.60.00.AND.TA.LE.79.99)) GO TO 5218                   00005800
 5215 PMM = 94.5-90.*COS(PI*(((TA-30.)/70.)*51.+4.)/180.)                 00005900
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SYSIN                                   NEW MASTER                                   IEBUPDTE LOG PAGE 0025

                                           GO TO 5240
                                      5218 IF(.NOT.(TA.GE.80.00.AND.TA.LE.89.99)) GO TO 5222                                 00006000
                                      5222 PMM = 94.5-90.*COS(PI*(((TA-30.)/70.)*61.-3.)/180.)                               00006100
                                      5240 EA=(PMM-(((TA-30.)/70.)*3.5+1.))*(RH-10.)/90.+((TA-30.)/70.)*3.5+                 00006200
                                          11.                                                                                00006300
                                           BC = .74-(( 3.5*(96.-TA)**1.67)/10**(4.+.3.*CLDCVR))                              00006400
                                           HA=(4.E-8)         *((TA+460.)**4)*(BC+.031*(EA**.5))                             00006500
                                           TA =(TA - 32.)* 5.0/9.0                                                           00006600
                                       200 CONTINUE                                                                          00006700
                                           RETURN                                                                            00006800
                                           END                                                                               00006900
IEB816I MEMBER NAME (AWTIND  ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.                                                    00007000
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./ CHANGE NAME=AAZ,LIST=ALL
./ NUMBER INCR=100,NEW1=1000

       SUBROUTINE AZ(ZONE1,ZONE2,ZONE3,ZONE4,ZONE5,ZONE6,TWBAY,NMAX,MMAX,00001000
      1NST,KRT)                                                         00001100
       COMMON SE(21,48),SFP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001200
      1C(21,48),NBD(85),MBD(85),MOBD(  4),NOBD(  4),H(21,48),           00001300
      2       W(20),F2(20),Z(20),F(20),HP(20),EP(20),HM(20),EB(20),     00001400
      3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),              00001500
      4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
      5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                       00001700
      6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)     00001800
C      TEMP OF BAY DETERMINATION FROM SIX ARBITRARY ZONES               00001900
       ZONE1A = CNP( 7,38)+CNP( 7,39)+CNP( 7,40)+CNP( 7,41)+CNP( 7,42)+ 00002000
      1CNP( 8,38)+CNP( 8,39)+CNP( 8,40)+CNP( 8,41)+CNP( 8,42)+CNP( 8,43)+00002100
      2CNP( 8,44)+CNP( 8,45)+CNP( 8,46)+CNP( 8,47)+CNP( 8,48)+CNP( 9,38)+00002200
      3CNP( 9,39)+CNP( 9,40)+CNP( 9,41)+CNP( 9,42)+CNP( 9,43)+CNP( 9,44)+00002300
      4CNP( 9,45)+CNP( 9,46)+CNP( 9,47)+CNP( 9,48)+CNP(10,41)+CNP(10,42) 00002400
       ZONE1B = CNP( 5,35)+CNP( 6,35)+CNP( 6,36)+CNP( 6,37)+CNP( 7,35)+ 00002500
      1CNP( 7,36)+            CNP( 7,37)+CNP( 8,35)+CNP( 8,36)+CNP( 8,37)+00002600
      2CNP( 9,35)+CNP( 9,36)+CNP( 9,37)                                 00002700
       ZONE1C = CNP( 4,33)+CNP( 4,34)+CNP( 5,32)+CNP( 5,33)+CNP( 5,34)+ 00002800
      1CNP( 6,32)+CNP( 6,33)+CNP( 6,34)+CNP( 7,31)+CNP( 7,32)+CNP( 7,33)+00002900
      2CNP( 7,34)+CNP( 8,31)+CNP( 8,32)+CNP( 8,33)+CNP( 8,34)+CNP( 9,31)+00003000
      3CNP( 9,32)+CNP( 9,33)+CNP( 9,34)                                 00003100
       ZONE1 =(ZONE1A/29. + ZONE1B/13. + ZONE1C/20. )/3.00              00003200
       ZONE2A = CNP(11,45)+CNP(11,46)+CNP(11,47)+CNP(11,48)+CNP(12,44)+ 00003300
      1CNP(12,45)+CNP(12,46)+CNP(12,47)+CNP(12,48)+CNP(13,40)+CNP(13,41)+00003400
      2CNP(13,42)+CNP(13,43)+CNP(13,44)+CNP(13,45)+CNP(13,46)+CNP(13,47)+00003500
      3CNP(13,48)+CNP(14,40)+CNP(14,41)+CNP(14,42)+CNP(14,43)+CNP(14,44)+00003600
      4CNP(15,40)+CNP(15,41)+CNP(15,42)+CNP(15,43)                      00003700
       ZONE2B = CNP(10,31)+CNP(10,32)+CNP(11,31)+CNP(11,32)+CNP(11,33)+ 00003800
      1CNP(11,34)+CNP(12,31)+CNP(12,32)+CNP(12,33)+CNP(12,34)+CNP(12,35)+00003900
      2CNP(12,36)+CNP(12,37)+CNP(12,38)+CNP(12,39)+CNP(13,31)+CNP(13,32)+00004000
      3CNP(13,33)+            CNP(13,34)+CNP(13,35)+CNP(13,36)+CNP(13,37)+00004100
      4CNP(13,38)+CNP(13,39)+CNP(14,31)+CNP(14,32)+CNP(14,33)+CNP(14,34)+00004200
      5CNP(14,35)+CNP(14,36)+CNP(14,37)+            CNP(14,38)+CNP(14,39)+00004300
      6CNP(15,31)+CNP(15,32)+CNP(15,33)+CNP(15,34)+CNP(15,35)+CNP(15,36)+00004400
      7CNP(15,37)+CNP(16,31)+CNP(16,32)+CNP(16,33)+CNP(17,31)           00004500
       ZONE2 =(ZONE2A/27. + ZONE2B/44. )/2.00                           00004600
       ZONE3A = CNP( 6,26)+CNP( 6,27)+CNP( 6,28)+CNP( 6,29)+CNP( 7,26)+ 00004700
      1CNP( 7,27)+CNP( 7,28)+CNP( 7,29)+CNP( 7,30)+CNP( 8,26)+CNP( 8,27)+00004800
      2CNP( 8,28)+CNP( 8,29)+CNP( 8,30)+CNP( 9,26)+CNP( 9,27)+CNP( 9,28)+00004900
      3CNP( 9,29)+CNP( 9,30)+CNP(10,26)+CNP(10,27)+CNP(10,28)+CNP(10,29)+00005000
      4CNP(10,30)+CNP(11,26)+CNP(11,27)+CNP(11,28)+CNP(11,29)+CNP(11,30)+00005100
      5CNP(12,26)+CNP(12,27)+CNP(12,28)+CNP(12,29)+CNP(12,30)           00005200
       ZONE3B = CNP( 2,20)+CNP( 2,21)+CNP( 2,22)+CNP( 3,20)+CNP( 3,21)+ 00005300
      1CNP( 3,22)+CNP( 4,20)+CNP( 4,21)+CNP( 4,22)+CNP( 5,20)+CNP( 5,21)+00005400
      2CNP(5 ,22)+CNP( 5,23)+CNP( 5,24)+CNP( 6,21)+CNP( 6,22)+CNP( 6,23)+00005500
      3CNP( 6,24)+CNP( 6,25)+CNP( 7,22)+CNP( 7,23)+CNP( 7,24)+CNP( 7,25)+00005600
      4CNP( 8,22)+CNP( 8,23)+CNP( 8,24)+CNP( 8,25)+CNP( 9,22)+CNP( 9,24)+00005700
      5CNP(9,25 )+CNP(10,25)                                            00005800
       ZONE3 =(ZONE3A/34. + ZONE3B/31. )/2.00                           00005900
```

```
      ZONE4  = CNP(14,22)+CNP(14,23)+CNP(14,24)+CNP(14,25)+CNP(15,20)+  00006000
     1CNP(15,21)+CNP(15,22)+CNP(15,23)+CNP(15,24)+CNP(15,25)+CNP(15,26)+00006100
     2CNP(15,27)+CNP(15,28)+CNP(15,29)+CNP(15,30)+CNP(16,20)+CNP(16,21)+00006200
     3CNP(16,22)+CNP(16,24)+CNP(16,25)+CNP(16,26)+CNP(16,27)+CNP(16,28)+00006300
     4CNP(16,29)+CNP(16,30)+CNP(17,21)+CNP(17,22)+CNP(17,23)+CNP(17,24)+00006400
     5CNP(17,25)+CNP(17,26)+CNP(17,27)+CNP(17,28)+CNP(17,29)+CNP(17,30)+00006500
     6CNP(18,23)+CNP(18,24)+CNP(19,23)+CNP(19,24)                       00006600
      ZONE4 = ZONE4/39.                                                 00006700
      ZONE5A = CNP( 8,16)+CNP( 8,17)+CNP( 8,18)+CNP( 8,19)+CNP( 8,20)+  00006800
     1CNP( 8,21)+CNP( 9,14)+CNP( 9,15)+CNP( 9,16)+CNP( 9,17)+CNP( 9,18)+00006900
     2CNP( 9,19)+CNP( 9,20)+CNP( 9,21)+CNP(10,14)+CNP(10,15)+CNP(10,16)+00007000
     3CNP(10,17)+CNP(10,18)+           CNP(10,19)+CNP(10,20)+CNP(10,21) 00007100
      ZONE5B = CNP(11,14)+CNP(11,15)+CNP(11,16)+CNP(11,17)+CNP(11,18)+  00007200
     1CNP(11,19)+CNP(11,20)+CNP(11,21)+CNP(11,22)+CNP(12,14)+CNP(12,15)+00007300
     2CNP(12,16)+CNP(12,17)+CNP(12,18)+CNP(12,19)+CNP(12,20)+CNP(12,21)+00007400
     3CNP(12,22)+CNP(12,23)+CNP(12,24)+CNP(13,16)+CNP(13,17)+           00007500
     4CNP(13,18)+           CNP(13,19)+CNP(13,20)+CNP(13,21)+CNP(13,22)+00007600
     5CNP(13,23)+CNP(13,24)                                             00007700
      ZONE5 =(ZONE5A/22. + ZONE5B/29.)/2.00                             00007800
      ZONE6  = CNP( 2,4 )+CNP( 2,5 )+CNP( 3,1 )+CNP( 3,2 )+CNP( 3, 3)+  00007900
     1CNP( 3, 4)+CNP( 3,5 )+CNP( 3,6 )+CNP( 4, 1)+CNP( 4, 2)+CNP( 4, 3)+00008000
     2CNP( 4, 6)+CNP( 4, 7)+CNP( 4, 8)+CNP( 4, 9)+CNP( 4,10)+CNP( 4,11)+00008100
     3CNP( 5, 7)+CNP(5 ,8 )+CNP( 5, 9)+CNP( 5,10)+CNP( 5,11)+CNP( 6, 9)+00008200
     4CNP( 6,10)+CNP( 6,11)+CNP( 6,12)+CNP( 6,13)+CNP( 6,14)+CNP( 7,12)+00008300
     5CNP( 7,13)+CNP( 7,14)+CNP( 7,15)+CNP( 8,12)+CNP( 8,13)+CNP( 8,14)+00008400
     6CNP( 8,15)                                                       00008500
      ZONE6 = ZONE6/36.                                                 00008600
      TWBAY = (ZONE1*62. + ZONE2*71. + ZONE3*65. + ZONE4*39. +ZONE5*51.+00008700
     1ZONE6*36.)/324.                                                   00008800
      SUM = 0.0                                                         00008900
      DO 10 M=1,MMAX                                                    00009000
      DO 10 N=2,NMAX                                                    00009100
      IF(IFIELD(N,M).EQ.0) GO TO 10                                     00009200
      NN = N-1                                                          00009300
      MM = M-1                                                          00009400
      IF(M.EQ.1) MM=M                                                   00009500
      SUM = SUM + CNP(N,M)*((H(N,M) +H(NN,M) +H(NN,MM)+ H(N,MM))*.25  + 00009600
     1SEP(N,M))                                                         00009700
      IF(NST.GT.1) GO TO 300                                            00009800
  300 CONTINUE                                                          00009900
   10 CONTINUE                                                          00010000
      IF(KRT.EQ.0) GO TO 400                                            00010100
  400 CONTINUE                                                          00010200
      RETURN                                                            00010300
      END                                                               00010400
IEB816I MEMBER NAME (AAZ     ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
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./ CHANGE NAME=ADIVE,LIST=ALL          C     SUBROUTINE CIVE                                                    00001000
                                             SUBROUTINE DIVE(NMAX,MMAX)                                         00001100
                                             COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001200
                                            1C(21,48),NBD(85),MBD(85),MOBD(   4),NOBD(   4),H(21,48),           00001300
                                            2       W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),       00001400
                                            3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),                00001500
                                            4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001600
                                            5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                         00001700
                                            6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)       00001800
                                             DIMENSION NO(40)                                                   00001900
                                             WRITE(6,5)                                                         00002000
                                             DO 1 N=1,NMAX                                                      00002100
                                             TNI=SNI/CSI                                                        00002200
                                           1 NO(N)=N                                                            00002300
                                             WRITE(6,6) (NO(N),N=1,NMAX)                                        00002400
                                             DO 2 M=1,MMAX                                                      00002500
                                             READ(5,3) (IFIELD(N,M),N=1,NMAX)                                   00002600
                                             DO 10 N=1,NMAX                                                     00002700
                                             NBD(N)=IFIELD(N,M)                                                 00002800
                                             IF(NBD(N).EQ.2) NBD(N)=0                                           00002900
                                          10 CONTINUE                                                           00003000
                                             WRITE(6,4) M,(NBD(N),N=1,NMAX)                                     00003100
                                             DO 2 N=1,NMAX                                                      00003200
                                           2 H(N,M)=FLOAT(NBD(N))                                               00003300
                                             RETURN                                                             00003400
                                           3 FORMAT(32I2)                                                       00003500
                                           4 FORMAT(1H ,I2,3X,32I2)                                             00003600
                                           5 FORMAT(1H1,10X,21HWATER LEVELS IN FIELD)                           00003700
                                           6 FORMAT(1H0,2H M,3X,32I2)                                           00003800
                                             END                                                                00003900
IEB816I MEMBER NAME (ADIVE   ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
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```
./ CHANGE NAME=APLOT,LIST=ALL
      SUBROUTINE PLOT(NO,A,N,M,NL,NS)                                   00001000
      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001100
     1 C(21,48),NBD(85),MPD(85),MOBD(4),NOBD(4),H(21,48),               00001200
     2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),            00001300
     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),               00001400
     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001500
     5 ACOSMT(6),ASINMT(6).CN(21,48),CNP(21,48),                        00001600
     6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175).BB(0175)      00001700
C                                                                       00001800
C     ..................................................................00001900
C                                                                       00002000
C        SUBROUTINE PLOT                                                00002100
C                                                                       00002200
C        PURPOSE                                                        00002300
C           PLOT SEVERAL CROSS-VARIABLES VERSUS A BASE VARIABLE         00002400
C                                                                       00002500
C        USAGE                                                          00002600
C           CALL PLOT (NO,A,N,M,NL,NS)                                  00002700
C                                                                       00002800
C        DESCRIPTION OF PARAMETERS                                      00002900
C           NO - CHART NUMBER (3 DIGITS MAXIMUM)                        00003000
C           A  - MATRIX OF DATA TO BE PLOTTED. FIRST COLUMN REPRESENTS  00003100
C                BASE VARIABLE AND SUCCESSIVE COLUMNS ARE THE CROSS-    00003200
C                VARIABLES (MAXIMUM IS 9).                              00003300
C           N  - NUMBER OF ROWS IN MATRIX A                             00003400
C           M  - NUMBER OF COLUMNS IN MATRIX A (EQUAL TO THE TOTAL      00003500
C                NUMBER OF VARIABLES). MAXIMUM IS 10.                   00003600
C           NL - NUMBER OF LINES IN THE PLOT. IF 0 IS SPECIFIED, 50     00003700
C                LINES ARE USED.                                        00003800
C           NS - CODE FOR SORTING THE BASE VARIABLE DATA IN ASCENDING   00003900
C                ORDER                                                  00004000
C                  0  SORTING IS NOT NECESSARY (ALREADY IN ASCENDING    00004100
C                     ORDER).                                           00004200
C                  1  SORTING IS NECESSARY.                             00004300
C                                                                       00004400
C        REMARKS                                                        00004500
C           NONE                                                        00004600
C                                                                       00004700
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED                  00004800
C           NONE                                                        00004900
C                                                                       00005000
C     ..................................................................00005100
C                                                                       00005200
      DIMENSION OUT(101),YPR(11),ANG(9),A(1)                            00005300
C                                                                       00005400
    1 FORMAT(//////////,60X,7H CHART ,I3,//////////)                   00005500
    2 FORMAT(1H ,F11.4,5X,101A1)                                        00005600
    3 FORMAT(1H )                                                       00005700
    4 FORMAT(10H 123456789)                                             00005800
    5 FORMAT(10A1)                                                      00005900
    7 FORMAT(1H ,16X,101H.          .          .          .          .  00006000
```

```
     1    .         .          .          .          .         .)         00006100
    8 FORMAT(1H0,9X,11F10.4)                                                00006200
C                                                                           00006300
C     ..................................................................... 00006400
C                                                                           00006500
      NLL=NL                                                                00006600
      IOUM = N*M                                                            00006700
C                                                                           00006800
      IF(NS) 16, 16, 10                                                     00006900
C                                                                           00007000
C        SORT BASE VARIABLE DATA IN ASCENDING ORDER                         00007100
C                                                                           00007200
   10 DO 15 I=1,N                                                           00007300
      DO 14 J=I,N                                                           00007400
      IF(A(I)-A(J)) 14, 14, 11                                              00007500
   11 L=I-N                                                                 00007600
      LL=J-N                                                                00007700
      DO 12 K=1,M                                                           00007800
      L=L+N                                                                 00007900
      LL=LL+N                                                               00008000
      F=A(L)                                                                00008100
      A(L)=A(LL)                                                            00008200
   12 A(LL)=F                                                               00008300
   14 CONTINUE                                                              00008400
   15 CONTINUE                                                              00008500
C                                                                           00008600
C        TEST NLL                                                           00008700
C                                                                           00008800
   16 IF(NLL) 20, 18, 20                                                    00008900
   18 NLL=50                                                                00009000
C                                                                           00009100
C        PRINT TITLE                                                        00009200
C                                                                           00009300
   20 WRITE(6,1)NO                                                          00009400
C                                                                           00009500
C        DEVELOP BLANK AND DIGITS FOR PRINTING                              00009600
C                                                                           00009700
      REWIND 13                                                             00009800
      WRITE (13,4)                                                          00009900
      REWIND 13                                                             00010000
      READ (13,5) BLANK,(ANG(I),I=1,9)                                      00010100
      REWIND 13                                                             00010200
C                                                                           00010300
C        FIND SCALE FOR BASE VARIABLE                                       00010400
C                                                                           00010500
      XSCAL=(A(N)-A(1))/(FLOAT(NLL-1))                                      00010600
      WRITE(6,100) XSCAL                                                    00010700
  100 FORMAT(5X,'XSCAL = ',E12.4)                                           00010800
C                                                                           00010900
C        FIND SCALE FOR CROSS-VARIABLES                                     00011000
C                                                                           00011100
      M1=N+1                                                                00011200
```

```
      YMIN=A(M1)
      YMAX=YMIN
      M2=M*N
      DO 40 J=M1,M2
      IF(A(J)-YMIN) 28,26,26
   26 IF(A(J)-YMAX) 40,40,30
   28 YMIN=A(J)
      GO TO 40
   30 YMAX=A(J)
   40 CONTINUE
      YSCAL=(YMAX-YMIN)/100.0
      WRITE(6,110) YSCAL
  110 FORMAT(5X,'YSCAL = ',E12.4,//)
C
C     FIND BASE VARIABLE PRINT POSITION
C
      XB=A(1)
      L=1
      MY=M-1
      I=1
   45 F=I-1
      XPR=XB+F*XSCAL
      IF(A(L)-XPR) 50,50,70
C
C         FIND CROSS-VARIABLES
C
   50 DO 55 IX=1,101
   55 OUT(IX)=BLANK
      DO 60 J=1,MY
      LL=L+J*N
      JP=((A(LL)-YMIN)/YSCAL)+1.0
      OUT(JP)=ANG(J)
   60 CONTINUE
C
C         PRINT LINE AND CLEAR, OR SKIP
C
      WRITE(6,2)XPR,(OUT(IZ),IZ=1,101)
      L=L+1
      GO TO 80
   70 WRITE(6,3)
   80 I=I+1
      IF(I-NLL) 45, 84, 86
   84 XPR=A(N)
      GO TO 50
C
C         PRINT CROSS-VARIABLES NUMBERS
C
   86 WRITE(6,7)
      YPR(1)=YMIN
      DO 90 KN=1,9
   90 YPR(KN+1)=YPR(KN)+YSCAL*10.0
      YPR(11)=YMAX
```

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                                     WRITE(6,8)(YPR(IP),IP=1,11)                                                00016500
                                     RETURN                                                                     00016600
                                     END                                                                        00016700
IEB816I MEMBER NAME (APLOT   ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
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```
./ CHANGE NAME=ADISPLY,LIST=ALL
                           SUBROUTINE DISPLY(NST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND)                   00001000
                           COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001100
                          1C(21,48),NBD(85),MBD(85),MOBD(   4),NOBD(   4),H(21,48),               00001200
                          2        W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),          00001300
                          3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),                    00001400
                          4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001500
                          5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                             00001600
                          6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)          00001700
                           DIMENSION T536(125),T636(125), T637(125),T535(125),T635(125),          00001800
                          1T735(125), T736(125),T737(125), T534(125),T634(125), T734(125),        00001900
                          2T834(125), T835(125), T836(125),T837(125),T838(125),A(1250),           00002000
                          3ZIF(1),ZIG(1),ZIH(1)                                                   00002100
                    C                                                                             00002200
                    C      INNER TEMPERATURES AROUND ROME PT                                      00002300
                    C                                                                             00002400
                           NHOLD=NST                                                              00002500
                           IF(NST.EQ.1) MD=1                                                      00002600
                       410 CONTINUE                                                               00002700
                           IF(MOD(NST,IPRIND).EQ.0) GO TO 409                                     00002800
                           GO TO 600                                                              00002900
                       409 NST=MD                                                                 00003000
                           IF(TBNB.EQ.0.00001) TBNB=1.0                                           00003100
                           T536(NST)=CNP(5,36)/TBNB                                               00003200
                           T636(NST)=CNP(6,36)/TBNB                                               00003300
                           T637(NST)=CNP(6,37)/TBNB                                               00003400
                           T535(NST)=CNP(5,35)/TBNB                                               00003500
                           T635(NST)=CNP(6,35)/TBNB                                               00003600
                           T735(NST)=CNP(7,35)/TBNB                                               00003700
                           T736(NST)=CNP(7,36)/TBNB                                               00003800
                           T737(NST)=CNP(7,37)/TBNB                                               00003900
                    C                                                                             00004000
                    C      OUTER TEMPERATURES ARCUND ROME PT                                      00004100
                           T534(NST)=CNP(5,34)/TBNB                                               00004200
                           T534(NST)=CNP(5,34)/TBNB                                               00004300
                           T634(NST)=CNP(6,34)/TBNB                                               00004400
                           T734(NST)=CNP(7,34)/TBNB                                               00004500
                           T834(NST)=CNP(8,34)/TBNB                                               00004600
                           T835(NST)=CNP(8,35)/TBNB                                               00004700
                           T836(NST)=CNP(8,36)/TBNB                                               00004800
                           T837(NST)=CNP(8,37)/TBNB                                               00004900
                           T838(NST)=CNP(8,38)/TBNB                                               00005000
                           MD=MD+1                                                                00005100
                    C                                                                             00005200
                    C                                                                             00005600
                           IF(NHOLD.EQ.MAXST) GO TO 301                                           00005700
                           GO TO 400                                                              00005800
                       301 CONTINUE                                                               00005900
                           NO= 1                                                                  00006000
                           M=9                                                                    00006100
                           N=NST                                                                  00006200
                           NL=NST                                                                 00006300
```

```
      NS=0
      DO 100 N=1,NST
      N1=NST+N
      N2=NST*2+N
      N3=NST*3+N
      N4=NST*4+N
      N5=NST*5+N
      N6=NST*6+N
      N7=NST*7+N
      N8=NST*8+N
      A(N)=N
      A(N1)=T536(N)
      A(N2)=T636(N)
      A(N3)=T637(N)
      A(N4)=T535(N)
      A(N5)=T635(N)
      A(N6)=T735(N)
      A(N7)=T736(N)
      A(N8)=T737(N)
  100 CONTINUE
      WRITE(6,120)
  120 FORMAT(1H1,25X,' ALL OF THE FOLLOWING TEMPERATURES ARE ON THE  INN
     1ER  RADIUS OF THE RCME PT AREA')
      WRITE(6,125)
  125 FORMAT(     5X, ' ALL OF THE FOLLOWING TEMPERATURES ARE IN DEG C,
     1DIVIDED BY TBNB IF TBNB NE 0.',//,5X,'1 = TEMP IN (5,36)',10X,
     2'2 = TEMP IN (6,36)',10X,' 3 = TEMP IN (6,37) ', 10X,
     3 ' 4 = TEMP IN (6,35) '    ,10X,/,5X,'5 = TEMP IN (7,35)'   ,10X,
     4  '6 = TEMP IN (7,35)', 11X,'7 = TEMP IN (7,36)', 12X,'8 = TEMP IN
     5 (7,37)')
      N=NST
      CALL PLOT(NO,A,N,M,NL,0)
      DO 200 N=1,NST
      N1=NST+N
      N2=NST*2+N
      N3=NST*3+N
      N4=NST*4+N
      N5=NST*5+N
      N6=NST*6+N
      N7=NST*7+N
      N8=NST*8+N
      A(N)=N
      A(N1)=T534(N)
      A(N2)=T634(N)
      A(N3)=T734(N)
      A(N4)=T834(N)
      A(N5)=T835(N)
      A(N6)=T836(N)
      A(N7)=T837(N)
      A(N8)=T838(N)
  200 CONTINUE
      WRITE(6,240)
```

```
 240 FORMAT(1H1,25X, ' ALL OF THE FOLLOWING TEMPERATURES ARE ON THE OUT00012000
    1ER RADIUS OF THE RONE PT AREA')                                    00012100
     WRITE(6,250)                                                       00012200
 250 FORMAT(    5X,'ALL OF THE FOLLOWING TEMPERATURES ARE IN DEG C,     00012300
    1DIVIDED BY TBNB IF TBNB NE 0.',//,5X,'1 = TEMP IN (5,34)',10X,     00012400
    2'2 = TEMP IN (6,34)',10X,'3 = TEMP IN (7,34)', 10X,' 4 = TEMP IN  00012500
    3(8,34)', /,5X, '5 = TEMP IN (8,35)',10X, '6 = TEMP IN (8,36)',    '00012600
    4          7 = TEMP IN (8,37)', 11X,'8 = TEMP IN (8,38)')          00012700
     N=NST                                                              00013200
     NO=2                                                               00013250
     CALL PLOT(NO,A,N,M,NL,0)                                           00013300
     WRITE(6,350)                                                       00013400
 350 FORMAT(1H1,5X,'1 = WEIGHTED AVERAGE ALL TEMP IN BAY (DEG C)',/5X, 00013500
    1' 2 = WEIGHTED AV. OF ALL TEMP AROUND ROME PT.(DEG C/10.)',/,      00013600
    25X, ' 3 = AVERAGE UP VELOCITY IN WEST PASSAGE IN YDS/SEC',         00013700
    3/,5X, ' 4 = AVERAGE UP VELOCITY IN OUTFALL AREA BOXS               00013800
    4',/,5X, ' 5 = AVERAGE VP VELOCITY IN OUTFALL AREA',/,5X,           00013900
    5  ' 6 = AVERAGE TEMP IN BAY(DEG C*10.)',/,5X,' 7 = AVERAGE TEMP IN00014000
    6 ROME PT AREA(DEG C*100.)')                                        00014100
     NO=3                                                               00014200
     N=NST                                                              00014300
     M=8                                                                00014400
     NL=NST                                                             00014500
     DO 340 N=1,NST                                                     00014600
     N1=NST+N                                                           00014700
     N2=2*NST+N                                                         00014800
     N3 = 3*NST+N                                                       00014900
     N4 = 4*NST+N                                                       00015000
     N5=5*NST+N                                                         00015100
     N6=6*NST+N                                                         00015200
     N7=7*NST+N                                                         00015300
     A(N) = N                                                           00015400
     A(N1) = ZID(N)                                                     00015500
     A(N2)=ZIF(N)/10.                                                   00015600
     A(N3) = ZIE(N)                                                     00015700
     A(N4) = AA(N)                                                      00015800
     A(N5)= BB(N)                                                       00015900
     A(N6) = ZIG(NST)*10.                                               00016000
 340 A(N7) = ZIH(NST)*100.                                              00016100
     N=NST                                                              00016200
     CALL PLCT(NO,A,N,M,NL,0)                                           00016300
C    BB=TWBAY THEN TEQ                                                  00016400
C    AA= HTOT THEN HTOE                                                 00016500
C    ZID = AVERAGE HT IN EACH BOX(MAIN), ZIE= VELOCITY AT MOUTH OF      00016600
C    WEST PASSAGE(VPMFHT)                                               00016700
C    NOTE THAT AA(N) IS DIVIDED BY 10**-3                               00016800
C    NOTE THAT ZIE(N) IS DIVIDED BY 100.                                00016900
 400 CONTINUE                                                           00017500
 600 NST=NHOLD                                                          00017600
     IF(TBNB.EQ.1.) TBNB=0.00001                                        00017700
     RETURN                                                             00017800
     END                                                                00017900

IEB816I MEMBER NAME (ADISPLY ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
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./ CHANGE NAME=AANLZE,LIST=ALL
      SUBROUTINE ANLYZE(MAXST,NTERM,AT,NST,ZIF)                         00001000
      COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001100
     1C(21,48),NBD(85),MBD(85),MOBD(   4),NOBD(   4),H(21,48),           00001200
     2       W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),       00001300
     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),               00001400
     4 ZIA(0175),ZIB(0175),ZIC(0175), UAVG(21,48),VAVG(21,48),ZIE(0175),00001500
     5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                        00001600
     6 IFIELD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)      00001700
      DIMENSION XIA(0175),ALINE(65),ZIF(1)                              00001800
      DATA BLANK,DOT,STAR/' ','.','*'/                                  00001900
      NSTEP=1800./AT                                                    00002000
      DO 10 K=1,61                                                      00002100
   10 ALINE(K)=BLANK                                                    00002200
C                                                                       00002300
      T=0.                                                              00002400
      IF(MAXST.GT.175) MAXST=175                                        00002450
       DO 30 N=1,MAXST,NSTEP                                            00002500
      S=0.                                                              00002600
      DO 20 I=1,17                                                      00002700
   20 S= F2(I)*Z(I)*COS(W(I)*T+ARN(I))+S                                00002800
      XIA(N)=S                                                          00002900
   30 T=T+1.0                                                           00003000
      ZA=0.                                                             00003100
      DO 40 N=1,MAXST,NSTEP                                             00003200
      IF(ABS(ZIA(N)).GT.ZA) ZA=ABS(ZIA(N))                              00003300
   40 IF(ABS(XIA(N)).GT.ZA) ZA=ABS(XIA(N))                              00003400
      ZS=ZA                                                             00003500
      WRITE(6,45)                                                       00003600
      WRITE(6,46)                                                       00003700
      DO 60 N=1,MAXST,NSTEP                                             00003800
      ALINE(31)=DOT                                                     00003900
      JM=31.+(ZIA(N)/ZS)*30.                                            00004000
      JS=31.+(XIA(N)/ZS)*30.                                            00004100
      ALINE(JM)=STAR                                                    00004200
      ALINE(JS)=DOT                                                     00004300
      WRITE(6,50) N,ZIA(N),XIA(N),(ALINE(J),J=1,61)                     00004400
      ALINE(JM)=BLANK                                                   00004500
      ALINE(JS)=BLANK                                                   00004600
   60 CONTINUE                                                          00004700
C                                                                       00004800
      T=0.0                                                             00004900
      DO 90 N=1,MAXST,NSTEP                                             00005000
      SB=0.0                                                            00005100
      DO 80 I=1,17                                                      00005200
   80 SB=F2(I)*HB(I)*COS(W(I)*T+ARGB(I))+SB                             00005300
      XIA(N)=SB                                                         00005400
   90 T=T+1.0                                                           00005500
      ZA=0.                                                             00005600
      DO 100 N=1,MAXST,NSTEP                                            00005700
      IF(ABS(ZIB(N)).GT.ZA) ZA=ABS(ZIB(N))                              00005800
  100 IF(ABS(XIA(N)).GT.ZA) ZA=ABS(XIA(N))                              00005900
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              ZS=ZA                                                               00006000
              WRITE(6,45)                                                         00006100
              WRITE(6,65)                                                         00006200
              DO 110 N=1,MAXST,NSTEP                                              00006300
              ALINE(31)=DOT                                                       00006400
              JM=31.+(ZIB(N)/ZS)*30.                                              00006500
              JS=31.+(XIA(N)/ZS)*30.                                              00006600
              ALINE(JM)=STAR                                                      00006700
              ALINE(JS)=DOT                                                       00006800
              WRITE(6,50) N,ZIB(N),XIA(N),(ALINE(J),J=1,61)                       00006900
              ALINE(JS)=BLANK                                                     00007000
              ALINE(JM)=BLANK                                                     00007100
          110 CONTINUE                                                            00007200
        C                                                                         00007300
              T=0.                                                                00007400
              DO 150 N=1,MAXST,NSTEP                                              00007500
              SP=0.0                                                              00007600
               DO 140 I=1,17                                                      00007700
          140 SP=F2(I)*HP(I)*COS(W(I)*T+ARGP(I))+SP                               00007800
              XIA(N)=SP                                                           00007900
          150 T=T+1.0                                                             00008000
              ZA=0.0                                                              00008100
              DO 160 N=1,MAXST,NSTEP                                              00008200
              IF(ABS(ZIC(N)).GT.ZA) ZA=ABS(ZIC(N))                                00008300
          160 IF(ABS(XIA(N)).GT.ZA) ZA=ABS(XIA(N))                                00008400
              ZS=ZA                                                               00008500
              WRITE(6,45)                                                         00008600
              WRITE(6,48)                                                         00008700
              DO 170 N=1,MAXST,NSTEP                                              00008800
              ALINE(31)=DOT                                                       00008900
              JS=31.+(XIA(N)/ZS)*30.                                              00009000
              JM=31.+(ZIC(N)/ZS)*30.                                              00009100
              ALINE(JM)=STAR                                                      00009200
              ALINE(JS)=DOT                                                       00009300
              WRITE(6,50) N,ZIC(N),XIA(N),(ALINE(J),J=1,61)                       00009400
              ALINE(JS)=BLANK                                                     00009500
              ALINE(JM) = BLANK                                                   00009600
          170 CONTINUE                                                            00009700
        C                                                                         00009800
           45 FORMAT(1H1,/,12X,'MODEL(*)',4X,'SERIES(.)',10X,'WATER LEVEL AT')   00009900
           46 FORMAT(52X,'NEWPORT'/)                                              00010000
           48 FORMAT(52X,'PROVIDENCE')                                            00010100
           65 FORMAT(52X,'BRISTOL')                                               00010200
           50 FORMAT(5X,I4,5X,2(F6.2,3X),'I',61A1,'I')                            00010300
              RETURN                                                              00010400
              END                                                                 00010500
IEB816I MEMBER NAME (AANLZE  ) FOUND IN NM DIRECTORY. TTR IS NOW ALTERED.
IEB818I HIGHEST CONDITION CODE WAS 00000000
IEB819I END OF JOB IEBUPDTE.
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LEVEL 20.1 (AUG 71)                         OS/360  FORTRAN H                                    DATE  73.156/04.43.34

         COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                          SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF
  ISN 0002            DIMENSION A(048),B(48),Q(48),R(48),S(48), F(48),P(48),              00001000
                     1KONVRT(21),NH(21),NPRINT(200),DAVG(80),         AHOLO(48),NT(30),  00001100
                     2NS(10),MS(10),SS(10),ZIF(0175),NTP(10),ZIH(0175),ZIG(0175)         00001200
                C                                                                         00001300
  ISN 0003            COMMON SE(21,48),SEP(21,48),V(21,48),VP(21,48),U(21,48),UP(21,48),00001400
                     1 C(21,48),NBD(85),MBD(85),MOBD(4),NOBO(4),H(21,48),                 00001500
                     2 W(20),F2(20),Z(20),E(20),HP(20),EP(20),HB(20),EB(20),              00001600
                     3 ARN(20),ARGP(20),ARGB(20),ARGLB(20),HL(20),EL(20),                 00001700
                     4 ZIA(0175),ZIB(0175),ZIC(0175),UAVG(21,48),VAVG(21,48),ZIE(0175),  00001740
                     5 ACOSMT(6),ASINMT(6),CN(21,48),CNP(21,48),                          00001900
                     6 IFIFLD(21,48),HS1(015),HS2(015),ZID(0175),AA(0175),BB(0175)       00002000
                C                                                                         00002100
  ISN 0004            LOGICAL READIN,DOSAL,ROCNP,DELTAT                                   00002200
                C                                                                         00002300
  ISN 0005            DATA YR,DAY,THR,TMIN /57.,195.,17.,48./                             00002400
  ISN 0006            DATA MSOURC,NSOURC /1,1/                                            00002500
  ISN 0007            DATA AL,AG,SALRIS,TMHOPE,TRIVER,TSOUND/1012.7,10.73,32.5,21.75,     00002600
                     122.2,18.50/                                                         00002700
  ISN 0008            DATA HINV,SEINV,PI,CMANN,WX,WY,CORAG,CRHO /0.,0.,3.1415927,         00002800
                     1.015,0.,0.,.0025,.00114/                                            00002900
                C                                                                         00003000
                C                                                                         00003100
                C     SET EXECUTION PARAMETERS                                            00003200
                C                                                                         00003300
                C     IMODES = 1 UPSTREAM DIIFERENCING                                    00003400
                C     IMODES = 2 CENTRAL DIFFERENCING                                     00003500
                C                                                                         00003600
                C                                                                         00003650
  ISN 0009            IMODES=2                                                            00003700
  ISN 0010       2871 IPUNCH=540                                                          00003800
  ISN 0011            AT = 120.                                                           00003900
  ISN 0012            EXTRA3=AT                                                           00004000
                C     IPRIND WILL SPECIFY TIME THAT VARIABLES ARE DISPLAYED               00004100
  ISN 0013            IPRIND=15                                                           00004200
  ISN 0014            ILD=1                                                               00004300
                C     SUMMING MODES REQUIRED FOR DISPLAYS                                 00004400
  ISN 0015            SUMZIG=0.0                                                          00004500
  ISN 0016            SUMZID=0.0                                                          00004600
  ISN 0017            SUMZIF=0.0                                                          00004700
  ISN 0018            SUMZIH=0.0                                                          00004800
  ISN 0019            SUMAA=0.0                                                           00004900
  ISN 0020            SUMBB=0.0                                                           00005000
  ISN 0021            MAXST=540                                                           00005100
  ISN 0022            NW=MAXST+1                                                          00005200
  ISN 0023            IDY=1                                                               00005300
  ISN 0024            HS1(IDY) = 2000.                                                    00005400
  ISN 0025            ROCNP=.FALSE.                                                       00005500
                C     ROCNP FOR READING IN PREVIOUS VALUES OF CNP                         00005600
  ISN 0026            READIN=.TRUE.                                                       00005700
  ISN 0027            DOSAL=.TRUE.                                                        00005800
  ISN 0028            IRMS=1000                                                           00005900
  ISN 0029            IMODE1 = 1                                                          00006000
                C                                                                         00006100
                C     SET COMPUTATION PARAMETERS                                          00006200
                C                                                                         00006300
                C                                                                         00006400
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                C      IF DELTAT IS TRUE MODEL WILL CALCUALTE TEMPERATURE ABOVE AMBIENT   00006500
ISN 0030               DELTAT=.TRUE.                                                       00006600
ISN 0031               TBN9=21.0                                                           00006700
ISN 0032               IF(DELTAT) GO TO 2873                                               00006800
ISN 0034               GO TO 2875                                                          00006900
ISN 0035          2873 TBN8=0.00001                                                        00007000
ISN 0036               TMHOPE=.00001                                                       00007100
ISN 0037               TRIVER=.00001                                                       00007200
ISN 0038               TSOUND=.00001                                                       00007300
ISN 0039          2875 CONTINUE                                                            00007400
                C      DIFFUSION CONSTANT IS UPCON                                         00007500
                C      FOR UPCON =500 THE ORDER OF MAGNITUDE OF HIGHEST DIFFUSION COEF     00007600
                C      IS ABOUT 350 YDSQ/SEC                                               00007700
                C                                                                          00007800
ISN 0040               UPCON=050.                                                          00007900
                C                                                                          00008000
                C      POWER PLANT                                                         00008100
                C      TIN =0.0 YOU WILL HAVE HYDRODYNAMICS OF POWER PLAT SITE BUT         00008200
                C      NO THERMAL LOAD ON BAY                                              00008300
                C      IF EFFECTS OF POWER PLANT ARE DESIRED SET TIN EQUAL TO 12.          00008400
ISN 0041               TIN=12.                                                             00008500
ISN 0042               QIN=2000.                                                           00008600
                C                                                                          00008700
                C      SITE SELECTION.  SEE HEATIN FOR DETAILS ON LOCATIONS                00008800
ISN 0043               SITE=100.                                                           00008900
                C                                                                          00009000
                C                                                                          00009100
ISN 0044               LNL = 0                                                             00009200
ISN 0045               ARHO=27.*1.940*(1.00+0.000841*SALRIS-0.000100*TSOUND)               00009300
                C                                                                          00009400
                C                                                                          00009500
ISN 0046               NMAX=19                                                             00009600
ISN 0047               MMAX=48                                                             00009700
ISN 0048               ANGLAT=41.6                                                         00009800
ISN 0049               NI=1                                                                00009900
ISN 0050               MOBD(1)=0103042                                                     00010000
ISN 0051               MOBD(2)=4808091                                                     00010100
ISN 0052               MOBD(3)=4811131                                                     00010200
ISN 0053               NOBD(1)=1923242                                                     00010300
ISN 0054               NOBD(2)=0410112                                                     00010400
ISN 0055               MINDO=4                                                             00010500
ISN 0056               NINDO=3                                                             00010600
ISN 0057               NSECT=80                                                            00010700
                C                                                                          00010800
ISN 0058            87 CONTINUE                                                            00010900
ISN 0059               ARG=ANGLAT*3.1415927/180.                                           00011000
ISN 0060               FF=3.1415927*SIN(ARG)/21600.                                        00011100
ISN 0061          2080 NST=0                                                               00011200
ISN 0062               IP=1                                                                00011300
ISN 0063               C1=AT*AG/AL                                                         00011400
ISN 0064               C2=AT/AL                                                            00011500
ISN 0065               C3=AT/4.                                                            00011600
ISN 0066               C4=8.*AT*AG                                                         00011700
ISN 0067               C5=2.*27.*AL                                                        00011800
                C     27 IS FOR CUFT TO CUYDS CONVERSION AND 2 IS FOR DISPLAYING           00011900
                C      ACTUAL CROSSECTIONAL FLOW IN FOR RIVER                              00012000
ISN 0068               C6=2.*CDRAG*CRHO*(1.687/3.)**2*AT                                   00012100
ISN 0069               C7=40.00*SQRT(AG)                                                   00012200
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                                                                                                          PAGE 003
ISN 0070            C8=1./AL                                                                     00012300
ISN 0071            C9=1./(AL**2)                                                                00012400
ISN 0072            C10 = 0.                                                                     00012500
ISN 0073            C11=C7                                                                       00012600
ISN 0074            C12 = 0.                                                                     00012700
ISN 0075            C13=1./AT                                                                    00012800
ISN 0076            C14=1./(4.*AL)                                                               00012900
ISN 0077            DO 8 M=1,MMAX                                                                00013000
ISN 0078            DO 6 N=1,NMAX                                                                00013100
ISN 0079            SE(N,M)=0.0                                                                  00013200
ISN 0080            SEP(N,M)=0.0                                                                 00013300
ISN 0081            CN(N,M)=0.0                                                                  00013400
ISN 0082            CNP(N,M)=0.0                                                                 00013500
ISN 0083             UAVG(N,M)=0.0                                                               00013600
ISN 0084            VAVG(N,M)=0.0                                                                00013700
ISN 0085            VP(N,M)=0.0                                                                  00013800
ISN 0086            UP(N,M)=0.0                                                                  00013900
ISN 0087            V(N,M)=0.                                                                    00014000
ISN 0088            U(N,M)=0.                                                                    00014100
ISN 0089            C(N,M)=0.                                                                    00014200
ISN 0090            H(N,M)=0.0                                                                   00014300
ISN 0091          6 F(N)=FF                                                                      00014400
ISN 0092          8 CONTINUE                                                                     00014500
ISN 0093            RA=0.0                                                                       00014600
ISN 0094            CALL KURIH(MAXST,AT,NTERM,FCHECK,YR,CAY,THR,TMIN,TS)                         00014700
ISN 0095            CALL DIVE(NMAX,MMAX)                                                         00014750
ISN 0096            CALL FIND(MIND,NIND,MMAX,NMAX,MINDO,NINDO,NSECT)                             00015000
ISN 0097            CALL DEPTH(NMAX,MMAX)                                                        00015100
ISN 0098            CALL CHEZY(NMAX,MMAX,CMANN)                                                  00015200
ISN 0099            CALL CHECK(NMAX,MMAX)                                                        00015300
ISN 0100            DO 26 I=1,5                                                                  00015400
ISN 0101            L=18*I                                                                       00015500
ISN 0102            M=18*(I-1) +1                                                                00015600
ISN 0103            READ(5,25) (NPRINT(N),N=M,L)                                                 00015700
ISN 0104         25 FORMAT(18I4)                                                                 00015800
ISN 0105         26 CONTINUE                                                                     00015900
ISN 0106            DO 62 M=1,MMAX                                                               00016000
ISN 0107            DAVG(M)=0.0                                                                  00016100
ISN 0108            DEP=0.0                                                                      00016200
ISN 0109            DO 61 N=1,NMAX                                                               00016300
ISN 0110            IF(H(N,M).EQ.0.0) GO TO 61                                                   00016400
ISN 0112            DAVG(M)=DAVG(M)+H(N,M)                                                       00016500
ISN 0113            DEP=DEP+1.                                                                   00016600
ISN 0114        61  CONTINUE                                                                     00016700
ISN 0115            DAVG(M)=3.*DAVG(M)/DEP                                                       00016800
ISN 0116         62 CONTINUE                                                                     00016900
ISN 0117            NUM=1                                                                        00017000
ISN 0118            DEP=0.0                                                                      00017100
ISN 0119            DEPSQ=0.0                                                                    00017200
ISN 0120            GRION1=0.0                                                                   00017300
ISN 0121          7 IF(NUM.EQ.NIND) GO TO 3                                                      00017400
ISN 0123            NSRCH=NBD(NUM)/1000000                                                       00017500
ISN 0124            N     =NBD(NUM)/10000    -NSRCH*100                                          00017600
ISN 0125            MF    =NBD(NUM)/100-NSRCH*10000-N*100                                        00017700
ISN 0126            L     =NBD(NUM)-NSRCH*1000000-N*10000-MF*100                                 00017800
ISN 0127            NN=N-1                                                                       00017900
ISN 0128            K=MF                                                                         00018000
ISN 0129            NGRID=L-K+1                                                                  00018100
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ISN 0130              GRIDN2=NGRID                                          00018200
ISN 0131              GRIDN1=GRIDN1+GRIDN2                                  00018300
              C                                                             00018400
              C       USED ONLY IF NO SE VALUES ARE READ IN                 00018500
              C                                                             00018600
ISN 0132               DO 2 M=K,L                                           00018700
ISN 0133              DEP=DEP+H(N,M)                                        00018800
ISN 0134              DEPSQ=DEPSQ+SQRT(H(N,M))                              00018900
ISN 0135              DIM1=M                                                00019000
ISN 0136              DIM1=DIM1-1.                                          00019100
ISN 0137              CN(N,M)=TBNB                                          00019200
ISN 0138              CNP(N,M)=TBNB                                         00019300
ISN 0139              SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV                     00019400
ISN 0140            2 SE(N,M)= SEINV*(1.-DIM1/46.)+HINV                     00019500
ISN 0141              NUM=NUM+1                                             00019600
ISN 0142               GO TO 7                                              00019700
ISN 0143            3 CONTINUE                                              00019800
ISN 0144              CN (3,1) = TBNB                                       00019900
ISN 0145              CNP(3,1) = TBNB                                       00020000
ISN 0146              CN (4,1) = TBNB                                       00020100
ISN 0147              CNP(4,1) = TBNB                                       00020200
ISN 0148              CN (19,23)=TBNB                                       00020300
ISN 0149              CNP(19,23)=TBNB                                       00020400
ISN 0150              CN (19,24)=TBNB                                       00020500
ISN 0151              CNP(19,24)=TBNB                                       00020600
ISN 0152              CN (08,48)=TBNB                                       00020700
ISN 0153              CNP(08,48)=TBNB                                       00020800
ISN 0154              CN (09,48)=TBNB                                       00020900
ISN 0155              CNP(09,48)=TBNB                                       00021000
ISN 0156              CN (11,48)=TBNB                                       00021100
ISN 0157              CNP(11,48)=TBNB                                       00021200
ISN 0158              CN (12,48)=TBNB                                       00021300
ISN 0159              CNP(12,48)=TBNB                                       00021400
ISN 0160              CN (13,48)=TBNB                                       00021500
ISN 0161              CNP(13,48)=TBNB                                       00021600
ISN 0162              DEP=3.*DEP/GRIDN1                                     00021700
ISN 0163              DEPSC=DEPSQ/GRIDN1                                    00021800
ISN 0164              DEPSQ=3.*(DEPSQ**2)                                   00021900
ISN 0165               NA=1                                                 00022000
ISN 0166            5 IF(NA.EQ.M(NDO) GO TO 31                              00022100
ISN 0168              M=MOBD(NA)/100000                                     00022200
ISN 0169              NBOT  =MOBD(NA)/1000   -M*100                         00022300
ISN 0170              NTOP  =MOBD(NA)/10  -M*10000  -NBOT*100               00022400
ISN 0171              DO 32 N=NBOT,NTOP                                     00022500
ISN 0172              DIM1=M                                                00022600
ISN 0173              DIM1=DIM1-1.                                          00022700
ISN 0174              SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV                     00022800
ISN 0175           32 SE(N,M)= SEINV*(1.-DIM1/46.)+HINV                     00022900
ISN 0176              NA=NA+1                                               00023000
ISN 0177              GO TO 5                                               00023100
ISN 0178           31 NA=1                                                  00023200
ISN 0179           33 IF(NA.EQ.NINDO) GO TO 34                              00023300
ISN 0181              N=NOBD(NA)/100000                                     00023400
ISN 0182              MLEF =NOBD(NA)/1000  -N*100                           00023500
ISN 0183              MRIG =NOBD(NA)/10    -N*10000  -MLEF*100              00023600
ISN 0184              DO 35 M=MLEF,MRIG                                     00023700
ISN 0185              DIM1=M                                                00023800
ISN 0186              DIM1=DIM1-1.                                          00023900
```

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ISN 0187            SEP(N,M)=SEINV*(1.-DIM1/46.)+HINV                                00024000
ISN 0188         35  SE(N,M)= SEINV*(1.-DIM1/46.)+HINV                               00024100
ISN 0189            NA=NA+1                                                          00024200
ISN 0190            GO TO 33                                                         00024300
ISN 0191         34 CONTINUE                                                         00024400
              C***********************************************************************00024500
              C                                                                      00024600
ISN 0192            CALL INVAL(MMAX,NMAX,GRIDN1 ,DEP,DEPSQ,READIN,ROCNP,DAVG)        00024700
              C                                                                      00024800
ISN 0193            CALL HEATIN(NS,MS,SS,TIN,NZ,SITE,NINPUT,QIN)                     00024850
              C***********************************************************************00024900
              C                                                                      00025000
ISN 0194            WRITE(6,2050) NS(5),MS(5)                                        00025040
ISN 0195       2050 FORMAT(//,5X,'NS(5) = ',I4    ,'MS(5) = ',I4)                    00025060
ISN 0196         40 ISTEP=2                                                          00025100
              C                                                                      00025200
              C***********************************                                   00025300
              C                                                                      00025400
ISN 0197            CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,        00025500
                   1HE,HC,SAVE,IPUNCH)                                               00025600
              C                                                                      00025700
              C**********************************************                        00025800
              C                                                                      00025900
ISN 0198         68 ISTEP=1                                                          00026000
ISN 0199            NST=NST+1                                                        00026100
ISN 0200            K=2*NST-1                                                        00026200
ISN 0201       2001 IF(NST.GT.MAXST) GO TO 501                                       00026300
              C                                                                      00026400
              C**********************************************                        00026500
              C                                                                      00026600
              C                SET OPEN BOUNDS                                       00026700
              C                                                                      00026800
              C                                                                      00026900
ISN 0203            CALL OPENBD(NST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,    00027000
                   1NTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN)        00027100
              C                                                                      00027200
              C***********************************************************************00027300
              C                                                                      00027400
              C     COMPUTE UP AND SEP CN RCW N ( FIRST HALF TIMESTEP)               00027500
              C                                                                      00027600
ISN 0204            CALL UPNFHT(WX,WY,C6,C1,C2,C4,AT,AG,NIND,F,NI)                   00027700
              C                                                                      00027800
              C***********************************************************************00027900
              C                                                                      00028000
              C                COMPUTE VP CN COLUMN M (FIRST HALF TIMESTEP)          00028100
              C                                                                      00028200
ISN 0205            CALL VPMFHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,    00028300
                   1C10,C7,C8,C9,C14,C1,MIND,F,NI,NST,NPRINT ,IP,TBNB,KRT,NMAX,MMAX, 00028400
                   2IDY,PI,DAY,THR,TMIN,HTOT,HA,BH,HE,HC,SAVE,NS,MS,SS,              00028500
                   3QIN,TIN,NZ,NW,UPCON,VAR1,DELTAT,NINPUT,ZIG)                      00028600
              C                                                                      00028700
              C**********************************************                        00028800
              C                                                                      00028900
ISN 0206            CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,        00029000
                   1HE,HC,SAVE,IPUNCH)                                               00029100
              C                                                                      00029200
              C***********************************************************************00029300
              C                                                                      00029400
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ISN 0207          CALL OPENBD(NST,IMODES,EXTRA1,KWRIT,K,KRT,IMODE1,T1,T2,T4,T5,      00029500
                 1NTERM,C5,TRIVER,TMHOPE,TSOUND,PI,THR,FCHECK,AT,TS,AL,QIN)          00029600
            C                                                                        00029700
            C***********************************************************************CCC29800
            C                                                                        00029900
ISN 0208          NXT=ILD                                                            00029910
ISN 0209          IF(NXT.FQ.0) GO TO 2020                                            00029920
ISN 0211     2010 IF(NST.LT.90) GO TO 2040                                           00029930
ISN 0213          GO TO 2020                                                         00029940
ISN 0214     2040 WRITE(6,2030) NXT,CN(5,36),CNP(5,36),QIN,TIN,NS(1),MS(1),NZ,       00029950
                 1NINPUT,SS(1), ZIA(NXT),ZIB(NXT),ZIC(NXT), ZIE(NXT),ZID(NXT),       00029955
                 2AA(NXT),BB(NXT),SITE,NS(5),MS(5),NST                               00029958
ISN 0215     2030 FORMAT(5X, 'NST= ',I4, '  CN(5,36) = ', E12.4, ' CNP(5,36) =',     00029960
                 1E12.4, 'QIN = ', E12.4,  ' TIN = ', E12.4, ' NS = ',I4, ' MS = ', 00029965
                 2I4,/,5X,' NZ = ',I4, ' ININPUT = ',I4, ' SS(1) = ', E12.4,         00029970
                 3'ZIA(NST) = ',E12.4,' ZIB(NST) = ',E12.4,'ZIC(NST=',E12.4,/,5X,    00029975
                 4'ZIE(NST) = ', E12.4, ' ZID(NST) = ',E12.4, 'AA(NST) = ',E12.4,    00029980
                 5'BB(NST) = ',E12.4,/,5X,' SITE = ',E12.4, 'NS(5) = ',I4,           00029985
                 6'MS(5) = ',I4,'NST = ',I4)                                         00029987
ISN 0216     2020 CONTINUE                                                           00029990
            C***********************************************************************00030100
ISN 0217      299 ISTEP=2                                                            00030200
ISN 0218          K=2*NST                                                            00030300
            C                                                                        00030400
            C                                                                        00030500
            C          COMPUTE VP AND SEP ON COLUMN M (SECOND HALF TIMESTEP)         00030600
            C                                                                        00030700
ISN 0219          CALL VPMSHT(WX,WY,C6,C1,C2,C4,AT,AG,MIND,F,NI)                     00030800
            C                                                                        00030900
            C***********************************************************************00031000
            C                                                                        00031100
ISN 0220          CALL UPNSHT(C2,C6,WX,WY,C4,AT,DOSAL,IMODES,NSOURC,MSOURC,C13,      00031200
                 1C10,C7,C8,C9,C14,C1,NIND,F,NI,NST,NPRINT,IP,TBNB,KRT,NMAX,MMAX,    00031300
                 2 IDY,PI,DAY,NS,MS,SS,QIN,TIN,NZ,THR,TMIN,HTOT,NW,UPCON,VAR1,       00031400
                 3NINPUT)                                                            00031500
            C                                                                        00031600
ISN 0221          SUM1=0.                                                            00031700
ISN 0222          GRIDT1 = 0.0                                                       00031800
            C                                                                        00031900
ISN 0223          SUM=0.0                                                            00032000
            C                                                                        00032100
            C                                   BAY AREA                             00032200
            C                                                                        00032300
ISN 0224          NUM=1                                                              00032400
ISN 0225       17 IF(NUM.EQ.NIND) GO TO 36                                           00032500
ISN 0227          NSRCH=NBD(NUM)/1000000                                             00032600
ISN 0228          N    =NBD(NUM)/10000   -NSRCH*100                                  00032700
ISN 0229          MF   =NBD(NUM)/100-NSRCH*10000-N*100                               00032800
ISN 0230          L    =NBD(NUM)-NSRCH*1000000-N*10000-MF*100                        00032900
ISN 0231          NN=N-1                                                             00033000
ISN 0232          NGRID = L-MF+1                                                     00033100
ISN 0233          GRIDN2=NGRID                                                       00033200
ISN 0234          GRIDT1=GRIDT1+GRIDN2                                               00033300
ISN 0235          DO 22 M=MF,L                                                       00033400
ISN 0236          MM= M-1                                                            00033500
ISN 0237          SUMTWT  =CNP(N,M)*(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))00033600
                 1*3.0                                                               00033700
ISN 0238          SUM=SUM+SUMTWT                                                     00033800
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ISN 0239            SUM1=SUM1+CNP(N,M)                                                00033900
ISN 0240        22  CONTINUE                                                          00034000
ISN 0241            NUM=NUM+1                                                         00034100
ISN 0242            GO TO 17                                                          00034200
ISN 0243        36  SUMZIG=SUM1/GRIDT1 + SUMZIG                                       00034300
             C      CONSTAN SHOULD EQUAL (AL**2)*9*DENS*9/5                           00034400
ISN 0244            CONSTA=1.00                                                       00034500
ISN 0245            SUMZID=CONSTA*SUM+SUMZID                                          00034600
ISN 0246            IF(MOD(NST,IPRIND).EQ.0) GO TO 45                                 00034700
ISN 0248            GO TO 41                                                          00034800
ISN 0249        45  IPRINZ=IPRIND                                                     00034900
ISN 0250            IF(DELTAT) GO TO 47                                               00035000
ISN 0252            IPRINZ=IPRINZ*10**4                                               00035100
ISN 0253        47  ZID(ILD)=SUMZID/IPRINZ                                            00035200
ISN 0254            ZIG(ILD)=SUMZIG/IPRINZ                                            00035300
ISN 0255            SUMZIG=0.0                                                        00035400
ISN 0256            SUMZID=0.0                                                        00035500
ISN 0257        41  CONTINUE                                                          00035600
ISN 0258            SUM=0.                                                            00035700
ISN 0259            SUM1=0.0                                                          00035800
ISN 0260            NUM=1                                                             00035900
ISN 0261            GRIDT3=0.0                                                        00036000
ISN 0262            NTP(1)= NBD(8)                                                    00036100
ISN 0263            NTP(2)= NBD(11)                                                   00036200
ISN 0264            NTP(3)= NBD(14)                                                   00036300
ISN 0265            NTP(4)= NBD(16)                                                   00036400
ISN 0266            NTP(5)= NBD(17)                                                   00036500
ISN 0267            NTP(6)= NBD(19)                                                   00036600
             C                                                                        00036700
             C                             POWER PLANT AREA                           00036800
             C                                                                        00036900
ISN 0268       300  IF(NUM.EQ.07) GO TO 310                                           00037000
ISN 0270       312  NSRCH=NTP(NUM)/1000000                                            00037100
ISN 0271            N=NTP(NUM)/10000-NSRCH*100                                        00037200
ISN 0272            MF=NTP(NUM)/100-NSRCH*10000-N*100                                 00037300
ISN 0273            L=NTP(NUM)-NSRCH*1000000-N*10000-MF*100                           00037400
ISN 0274            IF(MF.LT.32) MF=32                                                00037500
ISN 0276            IF(L.GT.42) L=42                                                  00037600
ISN 0278            NN=N-1                                                            00037700
ISN 0279            NNGD=L-MF+1                                                       00037800
ISN 0280            GRT4=NNGD                                                         00037900
ISN 0281            GRIDT3=GRIDT3+GRT4                                                00038000
ISN 0282            DO 330 M=MF,L                                                     00038100
ISN 0283            MM=M-1                                                            00038200
ISN 0284            SUMTPT  =CNP(N,M)*(.25*(H(N,M)+H(NN,M)+H(N,MM)+H(NN,MM)+SEP(N,M)))00038300
                   1*3.0                                                              00038400
ISN 0285            SUM1=SUM1+CNP(N,M)                                                00038500
ISN 0286       330  SUM=SUM+SUMTPT                                                    00038600
ISN 0287        60  SUMZIF=CONSTA*SUM+SUMZIF                                          00038700
ISN 0288            SUMZIH=SUM1/GRIDT3 + SUMZIH                                       00038800
ISN 0289            IF(MOD(NST,IPRIND).EQ.0) GO TO 65                                 00038900
ISN 0291            GO TO 70                                                          00039000
ISN 0292        65  IPRINZ=IPRIND                                                     00039100
ISN 0293            IF(DELTAT) GO TO 67                                               00039200
ISN 0295            IPRINZ=IPRINZ*10**2                                               00039300
ISN 0296        67  ZIF(ILD)=SUMZIF/IPRINZ                                            00039400
ISN 0297            ZIH(ILD)=SUMZIH/IPRINZ                                            00039500
ISN 0298            SUMZIF=0.0                                                        00039600
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ISN 0299            SUMZIH=0.0                                                        00039700
ISN 0300         70 CONTINUE                                                          00039800
ISN 0301            NUM=NUM+1                                                         00039900
ISN 0302            GO TO 300                                                         00040000
ISN 0303        310 CONTINUE                                                          00040100
              C                                                                       00040200
              C     VELOCITY COMPONENETS IN OUTFALL AREA                              00040300
              C                                                                       00040400
ISN 0304            SUM=0.0                                                           00040500
ISN 0305            SUM1=0.0                                                          00040600
ISN 0306        316 NZ=1                                                              00040700
ISN 0307            INS=NS(NZ)                                                        00040800
ISN 0308            IMS=MS(NZ)                                                        00040900
              C   CHANGE 5 TO NS(2) AND 36 TO MS(1) WHEN YOU RUN POWER PLANT          00041000
ISN 0309            SUM=UP(INS,IMS)+SUM                                               00041100
ISN 0310            SUM1=VP(INS,IMS)+SUM1                                             00041200
ISN 0311        375 CONTINUE                                                          00041300
ISN 0312            ANZ=NZ                                                            00041400
ISN 0313            SUM=SUM/ANZ                                                       00041500
ISN 0314            SUM1=SUM1/ANZ                                                     00041600
ISN 0315            SUMAA=SUM  + SUMAA                                                00041700
ISN 0316            SUMBB=SUM1+SUMBB                                                  00041900
ISN 0317            IF(MOD(NST,IPRIND).EQ.0) GO TO 75                                 00042000
ISN 0319            GO TO 80                                                          00042100
ISN 0320         75 AA(ILD)=SUMAA/IPRIND                                              00042200
ISN 0321            BB(ILD)=SUMBB/IPRIND                                              00042300
ISN 0322            SUMAA=0.0                                                         00042400
ISN 0323            SUMBB=0.0                                                         00042500
ISN 0324            IF(MOD(NST,IPRIND).EQ.0) ILD=ILD+1                                00042600
ISN 0326            NXT=ILD-1                                                         00042650
ISN 0327         80 CONTINUE                                                          00042700
              C                                                                       00042800
ISN 0328            WRITE(6,2070) ZID(NXT),ZIG(NXT).ZIF(NXT).ZIH(NXT)                 00042850
ISN 0329       2070 FORMAT(//,5X,'ZID(NXT) = ', E12.4, 'ZIG(NXT) = ',E12.4,           00042860
                   1'ZIF(NXT) = ', E12.4, 'ZIH(NST) = ',E12.4)                        00042890
              C     AVERAGE VELCCITY IN WEST PASSAGE                                  00042900
ISN 0330            ZIE(ILD)=(UP(8,47)+UP(9,47))/2.                                   00043000
ISN 0331            CALL DISPLY(NST,MAXST,TBNB,ZIF,ZIG,ZIH,IPRIND)                    00043400
              C                                                                       00043500
ISN 0332            IF(NST.LT.MAXST) GO TC 40                                         00043600
ISN 0334        110 CALL PRINT(ISTEP,NST,NPRINT,K,NMAX,MMAX,IP,AT,HTOT,HA,BH,         00043700
                   1HE,HC,SAVE,IPUNCH)                                                00043800
              C                                                                       00043900
              C***********************************************************************00044000
              C                                                                       00044100
              C                                                                       00044200
              C                                                                       00044300
              C     END OF MAIN COMPUTATIONAL SCHEME                                  00044400
              C                                                                       00044500
              C                                                                       00044600
              C***********************************************************************00044700
              C                                                                       00044800
ISN 0335        501 CONTINUE                                                          00044900
ISN 0336            CALL ANLYZE(MAXST,NTERM,AT,NST,ZIF)                               00045000
ISN 0337            RETURN                                                            00045100
ISN 0338            END                                                               00045200
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                                  /     MAIN /     SIZE OF PROGRAM 002986 HEXADECIMAL BYTES PAGE 009

NAME    TAG    TYPE  ADD.    NAME    TAG    TYPE  ADD.    NAME    TAG    TYPE  ADD.    NAME    TAG    TYPE  ADD.
      A        R*4   N.R.          B        R*4   N.R.          C S   C  R*4 005E80          E     C  R*4   N.R.
      F SFA    R*4 0C0860          H SFA C  R*4 007108          I SF     I*4 000654          K SFA    I*4 000658
      L SF     I*4 00065C          M SFA    I*4 000660          N SFA    I*4 000664          P        R*4   N.R.
      Q        R*4   N.R.          R        R*4   N.R.          S        R*4   N.R.          U S   C  R*4 003F00
      V S   C  R*4 001F80          W     C  R*4   N.R.          Z     C  R*4   N.R.         AA SF  C  R*4 00E23C
     AG SFA    R*4 000668         AL SFA    R*4 00066C         AT SFA    R*4 000670         BB SF  C  R*4 00E4F8
     BH SFA    R*4 000674         CN SF  C  R*4 00AFC8         C1 SFA    R*4 000678         C2 SFA    R*4 00067C
     C3 S      R*4 000680         C4 SFA    R*4 000684         C5 SFA    R*4 000688         C6 SFA    R*4 00068C
     C7 SFA    R*4 000690         C8 SFA    R*4 000694         C9 SFA    R*4 000698         E8     C  R*4   N.R.
     EL     C  R*4   N.R.         EP     C  R*4   N.R.         FF SF     R*4 00069C         F2     C  R*4   N.R.
     HA SFA    R*4 0006A0         HR     C  R*4   N.R.         HC SFA    R*4 0006A4         HE SFA    R*4 0006A8
     HL     C  R*4   N.R.         HP     C  R*4   N.R.         IP SFA    I*4 0006AC         MF SF     I*4 0006B0
     MM SF     I*4 0006B4         MS SFA    I*4 000920         NA SF     I*4 0006B8         NH        I*4   N.R.
     NI SFA    I*4 0006BC         NN SF     I*4 0006C0         NS SFA    I*4 000948         NT        I*4   N.R.
     NW SFA    I*4 0006C4         NZ SFA    I*4 0006C8         PI SFA    R*4 0006CC         RA S      R*4 0006D0
     SE S   C  R*4 000000         SS SFA    R*4 000970         TS SFA    R*4 0006D4         T1 SFA    R*4 0006D8
     T2 SFA    R*4 0006DC         T4 SFA    R*4 0006E0         T5 SFA    R*4 0006E4         UP SF  C  R*4 004EC0
     VP SF  C  R*4 002F40         WX SFA    R*4 0006E8         WY SFA    R*4 0006EC         YR SFA    R*4 0006F0
    ANZ SF     R*4 0006F4        ARG SFA    R*4 0006F8        ARN     C  R*4   N.R.        CNP SF  C  R*4 008F88
    C10 SFA    R*4 0006FC        C11 S      R*4 000700        C12 S      R*4 000704        C13 SFA    R*4 000708
    C14 SFA    R*4 00070C        DAY SFA    R*4 000710        DEP SFA    R*4 000714        HS1 S   C  R*4 00DF08
    HS2     C  R*4   N.R.        IDY SFA    I*4 000718        ILD SF     I*4 00071C        IMS SF     I*4 000720
    INS SF     I*4 000724        KRT SFA    I*4 000728        LNL S      I*4 00072C        MBD     C  I*4   N.R.
    NBD F   C  I*4 006E40        NST SFA    I*4 000730        NTP SF     I*4 000998        NUM SF     I*4 000734
    NXT SF     I*4 000738        GIN SFA    R*4 00073C        SEP SF  C  R*4 000FC0        SUM SF     R*4 000740
    THR SFA    R*4 000744        TIN SFA    R*4 000748        ZIA F   C  R*4 008528        ZIB F   C  R*4 0087E4
    ZIC F   C  R*4 008AA0        ZID SF  C  R*4 00DF80        ZIE SF  C  R*4 00ACDC        ZIF SFA    R*4 0009C0
    ZIG SFA    R*4 000C7C        ZIH SFA    R*4 000F38       ARGB     C  R*4   N.R.       ARGP     C  R*4   N.R.
   ARHO S      R*4 00074C       CRHO F      R*4 000750       DAVG SFA    R*4 0011F4       DIMI SF     R*4 000754
   DIVE SF  XF R*4 000000       FIND SF  XF R*4 000000       GRT4 SF     R*4 000758       HINV F      R*4 00075C
   HTOT SFA    R*4 000760       IRMS S      I*4 000764       MIND SFA    I*4 000768       MLEF SF     I*4 00076C
   MMAX SFA    I*4 000770       MOBD SF  C  I*4 0070E8       MRIG SF     I*4 000774       NBOT SF     I*4 000778
   NIND SFA    I*4 00077C       NMAX SFA    I*4 000780       NNGD SF     I*4 000784       NOBD SF  C  I*4 0070F8
   NTOP SF     I*4 000788       SAVE SFA    R*4 00078C       SITE SFA    R*4 000790       SUM1 SF     R*4 000794
   TBNB SFA    R*4 000798       TMIN SFA    R*4 00079C       UAVG S   C  R*4 008D5C       VAR1 SFA    R*4 0007A0
   VAVG S   C  R*4 009D1C      AHOLD        R*4   N.R.      ARGLB     C  R*4   N.R.      CDRAG F      R*4 0007A4
  CHECK SF  XF R*4 000000      CHEZY SF  XF R*4 000000      CHANN SFA    R*4 0007A8      DEPSQ SFA    R*4 0007AC
  DEPTH SF  XF R*4 000000      DOSAL SFA    L*4 0007B0      INVAL SF  XF I*4 000000      ISTEP SFA    I*4 0007B4
  KURIH SF  XF I*4 000000      KWRIT SFA    I*4 0007B8      MAXST SFA    I*4 0007BC      MINDO SFA    I*4 0007C0
  NGRID SF     I*4 0007C4      NINDO SFA    I*4 0007C8      NSECT SFA    I*4 0007CC      NSRCH SF     I*4 0007D0
  NTERM SFA    I*4 0007D4      PRINT SF  XF R*4 000000      RCCNP SFA    L*4 0007D8      SEINV F      R*4 0007DC
  SUMAA SF     R*4 0007E0      SUMBB SF     R*4 0007E4      UPCON SFA    R*4 0007E8       SQRT     XF R*4 000000
    SIN     XF R*4 0000D0     ACOSMT     C  R*4   N.R.     ANGLAT SF     R*4 0007EC     ANLYZE SF  XF R*4 000000
 ASINMT     C  R*4   N.R.     CONSTA SF     R*4 0007F0     DELTAT SFA    L*4 0007F4     DISPLY SF  XF R*4 000000
 EXTRA1 SFA    R*4 0007F8     EXTRA3 S      R*4 0007FC     FCHECK SFA    R*4 000800     GRIDN1 SFA    R*4 000804
 GRIDN2 SF     R*4 000808     GRIDT1 SF     R*4 00080C     GRIDT3 SF     R*4 000810     HEATIN SF  XF R*4 000000
 IBCOM# F   XF I*4 000000     IFIELD     C  I*4   N.R.     IMODES SFA    I*4 000814     IMODE1 SFA    I*4 000818
 IPRIND SFA    I*4 0C081C     IPRINZ SF     I*4 000820     IPUNCH SFA    I*4 000824     KONVRT        I*4   N.R.
 MSOURC SFA    I*4 000828     NINPUT SFA    I*4 00082C     NPRINT SFA    I*4 001334     NSOURC SFA    I*4 000830
 OPEN8D SF  XF R*4 000000     READIN SFA    L*4 000834     SALRIS F      R*4 000838     SUMTPT SF     R*4 00083C
 SUMTWT SF     R*4 000840     SUMZID SF     R*4 000844     SUMZIF SF     R*4 000848     SUMZIG SF     R*4 00084C
 SUMZIH SF     R*4 0C0850     TMHOPE SFA    R*4 000854     TRIVER SFA    R*4 000858     TSOUND SFA    R*4 00085C
 UPNFHT SF  XF R*4 000000     UPNSHT SF  XF R*4 000000     VPMFHT SF  XF R*4 000000     VPMSHT SF  XF R*4 000000

                                        *****  COMMON INFORMATION  *****
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                                                                                                          PAGE 010

         NAME OF COMMON BLOCK  *      *  SIZE OF BLOCK    00E784 HEXADECIMAL BYTES

VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.   VAR. NAME  TYPE  REL. ADDR.
       SE   R*4   000000            SEP   R*4   000FC0              V   R*4   001F80             VP   R*4   002F40
        U   R*4   003F00             UP   R*4   004EC0              C   R*4   C05E80            NBD   I*4   006E40
      MBD   I*4     N.R.           MOBD   I*4   0070E8           NOBD   I*4   0070F8              H   R*4   007108
        W   R*4     N.R.             F2   R*4     N.R.              Z   R*4     N.R.              E   R*4     N.R.
       HP   R*4     N.R.             EP   R*4     N.R.             HB   R*4     N.R.             EB   R*4     N.R.
      ARN   R*4     N.R.           ARGP   R*4     N.R.           ARGB   R*4     N.R.          ARGLB   R*4     N.R.
       HL   R*4     N.R.             EL   R*4     N.R.            ZIA   R*4   008528            ZIB   R*4   0087E4
      ZIC   R*4   008AA0           UAVG   R*4   008D5C           VAVG   R*4   009D1C            ZIE   R*4   00ACDC
   ACOSMT   R*4     N.R.         ASINMT   R*4     N.R.             CN   R*4   00AFC8            CNP   R*4   00BF88
   IFIELD   I*4     N.R.            HS1   R*4   00DF08            HS2   R*4     N.R.            ZID   R*4   00DF80
       AA   R*4   00E23C             BB   R*4   00E4F8
```

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 LABEL   ADDR              LABEL   ADDR              LABEL   ADDR              LABEL   ADDR          PAGE 011

  2871  001788 NR           2873  001832              2875  001846                87  0018F0 NR
  2080  00191E NR              6  001A88                 8  001A98                26  0018 3E
    61  001BC0                62  001BDE                 7  001C20                 2  001D96
     3  001DCA                 5  001EB0                32  001F96                31  001FC2
    33  001FCE                35  0020A2                34  0020C6                40  002114
    88  002126 NR           2001  002144 NR           2010  002190              2040  0021A0
  2020  002278               299  002278 NR             17  0022C2                22  00240A
    36  002442                45  002484                47  0024A2                41  0024F2
   300  00255E               312  00256A               330  0026CA                60  0026E6
    65  002718                67  002734                70  002780               310  00279C
   316  0027A8 NR            375  0027F6 NR             75  002860                80  0028F6
   110  002972               501  00297C

*OPTIONS IN EFFECT*      NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,

*OPTIONS IN EFFECT*      SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,NOID,NOXREF

*STATISTICS*      SOURCE STATEMENTS =      337 ,PROGRAM SIZE =      10678

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                          203K BYTES OF CORE NOT USED
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 F44-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED LET,LIST,NCAL,XREF
          DEFAULT OPTION(S) USED -  SIZE=(122880,16384)
IEW0461  DIVE
IEW0461  FIND
IEW0461  CHECK
IEW0461  CHEZY
IEW0461  DEPTH
IEW0461  INVAL
IEW0461  KURIH
IEW0461  PRINT
IEW0461  SQRT
IEW0461  SIN
IEW0461  ANLYZE
IEW0461  DISPLY
IEW0461  HEATIN
IEW0461  IBCOM#
IEW0461  OPENBD
IEW0461  UPNFHT
IEW0461  UPNSHT
IEW0461  VPMFHT
IEW0461  VPMSHT
****MAIN      NOW REPLACED IN DATA SET


                                        CROSS REFERENCE TABLE


 CONTROL SECTION                      ENTRY

   NAME     ORIGIN  LENGTH              NAME   LOCATION     NAME   LOCATION     NAME   LOCATION     NAME   LOCATION

 MAIN          00    2986
$BLANKCOM    2988    E7B4


 LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION            LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION

     1664                                                      1668
     166C                                                      1670
     1674                                                      1678
     167C                                                      1680
     1684                                                      1688
     168C           DIVE          $UNRESOLVED                  1690           FIND          $UNRESOLVED
     1694           CHECK         $UNRESOLVED                  1698           CHEZY         $UNRESOLVED
     169C           DEPTH         $UNRESOLVED                  16A0           INVAL         $UNRESOLVED
     16A4           KURIH         $UNRESOLVED                  16A8           PRINT         $UNRESOLVED
     16AC           SQRT          $UNRESOLVED                  16B0           SIN           $UNRESOLVED
     16B4           ANLYZE        $UNRESOLVED                  16B8           DISPLY        $UNRESOLVED
     16BC           HEATIN        $UNRESOLVED                  16C0           IBCOM#        $UNRESOLVED
     16C4           OPENBD        $UNRESOLVED                  16C8           UPNFHT        $UNRESOLVED
     16CC           UPNSHT        $UNRESOLVED                  16D0           VPMFHT        $UNRESOLVED
     16D4           VPMSHT        $UNRESOLVED
ENTRY ADDRESS       00
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F44-LEVEL LINKAGE EDITOR OPTIONS SPECIFIED MAP,LET,LIST,OVLY,XREF
         DEFAULT OPTION(S) USED -   SIZE=(122880,16384)
IEW0000            ENTRY MAIN
IEW0000            INCLUDE OBJLIB(MAIN)
IEW0000            OVERLAY ONE
IEW0000            INCLUDE OBJLIB(KURIH,DIVE,FIND,DEPTH,CHEZY.CHECK,INVAL)
IEW0000            INCLUDE OBJLIB(HEATIN)
IEW0000            OVERLAY ONE
IEW0000            INCLUDE OBJLIB(PRINT)
IEW0000            INCLUDE OBJLIB(OPENBD,UPNFHT,VPMFHT,VPMSHT,UPNSHT,WATDEP,WATIND)
IEW0000            INCLUDE OBJLIB(DISPLY,PLCT)
IEW0000            INCLUDE OBJLIB(ANLYZE)
****MAIN       DOES NOT EXIST BUT HAS BEEN ADDED TO DATA SET

                                                   CROSS REFERENCE TABLE


 CONTROL SECTION                            ENTRY

   NAME      ORIGIN  LENGTH  SEG. NO.        NAME    LOCATION     NAME    LOCATION     NAME    LOCATION     NAME    LOCATION

$SEGTAB         00       24     1
 MAIN           28     2986     1
 IHCSLOG *    29E0      186     1
                                            ALOG10      29E0     ALOG        29F8
 IHCSATN2*    2898      1C8     1
                                            ATAN2       2898     ATAN        28AC
 IHCSSCN *    2D68      109     1
                                            COS         2D68     SIN         2D80
 IHCSEXP *    2F48      192     1
                                            EXP         2F48
 IHCFRXPR*    30E0      183     1
                                            FRXPR#      30E0
 IHCECOMH*    3268      F41     1
                                            IBCOM#      3268     FDIOCS#     3324     INTSWTCH    418E
 IHCCOMH2*    41B0      650     1
                                            SEQDASD     4528
 IHCSSQRT*    4810      145     1
                                            SQRT        4810
 IHCFCVTH*    4958     119D     1
                                            ADCON#      4958     FCVAOUTP    4A02     FCVLOUTP    4A92     FCVZOUTP    4BE2
                                            FCVIOUTP    4F90     FCVEOUTP    5492     FCVCOUTP    56AC     INT6SWCH    5993

 IHCEFNTH*    5AF8      512     1
                                            ARITH#      5AF8     ADJSWTCH    5E64
 IHCEFIOS*    6010     1378     1
                                            FIOCS#      6010     FIOCSBEP    6016
 IHCERRM *    7388      58C     1
                                            ERRMON      7388     IHCERRE     73A0
 IHCUOPT *    7948      300     1
 IHCETRCH*    7C48      28E     1
                                            IHCTRCH     7C48     ERRTRA      7C50
 IHCUATBL*    7ED8      148     1
$BLANKCOM     8020     E784     1
$ENTAB       167D8       CC     1
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NAME    ORIGIN  LENGTH  SEG. NO.      NAME   LOCATION      NAME   LOCATION      NAME   LOCATION      NAME   LOCATION


LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.   LOCATICN  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.

  168C                                              1         1690                                              1
  1694                                              1         1698                                              1
  169C                                              1         16A0                                              1
  16A4                                              1         16A8                                              1
  16AC                                              1         16B0                                              1
  16B4          DIVE            DIVE                2         16B8          FIND            FIND                2
  16BC          CHECK           CHECK               2         16C0          CHEZY           CHEZY               2
  16C4          DEPTH           DEPTH               2         16C8          INVAL           INVAL               2
  16CC          KURIH           KURIH               2         16D0          PRINT           PRINT               3
  16D4          SQRT            IHCSSQRT            1         16D8          SIN             IHCSSCN             1
  16DC          ANLYZE          ANLYZE              3         16E0          DISPLY          DISPLY              3
  16E4          HEATIN          HEATIN              2         16E8          IBCOM#          IHCECOMH            1
  16EC          OPENBD          OPENBD              3         16F0          UPNFHT          UPNFHT              3
  16F4          UPNSHT          UPNSHT              3         16F8          VPMFHT          VPMFHT              3
  16FC          VPMSHT          VPMSHT              3         2B08          IBCOM#          IHCECOMH            1
  2B44          IHCERRM         IHCERRM             1         2C08          IBCOM#          IHCECOMH            1
  2D24          IHCERRM         IHCERRM             1         2E98          IBCOM#          IHCECOMH            1
  2EDC          IHCERRM         IHCERRM             1         3050          IBCOM#          IHCECOMH            1
  304C          IHCERRM         IHCERRM             1         31F0          IBCOM#          IHCECOMH            1
  31F4          IHCERRM         IHCERRM             1         31E8          ALOG            IHCSLOG             1
  31EC          EXP             IHCSEXP             1         3324          SEQDASD         IHCCOMH2            1
  4098          ADCON#          IHCFCVTH            1         4090          FIOCS#          IHCEFIOS            1
  409C          ARITH#          IHCEFNTH            1         40BC          ADJSWTCH        IHCEFNTH            1
  40B8          IHCUOPT         IHCUOPT             1         40A0          FCVEOUTP        IHCFCVTH            1
  40A4          FCVLOUTP        IHCFCVTH            1         40A8          FCVIOUTP        IHCFCVTH            1
  40AC          FCVCOUTP        IHCFCVTH            1         40B0          FCVAOUTP        IHCFCVTH            1
  40B4          FCVZOUTP        IHCFCVTH            1         4044          IHCERRE         IHCERRM             1
  4070          IHCCOMH2        IHCCOMH2            1         4074          IHCERRM         IHCERRM             1
  4048          IHCCOMH2        IHCCOMH2            1         404C          IHCCOMH2        IHCCOMH2            1
  4050          IHCCOMH2        IHCCOMH2            1         4054          IHCCOMH2        IHCCOMH2            1
  444D          IHCECOMH        IHCECOMH            1         4450          IHCECOMH        IHCECOMH            1
  41F8          IHCERRM         IHCERRM             1         41F4          IBCOM#          IHCECOMH            1
  4660          IHCECOMH        IHCECOMH            1         4670          IHCECOMH        IHCECOMH            1
  4680          IHCECOMH        IHCECOMH            1         48E0          IBCOM#          IHCECOMH            1
  4908          IHCERRM         IHCERRM             1         5954          IBCOM#          IHCECOMH            1
  5950          IHCERRM         IHCERRM             1         5EB4          IBCOM#          IHCECOMH            1
  5EB8          INTSWTCH        IHCECOMH            1         5E60          INT6SWCH        IHCFCVTH            1
  5E5C          IHCUOPT         IHCUOPT             1         5EC0          ADCON#          IHCFCVTH            1
  5EBC          FIOCS#          IHCEFIOS            1         5F2C          IHCERRM         IHCERRM             1
  6170          IHCERRM         IHCERRM             1         6FBC          IHCUATBL        IHCUATBL            1
  6FC8          IBCOM#          IHCECOMH            1         7934          IHCUOPT         IHCUOPT             1
  7938          IBCOM#          IHCECOMH            1         793C          IHCTRCH         IHCETRCH            1
  7940          FIOCSBEP        IHCEFIOS            1         70BC          IBCOM#          IHCECOMH            1
  70C0          ADCON#          IHCFCVTH            1         70C4          FIOCSBEP        IHCEFIOS            1
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CONTROL SECTION                       ENTRY

  NAME    ORIGIN  LENGTH  SEG. NO.       NAME   LOCATION      NAME   LOCATION      NAME   LOCATION    NAME   LOCATION

KURIH     168A8    204C     2
DIVE      188F8     3DC     2
FIND      18CD8     9EC     2
DEPTH     196C8     33A     2
CHEZY     19A08     3CA     2
CHECK     19DD8     432     2
INVAL     1A210     C84     2
HEATIN    1AE98     430     2


LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.   LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.

   17478                                             1        1747C                                             1
   1748C                                             1        17484                                             1
   17488                                             1        1748C                                             1
   17490                                             1        17494                                             1
   17498                                             1        1749C                                             1
   174A0          SIN             IHCSSCN            1        174A4          ATAN            IHCSATN2            1
   174A8          SQRT            IHCSSQRT           1        174AC          COS             IHCSSCN             1
   174B0          IBCOM#          IHCECOMH           1        18A90                                             1
   18A94                                             1        18A98                                             1
   18A9C                                             1        18AA0                                             1
   18AA4                                             1        18AA8                                             1
   18AAC                                             1        18AB0                                             1
   18AB4                                             1        18AB8          IBCOM#          IHCECOMH            1
   18E38                                             1        18E3C                                             1
   18E40                                             1        18E44                                             1
   18E48                                             1        18E4C                                             1
   18E50                                             1        18E54                                             1
   18E58                                             1        18E5C                                             1
   18E60          IBCOM#          IHCECOMH           1        197E8                                             1
   197EC                                             1        197F0                                             1
   197F4                                             1        197F8                                             1
   197FC                                             1        19800                                             1
   19804                                             1        19808                                             1
   1980C                                             1        19810          IBCOM#          IHCECOMH            1
   19810                                             1        19814                                             1
   19818                                             1        1981C                                             1
   19820                                             1        19824                                             1
   19828                                             1        1982C                                             1
   19830                                             1        19834                                             1
   19838          EXP             IHCSEXP            1        1983C          ALOG            IHCSLOG             1
   19840          IBCOM#          IHCECOMH           1        1A050                                             1
   1A054                                             1        1A058                                             1
   1A05C                                             1        1A060                                             1
   1A064                                             1        1A068                                             1
   1A06C                                             1        1A070                                             1
```

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LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.  LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.

  1A074                                            1        1A078          IBCOM#           IHCECOMH          1
  1A520                                            1        1A524                                             1
  1A528                                            1        1A52C                                             1
  1A530                                            1        1A534                                             1
  1A538                                            1        1A53C                                             1
  1A540                                            1        1A544                                             1
  1A550         IBCOM#          IHCECOMH           1        1AF98                                             1
  1AF9C                                            1        1AFA0                                             1
  1AFA4                                            1        1AFA8                                             1
  1AFAC                                            1        1AFB0                                             1
  1AFB4                                            1        1AFB8                                             1
  1AFBC                                            1

CONTROL SECTION                   ENTRY

 NAME     ORIGIN  LENGTH  SEG. NO.     NAME   LOCATION     NAME   LOCATION     NAME   LOCATION     NAME   LOCATION

PRINT     168A8     D20     3
OPENBD    175C8     790     3
UPNFMT    17D58    1EC2     3
VPMFMT    19C20    330C     3
VPMSHT    1CF30    1ECC     3
UPNSHT    1EE00    2A24     3
WATCEP    21828     5B6     3
WATIND    21DE0     830     3
DISPLY    22610    3F48     3
PLOT      26558     98E     3
ANLYZE    26F18     CBA     3


LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.  LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.

  16CA8                                            1        16CAC                                             1
  16CB0                                            1        16CB4                                             1
  16CB8                                            1        16CBC                                             1
  16CC0                                            1        16CC4                                             1
  16CC8                                            1        16CCC                                             1
  16CD0         IBCOM#          IHCECOMH           1        177B0                                             1
  177B4                                            1        177B8                                             1
  177BC                                            1        177C0                                             1
  177C4                                            1        177C8                                             1
  177CC                                            1        177D0                                             1
  177D4                                            1        177D8          COS              IHCSSCN           1
  18EE4                                            1        18EE8                                             1
  18EEC                                            1        18EF0                                             1
  18EF4                                            1        18EF8                                             1
  18EFC                                            1        18F00                                             1
  18F04                                            1        18F08                                             1
  18F14         SQRT            IHCSSQRT           1        181D4                                             1
  18108                                            1        181DC                                             1
  181E0                                            1        181E4                                             1
```

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LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.   LOCATION  REFERS TO SYMBOL  IN CONTROL SECTION  SEG. NO.

  1B1E8                                             1         1B1EC                                             1
  1B1F0                                             1         1B1F4                                             1
  1B1F8                                             1         1B224          FRXPR#        IHCFRXPR             1
  1B228          COS           IHCSSCN              1         1B22C          SQRT          IHCSSQRT             1
  1B230          IBCOM#        IHCECOMH             1         1B23C          WATDEP        WATDEP               3
  1B240          WATIND        WATIND               3         1E0BC                                             1
  1E0C0                                             1         1E0C4                                             1
  1E0C8                                             1         1E0CC                                             1
  1E0D0                                             1         1E0D4                                             1
  1E0D8                                             1         1E0DC                                             1
  1E0E0                                             1         1E0EC          SQRT          IHCSSQRT             1
  200B4                                             1         200B8                                             1
  200BC                                             1         200C0                                             1
  200C4                                             1         200C8                                             1
  200CC                                             1         200D0                                             1
  200D4                                             1         200C8                                             1
  200FC          SQRT          IHCSSQRT             1         219B0                                             1
  219B4                                             1         219B8                                             1
  219BC                                             1         219C0                                             1
  219C4                                             1         219C8                                             1
  219CC                                             1         219D0                                             1
  219D4                                             1         219E0          FRXPR#        IHCFRXPR             1
  219E4          SIN           IHCSSCN              1         219E8          COS           IHCSSCN              1
  22050                                             1         22054                                             1
  22058                                             1         2205C                                             1
  22060                                             1         22064                                             1
  22068                                             1         2206C                                             1
  22070                                             1         22074                                             1
  22078          FRXPR#        IHCFRXPR             1         2207C          SIN           IHCSSCN              1
  22080          COS           IHCSSCN              1         22084          EXP           IHCSEXP              1
  22088          IBCOM#        IHCECOMH             1         25E70                                             1
  25E74                                             1         25E78                                             1
  25E7C                                             1         25E80                                             1
  25E84                                             1         25E88                                             1
  25E8C                                             1         25E90                                             1
  25E94                                             1         25EB0          PLOT          PLOT                 3
  25EB4          IBCOM#        IHCECOMH             1         26950                                             1
  26954                                             1         26958                                             1
  2695C                                             1         26960                                             1
  26964                                             1         26968                                             1
  2696C                                             1         26970                                             1
  26974                                             1         26980          IBCOM#        IHCECOMH             1
  27468                                             1         2746C                                             1
  27470                                             1         27474                                             1
  27478                                             1         2747C                                             1
  27480                                             1         27484                                             1
  27488                                             1         2748C                                             1
  27498          COS           IHCSSCN              1         2749C          IBCOM#        IHCECOMH             1

ENTRY ADDRESS      28
TOTAL LENGTH    27808
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