SEMINARS AT SMHI 1976-03-29--04-01
ON NUMERICAL MODELS OF THE SPREADING OF COOLING-WATER

SEMINARIUM PÅ SMHI 1976-03-29--04-01
OM NUMERISKA MODELLER FÖR SPRIDNING AV KYLVATTEN

by Jonny Svensson (Editor)

SMHI Rapporter

HYDROLOGI OCH OCEANOGRAFI

Nr RHO 8 (1976)

SVERIGES METEOROLOGISKA OCH HYDROLOGISKA INSTITUT

SEMINARS AT SMHI 1976-03-29--04-01
ON NUMERICAL MODELS OF THE SPREADING OF
COOLING-WATER
SEMINARIUM PÅ SMHI 1976-03-29--04-01
OM NUMERISKA MODELLER FÖR SPRIDNING AV
KYLVATTEN

by Jonny Svensson (Editor)

SMHI Rapporter

HYDROLOGI OCH OCEANOGRAFI

Nr RHO 8 (1976)

LECTURES GIVEN AT THE MEETING

1. Studies of floating plumes at SMHI (Vasseur)
2. Jet models of integral and phenomenological type for surface thermal plumes (Policastro)
3. Some far field thermal consequences of various intake and discharge depths of cooling-water from thermal power plants (Audunson)
4. Two proposed models for sinking plumes - integral and numerical (Policastro)
5. A two-dimensional numerical model of a Swedish fjord with a heated-water outlet (Wilmot)
6. Application, verification, and improvement of numerical models for surface thermal discharges from power-plants' outfalls (Policastro)
7. Application of Monte Carlo method transport of sharp density gradients (Maier-Reimer)
8. A three dimensional model for thermal plumes and river discharge (Paul)
9. Results from the model and applicability to Swedish conditions (Paul)
10. Some experimental and computational results on two-layer flow in a stratified fjord (Audunson)
11. Modelling a proposed jetport island in Lake Erie, modelling Cleveland Harbor, and modelling Saginaw Bay on Lake Huron (Paul)

LECTURES

T Audunson	Vassdrags- och Havnelaboratoriet, Trondheim, Norge
E Maier-Reimer	Institute für Meereskunde, Hamburg, Väst-Tyskland
J Paul	Grosse Ile Field Laboratory, Michigan, USA
A Policastro	Argonne National Laboratory, Illinois, USA
B Vasseur	SMHI, Norrköping, Sverige
W Wilmot	Meteorologiska institutionen vid Stockholms universitet, Stockholm, Sverige

LEKTIONER UNDER MÖTET

1. Studier av flytande plymer på SMHI (Vasseur)
2. Jetmodeller av integral- och fenomenologisk typ för varmvattenplymer i ytlagret (Policastro)
3. Några temperatureffekter i fjärrområdet beroende på varierande djup på intag och utsläpp av kylvatten från kraftverk (Audunson)
4. Två föreslagna modeller för sjunkande kylvattenplymer - integral och numerisk (Policastro)
5. En tvådimensionell numerisk modell av en svensk fjord med ett varmvattenutsläpp (Wilmot)
6. Användning, verifiering och förbättring av numeriska modeller för flytande kylvattenutsläpp från kraftverk (Policastro)
7. Användning av Monte Carlo metoden för transport av skarpa täthetsgradienter (Maier-Reimer)
8. En tredimensionell modell för varmvattenplymer och flodvatten (Paul)
9. Modellresultat och applicering på svenska förhållanden (Paul)
10. Några experimentella och beräkningsmässiga resultat för tvålagerströmning i en skiktad fjord (Audunson)
11. Modellstudier av en föreslagen flygplats på en konstgjord ö i Lake Erie, modellstudier av Cleveland Harbour och Saginaw Bay i Huron (Paul)

FÖRELÄSARE

T Audunson	Vassdrags- och Havnelaboratoriet, Trondheim, Norge
E Maier-Reimer	Institute für Meereskunde, Hamburg, Väst-Tyskland
J Paul	Grosse Ile Field Laboratory, Michigan, USA
A Policastro	Argonne National Laboratory, Illinois, USA
B Vasseur	SMHI, Norrköping, Sverige
W Wilmot	Meteorologiska institutionen vid Stockholms universitet, Stockholm, Sverige

SEMINARS AT SMHI 1976-03-29--04-01 ON NUMERICAL MODELS OF THE SPREADING OF COOLING-WATER

A meeting was held at SMHI 1976-03-29--04-01 with the theme "Numerical modelling of cooling-water outlets". Guest scientists from USA, Germany and Norway presented the work being carried out in these countries at present. Abstracts of the lectures are presented below.

The guest scientists also partipated in discussions on SMHI's future planning of research on cooling-water problems. Contact with experienced scientists from abroad turned out to be most valuable and close contact is being kept with them concerning current work with numerical models.

The meeting was part of a research project at SMHI sponsored by Centrala Driftledningen. SMHI and the participants thank CDL for the opportunity to exchange knowledge and experience in this way.

1. STUDIES OF FLOATING PLUMES AT SMHI (Vasseur)

Abstract

A model was developed by Prych (1972) at SMHI for thermal pollution predictions. The model, which is a modified version of a model originally presented by Stolzenbach and Harleman (1971), is based on an integral analysis of a turbulent, bouyant, horizontal, surface jet into a large, deep, uniform, turbulent, flowing, ambient water body. In the analysis similarity functions are assumed for the temperature and velocity distibutions in the cross section of the jet flow. An attempt to verify, or test the accuracy of the model was done by Weil (1974) at SMHI with eight sets of data from a Swedish power station and data from two plants on Lake Michigan in the United States.

Discussion

Applicability: The model used at SMHI was developed for high Froude numbers; no boundary or bottom interaction is included. For such conditions the model will give fairly good results.

Stratification: At the locations where the model was applied stratification did not influence the jet.

Shortcomings: The model does not work without ambient current.

2. JET MODELS OF INTEGRAL AND PHENOMENOLOGICAL TYPE FOR SURFACE THERMAL PLUMES (Policastro)

The popular and promising models of integral and phenomenological type were presented. A review of each of the model formulations was given along with a critical discussion of each model in terms of theoretical considerations. Comparisons of these models to selected laboratory and field data were presented. Comparisons with laboratory data enable one to test the validity of the model within the geometry and conditions assumed in model development. Comparisons with field data indicate the extent to which prototype effects, not accounted for in the model formulation, limit the utility of the model. The principal conclusion is that

the available integral and phenomenological models, in their present stage of development, may be used to give only general estimates of plume characteristics; precise predictions are not currently possible. The Shirazi-Davis and Pritchard (no. 1) models appear superior to the others tested and are capable of correctly predicting general plume characteristics. The predictions show roughly factor-of-two accuracy in centerline distance to a given isotherm, factor-of-two accuracy in plume width, and factor-of-five accuracy in isotherm areas.

The state of the art can best be proven by pursuing basic laboratory studies on plume dispersion along with further development of numerical modelling techniques.

Discussion

Importance of wind: The models allow for ambient current. As such a current may be wind induced, the introduction of a "windparameter" will lead to an error.

Bottom interaction: In nearly all real cases the jet has bottom interaction; none of the models, however, are able to provide for bottom interaction even if they claim so.

3. SOME FAR FIELD THERMAL CONSEQUENCES OF VARIOUS INTAKE AND DISCHARGE DEPTHS OF COOLING-WATER FOR THERMAL POWER PLANTS (Audunson)

4. TWO PROPOSED MODELS FOR SINKING PLUMES - INTEGRAL AND NUMERICAL (Policastro)

A simple integral model may be developed for a sinking surface discharge for winter conditions. The model simulates the floating and sinking portions of the plume with separate integral equations and matches the two solutions at the cross-section of initial sinking. Top-hat shaped profiles for velocity and temperature may be assumed for both floating and sinking portions of the plume. For the floating portion of the plume, lateral spreading may be simulated with a functional form as used by Shirazi and Davis. Lateral and vertical entrainment may be simulated using the forms employed by Stolzenbach and Harleman. Once sinking begins, a new set of integral equations is employed: one each for conservation of longitudinal and vertical momentum, one for density deficiency, and two for trajectory. These equations are usually used for a submerged slot jet discharging horizontally into an ambient water body of greater density. Equations for a sinking plume from a two-dimensional submerged slot jet should apply here (approximately) in the sinking portion of the plume since the local aspect ratio of the plume cross section of initial sinking is large (>20, for two-dimensionality to hold). The model should be tuned to data for proper determination of coefficients.

Existing numerical models for floating plumes apply as well to the sinking plume case. The change in sign of the buoyancy term in the vertical momentum equation is handled automatically in the models. For steady-state sinking plume predictions, the implicit methods of Spalding should be most efficient (TRIC code). For time-dependent solutions, the SMAC method as developed by Pritchett, England and Taft is probably the best approach since it is probably closest to the present state-of-the-art of 3-D transient calculational methods.

It is expected that any model used will require some calibration to data, most probably in the turbulence coefficients.

Detailed laboratory and field data are sorely needed to provide a basis of physical understanding of the sinking process. Parametric studies should be carried out in the laboratory to determine the relative importance of the various physical phenomena in the sinking process and provide the basis for model assumptions. Field data should be taken to help assess the effects of the complicating phenomena of wind, boundary effects and ambient turbulence. Existing data is inadequate to provide a proper data base for the development of accurate models in this area.

In addition to the models proposed, results were presented of a two-month study of sinking plumes at the Point Beach Power Plant on Lake Michigan, USA. Eleven thermographs were placed in the lake and they recorded temperatures for the two month period. The frequency and amount of bottom warming was determined at the operating thermographs over the two-month period. The effect on the advance of hatching of lake herring eggs was calculated. From this temperature data as well as biological laboratory measurements, there was predicted a seven day advance in hatching for eggs located at a typical instrument in the intermediate field of the plume.

5. A TWO DIMENSIONAL NUMERICAL MODEL OF A SWEDISH FJORD WITH A HEATED-WATER OUTLET (Wilmot)

Abstract

In the search for possible sites for new nuclear power plants in Sweden a narrow fjord on the east coast was investigated. The Swedish Meteorological and Hydrological Institute received the task to evaluate the probable effects on the estuarine circulation from a planned plant at the mouth of the fjord. It was decided that besides field work a hydrodynamical numerical model for the entire estuary should be developed.

The model employs the basic equations of motion and conservation of salt and heat with appropriate approximations to make predictions. The primary approximation in the model consists of considering the estuary as a channel in which cross channel effects do not explicitly appear. The along channel motion is thus primarily determined by the along channel density gradients. The time dependent salt and heat conservation equations averaged across the fjord and the vorticity equation in the longitudinal-vertical plane along the center of the estuary are numerically integrated. Runoff, heat input, wind stress and the meteorological barotropic response are imposed as basic forcings.

A number of different cases have been investigated. The basic states in the summer and in the winter have been established in order to evaluate effects of heated water in two different conditions of thermal stratification. For each of these seasons two different intake configurations have been considered: a surface intake and a bottom intake. The outlet is located at the surface. The above situations have been considered for several wind conditions: no wind, a 5 m/s constant wind tending to transport water into the estuary, and a 12 m/s time dependent wind which gradually builds up blowing out of the estuary, changes

direction and then dies away. A series of experiments with various runoff values at the head of the fjord have been conducted. It appears that with the construction of a bottom intake located at the depth of about 40 meters there will be little noticable effect on the circulation or temperature or salinity fields in the model estuary in the summer. However in the winter the bottom intake offers only a partial improvement over a surface intake. During the winter the heated water would cause changes of as much as 50 % in the natural state. The surface intake would cause changes which sometimes are almost twice as big. The problem arises because the 10° heated water creates sizable horizontal density gradients which are sufficient to counteract the weak natural flow.

Discussion

The question was raised if the turbulent diffusion coeffecient could be changed to be dependent on the Richardsons number and what that could be expected to do to the result. W Wilmot answered that this change probably should sharpen the thermocline but not have any effect on the circulation in Bråviken.

Treatment of the near field

It was mentioned that the model handeled the near field in a very unsatisfactory way. For example the hot water core in the model was covering the whole width of Bråviken. The real situation could be that the plume covered only half of the width or less. A question was if this could change the result of the model inside the sill of Bråviken. The opinion of the author was, that in a model with a grid size of 1 kilometer you could not expect to model the near field. The model answers the question of what happens inside the sill if a big amount of warm water is discharged a couple of kilometers outside.

The hydrographic conditions chosen as examples

It was stated that the hydrographic situations used as examples in the model were not representative for normal conditions in Bråviken. However the conclusions are based on these examples. Wilmot replied that the situations chosen were not typical situations but limiting cases. These cases are important for the judgement of the site.

6. APPLICATION, VERIFICATION, AND IMPROVEMENT OF NUMERICAL MODELS FOR SURFACE THERMAL DISCHARGES FROM POWER-PLANTS' OUTFALLS (Policastro)

Abstract

Fifteen models of differential-numerical (grid) formulation were presented that have been developed to treat thermal plume problems. Some models have been developed to predict plume dispersion in rivers while others treat plumes discharged in a coastal environment. The models were discussed first in terms of common assumptions made: Boussinesq, hydrostatic, rigid lid approximations, turbulence theory used, etc. The models were then classified into type of formulation used in development. These classifications were:

a) method using direct integration of textbook form of governing equations

b) velocity corrector potential (VCP) method

c) divergence of Navier-Stokes equations (DNS) method

d) velocity - vorticity formulation

e) multi - layer model formulation

f) stream function/scalar potential/vorticity methods

g) subchannel balancing method

The sum total of models can treat a wide variety of plume problems. Unfortunately, the comparisons of these models to data attempted so far are few in number and have, in general, been poorly executed. The difficulties have typically involved the use of too small a computational grid, the poor choice of turbulence parameters, and the comparison to either incomplete or poor-quality data. The models discussed are in what might be called the germination stage. Some models have been used to provide predictions but have not been tested with data. (The only exception to the above comment is the model of McGuirk-Spalding, but this model is limited in application to coflow discharge in rivers).

The above-noted comparisons of model predictions with prototype data, although not sufficient for final judgements on the models, have aided in identifying major areas of needed work. Recommendations are made for the general improvement of numerical models for surface thermal descharges.

Discussion

Development in USA: The work on thermal plume models in USA has gone down to zero. No verification studies for this kind of model can be expected from USA. Work on lake-circulation models, however will continue.

Computer time: It is recommended to use the implicit method because it is faster and tends to reach a steady state solution faster.

7. APPLICATION OF MONTE CARLO METHOD TRANSPORT OF SHARP DENSITY GRADIENTS (Maier-Reimer)

Abstract

Commonly used numerical techiques to compute transport phenomena in turbulent flow are compared. It is shown that the applicability of difference schemes depends drastically on the relevant scales under consideration. When dealing with sharp gradients in the distribution of a dissolved matter, i.e. when the distribution changes essentially between neighboured grid points, Eulerien difference schemes, at least up to fourth order, fail. In many pollution problems this situation is common, however, due to the limited capacity of computers one can not use difference schemes of higher order.

Difference schemes in Lagrangian formulation fail when dealing with strong mesh distortions caused, for instance, by wind.

A realistic parametrization of subgrid scales can be introduced into random walk techniques (Monte Carlo methods) for the transport of passive substances when there is no interaction between the transported substance and the transporting currents. When dealing with temperature or salinity this intercation sometimes can´t be neglected. In this case, the known random walk technique would require an enormous amount of computer capacity in order to avoid instabilities caused by low statistics.

A new method, based on the conventional random walk mechanism, was presented which allows computing the transport of density gradients with reasonable computer capacity. Buoyancy and every kind of turbulence theory (in a given current field) can easily be incorporated.

Discussion

Time-factor: To get equally accurate results the Monte Carlo method needs twice the computer time that a competitive finite-upwind difference model needs.

Vertical integration: In the example shown complete vertical mixing can be assumed because of the strong tidal current. Heat loss to the atmosphere in this case is a function of depth. Using diffusivities in the order of magnitude as observed in nature, the grid-size for an Eulerian finite difference approach should be of the same order of magnitude as the depth.

Gaussion distribution: It is used from a phenomenological point of view. Note that the probability function mentioned is not a square distribution by itself but determined by the problem considered.

Direction of turbulent velocity: Only in the case of isotropic turbulence is the direction of turbulent velocity random.

8. A THREE DIMENSIONAL MODEL FOR THERMAL PLUMES AND RIVER DISCHARGE (THEORY) (Paul)

Abstract

The model presented used the hydrostatic form of the vertical - momentum equation. Variable bottom is handled through a local stretching transformation that maps an irregular bottom into one of constant depth. The complicated equations thus obtained are simplified by assuming an only gradual variation in depth.

As boundary conditions no-slip and adiabatic conditions are used at the shore and bottom grid boundaries, wind stress on the free surface, and zero second-order normal derivatives at the open-water boundaries. In addition, rigid-lid condition is used which artificially damps out unwanted oscillations of the free surface and allows larger time steps to be used. To compensate for the restrictions of the rigid-lid condition, surface pressure is introduced, which ostensibly corresponds to the pressure distribution that would have existed at the rigid-lid plane had surface deviations been allowed. An auxiliary two-dimensional Poisson-type equation is developed for the surface pressure distribution by taking the divergence of the Navier-Stoke equations and then integrating vertically over the domain of flow.

The vertical eddy coefficient is taken as dependent on the local temperature gradient.

To solve the equations numerically simple forward differencing in time and central differencing in space are used. The finit-differencing form of the advection terms is conservative. The time-dependent equations are written in a completely explicit form. To solve the two-dimensional Poisson-type equation the alternating-direction-implicit method is used.

Vertical diffusion coefficient: The simple assumption $A_v = \alpha + \beta \frac{\partial T}{\partial Z}$ is only used as a first approach to see what kind of results one gets. The value of α and β depends on the problem considered.

Boundary conditions: Note that u and v are supposed to be identical zero at the out boundary. At the outlet only one of the quantities: velocity, pressure or surface deviation can be spedified, otherwise the problem is over-specified.

Influence of ambient circulation: First a larger model can be used to define boundary conditions for a smaller one. Another possibility is to use variable grid size, i.e., a fine grid near the outlet.

Density field outside the boundaries: Such a density field can only correct the field inside if there is a flow into the area considered.

9. RESULTS FROM THE MODEL AND APPLICABILITY TO SWEDISH CONDITIONS (Paul)

Abstract

A numerical model for the time-dependent, three-dimensional, variable-density flow from a horizontal rectangular discharge into a basin has been developed. Steady-state results are presented for representative flow conditions of the Cuyahoga River entering Lake Erie and of the Point Beach Power Plant thermal discharge into Lake Michigan. Results for three different cases of the Cuyahoga River are given. Two cases are for heated discharges at different flow rates entering a constant depth basin. The lower rate corresponds to flows typical of the late summer months and the higher flow rate corresponds to flows typical of the spring. The third case is for the low flow rate heated discharge entering a variable-depth basin. The depth variation is such that the basin depth doubles in two and one-half river widths and then remains constant. This depth variation is not realistic for Cuyahoga River but it is used to indicate the importance of the variable-depth basin. For the Point Beach thermal discharge calculation, the vertical eddy coefficient is assumed to be a function of the local vertical temperature gradient and the actual bottom topography is used.

Discussion

Some critical remarks were made on the choice of mixing coefficients, and outfall temperature in both applications. Paul stated that the applications so far were mostly tests and that the model needed verification. There is only one comparison with field data yet. The run of the Cuyahoga River is made without field data comparison.

Applicability to Swedish conditions: The main change between application in the Great Lakes and in Swedish coastal waters is that salinity has to be taken into account when calculating the density field. This should not constitute any difficulty. To use the model for sinking plumes one has to use another turbulence theory for unstable conditions in the

vertical. It was agreed on that this model was able to solve most modelling problems that we have. It is however for the moment expensive to run and one has to use a big computor for the runs. The author is going to do some changes in the program and some more test runs for cooling-water outlets in USA to validate the model.

10. SOME EXPERIMENTAL AND COMPUTATIONAL RESULTS ON TWO LAYER FLOW IN A STRATIFIED FJORD (Audunson)

11. MODELLING A PROPOSED JETPORT ISLAND IN LAKE ERIE, MODELLING CLEVELAND HARBOR, AND MODELLING SAGINAW BAY ON LAKE HURON (Paul)

Abstract

This talk is to describe the application of a previously-developed three-dimensional, variable-density hydrodynamic model (Paul and Lick 1973 a, b, 1974 a, b) to the near shore Lake Erie area about Cleveland. The purpose of this application is to investigate the effect of a proposed jetport island in Lake Erie on the summer stratification pattern in the near shore lake area and on the flushing characteristics of the Cuyahoga River outflow into the lake. The effects of such a proposed jetport island are investigated by comparing the model results with and without the jetport in the lake.

For the purpose of this investigation, the model is applied to two different-sized areas of interest: 1. a sixteen mile by sixteen mile area in the lake near Cleveland; and 2. a two mile by six mile area around Cleveland Harbor. The larger area, hereafter referred to as the near shore model, is used to investigate the summer stratification pattern in the lake, while the smaller one, referred to as the Cleveland Harbor model, is for investigating the flushing characteristics of the Cuyahoga River outflow. This talk will concern itself with a discussion of the application of the model to these two areas of interest and of the initial results obtained from the model.

Notiser och preliminära rapporter

Serie HYDROLOGI

Nr 1 Sundberg-Falkenmark M
Om isbärighet. Stockholm 1963

Nr 2 Forsman, A
Snösmältning och avrinning. Stockholm 1963

Nr 3 Karström, U
Infrarödteknik i hydrologisk tillämpning: Värmebilder som hjälpmedel i recipientundersökningar. Stockholm 1966

Nr 4 Moberg, A
Svenska sjöars isläggnings- och islossningstidpunkter 1911/12-1960/61. Del 1. Redovisning av observationsmaterial. Stockholm 1967

Nr 5 Ehlin, U & Nyberg, L
Hydrografiska undersökningar i Nordmalingsfjärden. Stockholm 1968

Nr 6 Milanov, T
Avkylningsproblem i recipienter vid utsläpp av kylvatten. Stockholm 1969

Nr 7 Ehlin, U & Zachrisson, G
Spridningen i Vänerns nordvästra del av suspenderat materiel från skredet i Norsälven i april 1969. Stockholm 1969

Nr 8 Ehlert, K
Mälarens hydrologi och inverkan på denna av alternativa vattenavledningar från Mälaren. Stockholm 1970

Nr 9 Ehlin, U & Carlsson, B
Hydrologiska observationer i Vänern 1959-1968 jämte sammanfattande synpunkter. Stockholm 1970

Nr 10 Ehlin, U & Carlsson, B
Hydrologiska observationer i Vänern 17-21 mars 1969. Stockholm 1970

Nr 11 Milanov, T
Termisk spridning av kylvattenutsläpp från Karlshamnsverket. Stockholm 1971

Nr 12 Persson, M
Hydrologiska undersökningar i Lappträskets representativa område. Rapport I. Stockholm 1971

Nr 13 Persson, M
Hydrologiska undersökningar i Lappträskets representativa område. Rapport II. Snömätningar med snörör och snökuddar Stockholm 1971

Nr 14 Hedin, L
Hydrologiska undersökningar i Velens representativa område. Beskrivning av området, utförda mätningar samt preliminära resultat. Rapport I. Stockholm 1971

Nr 15 Forsman, A & Milanov, T
Hydrologiska undersökningar i Velens representativa område. Markvattenstudier i Velenområdet. Rapport II. Stockholm 1971

Nr 16 Hedin, L
Hydrologiska undersökningar i Kassjöåns representativa område. Nederbördens höjdberoende samt kortfattad beskrivning av området. Rapport I. Stockholm 1971

Nr 17 Bergström, S & Ehlert, K
Stochastic Streamflow Syntheses at the Velen representative Basin. Stockholm 1971

Nr 18 Berström, S
Snösmältningen i Lappträskets representativa område som funktion av lufttemperaturen. Stockholm 1972

Nr 19 Holmström, H
Test of two automatic water quality monitors under field conditions. Stockholm 1972

Nr 20 Wennerberg, G
Yttemperaturkartering med strålningstermometer från flygplan över Vänern under 1971. Stockholm 1972

Nr 21 Prych, A
A warm water effluent analyzed as a buoyant surface jet. Stockholm 1972

Nr 22 Bergström, S
Utveckling och tillämpning av en digital avrinningsmodell. Stockholm 1972

Nr 23 Melander, O
Beskrivning till jordartskarta över Lappträskets representativa område. Stockholm 1972

Nr 24 Persson, M
Hydrologiska undersökningar i Lappträskets representativa område. Rapport III. Avdunstning och vattenomsättning. Stockholm 1972

Nr 25 Häggström, M
Hydrologiska undersökningar i Velens representativa område. Rapport III. Undersökning av torrperioderna under IHD-åren fram t o m 1971. Stockholm 1972

Nr 26 Bergström, S
The application of a simple rainfall-runoff model to a catchment with incomplete data coverage. Stockholm 1972

Nr 27 Wändahl, T & Bergstrand, E
Oceanografiska förhållanden i svenska kustvatten. Stockholm 1973

Nr 28 Ehlin, U
Kylvattenutsläpp i sjöar och hav. Stockholm 1973

Nr 29 Andersson, U-M & Waldenström, A
Mark- och grundvattenstudier i Kassjöåns representativa område. Stockholm 1973

Nr 30 Milanov, T
Hydrologiska undersökningar i Kassjöåns representativa område. Markvattenstudier i Kassjöåns område. Rapport II. Stockholm 1973

SMHI Rapporter

HYDROLOGI OCH OCEANOGRAFI

Nr RHO 1 Weil, J G
Verification of heated water jet numerical model
Stockholm 1974

Nr RHO 2 Svensson, J
Calculation of poison concentrations from a hypothetical accident off the Swedish coast
Stockholm 1974

Nr RHO 3 Vasseur, B
Temperaturförhållanden i svenska kustvatten
Stockholm 1975

Nr RHO 4 Svensson, J
Beräkning av effektiv vattentransport genom Sunninge sund till Byfjorden
Stockholm 1975

Nr RHO 5 Bergström, S & Jönsson, S
The application of the HBV runoff model to the Filefjell research basin
Norrköping 1976

Nr RHO 6 Wilmot, W
A numerical model of the effects of reactor cooling water on fjord circulation
Norrköping 1976

Nr RHO 7 Bergström, S
Development and Appl. of a Conceptual Runoff Model
Norrköping 1976

Nr RHO 8 Svensson, J
Seminars at SMHI 1976-03-29--04-01 on Numerical Models of the Spreading of Cooling-water
Norrköping 1976