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WO- DIMENSIONAL NUMERICAL MODEL FOR THERMAL POLLUTION OF SINGEL SOURCE IN RIVER

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BSTRACT

he aim of this research was to apply a numerical model capable of describing the thermal pollution n rivers. For this purpose a two-dimensional numerical model was applied for estimating mperature distribution in a river .
omentum Conservation Equation and Thermal Energy Equation were used to describe the istribution and diffusion of temperature along the river subjected to thermal pollution point ource. Furthermore the model incorporates the (k-ε) turbulence model to calculate the distribution f turbulent viscosity .The pressure distribution was determined using hydrostatic pressure quation.
he partial differential equations were formalized and simplified to be solved using Alternative irection implicit- explicit method (ADI) with upwinding technique . The resulting system of linear imultaneous equations were then solved using Gauss-Elimination method .
aboratory physical model was built to find experimental data . These data were used for model erification with data obtained from Al-Daura power station and Tigris river.
he model was found to be sensitive to the variation of river velocity and density difference and the odel was found to be insensitive to the wind speed .The comparison of observed results from Al-aura power station and laboratory physical model with those computed by the numerical model how a good agreement . The maximum absolute difference percentage are (16.2%, 8.6%) espectively

الخلاصة

يهدف البحث الى بناء نموذج عددي لدراسة التلوث الحراري في الانهار الناجم عن مصدر
. ولهذا الغرض تم استنباط نموذج رياضي عددي لتمثيل هذه الظاهرة والتنبؤ بتوزيع درجات
النهر .تم استخدام معادلة حفظ الزخم ومعادلة حفظ الطاقة ومعادلات التوزيع الحـــراري لمعرفة
وانتشار درجات الحرارة خلال منطقة الدراسة وكذلك تضمن النموذج العددي معادلات الاضـــطراب
لحساب معاملات اللزوجة. كما تم اعتماد معادلة الضغط الهيدروستاتيكي لحساب الضغط في كل
بالدراسة .
تم تبسيط المعادلات التفاضلية المختلفة الاشكال بطريقة الاتجاه المتناوب (الضـــمني- الصـــريح)
المحددة (ADI) مع تطبيق منظومة Up Winding للحصول على معادلات جبرية خطية تم حلهـــا
الحذف المتناوب (Gauss – Elimination)كما تم بناء نموذج مختبري لاغراض عمل التحقق

دي .لقد وجد ان النموذج حساس الى سرعة النهر والى تغير الكثافة وان النموذج غير حســـاس لتغيـــر عة الريح .

لال مقارنة النتائج المقاسة في نهر دجلة اسفل محطة كهرباء الدورةالتي تعتبر مصدرتلوث حراريللنهر ج النموذج المختبري مع النتائج المحسوبة من النموذج العددي الرياضي نلاحظ انها مقبولة الى حد ما ة خطا مطلق مقداره (16.2%،8.6%) على التوالي.

INTRODUCTION

The rise of water temperature due to artificial effects is called thermal pollution .This ty pollution can be defined as excessive change in the natural or ambient water temperature caus the addition or removal of heat through man's activities .The heated water raise the temperatu the body of water above it's normal level and can harm animals and plants living in the (Richard,2000).

The major waste-heat producing industries are :steam-electric generation plants , petro refineries , steel mill , chemical plants(mathur,1976).

The discharge of heated water directly to the river can be more dangerous to the health o receiving water than organic pollution. Higher temperature reduces solubility of oxygen .Mor ,the chemical reactions will proceed to a faster pace, hence , the water may go anaerobic disastrous effects on its odor and appearance(Rute and Siliva,1997).

Al-Challabi (1994) developed a two- dimensional numerical model for the simulation of the sp and mixing of thermally polluted water disposed into the flow. This model considers the effe density difference between the pollutant density and the river water density

Li-Renyu and Righetto (1998) presented unsteady state two dimensional model to simulate velocity and temperature field in the estuary of the Yangtza River in Brazil. It was found th simulation by using (K-ε)model can provide more details of flow fields and temperature distrib than that once obtained by using

Phenomenological algebraic for models of eddy viscosity and diffusivity Catirolgu and Yu (1998) presented a mathematical model to predicts the long-term effects of once-through sy on local fish population. . The simulation indicates that entertainment and impingement may le a population reduction of about 2% to 8% in the long run. Joody (2001) developed one and dimensions numerical model for the simulation of the spread and mixing of thermally po water disposed into the river flow released from the AL-Daura Power Station starting from outfall up to 1000m downstream. The two dimensional model also discusses two cases, the case neglects the effect of vertical velocity distribution while the second case includ Comparison of observed data on Feb 3, 2001 and July 27,2001 with data computed by dimensional model shows a good agreement with percentage error of 0.57% and 1.95% respec In this research the finite difference method was used to solve the equations governing phenomena of heat disposal. The solution was verified by a laboratory experimental work a field data obtained from Al-Daura power station .

NUMERICAL MODELING

Numerical model of thermal pollution is used by the formulation of the following set of pa differential equations: (Rastogi and Rodi, 1978)

Momentum Conservation Equations

Horizontal Momentum Equation :

$$\rho\frac{\partial U}{\partial t}+U\frac{\rho\partial U}{\partial X}+W\frac{\rho\partial U}{\partial Z}=\frac{\partial}{\partial X}\mu\frac{\partial U}{\partial X}+\frac{\partial}{\partial Z}\mu\frac{\partial U}{\partial Z} \quad (1)$$

Vertical Momentum Equation :

$$\rho\frac{\partial W}{\partial t}+U\frac{\rho\partial W}{\partial X}+W\frac{\rho\partial W}{\partial Z}=\frac{\partial}{\partial X}\mu\frac{\partial W}{\partial X}+\frac{\partial}{\partial Z}\mu\frac{\partial W}{\partial Z}\quad\frac{\partial P}{\partial Z}+\rho g \quad (2)$$

Thermal Energy Equations :

$$\rho\frac{\partial T}{\partial t}+U\frac{\rho\partial T}{\partial X}+W\frac{\rho\partial T}{\partial Z}=\frac{\partial}{\partial X}\frac{\mu}{\sigma}\frac{\partial T}{\partial X}+\frac{\partial}{\partial Z}\frac{\mu}{\sigma}\frac{\partial T}{\partial Z}\quad\frac{\alpha(T\quad T_r)}{C_p*H} \quad (3)$$

K-ε turbulence model :

K-Equation :

$$\rho\frac{\partial K}{\partial t}+U\frac{\rho\partial K}{\partial X}+W\frac{\rho\partial K}{\partial Z}=\frac{\partial}{\partial X}\frac{\mu}{\sigma_K}\frac{\partial K}{\partial X}+\frac{\partial}{\partial Z}\frac{\mu}{\sigma_K}\frac{\partial K}{\partial Z}+G\quad\rho\varepsilon \quad (4)$$

ε-Equation :

$$\rho\frac{\partial \varepsilon}{\partial t}+U\frac{\rho\partial \varepsilon}{\partial X}+W\frac{\rho\partial \varepsilon}{\partial Z}=\frac{\partial}{\partial X}\frac{\mu}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial X}+\frac{\partial}{\partial Z}\frac{\mu}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial Z}+C_1\frac{\varepsilon}{K}G\quad C_2\rho\frac{\varepsilon}{K} \quad (5)$$

Density- Temperature relation ships.

$\rho=-0.0055T^2+0.0182\,T+1000.1$ (6)

Longitudinal velocity vertical distribution:

$U=2.5\,U_f\,Ln(Y/Y_0)$ (7)

Pressure distribution along the river depth $P = g\int_0^Z \rho\, dZ$ (8)

Finite difference was used for the solution of the above partial differential equations, and by using some assumption to transform these equation from non-linear to linear equations (Smith,1978).These equations are simplified in a two-dimensional vertical and horizontal direction . Computer programming was used to perform the computations of the simulation model . It was written in Fortran-77 which works with Visual Fortran -97 language:

Equations (1,2,3) are considered as the three_ dimensional governing differential equations while Equations (4,5,6,7)are the auxiliary equations .

EXPERIMENTAL WORK

Laboratory physical model as shown in **Fig. (1)** was built to simulate the case of thermal pollution of rivers in order to obtain data for verification of the numerical model mentioned above. This model was *built using galvanized steel pipes and tanks. Two pumps were used* one for the heated water and one for the water that simulate the river water. The water was heated using electrical water heater .The water pipe was connected to the ground tank (feed tank),which then lifted to tanks number 1 and 2.The water in those tanks were connected to a glass flume which simulate the river through pipes ended by a tap after passing through electrical heaters (plant 1,and plant 2). The flume was fed by water from a re-circulation tank (tank no. 3). The flow was controlled by a weir located at the end of the flume. The experiments was conducted to find the temperature along t flume downstream of the heated water outfall(the water from the tap). The temperature values we measured using thermometers distributed at selected distances from this tap.

Field data obtained from Al-Daura power station were also used to support this verificatio **Table(1)** shows the comparison of the temperature values along the Tigris river downstream of A doura Power station outfall with those obtained by the numerical model .The required informati about Tigris river obtained from (Euphrates center for studying and design or irrigati project, 2001)

Table (1) Observed and Predicted temperature from Al-Daura power station

Distance(m)	Observed Temp.° C	Predicted Temp. °C(by Numerical model)	Absolute difference %
Outfall	44	44	0
50	32.7	38	16.2
100	30.8	34.5	12
150	30.5	32	5
200	30.3	30.6	0.004
250	30	30	0
300	29.8	29.8	0
350	29.7	29.7	0
400	29.7	29.7	0
450	29.7	29.7	0
500	29.7	29.7	0

Table(2) shows the comparison of the temperature values observed from the laboratory mo downstream of the point source outfall with those obtained by the numerical model .

Table (2) Observed and Predicted Temperature Data from Laboratory Physical Model.

Distance (m)	Observed temp.° C (in the laboratory model)	Predicted temp.° C(by the numerical model)	Absolute Differ %
0	55	55	0
0.5	38	41.3	8.6
1	32	33.1	3.4
1.5	30	30.6	2
2	30	30.1	0
2.5	30	30	0
3	30	30	0
3.5	30	30	0
4	30	30	0

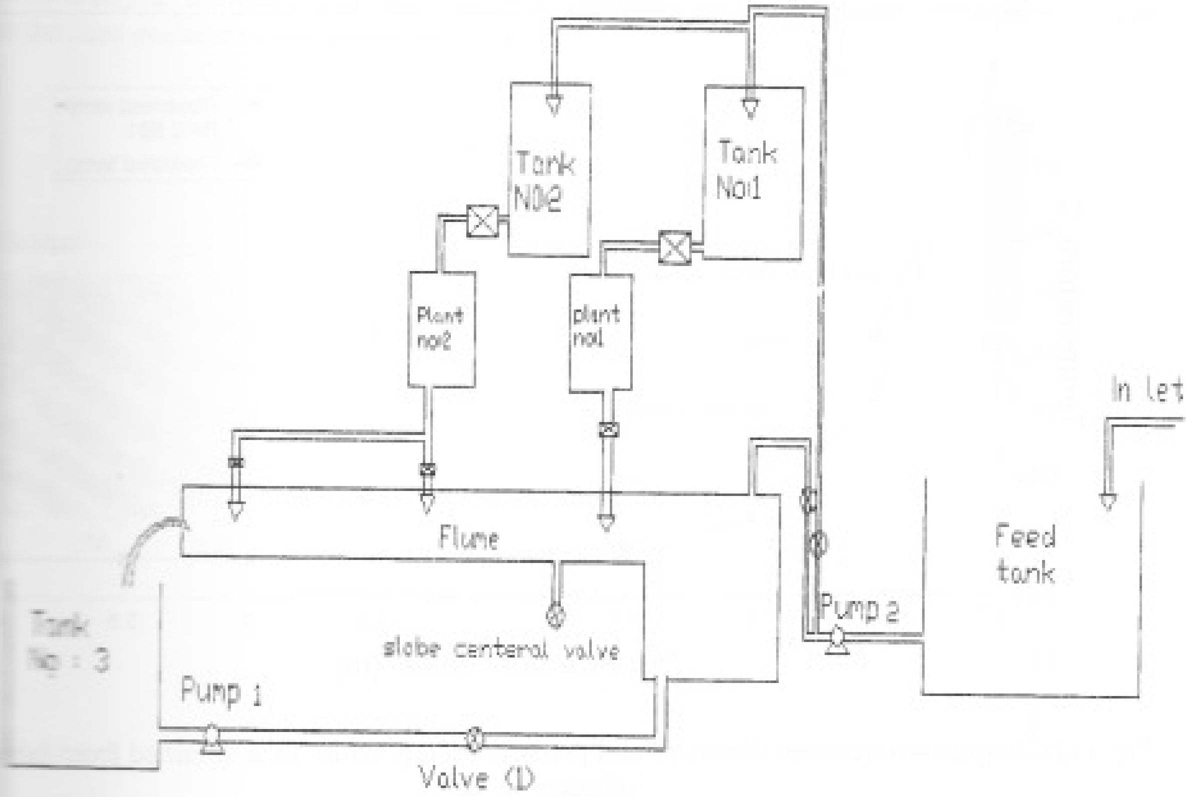


Fig. (1) Physical laboratory model

RESULTS AND DISCUSSION

Before using the results of the numerical model to study the effect of different parameters on the temperature distribution the model should be verified. The verification was carried out by conducting a comparison between the observed results from laboratory physical model and Al-Daura power station with predicted results obtained from numerical model as shown in **Figs. (2,3)**. The maximum percentage difference was found to be (16.2%,8.6%) ,and the correlation coefficient between those results are (0.917 , 0.991) respectively .

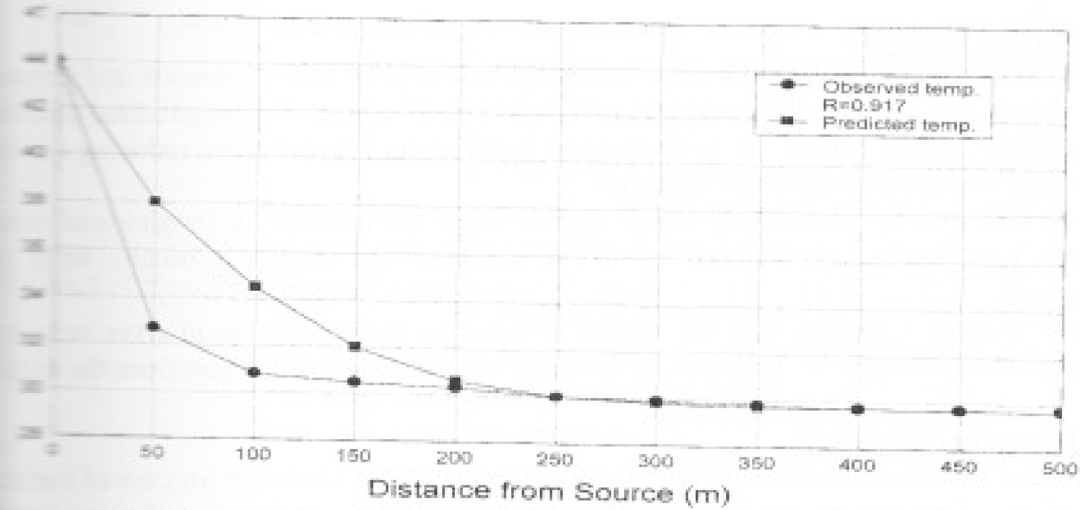


Fig.(2) Comparison between observed and predicted temperature data obtained from Al-Daura power station.

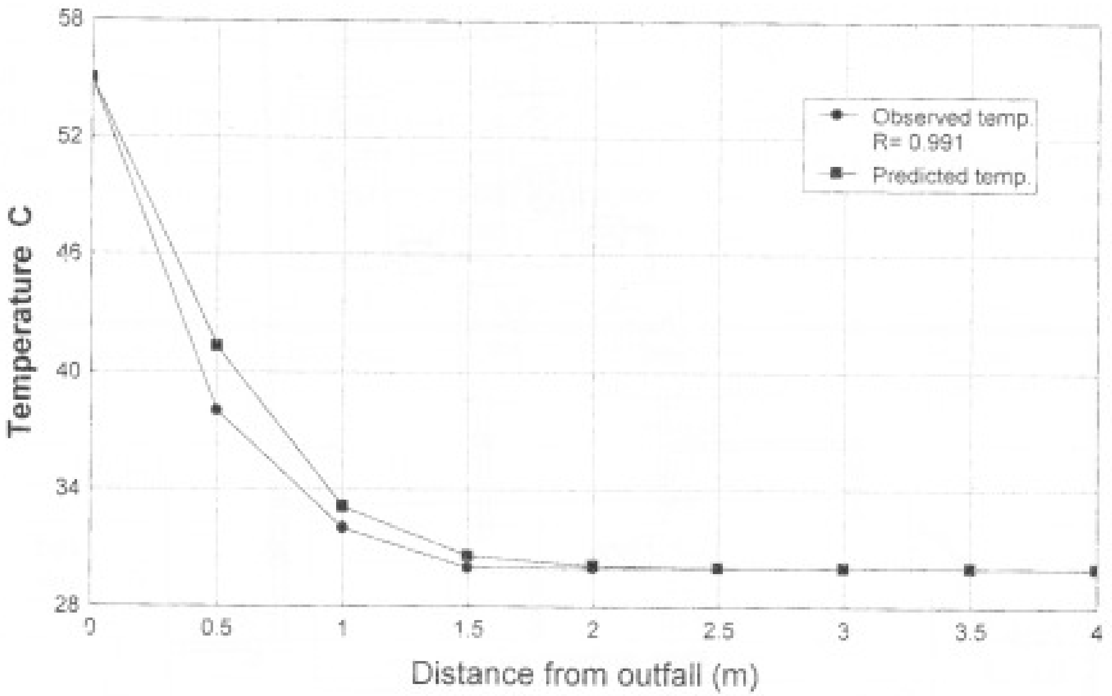


Fig. (3) Comparison between observed and predicted temperature data obtained from laborator physical model.

SENSITIVITY ANALYSIS

Sensitivity analysis was carried out to obtain the effect of the several important model parame on the temperature distribution as follows:

Effect of Wind Speed

Fig. (4) shows the comparison between the results obtained by excluding and including transfer coefficient respectively .From this figure , it can be found that excluding or including heat transfer from the water surface showed no noticeable change in temperature distribution .
The above analysis indicated that the model is insensitive to the variation in the wind speed. Thi obvious from the comparison of the temperature contours for the two cases which is almost simil

Effect of River Velocity

The river velocity is effected by the slope and roughness of river bed. (Roberson and Crowe, 19 **Fig. (5)** shows that decreasing the roughness height causes increase in longitudinal distributio the temperature .This is caused due to increase in longitudinal velocity .Also reducing the rough height causes vertical retardation of isotherms .

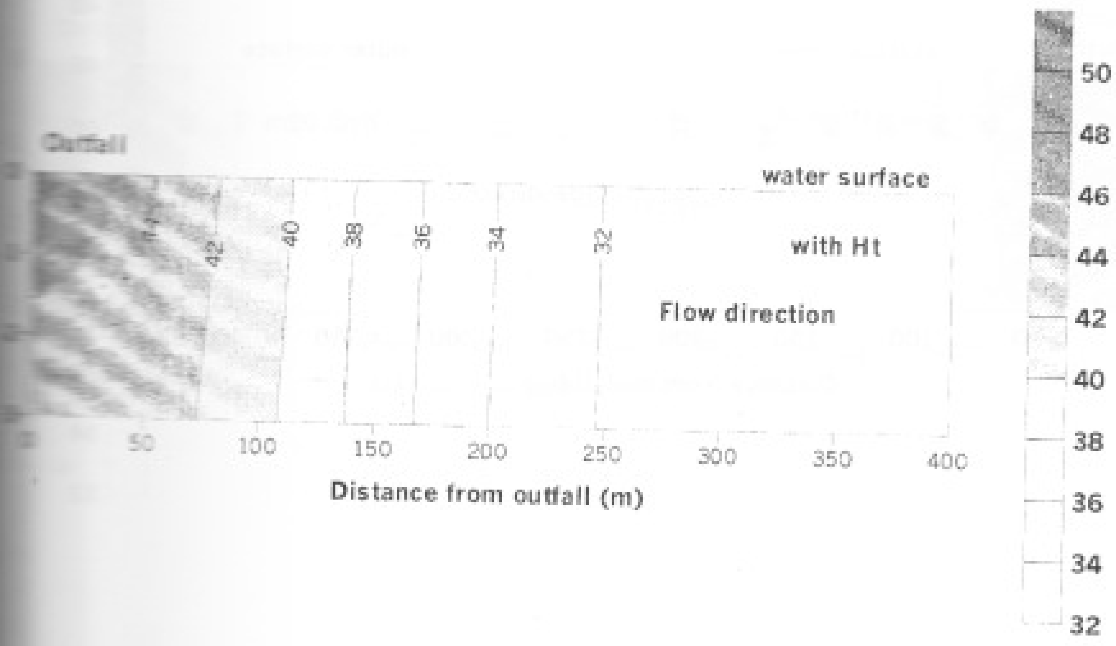
Fig. (6) shows that by increasing water surface slope an increase in longitudinal tempera distribution was obtained, in addition to this the isotherms are retarded vertically when the slope increase.

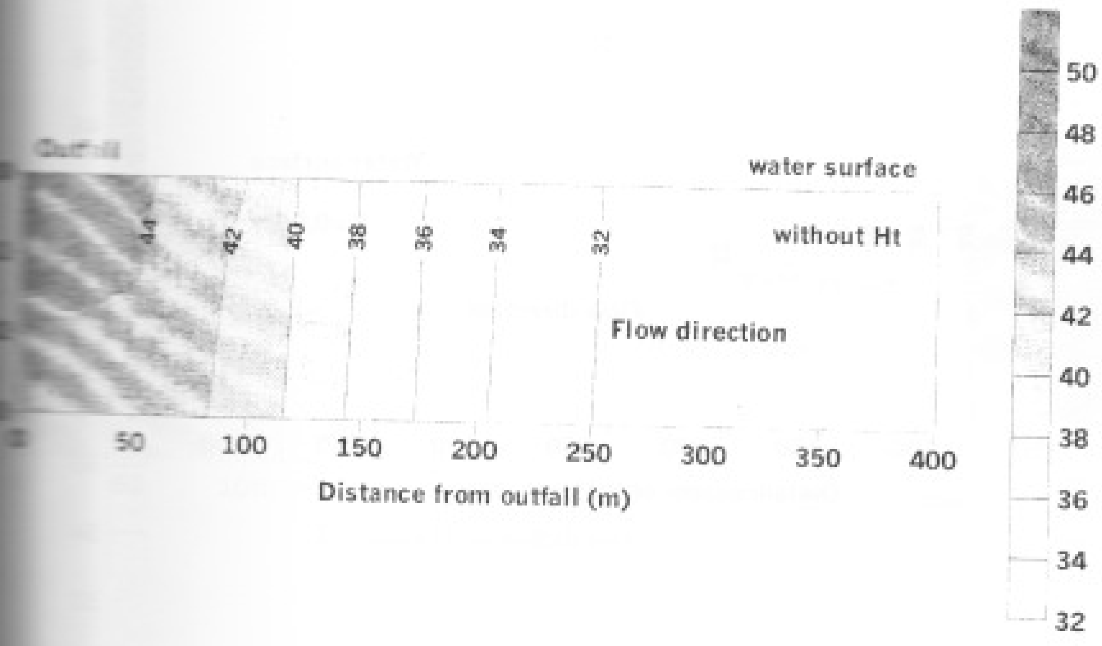
The above analysis indicates that the model is sensitive to the change in river velocity . indication is obvious since the temperature contours were shifted downstream from the outfall.

Effect of Density Difference:

Fig. (7) shows that the isotherms are retarded longitudinally and vertically in case of neglecting density effect . This can be attributed to the effect of a buoyancy force on the spreading o temperature .

above analysis indicates that the model is sensitive to the variation of density difference the heat polluted water and river water .





(4) Effect of Heat Transfer on Temperature Distribution .(Td=50 °C, Tr=30 °C, t=300sec)

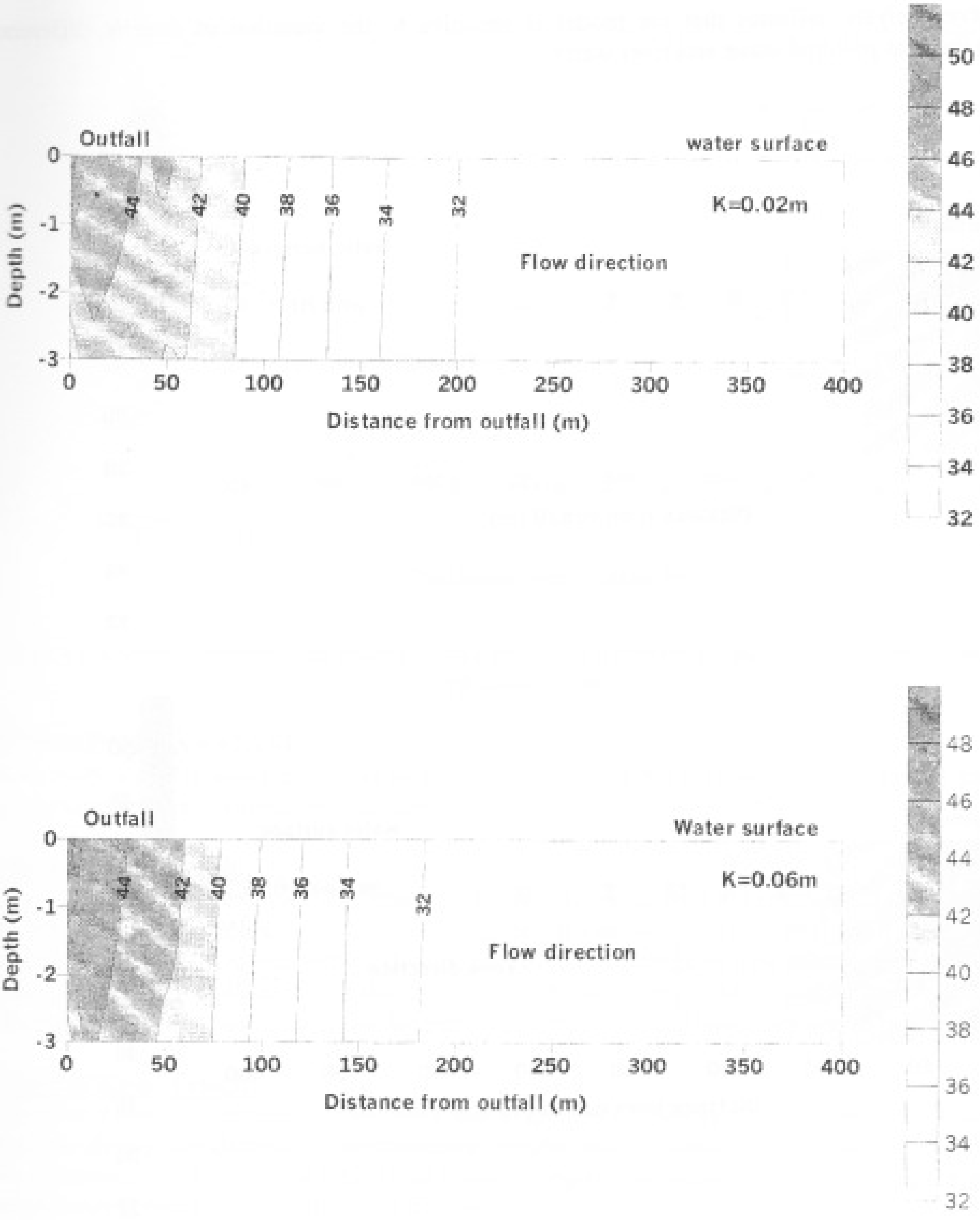


Fig. (5) Effect of Roughness Height on Temperature Distribution . (Tr=30 °C, Td=50 °C, t=300

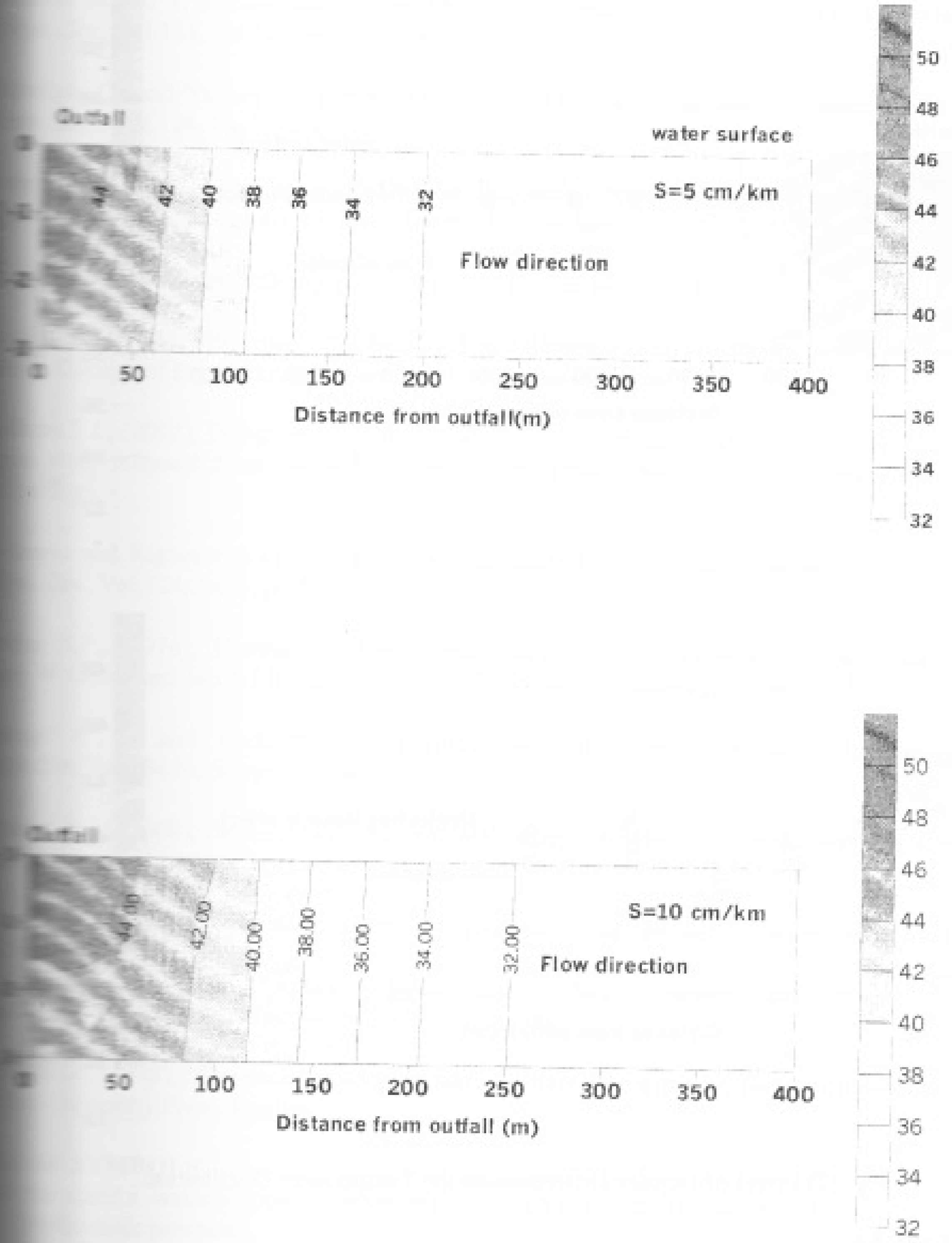


Fig. (6) Effect of River Slope on Temperature Distribution .(Tr=30 °C, Td=50 °C, t=300sec)

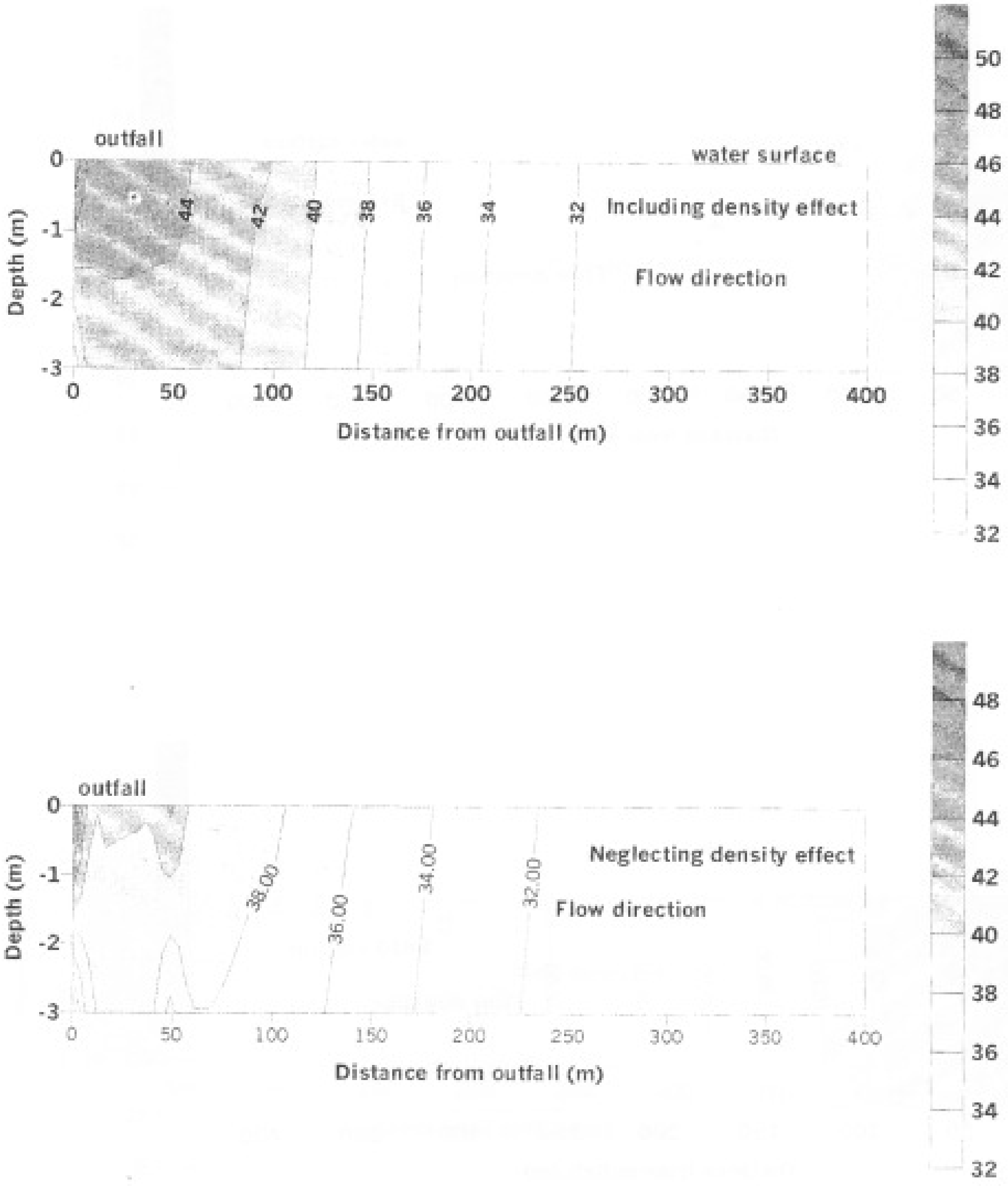


Fig. (7) Effect of Density Difference on the Temperature Distribution .

CONCLUSIONS

1- The numerical model is insensitive to the variations of wind speed .
2- The numerical model is sensitive to the variation of roughness height of the river bed , slop water surface , density difference between the heated water density and the river water densit
3- The model can be utilized to study the effect of various physical parameters on temperat distribution .

REFERENCES

Al-Challabi M. A., (1994) , Numerical Model of Thermal pollution Transport in river , M.S Thesis , College of Engineering University of Baghdad.

M and T.Webster Ian, (1998), Dynamics of temperature stratification in lowland rivers Hyd. Div, Vol.124, No.10 , pp.1059-1063.

C., and Yurteri, C., (1998), Methodology for predicting cooling water effects on fish , Env. Eng., Vol.124, No.7, pp.612-618.

A.J., (1987), Validation of Three -Dimensional Numerical model of a buoyant plume , Report No.SR121, Hydraulic Research Center, Waling ford.

Company for studying and design of irrigation projects (2001) .

A.S., (2001), Studying of the Heated Water Released from AL-Doura Power Station, M.Sc. Thesis, College of Engineering, University of AL- Mustanseryya.

T.J., (2002), Design of two-dimensional numerical model for thermal effluents transport in river released from South-Baghdad electric power station, M.Sc. Thesis, University of Technology.

and Righetto A.M. (1998), Tidal and transport modeling using turbulence K-ε model, Hyd. Div, Vol.124, No.3, pp.212-221.

S.P., (1976), Thermal discharges, Handbook of water resources and pollution control , W.Gehm and Jacob I.Bregrman,eds, Van Nostrand Reinhold Comp.pp.717-779.

A . K., and Rodi, W ., (1978), Prediction of heat and mass transfer in open channels, Hyd.Div. Vol.104,No.3, pp.397-420

N.L. (2000), Professor of environmental policy , department of environmental science and engineering , university of north Caroline , Email:pete_andrews@unc.edu.

J.A. and Crowe, C.T., (1997), Engineering fluid mechanics, John Wiley and Sons , New York.

Neves and Silvia Lourenco (1997), Thermal Pollution, www. physical/moor/messages/102.htm. Internet.

G.D., (1978), Numerical solution of partial differential equation, finite difference methods " University Press, England.

LIST OF SYMBOLS

the x,and,z water velocity components in x,and,z components respectively
Hydrostatic pressure
Gravitational acceleration
Surface wind velocity at distance yo from ground
Wind velocity at any depth y from ground surface
Water temperature
River Roughness Height
Water Density
Source Water Temperature
River Water Temperature