MODELING THE DISTRIBUTION OF (BOD) AND (TDS) IN PART OF TIGRIS RIVER WITHIN BAGHDAD

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الخلاصة:

تم تطبيق نموذج الخلايا المتعددة لغرض معرفة انتشار الملوثات والمتمثلة في (الاوكسجين الحيوي الممتص (BOD_5) ، المواد الذائبة الكلية (TDS) على نوعية مياه نهر دجلة في المنطقة الواقعة بين جسر الأئمة وجسر الجمهورية والممتدة على طول (9 كم) ضمن مدينة بغداد ، والتي تحتوي على اربعة محطات للصرف الصحي تصرف مباشرة الى النهر .

قسمت منطقة الدراسة الى احدى عشر خلية ذات احجام مختلفة ، وتم تشغيل البرنامج بعد تزويده بالبيانات الحقلية التي تم الحصول عليها من نتائج تحليل النماذج التي جمعت من اثنى عشر موقعاً من النهر ومن اربعة محطات للصرف الصحي الموجودة ضمن منطقة الدراسة تم جمعها كل اسبوعين للفترة من 2005/11/15 الى 2006/4/30 ، أنجز التحقق من النموذج وذلك بتطبيقه لاستنباط التراكيز للمتغيرات التي تم فحصها بصورة دورية ضمن منطقة البحث .

تم تطبيق برنامج جاهز يعتمد على طريقة الفروقات لغرض تقدير تراكيز المتغيرات ونمذجة نوعية المياه , وتم ملاحظة ان تراكيز الملوثات في النهر يزداد خاصة في المناطق التي يتم فيها الصرف مباشرة الى النهر حيث ان تراكيز BOD_5 بلغت (140ppm) على بعد 1.4km من بداية منطقة الدراسة و 170ppm على بعد 5km و 160ppm على بعد 6.5km و 155ppm على بعد 7.5km ثم تنخفض في المناطق البعيدة عن نقاط الصرف حيث انها تصل الى الحدود المسموحة بعد 300m من اخر نقطة صرف اي بعد 7.8km من بداية منطقة الدراسة, بينما قيم TDS كانت ضمن الحدود المسموحة على طول منطقة الدراسة ما عدا عند البعد 5km فانها تصل الى 1100ppm , ومن الضروري السيطرة على تصاريف محطات الصرف الصحي لجعل تراكيز الملوثات في مياه نهر دجلة ضمن الحدود المسموح بها حيث لوحظ عند تشغيل هذه المحطات بطاقتها القصوى (12 ساعة يوميا) فأن تراكيز الملوثات يزداد خصوصا عندما يكون تصريف نهر دجلة قليل (250 م^3 /ثا).

بتطبيق برنامج (Surfer) فانه تم توضيح انتشار الملوثات في النهر بالنسبة لنتائج النموذج (التي تم الحصول عليها من البرنامج السابق) وكذلك بالنسبة للنتائج الحقلية (التي تم الحصول عليها من الفحوصات المختبرية) وأجريت المقارنة بينهما .

ABSTRACT:

A multi-cells in serial model was developed to simulate the distribution of pollutants (which are BOD_5 and TDS) in Tigris river between Al-A'imma bridge and Al-Jumhuria bridge ,a reach which is about (9 km) length within Baghdad city; this includes four sewage pumping stations untreated discharged to the river.

This region was divided into eleven cells of different volumes. The model was operated using the field data, which were obtained from the results of laboratory test of samples which were collected from twelve stations in the river and four sewage pumping stations located within the study region twice a month from 15/11/2005 to 30/4/2006. Verification of the simulation model was accomplished by its application to predict the substances concentrations observed.

A package program of differential equation were applied to obtain the concentrations of parameters and modeling the water quality, it was concluded that the concentrations of pollutants were increased at the discharge points in the river, the concentration of BOD_5 reached 140ppm at 1.4km from the beginning of the study region, 170ppm at 5km, 160ppm at 6.5km and 155ppm at 7.5km, then BOD_5 became within the acceptable values in the other regions and finally it reaches the acceptable value after the last discharge point (7.8km) from the beginning of the study region, TDS was within the acceptable range except at 5km it reaches 1100ppm. sewage pumping stations shouldn't set at high discharge rate (12 hr/day) to decrease the pollutants concentrations in Tigris river in order to keep these concentrations within the acceptable values specially at low flow of the river (250 m^3/sec).

By using Surfer program to show the distribution of model results (obtained from the previous program) and the field results (which were obtained from the laboratory tests) and to compute the comparison between them.

INTRODUCTION:

Fresh waters are facing an increasing load of the disposal of polluted waters due to rapid growth of industrial and municipal activities as well as the increase of land drainage due to agricultural activities. Outfalls effluents with high pollutant concentrations are discharged to fresh water without treatment causing near field and far field pollution conditions in rivers (Petrus,1990).

The quantitative and qualitative study of water resources, their development and management become one of the major concerns of the society. The escalating demands on limited water resources, needs for maintaining suitable water quality for human, agricultural, and industrial uses and complex interactions of numerous elements of the man-water environment have necessitated the use of more sophisticated forecasting techniques. Such forecasting is essential in the planning, designing, and management of water resources system. [Hikmat , 2005]

Water quality studies have focused on cases where sever pollution problems are arises, especially in heavily populated urban areas. Baghdad city is over populated and produced a huge amount of wastewater from different sources which are disposed into Tigris River directly or after treatment. In the last few years, an increase of wastewater directly disposed in the river using pump stations of storm sewer network have caused high pollution levels in the river water.(Dahr,2004).

Most potential negative environmental impacts from the application of recycled water to the environment come from recycled water's origin as wastewater. These impacts include other water resources, potential contamination of surface and groundwater sources. Public health hazards, and other environmental impacts that may directly or indirectly affect the public. Fortunately, very few significant negative impacts have ever occurred. It is important that all public water systems serve water of the best possible quality to their customers(William,2001).

Water quality characteristics fall into the following four broad categories:

1- Physical.
2- Chemical.
3- Biological.
4- Radiological.

The concentration of pollutant in the river is affected by water discharges, velocities and the dispersion coefficient values which is continuously changes with time.

The estimation of the velocities which is the major factor affecting the pollutant movement, is often based on physical models or actual measurements. Both are time-consuming and relatively expensive.

Tigris river facing the effect of conservative pollution due to the discharge of wastewater in it.

The present research is to study the effect of pollution sources between Al-A'imma bridge and Al-Jumhuriya bridge on Tigris river water quality, the pollution sources include four sewage pumping stations: Fig.(1).

1- (RQ) sewage pumping station. (S1)
2- (T1) sewage pumping station. (S2)
3- (M112) sewage pumping station. (S3)
4- (M108) sewage pumping station. (S4)

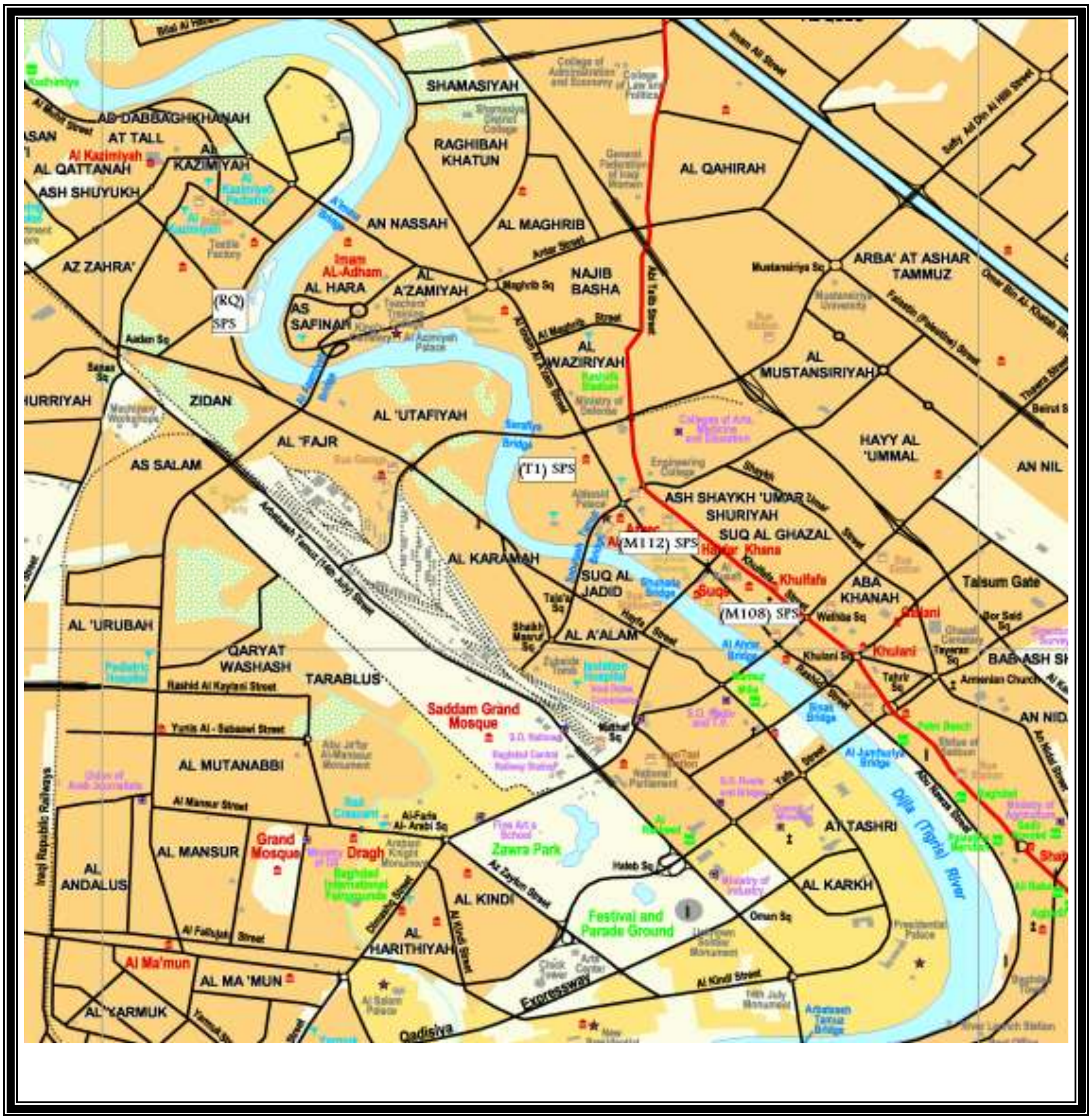

Figure (1) Tigris river between Al A'imma bridge and Al-Jumhuriya bridge. [Tourist map of Baghdad 2004]

EXPERIMENTAL WORK

The experimental work, in this study, can be divided into two parts; field work and laboratory work. In the following sections a brief description of the procedures and equipment were used.

FIELD WORK

Spot samples were collected in order to study the effect of discharge of wastewater from the sewage stations to Tigris river between Al-A'imma bridge and Al-Jumhuriya bridge on Tigris river water quality.

Twelve stations were chosen in the study region, which includes four discharge points as shown in Fig. (2), and four samples from the sewage pumping stations which were discharge directly to the river within the study region.

The samples were collected from the same stations twice a month from 15/11/2005 to 30/4/2006.Table (1) shows the location and distances of these stations.

RIVER-CROSS SECTIONS

An updating of the cross-sections measured in May 2000 for the Tigris river in Baghdad city which were conducted by the Ministry of Water Resources was utilized. Twelve cross-sections were surveyed along different selected stations on the river reach involved in the present study.

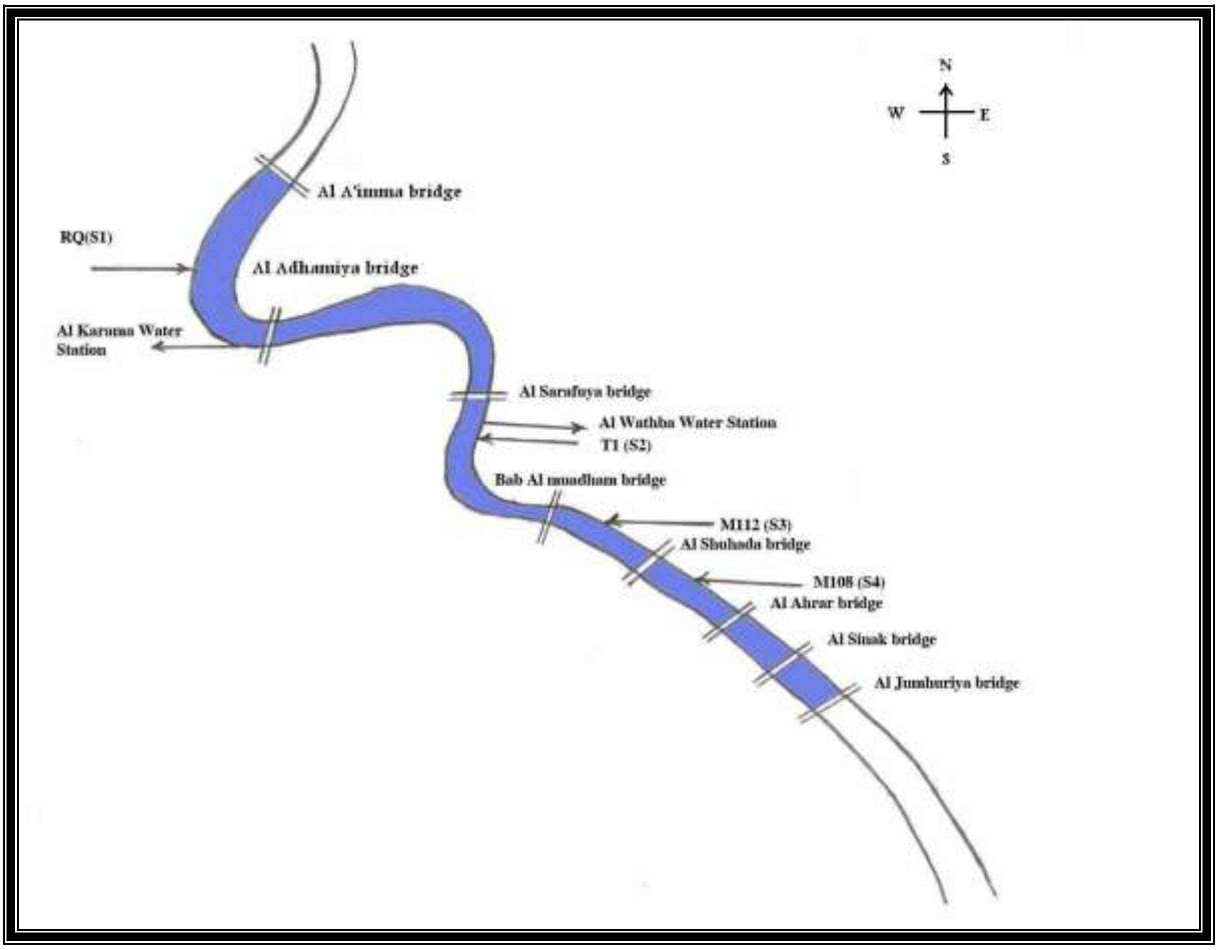

Figure (2) General layouts of the study region

Table (1) The locations and distances of the sampling stations on Tigris river.

St. No.	Distance(Km)	Locations	Coordinates	
1	0.0	At Al-A'imma bridge	33º22'29".82N	44º21'19".22E
2	1.2	At (RQ) pumping station	33º21'55".54N	44º2054".82E
3	2.0	At Al-Adhamiya bridge	33º21'33".71N	44º21'14".30E
4	4.0	At Al-Sarafiya bridge	33º21'27".50N	44º22'21".12E
5	5.0	At (T1) pumping station	33º21'02".14N	44º22'17".30E
6	6.0	At Bab Almuadham bridge	33º20'33".20N	44º22'44".99E
7	6.5	At (M112) pumping station	33º20'26".12N	44º23'03".80E
8	7.0	At Al-Shuhada bridge	33º20'17".03N	44º23'16".52E
9	7.5	At (M108) pumping station	33º20'09".70N	44º23'26".01E
10	7.9	At Al-Ahrar bridge	33º19'55".80N	44º23'43".17E
11	8.5	At Al-Sinak bridge	33º19'42".22N	44º24'00".99E
12	9.0	At Al-Jumhuriya bridge	33º19'28".46N	44º24'15".05E

The relationship between water level and flow of Tigris river was plotted as Rating Curve Fig.(3).

$$Q = 32.014\,(Z - 24.01)^{1.89}$$
$$R^2 = 0.99206$$

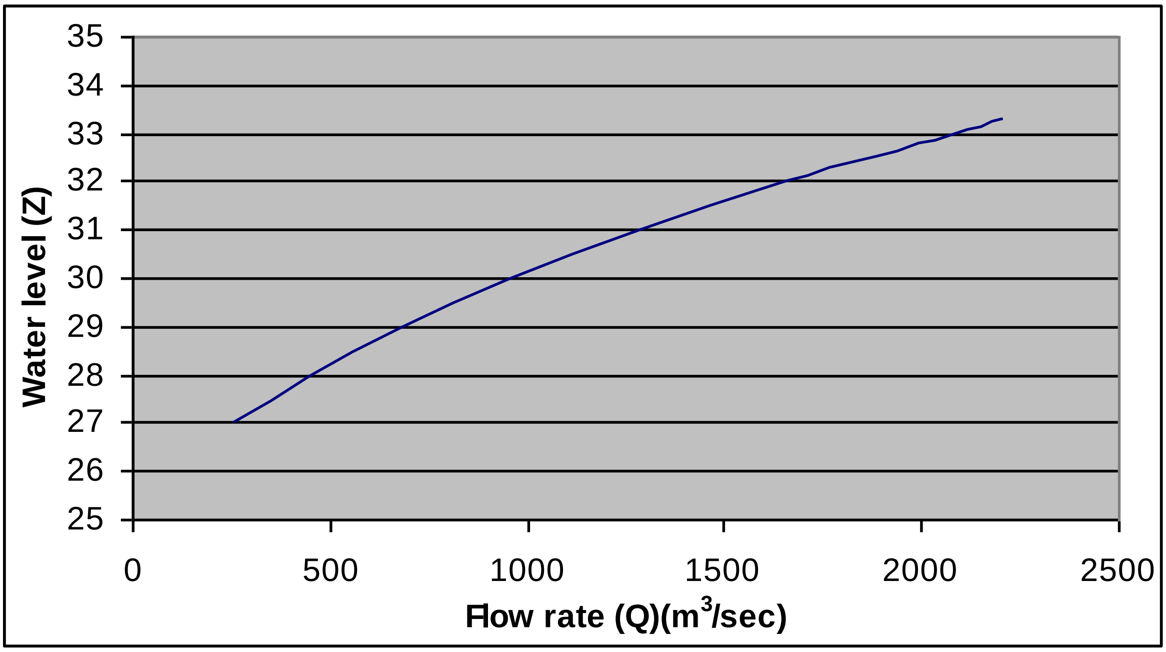

Fig.(3) Rating Curve at Sarai Baghdad Gauging Station.

The water level of Tigris river for the days when the samples collected were measured at Sarai Baghdad Gauging Station then the values of flow of the river were founded from the rating curve Fig. (3) and the results were tabulated in table (2).

Table (2) Water Level and Flow of Tigris river at Sarai Baghdad Gauging Station.

Date	W.L.(m) Sarai Baghdad	Flow (Q_{in}) (m3/sec)
15/11/2005	29.72	875
30/11/2005	29.08	698
15/12/2005	28.96	667
30/12/2005	28.90	652
15/01/2006	28.88	647
30/01/2006	28.94	660
15/02/2006	28.79	625
28/02/2006	28.72	607
15/03/2006	29.36	770
30/03/2006	29.20	730
15/04/2006	28.92	655
30/04/2006	28.88	645

LABORATORY WORK

River stream and outfalls sewage pumping stations samples were collected using bottles of one-liter capacity from the middle of the river at the depth of (0.5m), and the samples which collected twice a month were tested.

Two constituents were involved in the present work, Biological Oxygen Demand (BOD_5), Total Dissolved Solid (TDS).

BOD_5 TEST BY ELECTROMETER METHOD

The instrument used In this method is BOD meter. The electrode placed in (250 ml) diluted sample in order to measure the initial dissolved oxygen (D_1), and after 5 days the final dissolved oxygen was measured (D_2) (YOUNG,1981)
then BOD_5 was calculated by:

$$BOD_5,(ppm) = \frac{D_1 - D_2}{P}$$

Where:

D_1= DO of diluted sample immediately after preparation, mg/l
D_2= DO of diluted sample after 5 days incubation at 20ºC, mg/l
P = decimal volumetric fraction of sample used (dilution factor).

TDS TEST BY FILTRATION FOLLOWED BY OVEN DRYING

200 ml (V) of sample was filtered by filter paper to separate the suspended solid, then the beaker was weighted (A) and filled by the filtered sample ,the sample was dried in the oven at105^{o}C for 5 hours ,the beaker with the dissolved solid was weighted again (B) (Clesceri,1998).

Then TDS was calculated by :

$$TDS(ppm) = \frac{B - A}{V}$$

Figures (4) and (5) show the contaminants distribution of the average values of the field results.
The allowable limit of (BOD_5) according to the Iraqi standards is (40 ppm) and for (TDS) is (1000 ppm)

According to the Iraqi standards No.417 (2001), the allowable limit of (BOD_5) is (40 ppm) and for (TDS) is (1000 ppm).

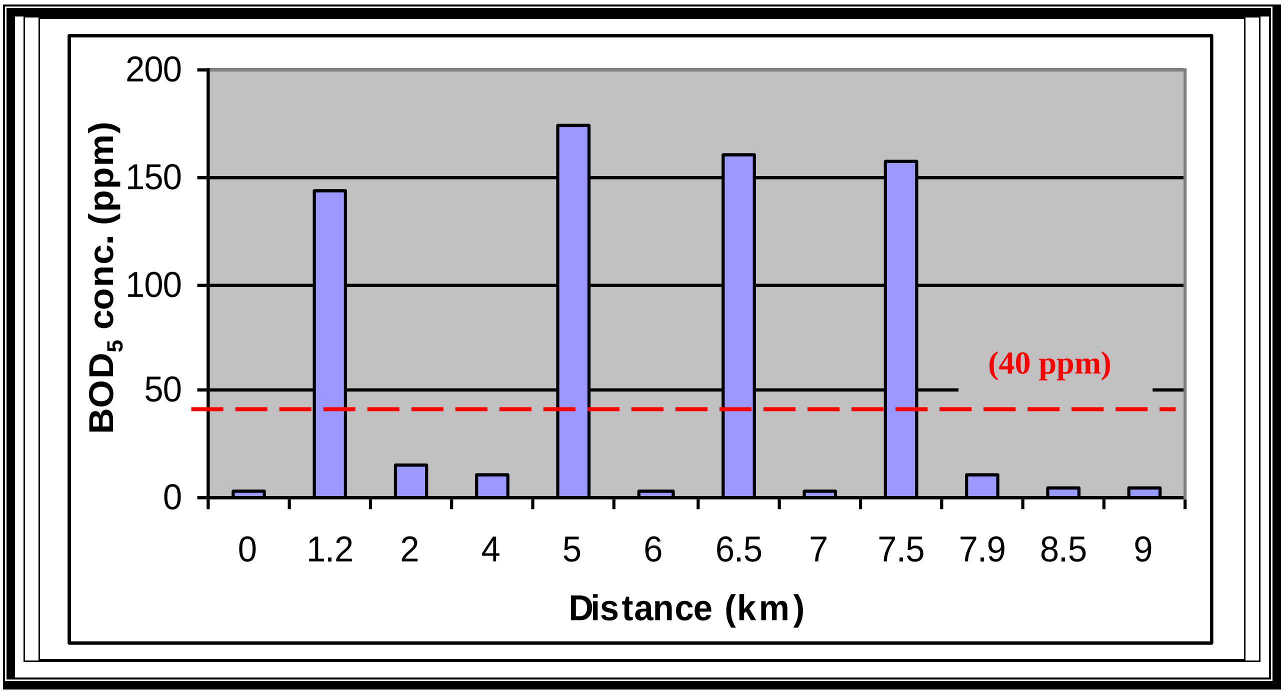

Figure (4) BOD_5 variation along the study region.

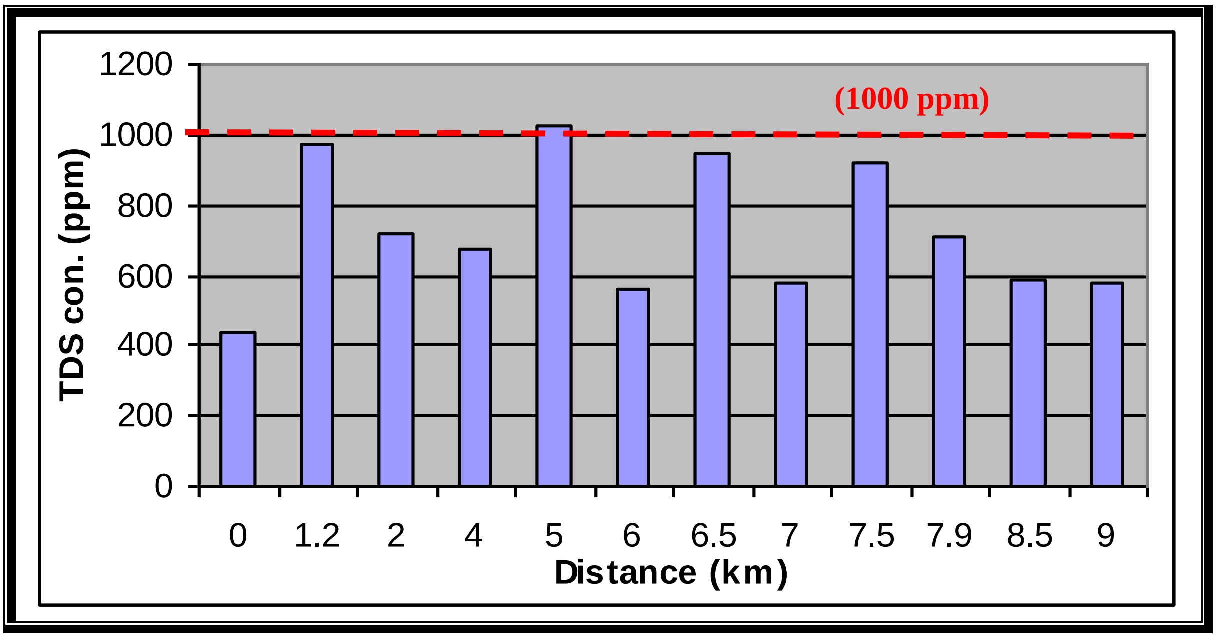

Figure (5) TDS variation along the study region.

MODEL, RESULTS, AND DISCUSION:

The model operation will be tested and compared, separately as quality part, with field results.

Input Data

In order to prepare the input data needed to operate the model and runs the computer program the following steps were followed:-

-The study region was limited from Al-A'imma bridge to AL- Jumhuriya bridge on Tigris river which is about (9) kilometers length within Baghdad city.

- The study region was divided into eleven cells as shown in Fig.(6).

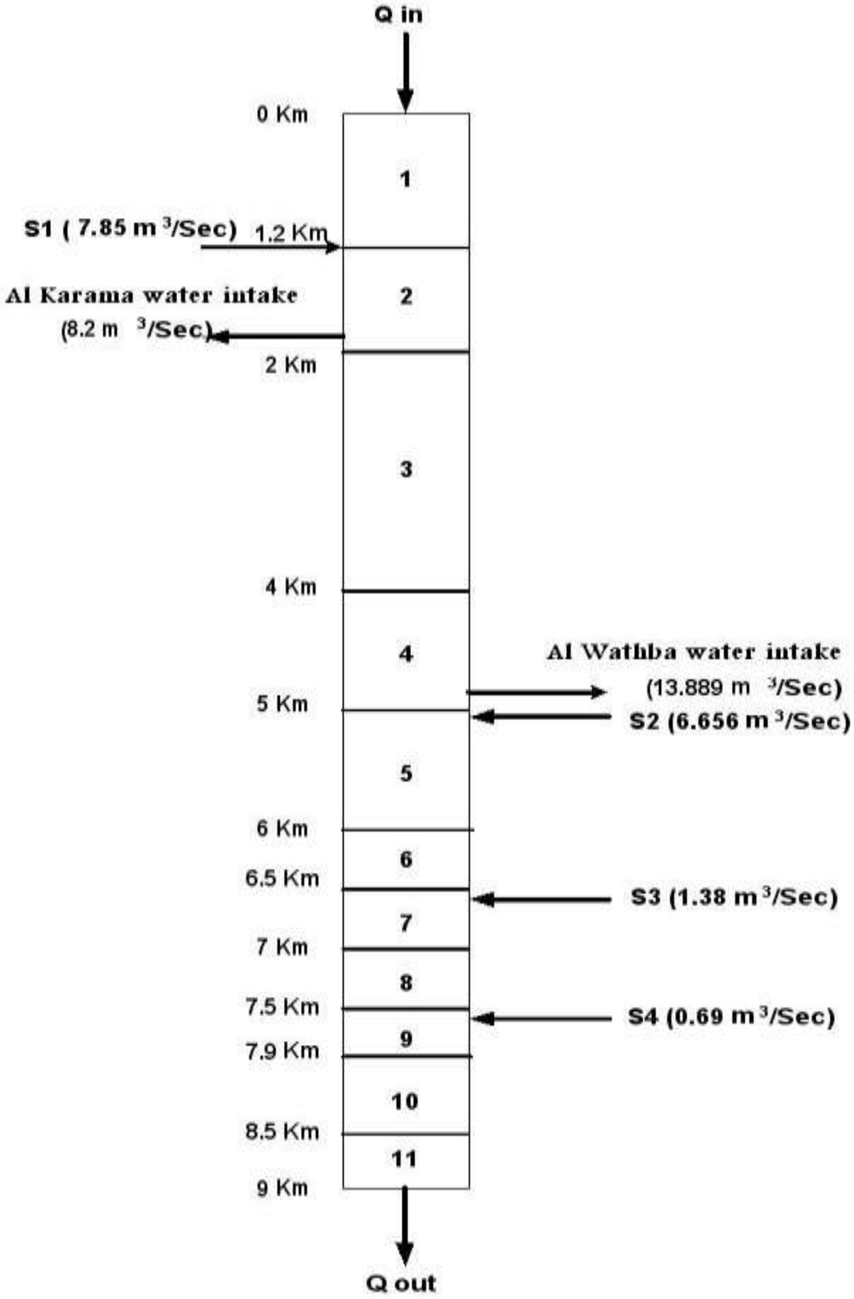

Figure (6) Sketch of the study region (AL-A'imma bridge to AL-Jumhuriya bridge)

- The cross sectional area of each cell (A_1) was calculated with the help of the cross sectional areas of the river (water resources ministry, 2000) .

To calculate the slope of the river within the study region the following steps followed:-

- The water level at Sarai Baghdad gauging station (6800 m from Al'Aimma bridge) (WL_1) was 28.88 m .
- The water level at Al-Jumhuriya bridge (9000 m from Al'Aimma bridge) (WL_2) was 28.73 m .

$Y= WL_1 – WL_2$
$= 28.88-28.73=0.15m$
$D= 9000-6800=2200$ m
Slope = Y/D
=0.15/2200=6.82*10^-5 = 6.82 cm/km
While:
Y = The different of water levels between two stations.
D = The distance between the two stations.

- The surface area of each cell (A_2) was calculated by multiplying the length by the width.
  $A_2 = L * W$
  While:
  L = the length of the cell
  W= the width of the cell
- The distance between each two neighboring cells (from center to center) (C_3) was setted.
- The volume of cells were calculated (V) .
  $V = A_1 * L$

- The concentration of the pollutant in the river (C) and from the sewage pumping stations (C_2) were taken from the laboratory tests.
- The flow rate of water into the cell was measured (Q_{in}) (Table (2))
- The flow rate of the sewage pumping stations discharge (Q_2) are listed In table (3) :-

Table(3)The flow rate of the sewage pumping stations
(Baghdad sewage authority, 2006).

SPS	Q_2 (m^3/ sec)
S1	7.85
S2	6.656
S3	1.38
S4	0.69

- The withdraw flow of water pumping stations were shown in table (4) :-

Table (4) Withdraw flow of water intake stations
(Baghdad water authority, 2006).

Water stations	Q_w (m^3/sec)
Al Karama	8.2
Al Wathba	13.889

-The monthly rainfall and evaporation rate are tabulated in table (5) which used in the equation:-

$$Q_{out} = Q_{in} + Q_2 - Q_w + Q_P - Q_{E'}$$

Table (5) The monthly rainfall and evaporation rate (Iraq Climate, 2006)

Months	Rain fall (P) (mm)	Evaporation (E') (mm)
11	9.9	113
12	13.4	89
1	11.9	45
2	10.8	67
3	20.5	112
4	24.7	154

- The dimensions of the cells are tabulated in table (6):-

Table (6) Some dimensions of the cells in the study region

Cell number	W(m)	L(m)	C_3 (m)	A_1 (m^2)	A_2 (m^2)	V (m^3)
1	230	1200	1000	1084.7	276000	1301640
2	240	800	1400	580.3	192000	464240
3	130	2000	1500	924.2	260000	1848400
4	230	1000	1000	793.6	230000	793600
5	175	1000	750	532.9	175000	532900
6	150	500	500	527.9	75000	263950
7	150	500	500	879.0	75000	439500
8	175	500	450	903.2	87500	451600
9	200	400	500	1479.4	80000	591760
10	230	600	550	157.9	138000	945540
11	260	500	/	1467.2	130000	733600

- To compute the longitudinal dispersion–coefficient there are several empirical and analytical equations have been recommended by various investigators.
  Elder (1959), derived a formula for the dispersion coefficient for an infinitely wide two-dimensional flow down a plane as followes:-

  $$D_L = 5.93\ H\ U \qquad (1)$$

  Where:
  D_L is the longitudinal dispersion coefficient (m^2/sec.).
  H is the depth of flow (m).
  U is the velocity of flow (m/sec.) ($U = Q / A_1$).

SIMULATION MODEL

The computer program is an essential research tool used for performing computation of simulation model, it was mainly consists of two parts, the first part was used to perform the out flow rate of each cell by applying a water flow balance for each cell

$$Q_{out} = Q_{in} + Q_2 - Q_w + Q_P - Q_E \quad (2)$$

The second part of the computer program was used to perform the computations of water quality model by applying multi-cells in serial by substitute the results of eq. (2) in the following equation: (Shanahan and Harleman, 1984).

An increase in the dispersion coefficient would make the peak concentration reach the outlet at a shorter time, and reduce the variation of the cells concentrations.

$$V\frac{dC}{dt} = \sum\left[Q_2C_2 - Q_{out}C + \frac{D_LA_1}{C_3}(C_2 - C)\right] \quad (3)$$

In order to keep the stability of the model , the calculation of pollutants of every record was done by divided the step into multi steps and calculate the concentration in each step , then the results were used as an initial concentration to the following step , and the computer program was calculated the concentration in the second cell in the same way by using the final step concentration from the first cell as an input concentration to the second cell and so on for all cells and records the results .

This method depends on many assumptions, the main ones of which are:

1- The water enters the cell or leaves it as a pulse at the start of the simulation time step.
2- The resultant of inflow and outflow of cell across its boundary is uniformly distributed, so it would be at the same level in the cell at the start of the simulation time step.
3- The cells volumes were remain constant.
4- The concentration of pollutants in dropped rain and evaporated water are equal to zero.

RESULTS AND DISCUSSION

1- The concentrations of the contaminants increase at the discharge points in the river and decrease in the other regions, due to the mixing with the river's water.

2- From the results of laboratory tests, the concentrations of the samples at stations 2, 5, 7, and 9 were very high compared with the other stations, because they were collected from the stations at the river at the discharge of the sewage pumping stations (S1, S2, S3, and S4).

3- The BOD_5 and TDS concentrations at station (5) were higher than the other stations (2, 7, and 9) because of the higher concentrations of the discharge sewage from (S2) than those from (S1, S3, and S4).

4- The BOD_5 concentration levels increase at the river at the discharge points, Fig. (4) and (5), so they increase at distance 1.2 km by 350% of the acceptable limit , at distance 5 km by 420% of the acceptable limit, at distance 6.5km by 400% of the acceptable limit, and at distance 7.5 km by 380% of the acceptable limit, then they decrease at the other regions, and at (7.8 km) they reach the allowable values.

5- The TDS concentrations increase at the discharge points , these values were between (400 ppm - 1100 ppm) so they were within the acceptable values (1000 ppm) except at station (5) it was reached (1100) ppm due to high TDS concentration in the discharge sewage from (S2) at (5 km).

6- Al-Karama water intake locate at (1.8 km) on the study region and Al-Wathba water intake locate at (4.8 km) on the study region,, at these stations BOD_5, TDS are acceptable according to the allowable Iraqi standared .

7-The results which obtained from that computer program were plotted as a model results, and the field results which obtained from the laboratory test were plotted as a field results in order to compare between the two results

8- There are perfect results and a good agreement between measured and predicted results especially in November and March, due to the operation of the pumping stations with the designed discharge rate (Q_2) during sampling period, while in some days the stations set at low discharge rate, so the field results were less than the model results on these days especially in February and April.

Surfer program was applied to explain the contour map and vector map for model results, field results, and the comparison between them as a residual Fig. (7 & 8) .

A contour map is a two-dimensional representation of three-dimensional data; the first two dimensions are the XY coordinates which refer to the cell number and the collecting time, while the third dimension Z is represented by lines of equal value which refer to the concentration.

A vector map shows the direction and magnitude of data at points on a map; they are automatically generated from a single grid by computing the gradient of the concentration. At any given grid node on the map, the arrow points in the direction of the steepest ascent, the magnitude of the arrow changes depending on the steepness of the ascent.

CONCLUSIONS

1- Results of laboratory tests the concentrations of the samples at stations (2, 5, 7, and 9) were very high (about six times for BOD_5 and double for TDS) compared with the other stations, because they were collected from the stations in the river at the discharge of the sewage pumping stations (S1, S2, S3, and S4).

2-There are good agreement between measured and predicted results, which confirms the validity of the selection of the pertinent specified.

3-Field measurements on laboratory tests present that:

* BOD_5 concentration level are exceed the allowable Iraqi standards (40 ppm) in the river at the discharge points then they return to the acceptable values in the other points, and they reach the allowable Iraqi standard at (7.8 km) due to the mixing in the river.

* TDS are within the allowable standard (1000 ppm) except in the position (5) at (5 km) it reached (1100 ppm) because of high TDS concentrations in (S2).

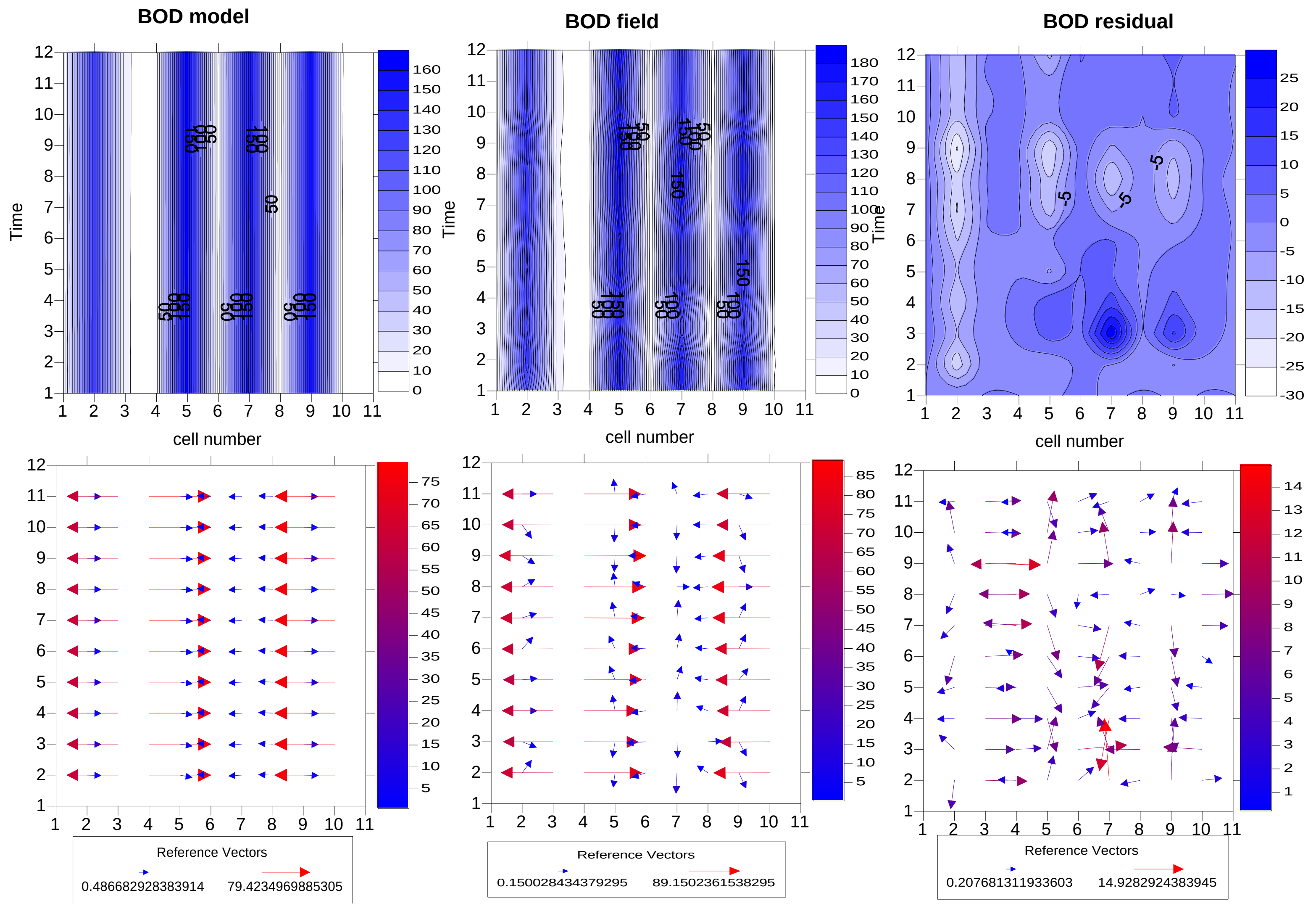

Fig.(7) BOD distribution

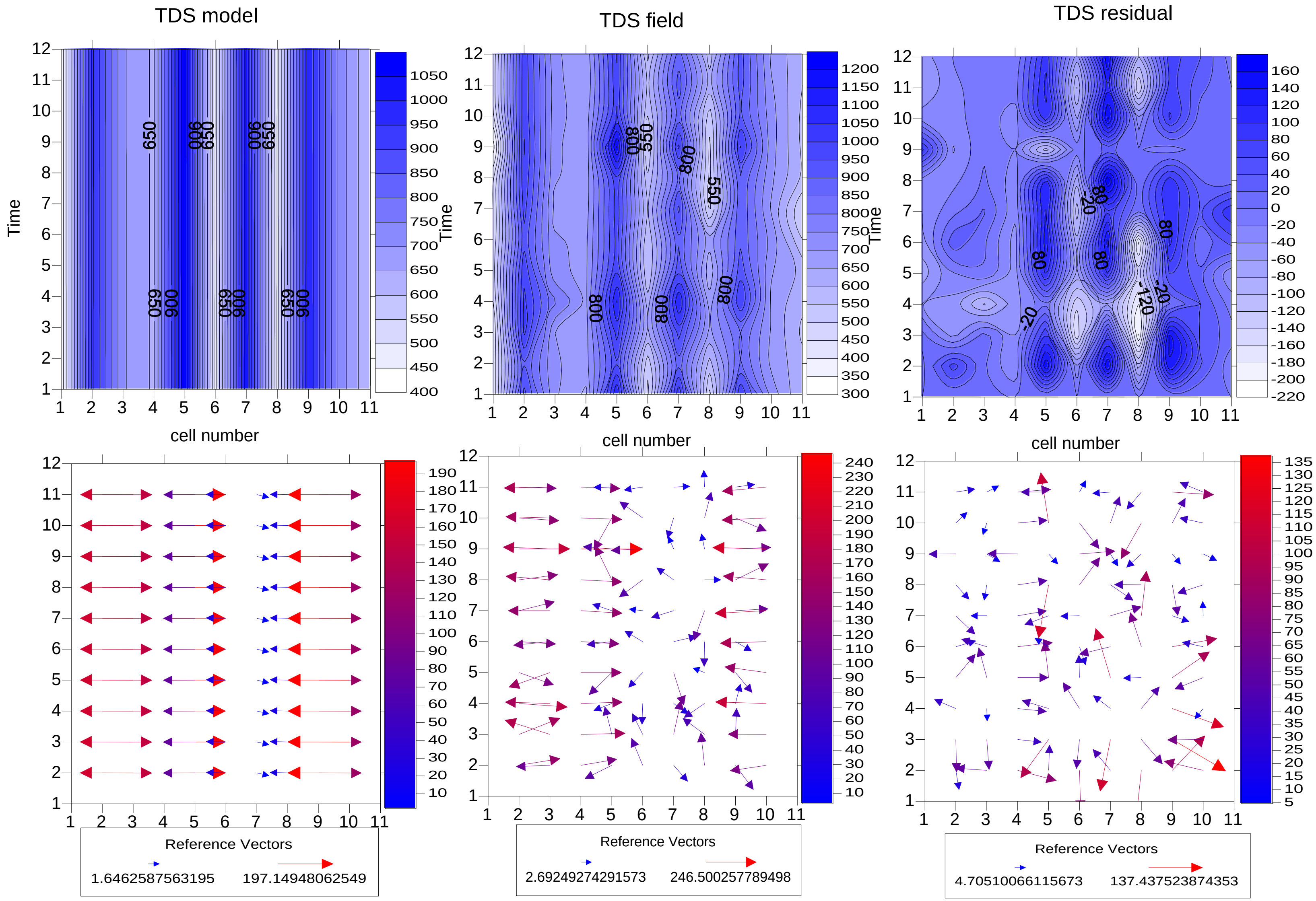

Fig.(8) TDS distribution

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List of Abbreviations

Abbreviate	***Description***
BOD	Biological Oxygen Demand
Conc.	Concentration
DO	Dissolved Oxygen
E	East
Eq.	Equation
Fig.	Figure
N	North
ppm	Part Per Million
P.S.	Pumping Station
SPS	Sewage Pumping Station
St.no.	Station number
S1	(RQ) sewage pumping station
S2	(T1) sewage pumping station
S3	(M112) sewage pumping station
S4	(M108) sewage pumping station
T.D.S	Total Dissolved Solids
WL	Water Level

Symbol	Description	Units
A_1	The cross sectional area of the cell.	m^2
A_2	The surface area of the cell.	m^2
C	Constituent concentration	mg/l
C_2	The concentration of completely mixing water at the final time step	mg/l
C_3	Distance from center of the cell to the center of the neighbor cell	m
E'	Rate of evaporation from the cell surface	mm
P	Rate of rain fall on the cell surface	mm
Q_2	Flow rate of the pumping sewage station	m^3/sec

List of Symbols

$Q_{E'}$	The flow of evaporation	m^3/sec
Q_{in}	The in flow of water into the cell .	m^3/sec
Q_{out}	The out flow of water from the cell .	m^3/sec
Q_p	The flow of rain	m^3/sec
Q_w	Withdraw flow of water pumping station	m^3/sec
t	Time	sec.
V	The volume of the cell.	m^3