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The Effect of Diyala River Water Quality on the Quality of Tigris River Water using GIS Mapping

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ABSTRACT

The assessment of a river water' quality is an essential procedure of monitor programs and is used to collect basic environmental data. The management of integrated water resources in a sustainable method is also necessary to allow future generations to meet their water needs. The main objective of this research is to assess the effect of the Diyala River on Tigris River water quality using Geographic Information System (GIS) technique. Water samples have been collected monthly from November 2017 to April 2018 from four selected locations in Tigris and Diyala Rivers using the grab sampling method. Fourteen parameters were studied which are Turbidity, pH, Dissolved Oxygen, Biological Oxygen Demand, Electrical Conductivity, Total Dissolved Solids, Total Hardness, Calcium, Magnesium, Chloride, Sulphate, Phosphate, Sodium, and Total Alkalinity. The results of GIS maps showed that the water quality of the Tigris River nearly affected by the water quality of the Diyala River within the locations selected. The maps also reveal that in March and April 2018 the quality of surface water got a sudden peak compared with the other months. This is due to the increase in both the parameter of Turbidity and Total Dissolved Solids.

Keywords: Geographic Information System, Diyala river, Water quality, Tigris river, Water quality index.

تأثير نوعية مياه نهر ديالى على نوعية مياه نهر دجلة باستخدام خرائط نظم المعلومات الجغرافية

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الخلاصة

يُعد تقييم نوعية مياه النهر إجراءً أساسيًا في برامج المراقبة ويستخدم لجمع بيانات بيئية أساسية. كما تعد إدارة الموارد المائية المتكاملة بطريقة مستدامة أمرا أساسيا للسماح للأجيال القادمة بتلبية احتياجاتها من المياه. الهدف الرئيسي من هذا البحث هو تقييم تأثير نهر ديالى على نوعية مياه نهر دجلة باستخدام تقنية نظم المعلومات الجغرافية. تم جمع عينات المياه شهريًا من تشرين الثاني2017 إلى نيسان 2018 من أربعة مواقع مختارة في نهري دجلة وديالى باستخدام grab sample. تمت دراسة

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أربعة عشر عنصر وهي العكارة ، الأس الهيدروجيني ، الأوكسجين الذائب ، المتطلب الحياتي للأوكسجين ، الأيصالية الكهربائية ، المواد الصلبة الذائبة الكلية ، المواد الصلبة الكلية ، الكالسيوم ، المغنيسيوم ، الكلوريد ، الكبريتات ، الفوسفات ، الصوديوم ، والقلوية الكلية. وأظهرت نتائج خرائط نظم المعلومات الجغرافية أن نوعية مياه نهر دجلة تتأثر تقريبا بجودة مياه نهر ديالى داخل المواقع المختارة. تكشف الخرائط أيضًا أن جودة المياه السطحية في آذار و نيسان من عام 2018 وصلت إلى ذروة مفاجئة مقارنة بالأشهر الأخرى. ويرجع ذلك إلى الزيادة في كل من عناصر العكارة والمواد الصلبة الذائبة الكلية.

الكلمات الرئيسية : نظم المعلومات الجغرافية، نهر ديالى، نهر دجلة، نوعية الماء و معامل نوعية الماء

1. INTRODUCTION

Tributaries of rivers may have a direct effect on physicochemical characteristics of a river itself by discharging significant amounts of domestic and industrial water to rivers that affect salinity; they also work to add plant nutrients to rivers, **Turkoglu and Koray, 2002**. The monitoring of water quality has the highest priority in the policy of environmental protection. The main objective of this monitoring is to control pollution problems, reduce their incidence and provide quality appropriate for water to serve different purposes like irrigation, drinking water supply, etc., **Boyacioglu, 2006**. Thus, assessing water quality is an essential process in water resources development. It can be assessed according to various techniques method that ranges in complexity and sophistication, **Lamparski, 2004**.

The simplest method for evaluating the condition of water quality is Water Quality Index (WQI), where it becomes easy to compare quality levels in various sites of a river and to give priority for the necessary treatment of a site **Kavitha and Elangovan, 2010**. Thus, WQI has been utilized as a powerful tool to get overall information of environmental performance on water quality condition in a readily and evident form that can be used by decision makers, administrators and people in an understandable pattern.

The visual presentations of water quality monitoring results help us to give a clear picture of surface water quality at a glance, where this can be achieved by the Geographic Information System (GIS). The complex relationships of the different water quality index in multiple locations can be easily studied if the results of water quality are displayed in a visually appealing manner as a map instead of a set of columns and rows. GIS is designed in a way that is easily combined with other programs **Hoover, 1997**.

2. STUDY AREA

The most important stem of the Tigris River is Diyala tributary, which is considered one of the primary water resources in Iraq. The Diyala River is located between longitude (44° 30´E- 45° 20´E) and latitude (33° 130´N- 35° 50´N) and passes through the Diyala province north-eastern Baghdad, **AL-Dulaimi, 2017**. River water samples were collected from four stations to examine the physical and chemical characteristics; two stations were selected from Tigris River and the other two from Diyala River as shown in **Fig. 1** to know the impact of Diyala River water quality on Tigris River water quality. The Global Positioning System (GPS) has been used to record the accurate latitudinal and longitudinal coordinates of each site to be identified later on digital maps. **Fig. 2** refers to the locations of the sampling and their profile in kilometers along the two rivers reach, with an indication to the most polluted site among all.

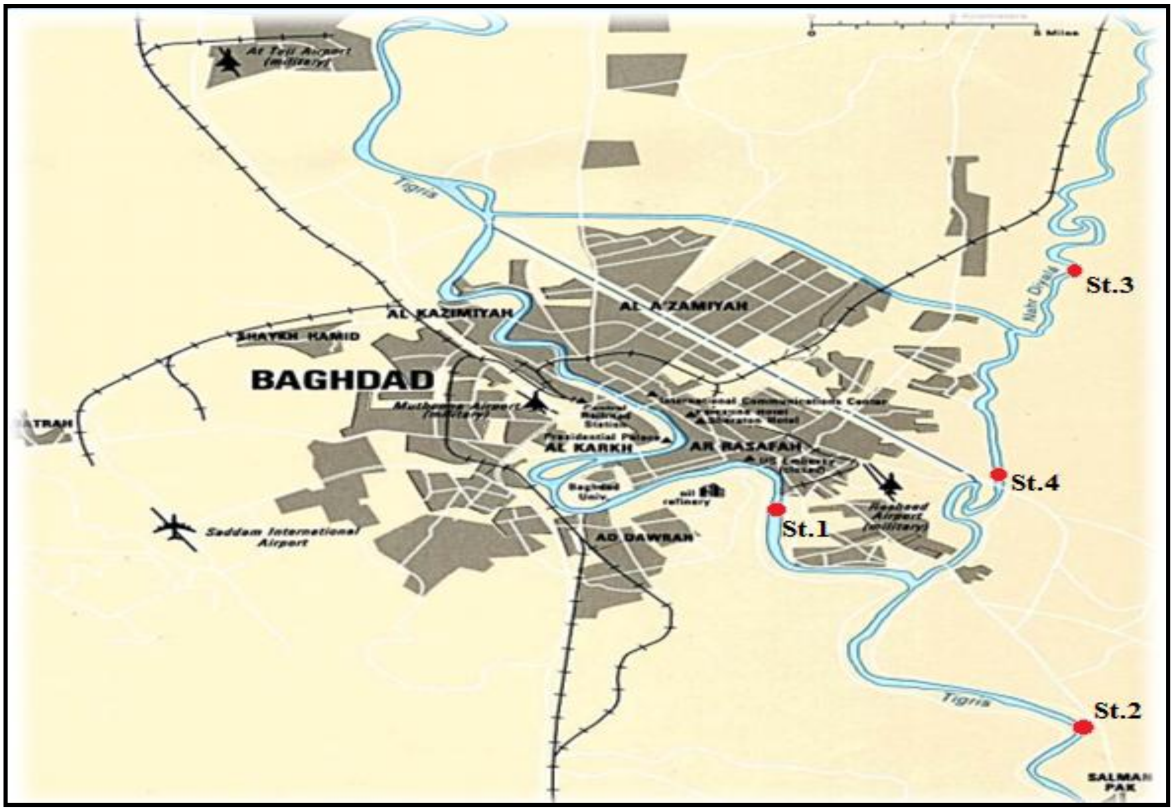


Figure 1. Sampling stations on Tigris River and Diyala River at Baghdad city.

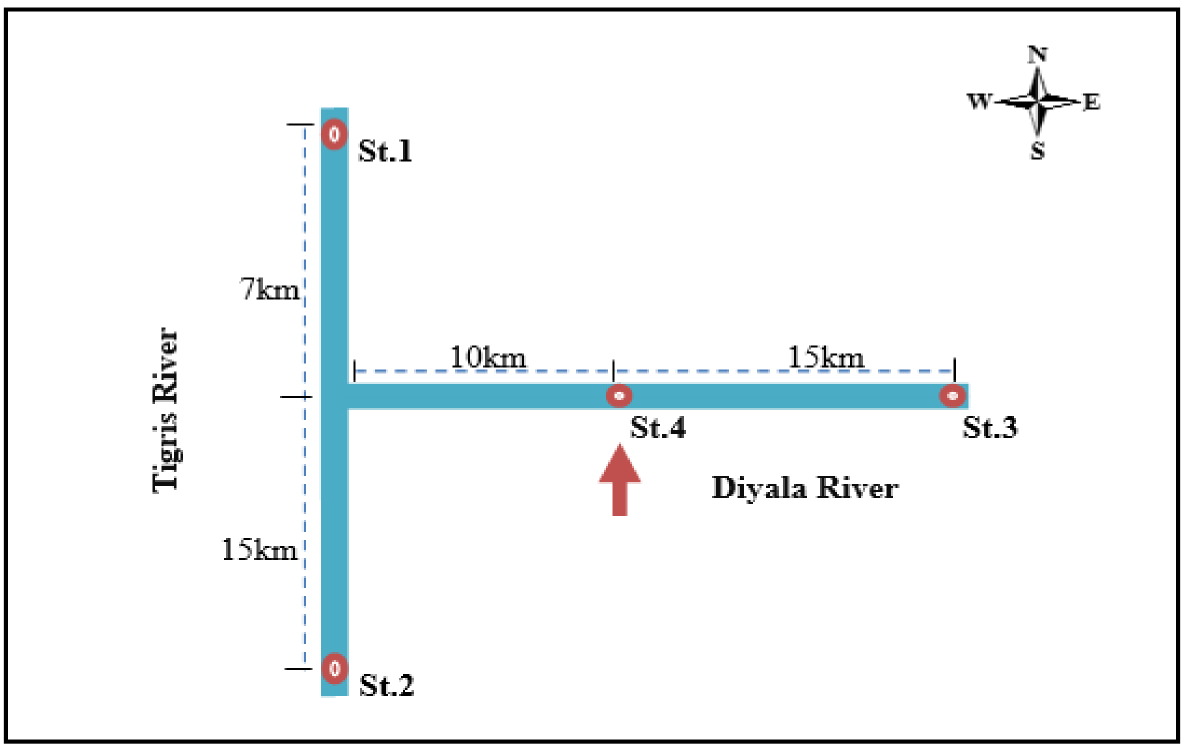


Figure 2. Sampling profile in kilometers for the selected stations.

3. SAMPLE COLLECTION

Water samples have been collected monthly from November 2017 to April 2018 from four selected locations in the Tigris and the Diyala Rivers using the grab sampling method. They were collected using polyethylene containers and placed in glass bottles of 2-liter capacity. They were rinsed several times before filling. These samples are kept in a refrigerator and are analyzed as soon as possible after collection in the environmental laboratory in Environmental Ministry at Baghdad city. Sampling usually started at 8:30 am to 11:30 am. Water samples were taken on a distance of 5 m from the bank of the river with high ranges between (25-35) cm below the water surface. These procedures used for sampling are by standard methods for American Public Health Association, **APHA, 1998**.

4. WATER QUALITY INDEX

The Water Quality Index (WQI) is a reliable and straightforward approach because it provides an outline of overall water quality. Also, it also facilitates the comparison between various sampling sites at different points of time, so that it can be utilized for furnishing a comprehensive summary of ecological performance which can be expressed understandably by the public **Nathan, et al., 2017**.

The concept of WQI depends on the principle of collating water quality parameters and comparison with permissible limits of regulatory standards to produce a single number that expresses the overall water quality at specific sites according to some water quality characteristics. The WQI improves the understanding of water quality issues by complex data integrating and generates a score that describes the status of water quality and evaluates the trends of water quality, **Singh and Khan, 2011**. In this research, the Arithmetic Weighted Index method was used to compute WQI.

4.1 Weighted Arithmetic Index method

According to this method, water quality is classified based on the purity degree utilizing the most common water quality parameters, **Paun et al., 2016**. In general, weighting method means the relative significance of each factor in the overall water quality, and it depends on standards permissible for drinking water quality recommended by the Iraqi standard organization (ISO/417, 2001) as shown in **Table 1**. Factors that have high allowable limits are considered less harmful and have low weighting, **Al-Hashimi, 2017**. The water quality index was calculated using the following equation (Eq. 1, 2, 3 and 4) according to **Brown, et al., 1973**:

$$WQI = \frac{\sum_{n-1}^{n}(Q_i \times W_i)}{\sum_{n-1}^{n} W_i} \quad (1)$$

Where: n= Represents the parameters of water quality.

Q_i= Scale of quality rating for each parameter and is given as:

$$Q_i = 100 \times \left(\frac{V_i - V_{I0}}{S_i - V_{I0}}\right) \quad (2)$$

V_i= Measured value at the sampling point of the n^{th} parameter, S_i= Standard value of the n^{th} parameter and V_{I0}= Ideal value in the pure water of the n^{th} parameter.

Each of the ideal values (V_{10}) are considered zero value for the drinking water, while the ideal values for pH and DO are 7.0 and 14.6 mg/l respectively.

The unit weight (W_i) was calculated by a value inversely proportional to the permissible standard values (S_i) for corresponding parameters, and this value ranges from (0-1).

$$W_i = \frac{K}{Si} \quad (3)$$

K= proportionality constant and measured by the following equation:

$$K = \frac{1}{\Sigma\left(\frac{1}{S_i}\right)}$$

(4)

Table 1. Iraqi drinking water quality specifications standard IQS/417, 2001.

Parameter	Symbol	Unit	Guideline
Hydrogen Ion	pH	-	6.5-8.5
Phosphate as Ortho-phosphate	PO_4^{-3}	mg/l	1
Chloride	Cl^-	mg/l	250
Calcium	Ca^{+2}	mg/l	50
Magnisium	Mg^{+2}	mg/l	50
Total Hardness	TH	mg/l as CaCO3	500
Sulfate	SO_4^{-2}	mg/l	250
Turbidity	Turb.	NTU	5
Dissolved Oxygen	DO	mg/l	>5
Biological Oxygen Demand	BOD_5	mg/l	<5
Total Dissolved Solids	TDS	mg/l	1000
Electrical Conductivity	EC	µS/cm	2000
Total Alkalinity	TA	mg/l as $CaCO_3$	500
Sodium	Na	mg/l	200

4.2 Classification of water quality

Any source of water can be classified into different classes indicating the beneficial use(s) to which it can be put to. The classes are based on the allowable limits of relevant water quality parameters or set of standards developed by various authorities. Water quality of the region can be determined according to how suitable for use. The study of the region case was classified according to specifications of drinking water using **Table 2** for arithmetic weighted index method.

Table 2. Water quality classification based on WQI value for drinking proposes, **Tyagi et al., 2013**.

class	Water Quality Index Level	Water quality classification
1	0-25	Excellent water quality
2	26-50	Good water quality
3	51-75	Poor water quality
4	76-100	Polluted water quality
5	More than 100	Very polluted water quality

5. GEOGRAPHIC INFORMATION SYSTEM

To analyze, visualize and create geospatial data, a set of software represented by GIS technique is used. Information about the geographic locations is referred by geospatial data, which include a geographic coordinate, like a longitude or latitude value. While spatial data contains geographic data, GIS data, map data, spatial geometry data, and location data, **Sherman, et al., 2005**, so that this data can be analyzed and integrated to derive useful outputs and modeling.

GIS techniques have been developed to facilitate the integration and analysis of large amounts of multidisciplinary data whether spatial and non-spatial within the same geographic reference. To interpolate the water quality parameters at unknown locations through known values, the spatial analysis of GIS can be used for creating a continuous surface that helps to understand the water quality condition scenarios of the study area, **Singh and Khan, 2011**. Hence, tools of the spatial analysis are used to re-classify the water quality parameter and WQI into various categories, and each category is specified with a unique number. Spatial distribution model has been adopted to create analytical maps for the water quality index. The Inverse Distance Weighted (IDW) is one of the deterministic interpolation techniques that is used in this study to obtain thematic maps. This method does not extrapolate beyond the maximum and minimum values, and it gives accurate and detailed results on an observation area. **Fig. 3** presents the methodology adopted for the GIS study**.**

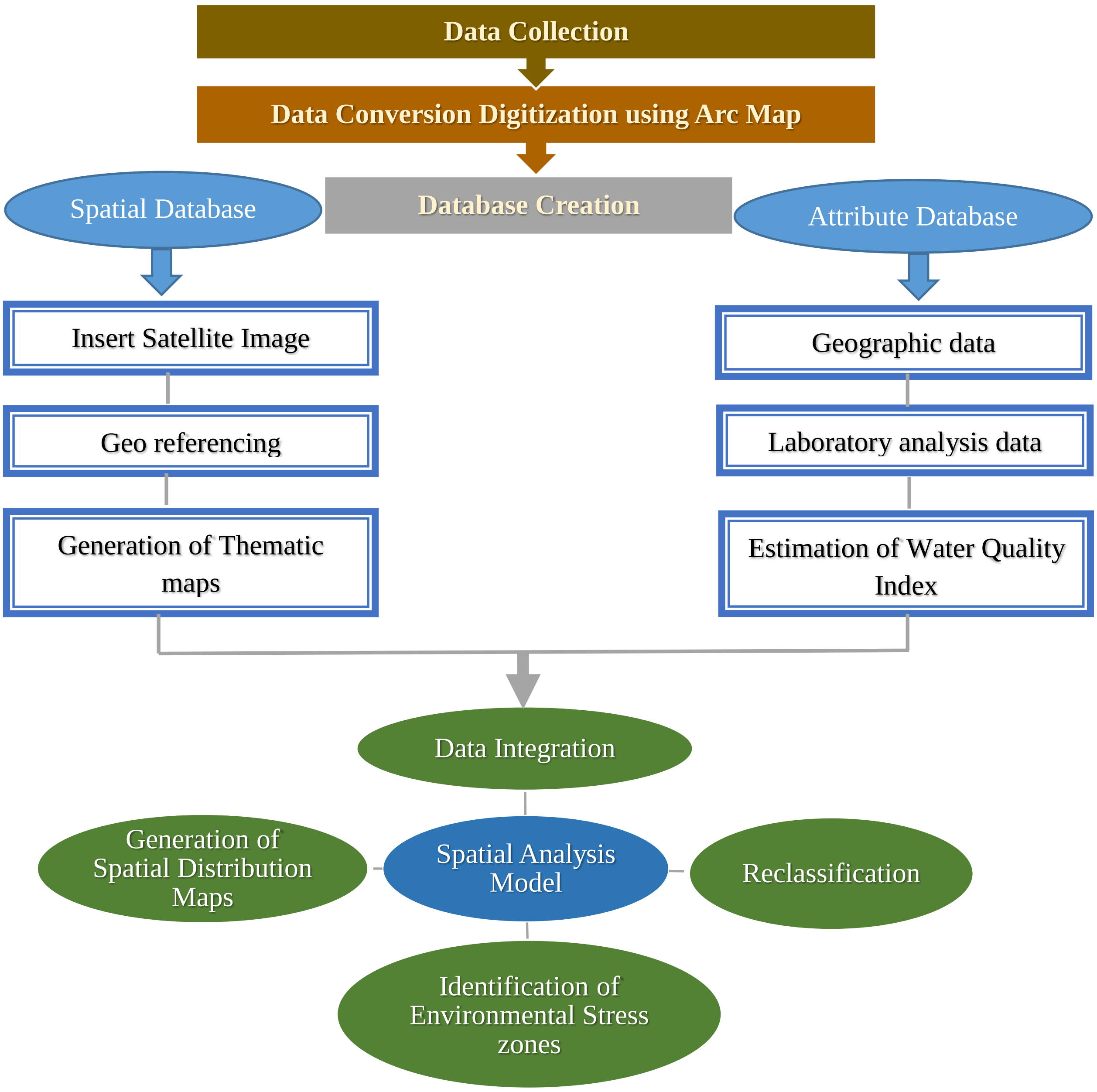


Figure 3. Flowchart for GIS methodology in this research.

6. RESULTS AND DISCUSSION

6.1 Calculations of Water Quality Index (WQI)

The results of the physic-chemical parameters of water stations are pH, Turbidity, DO, BOD_5, PO_4^{-3}, Ca^{+2}, Mg^{+2}, TH, Na, SO_4^{-2}, Cl^-, TDS, EC, and TA. The WQI values calculated in this research indicate the degradation of the Tigris River's water through the Diyala River water as shown in **Table 3**. The water quality of the Tigris and the Diyala Rivers can be classified according to weighted arithmetic index values and distribution results based on their respective quality classes as present in **Table 4**.

According to WQI values, the maximum value was 364.56 at Al-Kargholea station in February 2018, while the minimum value was 58.655 at AL-Zaaforania station in December 2017. Thus, the quality of the Tigris River water and the Diyala River were classified as poor to very polluted for drinking water respectively.

The results of weighted arithmetic water quality index showed that the quality of the Diyala River water classified as a very polluted class especially at station 4. Also according to a weighted arithmetic index, the Tigris River was classified as a poor class at station 1, while was classified as polluted class at station 2 after its meeting the Diyala River, which indicates the effect of the Diyala River water in the quality of the Tigris River water.

Table 3. Monthly WQI variations for all stations along Tigris and Diyala Rivers within Baghdad City.

Station	Tigris River		Diyala River		Min.	Max.
	AL-Zaaforania	AL-Madian	9 Nissan	Al-Kargholea		
November 2017	74.436	94.895	82.873	277.3	74.436	277.3
December 2017	58.655	76.965	104.37	211.47	58.655	211.47
January 2018	58.856	65.041	61.308	215.89	58.856	215.89
February 2018	62.576	95.211	58.846	364.56	58.846	364.56
March 2018	127.3	147.34	109.44	270.64	109.44	270.64
April 2018	104.29	114.71	108.73	239.43	104.29	239.43
Min.	58.655	65.041	58.846	211.47	58.655	211.47
Max.	127.3	147.34	109.44	364.56	109.44	364.56

Table 4. The classification of water quality of Tigris and Diyala Rivers according to WQI values.

Station	Tigris River		Diyala River	
	AL-Zaaforania	AL-Madian	9 Nissan	Al-Kargholea
November 2017	Class 3 poor	Class 4 polluted	Class 4 polluted	Class 5 Very polluted
December 2017	Class 3 poor	Class 4 polluted	Class 5 Very polluted	Class 5 Very polluted
January 2018	Class 3 poor	Class 3 poor	Class 3 poor	Class 5 Very polluted
February 2018	Class 3 poor	Class 4 polluted	Class 3 poor	Class 5 Very polluted
March 2018	Class 5 Very polluted	Class 5 Very polluted	Class 5 Very polluted	Class 5 Very polluted
April 2018	Class 5 Very polluted	Class 5 Very polluted	Class 5 Very polluted	Class 5 Very polluted

6.2 Geographical Information System (GIS) model

Spatial analysis model in GIS software version 10.3 has been used in this research. The thematic maps were prepared by toposheet on 1:130,000 scale using Arc/Info GIS. Spatial analysis of water quality index was carried out by interpolation of sampling stations by the algorithmic method 'Inverse Distance Weighted'. The cells values can be predicted by using the interpolation method at locations lacking sampled points. This method depends on the principle of spatial reliance or spatial autocorrelation, which works on the measurement of the degree of reliance/relationship between distant and near objects. The attributes table appears in **Table 5** to show stations coordinates and WQI values

To control the characteristics of the interpolated surface, the input points utilized to calculate the values of the output cells can be specified. This can be done by determining the number of sampling points or sampling area. Determining the maximum number of sampling points will come back the points nearest to the location of the output cell until reaching the maximum number.

Table 5. The attribute table for the four stations.

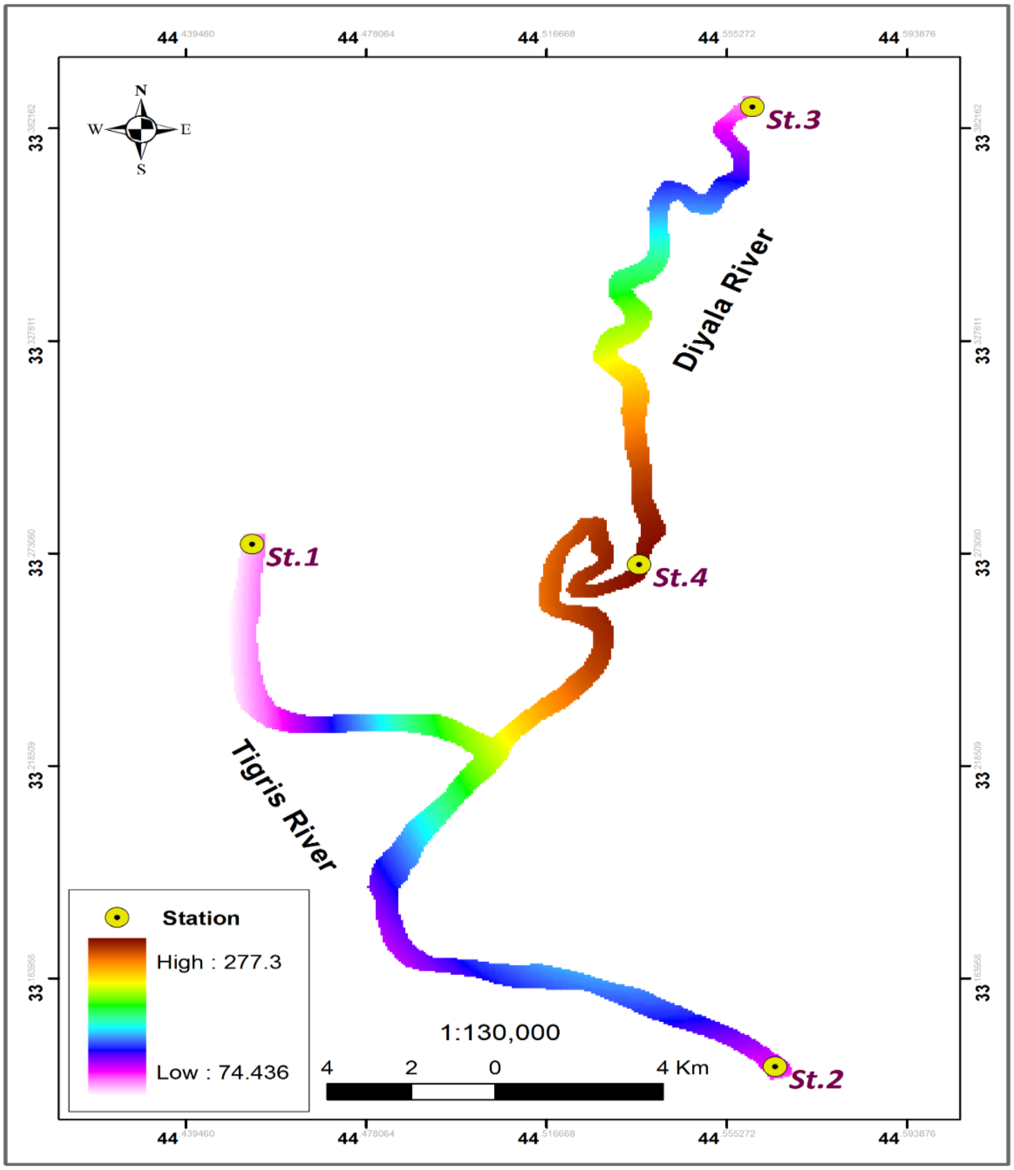
Attributes of 4 stations

FID	Shape *	Stations	X1	Y1	Nov.(2017)	Dec.(2017)	Jan.(2018)	Feb.(2018)	Mar.(2018)	Apr.(2018)
0	Point	St.1	44° 27' 12.737" E	33° 16' 31.147" N	74	59	59	63	127	104
1	Point	St.2	44° 33' 55.948" E	33° 8' 28.134" N	95	77	65	95	147	115
3	Point	St.3	44° 33' 38.517" E	33° 23' 15.407" N	83	104	61	59	109	109
2	Point	St.4	44° 32' 10.945" E	33° 16' 12.246" N	277	212	216	365	271	239

6.2.1 Spatial Distribution of Water Quality Index

The water quality index maps have been created from November 2017 to April 2018 and are shown in **Fig. 4** to **Fig. 9**. The maps show that the quality of the Tigris River water was nearly affected by the quality of the Diyala River water within the locations selected. The maps also reveal that in March and April 2018, the quality of surface water got a sudden peak compared with the other months. The reason may be due to the rainfall over the catchment area of the River or discharge quantity of sewage effluent from treatment plants in Al-Rustamiya.

In November 2017, as shown in **Fig. 4,** the WQI values are between 74.436 and 277.3 and the categories are 'poor' to 'very polluted'. In December 2017 and January 2018 also WQI values are almost between 58 and 200, 'poor' and 'very polluted 'categories as shown in **Fig. 5** and **Fig. 6** respectively. In February 2018 as shown in **Fig. 7**, WQI was between 62.576 and 364.56; this reveals that the water quality is in the categories of 'poor' to 'very polluted'. While in March and April 2018, WQI values were nearly between 100 and more than 200; this reveals that the water quality is in the 'very polluted' categories as shown in **Fig. 8** and **Fig. 9** respectively. From the results the overall characteristics of the Tigris River show 'poor' and 'very polluted' quality while the Diyala River show 'polluted' and 'very polluted' quality in terms of WQI.



Fiqure 4. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in November 2017.

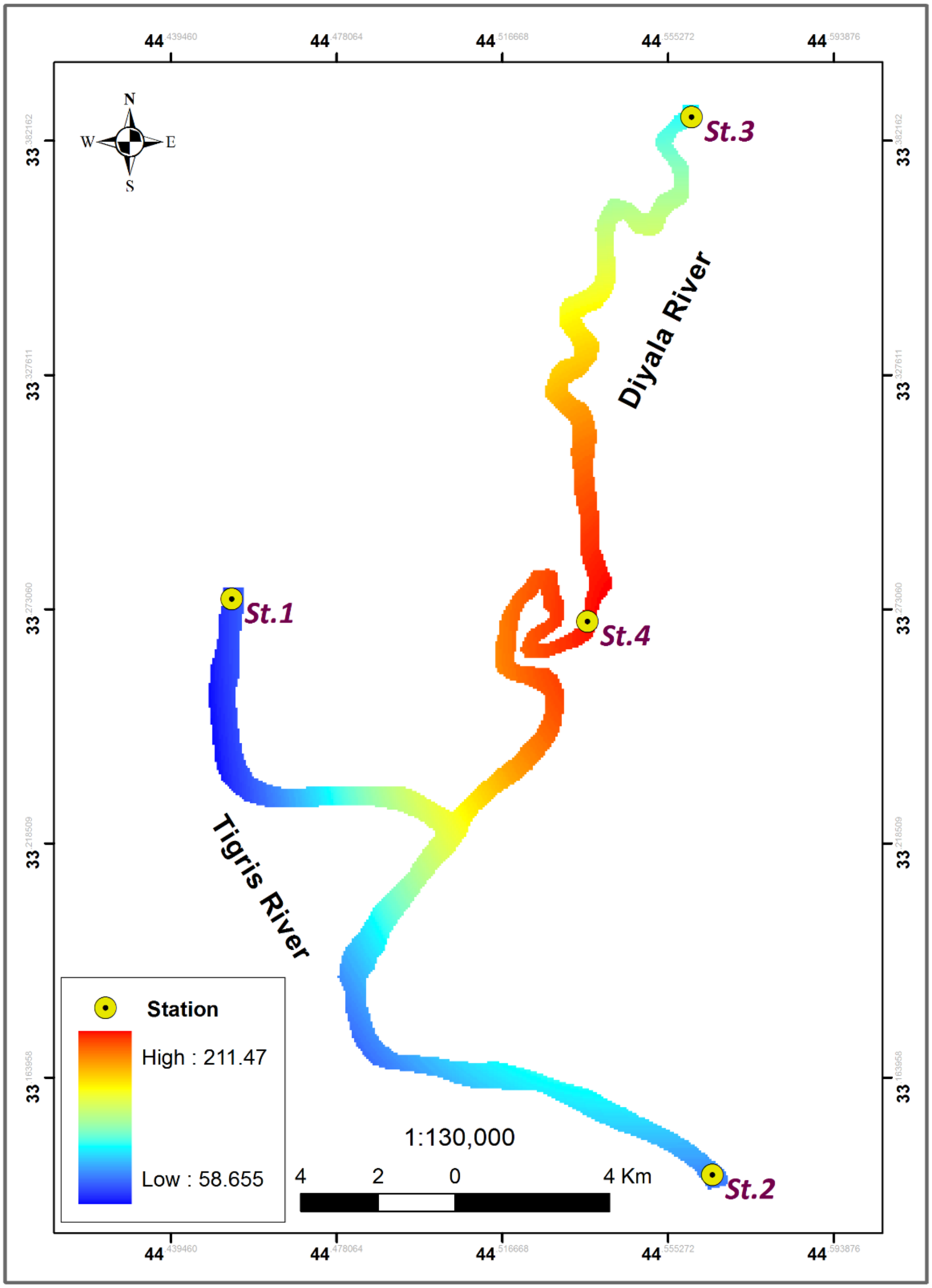


Figure 5. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in December 2017.

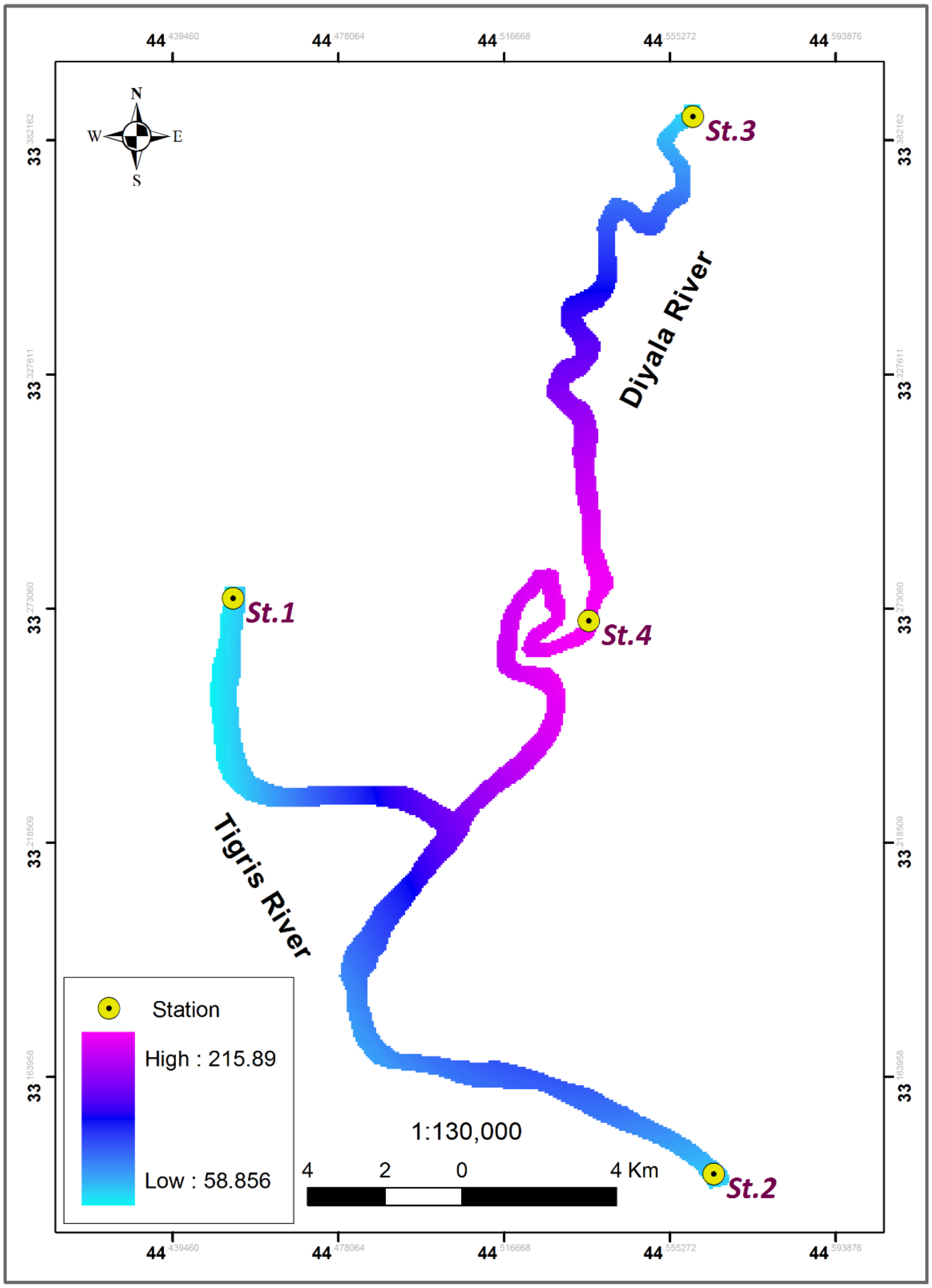


Figure 6. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in January 2018.

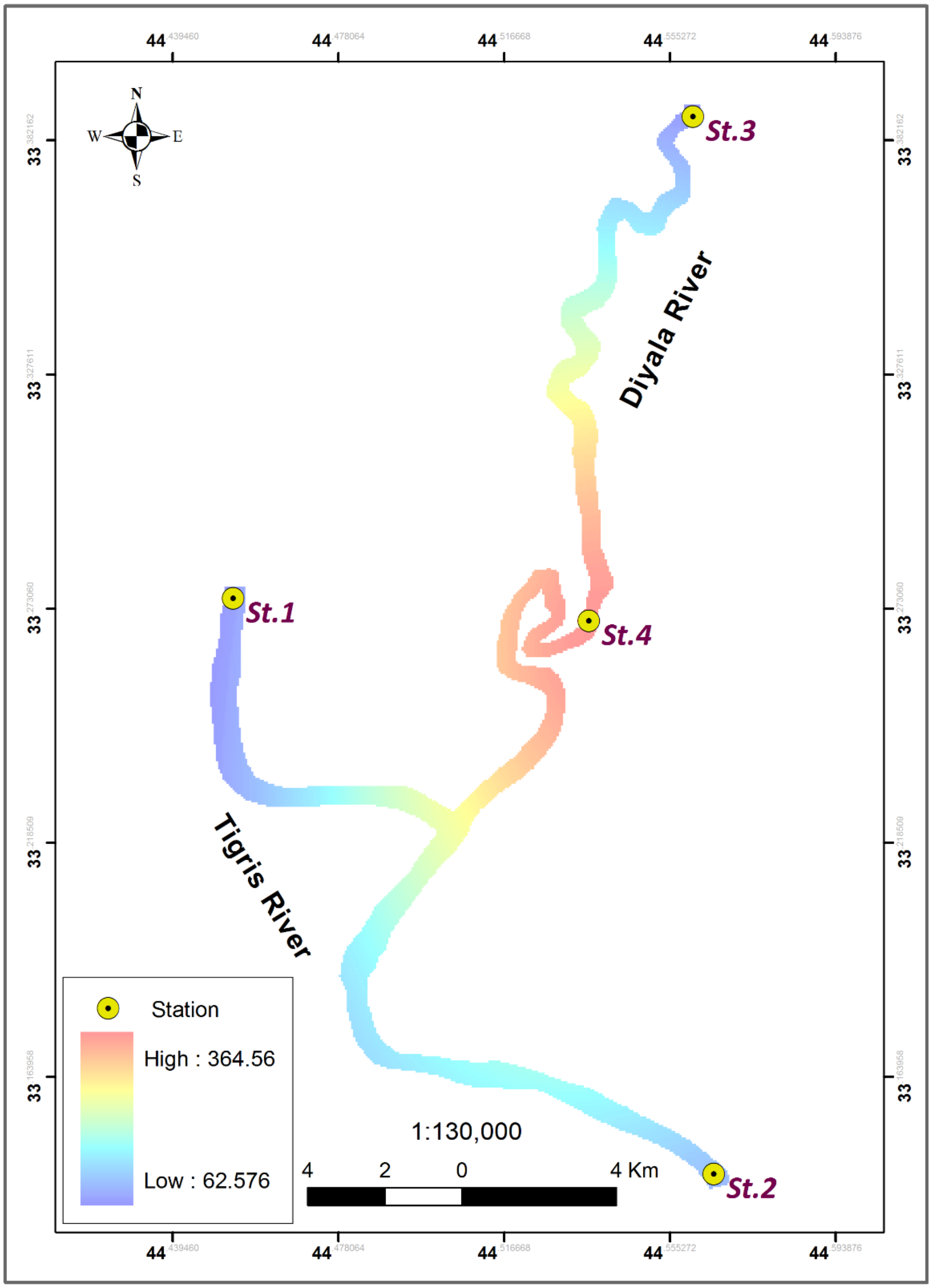


Figure 7. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in February 2018.

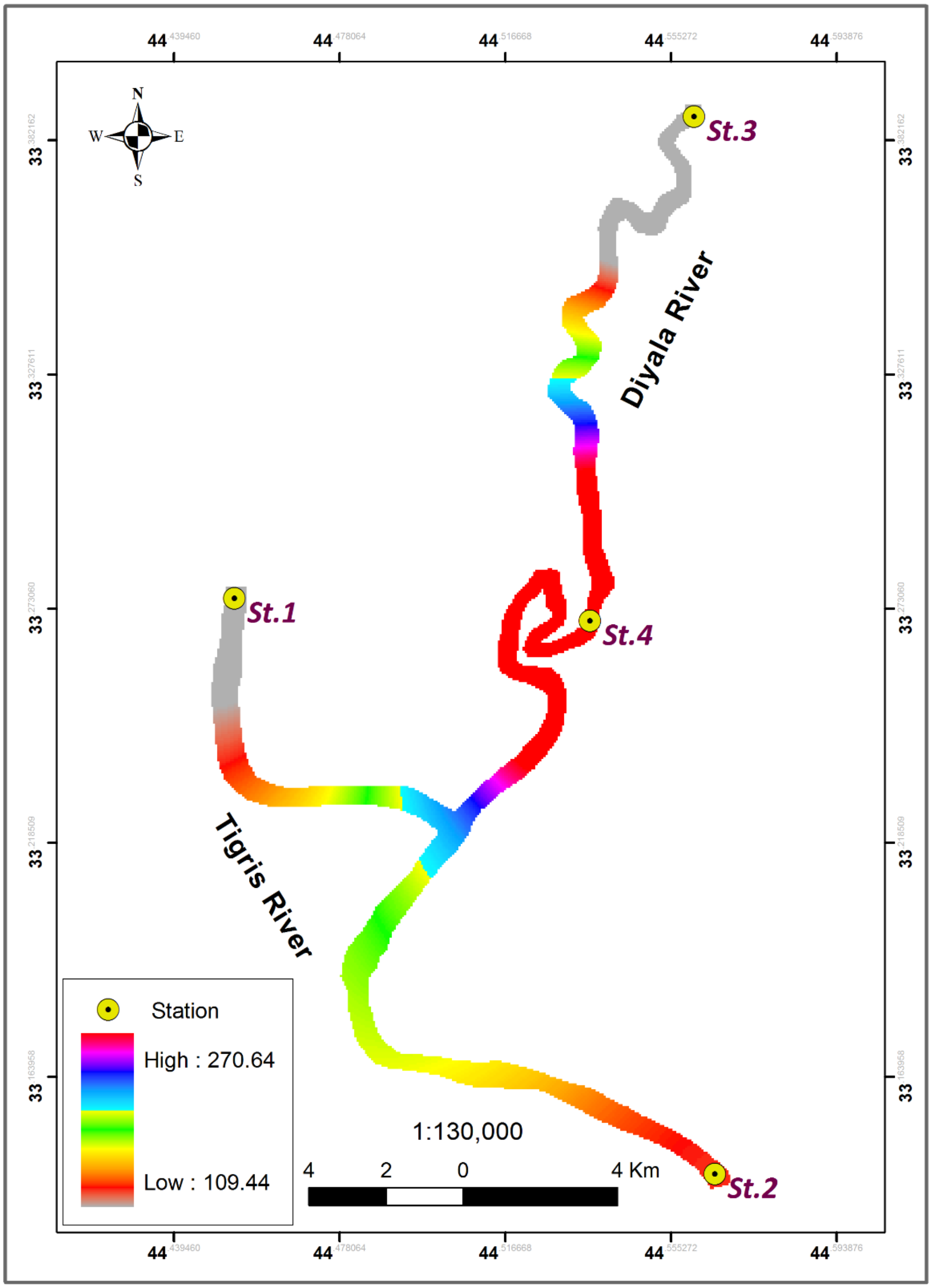


Figure 8. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in March 2018.

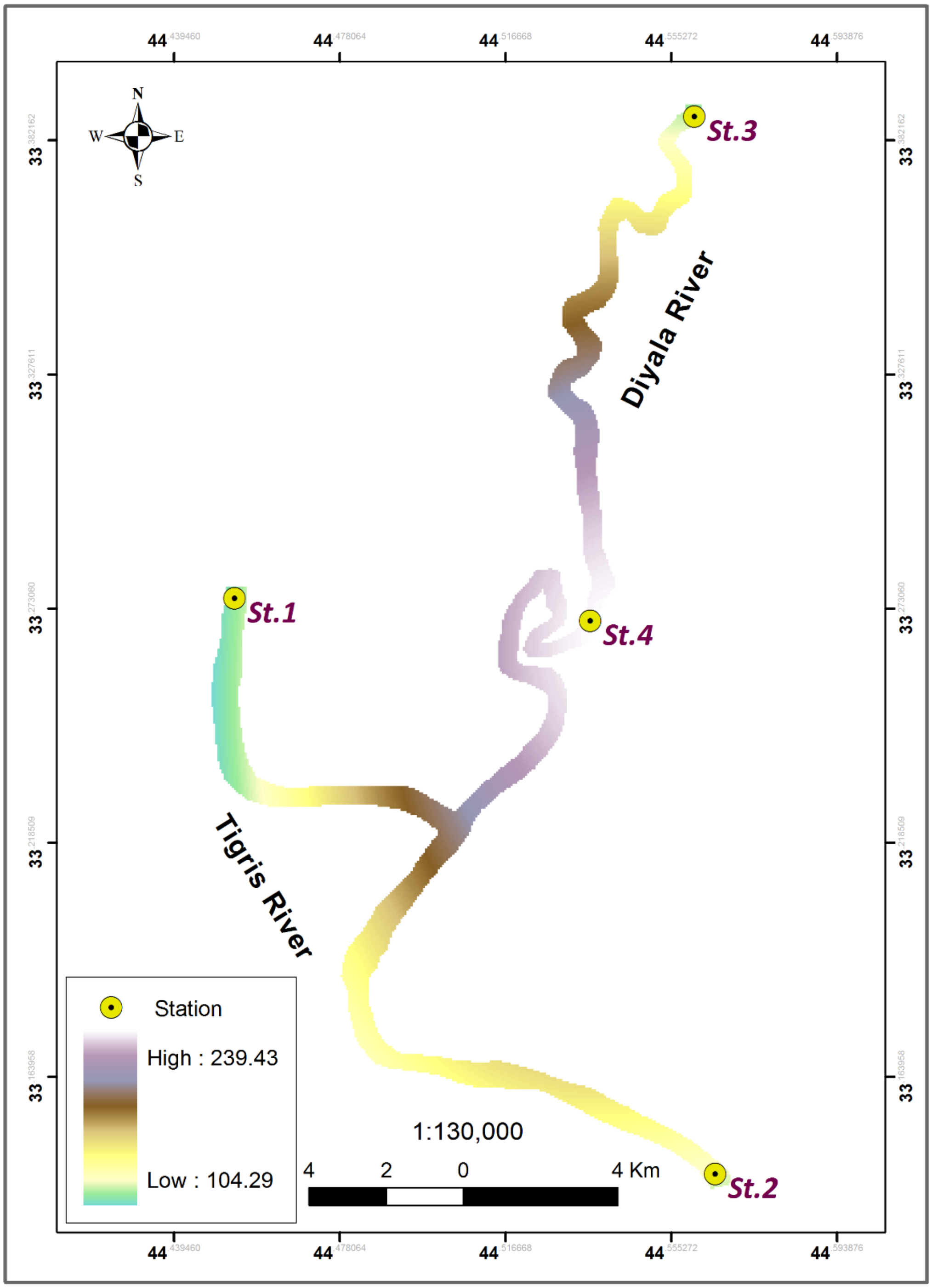


Figure 9. Spatial variation of Water Quality Index in Tigris and Diyala Rivers in April 2018.

7. CONCLUSIONS

1. Station 4 in the Diyala River is the most polluted site because it is being subjected to the influences of Al-Rustamiya sewage treatment plants (STPs) which is discharged directly into the Diyala River.

2. The Weighted Arithmetic Water Quality Index was used for evaluating the effect of the Diyala River water quality on the Tigris River water quality, where it is shown that the Diyala River contributed to converting the quality of the Tigris River water from poor class to polluted class.

3. Poor water quality in the Tigris River after the confluence with the Diyala River indicates deterioration in the quality of this water and its inability to support aquatic life, which means the presence of a negative effect on drinking water and biodiversity in the study region.

4. The colored maps of water quality index give a clear picture of its spatial distribution. The water quality parameters namely chloride, calcium, total dissolved solids, sulphate, total hardness, and phosphate are found to be excessive at Al-Kargholea station (St.4). Dissolved oxygen is found to be nil there. A large quantity of sewage generated in Baghdad city reaches the river through Al-Rustamiya WWTPs, and that is the main reason for the deterioration of water quality in the Diyala River and its effect on the Tigris River. The problem can only be solved by installing adequate treatment sewage plant to accommodate the large wastewater quantities.

8. RECOMMENDATIONS

1. Finding proper solutions which include improving and increasing the design capacity and fixing the damage that occurs to wastewater treatment plants placed south of Baghdad City on the Diyala River (Northern Al-Rustamiya and Southern Al-Rustamiya) to accommodate the large quantities of wastewater.

2. Investing the political and diplomatic momentum in activating the international and binary agreements of shared states for water resources and preserving the quality and quantity of water entering the Iraqi boundaries with all of (Syria, Iran, and Turkey), which have a direct impact on water quality and its ability to tolerate the accommodation of pollutants and self-purification.

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