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SURVEY AND DISCHARGE MEASUREMENTS OF THE IRAQI BORDER CROSSING RIVERS

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Abstract

There are many wadies, and streams crossing the Iraqi-Turkish and Iraqi-Iranian borders and some of these are permanent and others are seasonal. Most of the catchment areas of these rivers, wadies and streams lie outside Iraq. In this paper, an extensive review of literature related to these rivers, wadies, and streams crossing the Iraqi border was conducted and discharge measurements on them was carried out at points close to the Iraqi borders. The measured discharge of all rivers and wadies were carried out in three measuring dates. These forty two rivers, streams, and wadies are spread along the Iraqi Border of which two rivers are within Wasit Governorate, two rivers are within Maysan Governorate, nine wadies within Diyala Governorate, twenty rivers are within AsSulaymaniyah Governorate, five rivers are within Erbil Governorate and four rivers are within Dahuk Governorate. It was found that there was a lack in studies, information, and reports related to border crossing rivers, and no information were available regarding nineteen rivers within Kurdistan Region. Some of the wadies were dry during the measurements, and the maximum discharge among all measurements was 888.8 m^3/s.

Keywords: Border crossing rivers, Discharge measurement, Iraqi rivers, Water resources of Iraq.

1. Introduction

Throughout its long history, Iraq has abundant of surface water. Controlling the flood is the main challenge in the country. The change in climate reflected in less rainfall, and dams and irrigation projects erected on the rivers and wadies crossing the boundaries by Turkey, Syria, and Iran, as a result, the flow of water into Iraq has greatly decrease. Consequently, with the population growth and the increasing needs for irrigation, water shortage is intensifying and became the most challenging problem.

After years of wars, sanction and lack of budget, there are limited historical records or water resources studies on Iraq-Iran and Iraq-Turkey borders crossing rivers. Most of the available data, information, reports and studies are old, conflict in its information, and are not representing the current actual situation. Therefore, it is necessary to update the available data to support the decision makers to optimally manage the available water resources to overcome water shortage problem as possible.

There are more than fifty rivers, wadies, and streams crossing the Iraqi-Turkish and Iraqi-Iranian borders, some of them are permanent and others are seasonal. Most of their catchment areas lie outside Iraq. In general, the flow of some rivers, wadies, and streams suddenly increases during rain events. High flow may last either for few hours or days depending on the rainfall intensity and duration. Meanwhile, during summer, some of these rivers and wadies have a low or no flow.

This paper aimed at summarizing available literature related to rivers, wadies, and streams crossing the Iraqi borders, and reporting discharge measurements at selected sections on each of these rivers, wadies, and streams close to the Iraqi borders.

2. Review of Literature on the Iraqi Border Crossing Rivers

An extensive search on the literature survey related to rivers, wadies, and streams crossing the Iraqi border were carried out beside personal efforts to get information from directories of the Ministry of Water Resources in Baghdad and that in Kurdistan Region. It was found that there is lack of studies, information, and reports related to the rivers crossing the borders, contradicting information in some of the available studies. No information are available regarding Hawar, Bayyara, Khormal, Qadafari, Tutaqach, Nallpareze, Panjwin, Rawjan, Golee, Ahmed Awa, Seyaquaze, Palkybeshder, KandeelBeshder, Sanksar, Choman, Sowarri, KaniKaymah, and Shiransh rivers. Available information concerning the rivers and wadies are summarized below:

Dwayreach river, according to the data provided by the Department of the Water Resources of the Directorate of Water Resources of Missan Governorate, most of the catchment area of the river lies inside Iran and it is estimated to be 3310 km^2 with a total length of 159 km. The maximum elevation of the catchment area is about 2250m.a.m.s.l. and it enters Iraq at an elevation of about 100 m.a.m.s.l. The annual volume from this river is estimated to be 0.36 to 0.8 billion m^3 with a maximum discharge of 1600 m^3/sec and a minimum discharge of 1 m^3/sec. The river discharges into AsSainaf Marsh. Generally, the river water is found with high salt content. The Center for Restoration of Iraq Marshlands carried out a study on rehabilitation of Al Huwayza Marsh during 2006 [1]. The study presents the results of water sampling and water quality tests and discharge measurements of the marsh feeders including Dwayreach river. The tested water quality parameters are dissolved oxygen, acidity,

electrical conductivity, total dissolved solids, NO_3, SO_4, turbidity, and biochemical oxygen demand.

Water sampling and discharge measurements were carried out at upstream of Dwayreach Bridge, which is located at 735669 E and 3554353 N. Testing water quality and discharge measurements were carried out during January to July 2006 with two measurements each month. The discharge measurements are listed in Table 1. The average of the recorded discharges during this period was 24.3 m^3/s and maximum and minimum of 202 and 0 m^3/s, respectively**.**

Table 1. Discharges of Dwayreach River during 2006.

Month	**Jan**	**Feb**	**March**		**April**		**May**		**June**		**July**	
	23	**8**	**16**	**30**	**13**	**27**	**1**	**25**	**8**	**22**	**6**	**20**
Discharge, m^3/s	202.0	94.0	0.18	0.16	0.15	0.06	0.06	0.0	0.0	0.0	0.0	0.0

AtTeeb river, the catchment area of the river is estimated by about 2935 km^2, which is mostly lies inside Iran, having a maximum elevation of about 2500 m.a.m.s.l. It enters Iraq at an elevation of about 100 m.a.m.s.l. The river length is 202 km, and its annual inflow is estimated of about 0.45 billion m^3. Its maximum discharge varies between 1100 and 1400 m^3/sec and its minimum discharge is about 1 m^3/sec or less. The water of the river is considered of high quality. The river discharges its water into AsSainaf Marsh [1]. CRIM studied AtTeeb river as one of Al Huwayza Marsh feeders as mentioned previously. Water sampling and discharge measurements were carried out at upstream of AtTeeb bridge located at 712071 E and 3549412 N. The measured discharges during the period of the study are listed in Table 2. The recoded discharges varied between 0.51 to 154 m^3/s with an average of 18 m^3/s.

Table 2. Discharges of AtTeeb River during 2006.

Month	**Jan**	**Feb**	**March**		**April**		**May**		**June**		**July**	
	23	**8**	**16**	**30**	**13**	**27**	**1**	**25**	**8**	**22**	**6**	**20**
Discharge, m^3/s	154.0	55.2	1.55	1.55	1.4	1.38	1.3	0.74	0.51	0.72	0.74	0.71

According to the data provided by the Department of the Water Resources of the Directorate of Water Resources of Missan Governorate, the mean monthly discharges of Atteeb River, are listed in Table 3, were measured during the period extended from 1999 to 2007. The maximum mean monthly discharges during this period are 1000 m^3/s of February, and the minimum is 10 m^3/s of July, August, and September [2].

Table 3. Mean monthly discharges of Atteeb River.

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Mean monthly discharge, m^3/s	400	1000	700	125	50	12	10	10	10	15	18	75

AshShihabi river is also known as Al Chabab river. According to the data provided by the Department of the Water Resources of the Directorate of Water Resources of WASIT Governorate, the catchment area of the river is estimated to be 1270 km^2, which is mostly located in Iran. The length of the river before it enters Iraq is equal to 87 km and runs for 50 km within Iraq. It discharges its water into

Tigris river at a point located at 27 km south of Al Kut City. The river water is of high saline quality, especially during summer. The annual inflow of the river is estimated to be about 0.15 billion m^3. The discharge of the river during floods is estimated to be 700 to 850 m^3/s. These flood discharges may remain for few hours or for limited period no more than two days. The flood discharge of the river during 1994, which was estimated to be 400 m^3/s, caused the water level within the Tigris River at Al Amarah City to rise to a level of 8.2 m.a.m.s.l. This level is recorded during the high Tigris river flood in 1988 [3].

According to the data provided by the Department of the Water Resources of the Directorate of Water Resources of Wasit Governorate, the mean annual volume of the inflow of AshShihabi river for the period extended from 2000 to 2013 is 0.115 billion m^3. The maximum recorded monthly mean discharge during the same period is 19.4 m^3/s of December 2003. Table 4 shows the mean monthly discharge for the period 2000 to 2013. The maximum mean monthly discharge is 8.86 m^3/s of May and the minimum is 1 m^3/s of August.

Table 4. Mean monthly discharges of AshShihabi River.

Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Mean monthly discharge, m^3/s	5.67	5.84	3.86	2.61	8.86	1.07	1.06	1	1.26	2.15	4.9	5.74

Khallal Badrah river, most of catchment area of the river lies inside Iran and it is estimated to be 1244 km^2. The total length of the river is about 128 km of which 42km within the Iraqi borders. The maximum elevation of the river catchment area is about 2613m.a.m.s.l. It enters Iraq at an elevation of about 200 m.a.m.s.l.. The river ends at AshShwaycha Marsh. The annual inflow of the river is estimated to be about 0.2billion m^3 and its maximum discharge is 830m^3/sec [4].

According to the data provided by the Directorate of Water Resources of Wasit Governorate, the mean annual volume of inflow of Badrah River for the period extended from 1989 to 2006 is 0.321 billion m^3. The maximum and minimum annual mean discharges during this period are 32.9 m^3/s of 1994 and 4.33 m^3/s of 2001, respectively [5].

Terssag Wadi, the catchment area of the wadi lies inside Iran and it is estimated to be 1250 km^2 and its recorded maximum discharge is 814 m^3/s [3]. According to the data provided by the Directorate of Water Resources of Diyala Governorate, the water of the river is of high saline that may reach an EC of 4200 µs/cm. The annual runoff volume to the wadi was estimated to be 0.498 billion m^3 during 2007 and 0.464 billion m^3 during 2008. Table 5 presents the measured monthly discharges of the wadi during 2002, 2003, 2005, and 2008. The maximum discharge during these years was 120 m^3/s, recorded during January 2003, while the minimum was 0.9m^3/s, recorded during August 2003. The discharge of the wadi was measured during a heavy rain of 79 mm that last for two days on its catchment area on 14th Dec 2002. The measured discharge reached 1056m^3/s and last for 65hr. This high discharge caused flooding of most of villages along the wadi. The recorded discharge of the wadi on 25th Feb 2010 was 987 m^3/s.

Table 5. Discharges of Terssag Wadi.

Year	Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2002		17	3	2	2	2	1.8	1.4	1.2	1.3	1.2	3.4	7.9
2003	**Discharge**,	120	44	21	12	5	2	1.2	0.9	1.2	1.3	50	65
2005	m^3/s	8	6.7	7.6	5.7	3.5	2.6	1.78	1.1	1.1	1.8	3.5	6.7
2008		3.4	6.5	5.8	4.3	3.1	1.7	1.3	1.2	1.0	1.5	4.1	4.9

Leema Wadi, According to the data provided by the Directorate of Water Resources of Diyala Governorate, most of the catchment area of the wadi lies within the Iranian borders and it is estimated to be 780 km^2. The volume of inflow is about 0.165 billion m^3. The water salinity is about 3370 µs/cm. The length of the wadi within the Iraqi borders is 52km, and ends at AshShwaycha Marsh. The maximum recorded discharge of the wadi is 400 m^3/s. Table 6 presents the measured monthly discharges of Leema Wadi during 2002, 2003, and 2008 . The maximum discharge during these years was 23 m^3/s that was recorded during January 2003. No flow within the wadi was recorded during June, August, and September of these years in addition to June of 2008. The recorded discharge of the Leema Wadi on 25th Feb 2010 was 675 m^3/s.

Table 6. Discharges of Leema Wadi.

Year	Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2002	**Discharge**,	1.76	0.89	0.85	0.09	0.008	0.008	0	0	0	0.009	1.1	2.9
2003	m^3/s	23	7	2	1.2	0.2	0.002	0	0	0	0.01	13	14
2008		1.5	1.3	1.0	0.59	0.54	0.0	0	0	0	0.076	1.0	1.87

Hizam Wadi, According to the data provided by the Directorate of Water Resources of Diyala Governorate, the catchment area of the wadi is about 420 km^2; most of it lies within the Iranian borders. Its salinity is of about 2200 µs/cm. The maximum recorded discharge was 300 m^3/s. Its length within the Iraqi borders is 35 km, and it ends at AshShwaycha Marsh. The maximum annul inflow of the wadi is 0.057 billion m^3. Table 7 shows the monthly recorded discharge of Hizam Wadi for the years 2002, 2005, and 2008. The maximum discharge within the records of these years was 2.4 m^3/s and it was recorded during December of 2008. During summer season, the discharge of the wadi was zero or nearly zero. The recorded discharge of the wadi on 25th Feb 2010 was 543 m^3/s.

Table 7. Discharges of Hizam Wadi.

Year	Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2002	**Discharge**	1.3	0.65	0.76	0.07	0.004	0.002	0	0	0	0.007	0.98	1.87
2005	, m^3/s	0.67	0.23	0.65	0.22	0.12	0	0	0	0	0.45	0.98	1.7
2008		1.0	1.87	1.1	0.67	0.87	0	0	0	0	0.9	1.1	2.4

Al Muwayllah Wadi, According to the data provided by the Directorate of Water Resources of Diyala Governorate, the catchment area of the wadi is about 770 km^2; most of it lies within the Iranian borders. The salinity of its water varies between 1980 and 2200 µs/cm. The maximum discharge of the wadi was 300 m^3/s. Its length within the Iraqi borders is 15 km. This wadi joints Harran Wadi at a loction just upstream Khazanya Dam. The monthly discharge measurements of Al Muwayllah Wadi for the years 2002, 2003, 2005, and 2008 are listed in Table 8. The maximum recorded discharge was 42 m^3/s, recorded during January of 2003. No flow was recorded during July, August, and September of these years. The recorded wadi discharge on 25th Feb 2010 was 453 m^3/s.

Table 8. Discharges of Al Muwayllah Wadi.

Year	Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2002		1.4	0.32	0.54	0.23	0.005	0.003	0	0	0	0.009	0.87	1.65
2003	**Discharge**,	42	12	4	0.5	0.4	0.01	0	0	0	0.02	12	21
2005	m^3/s	0.7	0.54	0.43	0.32	0.23	0	0	0	0	0.34	0.67	1.3
2008		0.98	1.1	1.1	0.87	0.76	0	0	0	0	0.87	1.2	2.2

Harran Wadi, according to the data provided by the Directorate of Water Resources of Diyala Governorate, the catchment area of the wadi is about 1720 km^2. Its length is about 133 km within the Iranian borders. Its length within the Iraqi borders is 97 km and ends at AshShwaycha Marsh. The maximum discharge of the wadi was 400 m^3/s. The maximum annual inflow volume of the Harran Wadi is 0.226billion m^3 [3]. The monthly discharges of the wadi are presented in Table 9. The discharge of the wadi was found to be 654 m^3/s, which was resulted from two days rainfall storm of 79 mm occurred on 14th Dec 2002. This discharge caused flood to the villages along the Wadi. The recorded discharge of the wadi on 25th Feb 2010 was 534 m^3/s.

Table 9. Discharges of Harran Wadi.

	Month											
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	Discharge, m^3/s											
2002	3.5	2.43	2.76	1.65	1.2	1.0	0.87	0.98	1.3	1.32	5.76	7.87
2003	87	20	22	4	2.2	2.1	1	0.9	1.2	1.2	55	70
2005	5	3.4	2.5	2.2	2.67	1.2	1	0.82	0.97	1.2	3.4	7.8
2008	2.3	1.87	1.54	1.32	0.98	0.88	0.87	0.98	1.2	1.32	3.65	4.5

Naft Wadi, the wadi catchment area is about 1940 km^2 of which 960 km^2 are inside Iraq [3]. Based on the data provided by the Directorate of Water Resources of Diyala, the wadi runs within the Iraqi borders for 87 km then it ends at AshShwaycha Marsh. Its maximum discharge during winter was about 400 m^3/s. The recorded flood discharge was 1150 m^3/s and the annual runoff volume was 0.0528 billion m^3 [3]. The recorded monthly discharges of Al Naft Wadi for the years 2002, 2003, 2005, and 2008 are presented in Table 10. The maximum recorded discharge was 67m^3/s during January 2003. The discharge of the wadi was zero or nearly zero during summer season of these years. After two days duration of rainfall event on 14th Dec 2002, the recorded discharge and rainfall were 786 m^3/s and 79 mm, respectively. The wadi discharge recorded on 25th Feb. 2010 was 678 m^3/s.

Table 10. Discharges of Al Naft Wadi.

	Month											
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	Discharge, m^3/s											
2002	1.2	1	1.3	0.5	0.32	0.32	0.001	0	0	0	1.67	2.12
2003	67	35	13	1	0.6	0.1	0.001	0	0.01	0.1	22	32
2005	2	1.23	1.7	0.98	0.87	0.034	0	0	0	0.65	1.2	5.6
2008	0.98	0.76	0.43	0.34	0.001	0	0	0	0.001	0.003	0.43	0.98

Al Wind river, 80% of the catchment area of the river lies within the Iranian Borders, which is found to be 3340 km^2. The length of the river is 152 km, of which 63 km is within the Iraqi Borders, and joints Diyala River. The total annual inflow

volume and its maximum discharge were estimated to be 0.45 billion m^3 and 2200 m^3/s, respectively [3].

Qarratoo river, based on the data provided by the Directorate of Water Resources of Diyala, the catchment area of the river is estimated to be about 750 km^2; 67% of which lies within the Iranian borders. The river runs along the Iraqi-Iranian borders for 37.5 km then it runs within the Iraqi borders for a distance of 20 km and it joins Diyala river. The river discharge was about 1 m^3/s during winter and less than 1 m^3/s during summer.

Maydan river, known as Abbasan river. The catchment area of the river is about 860 km^2 of which 78% lies within the Iranian Borders. The river length within the Iraqi Borders is about 14 km and then joins Diyala river.

Sirwan river, according to the data provided by the General Commission for Dams and Reservoirs of the Ministry of Water Resources of Iraq, the catchment area of the river is about 12100 km^2, most of it lies within Iranian Borders. The river runs along the Iraqi-Iranian borders for 25 km then it runs within the Iraqi borders before joins Diyala River. The catchment area of this river forms 37% from the total catchment area of Diyala River. Its mean discharge during summer is about 25 m^3/s. the mean volume of the annual inflow of Sirwan River during the period extended from 1970 to 2006 is 5.16 billion m^3. The maximum and minimum mean monthly discharges of the river during this period are 1357 m^3/s of March 1974 and 2 m^3/s of August 2000. The mean monthly discharges of the river during this period were calculated and presented in Table 11. The maximum mean monthly discharge during this period is 400.8 m^3/s of March and the minimum is 53.7 m^3/s of September [6].

Table 11. Mean monthly discharge of Sirwan River.

Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean monthly discharge, m^3/s	160.4	226.8	400.8	398	221.9	101.2	65.3	55.4	53.7	60	93	124.7

Tawela river runs between Bayyara and Sirwan rivers. Its catchment area lies within the Iranian Borders. Farmers within Khormal area make uses of the river water for irrigation and drinking.

Mout river also known as Chmai Mout. According to the data provided by the Directorate of Water Resources of Kurdistan, the catchment area of the river is about 1506 km^2 and the length of the river is 36 km. The minimum and the maximum of the average discharges of the river are 1.9 and 17 m^3/s with a mean average discharge of 13.5 m^3/s. The annual inflow volume of the river is about 420 million m^3. The river discharges its water into Lower Zab river.

Lower Zab river is one of the main tributaries of Tigris river. Its catchment area is about 49562 km^2, 81% of it lies within the Iraqi borders and the remaining catchment area lies within the Iranian borders. The total length of the river is about 400 km, of which 33 km runs along the Iraqi-Iranian borders. The river joints Tigris river at a point located at 220 km north of Baghdad city. The average annual volume of inflow from the catchment is estimated to be 7.9 billion m^3; 66% of this volume is occurred in Iraq. Table 12 shows the monthly and annual mean discharges, and the annual inflow of Lower Zab river recorded during the period 1999-2011, which was provided by the National Center for Water Resources Management.

Hero river, according to the data provided by the Directorate of Water Resources of Kurdistan, the catchment area of the river is about 43 km^2 and its length is about 14 km and ends at Lower Zab river. The minimum and the maximum of the average discharges are 0.025 and 0.5 m^3/s with a mean discharge of 0.38 m^3/s. The inflow of the river is about 6 million m^3.

Qalat Dizah river is also known as Sharwet river. According to the data provided by the Directorate of Water Resources of Kurdistan, the catchment area of the river is about 46 km^2. The length of the river is 22 km and discharges its water into Lower Zab. The minimum and maximum average discharges are 0.07 and 0.7 m^3/s, with a mean discharge of 0.5 m^3/s. The annual inflow of this river is about 16 million m^3.

Hawadian river is known as Balakian river. According to the data provided by the Kurdistan Directorate of Water Resources, the maximum discharge of the river is 165.8 m^3/s, which was recorded on 5th Nov 2006, and the minimum discharge was 0.22 m^3/s, which was recorded on 18th Jan. 2001.

Upper Zab river is the main tributary of Tigris river. Its confluences Tigris river at a point located 49 km south of Mosul city. The total length of the Upper Zab is 473 km of which 215 km within the Iraqi borders [7]. Its catchment area lies within both the Turkish and Iranian Borders, which is estimated to be 26470 km^2. Its mean annual discharge is 421 m^3/s with an annual inflow of 14.07 billion m^3 [4]. Table 13 shows the monthly and annual mean discharges, and the annual inflow volume of the Upper Zab recorded during the period 1999-2011, which were provided by the National Center for Water Resources Management.

Table 12. Discharges of the Lower Zab river.

Monthly mean discharge, m^3/s													**Annual**	
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**		**Mean** m^3/s	**Inflow** billion m^3
1999-2000														
16	23	41	110	126	148	160	85	32	16	12	13		65	2.06
2000-2001														
13	20	58	44	110	203	130	65	26	15	12	12		59	1.86
2001-2002														
14	26	137	350	273	303	490	230	150	52	27	30		174	5.47
2002-2003														
29	62	273	278	383	595	569	290	136	63	35	33		229	7.22
2003-2004														
42	104	210	570	520	440	362	350	130	60	40	42		239	7.56
2004-2005														
42	132	117	170	513	635	305	187	85	52	40	35		193	6.08
2005-2006														
58	112	177	220	323	452	455	275	127	68	50	49		197	6.21
2006-2007														
71	180	52	82	285	232	415	240	90	41	33	28		146	4.55
2007-2008														
31	33	48	39	92	207	93	48	26	13	9	9		54	1.70
2008-2009														
26	30	30	32	53	155	160	120	47	23	14	11		58	1.84
2009-2010														
17	66	125	138	205	350	230	235	80	43	32	19		128	4.04
2010-2011														
23	26	36	68	161	209	320	287	77	33	28	23		107	3.38

Rizan river, According to the data provided by the Directorate of Water Resources of Kurdistan, the maximum discharge was 146.3 m^3/s, was recorded on 4th February 2006, and the minimum discharge was 8.9 m^3/s, was recorded on 18th Septmber 2001.

Al Khabur river is the shortest tributary of the Tigris river with a total length of 160 km. Most of its catchment area, estimated by about 6270 km^2, lies within Turkish borders. The annual inflow is about 2.1 billion m^3. Its maximum flood discharge is about 360 m^3/s, and its average discharge is 60 m^3/s. Its confluences with the Tigris river at a point located just north of FeashKhabor City [7].

Table 13. Discharges of Upper Zab river during the period 1999-2011.

Monthly mean discharge, m^3/s												Annual	
Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Mean** m^3/s	**Inflow billion** m^3
1999-2000													
87	75	105	165	205	285	513	347	162	102	73	71	183	5.77
2000-2001													
66	80	235	155	200	440	520	345	240	160	115	80	220	6.93
2001-2002													
85	85	225	485	365	600	1375	1085	560	260	150	123	450	14.19
2002-2003													
107	135	270	315	454	1150	-	1600	850	232	152	110	-	-
2003-2004													
140	275	255	525	550	900	575	750	480	275	180	145	421	13.31
2004-2005													
120	280	190	270	500	700	650	620	370	225	165	135	352	11.10
2005-2006													
130	150	160	265	1025	560	1100	915	400	200	175	135	435	13.71
2006-2007													
145	390	185	150	400	500	750	900	420	230	185	140	365	11.52
2007-2008													
130	145	185	200	240	375	390	315	185	130	105	85	207	6.52
2008-2009													
100	115	120	150	160	500	500	570	320	150	105	70	239	7.53
2009-2010													
75	210	240	395	475	620	580	675	350	180	130	110	337	10.59
2010-2011													
140	130	135	140	300	450	1050	1100	490	240	175	135	374	11.78

3. Discharges Measurements in Present Work

Coordinates of the points of discharge measurements on border crossing rivers are presented in Table 14. Figure 1 shows the locations of these points along the borders. The stream discharge measurement was carried out following the U.S. Geological Survey, USGS, midsection method. Description of this method can be found in references dealing with the discharge measurements such as reference [8]. Different sizes and types of current meters were used depending on water depth and flow velocity. A USGS Type AA current meter model 6200, universal current meter model 6500, and miniature current meter model 6505 made by Rickly Hydrological Company were used to measure the rivers and wadies discharges.

Table 14. Coordinates of the points of discharge measurements.

No.	River	Governorate	Coordinates		Border
			N	E	
1	Dwayreach	Maysan	32º 4' 10.00''	47º 37' 17.20''	
2	AtTeeb		32º 25' 43.65''	47º 10' 32.22''	
3	AshShihabi	Wasit	32º 55' 48.30''	46º 26' 41.54''	
4	Khallal Badrah		33º 7' 51.37''	46º 2' 43.61''	
5	Wadi Terssag	Diyala	33º 29' 29.68''	45º 52' 5.21''	
6	Wadi Leema		33º 38' 13.86''	45º 41' 58.72''	
7	Wadi Hizam		33º 39' 43.18''	45º 40' 24.36''	
8	Wadi Al Muwayllah		33º 42' 43.73''	45º 38' 9.14''	
9	Wadi Harran		33º 47' 33.93''	45º 36' 11.00''	
10	Wadi Al Naft		33º 57' 4.98'	45º 22' 53.83''	
11	Al Wind		34º 19' 50.50''	45º 23' 15.30''	
12	Qarratoo		34º 39' 19.43''	45º 27' 58.83''	
13	Maydan		34º 54' 14.67''	45º 36' 58.23''	
14	Sirwan	AsSulaymaniyah	35º 6' 18.75''	45º 54' 19.39''	
15	Hawar		35º 9' 20.60''	46º 7' 20.53''	
16	Tawela		35º 11' 44.30''	46º 11' 1.70''	
17	Bayyara		35º 13' 21.63''	46º 5' 29.60''	Iran
18	Khormal		35º 18' 17.45''	46º 0' 54.78''	
19	Qadafari		35º 20' 14.14''	45º 57' 10.31''	
20	Tutaqach		35º 29' 20.07''	45º 52' 6.79''	
21	Nallpareze		35º 34' 54.98''	45º 51' 45.68''	
22	Panjwin		35º 39' 7.35''	45º 65' 9.67''	
23	Rawjan		35º 41' 6.13''	45º 56' 27.30''	
24	Golee		35º 46' 32.39''	45º 49' 45.35''	
25	Ahmed Awa		35º 47' 52.40''	45º 59' 52.80''	
26	Seyaquaze		35º 46' 40.63''	45º 49' 3.71''	
27	Mout		35º 52' 2.54''	45º 24' 11.81''	
28	Lower Zab		36º 7' 10.85''	45º 10' 28.62''	
29	Hero		36º 7' 28.95''	45º 10' 10.96''	
30	Qalat Dizah		36º 10' 23.78''	45º 8' 35.98''	
31	Palkybeshder		36º 16' 21.58''	45º 8' 58.27''	
32	KandeelBeshder		36º 16' 29.41''	45º 7' 32.67''	
33	Sanksar		36º 17' 2.31''	45º 0' 19.33''	
34	Choman	Erbil	36º 38' 27.16''	44º 53' 31.69''	
35	Hawadian	Dahuk	36º 41' 46.61''	44º 29' 40.90''	
36	Upper Zab-2		36º 42' 50.63''	44º 16' 57.26''	Turkey
37	Rizan		36º 51' 53.62''	44º 7' 19.90''	Iran
38	Sowarri		37º 1' 32.14''	43º 50' 34.73''	
39	Upper Zab-1		37º 3' 18.26''	43º 39' 15.21''	
40	KaniKaymah		37º 10' 55.54''	42º 58' 26.51''	Turkey
41	Shiransh		37º 13' 32.63''	42º 50' 36.84''	
42	Al Khabur		37º 8' 10.45''	42º 41' 42.86''	

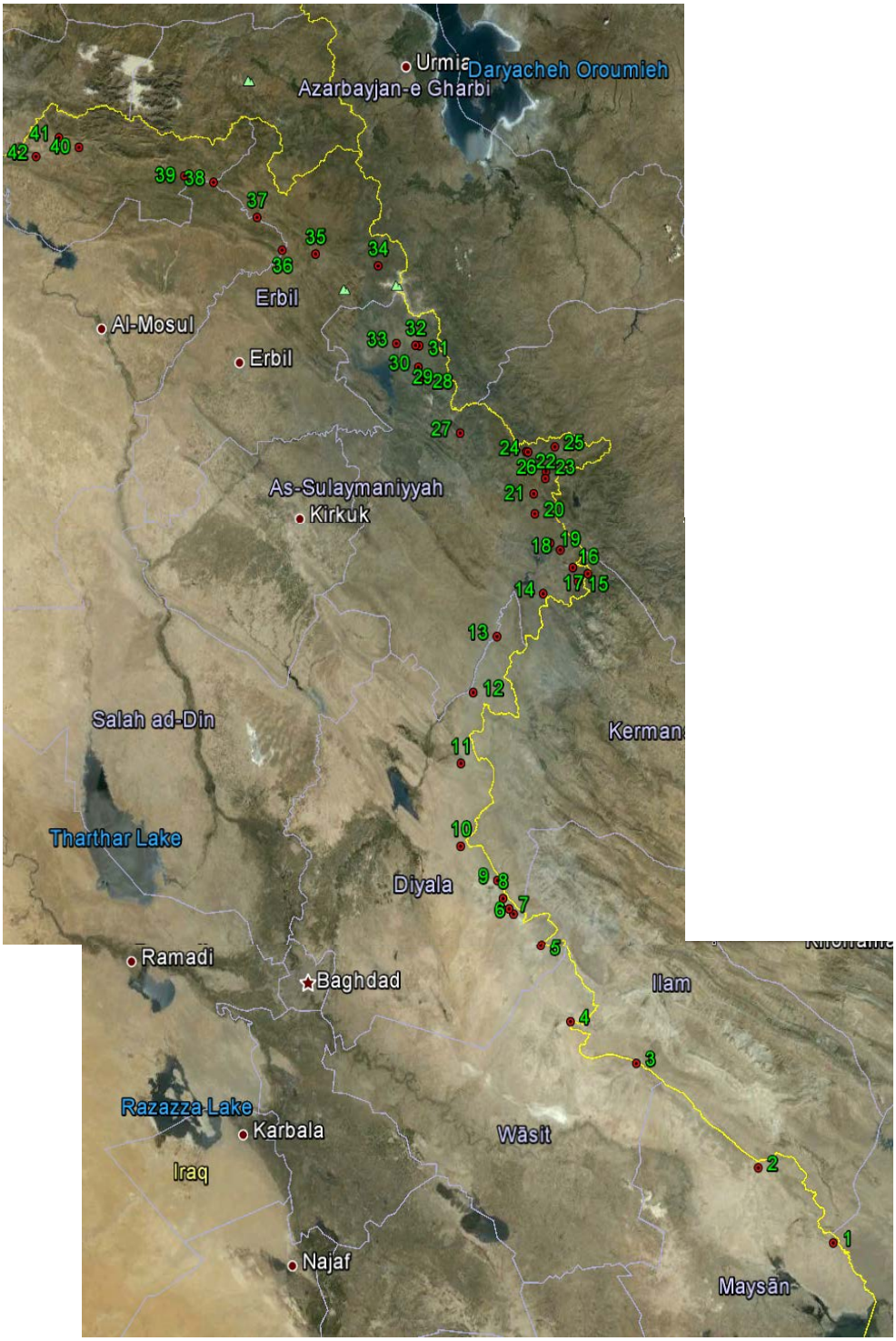

Fig. 1. Location of the points of discharge measurements on a satellite image.

4. Results and Analysis

The measured discharges and the measurements dates at each of the measuring point of the border crossing rivers are presented in Table 15.

Table 15. Measured discharges of the border crossing rivers and wadies.

No.	River	Date	Discharge m^3/s	No.	River	Date	Discharge m^3/s
1	Dwayreach	25/12/2012	0.08	16	Tawela	5/1/2012	0.01
		27/1/2012	Dry			1/3/2012	0.07
		25/2/2012	0.01			12/4/20	0.02
2	AtTeeb	25/12/2012	0.60	17	Bayyara	5/1/2012	0.21
		27/1/2012	0.66			1/3/2012	0.47
		25/2/2012	0.44			12/4/2012	0.95
3	AshShihabi	28/12/2012	0.55	18	Khormal	5/1/2012	0.58
		28/1/2012	0.44			1/3/2012	3.45
		23/2/2012	0.34			12/4/2012	3.50
4	Khallal Badrah	22/12/2012	0.36	19	Qadafari	5/1/2012	0.26
		22/1/2012	0.22			1/3/2012	0.96
		23/2/2012	0.14			12/4/2012	3.25
5	Wadi Terssag	6/1/2012	0.75	20	Tutaqach	5/1/2012	0.36
		10/2/2012	0.77			1/3/2012	1.61
		8/3/2012	1.84			12/4/2012	3.28
6	Wadi Leema	5/1/2012	Dry	21	Nallpareze	31/12/2011	0.32
		10/2/2012	Dry			25/1/2012	0.43
		8/3/2012	Dry			29/3/2012	3.30
7	Wadi Hizam	5/1/2012	Dry	22	Panjwin	31/12/2011	0.36
		10/2/2012	Dry			25/1/2012	0.43
		8/3/2012	Dry			29/3/2012	10.72
8	Wadi Al Muwayllah	5/1/2012	Dry	23	Rawjan	31/12/2011	0.03
		10/2/2012	Dry			25/1/2012	0.07
		8/3/2012	Dry			29/3/2012	1.92
9	Wadi Harran	5/1/2012	0.15	24	Golee	31/12/2011	0.77
		11/2/2012	0.44			25/1/2012	1.33
		8/3/2012	1.08			12/4/2012	6.00
10	Wadi Al Naft	6/1/2012	0.10	25	Ahmed Awa	7/1/2012	0.22
		11/2/2012	0.17			25/1/2012	1.88
		9/3/2012	0.31			29/3/2012	3.27
11	Al Wind	6/1/2012	3.84	26	Seyaquaze	25/1/2012	0.08
		17/3/2012	3.96			1/3/2012	0.45
		13/4/2012	7.04			12/4/2012	1.61
12	Qarratoo	6/1/2012	0.74	27	Mout	31/12/2011	2.68
		17/3/2012	1.05			25/1/2012	5.44
		13/4/2012	0.92			29/3/2012	10.38
13	Maydan	6/1/2012	1.57	28	Lower Zab	30/12/2011	19.47
		17/3/2012	14.75			26/1/2012	19.60
		13/4/2012	3.36			21/4/2012	325.6
14	Sirwan	7/1/2012	3.07	29	Hero	30/12/2011	0.14
		17/3/2012	22.59			26/1/2012	0.15
		13/4/2012	146.20			28/3/2012	2.16
15	Hawar	5/1/2012	0.37	30	Qalat Dizah	30/12/2011	0.17
		17/3/2012	1.35			26/1/2012	0.22
		13/4/2012	1.92			28/3/2012	3.35
31	Palkybeshder	30/12/2011	1.77	37	Rizan	13/1/2012	26.40
		26/1/2012	1.80			15/3/2012	81.90

		28/3/2012	12.55		19/4/2012	239.90
32	Kandeelbeshder	30/12/2011	0.44	38	Sowarri	13/1/2012	21.65
		26/1/2012	0.48			15/3/2012	55.45
		28/3/2012	6.22			20/4/2012	275.90
33	Sanksar	30/12/2011	1.40	39	Upper Zab-1	13/1/2012	17.42
		26/1/2012	1.10			15/3/2012	46.35
		28/3/2012	11.84			20/4/2012	226.70
34	Choman	11/1/2012	1.16	40	KaniKaymah	14/1/2012	0.54
		14/3/2012	3.62			15/3/2012	1.38
		19/4/2012	4.44			20/4/2012	0.66
35	Hawadian	11/1/2012	4.45	41	Shiransh	14/1/2012	Dry--ICE
		14/3/2012	9.77			15/3/2012	0.17
		21/4/2012	325.6			20/4/2012	0.01
36	Upper Zab-2	11/1/2012	65.2	42	Al Khabur	13/1/2012	14.74
		14/3/2012	250.10			16/3/2012	34.40
		19/4/2012	888.80			20/4/2012	174.70

The measured discharge of all rivers and wadies varied between 0 and 888.8 m^3/s. Wadi Leema, Wadi Hizam, and Wadi Al Muwayllah were dry in all the measurement visits. It is worth mentioning that the field team found that Tahlawi and Al Moala Wadies within Diyala Governorate, which were not included in this study, were also found dry during the measuring period. Dwayreach river was dry during the second measurement date and Shiransh river was frozen during the first measurement date. The maximum discharge value of 888.8 m^3/s was measured at the Upper Zab-2 measuring location during the third measurement date. In general, the discharges measured during the third measurement date were higher than that during the first and second measurement dates. Figure 2 shows the measured discharge of the rivers and wadies that not exceeded 15m^3/s during all measurement dates. Figure 3 shows measured discharges of Sirwan, Lower Zab, Upper Zab, Rizan, Sowarri, and Al Khabur rivers that varied between 14.4 to 888.8 m^3/s. The discharges of these rivers during the measurement period were much higher than other rivers and wadies. Therefore, these rivers represent the most significant border crossing rivers.

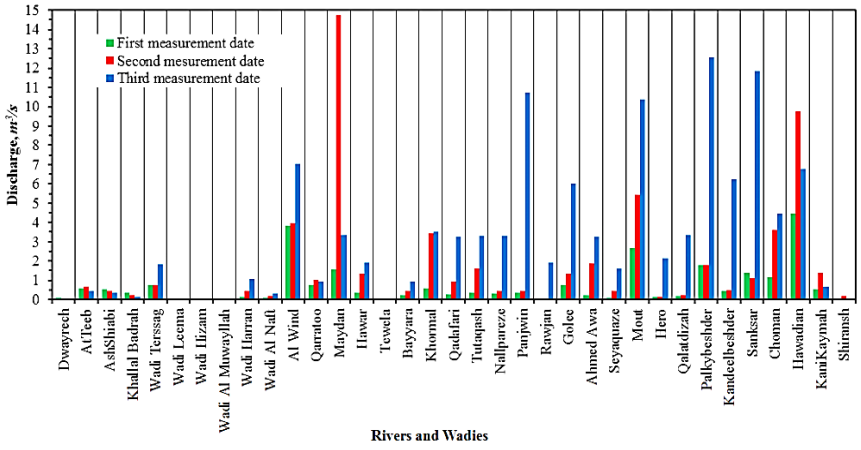

Fig. 2. Measured discharges of the rivers and wadies, less than15 m^3/s.

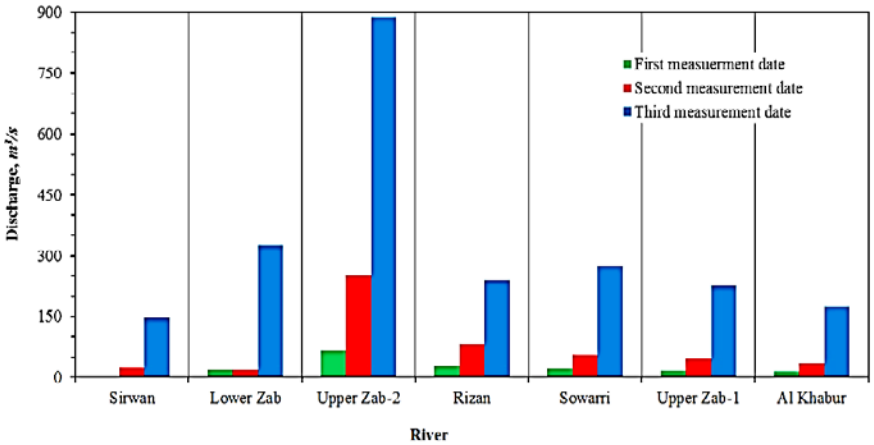

Fig. 3. Measured discharges of Sirwan, Lower Zab, Upper Zab, Rizan, Sowarri, and Al Khabur rivers.

5. Conclusions

An extensive review of literature on forty two rivers, wadies, and streams crossing the Iraqi-Iranian and Iraqi-Turkey borders was conducted. Discharge measurements on them were carried out in three different measuring dates at points close to these borders. Based on the field measurements, the following conclusions can be drawn:

- The measured discharge of all rivers and wadies varied between 0 and 888.8 m^3/s.
- Wadi Leema, Wadi Hizam, and Wadi Al Muwayllah were dry in all visits.
- Field team found that Tahlawi and Al Moala Wadies within Diyala Governorate were also dry during the measuring period.
- In general, the discharges measured during the third measurement date were higher than that during the first and second measurement dates.

References

1. Al Zubaidy, R.Z.; Al Thamiry, H.A.; and Al Khafaji, M.S. (2008). Hydrological modeling of AsSanna'f marsh. *Journal of Engineering*, 14(4), 3209-3229.
2. Atiaa, A.M.; Al-Shamma'a, A.M.; Aljabbari, M.H.A.; and Al-Kaabi, F.K. (2013). Impact of climate change on the hydrological regime of Teeb river, Missan Governorate, South of Iraq. *Marsh Bulletin*, 8(2), 148-158.
3. Khawer, J.M. (2002). *Iraq-Iran common borders, water, and the possibility of investment some of them for different uses in Iraq*. Ministry of Irrigation, Iraq.
4. Kareem, K.A.; and Al-Thamiry, H.A. (2019). Identification of scouring zones in ungauged river by simulation: The case of Galal Badrah river, Iraq. *Association of Arab Universities Journal of Engineering Sciences*, 26(3), 57-67.
5. Al Rekabi, N.K; and Kadum, H.K. (2016), Water harvesting and sustainable spatial development, a case study of the province of Badra-Zurbatiyah, *Journal of the College of Education for Women*, 27(5), 1545-1566.

6. Thalani, E.J. (2009). The effect of the water sources of the Sirwan river (Diyala) on the monthly discharge rate (by using the quantitative flow technique) (in Arabic). *Kirkuk Journal for Human Studies*, 4(2), 155-169.
7. Assmmawi, H. (2011). Tigris river and its tributaries, branches, historical designations, and its new structures to its confluences with Diyala river South of Baghdad. *Journal of Atta'a ArRafidain*, 53, 1-12.
8. USGS (1976). *Discharge measurements at gaging stations*. Publications of the USGS on techniques of water-resources investigations.