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Improvement of Erbil City Environment and Increasing Irrigated Areas through Simulated Hydraulic Design from Greater-Zab River Water

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ABSTRACT: Climate change, drought years, industrialization and oil production, investment, increase number of vehicles, air-conditioning systems, private electric generators and projects impacted on the Erbil City Environment. Green and planted areas were decreased; while desertification, groundwater problem and temperature increased. The objectives of the present research were to improve environment, increasing irrigated, groundwater table and tourist areas, and decreasing flood in Erbil City. To conduct the research, design of pumping station, pipe lines, ponds and artificial channels for conveying raw water from Greater-Zab River (GZR) to the surrounded areas of Erbil City was studied. Surveying data were collected through site visits to the selected areas. Hydraulics design for the pumping station, pipe line, ponds and the channels were carried out. Prosed discharge was 0.8 m^3/s. Results revealed that the ponds can store 9000 m^3 of the water and the best cross-section for the channels were 1.5 m Width and 1 m depth. The proposed hydraulic channels can irrigate 16 donums of the land. It can be concluded that design of ponds and channels surrounded to Erbil City decrease temperature, groundwater and flood problems, and desertification. On the other hand, the proposed design enhances environmental conditions, irrigated lands, and tourist.

Keywords: Channel, Erbil City, Environment, Hydraulic design, Irrigation, Greater-Zab River.

1. Introduction

Water is known as a most abundant substance in the world; however, the availability of potable water is differing from place to another. The great civilization from the ancient time was build up close to or along water sources, it indicates the importance of water. In addition, water resources have been measured for socioeconomic status worldwide. At the beginning of the time till now in the different part of the world, rivers, springs, lakes, and wells those which can be drunk directly, are the main sources of water for human using purposes and their water has been used for irrigation, drinking, and industries. As the demand for energy and agricultural products rises in developing world, greater emphasis must be placed on enhancing the management effectiveness of existing storages in order to optimize the positive applications of these projects. The requirement for integrated operational plans, on the other hand, presents system managers with a challenging challenge. Extending the working system's scope for more integrated analysis considerably increases (Labadie, 2004).

The water resources in the Greater Zab River (GZR) basin have suffered numerous challenges as a result of rising requirements and environmental issues, which have reduced rainfall from about 15% over the last 15 years; on either side, the population is increasing due to migration of people to Erbil from Iraq's mid provinces (Khoshnaw and Karpuzcu, 2018).

In Iraq, there is a plenty of water bodies in the country which is scattered in the whole region including rivers, lakes, streams, reservation, and channel. During past four decades, studies on these water sources have been conducted on different aspects, and ecologists were focused mostly on the phycology and limnology of water. Many studies were succeeding with establishing and developing universities from southern to northern of Iraq (Shekha, 2008; Ali and Jiwar, 2007). Aziz (2004) studied the seasonal variation of some physical and chemical parameters for the Greater-Zab River, groundwater, and Erbil municipal wastewater. Another study observed the GZR water for 14 months in 2008 (Aziz, 2008). Toma (2013) and Aziz and Fakhrey (2016) conducted different studies on the GZR water and water treatment plant (WTP).

Correspondingly, applying aquatic insects to analyze the water quality of several sections of the GZR inside Erbil city conducted by Hanna and Shekha (2015). In addition, Aziz and Mustafa, (2021) designed water treatment plant units on GZR stage by stage, also the relevant estimates and WTP component details are presented. Al-Naqeshabandi (2002) assessed water quality of Greater Zab at old and new Ifraz project; represent a line life of this area. Aziz (2000) conducted 100 filter runs on Greater-Zab water by using a pilot-plant, and compared his result with the effluent water of Erbil water project.

The optimization technique will find the best resource management program for the GZR basin reservoir system. The goal is to optimize the overall advantages from water supply, hydropower generation, irrigation, and flood prevention. Optimized hydraulic systems administrators will be modelled from 1932 to 1978, the longest time with known historical flow measurements (Tejada- Guibert et al., 1993).

Climate change, drought years, industrialization and oil production, investment, increase number of vehicles, air-conditioning systems, private electric generators and constructed projects impacted on the Erbil City Environment. Green and planted areas were decreased; While desertification and temperature increased. Additionally, flood and depletion of the ground water level are other problems. The objectives of the current research were to enhance environment, increasing irrigated, groundwater level and tourist zones, and decreasing flood in Erbil City. To carry out the research, design of ponds and artificial channels for transmission fresh water from Greater-Zab River to the surrounded areas of Erbil City was studied. To date, this sort of study has not been published yet.

2. Material and Method

2.1. Study Area and Data Collection

Erbil is the Kurdistan’s capital and it is bordered by longitude 43° 15' E to 45° 14' E and from latitude 35° 27' N to 37° 24' N and its climate characterized by cold winter and warm dry summer. The most precipitation takes place in the winter and spring, its rainfall about 337 mm annually (Toma, 2013). Erbil City currently is served by two types of water resources, groundwater and surface water. The only drinking source of water as the surface water in the Erbil city is GZR.

The GZR, combined by Iraq and Turkey, starts from Turkey's Ararat Mountains, passes through the central northern portion of Iraq, and interfaces with the Tigris Stream south of Mosul City traversing a separate of 372 km, Figure 1. Greater-Zab and its branches namely Shamdinan, Haji Beg, Rawanduz, and Khazir-Gormal, are situated between latitudes 36° N and 38° N, and longitudes 43.3° E and 44.3° E (Abbas et al., 2016). It drains an area of 26473 km2, 65% of which is in Iraq and the rest in Turkey (Al-Ansari et al., 2014). Greater-Zab basin may be a hilly region with a height extending from 180 m to 4000 m over the ocean level.

Figure 1: Greater-Zab River on the map (Aziz and Mustafa, 2021).

Figure 2: Greater-Zab River.

The mean annual temperature for GZR is 14.3 C° and the mean annual rainfall is 570 mm, ranging from 350 mm to 1000 mm (Abbas et al., 2016). Together with Rawanduz, the upper or Grater-Zab River is the only surface water supply accessible for drinking water and other purposes in Erbil City (Shareef and Muhamad, 2008).

Table 1: Survey data collection

No.	Station	Name	E	N	Altitude
1		Maroda station	406688.691	4014113.888	389.84
2	0+000	Ifraz Kamal Agha	394100.901	4030969.715	257.87
3	5+000	Dareshekran junction	397377.77	4032741.84	310.15
4	10+200	Rashwan Village	402479.255	4032368.715	325.73
5	13+800	Grdi Mawan Village	405825.361	4031086.975	332.57
6	18+700	Darashekran Sub-District	410111.321	4029341.455	349.93
7	24+100	Parpitan	413762.869	4025627.058	466.64
8	28+700		417959.642	4025221.888	481.16
9	29+800	Barbian Bchook	418966.981	4024865.739	496.2
10	31+100	Judi Mosque	420154.105	4024508.273	537.29
11	33+800	Sawagul Vilalge	422713.63	4023719.855	594.1
12	36+700	Bastora Road	424951.762	4022191.508	631.47
13	37+800	Bastora- Pirmam Intersecti	425590.628	4021579.869	627.6
14	40+900	Khanzad Hotel	424422.295	4019515.747	706.77
15	46+900	Mala Omer Road	421283.735	4017511.554	599.28
16	56+300	150 m Road	418825.748	4014252.638	560.88
17	59+600	Perzeen	416869.205	4012078.285	499
18	63+000	120 m Road	415181.508	4010209.351	454.27
19	65+100	Water Tank-120 m.	415823.986	4009136.49	467.1

20	0+000	150 m Road	418872.62	4013335.336	512.27
21	0+750	K_{24} Tv Entrance	419401.853	4013585.897	541.26
22	4+050	Kolaki Gawra	422667.052	4013382.209	609.32
23	4+830	College of Police st. 1	423332.01	4013471.837	680.37
24	5+060	College of Police st. 2	423154.789	4013291.139	678.84
25	5+240	College of Police st. 3	423137.575	4013132.437	673.81
26	5+780	College of Police st. 4	422821.457	4012720.683	665.59
27	6+070	College of Police st. 5	422677.068	4012507.533	665.1
28	6+270	Gate of College of Police	422691.159	4012343.894	63884
29	7+470	Civil Defense Directorate	422671.489	4011140.903	631.33
30	8+100	Pir Rash Village	422687.416	4010525.868	612.88
31	8+670	End of Pir Rash	422589.626	4009978.291	601.28
32	9+580	Dashty Bahasht Project	422509.884	4009086.445	604.9
33	10+090	Dashty Bahasht Project Ga	422450.29	4008651.903	587.34
34	11+390	Majidi Land	422152.066	4007496.883	590.57
35	11+930	150m-Koya Road	421832.52	4007231.399	589.4
36	19+500	Monument Location	426319.513	4007945.761	713.27
37	20+800	Monument- Peak point	426128.713	4008809.969	767.72
38	21+800	Monument-front	425598.368	4008280.351	701.04
39	23+200	Erbil zoo	424840.46	4008171.043	656.29
40	28+600	PVI Location	422092.822	4004386.242	548.94
41	30+100	Hiran City 1	421823.11	4003029.754	482.05
42	30+740	Mzoran Watershed	421689.125	4002421.724	497.83
43	31+260	Directorate of Agriculture Bnaslawa	421341.481	4002164.272	498.1
44	32+160	Directorate of Water-Bnaslawa	421388.845	4001290.047	503.8
45	32+510	Banaslawa District	421336.771	4000971.923	505.64
46	32+740	End of Banaslawa Distric	421340.304	4000784.752	505.76
47	33+220	Road Intersection- Bnaslaw	420871.994	4000792.309	505.78
48	33+900	Hospital-Banaslawa	420889.71	4001466.939	504.76
49	34+420	Sharawani-Banaslawa	420389.427	4001496.11	501.39
50	37+020	Altun Mosque	418217.067	4001626.001	462.67
51	38+620	Kornish- Banaslawa Roac	417281.682	4002218.422	442.71
52	40+820	End of Box Sewer-Kornisl	416391.374	4000637.576	428.4
53	41+920	Zaiton Intersection	415748.368	4000481.57	430.41
54	44+020	Roshnbiry Intersection	413722.11	4000022.222	404.28
55	45+320	120m-Kornish	412818.928	3999700.827	405.73
56	45+870	End of Kornish	412394.739	3999520.475	398.79

Table 2: Collected Survey data for the proposed channel using Google map

No.	Station	Name	Latitude	Longitude	Altitude
1		Maroda Station	36.267452	43.961174	389.84
2	0+000	Ifraz Kamal Agha	36.418083	43.818768	257.87
3	2+700	Duhok Road	36 25 29.45	43 50 28.51	299.314
4	6+040	Mamandan	36 25 34.39	43 52 34.24	321.564
5	8+280		36 25 36.7	43 53 47.97	337.109
6	9+720		36 25 41.77	43 54 44.54	347.472
7	11+680		36 25 22.32	43 55 58.79	362.407
8	13+210		36 25 0.52	43 56 43.81	369.417
9	17+320		36 24 13.83	43 59 10.47	404.469
10	23+740		36 21 47.24	44 02 01.35	465.43
11	29+890	Qeremukyan	36 21 39.09	44 05 55.75	527.304
12	31+510		36 21 13.29	44 06 48.55	541. 63
13	33+430		36 20 52.62	44 07 56.9	560.527
14	35+060		36 20 20.35	44 08 43.73	577.291
15	36+460		36 19 53.47	44 09 27.87	591.921
16	37+330	Bastora	36 19 52.23	44 09 52.56	600.456
17	37+590	Shaqlawa road	36 19 48.63	44 10 02.01	604.113

2.2. Surveying Tools

Surveying is the science of determining the relative positions of points (any physical thing: a highway, culvert, ditch, storm drain inlet, or property corner) on or beneath the earth's surface. Horizontal positions (Easting and Northing) of these points are determined by measuring distances and directions, while vertical positions are determined by differences in elevations measured from two different points (Walker et al., 2002).

The main parts in the process of measurements are the surveyor and his instrument. In the early 1920's, there was a rapid development of new types of instruments, compared to today's instruments, at the beginning of this century, surveying instruments were large in form and heavy, but already had a high degree of precision, (Holsen, 1984). Nowadays there are many survey instruments and applications that used to determine relative positions of any points on or under the earth's surface,

In this study, mobile and computer applications, (Mobile Topographer and MAPS. ME, Satellite images and Google Earth) are used to collect coordinates and elevations of all points in tables (1) and (2).

Data collected is the first step of surveyor work; the next step is how this data can be as a fundamental result of any project. Results can be obtained manually or with using surveying software. In our thesis, Geographic Information System (GIS) and Google Earth are used to arrange the data to find main required information of this study.

2.3. Hydraulic Design Procedure

$$\frac{dH}{dx} = \frac{dZ}{dx} + \frac{dy}{dx} \tag{1}$$

Where:

$\frac{dH}{dx}$ = Represents the energy slope, $\frac{dZ}{dx}$ = denotes the bottom slope, and $\frac{dy}{dx}$ = represents the water surface slope (Subramanya, 2009).

$$\frac{d}{dx}\left(\frac{V^2}{2g}\right) = \frac{d}{dy}\left(\frac{Q^2}{2gA^2}\right)\frac{dy}{dx} \qquad (2)$$

$=-\frac{Q^2}{gA^3}\frac{dA}{dy}\frac{dy}{dx}$, Since dA/dy = T

$$\frac{d}{dx}\left(\frac{V^2}{2g}\right) = -\frac{Q^2T}{gA^3}\frac{dy}{dx} \qquad (3)$$

Where $\frac{V^2}{2g}$ = Velocity Head

Equation 3 can be be rewritten as follow:

$$-S_f = -S_o + \frac{dy}{dx} - \left(\frac{Q^2T}{gA^3}\right)\frac{dy}{dx}$$

Re-arranging $$\frac{dy}{dx} = \frac{S_o - S_f}{1 - \frac{Q^2T}{gA^3}} \qquad (4)$$

Another form of Equation 4 is Equation 3 and can be written as follow:

$$\frac{dE}{dX} = S_o - S_f \qquad (5)$$

Writing this in the finite- difference form

$$\frac{\Delta E}{\Delta X} = S_o - \bar{S}_f \qquad (6)$$

Where $\bar{S}_f$= Average friction slope in the reach ΔX

$$\Delta X = \frac{\Delta E}{S_o - \bar{S}_f} \qquad (7)$$

And between two sections 1 and 2:

$$(X_2 - X_1) = \Delta X = \frac{E_2 - E_1}{S_o - \frac{1}{2}(S_{f1} + S_{f2})} \qquad (8)$$

Where:

y is the depth of the flow in the channel,

v is the average velocity of the water flow in the channel, and

z is the height of the canal invert (bottom of channel). = S*o ΔX*

In open channel flow, the energy (H) is equal to the total of the channel elevation, z, the depth of water flow, y, and the velocity head V2 /2g, as shown in the equation below (Subramanya and Sahu, 1991).

$$H = y + \frac{v^2}{2g} + z$$

Bottom slop (So) not necessarily equal to EGL slope (Sf).

$$\Delta E = \Delta[y + \frac{V^2}{2g}] = \Delta[y + \frac{Q^2}{2gA^2}] \qquad (9)$$

$$\Delta E = E_2 - E_1 = \left[Y_2 + \frac{Q^2}{2gA_2{}^2}\right] - \left[Y_1 + \frac{Q^2}{2gA_1{}^2}\right] \qquad (10)$$

$$\bar{S}_f = \frac{1}{2}\left(\bar{S}_{f_2} + \bar{S}_{f_1}\right) = \frac{n^2Q^2}{2}\left[\frac{1}{A_2^2R_2^{\frac{4}{3}}} + \frac{1}{A_1^2R_1^{\frac{4}{3}}}\right] \qquad (11)$$

From Equation 7, Δx can be evaluated by using Equations 10 and 11.

Figure 3 illustrates energy relations for the open channel flow.

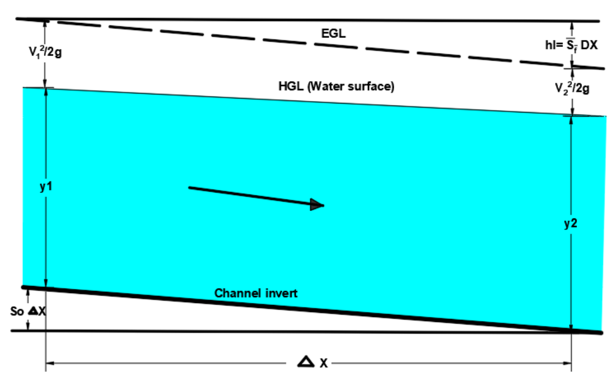


Figure 3: Open Channel Flow- Energy Relations (Subramanya and Sahu, 1991).

2.4. Design of flow piping system

Flow expert computer program was applied for design flow pipe and pump system. Pipe flow expert is a very useful for hydraulic circulation, pump design, line sizing, and pressure drop relation. So, it's a very useful for piping design. Consequently, fluid type, fluid temperature, and units were selected. In the present work, fluid was raw river water with temperature of 20 oC. Later, elevations of inlet and outlet were added. Head of water regarded as 2 m above the bottom. For the pipe part, length, diameter, roughness and material of the pipe were added. In the software, all parameters of the pipe line can be changed. Galvanized pipes and fittings were used in the design. Distances between stations and elevation were taken from Tables 1 and 2.

To determine the power of the pump station, this equation can be used:

Power = γ Q Hp ……. (Streeter et al., 1988)

Where:

γ is specific weight of water (N/m^3)

Q is flow of water (m3/sec.)

Hp is the head of pump (m)

Regarding design of pumps, flow rate of 0.8 m3/sec was selected. Design outputs of the program are shown in Tables 3 and 4.

Table 3: Fluid zone and Pump data for section 1 and 2 from Pipe flow software PF Expert V.7.40 Solution

Item	Greater Zab	DaraShakran
	DaraShakran	Bastora
Fluid Zone	Water 20℃	Water 20℃
Density (Kg/m3)	998	998
Material	800 mm Steel (ANST) Galvanisec Sch 40	800 mm Steel (ANST) Galvanised Sch 40
Inner diameter (m)	0.778	0.778
Roughness (mm)	0.15	0.15
Wall thickness (m)	0.018	0.018
Length (m)	18700	18000
Vol. Flow (m3/sec.)	0.8	0.8
Velocity (m/sec.)	1.683	1.683
Pump head (m.hd)	810.599	608.729
Entry Pressure (bar.g)	0.3915	0.1957
Exit Pressure (bar.g)	37.5822	27.599
Pump Efficiency %	-	-
Pump Power (Kilowatt)	6358.98	4775.36
Total Friction loss in all pe (m.hd)	49.95	48.08
Lowest Elevation of any ode (m)	0	0
Highest Elevation of an ode (m	380	280
System Volume (m3)	8889.773 ≈ 9000	8557 ≈ 9000

3. Results and Discussions

3.1. Surveying Data Analysis

Geographic information system (GIS) software applied for plotting all collected in the field Table 1 and data in Table 2 (by using computer application) in Figure 4. Black color in Figure 4 represents fifty six collected data in the field and red color for the collected data by Google map.

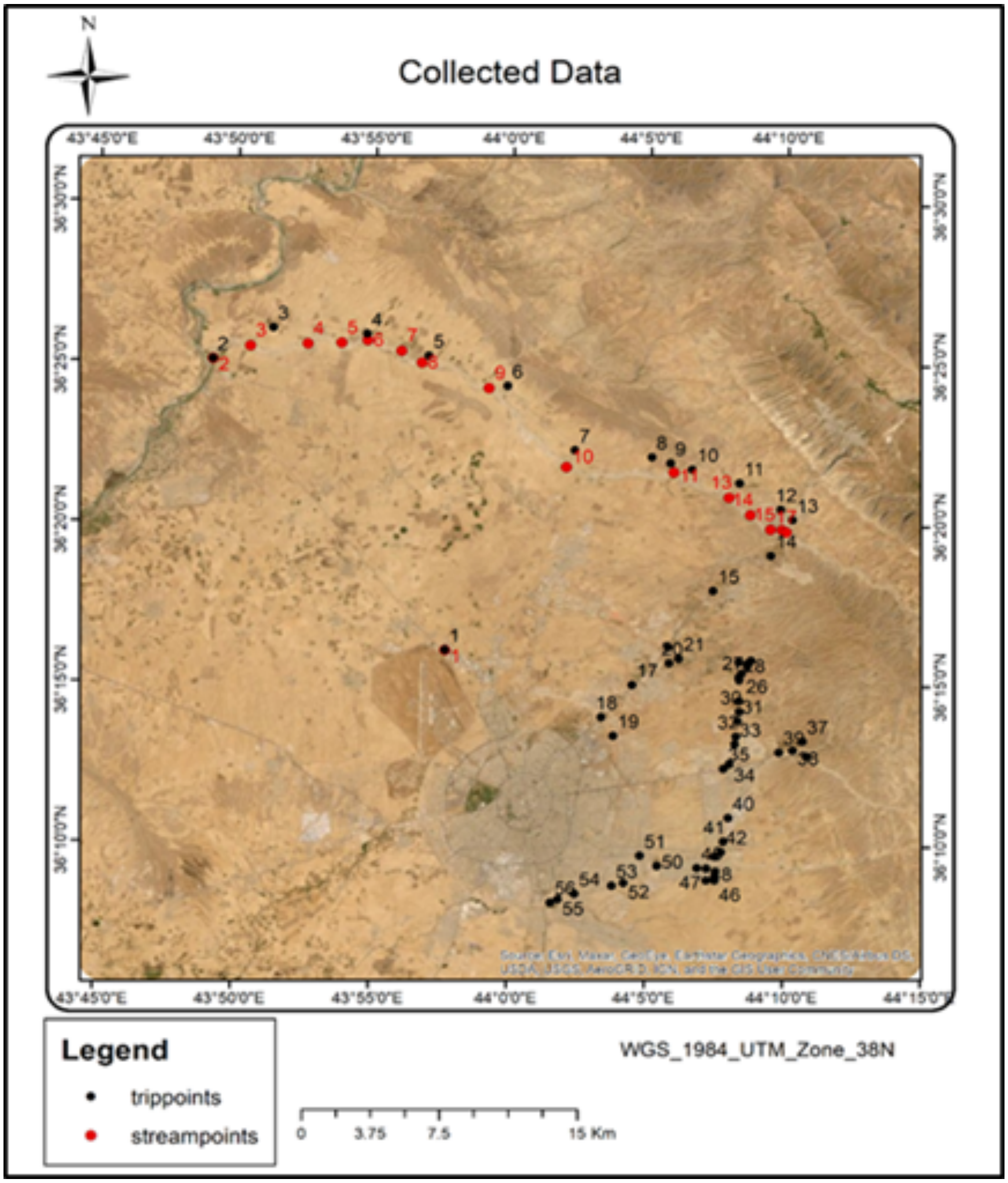


Figure 4: Collected survey data.

The Digital Elevation Model (DEM) (12.5 x 12.5 m resolution) in Figure 5 was downloaded by using Earth Data (https://search.asf.alaska.edu) and selecting ALOS PALSAR satellite, contains study area and ground gradation where lowest elevation equal to 232 m above mean sea level, and elevation of highest point is 1968 m above mean sea level. While, Figure 6 illustrates digital elevation model of study area and lowest elevation in it is 263 m above mean sea level, and highest point equal to 1265 m above mean sea level.

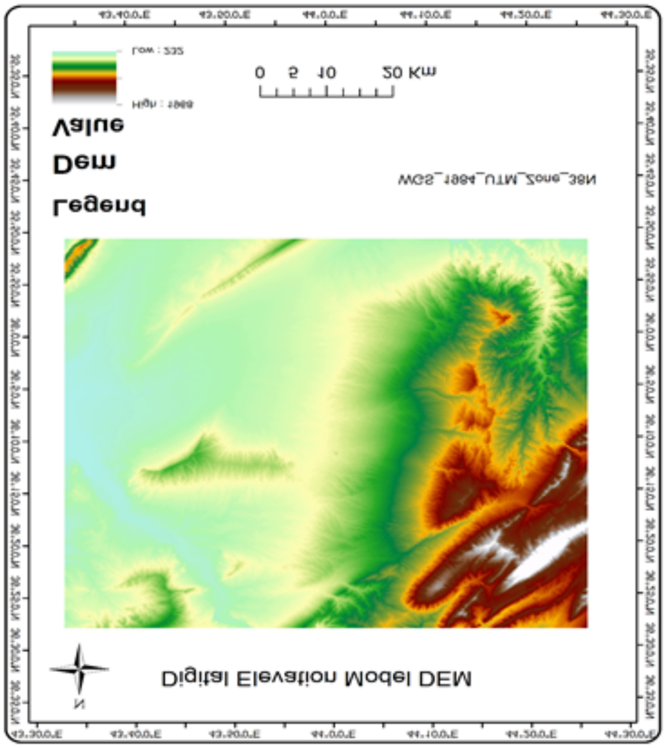


Figure 5: Digital Elevation Model.

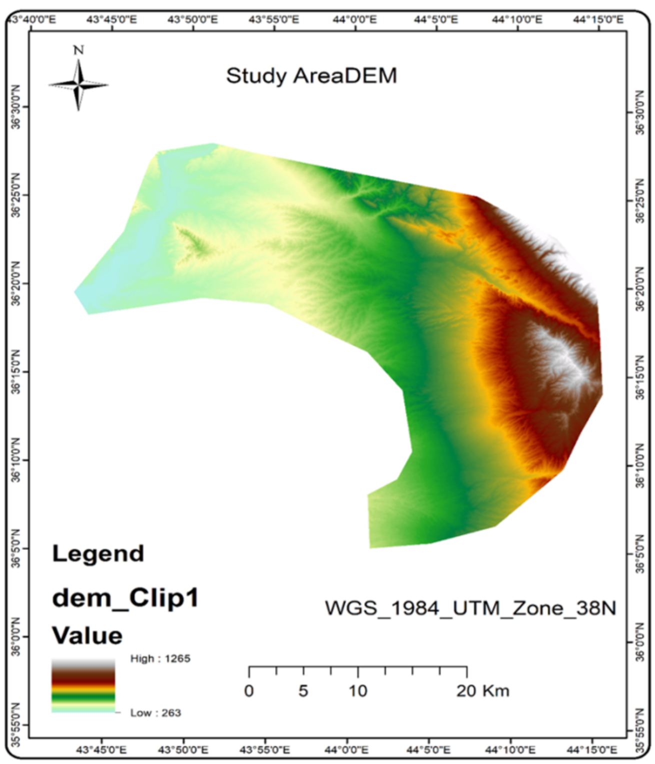


Figure 6: DEM of study area.

The roads in the study are shown in Figure 7. A number of ring roads such as 60 m, 40 m, 100 m, 120 m and 150 m are illustrated in the Figure 7.

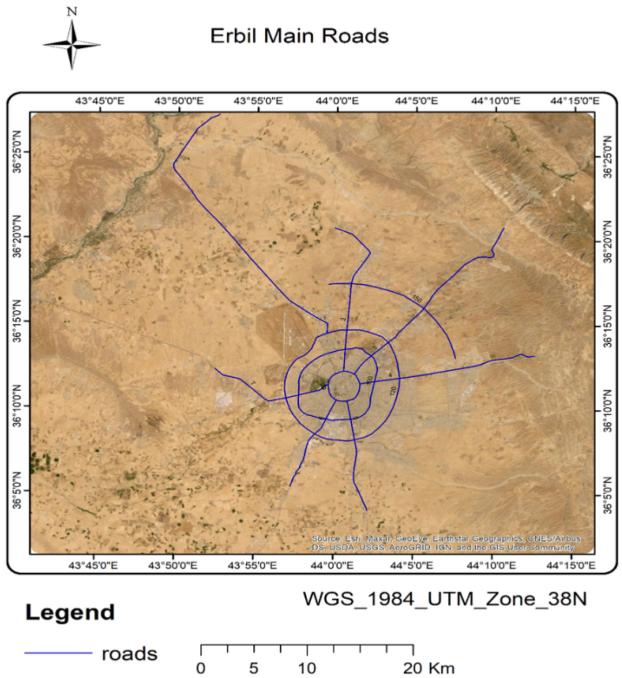


Figure 7: Main roads in Erbil city.

DEM of study area, main roads and all collected data are located are given in Figure 8 by using GIS software.

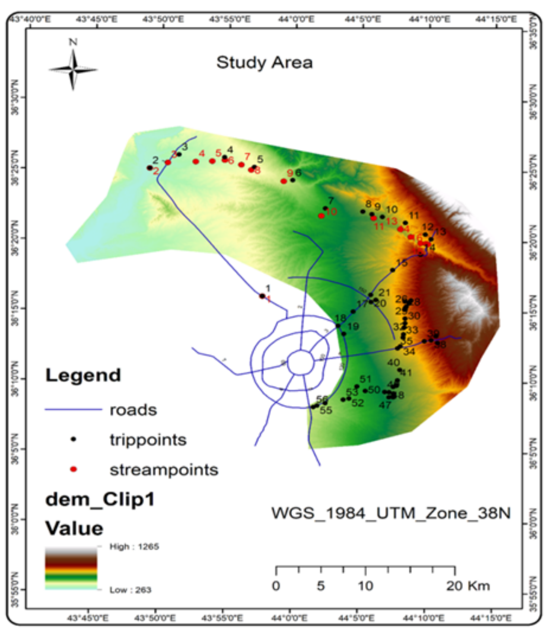


Figure 8: DEM of study area, main roads and all collected data using GIS software.

Depending on the DEM of study area, and by using GIS (hydrology analysis) direction of flow for the study area has shown Figure 9. Numbers and legends in Figure 9 are explained in Table 4 and Figure 10.

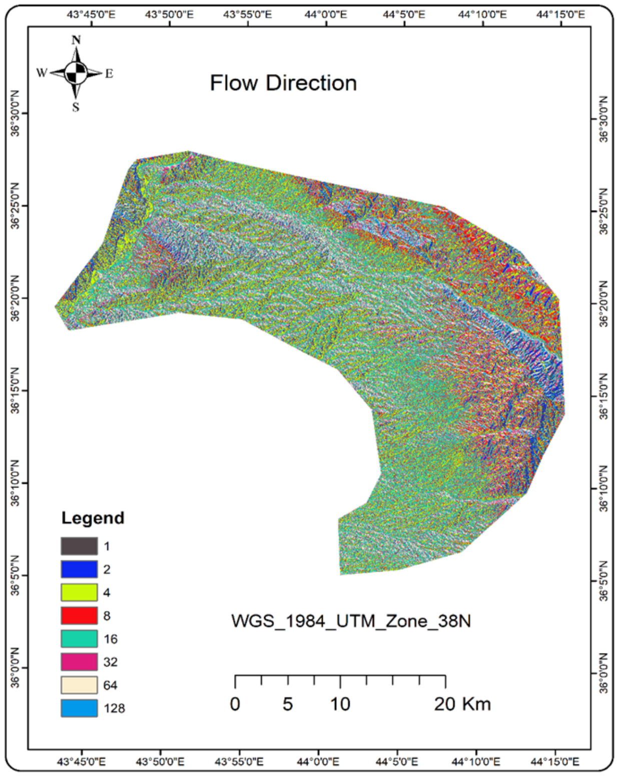


Figure 9: Flow direction in the study area.

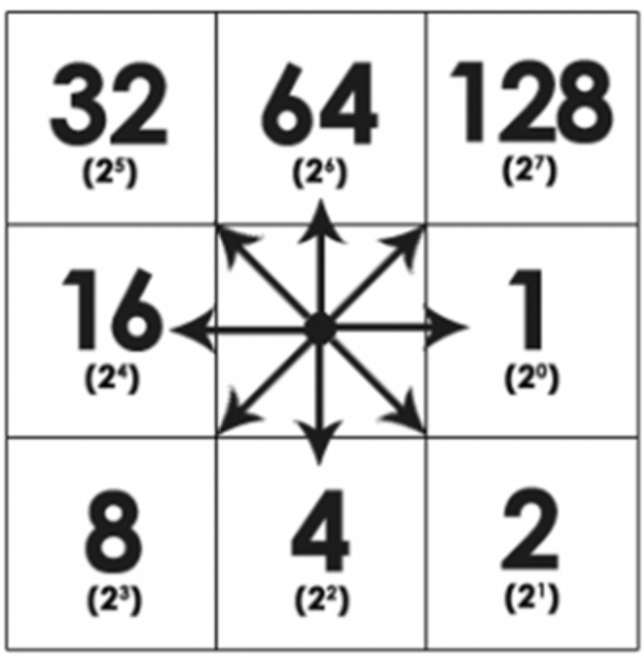


Figure 10: Flow direction coding.

Table 4: Numbers in legend refers to direction of flow, as the table below.

NO.	Flow direction explanation
1	Water in these color flows toward east
2	Water in these color flows toward south-east
4	Water in these color flows toward south
8	Water in these color flows toward south-west
16	Water in these color flows toward west
32	Water in these color flows toward north-west
64	Water in these color flows toward north
128	Water in these color flows toward north-east

3.2. Greater-Zab River Quality and Quantity

Raw water is classified by its physical, chemical, and biological features. Table 5 provides the water quality of the GZR characteristics in literature. Water quality parameters, such as pH, electrical conductivity (EC), total dissolved salts (TDS), chloride (Cl-), alkalinity, Ca++, Na+, K+, Mg++, nitrate (NO3), and SO4, maintained within WHO (2011) (DOW, 2017). However, the turbidity parameter which is ranged between (0.8 to 347) exceeded the drinking water quality criteria WHO (2011). As a result, treatment techniques for the GZR are necessary (Aziz and Fakhrey, 2016). Aziz (2006) concluded that fresh GZR water is acceptable for irrigation purpose. Additionally, Omar and Aziz (2021) reported that GZR water is safe for irrigation and construction.

Table 5: Quality of Greater Zab River.

Date	Turbidi NTU	pH	EC µ.s/c	TDS mg/	Cl- mg/l	T. Alkalinity mg/L	T. Hardness mg/L	Ca^{++} mg/l	Na+ mg/	K^{+} mg/	Mg^{+} mg/l	NO_3 mg/	SO_4 mg/
Feb.2002	15	8.29	380		18	191	276	26	7.6	0.9	51	5.8	
Mar.2002	14	8.42	363		14	174	134	27	4.7	0.9	16	6.5	
Apr.2002	150	8.51	407		14	174	262	25	4.7	1.1	48	8	
May-02	186	8.52	296		21	165	200	25	4.1	0.73	33	5.3	
Jun.2002	100	8.32	272		21	146	144	28	2	1	17.9	4.6	
Jul.2002	36	7.15	286		11	150	156	35	3.32	0.5	16	4	
Oct.2004	2.6	8.08	342	219	18	190	244	32	4.3	1.2	39.4	7	124
Nov.2004	83	6.79	348	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
Dec.2004	12	7.99	488	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
Jan.2005	16	8.23	329	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R

Feb.2005	31	8.54	752	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
Mar.2005	26	8.4	421	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
Apr.2005	44	8.09	337	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
May.2005	65	8.25	290	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R
Jan.2012	16	7.28	776	388	4	200	264	64	8.2	1.1	25	6	66
Feb.2012	323	6.66	702	351	6	132	257	82	8.4	1.3	12.5	13	152
18/03/2012	64	7.33	719	360	6	153	202	59	6.8	1.7	13.1	15	75
15/04/2012	352	7.61	734	367	5	129	181	64	3	1.1	5.04	13	65
13/05/2012	114	7.72	0	0	9	131	175	61	3.1	0.5	5.4	7.5	23
12/6/2012	31	7.4	338	169	10	133	178	51	3.7	0.6	12.1	6	61
16/07/2012	54	7.41	411	206	13	136	191	53	5.2	1.2	14	8.5	54
26/08/2012	106	7.63	478	239	11	136	209	32	14	1.3	31	7	96
16/09/2012	120	7.78	483	242	10	146	218	56	4.8	0.9	18.7	12	105
15/10/2012	108	7.64	438	219	7	202	226	68	7.5	1.7	13.4	12	200
18/11/2012	254	7.73	170	85	5	168	230	61	6	2.2	18.6	19	158
16/12/2012	12	6.69	295	148	6	154	194	68	6.8	1.5	5.76	13	121
14/01/2013	160	7.84	322	161	7	216	256	69	6.4	0.9	20	15	71
19/02/2013	70	8.01	352	176	8	231	239	83	5	5.4	7.56	12	103
13/03/2013	30	7.72	334	167	13	172	300	91	4.7	1.1	17.4	11	67
15/04/2013	411	8.32	303	152	6	171	183	48	3	1.1	15.1	13	56
12/5/2013	1.8	8.15	275	138	10	130	208	59	3.1	0.5	14.5	7	39
18/06/2013	111	7.63	307	154	11	182	208	69	3.9	0.8	8.52	7	46
15/07/2013	5.7	7.39	403	202	11	141	196	55	5.5	1.3	14	5	38
18/08/2013	32	8.02	424	212	12	166	215	57	7.7	1.4	17.4	5	60
15/09/2013	16	8.22	422	211	6	164	223	57	8.5	1.5	19.3	6.5	69
20/10/2013	8.9	8.5	423	212	4	167	216	86	9.9	1.6	0.24	6.5	70
17/11/2013	1.3	7.9	408	204	7	159	232	86	10	10	4.08	8.5	70
15/12/2013	89	7.6	344	172	3	150	225	79	17	3.2	6.6	13	68
Jan.2015	11	8.32	388	400	2.4	178.8	170	-	-	-	-	-	-

March.2015	20	7.84	358	300	6	160	196	-	-	-	-	-	-
May-15	149	7.56	338	200	4	140	156	-	-	-	-	-	-
2/7/2016	77	8	425	213	11	187	178	44	6	0.8	16.3	9	55
4/11/2016	29	7.2	388	194	10	181	173	40	3	0.4	17.5	4	35
6/7/2016	268	7.7	293	147	20	143	145	36	2.8	0.7	13.2	4	40
12/18/2016	159	7.5	442	221	11	199	368	92	7	1.14	33.1	11	66
2/5/2017	46	7	456	228	15	176	348	87	8	0.9	31.3	8	70
5/23/2017	31	7.4	338	169	10	133	178	51	3.7	0.6	12.1	6	61
7/18/2017	347	7.6	393	197	13	211	300	75	3.4	0.8	27	4.2	53
9/28/2017	45	7.5	388	194	14	189	203	53	4	1	16.9	4	53
12/18/2017	24	7.4	456	228	10	221	375	##	5	1.2	28.8	8	75
2/6/2018	36	7.5	500	250	11	176	377	87	9	0.6	38.3	8	70
5/10/2018	45	7.5	380	190	11	160	175	40	5	1.4	18	10	45
10/25/2018	103	7.5	412	206	11	175	198	46	8	1.3	19.9	5	50
1/6/2019	17	7.2	424	212	10	207	380	95	8	1	34.2	12	10
4/3/2019	56	7.7	412	206	11	350	302	70	12	1	30.5	6	45
7/29/2019	65	7.3	315	158	10	425	356	68	11	1.6	44.6	5	37
9/12/2019	52	7.4	456	228	10	425	392	40	11	1.9	70.1	8	30
10/10/2019	14	7.2	425	213	18	180	290	72	11	0.9	26.4	4.3	30
WHO Standard	5	6.5-8	1000	500	250	200	200	##	200	10	30	50	250

*N.R. means non recorded data

GZR has an annual flow of around 13.3 billion cubic meters (13300 Mm3). Furthermore, due to a lack of large projects within the river basin, the administration did cannot reap considerable benefits from the river's flow. The rate of river flow in winter can be more than 2500 m3 /sec. because it is the rainy season, and this may cause floods in the area. Whereas, in the summer, the discharge may reach 50 m3/ sec. This rate may have a negative impact on the environment, which including water contamination because to a shortage of waste water treatment plants in urban areas within this basin (Sharef and Dara,2021).

The quantity of the GZR water is indicated in Table 6. In September 2001, the minimum rate of GZR water flow was 57 m3/sec. while, the maximum flow rate of 1182 m3/sec and 1033 m3/sec were reported in February 2006 and March 2005, respectively by directorate of Irrigation. Since the minimum reported quantity for GZR was greater than 50 m3/sec; so, the river has ability to feed the proposed channel with 0.8 m3/s.

Table 6: Quantity of Greater-Zab River water

	Average Discharge (m^3/sec)											
	Jan.	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept**	**Oct.**	**Nov.**	**Dec.**
2001	*N.R	N.R	N.R	N.R	N.R	N.R	N.R	N.R	57	59	70	309
2002	223	222	394	1047	859	500	294	106	87	85	87	259

2003	242	352	N.R	N.R	N.R	380	193	N.R	N.R	N.R	N.R	121
2004	392	401	826	658	674	666	340	114	74	72	80	171
2005	481	767	1033	842	644	560	327	108	72	73	80	127
2006	366	1182	987	933	733	587	302	155	140	152	262	191
2007	335	756	742	728	708	445	240	124	100	95	101	119
2008	98	157	343	324	235	153	89	67	58	75	77	85
2009	104	132	384	433	486	275	141	84	74	71	174	194
2010	304	334	439	471	503	317	178	124	102	80	72	75
2011	90	203	324	613	622	391	227	143	120	117	124	120
2012	142	206	282	563	513	248	155	119	106	111	140	144
2013	398	505	540	581	535	402	368	210	185	177	190	225
2014	242	250	412	393	338	239	182	154	138	202	233	265
2015	247	253	305	435	407	260	181	149	140	166	211	197
2016	408	341	535	582	498	318	202	151	135	129	138	178
2017	164	176	325	578	483	N.R	N.R	N.R	N.R	N.R	N.R	N.R
2019	304	45	64	249	381	NR	530	533	490	298	329	NR
2020	308	297	NR	NR	NR	NR	NR	NR	496	412	251	297
2021	NR	NR	312	303	378	463	533	387	406	442	394	310

3.3. Simulated Hydraulic Design

A number of hydraulic designs were prepared to transport water from the GZR to North-West, North-East and East parts of Erbil City. A pump station was required to transport water from the GZR to DaraShakran station because the transfer is at a high elevation, Figure 11. The water shape was shifted from Darashakran to Bastora, Figure 12. However, because the water transfer from Bastora to other regions is more difficult due to the lower elevation, the researchers proposed to design a trapezoidal channel for the water. The details are shown in Table 3 and table 7 shows ponds location and cross section. Figure 13 shows pipe cross section. Figure 14 illustrates plan of the proposed pumping station, pipe line, ponds and channels. Typical section of the proposed channel is shown in Figure 15.

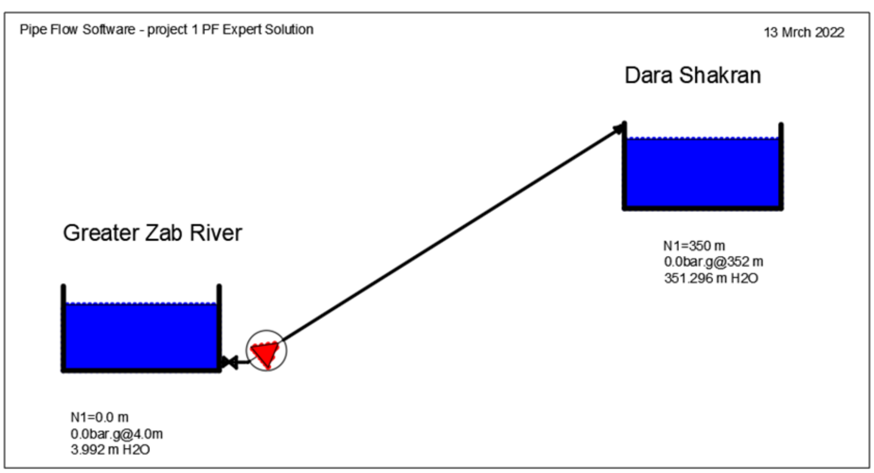


Figure 11: Pump station to convey water from GZR to DaraShakran Station (Pipe Flow Expert software V. 7.40).

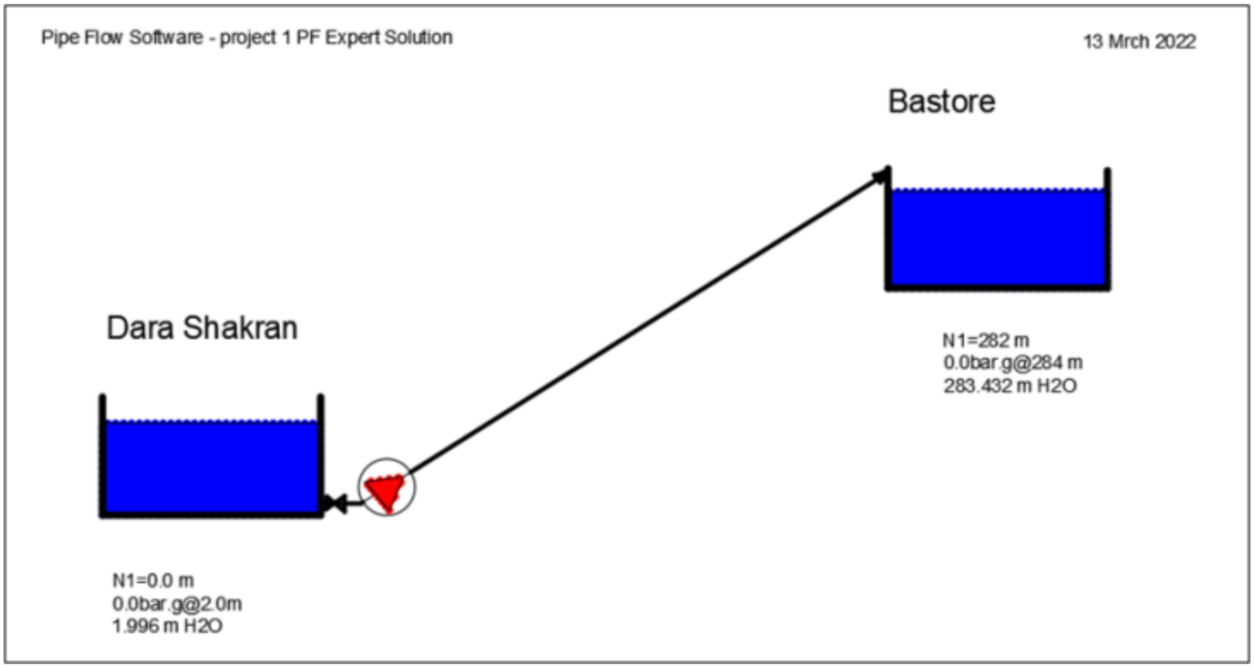


Figure 12: Conveying water from Dara Shakran to Bastora Station (Pipe Flow Expert software V. 7.40).

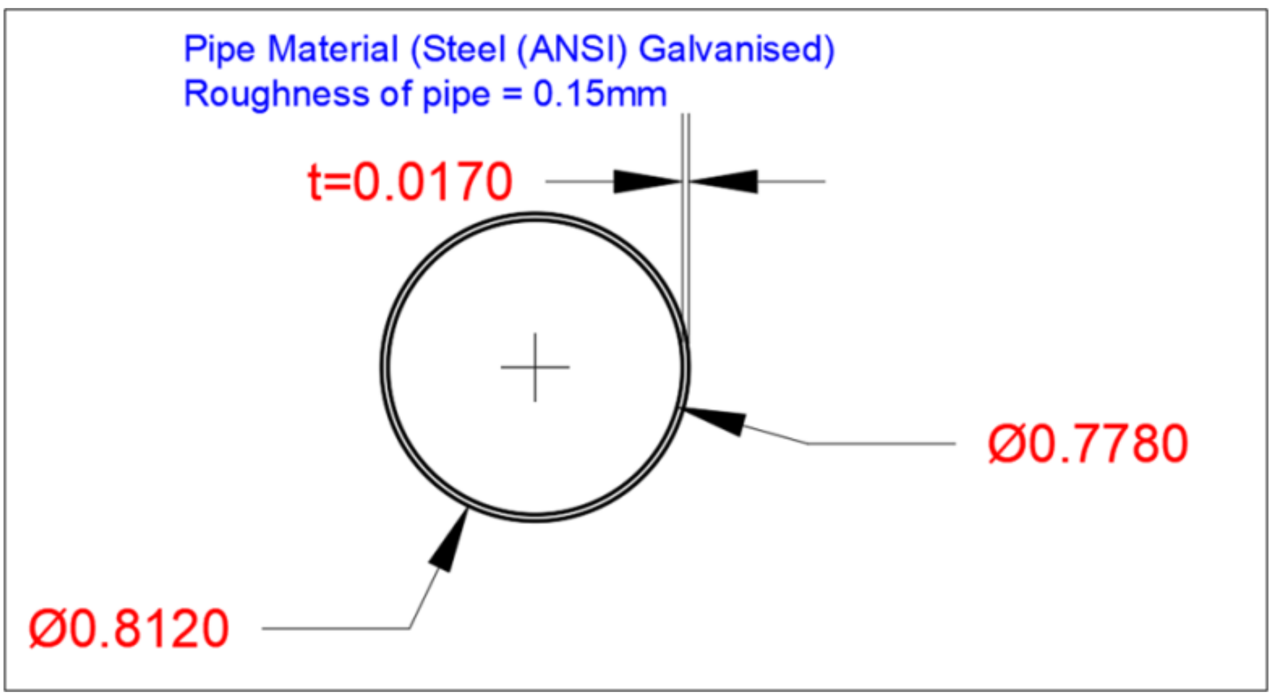


Figure 13: pipe cross section (Auto CAD 2022).

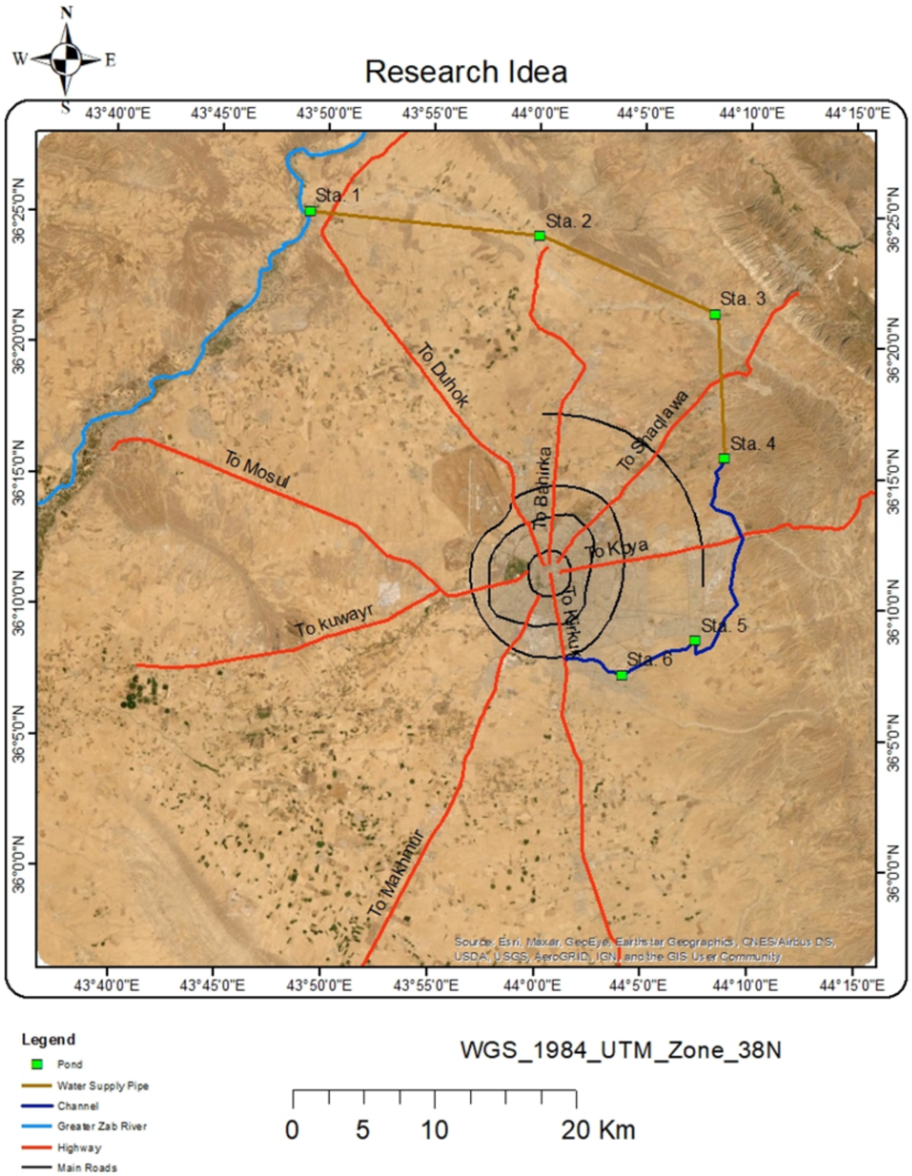


Figure 14: Proposed pumping station, pipe line, ponds and channel.

Table 7: ponds location and cross section

Station	Pond location	Pond length m	Pond width m	Pond depth m	Pond elevation m
Sta. 1	Greater Zap	250	250	2	257.87
Sta. 2	Darashekran	250	250	2	349.93
Sta. 3	Bastora	250	250	2	594.1
Sta. 4	Mala Omer	250	250	2	680.37
Sta. 5	Banaslawa	250	250	2	505.64
Sta. 6	Daratoo	250	250	2	441.04

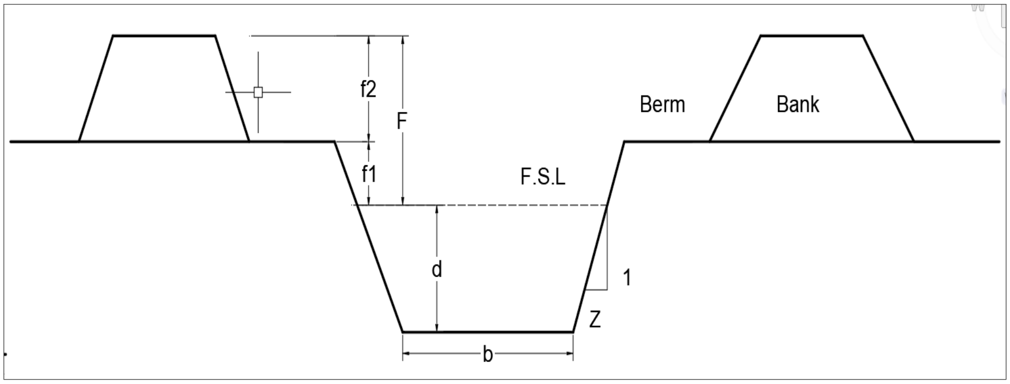


Figure 15: Canal cross section elements.

F.S.L: Full supply level,

b: Canal bed,

1:Z: Side slope,

Bern or Berm: A short strip of land formed on both sides of a channel at G.L. Its width is determined by the channel's size. The berm is constructed in such a way that the bed and bank lines are parallel. If the cutting slop is S1:1 and the filling slop is S2:1, the initial berm width is (S2 – S1) d1. Shows in Figure 16. They were used to keep the earthwork from collapsing into the canal, and they allow the canal to be widened in the future (Subramanya, 2009).

Free board for lined canals is the height of the lining measured from the F.S.L. shown in Figure 17. This spacing ought to be adequate to avoid wave-induced overtopping of the canal's banks or lining. The size, location, velocity, and depth of the flow all affect how much free board is offered. According to the applicable Indian requirements, the minimum free board should be as follows:

Table 8: Discharge and depth of free board (Subramanya, 2009)

Q (m^3/s)	< 0.15	0.15-0.75	0.75-1.5	1.5-9.0	>9.0
Free board (m)	0.3	0.45	0.6	0.75	0.09

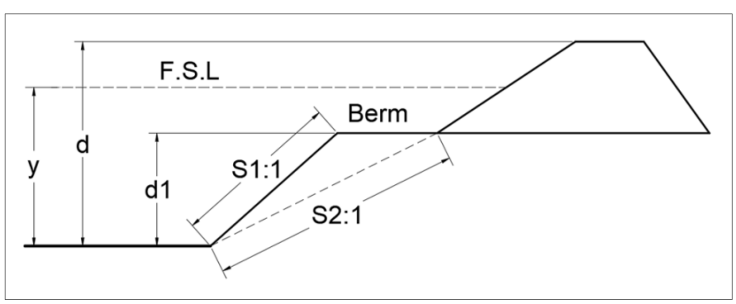


Figure 16: berm of both side of cannel (Subramanya, 2009).

On canals, service roads are provided for inspection purposes and may also be used as a form of communication in distant places. Depending on the size of the channel, they are provided 0.4 m to 1.0 m above F.S.L. (Subramanya, 2009).
Its application is limited due to its expensive initial cost; yet, it has outstanding hydraulic qualities. M 15 concrete has a thickness of 5-10 cm, while M 10 concrete has a thickness of 7.5 to 15cm.

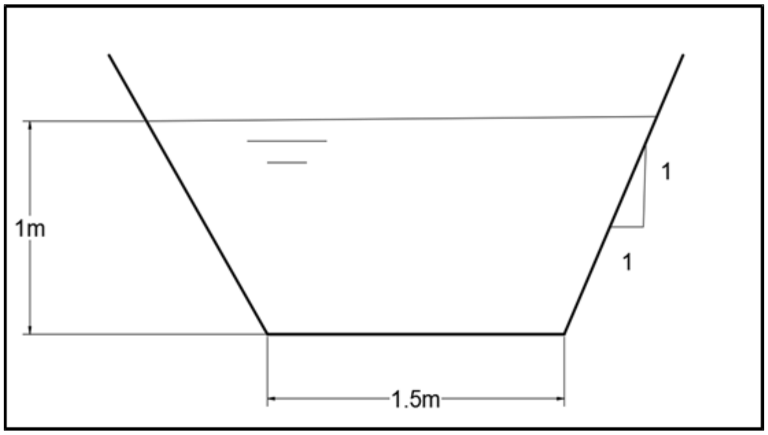


Figure 17: Section of the proposed channel.

$$Q = \frac{1}{n} A R^{\frac{2}{3}} \sqrt{S_f}$$

Sample Calculation:
Side slope 1H: 1V
Q=4 m^3/s (assume for design)
Manning coefficient (n) = 0.014 (average value for concrete)
Area of trapezoidal= (B+ my) y =2.5 m^2
Wetted Parameter (P)=B+2y$\sqrt{(1+m^2)}$ =4.33 m
Hydraulic Radius (R) = $\frac{A}{P}$ = 0.577 m
For various types of materials, the allowable velocity in the lined channel falls into the following range. 2-2.5 m/s for concrete lining. (Subramanya, 2009)
Velocity (v) = $\frac{Q}{A} = 1.6\ m/s \cong 2$ m/s its ok .
Energy (E_1)= y1+$\frac{V_1^2}{2g}$ =
$S_o = \frac{250}{10200}$ = 0.0245
Q = $\frac{1}{n} A R^{\frac{2}{3}} \sqrt{S_f}$
Let Y2= 1.2 m then

$$\Delta X = \frac{\Delta E}{S_o - S_f}$$

$\Delta E = E2 - E1$
Volume of pond = Q*Time = 4$\frac{m^3}{sec.}$* 24*3600 sec.
=345600 $m^3 \cong 350000\ m^3$
Vol. = B * L * D

= 250*250*5.6
=350000 m^3
Roughness of concrete pond = 0.012
The cross section areas of the ponds are shown in Figure 18.

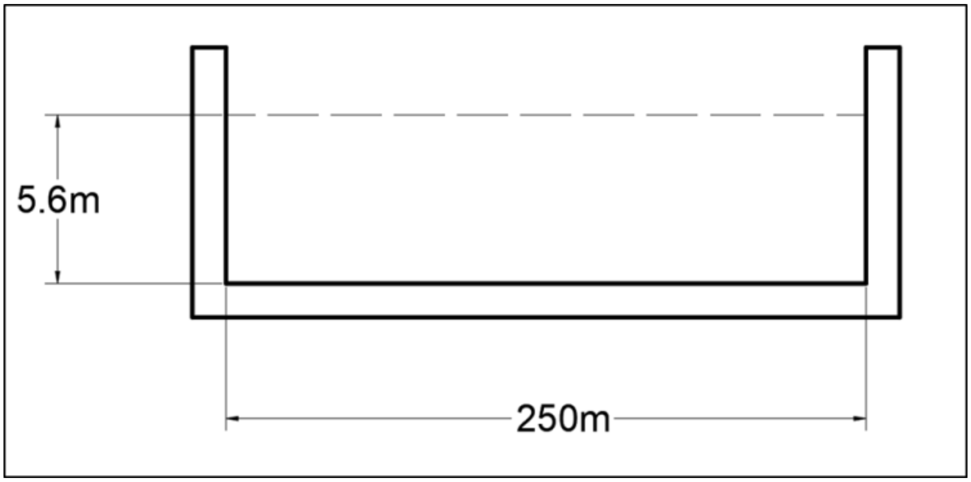


Figure 18: Reservoir Pond cross section areas.

Table 9: Details of hydraulic calculations for the stations

Parameter	Part				
	1	2	3	4	5
Station and Locatic	Gretear-Zab Riv DraShkran	DaraShkara Bastora	Bastora Mala Omer	Mala Omer Bnaslawa	Bnaslawa Daratwoo
Elev. (m)	349.93	631.47	599.28	505.64	441.05
Length (m)	18700	18000	10200	14390	5901.52
Pipe dia(m)	0.778	0.778			
Y(m)	2	2	1-1.2	1-1.2	1-1.2
A(m^2)			2.5-3.24	2.5-3.24	2.5-3.24
P(m)			4.33-4.89	4.33-4.89	4.33-4.89
R(m)			0.577-0.662	0.577-0.662	0.577-0.662
V(m/S)	1.683	1.683	1.6-1.23	1.6-1.23	1.6-1.23
Q (m^3/s)	0.8	0.8	4	4	4
E (m)			1.13-1.277	1.13-1.277	1.13-1.277
ΔE (m)			0.147	0.147	0.147
Sf			0.00104-0.00051	0.00104-0.00051	0.00104-0.00051
Avg.Sf			0.000779	0.000779	0.000779
So-Avg.Sf			0.024	0.0035	0.01122
ΔX(Friction losse)	52	50	6.13	42	13.1
Ph	752	614			
Slope So	0.019	0.016	0.0245	0.0043	0.012

3.4. Improvement of Erbil Environment

Erbil is a plain location surrounded by mountains in the Kurdistan Region's core. As a result, the majority of the locations, particularly the mountainous ones, are used for tourism, and many people visit throughout the year. Many places near Erbil, on the other hand, have been unable to benefit from the shortage of water. As a result, the authors wanted to take advantage of the GZR's water and explore what might be done in some regions so that we could expand our tourism destinations and boost the city's economic benefits. On the other hand, creating flora both outside and inside the city would help to minimize the amount of dust that falls on our city each year. Also, there's the greenery. Decades of research have provided the scientific foundation for understanding the role of the environment in disease. For many pollutants, scientists know with some certainty that exposure to these pollutants, at sufficiently high concentrations; can cause a variety of health effects. For other pollutants, where scientific evidence is less conclusive, scientists can only establish an "association" between exposure and health problems (Azez, 2013). To treat and decrease diseases, more green space should be created. The pollution in the inner city will be reduced. Erbil's center is flat, with various mountainous locations surrounding it.

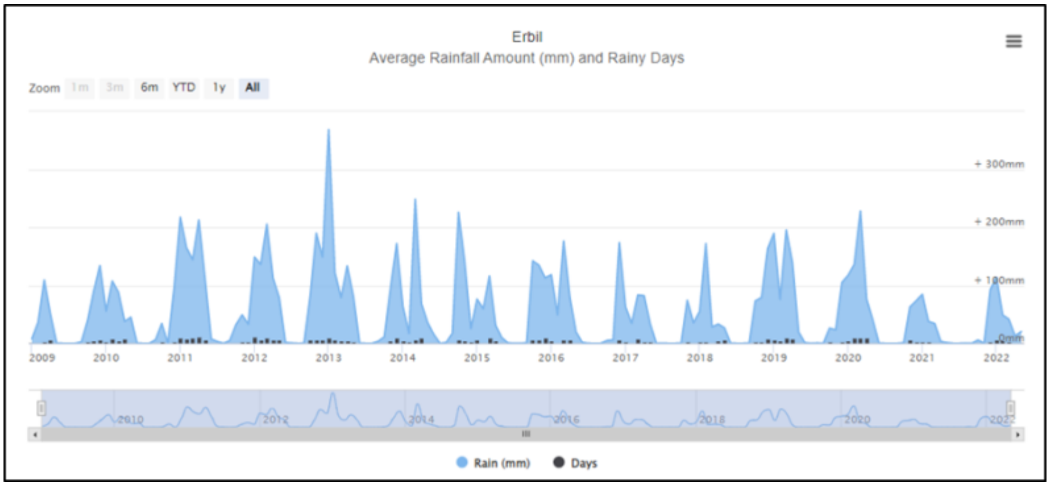
Climate alternate has impacted a big agricultural element in Iraq via way of means of growing desertification, deteriorating agricultural expansion, and diminishing livestock, which resulted from degradation and absence of herbal vegetation. This in flip has negatively impacted the human and food protection of the country. Continued reduced rainfall and runoff were a widespread contributor to enormous desertification and sand and dirt storms ensuing in arable ground loss (Adamo et al., 2018).

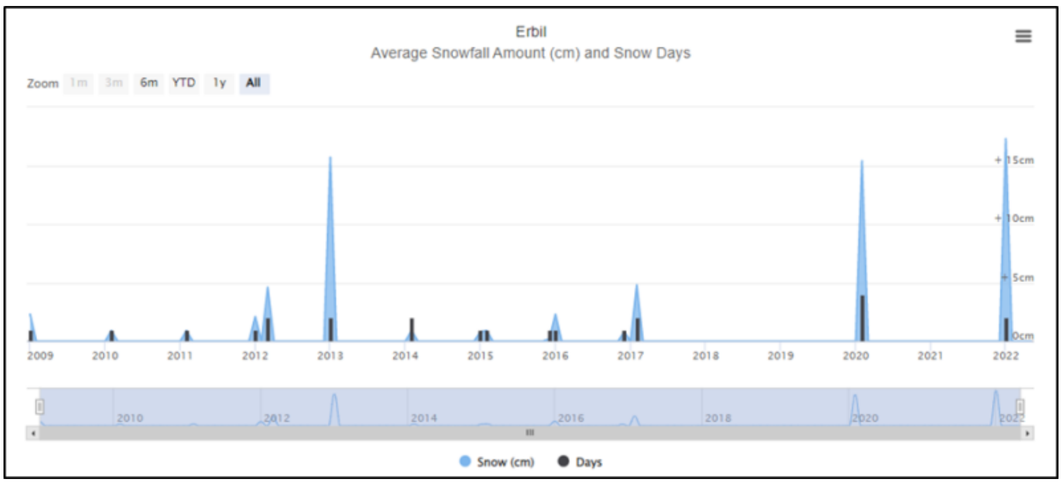
To keep away from future generations having to produce top-class rates to address the unfavorable outcomes of weather alternate, it's far vital that those components are considered in formulating weather alternate guidelines for the region. Relevant policies to deal with climate change in the field of water resources may include, for instance, recycling of waste water, steps and measures to mitigate and adapt to these impacts through (for example) water-reuse measures, water-sensitive urban infrastructure design such as rainwater tanks, rain gardens and constructed wetland, and growing plants tolerant to drought (Al-Ansari et al., 2021).

Climate change, industrialization, investment projects, oil productions, decrease of green and planted areas, increase number of vehicles, air conditioning split units, and electric generators impacted on the Erbil Environment. Variation of rainfall, snow, temperature, wind, cloud, UV index, visibility, and pressure in Erbil are shown in Figure 19. It can be noticed that commonly rainfall, snow, cloud, UV index, visibility, and pressure decrease; while, temperature, and wind, increase. Additionally, in 2022 dust storm several times hit Erbil which caused in visibility reduction and air pollution. The goal for conveying fresh water from GZR to Erbil City is to increase chance of rainfall and snow, humidity, visibility, green areas and tourist; and to decrease of air pollutants, dust storm, temperature, and desertification.

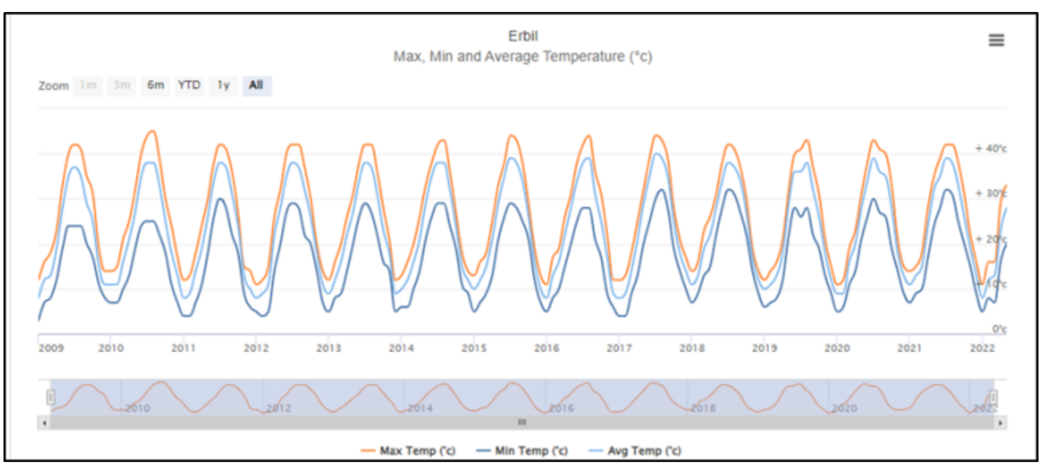
On the other hand, construction of ponds and channels cause retention and diversion of flood problems in this area. Additionally, storage GZR water in the ponds and flowing in the channels led to improvement of groundwater table in the selected area.

Rainfall



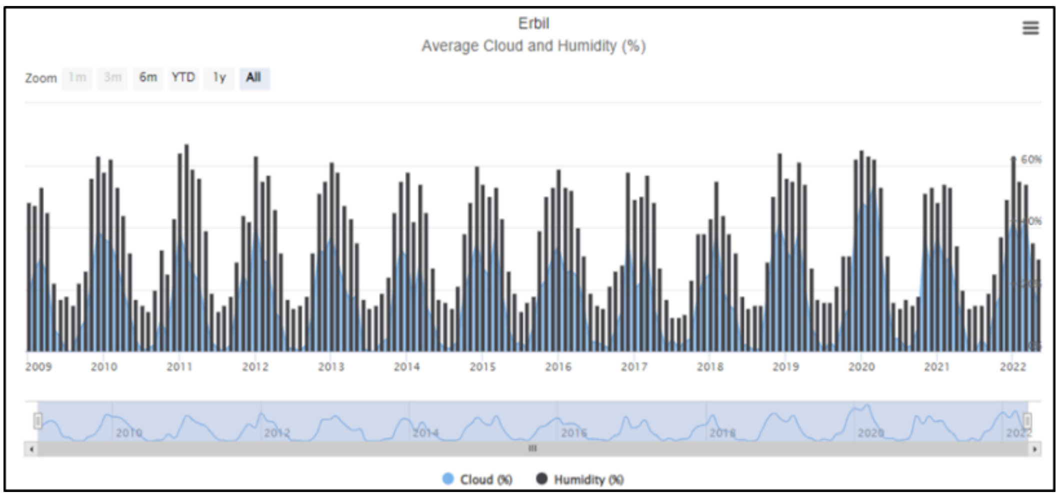


Snowfall

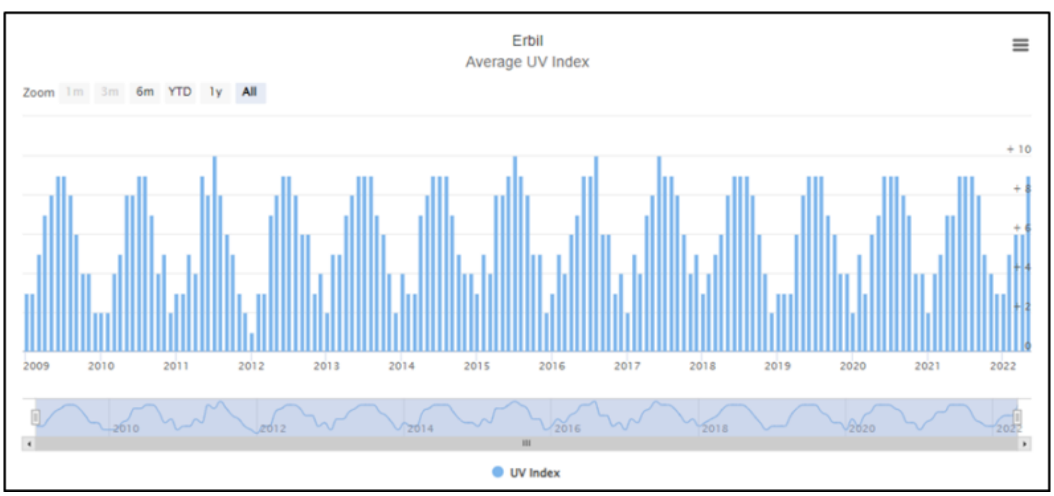


Temperature

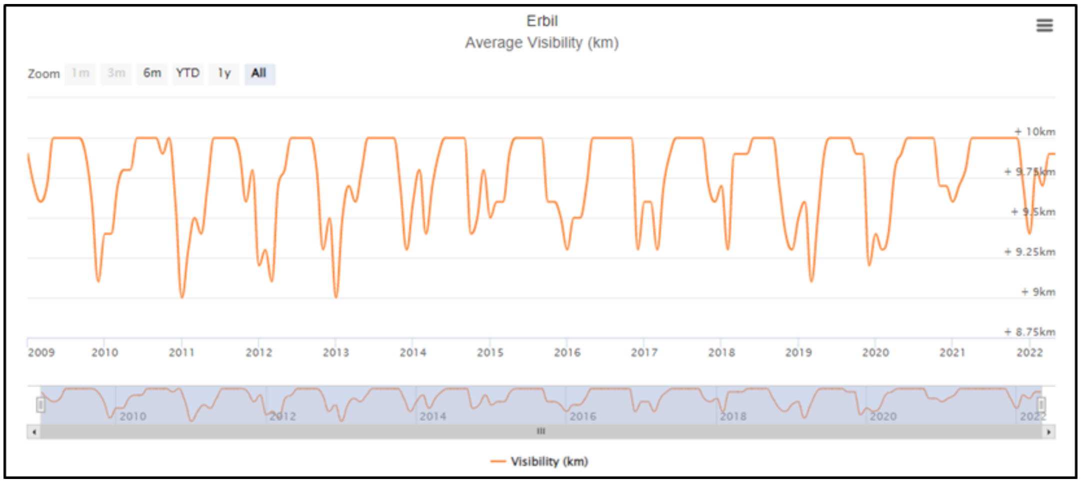
Wind



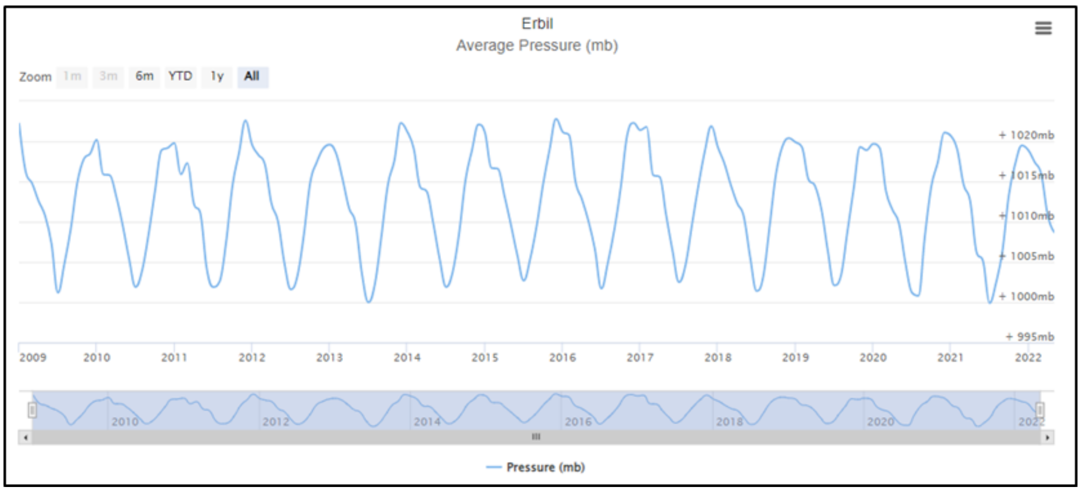
Cloud



UV Index



Visibility



Pressure

Figure 19: Variation of rainfall, snow, temperature, wind, cloud, UV index, visibility, and pressure in Erbil (Sources: https://www.worldweatheronline.com/erbil-weather-averages/arbil/iq.aspx)

3.5. Increasing Irrigated Areas

Adopting stepped forward irrigation generation has been superior to lessening offsite water amount and quality issues. It might appreciably grow water-use performance on the farm level. Whether generation adoption can reap considerable water financial savings for nonfarm and in-stream uses, however, will rely upon many factors. The effectiveness of generation in attaining environmental desires has vital implications for nearby water guidelines.

The time period performance may be very frequently used for specific irrigation systems performance. It is generally carried out to every irrigation sub-machine: storage, conveyance, distribution off- and on-farm, and on-farm utility sub-structures. It may be described via way of means of the ratio among the water intensity added via way of means of the sub-machine below attention and the water intensity furnished to that sub-device (Wolters, 1992; Pereira, 1999).

Expansion of irrigated regions includes a metamorphosis of rain-fed cropland regions or the conversion from forested or different herbal lands. Upgrade upgrades are accomplished with the aid of using changing present irrigated regions from low-performance systems (such as flood/gravity systems) to more efficient systems (such as drip and sprinkler systems). Efficiency enhancements may be carried out through improvements made to present flood/gravity irrigation structures thru land leveling, better irrigation scheduling, or stepped forward water distribution (Miao et al., 2018).

For Irrigation area 1 litter/sec for 1 hectare, while one hectare equal to 4 donums

Hence the area will be irrigated by 16000 donums

Q available = 4 m^3/s

Q demand $= \frac{\text{Area (donum)}}{4} * 1\ L/s = \frac{16}{4} = 4\ m^3/s$

So there is no need for a wise weir to irrigate the lands. (Bedient, 2008)

4. Conclusions

Pumping station, pipe line, ponds and channels were deigned to convey water from GZR to upper part of Erbil City. Prosed discharge was 0.8 m^3/sec. Pond with capacity of 9000 m^3 and hydraulic channels with dimensions of 1.5 m Width and 1 m depth were designed. Rainfall, snow, cloud, pressure, UV index, and visibility decrease in Erbil City. Whilst, temperature, dust storm, desertification, deepen of groundwater level increased. Receiving fresh water from GZR improves Erbil City environment, increases groundwater table and tourist, decreases desertification. Additionally, the proposed hydraulic channels can irrigate 16000 donums of the land. Proposed ponds and channels led to decrease flood problem in the selected area.

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