Analyzing and Estimating the Highway Drainage Capacity With the Aid of Geographic Information Systems (GIS)

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Abstract—**In this research, geographic information systems (GIS) were used to analyze the basic features of the catchments whiten the study area. The GIS were used to calculate the data required to design several bridges and culverts of the Ramadi-Nukhaib highway in the western region within Al-Anbar province. Hydrological and climatical data were collected, and soil texture analyses were performed on selected soil samples from the study area. Hydraulic calculations were designed to estimate the maximum flood discharge of the valleys crossing the road for different flood return periods. Also, the points of intersection between the valleys and the road were identified. Additional information was obtained from digital elevations models (DEM), rational method, and the Soil Conservation Service (SCS) method in order to suggest suitable sites, sizes, and types of the bridges and culverts along the route of the highway within the study area.**

Key Words- Highway Hydrology, GIS, Engineering Hydrology, Culvert design.

I. Introduction

A considerable part of the total cost of highways construction (some sources suggested as high as 25 percent) is due to the high cost of installations of stormwater drainage structures such as bridges and culverts. These structures are built to drain rain water between the two sides of the road during and after rainstorms [1]. Adequate designs of these types of hydraulic structures require careful studies of the basin that intersects the highway and the soil properties. In addition, the climate, land use, and vegetation must be investigated to obtain a precise estimation of the peak flood of the basin at a specified return period. Specifically, the precise estimation of the peak flood will reduce the additional costs which may result from the use of over-conservative designs. Furthermore, the precise estimation of the peak flood will lead to a safe design that reduces the probability of a flood wave to submerge the road when the hydraulic structures are unable to release the discharge that coming from the rainstorm. Consequently, the economic and safe design will reduce the total cost of the project and reduce the probability of the failure of the hydraulic structures which may cause many losses of properties and lives.

A culvert is a hydraulic structure that allows water to flow under the road. The culverts are constructed at road-stream crossings by making an opening under the road to allow water to flow during the rainy season [2].The design procedure of the culverts and bridges for the highways work in the western region of Iraq has been faced by many difficulties. Specifically, the topographical and hydrological information have been based on limited measurements and data obtained from a few small areas. Moreover, processing of these measurements and data may take considerable amounts of time, efforts, and money. The completion of topographic maps by performing site survey on the study area that located in the Iraqi Western desert would be a difficult work and would require high cost because of the large scale area of this region that is mostly uninhabited and the absence of the infrastructures. Therefore, searching for new methods to overcome these difficulties is very important. The available modern technologies such as remote sensing and geographic information systems provide valuable alternatives for fast and reliable determination of the data required for the design such as areas of drainage basins, waterway lengths, slopes of main waterway, the main points of intersections between the stream and the road, and other information tasks.

The remote sensing is the science and art that is used to obtain information about objects, or regions or particular phenomena through information obtained by the analysis of a sensor that is not in contact with these objects to be verified [3]. Geographic Information Systems is a method to regulate the geographical and non-geographical information by using a computer and then it is linked to their geographical positions depending on the specific coordinates. Geographic Information systems consists of three parts: (System) which is a computer technology and software associated with it; (Information) which is about the data that comparing these systems and methods of management; organization and use of the third part is the (Geographic). Geographic represent the spatial component of these systems, which is a ground and the real world in which that information is located [4].

The GIS has been considered in extracting information from satellite images for several factors including speed and thoroughness, repeatability and accuracy in addition to its lower cost compared with the conventional methods that have been utilized in such studies. The hydrological data obtained from the equations that is based on geometrical properties of basins can as an alternative to the unavailable data of the study area. The GIS has been used in the hydrological analyses for different objectives, as reported by [5], the remote sensing and GIS software techniques were employed to create topographic maps of Ga'ara Dam, located in the western region of Iraq, as well as the definition of the geometrical characteristics of the basin upstream the dam. In this study, the calculated hydrological information was used to the design of the dam. Specifically, this information was used to determine the storage capacity and the maximum runoff which are required to design the spillway of the dam. The research showed that using the data from remote sensing techniques saved efforts and time and provided cost-benefits and reliable quantities calculations with an acceptable accuracy comparing with traditional methods. The geographic information systems was also used to extract data from satellite images that can be used to generate a reliable hydrological model that can be utilized for the design of structures such as highway roads and bridges [6]. Furthermore, the GIS was used to facilitate the design of culverts under the highways by reducing the time and increasing the accuracy of the calculations of the maximum probable discharge in the study area. It was found that these calculations were more representative of the drainage basins specifications [7].

The purpose of this study is to estimate the maximum discharge flood for different return periods for valley basins that intersect the highway that connected between Ramadi and Nukhaib cities. The hydrological design data was created and processed by using the geographic information systems. Moreover, the appropriate structures to safely accommodate the maximum flow discharge were chosen using the commercially available software for hydraulic design of culverts (HY-8) issued by the United States Federal Highway Administration (FHWA).

The importance of this study is to deal with the major problems faced by highway continuously as the poor design and selection of culvert sites led to the collapse and Considerable material losses in many of the roads in Iraq, such as Rutba - Akkashat and Ramadi –Heet highway and other as shown in Fig.(1).

II. LOCATION OF CASE STUDY

The study area instigated by this research was along the Ramadi-Nukhaib highway within AL- Anbar province west of Iraq in latitude (32 0 36' 50”), (33 0 24' 44") and longitude line (42 0 42' 48"), (43 0 10' 58"). The highway segment that was investigated started at station 0+00 km east near Ramadi City and ended at station 90+00 km west, near Nukhaib City, as shown in Fig.(2).

Figure 1. Failure of hydrological structur along the highway

Figure 2. Location of the study area.

Area of study is a dry desert area where the most annual rainfall is between the late October and the beginning of May. An annual rate of rainfall of 140 mm has been recorded and the temperature rates vary from minimum temperature rate of (2.7 ^{O}C) in December to maximum temperature rate of (41.7 ^{O}C) in July. The main geological formations in the study area are the limestone formations [8].

III. THE RESEARCH METHODOLOGY

The route of the highway was identified and the coordinates of the every 50 meters along the route of the highway was created to ensure that the locations of the intersections of the culverts with the road are accurate. A site reconnaissance was performed to identify the valleys locations and to determine their coordinates using a GPS device. A nine soil samples were obtained from selected locations within the study area for sieve analysis and chemical tests. The sieve analysis tests showed that most of the soil samples were classified as loam to sand, while the chemical tests showed that the samples consist of a high percentage of lime content. The lime content was 289.7 g/kg for the sample number 6 and it decreased to 47.9 g / kg for the sample number 2. The gypsum content rage was from 15.3 g / kg for the sample number 4 to 3.8 g / kg for the sample 7 as listed in Table 1. Analysis of soil texture has an important role to determine the amount of surface runoff and to draw the hydrograph and this will be considered in the calculations of the hydrological basin. As it was identified from the field visits to the study area, there was a scarcity of vegetation density.

TABLE 1. Summary of sieve and chemical tests of the soil at depth 0 to30 cm.

Sample No.	*sand %*	*Silt %*	*clay %*	*Texture*	*Lime gm/kg*	*gypsum gm/kg*
1	65.3	8.2	26.5	Sandy clay loam	222.1	14.9
2	71.9	23.2	4.9	Sandy loam	47.9	9.1
3	44.8	30.2	25	loam	87.1	13.2
4	77.2	14	8.8	Sandy loam	55.3	15.3
5	39.9	25.2	34.9	Clay loam	132.7	13.8
6	61.8	8.9	29.3	Sandy clay loam	289.7	4.3
7	73.5	12.2	14.3	Sandy loam	105.1	3.8
8	80.3	10.8	8.9	Loamy sand	101.6	14.2
9	63.4	13.1	23.5	Sandy clay loam	256.7	12.5

Due to the lack of adequate studies about the flow incomes to the different valleys within the study area, the satellite images were used to derive the necessary data to calculate the maximum discharge passes through the various valleys during the design age of the highway, as follows:

1- Use satellite data of the study area from the United States National Aeronautics and Space Administration (NASA) with DEM format at a discriminatory accuracy of 30 meters. The data were processed utilizing commercial software (Global Mapper 14) in order to repair the gaps and defects in this data. The DEM data are essential for the GIS software to determine the topographic and spatial characteristics of the study area. Fig. 3 shows the digital elevation model of the study area.

2- Extract survey and morphology properties of the drainage basins by using commercial software (Watershed Modeling System WMS 9.0), which is specialized and integrated in geographical information systems in the field of hydrological studies of drainage basins software as demonstrated in [9].The program was used to determine the boundaries of the drainage basins of the study area that cross the Ramadi-Nukhaib highway. Furthermore, it was used to identify some properties of the drainage basins such as the area, length, and length of the longest valley of the drainage basin; in addition to the distance from the center of the drainage basin to the point of intersection with the highway, slopes, surface runoff, the coordinates of the intersections of the valleys, and other specifications as described by [6]. Fig. 4 shows the drainage basins in the work area as derived from satellite images by utilizing the software (WMS 9.0). It can be identified a 50 drainage basins of different sizes within the study area.

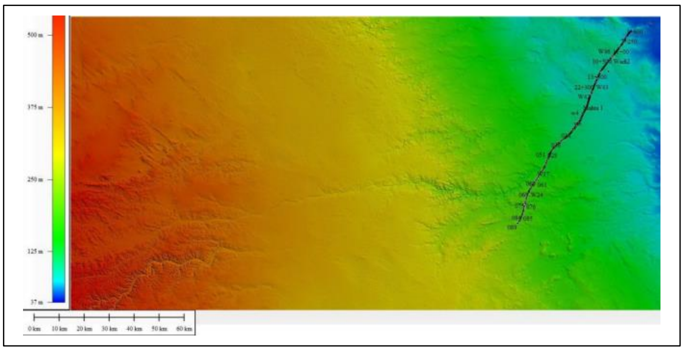

Figure 3. The digital elevation model of the study area

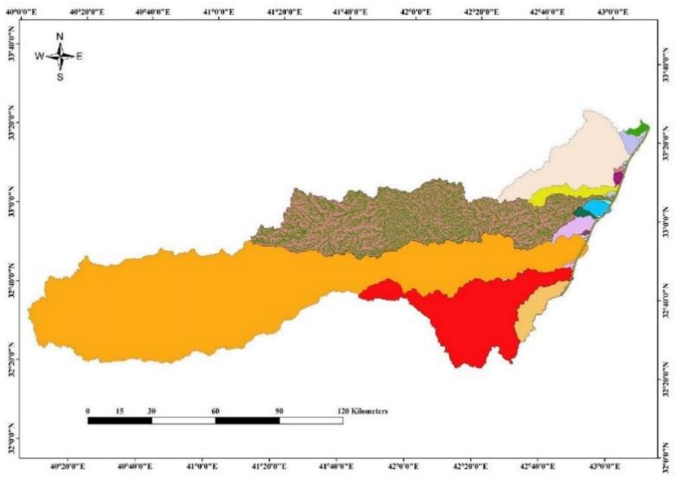

Figure (4): The drainage basins that derived from satellite images

3- The largest drainage basin that intersect the highway route was basin C38 that is locally known as Ghadaf valley. This valley has a total area of 7790.71 km^2 and borders length along the main valley of 338 km. The smallest drainage basin (C36) has an area of 0.29 km^2 and a length of the main valley of 0.9 km. Table 2 shows the drainage basins specifications of the study area as taken from the DEM.

4- The SCS method was used to estimate the unit hydrograph for the drainage basins with areas of about 2.5 km^2 due to the lack of sufficient studies on flow income of various valleys of the study area. These basins is called medium drainage basins. For small basins of areas less than or equal to 2.5 Km^2, the Rational Method (Equation 1) was used to estimate the maximum runoff hydrograph as described by [10].

$$Q_p = 0.278\, C\, I\, A \qquad (1)$$

Where: Qp = Max. Discharge (m^3 /sec).

C = discharge coefficient take from Table 3.

I = rainfall intensity (mm/hr).

A = area of drainage basin (Km^2).

TABLE (2): THE DRAINAGE BASINS SPECIFICATIONS IN THE STUDY AREA TAKEN FROM SATELLITE IMAGES.

Catchment Symbol	Basin Area (km2)	Basin Slope (m/m)	Distance from Centroid to Outlet (m)	Mean Stream Distance (m)	Mean Stream Slope (m/m)	Basin Length (m)	Sinuosity	Perimeter (m)	Mean Elevation (a.s.l)
C1	36.25	0.0092	5847.33	13572.25	0.002947	11554.62	1.175	45146.85	86.77
C2	8.08	0.0114	3428.94	6939.63	0.004887	6578.95	1.055	20537.68	87.62
C3	2.18	0.0125	897.91	2410.45	0.009179	2679.07	0.900	8548.13	86.55
C4	3.865	0.01231	1188.625	1823.674	0.00251	2145.919	0.850	10519.145	96.90
C5	0.89	0.0091	674.65	833.93	0.004555	1305.02	0.639	5076.18	94.69
C6	64.61	0.0083	6138.41	14734.24	0.001632	11710.43	1.258	53290.60	98.30
C7	1148.11	0.0073	34151.66	82606.14	0.002386	65178.61	1.267	276670.97	132.52
C8	0.28	0.0088	140.13	140.13	0.010851	911.55	0.154	2861.97	91.90
C9	0.78	0.0103	508.80	834.64	0.008604	1477.15	0.565	4824.06	92.91
C10	1.90	0.0080	1128.26	1975.40	0.004289	2096.67	0.942	7943.34	93.32
C11	0.40	0.0083	621.66	621.66	0.003488	1320.72	0.471	4607.57	90.73
C12	2.12	0.0095	680.39	1809.42	0.005477	2218.59	0.816	7955.47	90.39
C13	9.69	0.0061	3629.69	7198.05	0.001506	5692.66	1.264	21914.32	93.16
C14	1.59	0.0069	226.90	791.67	0.001392	1382.89	0.572	7082.37	93.64
C15	0.39	0.0056	90.69	90.69	0.007472	968.53	0.094	3702.39	94.62
C16	22.50	0.0054	2414.17	6652.66	0.001026	5292.79	1.257	29568.30	93.55
C17	187.96	0.0071	31265.11	57595.95	0.002506	44779.87	1.286	151248.94	160.52
C18	1.03	0.0063	452.82	612.10	0.003809	1150.00	0.532	4977.57	101.34
C19	11.06	0.0043	4368.15	8537.95	0.001582	7286.26	1.172	24371.30	106.97
C20	0.31	0.0054	192.38	192.38	0.003588	818.25	0.235	2851.78	101.64
C21	0.84	0.0042	552.21	769.17	0.000056	1283.93	0.599	4569.50	102.30
C22	2.50	0.0061	1093.41	2388.69	0.00129	2201.20	1.085	7845.61	104.55
C23	1.08	0.0074	1056.85	1476.54	0.001501	1660.55	0.889	6164.65	103.90
C24	3414.89	0.0104	128537.59	243811.62	0.001785	171335.59	1.423	652527.48	358.29
C25	7.13	0.0043	3212.57	6391.14	0.001856	6136.87	1.041	18629.77	108.47
C26	71.53	0.0065	6847.10	17322.31	0.002743	13914.76	1.245	53051.77	123.22
C27	2.67	0.0040	1590.98	2988.11	0.002357	2817.98	1.060	10167.98	114.69
C28	1.18	0.0070	1012.66	1374.68	0.005411	1833.32	0.750	5437.89	124.67
C29	30.98	0.0064	8792.04	15777.41	0.002313	12572.80	1.255	42783.22	145.43
C30	1.13	0.0059	206.65	489.03	0.001257	1436.63	0.340	5473.10	125.43
C31	121.13	0.0070	12903.76	30565.29	0.003105	23685.89	1.290	84787.89	167.93
C32	123.13	0.0070	12903.76	30565.29	0.003105	23685.89	1.290	84787.89	167.93
C33	8.16	0.0093	2912.16	5489.78	0.005508	5572.83	0.985	17333.82	146.82
C34	4.58	0.0089	2959.09	4761.94	0.006313	4861.82	0.979	16403.31	153.77
C35	0.57	0.0076	1101.41	1340.34	0.004325	2346.27	0.571	6388.95	146.30
C36	0.29	0.0134	897.92	897.92	0.004656	1869.86	0.480	4663.62	149.78
C37	1.86	0.0148	768.40	1340.43	0.007494	1947.94	0.688	7357.36	149.00
C38	7790.71	0.0219	202445.70	337338.78	0.001969	264903.13	1.273	982754.69	548.04
C39	5.46	0.0090	1425.18	4512.97	0.004986	5390.21	0.837	16310.35	161.32
C40	4.13	0.0083	1976.10	3944.52	0.00575	3964.09	0.995	13701.45	176.07
C41	0.52	0.0097	663.22	663.22	0.005053	1486.79	0.446	4421.98	181.78
C42	0.62	0.0113	389.24	389.24	0.000679	1230.96	0.316	3984.94	196.44
C43	9.82	0.0075	3274.68	6612.36	0.002917	5901.61	1.120	22382.58	201.06
C44	0.61	0.0085	750.12	750.12	0.005196	1336.24	0.561	4004.42	196.87
C45	0.90	0.0123	420.32	463.77	0.008876	1549.91	0.299	5371.92	196.25
C46	1908.90	0.0067	96961.20	140412.44	0.00183	101586.02	1.382	452387.50	319.28
C47	0.91	0.0052	562.24	810.08	0.003217	1099.86	0.737	5756.53	196.26
C48	272.81	0.0099	24081.66	49233.77	0.002124	35863.21	1.373	134970.11	262.61
C49	1.27	0.0070	460.13	787.36	0.000506	1115.26	0.706	6046.41	210.48
C50	1.38	0.0077	449.77	1263.02	0.003318	1761.26	0.717	6767.33	223.37

TABLE 3. DISCHARGE COEFFICIENT, C (FROM [11]).

Value of C	Topography or terrain
0.2	Flat cultivation sand , Sandy sand
0.5	Hilly areas, Forests, Clay and loamy soil
0.8	Build and urban areas (impervious)
0.4	Flat residential areas
0.6	Moderately steep residential area

For a small catchment, the time of concentration t_c is assumed to be equal to the lag time of the peak flow [17]. The intensity-duration-frequency curves for the hydrological station located in Heet City that shown in Fig. 5 were used to estimate the design rainfall intensity depending on time of concentration from kripich formula and a rainfall frequency of 25 years [15].

$$t_c = 0.01947\, L^{0.77}\, S^{-0.385} \quad (2)$$

Where: t_c = time of concentration (min.).
L = maximum length travel of water (m).
S = slope of catchment.

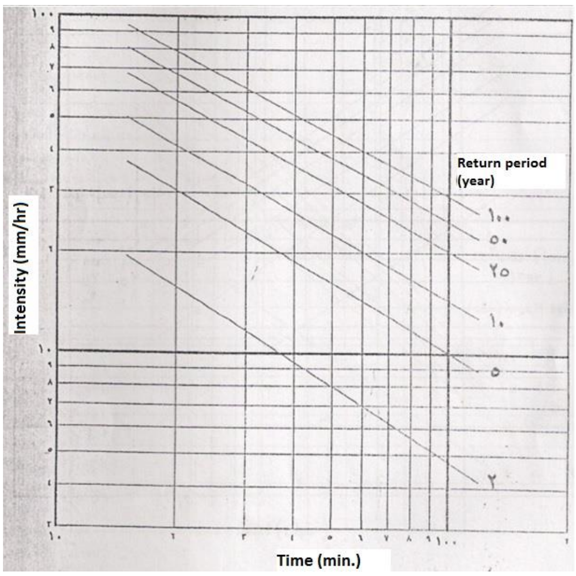

Figure (5): The intensity-duration-frequency curve for Heet Station

The SCS method is most frequently used method to estimate the depth of the effective rainfall for the basins because it considers the soil type, land use, depth of rainfall and soil moisture for days that preceded the rain storm affecting [12]. The SCS method uses the following relationships to estimate the maximum flow rates.

For P > 0.2 S,

$$Q = (P - 0.2\,S)^2 / (P + 0.8\,S) \quad (3)$$

S= 1000 / CN – 10 (4)

For P < 0.2 S, Q = 0 Where:
P = depth of rainfall (mm).
Q = depth of flow (mm).
S = Maximum energy detention.
CN = Curve number rages between (0 – 100).

The US Soil Conservation Service has prepared a special schedule, in which the soil is classified to four categories (A, B, C, and D) and each class expresses a hydrologic condition depending on the soil type and the nature of the land use. Table 4 shows the procedure to obtain the curve number of (CN) for different types of soils.

TABLE 4. CURVE NUMBER FOR SCS (FROM [13]).

Cover Description		Curve Numbers for Hydrologic Soil Group			
Cover Type	*Hydrologic Condition*	*A*	*B*	*C*	*D*
Herbaceous-mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosote bush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

Depending on the tests results of nine soil samples, the soil of drainage basins that intersect the highway in the study area are classified as sandy and loam and it can be represented by the type B,. The examination of the field of land use in the study area shows that the drainage basins located in a desert area untapped for agriculture, so the CN that was used in the calculations was estimated to be 77. By using the morphological properties that were obtained using the software (WMS 9.0), the time to peak (t_P) was calculated. The t_P, which can be calculated from Equations 4 to 6, is the time required for the stormwater to flow from the farthest part of the basin to the point of intersection between the valley and the highway.

$$t_L = \frac{L^{0.8}\,(2540-22.86\mathrm{CN})^{0.7}}{14104\, CN^{0.7} Y^{0.5}} \quad (5)$$

$$t_P = \frac{t_r}{2} + t_L \quad (6)$$

$$\frac{t_P}{t_r} = 5 \quad (7)$$

Tb = 2.67 tp (8)

Where: t_L = Lag Time (hr)
L = Length of main basin (m)
Y = average slop of flow basin (m/m)
CN = Curve Number
t_P = Time to peak (hr)
t_r = Time of rainfall. (hr)
Tb = base time for standard hydrograph. (hr)

By using (SCS) method, the estimating of peak flow of basin valleys under study was achieved with a storm of 10 mm according to the following equation:

$$Q_P = \frac{2.08\,A}{t_p} \quad (9)$$

Where: Q_p = Peak flow (m^3 /s)

A= Area of basin (km^2).

A rainfall frequency of 25 years [1] was used to calculate the design rainfall intensity based on the value of the time of rainfall (tr) taken from the value of lag time (t_L) to calculate the peak flow of water that passed the culverts and the pipes. The intensity-duration-frequency curves for the hydrological station located in Heet City were used [15].

Table 5 shows the hydrological calculations of the study area, which has to extract the maximum discharge of the water that passes through the valley at its intersection with the highway from basin with symbol (C1) to the basin with symbol (C50).

TABLE 5 THE HYDROLOGICAL CALCULATIONS OF THE STUDY AREA

Catchment Symbol	time lag t_L (hr)	time to peak tp (hr)	duration of rainfall tr(hr)	t_c (hr)	t_c (min)	Q max for 1 cm SCS (m3/hr)	Intensity for 25 year frequency (mm/hr)	Q max for Intensity of 25 year frequency SCS (m3/s)	Q max rational method (m3/s)	Q max Final (m3/S)
C1	8.1	9.0	1.8			8.39	10.05	19.63		**19.63**
C2	4.6	5.1	1.0			3.27	17.00	6.35		**6.35**
C3				0.79	47.65		32.00		11.61	**11.61**
C4	1.8	2.0	0.4			3.97	25.00	5.24		**5.24**
C5				0.46	27.56		43.00		6.38	**6.38**
C6	8.6	9.6	1.9			14.04	9.00	39.32		**39.32**
C7	36.2	40.2	8.0			59.36	4.00	144.45		**144.45**
C8				0.08	5.00		100.00		4.74	**4.74**
C9				0.36	21.59		55.00		7.20	**7.20**
C10				0.91	54.79		30.00		9.50	**9.50**
C11				0.41	24.36		44.00		2.96	**2.96**
C12				0.78	46.61		33.00		11.64	**11.64**
C13	5.7	6.3	1.3			3.21	14.00	8.30		**8.30**
C14				0.70	41.79		32.00		8.50	**8.50**
C15				0.07	4.13		110.00		7.13	**7.13**
C16	5.7	6.3	1.3			7.44	12.00	18.00		**18.00**
C17	27.2	30.2	6.0			12.93	5.00	48.74		**48.74**
C18				0.39	23.27		35.00		6.02	**6.02**
C19	8.2	9.1	1.8			2.52	13.00	6.78		**6.78**
C20				0.16	9.77		82.00		4.19	**4.19**
C21				2.35	140.84		17.00		2.37	**2.37**
C22				1.68	100.73		21.00		8.77	**8.77**
C23				1.09	65.61		23.00		4.13	**4.13**
C24	65.9	73.2	14.6			96.98	3.00	303.64		**303.64**
C25	7.1	7.9	1.6			1.88	14.00	4.09		**4.09**
C26	11.2	12.4	2.5			11.99	10.00	34.62		**34.62**
C27				1.58	94.89		21.00		9.37	**9.37**
C28				0.63	37.90		36.00		7.09	**7.09**
C29	10.4	11.6	2.3			5.57	10.00	15.97		**15.97**
C30				0.50	30.00		42.00		7.91	**7.91**
C31	16.5	18.4	3.7			13.71	7.50	43.83		**43.83**
C32	16.5	18.4	3.7			13.94	7.50	44.55		**44.55**
C33	4.5	5.0	1.0			3.40	17.00	5.27		**5.27**
C34				1.55	92.97		21.00		16.05	**16.05**
C35				0.68	40.52		35.00		3.32	**3.32**
C36				0.48	28.93		45.00		2.19	**2.19**
C37				0.55	32.79		30.00		9.31	**9.31**
C38	64.3	71.5	14.3			226.75	3.00	658.00		**658.00**
C39	4.4	4.9	1.0			2.30	21.00	3.93		**3.93**
C40				1.39	83.36		22.00		15.17	**15.17**
C41				0.37	22.20		51.00		4.45	**4.45**
C42				0.53	31.90		40.05		4.14	**4.14**
C43	5.2	5.8	1.2			3.51	15.00	7.07		**7.07**
C44				0.40	24.15		46.00		4.70	**4.70**
C45				0.23	13.57		71.00		10.62	**10.62**
C46	54.2	60.3	12.1			65.89	4.00	178.14		**178.14**
C47				0.51	30.81		40.02		6.10	**6.10**
C48	19.3	21.5	4.3			26.44	5.00	65.89		**65.89**
C49				1.02	61.45		28.00		5.93	**5.93**
C50				0.71	42.86		34.00		7.84	**7.84**

5- Hydraulic Design for Culverts: It was used the hydraulic design software (HY - 8) issued by the FHWA [16] to estimate the pipes diameters and box dimensions of the culverts in the study area to discharge a maximum flow of water at the intersection of the valleys with the proposed highway route. The program (HY-8) is dependent of the following inputs: the culverts type, slope, length, slope of the valley, width and height of the street on top of the culverts, and other necessary information. Figure 6 illustrates the typical longitudinal section of a culvert at station 31+100.

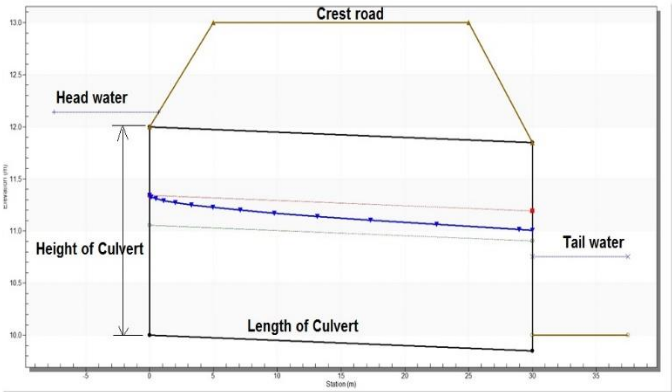

Figure (6): Longitudinal section for culvert by using (HY-8).

Table 6 shows the locations of the culverts, types, dimensions, and geographical coordinates along the Ramadi-Nukhaib highway between from station 0+00 to station 90+00.

IV. Conclusions

1. Using radar data from the DEM that was processed using GIS software provided fast and cost-effective method to obtain information to identify the cadastral and topographical properties in addition to the drainage basins specifications of the valleys that intersect the proposed highway route. The presented method greatly facilitated the process of making the necessary calculations to determine the maximum discharge through the valleys during the design life of the road.
2. Using the SCS method and the Rational method to calculate the maximum discharge passing through the valleys that intersect the road provided valuable information for designers to select the sizes and types of the culverts required for a safe discharge of the peak flow under the roads.

V. Recommendations

1. Modern satellite images with high accuracy are essential because the accuracy of the information derived from them greatly affects the accuracy of the hydraulic design of the culverts
2. Assertion on the importance of the hydrological design of highways before construction in order to avoid potential problems such as immersion and failure of the hydraulic structures.

TABLE (6): HYDRAULIC DESIGN OF CULVERTS FOR (RAMADI - NUKHAIB) HIGHWAY.

Intersection Station	**Intersection Coordinate with Highway Road (UTM)**		**Type of Road Crossings Conveyance Structures**	**Dimension of conveyance Structures**			**Number of conveya**	**Pipe Slope**
	Easting	***Northing***		***Diameter (m)***	***B (m)***	***H (m)***		
1+350	328463.991	3696244.198	Concrete Pipe	1	-	-	1	0.005
1+850	328565.099	3695805.704	Concrete Pipe	1	-	-	1	0.005
2+550	328722.377	3695123.602	Concrete Box Culvert	-	2	1	2	0.005
3+300	328885.273	3694417.139	Concrete Box Culvert	-	2	1	1	0.005
4+200	329093.106	3693515.789	Concrete Pipe	1	-	-	1	0.005
4+350	329089.66	3693362.18	Concrete Box Culvert	-	2	1	2	0.005
4+750	329184.13	3692966.40	Concrete Pipe	0.75	-	-	1	0.005
5+350	329362.727	3692346.471	Concrete Pipe	1	-	-	1	0.005
6+800	329227.893	3691114.354	Concrete Pipe	1	-	-	2	0.005
7+000	329086.90	3690925.46	Concrete Pipe	1	-	-	2	0.005
7+350	328827.05	3690596.01	Concrete Pipe	1	-	-	1	0.005
7+550	328738.85	3690500.77	Concrete Pipe	1	-	-	1	0.005
8+450	328236.62	3689804.76	Concrete Pipe	1	-	-	1	0.005
8+475	328199.64	3689751.25	Concrete Pipe	1	-	-	1	0.005
10+350	327074.00	3688130.00	Concrete Pipe	1	-	-	2	0.005
11+000	326627.72	3687636.05	Concrete Pipe	1	-	-	1	0.005
11+300	326512.516	3687364.424	Concrete Pipe	1	-	-	1	0.005
12+250	325950.55	3686598.464	Concrete Pipe	1	-	-	2	0.005
13+300	325329.431	3685751.877	Concrete Box Culvert		3	1.5	2	0.005
15+250	323791.420	3683655.565	Concrete Pipe	1			1	0.005
17+914	322690.7023	3681969.749	Concrete Box Culvert		3	1.5	4	0.005
19+150	322045.9796	3680681.094	Concrete Pipe	1			1	0.005
19+843	321856.5436	3680232.542	Concrete Pipe	1			2	0.005
20+650	321599.6262	3679547.866	Concrete Pipe	0.75			3	0.005

21+050	321429.0303	3679048.982	Concrete Pipe	1			1	0.005
22+300	321041.903	3677915.066	Concrete Box Culvert		2	1	1	0.005
24+050	320363.401	3675927.698	Concrete Pipe	1			1	0.005
26+750	319646.6916	3673828.422	Concrete Box Culvert		2	1	2	0.005
27+650	319313.337	3672852.008	Concrete Pipe	1			2	0.005
30+650	318344.047	3670012.910	Concrete Pipe	0.75			1	0.005
31+100	318230.964	3669681.682	Concrete Box Culvert	-	2	1	9	0.005
33+750	317307.1226	3666975.704	Concrete Pipe	1			2	0.005
34+000	317261.674	3666842.584	Concrete Pipe	0.75			1	0.005
35+000	316935.544	3665897.277	Concrete Pipe	1			2	0.005
35+800	316883.449	3665756.615	Concrete Pipe	0.75			1	0.005
36+400	316724.8841	3665352.836	Concrete Pipe	1			1	0.005
37+000	316395.248	3664606.286	Concrete Box Culvert		2	1	1	0.005
38+050	316069.3116	3663960.137	Concrete Pipe	1			1	0.005
39+450	314874.530	3661964.624	Concrete Box Culvert		3	1.5	5	0.005
40+250	314534.235	3661410.82	Concrete Pipe	1			1	0.005
40+800	314167.764	3660814.415	Concrete Box Culvert		3	1.5	4	0.005
40+900	314115.411	3660729.215	Concrete Box Culvert		3	1.5	4	0.005
41+000	314063.057	3660644.014	Concrete Box Culvert		3	1.5	4	0.005
41+100	314010.704	3660558.813	Concrete Box Culvert		3	1.5	4	0.005
42+350	313356.291	3659493.805	Concrete Pipe	0.75			1	0.005
43+150	312937.104	3658812.423	Concrete Pipe	0.75			1	0.005
44+825	311987.595	3657464.021	Concrete Pipe	0.5			1	0.005
45+700	311508.208	3656887.332	Concrete Pipe	0.75			1	0.005
47+800	309869.041	3655276.918	Concrete Pipe	1			1	0.005
48+300	309529.530	3654981.567	Concrete Pipe	1			1	0.005
48+500	309303.189	3654784.666	Concrete Pipe	1			2	0.005
49+845	308360.103	3653964.247	Concrete Pipe	1			1	0.005
50+400	307945.817	3653602.497	Concrete Box Culvert		3	1.5	3	0.005
51+500	307168.257	3652825.206	Concrete Box Culvert		3	1.5	3	0.005
51+820	306971.450	3652598.799	Concrete Pipe	1			2	0.005
53+800	305843.105	3650951.522	Concrete Pipe	0.75			1	0.005
55+800	305074.517	3649215.707	Concrete Pipe	1			1	0.005
56+650	304707.301	3648285.571	Concrete Pipe	1			2	0.005
58+000	304229.921	3647076.394	Concrete Pipe	1			2	0.005
58+850	303936.148	3646332.285	Concrete Box Culvert		2	1	2	0.005
60+050	303477.129	3645169.616	Concrete Pipe	0.5			2	0.005
60+950	303146.635	3644332.493	Concrete Pipe	1			2	0.005
61+800	302846.632	3643590.917	Concrete Pipe	0.75			1	0.005
62+415	302234.595	3642332.351	Bridge Al-Ghadaf					
63+550	302063.444	3642027.061	Concrete Box Culvert		2	1	3	0.005
64+000	301806.965	3641597.876	Concrete Pipe	1			1	0.005
66+200	300605.928	3639636.369	Concrete Pipe	1			1	0.005
66+800	300344.834	3639209.954	Concrete Pipe	0.5			1	0.005
67+250	300162.067	3638911.464	Concrete Pipe	1			1	0.005
68+200	299613.768	3638015.993	Concrete Pipe	1			1	0.005
68+600	299404.892	3637674.862	Concrete Pipe	1			1	0.005
69+750	298804.388	3636694.099	Concrete Pipe	1			1	0.005
70+160	298526.554	3636219.469	Concrete Pipe	1			1	0.005
70+950	298266.306	3635734.972	Concrete Pipe	1			1	0.005
72+600	297576.704	3634182.117	Concrete Pipe	1			2	0.005
73+350	297314.028	3633426.571	Concrete Pipe	1			1	0.005
73+700	297211.850	3633091.827	Concrete Box Culvert		2	1	2	0.005
74+000	297117.509	3632754.789	Concrete Pipe	1			1	0.005
74+200	297079.490	3632609.688	Concrete Pipe	1			1	0.005
74+700	296968.569	3632173.573	Concrete Pipe	1			2	0.005
76+200	296623.599	3630816.740	Concrete Pipe	1			1	0.005
76+650	296500.395	3630332.157	Concrete Pipe	1			2	0.005
77+325	295520.4587	3626485.845	Bridge Abo-Kahaf					
77+600	296229.347	3629266.074	Concrete Pipe	1			1	0.005
77+800	296192.386	3629120.699	Concrete Pipe	1			1	0.005
78+800	295970.619	3628248.449	Concrete Pipe	1			1	0.005
80+450	295538.450	3626552.655	Concrete Pipe	1			1	0.005
80+800	295444.381	3626215.541	Concrete Pipe	1			1	0.005
83+035	294655.064	3624110.786	Concrete Box Culvert		3	1.5	8	0.005

83+950	294252.522	3623305.978	Concrete Pipe	1			1	0.005
85+150	293666.23	3622281.20	Concrete Pipe	1			1	0.005
85+975	293170.656	3621565.943	Concrete Pipe	1			1	0.005
86+550	292864.463	3621109.055	Concrete Pipe	1			1	0.005

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