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Reservoir Axis Modeling along the Arghastan River by GIS

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Abstract:- Most of the countries around the world are facing water scarcity, and many of the problems that are caused by bloodshed between countries, nations and people in the world due to water. Arghastan district is located in the southeast of Kandahar city. The Arghastan River, which originates in the northeast of Gardez city, passes through this district, so the river is called Arghastan River. Water flows in the river during winter and spring seasons, thus due to lack of environmental flow during the dry period leads to losing of various animals specifies lives. The main objective of the study is proper dam site location selection on Arghastan River using Remote-sensing and GIS. Contour map of the basin was created by using 5-meter resolution DEM. Based on various technical criteria's for dam site selection the most suitable site for the dam is proposed at GPS coordinates of 66°48'34.468"E 31°35'4.512"N, with a maximum possible height up to 170 m and a storage capacity of 1700 million cubic meter. While the hydrological modeling of the basin indicates an average monthly discharge of 38.6 m^3/s which can irrigate up to 35,000 hectares agriculture area with a good power potential capacity of 38 MW, sufficient for lighting of around 38 houses of the region.

Keywords:- *Dam Site, Reservoir Volume, Power Potential, Spillway.*

I. INTRODUCTION

The flow rate of a river or natural stream may vary considerably during different seasons of a year. It may carry little or no water during some periods of a year and may carry huge amount of water after heavy rain causes a raging torrent and a hazard all along its banks. During extremely low flows it impossible to meet the demands of the consumers, because water is drawn directly from a river. Hence, it is essential to create a reservoir or an artificial lake by constructing a dam across the river which can store excess water during high floods for use during low flow seasons and droughts. According to their type of function, reservoirs are classified as; flood control, irrigation, power generation, navigation, recreation, water supply (domestic and industrial uses), development of fish and wild life, soil conservation and other miscellaneous purposes. Recently, remote sensing techniques has provided valuable datasets to examine hydrological variables and morphological changes over large regions at different spatial and temporal scales, GIS and its related tools (a group of remote sensing technology) can provide a huge amount of valuable data in spatial and temporal resolutions for areas where ground data are not easily accessible. Remote Sensing technique gives us directly the water spread area of the reservoir at a particular elevation on the date of pass of the satellite Narasayya, K. 2013.Schumann. Moreover, A. H., & Geyer, J. (1997) used GIS and remote sensing method for designing flood reservoir and it was indicated that the planning of flood reservoirs within a river basin can be improved significantly by the application of GIS. Remote sensing techniques and more detailed climatologically and process models are available to provide new possibilities for detailed modeling of small reservoirs in order to capture their surface areas for estimating their storage capacities to have a clear picture of available water resources Sawunyama, et al. 2005. For evaluation sub-surface dam construction within Isayi watershed, Kurdistan region GIS used by Ali, S. et al. 2014 for selecting site location. GIS and remote sensing through satellite images and DEM interpretation and analysis have facilitated the investigation with more accuracy.

Problem Statement

In recent years, water scarcity is a big problem throughout the country which has very badly affected agricultural products. This river basin covers about 34000 km2 area with no storage structures built up along the river to store and regulate the natural flow regime of the river. Main of Arghastan Water Resources related problems can be summarized as follows:

a) Due to lack of regulatory measures, an integral part of the surface water of this river basin is flowing out of the basin with no or very limited use along the river.
b) During the rainy seasons, people lose their properties due to flood flows and during dry seasons, there is no water even for livelihood.
c) Ground water table is continuously drawing down, which is warring the residents that there will be no sufficient water for drinking in the near future.

Research Objectives

The main objective of this research is Reservoir axis modeling along the Arghastan River, and recognition of the hydrological system along the valley in order to provide reliable instruction to managing water resources in a sustained method to support the managerial process about the

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future development of the water resources in this river basin. This will tune up a series of development of agricultural, water supply and electricity sectors. Therefore, the objectives of the present study are:

A. To locate and model the reservoir axis along the Arghastan river
B. To estimate water volume that can be stored in this reservoir and the land that is supposed to submerge at different elevations of the dam once the reservoir is formed.
C. To identify the area the can be watered from this reservoir.
D. To estimate power potential of the dam at various water-heads.

Site Description

Afghanistan, a mountainous landlocked country within in Central Asia, has generally five water regions or river basin i.e. Helmand River basin, Kabul River basin, North River ba-sin, Amo River basin and Harirod River basin. Due to no strategic planning for the water sector, Afghanistan still has not found a chance to efficiently utilize its water potential. Every year most of its national water flows into bordering countries. There is still need for time and management to control loses of about two-thirds of its water that flowing to Pakistan, Iran, Uzbekistan, and Turkmenistan. Afghanistan has specific seasons; summers are hot and winters can be bitterly cold. In summers the temperatures as high as 49 °C have been documented in the south-western parts of the country while midwinter temperatures as low as -15 °C are common nearby the Hindu Kush.

As just mentioned, there are generally fife river basins over the country, out of them Shamal is a national River Basin that flows and ends inside the northwestern and northern territories of the country. Helmand although is a transboundary river, is very important as per the irrigation point of view since it covers about 47.2% of the country. This river basin having numerous tributaries, originates from the central Hindu Kush (Western Parts of Koh e Baba) is located in the southern part of the country. Arghandab River is the main tributary of Helmand River that covers about 75000 km2, which is formed of three sub-tributaries such as, Tarnak, Durai, and Arghastan. As per the agriculture point of view, Arghandab is a very important valley. Its geographical coordinates are 31.33 to 33.57 N and 66.46 to 69.34 E as illustrated in the Fig.1.

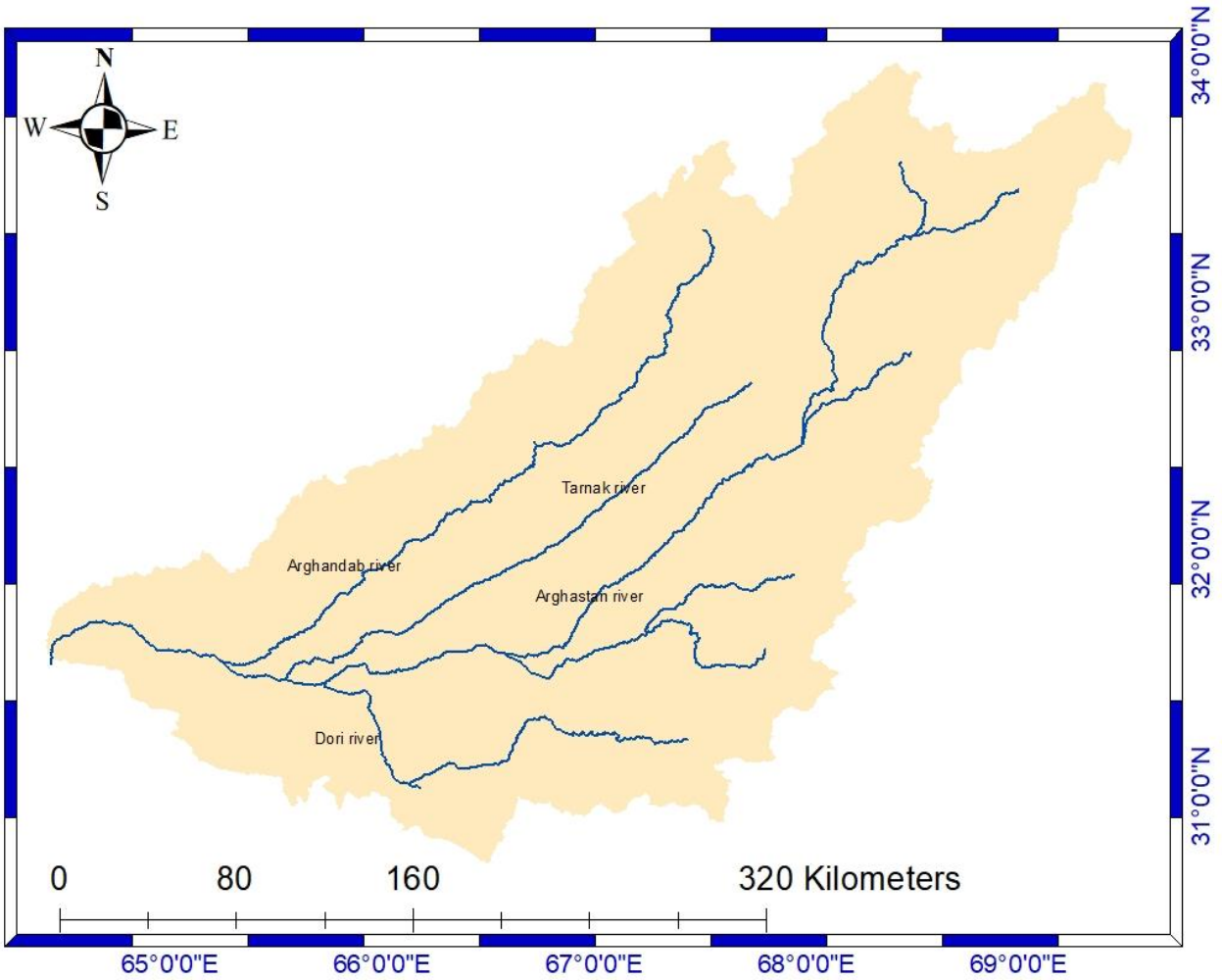

Figure 1: Arghandab River basin

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Arghastan River, the longest in Arghandab river basin, originates in about 34 km from the northeast of Gardiz city and runs about 715 km to southwest direction before joining the Durai River in the south-west of Kandahar city. Arghastan River flows through four provinces such as Paktika, Ghazni, Zabul and Kandahar. Arghastan River is an intermittent river, which means most of the times, water flows only in winter and spring season or after a storm. Overall, Arghastan river basin has a catchment area of about 34,050 sq. kilometer. The major crops types that are cultivated in this river basin are wheat, cotton, maize, fruits (grapes, figs and apple) and nuts.

II. MATERIAL AND METHODOLOGY

In this study, remote sensing and Arc-GIS has been used to identify site location of the reservoir on Arghastan River and its maximum capacity. To achieve a result with high accuracy, an attempt was made to collect and use more accurate data that, are available with different governmental agencies i.e. the directorate of Agriculture, Rural Rehabilitation and Helmand River Basin's Agency.

DEM is a general term for the digital cartographic representation of the elevation of the land at regularly spaced intervals in x, y and z directions. All forms of DEM data are useable to model and analysis the earth's topography in three-dimensions. For identifying of the site of reservoir and for estimation of its storage volume, DEM images with 5m resolution collected from the Ministry of Energy and Water currently emerged to National Water Affairs Regulatory Authority (NWARA) were used.

As shown in figure 2, contour map of the Valley was created (with 10m contour interval) using the create contour option and then by zooming and eye judgment a suitable location was selected for the dam and its proposed reservoir. In 3D analysis tool, surface volume option was used to estimate the capacity of the reservoir and water spread area at different elevations of the dam. Having the above mentioned data, it is possible to calculate the projected area, surfaced area, and hence, create a Level-Volume-Area (LVA) relationship dataset.

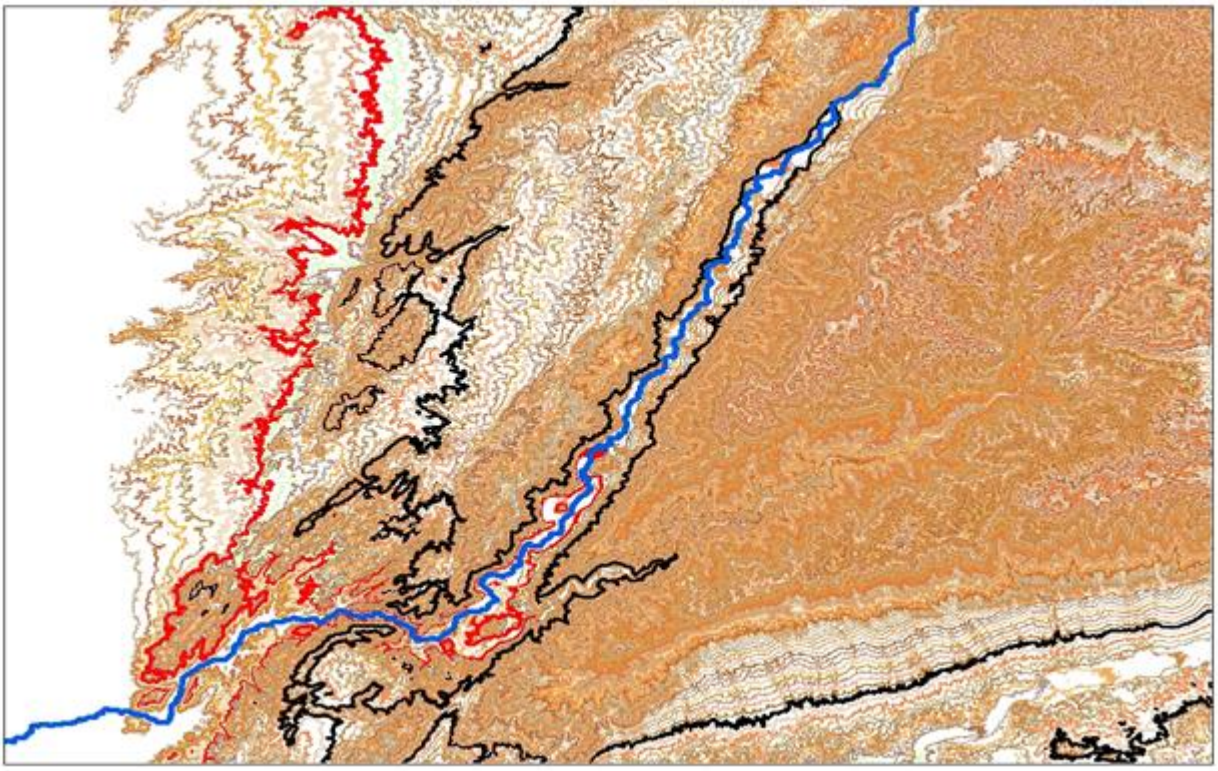

Figure 2: contour map of the study area

III. RESULTS AND DISCUSSION

Arghastan is the longest in the tributaries of Arghandab River that flows around 715km to the Southwestern direction although carries several hundred million cubic meters of water on yearly basis, no hydraulic structure to store and regulate its flow regime has been built on it to date. Studying the dam-site location, can be considered as a step picked up towards the management regulation of the flow regime along the river. As mentioned above, in this study, GIS was used to identify suitable site for a dam, its reservoir, storage volume and water spread area at different elevations.

Dam Site:

As mentioned early, 5-meter resolution digital elevation model image was used to construct contour map of the valley and hence to find a suitable location of the dam axis. Several points along the river to construct small dams but the most strategic location that was selected in this

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research is the point with coordinates 66°48'34.468"E and 31°35'4.512"N, as shown in figure 3.The red contour line indicates the bed elevation of the river at that point (having zero elevation) and the block line having 170m height from the stream bed at that point indicates the maximum reservoir level. It shows that if the foundation material is good (Rocky Foundation), it is possible to construct a dam 170 high from the stream bed.

For the dam to be cost-effective and have well stability, its length should be as small as possible. The selected site is the narrowest one along the river with the required height. In this site, the width of the stream at the bed level is about 95m, while it should become wide up to 485m at the elevation of 170 m from the stream bed. Moreover, there are very least amount of land and other property of the residents that will submerged in upstream side of the dam, after the formation of the reservoir which also adds to the suitability of the construction of the dam.

Whatever the type of the dam that should be, it necessarily requires a passage with enough capacity to safely pass flood-flows to the downstream. Therefore, spillway is an important part of the dam complex and is located either as a part of the main dam body or as a separate channel at a suitable place near the dam. Henceforth, selecting a location and type of the spillway is an important aspect in dam design and construction practices. Selecting a proper type and location for the spillway, makes the dam project very cost-effective. In this study, the dam-site has a proper place for a spillway construction on the left bank of the reach, as illustrate in the figure 3, &4.

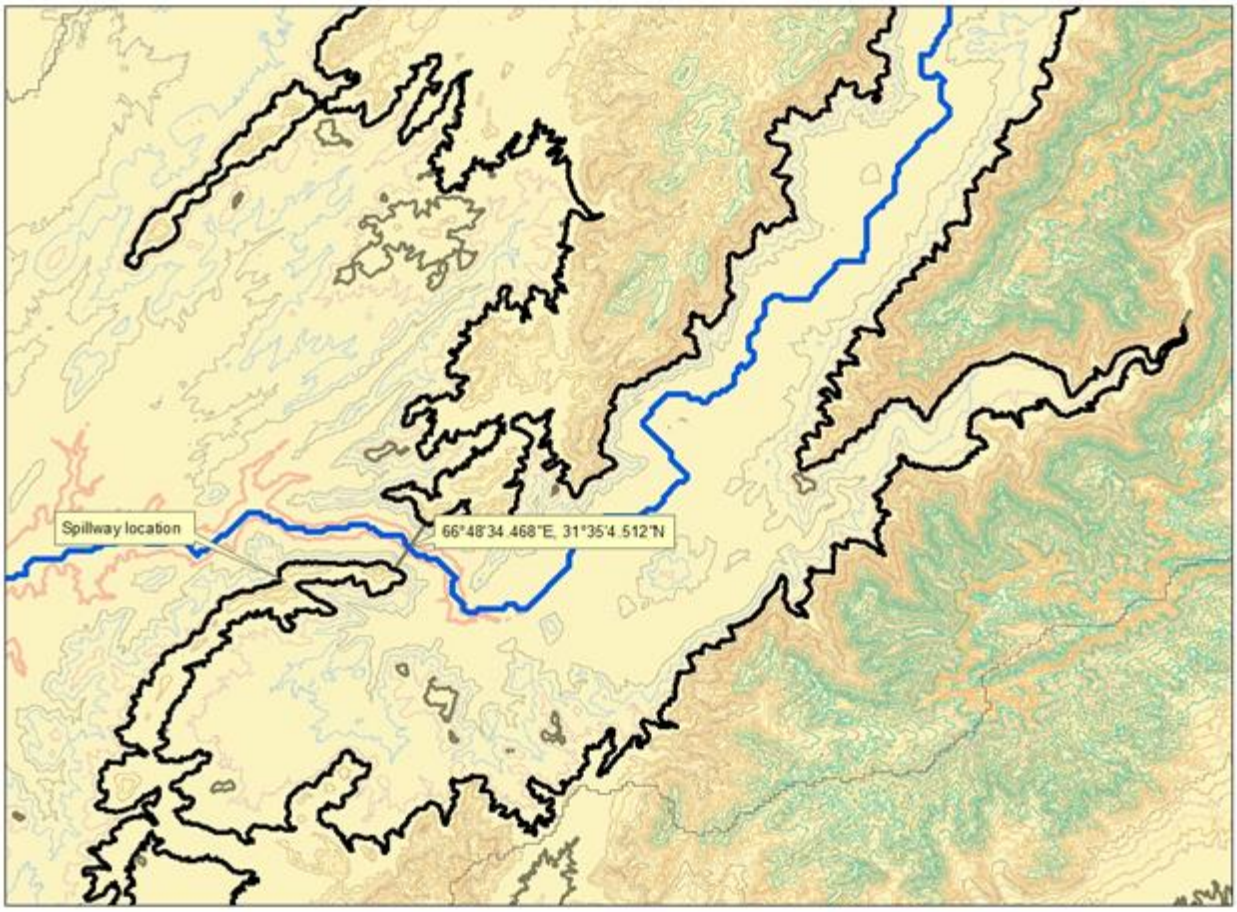

Figure 3: Location of Dam & Spillway

Reservoir volume:

Storage volume estimation is a crucial element of the study which influence the result of the research. In this study, 3D analysis tools in GIS were used to estimate the reservoir volume at different elevations and then the area-volume relationship was determined. From the contour plan of the site, the water spread area of the reservoir at any elevation is also determined by measuring the area enclosed by the contour corresponding to that elevation. As illustrated in table 1, about 18 different elevation starting from zero at a specific location of the dam up to 170 meter height from the bed of the river were used to find out the water spread area a. The storage volume and water spread area at different elevations are determined and plotted against elevations to obtain storage-elevation and area-elevation curve as shown in Figure 5. It shows that the reservoir has the capacity to store up to 1467 and 1744 Million cubic meters of water for dam heights 160 and 170m respectively that is sufficient to regularly and manage water of this river for agriculture land downstream of the dam during the dry seasons.

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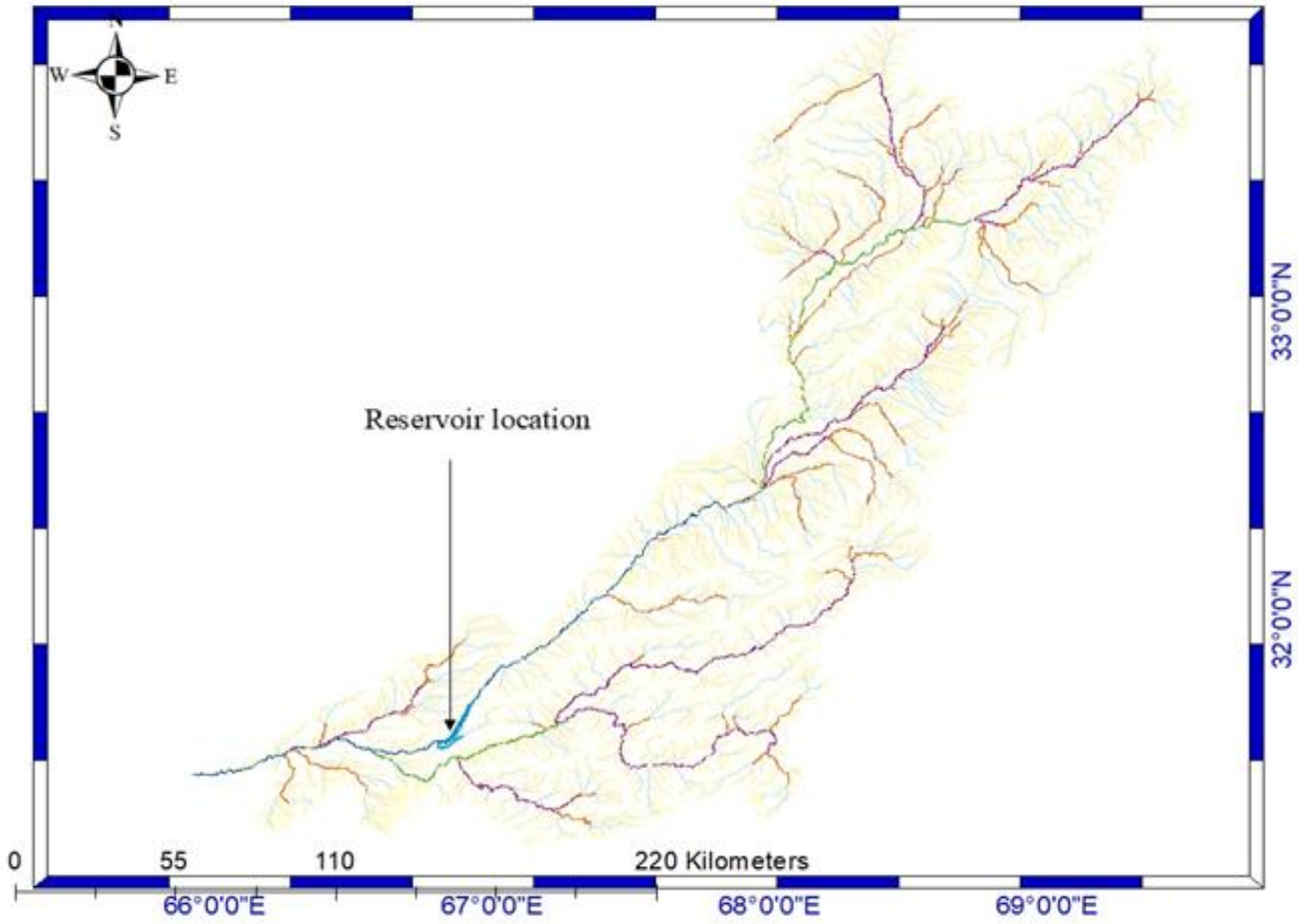

Figure 4: Location of Reservoir

Table 1: Arghastan Dam Area-Volume

Arghastan dam area-volume				
NO	Elevation of the dam-crest from river bed in m	Elevation of the dam-crest from mean sea level in m	Reservoir water spread area km^2	Reservoir volume in million cubic meter
1	0	1450	0.00	0.00
2	10	1460	0.12	0.46
3	20	1470	0.55	3.53
4	30	1480	1.24	12.19
5	40	1490	2.15	28.68
6	50	1500	3.19	55.26
7	60	1510	4.72	94.06
8	70	1520	6.16	148.25
9	80	1530	7.64	217.32
10	90	1540	9.20	301.43
11	100	1550	10.81	401.22
12	110	1560	12.68	518.54
13	120	1570	14.95	656.28
14	130	1580	17.39	817.73
15	140	1590	20.10	1005.06
16	150	1600	23.12	1221.05
17	160	1610	26.19	1467.73
18	170	1620	28.81	1744.43

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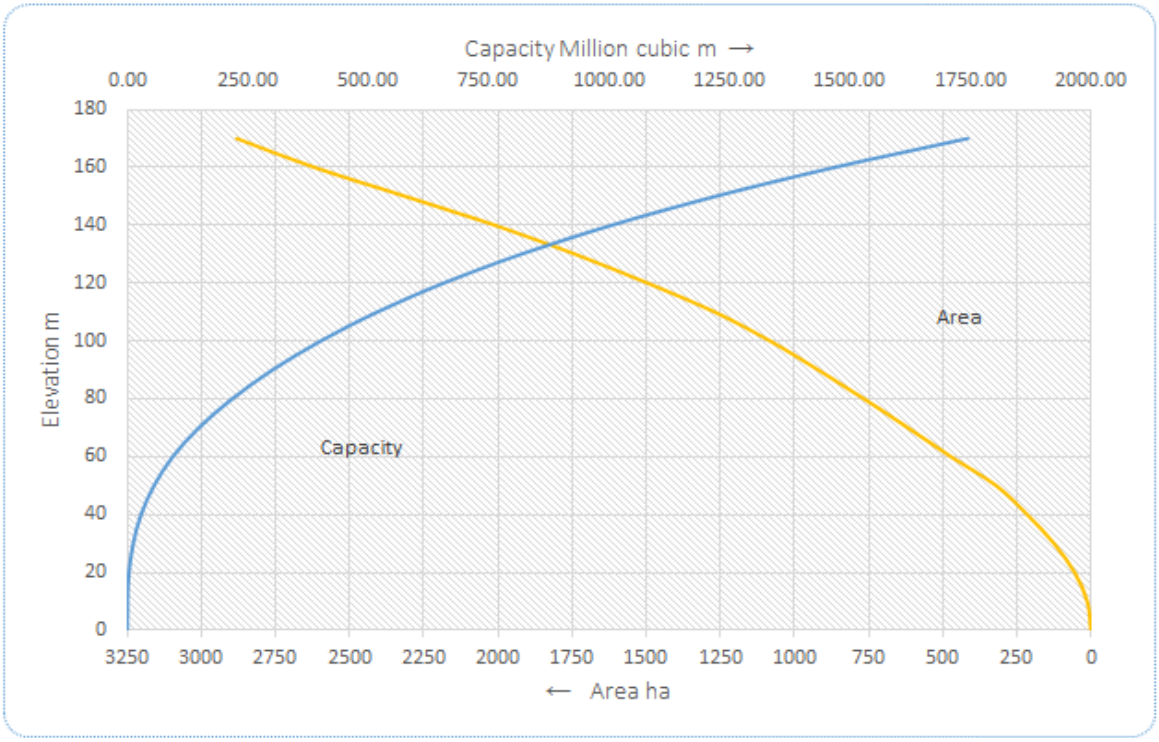

Figure 5: Capacity-Area Curve

Irrigation capability

There is no hydro-meteorological data available for the river since no hydrological nor meteorological station is installed on this river, therefore, only modeled data were used with no calibration. A 34-year annual-average stream flow was modelled that becomes about 53m^3/ (Wali & Singh, 2017). This is an amount that has to be stored in a reservoir and used for irrigation and water supply purposes during dry seasons. As types of losses from the reservoir, evaporation and infiltration are the main ones that are dependent mainly on the geology and morphology of the area, spread area of the reservoir, relative elevation of the territory, quality of water, temperature of the surrounding environment and wind flow characteristics; and before to commence, both of these main losses have to be measured in each season of a year. As a rough estimation, the amount lost due to these two and non-stable rainfalls, was assumed to be 13m^3/s, hence, 40m^3/s is considered to fulfill the irrigation and water supply demands. As per HAVA (Helmand and Arghandab Valley Authority) irrigation practices, 1m^3/s can irrigate about 1000 ha in an irrigation interval (7 days in summers). Hence, can say that this dam can irrigate at least about 40,000 ha of agriculture lands.

Power capacity

As mentioned earlier, a dam of up to 170 meters may be built in this area. And deep water bodies in comparison to shallow water bodies are very significant in losing water due to evaporation, since the area chosen for the dam has a hot climate and very high annual evaporation. Hence, having a dam with 170m height will form a very deep reservoir behind. Moreover, the height of water level (water head H) besides the amount of water in the reservoir, is very essential to operate the Hydro-Electro-Power-Plant (HEPP). The higher the level of water in the reservoir, the higher it has a capacity to generate Hydro-Power. As just mentioned, the average annual runoff of the river was estimated to be about 53m^3/s, and out of that, a 13m^3/s was assumed to be lost due to evaporation, infiltration and others. Hence, a 40m^3/s is considered to be used to operate the HEPP and fulfill the irrigation and water supply demands simultaneously. For every 5-m increase of net head (H), the power generation capacity of the dam (watt) was estimated as $P_w = \eta Q \rho G H$ and the result was brought in the following table: Here, η represents the efficiency of Hydro-Turbine and Generator i.e.$\eta_T * \eta_G$, Q represents the flow rate (m^3/s), ρ the density of water (1000kg/m3), G the acceleration of the ground (9.81 m/s^2) and H represents net head of water (meter). It concludes that this dam has the capacity of power potential up to 46 MW that is sufficient for lighting around 40 housed in this area.

Table 2: Power potential of the dam

POWER GENERATION FOR THE ARGHASTAN PROPOSE DAM							
NO	Q	n	p	G	H	PW	P, MW
1	40	0.85	1000	9.81	60	21189600	20.0124
2	40	0.85	1000	9.81	65	22955400	21.6801
3	40	0.85	1000	9.81	70	24721200	23.3478
4	40	0.85	1000	9.81	75	26487000	25.0155
5	40	0.85	1000	9.81	80	28252800	26.6832
6	40	0.85	1000	9.81	85	30018600	28.3509
7	40	0.85	1000	9.81	90	31784400	30.0186
8	40	0.85	1000	9.81	95	33550200	31.6863
9	40	0.85	1000	9.81	100	35316000	33.354
10	40	0.85	1000	9.81	105	37081800	35.0217
11	40	0.85	1000	9.81	110	38847600	36.6894
12	40	0.85	1000	9.81	115	40613400	38.3571
13	40	0.85	1000	9.81	120	42379200	40.0248
14	40	0.85	1000	9.81	125	44145000	41.6925
15	40	0.85	1000	9.81	130	45910800	43.3602

IV. CONCLUSION

A. Water is the most important element of life, management of this vialed source is very essential for the residents and related state. In the present study, it's tried to work on water resource management of the Arghastan River basin that cover about 34,050 sq. km, area and located to the south-east of Kandahar city.

B. Along the Arghastan river, a most important site with coordination 66°48'34.468"E and 31°35'4.512"N was selected for a dam construction with a height of up to 170m if not restricted due to geological limitations and with a proposed reservoir of 1700 Mm3 capacity.

C. Due to evaporation and infiltration losses of water from the reservoir and non-stability of rainfalls on the catchment, only 40m3/s out of 53m3/s of stream flow is considered for irrigation and other demands which is sufficient to watered about 40000 hectares of agriculture lands downstream of the dam.

D. The study also concludes that this dam has the capacity of power potential up to 40 MW that is sufficient for lighting around 40,000 households around the area.

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