

Original article

THE ROLE OF WATER IN ISFAHAN:
A STUDY OF SAMPLES OF BRIDGES AND DAMS ON ZĀYANDÉ-RŪD

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Abstract

This paper is aimed to study the main characteristics of the bridges in Isfahan at the Safavid Period through an archeological scope, along with adopting other scientific methods to have a holistic vision of the creativity of the bridges around the most important river in Iran plateau.

Keywords: *Joui, Khaju, Marnan, Shaa Abbas, Si-o-Se Pol*

1. Introduction

Iran is located in an arid, semi arid area, which is located in the south of Asia between 44° 02 and 63° 20 eastern longitudes and 25° 03 to 39° 46 northern latitude, with 73% of it covered by dry weather [1]. Isfahan is located on the main north-south and east-west routes crossing Iran, thus, it is situated on the trade routes which traverse the country, fig. (1). Zayandeh Rud means the valley of gold [2], or the life giving river^(a). The basin constitutes of an area of 41,500 km.², altitude from 3,974 m. to 1,466 m., an average rain fall of 130 mm. and a monthly average temperature of 3 °C (37 °F) to 29 °C (84 °F) [3]. There are 2,700 km. of irrigated land in the Zayandeh River basin, with water derived from the nine main hydraulic units of the River, wells, channels and springs in lateral valleys. Zayandeh Rud springs from the Zagros Mountains, goes to the east, passes over Bakhtiari, Fars, and Yazd and ends at the Gavkhuni swamp [4]. The allocation of the water to the different diversion channels branching off the

Zayandeh Rud and the springs below were established earlier in the 16th century, as documented in "Sheikh Bahaii Documents". The construction of the Chadegan dam was in 1972 and the modern irrigation infrastructures overrode. Allocation is now decided by the provincial authorities, while qanat (channel) based irrigation is based on traditional communal rights [5]. Beside the role of climatology which represents the importance of water in the Iranian life, the researcher is faced with the role of the Shiite ideology which reformed this role and increased it by establishing many hydraulic structures and water management building systems to use water wrought by the faith of Hussain tragedy. This is why, in the Safavid Period, Isfahan was seen as different from any other time, as it became a city of gardens. Shah 'Abbas was keen to establish new buildings around the river, some of them to manage the river, and others to amuse himself by the water view. He built a new channel to transfer the water to all of the mosques

and madrasas in his new capital. Hence, the Zayandeh Rud plays an important role in the growth of the city, compared to its neighboring cities especially in the Safavid Period. Also, the bridges play an important role in the reformation of the urban planning of the city according to the garden style. Conditions on the

Zayandeh River have considerably changed since the construction of the Shah 'Abbās Dam [6]. The role of Shah Abbas Dam is clear when there is a look at its progress according to electricity, cultivation and also the existence of drinkable water throughout the day after many centuries, tab_s. (1& 2).

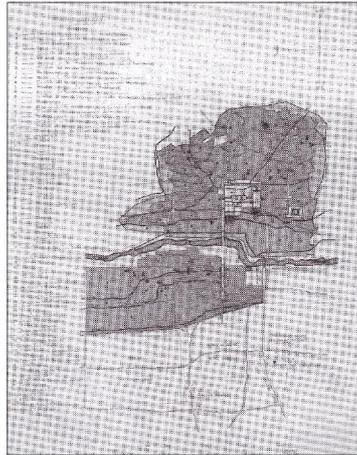


Figure (1) plan of Isfahan , PL. LIV (*after Coast ,1867*) [7]

Table (1) major reservoir dams on the Iranian plateau, <http://www.iranicaonline.org/articles/ab-iii-the-hydrology-and-water-resources-of-the-iranian-plateau>

Dam	River	Capacity million m ³	Area under cultivation (hectares)	Annual electricity million KW/hrs	Year completed	Cost (million rials)
Shah Esmā'īl	Golpāyghān	44	5,500	—	1957	163
Amīr Kabīr	Karaj	205	21,000	130	1961	n.a.
Šanāz Pahlavī	Ābšīna	8	2,000	—	1963	919
Farahnāz Pahlavī	Jāj	95	30,000	22	1967	4,326
Shah 'Abbās Kabīr	Zāyanda	1,250	95,000	174	1970	3,600
Daryūš Kabīr	Kor	993	41,000	—	1972	1,700
Jiroft (under construction)	Ĥalīl	440	10,500	—	—	—

Table (2) discharge of selected rivers on the Iranian plateau, <http://www.iranicaonline.org/articles/ab-iii-the-hydrology-and-water-resources-of-the-iranian-plateau>

River and gauging station	Basin area km ²	Annual discharge (million m ³)	Ratio of maximum to minimum mean monthly discharge	Annual runoff m ³ /km ²	Month of mean maximum discharge	Month of mean minimum discharge
Habla at Bonekūk	3,995	197.92	2.79	61,947	March-April	Aug.-Sept.
Jāj at Lātīān	710	256.10	9.90	360,704	April-May	Aug.-Sept.
Karaj at Pol-e Kāb	725	384.78	8.47	530,731	April-May	Dec.-Jan.
Kordān at Deh Soma	380	107.91	39.27	283,974	April-May	Aug.-Sept.
Vafreghān at Sāva	17,800	268.54	22.65	15,087	March-April	Aug.-Sept.
Qom at 'Abbāsābād	10,230	147.05	9.37	14,374	March-April	Aug.-Sept.
Zāyanda at Pol-e Zamānkān	4,850	881.94	4.41	181,843	March-April	Sept.-Oct.
Zāyanda at Pol-e Mazra'ā	7,820	776.91	4.67	99,349	March-April	Aug.-Sept.
Zāyanda at Pol-e K'ājū	14,320	362.98	27.40	25,348	March-April	Aug.-Sept.
Zāyanda at Pol-e Varzāna	30,840	89.00	44.94	2,886	March-April	Aug.-Sept.
Kūr at Dorodzon	5,180	667.50	4.28	130,882	Feb.-March	Aug.-Sept.

2. Bridges of Isfahan City

Most of the bridges in Isfahan province were built in the Islamic period, especially in the Safavid time. They built bridges and dams which represent water-art, the total of which are 11 bridges^(b) in which some of them were used as bridges, dams, and pedestrian paths, like Si-o-Se Pol and Khaju Bridges. Although both of them were built as a bridge and a dam in the first place, they are now used as a passage, park and café, fig. (2), to sit at its stairs and between its arches. At the current time, it is rarely used as a dam because the government built a reservoir and a new dam at the source of the river, and the water is stored and transported to through another direction. It must be noticed that at the Safavid Period the garden was expanded because of the increase in the number of dams and cannels which were built upon the river to help reduce the wastage of water. For that, the Mola and some others wrote

volumes about the Alma Shari'a, the rights of people and the government in the water, and the most suitable way to divide water between people and the irrigated land. At the time of Shah Tahmasp, he selected the amount of water shares, which differed from year to another according to the increase or decrease in the water level [3]. Also, Shahs at the beginning of the Safavid Era divided the river to many branches^(c) to reach all Isfahan, to be used for domestic reasons and for irrigation. Fortunately, the Zayandeh Rud is not navigable, so the architecture of the bridges was not concerned with the height of the boats or the traffic. Architects planned and paved the bridges based upon two things; the first was to reserve and divide the water to distribute it at times of need, and the second was for the luxury and amusement of the Shah and the people.



Figure (2) coffee shop at Si-o-Se Pol

3. The Style of the Bridges

Bridges in Isfahan are divided into two styles; the first constitutes of two floors like Si-o-Se Pol and Khaju

3.1. The first style

The main bridges that reflect the characteristics of this style in Zayandeh River are Khaju and Si-o-Se Pol, because of their construction and function to irrigate “many square miles of richest meadow-land...on both sides” [8][9]. The bridge is constructed on two tiers. At the

Bridges, while the second is made of one floor only, like the rest of Isfahan bridges.

lower level, the open niches and closed pylons alternate and accommodate visitors with shaded places to sit and water flows with structures to regulate it. The upper level consists of a “walled” passageway that is lined with an arcade of double niches. The main central aisle

at the upper level was slightly lower and was used by horses and carts, while the raised outer vaulted paths on both sides of the bridge were for pedestrian use. Until the 19th century the interior arches

3.1.1. Si-o-Se Pol

It was known as Alla-hverdi Khan bridge and was built in 1632. It was established at the time of Shah Abbas as an integral part of his new town planning, becoming a major work combining the elements of the bridge, dam, and pedestrian path together, fig. (3-a) [11]. It measures approximately 300 m., and consists of 40

in Si-o-Se Pol and Khaju were decorated with paintings or mosaic of humanity or floral subjects often referred to by European travelers [8][10].

springs, 7 of which were distorted, so it is known as the 33 spring bridge, fig. (3-b) [3]. It consists of two rows of arches, and each row contains 33 arches. Along the walkway, the arches form small pavilions, where passersby can rest, fig. (3-c).

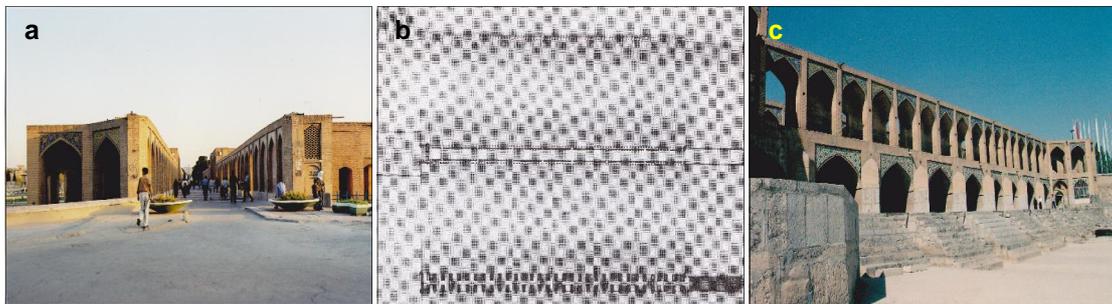
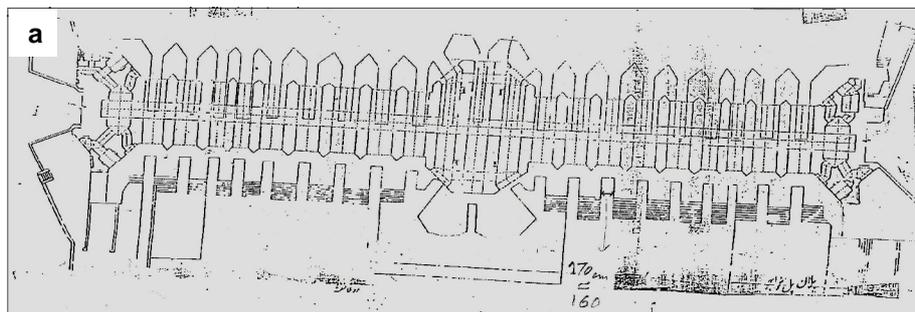


Figure (3) **a** one of the entrance of the Si-o-Se Pol passageway. **b** plan of Si-o-Se Pol, shows the channel of the bridge, PL.XLVIII (*after Coste ,1867*) [7], **c** multi-storey of Si-o-Se

3.1.2. Khaju bridge,

It was known as “Pol of Hassanabad, Baba Roken El Dine, Goberha, Seurat, Shiraz, Shahi Tumor Pol” and was built in 1650. It was established on one of the deepest parts of Zayandeh Rud. It was constructed as both a dam and a bridge. With a length of 150 meters and width of 14 meters, it includes a walkway of the deck that has a width of 6 meters. It consists of 21 springs, fig. (4-a, b), and each spring’s diminution is 2 meters. The depth of water out of the springs is 1/3 meter, although the width of the river is 42 meters. It was used as a dam until the second half of the 20th century, in which

every one second, 504 cubic meters of water passed through that dam in 1930 [3]. The water passes through the bridge along 26 paths. Between the water paths, there are 51 room-like spaces on each side of the bridge, fig (4-c). This bridge is characterized by the middle pavilion that centered the length of the bridge, fig (4-d). At its basement, the water passes from one channel then is divided into three water channels, fig (4-e). The pieces of stone used in this bridge are over 2 meters long and the distance between every channel and the ceiling base is 21 meters. The existing inscriptions suggest that the bridge was repaired in 1873.



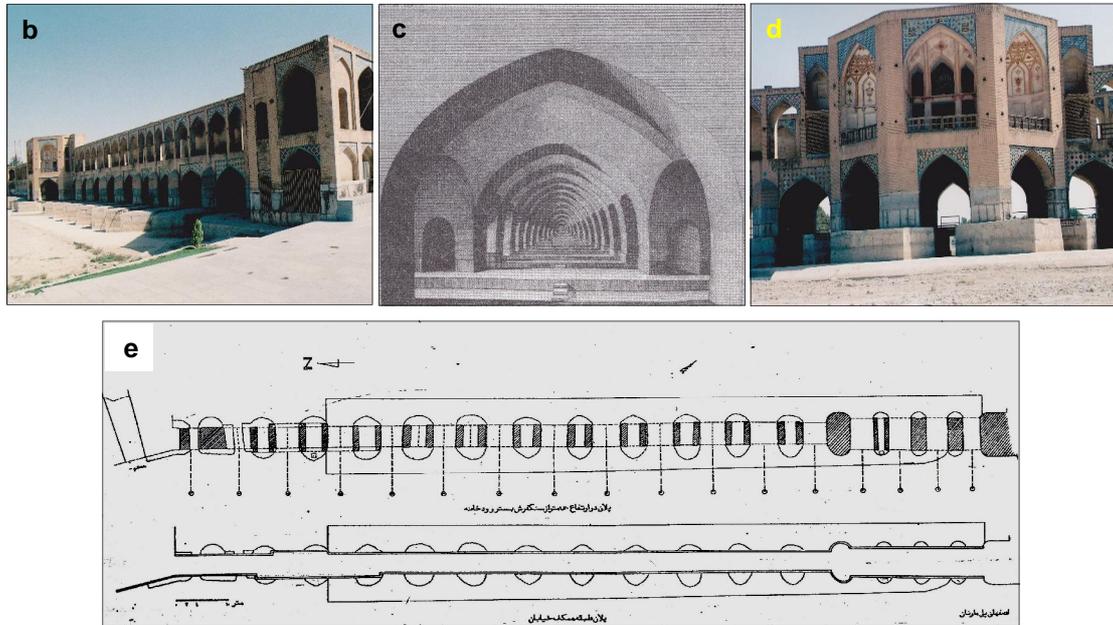


Figure (4) **a** plan of Khaju bridge, (after Isfahan heritage center), **b** the extent of Khaju bridge, **c** sample of multi- rooms in Si-o-Se Pol, shows the kind of the arches, the terrace, PL.XLIV-PL.XLIV, (after Chardian, 1956), **d** the pavilion of Khaju bridge and its multi-channel, **e** Marnan bridge (after Isfahan heritage center)

3.2. The second style

It consists of one floor only, in which some of the bridges have a small pavilion in the middle while others do

not have. Their design is simple and modest, for example:

3.2.1. Marnan bridge

It was built in 1599. It represents pedestrian path, and has 17 main arches in between them 14 small arches based

on stone pillars that combine the two arches together, fig. (5-a, b).

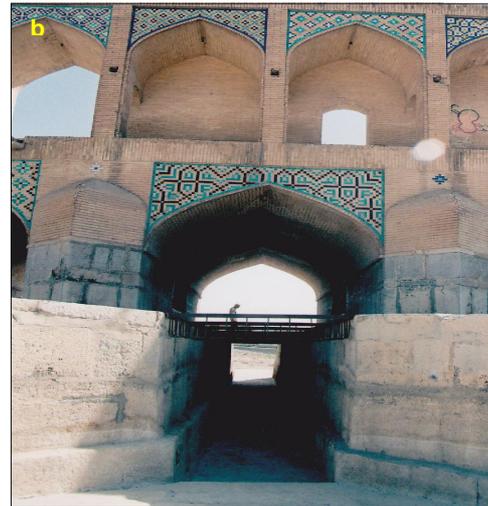
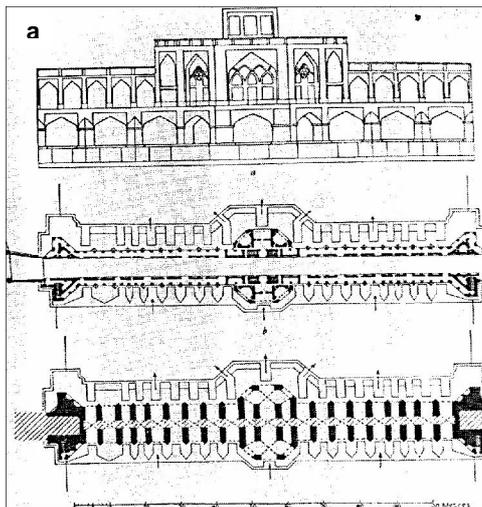


Figure (5) **a** plan and elevation of the Pol Khaju (after Isfahan heritage center), **b** water passage at Khaju bridge; by author

3.2.2. Joui bridge

It was built in 1665. It is located between Khaju and Ferdowsi bridges. It is 147 meters long and 4 meters wide,

with 21 arches, fig. (6-a). It was built to irrigate and inter-relate the kings' gardens on both sides of the river. The

bridge and the two pavilions within were for the exclusive use of the Shah and his courtiers, fig. (6-b, c). Nowadays the pavilions are being used

as tea houses, for the exclusive use of the harem for connecting the riverfront palaces across the two banks of the River [12][13][14].

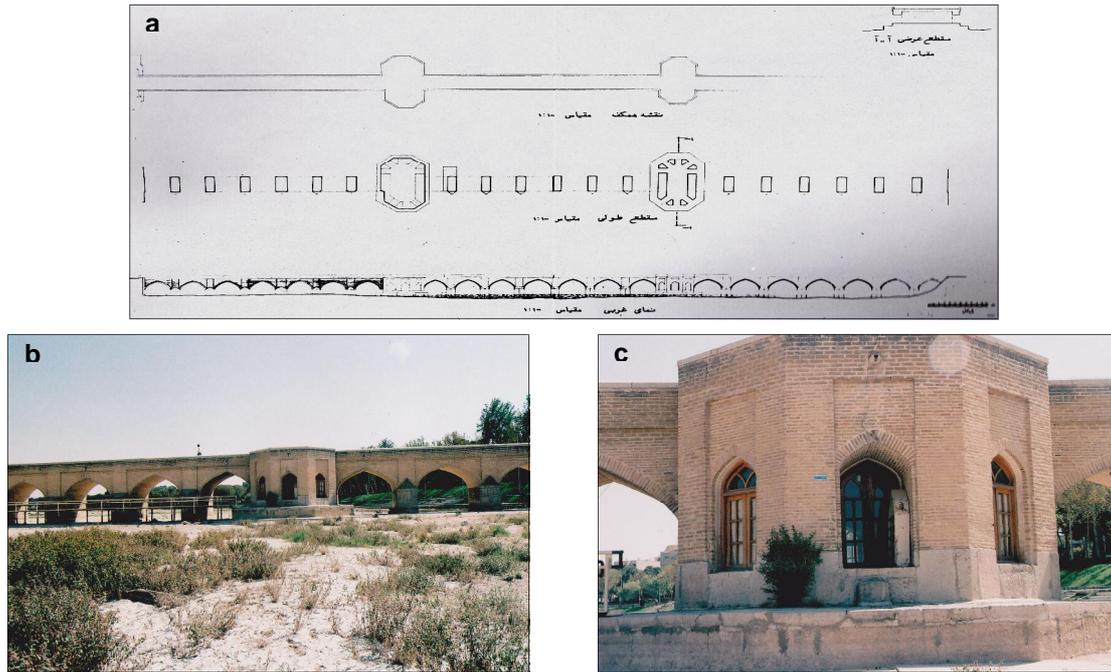


Figure (6) Joui bridge **a** its plan (after Isfahan heritage center), **b** its arches, **c** its pavilion

4. The Materials and Construction of the Bridges

4.1. The materials

The architect used the dressed stone blocks with special mortar called Sarooj made of sand, ash, clay, lime and other materials [15], which were subject to the continuous action of water. Important differences can be observed in the consistency of the mortar used in the piers and in the vaulted portions of the bridge. Squared stones in the main body of the bridges, and the gravel at the building foundation, fig. (7) in the middle of each arch were made of wooden boards [16], to reduce the load resulting from the rise of the arch, and at the same time it is the best

building material to react against water. Wood played only a subordinate role in such constructions, being used for scaffolding, building forms, pulley weights, temporary supports, to link between the bridge shoulders, and often for reinforcement in the vaulting. Clamps were used to link arches, piers, or bands together, and were mostly from iron which is an old technique used in ancient Iran. Some stones of the structure are replaced and have been dropped into the water. This has made the depth of the water become less.

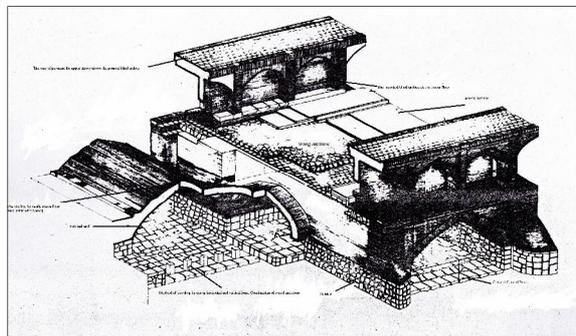


Figure (7) the bridges' materials, way of the building, and the used arches (after Isfahan heritage center and author modification),

4.2. The design and units

This part will briefly discuss the main units used in the bridges and dams'

4.2.1. The vaulted arches

In the bridges and dams, many samples of arches are used, some of which were decorated arches like the segmental, half, fig. (8) and horseshoe arches, and some others were used for functional reasons like the elliptical arch, Tudor arch and the most noticeable arch that has been used is the pointed arch because it bears pressure and height, fig. (4-b, c). Also, an Iranian arch known as five and nine part

construction and the reasons for using them.

can be noticed, according to the parts it is divided into like the Si-o-Se bridge center [17]. Some of those arches were essentially used for decoration like the horseshoe arch and the Tudor arch, and some others bear the level of pressure especially at the open gate and channel. So, the architect used the pointed arches in these particular places which are directly connected with water, flooding and receding water, fig. (6).



Figure (8) the segmental and half arches used in bridges' corridor

4.2.2. The ceiling

The main unit was the vault, especially the pointed one, and the shallow dome which was built directly on

the arches without squinches or any other transition zones. Those domes have been built at the pavilion and rooms, fig. (9)



Figure (9) the shallow dome

4.2.3. The slanting wooden door under the archways

It is located above the water tunnel to prevent water from passing, which affects the water level to become approximately 2 meters higher, causing

cascades over the steps of the bridges. Due to this sliding, they can control the water level in the river or in some branches more than the others.

4.2.4. The pavilion

The main bridges in Isfahan had an octagonal plan, figs. (3-c & 6-c), located in the center of the bridge on

4.2.5. The stairs

At the first level of the Si-o-Se Pol and Khaju, there are many steps, which are used to determine the water level, figs. (3-c & 4-a), and at the same

both the bottom and upstream sides. Those pavilions were dedicated to the Shah, his visitors and the harem.

time they function as stairs to the upper level. However, they are also used as places for sitting to watch water games at night.

5. The decoration

The main bridges in Isfahan have many kinds of decorating units. The artist used mosaic and ceramic tiles to decorate mostly architrave and arched culvert. They used the floral and geometrical

motives in general, figs. (4-c, e & 10), however, some of European travelers said that there was a human figure in some arches looking like the one existing in Qasre Chehlseton (Palace).

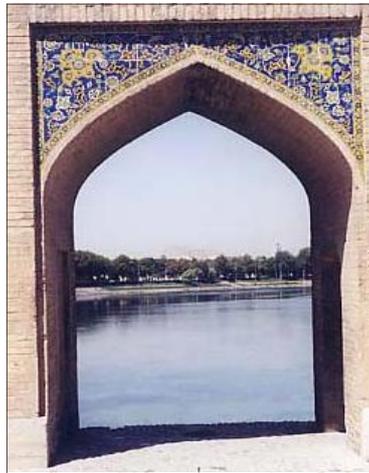


Figure (10) the geometrical decoration in the architrave

6. Conclusion

This hydraulic building played a major role in organizing and managing the water issue, and used every diameter of water without any wasting to irrigate the city and the village around. At the same time, the spread of bridges and dams in Isfahan related to the Safavid Period came with the great Shah who wanted Isfahan to become the most beautiful city in the world. Hence, he was determined to make Isfahan look like paradise by adding many kinds of gardens and he succeeded in that. In a semi arid area, and thanks to the hydraulic building which was established in the Zayandeh Rud, but not in use now, Isfahan was a piece of heaven.

Endnotes

(a) This river, unlike most others, has four gauging stations in its basin, which permits a study of discharge variations along its length, in its upper reaches above Zamānkān Bridge; the Zāyandé-Rūd is a typical Zagros stream. It raises high on the flanks of Zard Kūh (4,548 m) and then flows eastward toward Isfahan. Owing to the high altitude in this part of the basin,

snowfall is of great importance, and the regime of the river reveals a very marked snowmelt discharge peak in March-April. The most important man-induced water losses are the result of irrigation and associated evapotransportation. The main area of irrigation in the basin of the Zayandeh River begins downstream from the Mazra'a Bridge and reaches its peak in the

stretch about 25 km above and below the K^vājū Bridge. The K^vājū Bridge is situated in the center of Isfahan. By the time the river reaches Varzāna Bridge, just upstream from the salt desert known as the Gā^vūnī, the annual discharge value dropped to 89 million m³-almost exactly one tenth the discharges recorded at the upstream gauging station of Zamānkān Bridge (Beaumont, 1982).

(b) Orkan Pol , Baba Mahmud Pol, Zman khan Pol, Wrznh Pol, Srouch Pol,

Goum Pol, Goby Pol, Flowerjan Pol, Nyaserm Pol, Marnan Pol, Shahrestan “Gee- Housien” Pol, Khaju Pol, Si-o-So Pol, Golh Pol, Sherry Pol (Janab, Chardian, p.197).

(c) Up to 77 branches as Sheikh Bahaii documents and Mosa Ansare Athar, (Janab, Chardian, p.197) [18] for more information about Zayandeh water rights (Francois, Iran, Hammond, 2009, pp196-213)

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