

ASSESSMENT OF RIVER GHANATS SHUSHTAR

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ABSTRACT

In Khuzestan province due to the existence of 34 percent of the country's surface water, ground water has received less attention. Despite all these issues, people in this province, owing to the hot and dry climate, for using surface water need to transfer it to urban areas and farmlands higher than rivers. The result of the diligent people's efforts leads to drilling river (Softoh or Ghomsh) and underground (Kariz) Ghanats with unique characteristics. Of the important areas with river Ghanats are Shushtar city and its suburbs. In this city existed both surface and under ground water transfer. These Ghanats are 130 to 2000 years old. The present study assesses 8 Ghanats, out of them 5 are identified for the first time.

Key words: Ghanat, Softoh, Hydraulic, Shushtar, Gargar, Darioon.

INTRODUCTION

By the civilization development in ancient Iran, the use of wells with animals' force does not meet the progressive needs of people. From several thousand years ago, therefore, people innovated a new technique by the using the earth gravity to collect ground water and bring it to the surface. Besides drilling Ghanats which feed from ground water, they dig canals resembling Ghanats with different names such as Softoh, Kahriz, Kariz, Ghomsh, or Komeshe to transfer water to the areas that had difficulties to access surface or ground water. In this study, it is attempted to assess the two types of Ghanat mentioned above in shushtar in order to identify these hydraulic structures that transferred water around shushtar and also open a view for researchers to assess ancient irrigation regime and find stable one for better irrigation.

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HYDRAULIC VIEWPOINT OF GHANAT PERFORMANCE

Ghanat comprised of a number of vertical wells linked by means of underground canals in which water flows due to the slope related to the main canal length and the height difference between farmland and the bottom of the main canal. Ghanats usually feed from underground layers filled with water, rivers, and infiltration of surface water. From hydraulic viewpoint Ghanats can be divided into 3 areas of inundated, semi-inundated, and seepage. The inundated area follows the deep drainage pipes hydraulics but the semi-inundated area follows the open drainage canals hydraulics. Water in these sources flows in the underground canal with suitable slope under the influence of the earth gravity and then it is used by the people after draining out of the land [8]. Non-agricultural buildings and facilities related to Ghanats are briefly explained.

1. In certain areas, the slope of the Ghanat horizontal canal of the Ghanat was established in a way to operate with the power of water in the mills. [3]
2. In certain areas of the city, by using Ghanat water and a handle or on the main Ghanat people built bathrooms.[3]
3. In order to provide water for people to meet their needs, facilities called tailwater were built on the Ghanats. Each tailwater comprised of a curved channel reached to the main canal for water transfer.[3]

CLASSIFICATION OF GHANATS

Ghanats are classified based on length, discharge, depth, and feeding source. In this assessment only the classification based on feeding source will be considered.

1. Ghanats feed from groundwater.
2. Ghanats feed from surface water (such as rivers, springs, ponds, and lagoons) which are called Softeh in the local accent of people in Shushtsr.[1]

RIVER GHANATS

In the past time, these kinds of Ghanats called Kariz were found in Khuzestan province in galore. It means that water was not abstracted from the water table (aquifer) but from the river. This technique was used when the topographic condition of the land did not allow establishment of open channels for transferring water. Therefore in order to reduce excavation cost, Ghanat system was used as the continuation of irrigation canals originated from rivers. A large number of these Ghanats are found in certain cities of Khuzestan as Izeh, Behbahan, Dezful, Andimeshk, Shushtar, Ramhormoz, and Baghmalek[1]. These kinds of Ghanats were drilled in rivers with hard and vertical banks in each side or areas in which establishing channels was not possible due to the variations of heights. By drilling Ghanats in these areas water can be transferred to remote areas. There are two ways for drilling Ghanats:

1. In the first, a well is drilled near the river bed. The water entered this well from the river will be transferred to remote and low lands via certain horizontal canal of the Ghanats. "Figure 1a"

2. In the second, Ghanats are drilled at the same level as the feeding river. Most of the Ghanats (Kariz) are drilled in this way [1]. "Figure 1b"

Therefore in order to reduce excavation cost, Ghanat system was used as the continuation of irrigation canals originated from rivers [4].

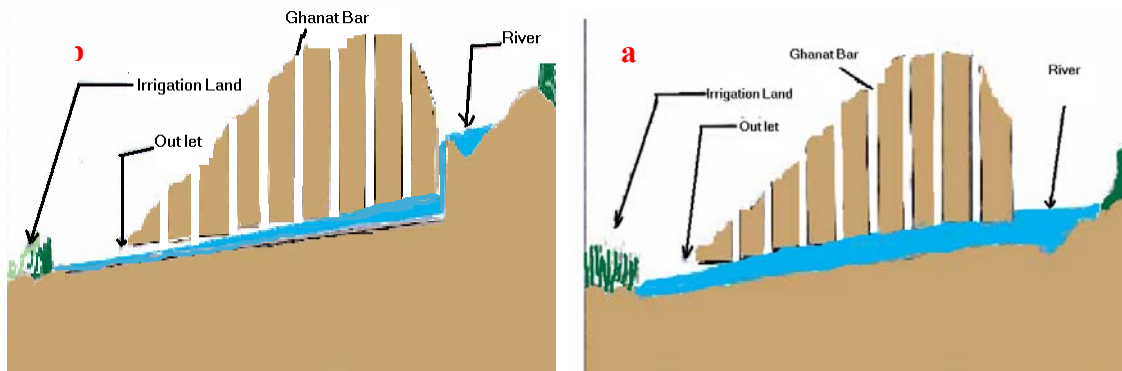


Figure 1 A. First class Softeh **B.** Second class Softeh

ASSESSING GHANATS AND SOFTEH IN SHUSHTAR

In north of Khuzestan province specifically in Dezful and Shushtar cities, drilling Ghanats was common due to the special topography of the area and the existence of high flow rivers. These Ghanats fed from the rivers instead of groundwater. Low level of rivers, by considering the level of farmlands and the cities, followed the innovation of these special kinds of Ghanats. These river ghanats or Kariz were called Softeh and Ghomsh in Shushtar and Dezful respectively [5]. Some of the Softeh in Shushtar were dried and destroyed after about a century; only one of them and certain parts of the others are available now. Identifying these structures and their capabilities in transferring water to remote and higher areas and saving the costs of establishing channels and other structure can be an appropriate pattern for the same areas. Unique specifications of these Ghanats deserve an accurate identification and assessment.

CLASSIFICATION OF SHUSHTAR GHANATS ACCORDING TO FEEDING SOURCE

1. River Ghanats (Softeh): Gargar Softeh including right bank Softeh (Softeh Bagh Khan Bozorg) and left bank Softeh (Softeh Bagh Agha Bagher), Shoteit Softeh, Karun Softeh (Galoogerd), Softeh Pol Band Mahibazan, Sofyeh Pol Band Dokhtar.
2. Ghanats feeding from groundwater: Jijal Ghanat (Pirgoori), Abid Ghanat (Abid village)

HISTORY OF RIVER GHANATS(SOFTEH) IN SHUSHTA

Although it's a long time that these Ghanats are dried, well bars are still available in the Gargar, Shoteit, and Karun rivers. Establishment of these Ghanats goes back to the Sasanid era and the time of Shadorvan weir establishment. The possibility of its establishment in Sasanid era is more because Shadorvan weir established for irrigating and cultivating lands. Nevertheless establishment of this weir had no economical values by taking into account the costs, time and available facilities. The existence of Darioon canal which goes back to 2000 years ago and comparing it with the Shadorvan weir proves this fact [2].

GARGAR SOFTEH

In order to irrigate the downstream lands of Gargar River, Gargar Softeh was established in the Gargar River bank due to the fact that irrigation was impossible during hot and low flow seasons. These Softeh fed water from beneath of the Shshtar waterfalls called Sika located at the 32", 02', and 45° northern and 50", 51', and 48° eastern geographical coordinates. These Softeh consist of two parts:

1. Left bank Softeh called Bagh Agha Bagher Softeh had approximately 1-1.5 km length. At the present time, 5 bars are available and others are not visible due to the total destruction or coverage with sediments. Measuring the length of this Ghanat both, inside and outside, is impossible due to the damage and destruction of the walls [9]. This Ghanat not only transferred water but also fed the ground water because at this time it has a good discharge by taking into account that certain parts has fallen down and filled. Also through performing some chemical experiments the Gargar River has a better quality (comparing with this Ghanat). In the Table no. 1 you can compare the quality of water in Gargar River and Gargar Ghanat (Softeh). In the other words, through the length of the Ghanat, water enters the Ghanat from the Aghajary formation that has a negative effect on the quality of water and the difference in water quality shown in the table 1 is due to this fact. At the present time this Ghanat has 3 to 4 l. discharge and feed from the aquifer. Figure 2a illustrates one of the bars of this Ghanat. Figure 2b illustrates a part of the Ghanat horizontal canal of the Ghanat.

Table 1. The results of Gargar river and Ghanat chemical assessments

num	location	10 ⁶ EC	PH	T.D.S P.P.M	CATIONS(Mill Equiv./Liter)					ANIONS(Mill Equiv./Liter)				S.P.	S.A.R	CLASS	Cl ⁻
					Ca	Mg	Na	K	SUM	HCO ₃	CL	SO ₄	SUM				
..	Gargar Softoh	905	7.9	2597	15.4	11.3	1160	1.83	40.13	2.60	11.4	25.82	39.82	28.9	3.2	C4-S1	—
..	Gargar River	905	8.4	570	2.36	1.34	5.3	0.18	8.98	1.96	5	2.09	9.25	57.9	3.9	C3-S1	0.22

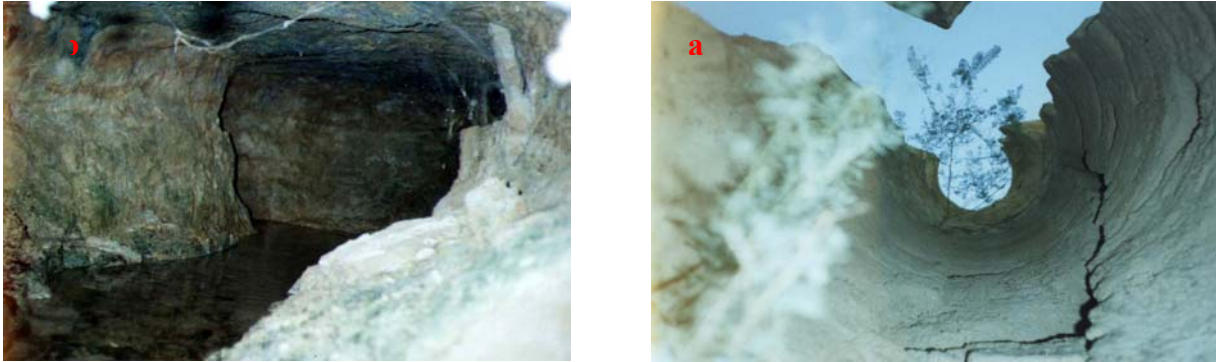


Figure 2- Pictures from Ghanat in the left bank of Gargar called Bagh Agha Bagher Ghanat

a) Ghanat bar b) Ghanat horizontal canal of the Ghanat

2. Right bank Softeh called Softeh Bagh Khan had supplied water for irrigating lands called Bagh Khan and a bathroom called Khan Bathroom [9]. The length of this softeh (Ghanat) is 500 m. After transfer, water in this Ghanat collected in a pool and when other parts of the land required water, they opened the pool. At the upper part of this Ghanat, in a place called Khan Bathroom, water transfer was performed by using a tool called Charkh dool or water wheel.

DARIOON GHANAT (CANAL)

This large canal used for irrigating 33 thousand hectares of Mian Ab lands is located in $32^{\circ} 03'$ north and $48^{\circ} 01'$ east. This canal is known as Darioon Ghanat or Softeh. It is placed between Mizan weir and Shadorvan weir. This Ghanat goes back to about 2000 years ago based on the new drillings, Ashkanid era. The general shape of this water supplier canal has 2 canals drilled beneath an old castle called Salasel which is like a hill at the present time. These 2 canals joined after getting out of the castle and formed one canal. After passing a curved path about 700 to 800 m. in a form of a closed conduit, before Shadorvan weir, it continues its path in a form of an open canal. This canal continues about 2 km. in a form of one canal and then in a place called Khak weir divided into two branches. Khak weir is one of the important hydraulic structures of Darioon system that had a significant role in controlling floods, and other applications such as water storage and water mill. This weir was the bypass of Darioon canal in the curved part of this canal [7]. The first branch of Darioon canal continues to the west and after about 33 km. enters Shoteit River in a weir called Arab Hasan. The minor branch called Raghat after passing a short way (5 km.) reaches the Gargar River. At the Salasel castle, this canal has several tail water for water abstraction, two are inside and the rest outside of the castle; out them, two are without any damage. By taking into account the appearance, the first tail water inside the castle probably was used in hot summer. Many canals were drilled beneath this castle and the water marks on them prove the fact that water had passed through them. The reason for drilling these canals is unclear, but it can be assumed that they were used for water abstraction due to the fact that in places like

tail water, ladders can be seen with wide areas probably for water abstraction. The geographical coordinates of the two tail water that are in shape are as follow:

The tail water inside the castle: 32°03'14" north and 16°51'48" east.

The tail water outside the castle: 32°03'15" north and 16°51'12" east.

This large canal doesn't have the known characteristics of a Ghanat, e.g. due to its large dimensions and long horizontal canal of the Ghanat no one considers it as Ghanat. But by a closer look, we can consider that it is oriented from other Ghanats of Shushtar which is used for irrigating 33 thousand hectares of Mian Ab farmlands and until 2000 had the main role in water supply for Mian Ab. Recently Khuzestan Water and Power Authority has revived this canal for irrigating farmlands in Mian Ab.

GALOOGERD GHANAT

This Ghanat or Softeh for the first time introduced in a book Water and Technology [2]. The main water supplier of this Ghanat is Karun River. The end of the Ghanat, the place where water comes out of the Ghanat, is located approximately 2 km upstream of Karun divergence to Shoteit and Gargar (Sabzeh Meidan village) in order to irrigate farmlands in Mehdi and Maleki villages. As it is quite clear from the pictures, taken in 1964, it seems that this Ghanat was in operation until this year. According to the local people, before the entrance of sewage water from Shoshtarno area and coastal town, this Ghanat was a resting place for livestock. This Ghanat or Softeh destroyed and changed to a settling area. Based on the 1964 pictures (Figure 3), the length of the Ghanat was 2 km. and it had 94 bars and most parts of it had drilled in Aghajari formation.

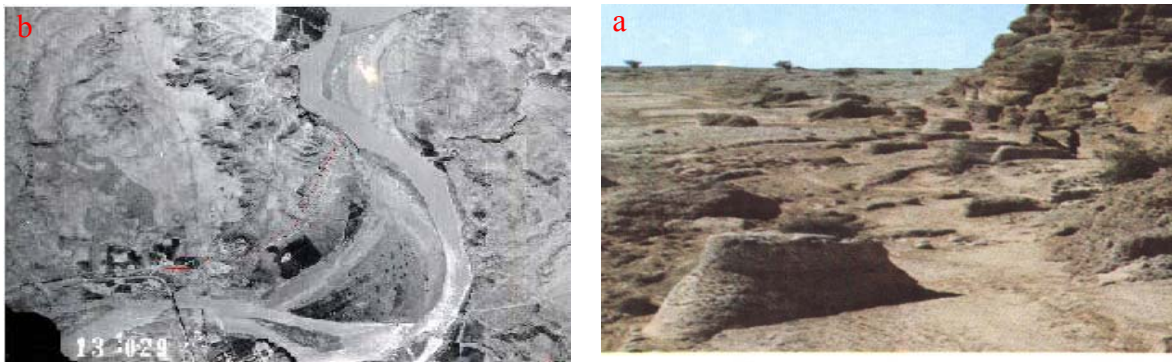


Figure 3 A) Bars of galooqred Ghanat [2] b) The aerial pictures of Ghanat and under irrigation lands (red points).

MAHIBAZAN WEIR

Approximately 4 km. downstream of Shushtar, a natural sand and stone layer has covered all over the width of Gargar stream that protrude out of water during summer. The natural condition of this layer indicates that the primary residents of this area were familiar with dam construction technology. Therefore they constructed a weir and bridge from stone and 3 of its pillars are still present [2]. The condition of this structure is the same as other Sasanid structures. The goal of its construction was not only crossing the river but also supplying water for both sides of the river. The water enters

underground canals (that are like Ghanat or Softeh) and in a slightly far distance flows on the ground. Its shape and water supply process resembles Arjan weir on Marun River near Behbahan city [3]. But at the present time no structure was found to be similar to Softeh or Ghanat and the river route has changed during past years, right bank has enlarged, left bank has ruined and changed to bed. There are only three pillars located in a fish farming basin completely stick out of water. The condition of the mentioned sand stone layer is apparent in this weir. Just one point should be taken into account which is the existence of a spring with high discharge near this weir. This spring is supplied by the river and perhaps the high flow is from one of the above mentioned Softeh which is routed to this point. It also should be pointed out that this spring now is used for growing rice and moreover its discharge almost has no change during a year. Since several years ago certain parts of this structure were present and it was used as a resting place, but it is completely wiped out due to the construction of Gargar fish farming basin in its right bank.

DOKHTAR WEIR

Of other Ghanats which had existed in Sushtar were Dokhtar weir Ghanats but at this time none of them are present. Only in some books there are indications of these Ghanats. Certain parts of a large weir still exist in north of Shushtar known as Dokhtar weir that are assigned to Anahita, the goddess of flowing water [4]. Dokhtar weir had stored Karun water in a reservoir and after that water flown out of this weir from 4 Ghomsh or Softeh on both sides of the weir and irrigated the farmlands at both sides of the Karun River. Certain wells of these ghants are still present around the Karun River.

JIJAL VILLAGE GHANAT

This Ghanat is located 8 km. east of the Shushtar in 32° and 01" northern, 48° and 56" eastern geographical coordinates. The exact length of this Ghanat is not known and about 84.3 m of its length is in Aghajari formation. The history of this Ghanat goes back to the period before Islam by considering other stone Ghanats in southwest of the country, at the time of the Shushtar progress in Sasanid era. This Ghanat which is the sample of past people hard labour and is an honor for people today, was not completely active and water goes out through bars. According to the owner of the Ghanat, it has 3-4 liter discharge now. (Table 2 shows the quality of this Ghanat in 7 samplings). Although stone Ghanats are less in number they have a significant role. A number of these Ghanats are found in southwest of Iran which have a main well and some bars in stone and other in alluvium. Jijal Ghanat is one these stone Ghanats.

Table 2. the results of chemical experiments of Jijal Ghanat water.

num	10 ⁶ EC	PH	T.D.S P.P.M	CATIONS(Milli Equiv./Liter)					ANIONS(Milli Equiv./Liter)				S.P.	S.A. R	CLAS S	C ₃ ²
				Ca	Mg	Na	K	SUM	ICO	CL	SO ₄	SUM				
1	2232	8	1757	11.20	7.30	7.80	0.17	26.47	2.40	3.90	19.90	26.25	29.50	2.60	C3-S1	—
2	2120	8	1736	11.7	6.80	7.70	0.14	26.34	1.80	3.70	20.62	26.12	29.20	2.50	C3-S1	—
3	2110	8.6	1731	10.6	7.90	7.70	0.14	26.34	1.81	3.70	20.61	26.52	29.20	2.50	C3-S1	0.4
4	2126	8.5	1733	11	7.30	7.80	0.13	26.33	1.60	4	20.21	26.21	29.70	2.60	C3-S1	0.38
5	2110	8.2	1727	10.9	7.50	7.70	0.14	26.24	1.80	3.70	20.52	26.02	29.30	2.50	C3-S1	—
6	2150	8.3	1739	10.42	8.03	7.30	0.13	25.88	2.26	3.70	19.70	25.66	28.20	2.40	C4-S1	—
7	1970	8.4	1698	9.70	8.70	6.85	0.11	25.36	1.80	2.90	20.43	25.13	27.01	2.30	C3-S1	0.22

ABID GHANAT

The ruins of this system are located somewhere between Dezful and Shushtrar cities near farmlands in Abid County where traces of Aghajari and Bakhtiary formations are found. One of the Ghanats in this system is at N 32° 17' and 48° 42' E, however, the geographical location of two other Ghanats is not known yet. This system dates from 1847. Three Ghanats have been established in this area while only two of them have been investigated through observations. The local residents believe that the water supply to the system was a surface supply, but due to the extensive changes to the surface over years the hypothesis is very difficult to measure. The remainders are now only consisted of several bars. Based on the observations and evidence it can be concluded that these Ghanats contained water until 18 to 20 years ago. Even today some of the bars still hold small quantities of water. It should be noted that over time this system has been buried under alluvial yields from Bakhtiari formation. The depth of the horizontal canal of the Ghanat is estimated to be 2 to 3 m. Also the remains of the old water mills using the water supplied by these Ghanats can be seen in the area indicating a high discharge at the Ghanats.

Discharge & covered area of Ghanats

"Table3" the high discharge from Shushtar's Ghanats and softeh and their relatively vast covered area.

Table 3. Discharge rate and the mentioned Ghanats and Softeh under irrigation lands.

num	Name of Ghanat	Average discharge (lit/sec)	Length of Ghanat (m)	irrigation lands (km2)	Source
1	<i>Jijal</i>	10	84.3	—	Water grand
2	Abid	250	3000	1	Water grand
3	Darioon	6556	200	330	Shotate river
4	<i>Gargar</i>	70	800	0.03	Gargar river (RHITE)
5	Gargar	70	1500	0.15	Gargar river (left)
6	Galoogerd	520	1200	2	Karoon river (RHITE)

CONCLUSIONS

Applying knowledge and complicated water structure of the time such as softeh (Darion and Gargar), Ghanats (Galooard and jijal), dykes (Band-e Mizan and Band-e Khak,) weirs (Shadorvan and Lashkar), water storages (Aghili), water mills (Shushtar waterfalls) bathes (Khan bath), traditional streams (Darion irrigation network), ancient Iranian engineers in Shushtar supplied water to satisfy various drinking water, agricultural, health, etc, demands through an proper and efficient management practices. These hydro structures can be of interest to water science investigators and engineers. Water demand in residential and agricultural areas above the water supplies level (mainly rivers) led to the invention of river karizes in Shushtear and Dezful with unique characteristics in order to exercise a proper management over land farms and efficient use of surface water resources. Recently, eight different Ghanat systems were recognized across Shushtar district, 4 of which were fed by Karun River. While theses Ghanats display an interesting ancient engineering and architecture, they have been severely damaged and disappeared in recent years due to the exceeding use of pumps, wells and other water structures in the area. Through extensive, yet careful investigations it will be likely to use these cost-effective and easy-to-build systems or a mix of them as alternatives to the current high-cost irrigation water network and municipal water system projects with least probable disturbance to the ecosystem and environment of the region.

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