Karez – A Cultural Heritage of Natural and Agricultural Sectors and an Interminable System of Harvesting Groundwater in Balochistan

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1. History of Karez

1.1. Karez Development

History of harvesting groundwater is less known. ***For shallow water table and aquifer with soft water-bearing material, dugwells can be developed manually and that is a method as old as mankind.*** The techniques of digging wells definitely improved during the last millennia with the development of irrigated agriculture, the rise of large settlements and lining techniques of dugwells. These improvements made it possible to reach deep aquifers. Brick-lined dugwells are discovered in the Indus valley civilization at Mohenjodaro, Pakistan in 2500 BC (**Figure 1**).

Figure 1. Well in the city of Mohenjodaro

Another technology for harvesting groundwater, as old as the shallow dugwells, was well tunneling (i.e. excavation of horizontal galleries) to increase the flow of a low-yield dugwell in arid zones. Such galleries can be found all over the Mediterranean and Middle East, dated back to the early Neolithic. Such dugwells are also found in: a) arid zones of Sindh and Balochistan; and b) peri-urban areas.

Karez system becomes the more advanced technological innovation when it becomes a system that gave birth to a new spring – man made spring. Such systems can be of different kinds, but the well documented is conveying aquifer waters to the daylight point by the underground galleries. ***The first historical appearance of Karez is believed to have happened in the mining works during the Urartu kingdom (North Iran, 8th century BC) for drainage of groundwater because water collected in mining ditches poses serious problem of drainage*** (**Figure 2**; www.waterhistory.org).

Figure 2. Areal view of Karez system in Iran

1.2. Karez Expansion

During the 1st millennium BC (550-331 BC), when Persian rule extended from the Indus to the Nile, Karez technology spread throughout the empire. The Achaemenid rulers provided a major incentive for Karez builders and their heirs by allowing them to retain profits from newly-constructed Karez systems for five generations. As a result, thousands of new settlements were established and others expanded. To the west, Karez systems were constructed from Mesopotamia to the shores of the Mediterranean, as well as south-ward into parts of Egypt. To the east of Persia, Karez systems were constructed in Afghanistan, the Silk Route oases settlements of central Asia and Chinese Turkistan (**Figure 3**; www.waterhistory.org).

Figure 3. Karez gallery, Turpan, Xinjiang, China

During the Roman-Byzantine era (64 BC to 660 AD), many Karez systems were constructed in

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Syria and Jordan. From here, the technology diffused to north and west into Europe. There is evidence of Roman Karez systems as far away as the Luxembourg area (www.waterhistory.org).

Under the Arabs, underground galleries spread from the Middle East to Cyprus, Sicily, Morocco, Spain, Canary Islands; under the Abassides from East Iran to Central Asia and Mecca. After the conquest of America the Spanish diffused them to Mexico and Peru (Figures 4-6).

Figure 4. Exit of a Foggara in Libya

Figure 5. Water "metering" through a distribution weir on a *Foggara* in Algeria

Figure 6. Monitoring the groundwater level in Pechi Karez, Ziarat, Balochistan.

Underground galleries are called by different names in different parts of the world: *Qanat* in Iran; *Karez* in eastern Iran, Balochistan and western and eastern Central Asia; *Falai* in Arabia; *Foggara* in Maghreb; *Rhettara* in Morocco; *Pozeria* or *Galeria Filtrante* in Spain; *Falaj*, *Mambo* or *Alcavor* in Mexico; *Fuques* or *Pukios* in Peru (www.waterhistory.org). ***All these names have same meaning – system bringing groundwater to the daylight point.***

While the diffusion model presented by the website of Water History is nice and neat (**Figure 7**), human activities are rarely so orderly. The diffusion model illustrates the expansion of Karez system in the three major Empires: a) Persian; b) Roman; and c) Arab.

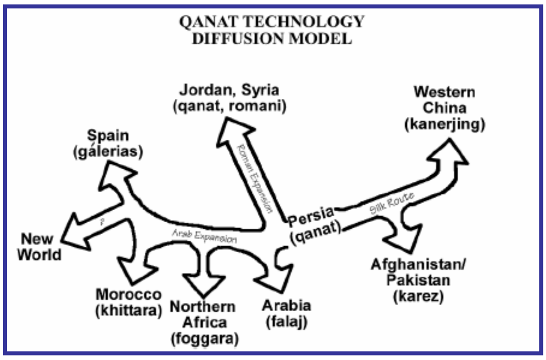

Figure 7. Model for the diffusion of Karez technology (www.waterhistory.org).

Karez systems were an important factor in determining where people lived. The largest towns were still located at lower elevations in river basins or broad valleys. Most of these settlements were defended by a fortress and water was supplied from shallow dugwells. Karez enabled these settlements to grow by tapping deep aquifers.

Karez systems supported establishment of permanent settlements on the alluvial fans, as earlier settlers had bypassed these areas because water tables were too deep for dugwells, and the Wadis on these slopes were too deeply incised in the fans for diversion channels. In these locations, Karez made it possible to harvest deep groundwater and for the first time, at these higher elevations, Karez-fed hamlets appeared.

Currently, in the world, 15 million ha (6% of World's irrigated lands) are irrigated by Karez system: half of the area is situated in Iran and the rest in other countries (Afghanistan, Pakistan, Turkmenia, Azerbaijan, Tarim, Oman, Maghreb, Morocco, and Mexico).

In fact, the Iranian plateau has always been the region where Karez represents the main system of irrigation, where a privileged class of specialized diggers exists, and where Karez technology was continuously ameliorated and exported.

2. Karez System in Balochistan

2.1. Recent Historical Background

In Balochistan, during 1904 there were 496 Karez systems and 1803 springs in the administered area and were important source for irrigated agriculture, as the two-third of the cropped area in Quetta and Pishin Districts was irrigated by Karez and springs (*Gazetteer of Balochistan*). In reality, the number of Karez systems must be much more if the un-administered area is included.

Before discussing further details it may be interesting to quote a statement from the Gazetteer of Makran District ***"the importance attached to irrigation from Karez systems may be gauged from the Baloch saying: 'A mosque should be demolished if it obstructs the course of Karez (Makran District Gazetteer, P-187, published 1906, reprinted 1986)".***

It is believed that in Balochistan, until 1970, around 3000 Karez systems were in use, providing water supply to towns and for irrigated agriculture. Afterwards, with the availability of electric power and tubewell technology, the Karez systems started declining and over one-third are still functioning, constituting as one of the major water source in Balochistan.

The internationally sponsored irrigation surveys in the 1970s viewed the Karez as traditional and outdated system not amenable to updating. The transition to dugwells and tubewells was encouraged, lowering the water-table and decreasing the flow of water in the Karez.

2.2. Number and Distribution of Karez

During the drought period (1998-06), the survey conducted by the Irrigation and Power Department (IPD) revealed a different set of Karez distribution in the province. ***The highest concentration of Karez systems is found in Qilla Abdulla (243) followed by Panjgoor (188), Turbat (138), Pishin (123), Qilla Saifulla (122), Zoab (70), Ziarat (67), Chagai (56) and Loralie (50).*** Rest of the districts each is having less than 50 Karez systems. The sample survey includes documentation of 1146 Karez systems in Balochistan (**Figures 8, 9**).

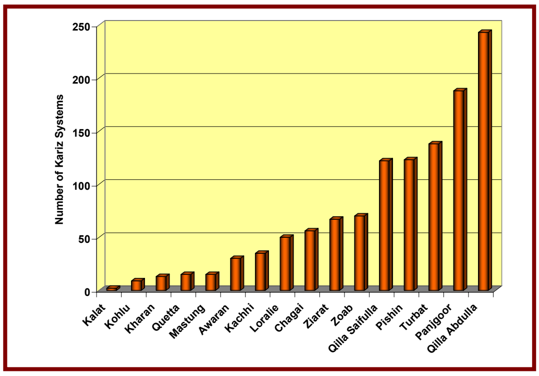

Figure 8. Distribution of Karez in Balochistan

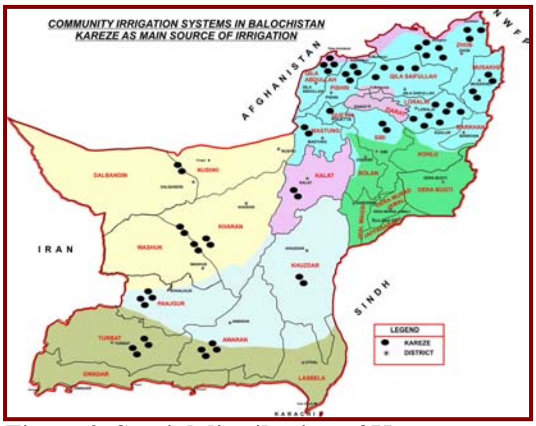

Figure 9. Spatial distribution of Karez systems in Balochistan

2.3. Probability of Karez Command Area

The survey conducted by the IPD for 1146 Karez systems in Balochistan was used to develop probability distribution for the command area (**Table 1**). There is wide variation in command area as 90% schemes are having command area of <100 ha, 75% schemes <70 ha, 50% <35 ha and 10% schemes <8 ha. The command area is quite high for 25% schemes.

Table 1. Probability distribution of Karez command area in Balochistan

Probability (%)	Command Area of Karez (ha)
Minimum	1
10	8
25	16
50	34.
75	**67**
90	**97**
Maximum	**1670**

2.4. Probability of Karez Discharge

There is wide variation in Karez discharge in Balochistan as 90% schemes are having discharge of <57 litres/sec, 75% schemes <50 litres/second, 50% schemes <21 litres/sec and 10% schemes <7 litres/sec. Thus, the discharge of 25% of the schemes is very high (**Table 2**).

Table 2. Probability distribution of Karez discharge in Balochistan

Probability (%)	Discharge of Karez (litres/sec)
Minimum	1
10	7
25	11
50	21
75	**50**
90	**57**
Maximum	**227**

2.5. Water Allowance of Karez Systems

Probability analysis was made for assessment of water allowance of Karez (lps/100 ha) to evaluate the potential of irrigated agriculture. The distribution indicated that hardly 6% schemes are suffering from scarcity of water having water allowance of <28 lps/100 ha. Around 75% schemes are having water allowance of >56 lps/100 ha (equivalent to 8 cusecs/1000 acres considered as very high water allowance in canal irrigated areas). ***If the survey data is accurate, then there is ample opportunity to enhance command area and water productivity because of higher water allowance*** (**Table 3**).

Table 3. Probability distribution of water allowance for the command area, Balochistan

Probability (%)	Water Allowance of Karez (lps/100 ha)
Minimum	2
10	39
25	56
50	70
75	87
90	122
Maximum	1167

2.6. Contribution of Karez to Groundwater

Almost equal area is irrigated by canals and groundwater in Balochistan. A total of 0.595 million ha are irrigated through three main sources Karez/springs (140001 ha), dugwells (80976 ha) and tubewells (373774 ha) corresponding to 24, 14 and 62% irrigated area, respectively (**Figure 10**). Thus, ***roughly one-fourth of the area irrigated by groundwater is contributed by Karez and springs.***

There are four main kinds of abstractions: a) electric-operated deep tubewells; b) diesel-operated tubewells/dugwells (shallow to medium depths); c) bucket-operated or small motors fitted shallow dugwells; and d) perennial irrigation schemes. The groundwater abstractions from electric-operated tubewells are 2.025 billion m^3, the diesel-operated tubewells/wells abstract 0.712 billion m^3 and dugwells abstraction is 0.427 billion m^3 per annum. About 294 perennial schemes (Karez and springs) provide 0.862 billion m^3 of groundwater annually (**Figure 11**).

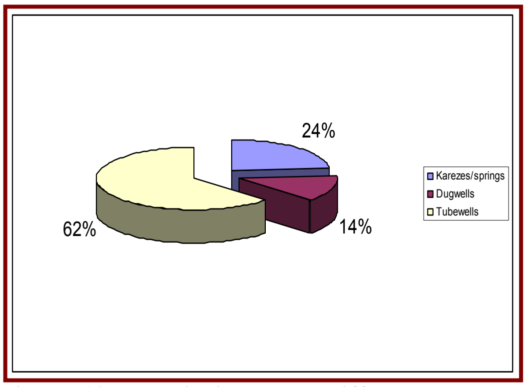

Figure 10. Area irrigated by different sources

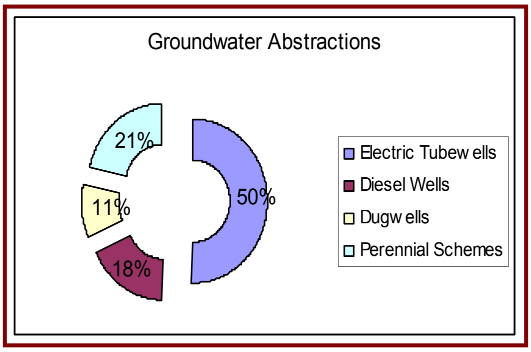

Figure 11. Groundwater abstractions by different sources

3. Characterizing Karez System

3.1. Physical and Hydraulic Dimension

In the beginning of the 1st millennium BC, under the Persian influence, the Balochistan farmers started constructing Karez systems for harvesting groundwater in the river basins of Balochistan.

Karez underground galleries were manually dug, just large enough to fit the person while digging. Along the length of a Karez, which can be several kms, vertical wells were dug at intervals of 20 to 30 m to remove excavated material and to provide ventilation and access for maintenance. The Karez underground gallery sloped gently down from pre-mountainous alluvial fans to an outlet at the command area. These structures allowed farmers to have sustainable farming even during droughts when surface water is not available. The components of Karez/Qanats are (**Figure 12**):

- Water table
- Infiltration part of the tunnel
- Water conveyance part of the tunnel
- Vertical wells or access shafts
- Qanat outlet (daylight point)
- Open channel
- Storage pond
- Irrigated command area

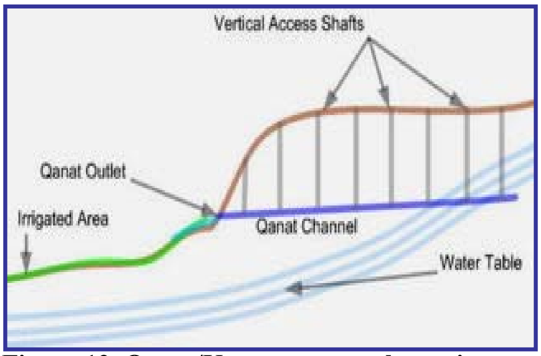

Figure 12. Qanat/Karez system schematic

The advantages of Karez system are: a) major part of the channel is underground and it reduces seepage and evaporation losses; b) gravity fed system and it does not require any energy for pumping; and c) abstracts groundwater as a renewable resource by posing maximum limits.

The rate of flow of water in a Karez is controlled by the water table. Thus a Karez cannot cause significant drawdown in an aquifer because its flow varies directly with the subsurface water supply. When properly maintained, a Karez is a sustainable system that provides water indefinitely. The self-limiting feature of a Karez is its biggest drawback when compared to the range of technologies available today. Water flows continuously in a Karez, and it is largely needed during spring and summer seasons. Farmers also prefer to irrigate during day-times.

Although, the continuous flow in a Karez is frequently viewed as wasteful, it can be managed. During periods of low water use (fall and winter), water-tight gates can seal off the Karez opening damming up and conserving groundwater for periods of high demand. In spring and summer, night flow may be stored in small reservoirs at the mouth of the Karez for daytime use.

3.2. Building the Karez System

In Balochistan the ancient Karez systems are still in use. It is in the Qilla Abdulla and Panjgoor districts having the biggest concentration of Karez systems and the most skilful diggers. Their building methods are very traditional using ancient technologies. ***For the building of a Karez three phases can be distinguished: a) investigation and planning; b) construction; and c) maintenance.***

Generally, in order to increase the water flow to a required volume, not one but several mother wells are built, together with relative galleries bifurcating from the main one. Karez systems built parallel to seasonal streams bring groundwater to the surface during a dry period; and provide filtered clean water out of the muddy flow during the wet periods. In the ADB TA Grant Study on “Perennial Irrigation Schemes”, the Consultant found that in Balochistan, exceptionally upto 50 mother wells have been dug for a Karez system to increase the yield over centuries.

In late 60s and early 70’s, the construction cost of a Karez of 1 km long with a mother well’s water surface at 50 m, a Party of 4-5 specialized workers with 17 years of work was Rs. 600,000. In other words a Party can produce 3-7 wells a year at the cost of Rs. 6000-12000 each.

The Karez stops functioning as soon as the water table falls below the drainage level of the mother well; and it restarts as soon the water level rises back. So it constitutes a sustainable way of exploitation of water resources, with the geological and technical features of the mother well fixing and regulating the rates of drainage.

3.3. Maintaining the Karez System

The case study conducted by ICARDA in Syria is given in **Box. I**.

Box. I. Renovation of Qanats in Syria

ICARDA published a Paper on “Renovation of Qanats in Syria” to assess the technical impact of cleaning by measuring increase in water supply of Qanat. Around 16 young men were trained for maintaining the Qanat. Whether this intervention is socially sustainable can only be observed on longer term basis. During summer 2002, the village was divided in different descendant groups like before the cleaning and social tension *was still present, but the Qanat was flowing successfully. The cleaning raised attention of Syrian and international officials, which benefited to have public awareness regarding sustainable water supply systems to ensure future of Qanats. From the experience of cleaning the Shalalah Saghirah Qanat, the ICARDA developed the following feasibility criteria:*

- ***A stable groundwater level**: Pumping is a major threat to Qanats. If there is a fast decrease of groundwater level, it is impossible to re-use Qanats for agriculture unless the pumping stops within a range of 3.5 km from the Qanat tunnel.*
- ***Consistent underground tunnel construction**: Many of the ancient Qanat workers died because of the danger of job and potential of collapsing of tunnels. If there is any doubt about the consistency of the underground construction, care should be taken and renovation reconsidered out of safety reasons.*
- ***Strong social cohesion in community**: This is a condition for management of any Qanat as a common water resource system. It should be noted that social cohesion differs and that it therefore should be studied on a case to case basis. In the Arab rural areas, a strong village or family leader is usually a condition for good social cohesion.*
- ***Clear ownership of Qanat**: This is a condition, not to have any problems or conflicts about claiming ownership when there is more water coming from the Qanat.*
- *Existing system of rights and regulations on water, to be used when water increases.*
- *Willingness of users, who are the ultimate beneficiaries and if they are not willing to clean, the work is not likely to be sustainable.*

3.4. Social and Cultural Dimension

The cost, time and skills necessary for building and maintaining a Karez are very high. But in arid zones, when in function, the Karez represents a kind of miraculous pure spring, capable of determining the survival of a whole village and so carrying economic, social and cultural impacts. Around 90% Karez are having discharge exceeding the deep tubewells and as large as equal to 5-20 tubewells. In fact, the successful construction and utilization of a Karez system doesn't just depend upon its technical and structural arrangements but also upon several social factors. On one side, it has high costs, on the other it provides economical profits because of low operational cost of water compared to the pumped water. It also promotes social integration.

The pre-conditions of the functioning of a Karez are the existence of a very cheap class of workers supporting its material construction and maintenance; the commitment of tribal leaders, landlords, rich families, kinship groups promoting the construction; a class of skilful specialists that guarantee the technological aspects; and a perfect social cohesion. Any disharmony and conflict between or inside each of these protagonists will undermine the functioning of some parts of the system.

The government of Balochistan could not provide the required support to train the labour for the construction of Karez systems; and today labour costs are sufficiently high and such labour is hard to find for functioning the old Karez systems or for building new ones.

In the past, the tribal leaders use to give incentives for the construction of Karez systems by allowing the diggers and their heirs to retain profits for an agreed period. In fact to build and manage a Karez doesn't only give local privileges in the use of valuable water but represents also a profitable business. The ownership can be individual, or by kinship clan, or collective.

The Karez gives an oasis to the people; to the owners it gives privileges and profits. Most probably a cast of water-wizards existed from ancient times, which, cooperating first with the miners and then with the tribal leaders. The builders of Karez are semi-nomadic kinship groups with secret hereditary transmission of knowledge. Their difficult and hazardous work encounters many problems and frequent death accidents: from very young age the Karez digger risk their life, with the father helping and directing the operations from outside, so that only few of them reach an old age. The job requires skill, courage and a specific spiritual taint that attires honor and devotion. They are well paid and highly respected; they work only during favorable days and prayers are said over them by the villagers every time they descend in the wells.

The Chinese government has accorded high priority to Karez systems in Xinjiang China by including Karez in the list of items identified for Agricultural and Cultural Heritage in Xinjiang, China. The Case Study conducted by Chinese Silk Road Adventures Co Ltd is given in **Box-II**.

Box. II. Karez – An Agricultural and Cultural Heritage in Xinjiang China

According to an estimate, Xinjiang China is losing 20 Karez systems per annum. ***The Silk Road Adventures Co Ltd. indicated that for the purpose of "world heritage and society development", the karez systems were considered as experimental item for declaring cultural heritage by Iran.*** *Though this item was not confirmed by the International Organization but it gives the Chinese an alert. The Chinese experts suggested that they will investigate further and make a list of agricultural and cultural heritage in China.*

Karez is regarded as one of the three big, important projects in China, the other two are the Great wall and Beijing-Hang Zhou canal. *It is the main water resource of Turpan in Xinjiang. It is a contributor of the ancient Turpan people wisdom.* ***There is a saying that "if there is no karez there would not be Turpan".*** *In terms of the special geographical situation of Turpan, the Karez is considered as most efficient irrigating system.*

The average temperature of Turpan in summer goes around 30 °C. The annual rainfall is only 16mm while the evaporation is more than 2500 mm. The high temperatures can further enhance the evaporation rate. The accumulating snow on the top of the Tian Shan mountain system is the beginning point of Karez. With the melting of snow in summer, the water percolates deep into the aquifer and that is harvested through Karez. It is still playing a significant role in daily life of Turpan. Because of deferred maintenance and other climatic-socio-economic reasons many Karez dried in Turpan. Fifty years ago there were 1784 Karez in Turpan but at present only 500 are operational.

Since 2002, the UN-FAO, UNDP and GEF began to set up a list of globally important agricultural items – "world agricultural heritage". In short time this organization chose 100-150 heritages. More than 30 items applied to be world heritage including the "Karez" item, and 5 items were initially set up for an experiment.

The case of China indicates that Balochistan may also consider Karez as cultural heritage in natural and agricultural sectors.

4. Present Day Karez Systems

4.1. Common Features of Regions using Karez Technology

The Karez technology was used most extensively in areas with the following characteristics:

- absence of perennial rivers to support surface irrigation;
- proximity of potentially fertile areas to precipitation-rich mountains or mountain ranges;
- arid climate with high evaporation rates so that shallow surface reservoirs and smaller canals would result in higher losses; and
- aquifer at the potentially fertile area which is too deep for shallow dugwells.

The investment and organization required by the construction and the maintenance of a Karez is typically provided by local landowners in small groups. At the end of 60s, it is estimated that over 3,000 Karez systems were in use in Balochistan, each commissioned and maintained by local users. The Karez system has the advantage of being relatively immune to natural disasters (earthquakes, floods) and human destruction. Further, it is relatively insensitive to the levels of precipitation; a Karez typically delivers a relatively constant flow with only gradual variations from wet to dry years.

4.2. Settlement Patterns

A typical town or city in Balochistan and elsewhere where the Karez is used, command area is located both over the Karez a short distance before they emerge from the ground and after the outlet. Water from the Karez defines both the social regions in the city and the layout of the city. The water is fresh, clean, and cool in the upper reaches and more prosperous people live at the outlet or immediately upstream of the outlet. Downstream of the outlet, the water runs through surface canal with laterals to carry water to the command area. The water grows progressively more polluted as it passes downstream. In dry years the lower reaches are the most likely to see reductions in flow.

5. Impact on Functioning of Karez

5.1. Role of Karez in Securing Water Supply

Since the last 40 years, the role of Karez systems in securing water in Balochistan has been diminishing. The same has been adversely affected due to the drought (1998-06) and inadequate support from the public-sector. The labour required for maintaining or constructing the Karez system is also diminishing.

The civil society and the public-sector both have assumed that the 'age' of Karez is over. Due to inadequate policies in Balochistan, lack of awareness about the indigenous technologies and poor understanding of the interactions between Karez systems and the local community and productivity patterns, the original and critical role of Karez has been somewhat neglected due to the availability of electric-power through the national grid system and subsidy on electric-tariff, which resulted in installation of deep tubewells and abstracting groundwater beyond the sustainable levels.

The real question is that why the society could not learn from the Karez system and due to short-sightedness, the groundwater aquifer was over-mined in a very short period of 40 years resulted in creating inter-generational issues, because we might deprive our coming generations to have right to groundwater.

5.2. Wells as Alternatives to Karez

Since 1970s wells/tubewells have succeeded in replacing or affecting the Karez systems. These electric- or diesel-operated tubewells/wells have been excavated without considering the original location of Karez. However, in comparison to Karez, tubewells/wells have a shorter life span (currently that is between 10-15 years) whereas; Karez system holds good for centuries. Installation of deep tubewells in the last 40 years has further led to the drying up of shallow dugwells and Karez systems.

The study conducted in the ADB TA Grant Project [TA-4560 (PAK)] under the Package Assignment indicated that average recharge to groundwater in Balochistan is 2.21 billion m^3. The groundwater abstraction during 2006-07 was 2.659 billion m^3 (domestic 0.094; stockwater 0.094; and agriculture 2.474 billion m^3). Thus over-abstraction is 0.459 billion m^3 resulting in lowering of water table and mining of groundwater. The lowering of water table in alluvial aquifer ranges between <1 m to 3 m per annum, whereas in the hard-rock aquifer the lowering is at a higher rate.

There is no doubt that in Balochistan tubewells/wells are absolutely necessary. But these must be considered as a complementary feature to Karez; however, these have been excavated in exactly the same areas where Karez use to provide water for centuries.

There is a feeling that Karez systems are being abandoned because it is not cost-effective to sustain these systems without conducting any study. Similar is the case with Sailaba agriculture, which is not outdated compared to Karez and constitute around two-third of total water resource available in the province but a similar treatment has been given. I believe that it is the thinking of modernizing the irrigated agriculture without considering the sustainability. One should not forget that energy is a critical issue in Pakistan's economy and how long the federal and provincial governments would continue to provide huge subsidy to over 15206 electric-operated tubewells in Balochistan. The un-planned investments on tubewells in terms of subsidy also resulted in increasing the cost of production and now tubewell agriculture is not profitable for field crops.

<u>Advantages of a Karez over a well</u>

- Even though the cost of excavating a Karez proves to be higher than installing the deep tubewell including the pumping system. But if Karez systems are regularly dredged and repaired they have prolonged and unlimited life. Whereas, life span of a well/tubewell is about 10-15 years. The cost-effectivity of Karez seems much higher than tubewell.
- Water output of a Karez within a definite period of time is determined, large and much more reliable. Thus, Karez proves to be a safer source of water supply.
- Karez has no reliance on electric power, whereas oil products have to be imported requiring foreign exchange.
- Low expenditure of Karez in comparison to high maintenance charges of wells/tubewells and pumping system is a definite advantage.
- Karez systems do not impair the quality or quantity of groundwater. This is due to the fact that they are utilized gradually and assist in keeping the balance of groundwater in various layers of ground intact. In fact, even during periods of severe drought, Karez systems are not detrimental to groundwater reservoirs.
- Karez reflects collective and cooperative work, and in areas where Karez are constructed labour or work opportunities are provided to the local community. The skills

for maintaining Karez systems are part of the indigenous knowledge of the province and have heritage value.

- Karez has the ability to collect wastewater that penetrates into the soil and it is for this reason that the excavation of Karez in arid zones tends to save more water.
- Freshwater from the mountain plateau is transferred to the low lying plains. Thereby, soil salinity is kept under control which also helps in combating desertification.
- Watermills can be installed on the vertical wells of the Karez system, which can provide water for domestic and stockwater purposes.

5.3. Impacts of Tubewell Revolution

Based on the study conducted by IWMI (Molle, *F., T. Shah, and R. Barker. The Groundswell of Pumps: Multilevel Impacts of a Silent Revolution*)**,** several lessons can be drawn. The study revealed that tubewells in Balochistan helped to tap deep or shallow aquifers to expand irrigated agriculture. These developments are in most cases the result of unchecked individual initiatives and are very hard to control. Aquifer mining, declining water table and water quality and rising pumping costs are the most common threats. Management problems are those related to open-access resources and/or associated with lack of regulation and enforcement capacity. Poor farmers also cannot generally afford costs. The impacts as outlined by the Study and relevant to Balochistan are summarized as under:

Hydrological impacts: Pumps in large numbers may alter the hydrological regime. They may not only deplete aquifers but by doing so also dry springs and Karez, and reduce the baseflow to rivers. These modifications of flow regimes also impact the quality of water and, through irrigation, the evolution of soil salinity. Overall, the actual degree of overdraft of groundwater in Balochistan is a very critical question with implications on the sustainability of irrigated agriculture.

Social impacts: In a majority of cases, pumps tend to be owned individually. They may be used for the owner's benefit and also to sell water to other users. Since they require access to capital, they also tend to exclude poorer users. The hydrological disruptions also impact on pre-existing uses. Whenever collective dependency upon vital water resources defines a tight-knitted relationship between the social structure and arrangements around water management, the disruption of supply, as for example caused by the expansion of area served by private pumps, necessarily has social implications.

Management impacts: Because pumps easily multiply in large numbers and they are not easily taken into consideration in basin-level water management. By altering the balance and the flows between surface and groundwater, they make IWRM more complex. On the one hand, pumps are managed locally and by users, obviating the need for large-scale infrastructure and bureaucracies, and they pose challenges both at the scheme level (when they complement surface irrigation water supply) and at the basin level. Their control, when becoming necessary, calls for the provision of laws and regulations. These, however, are typically marred with enforcement problems.

Economic aspects: The first economic impact of pumps is that their action on the hydrological cycle is often tantamount to a redistribution or spatial re-appropriation of water. Third-party impacts are very common, especially in closed basins, although they are often made "invisible" by the complexity of surface or groundwater interactions. A second economic impact is that pumps often tap a resource that could otherwise be diverted by gravity somewhere further downstream, thus adding energy costs to the reallocation. Last, because their main attractiveness resides in the flexibility and security of the supply of water they allow, there is a tendency towards overcapacity.

This brief review of the "pump revolution" in diverse contexts has shown the variety and complexity of the implications of the spread of pumping devices. It claims that this revolution has often been "silent" and that its importance and significance are generally overlooked. Pumps are the main instrument of tapping groundwater: as such, they are central to the most crucial aspects of the closing of river basins and to the much-heralded need for IWRM.

5.4. Dams as an Alternative to Karez

In Balochistan, the government is responsible for the construction of dams, whereas wells/tubewells have been mostly constructed by the farmers. If dams were considered as complementary to the Karez system for the purpose of improving agricultural development (with parallel investments in both areas) we would have had a better surface cover in the province and extensive agriculture as well as reduced drought and flood events.

Although the numbers of dams in Balochistan till the year 1990 was somewhat limited, ever since dam construction has become a dominant priority of the government policy to fulfill demand for recharge and water supply. In the year 2007 the amount of water that has been secured from dams in the province has been reported as 0.20 billion m^3. Most of the water stored in the dams has been used for agriculture and domestic purposes. A Case Study of Iran comparing dams and Karez systems is given in **Box. III**.

Box. III. A Comparative Case Study on Dams and Karez Systems in Iran

In the province of Khorassan, which is the largest province of Iran and has common borders with Afghanistan, there was a network of 7388 Karez systems with annual abstraction of 2.5 billion m^3 *in 1990.*

In the same year a few large dams were taken advantage of namely "Torogh" and "Kardeh". The Kardeh Dam has an elevation of 67 m from its foundation and has been engineered to provide 31 million m^3 *of water per annum, according to which the amount of water to be secured is 1* m^3*/sec. If the water output of Karez of Khorassan was to be compared to the water output of the dam, it can be noticed that in the year 1990 Karez systems of the province secured 78 times more water than the Kardeh Dam.*

Three years later, according to official statistics issued by authorities, the water output of the same Karez showed a reduction. The decline revealed that water output was equivalent to 15 times less the amount of water stored in the Kardeh Dam. So in the same year, if X-million $ was spent as investment for the construction of the dam, instead 15X million $ was lost in financing such a project.

6. Are the Present Policies Sustainable in Long-term?

Currently, in Balochistan, the IWRM Policy although emphasize the need for IWRM covering all sub-sectors of water use and all sources of water including Karez systems, but still the emphasis of water development and management is for canal and tubewell irrigated areas and minor perennial irrigation schemes (MPIS). The MPIS include Karez and spring irrigation systems but the major emphasis is on surface waters. There is hardly any support available for either development of new Karez systems or improvising the existing Karez systems. The emphasis is only on rehabilitation due to deferred maintenance. The communities managing the Karez systems have adapted to present conditions despite being weakened to a great extent. However, there are some strength of the Karez systems especially in areas like Qilla Abdulla, Panjgur, Turbat and Qilla Saifulla having major concentration of the Karez systems; the communities are still managing the systems because of strong social action by all stakeholders.

The ADB TA Grant Project is now executing a study on "Basin Management Plans" for the Pishin-Lora, Zoab and Nari basins, where planning will be done considering all sources of water (surface and groundwater). The groundwater includes wells, tubewells and Karez systems. In addition, there is a need to balance the policy of according higher priority for tubewells and dams, which is affecting the Karez systems rather replacing these with deep wells. The tubewells that are hardly 40 years old overrule and overlook the role of Karez systems that were sustainable for millenniums in harvesting groundwater even under severe droughts and all other threats.

Considering the recent drought of 1998-06, which ended up with flood in the province, the impacts on various methods of water use are:

Water from Indus River System: The Indus river flows during 2001-02 were lowest in the history since 1937 (112.5 billion m^3), which were even less than the average canal diversions (130 billion m^3). The canal diversions during 2001-02 were 30% less than the average diversions (90.3 billions m^3). This reduction in canal diversions also adversely affected the Pat Feeder and Khirther canals in Balochistan even more severe because both the canals are in the tail end of the system.

Floodwater: The probability of exceedance computed under the ADB Package Assignment of the TA Grant Project indicated that 25.2, 10.8 and 3.3 billion m^3 of water were available under 25, 50 and 75% probability of exceedance. This shows that during drought the floodwater may reduce to ⅓ to ¼ from that of an average year. Most of the river basins of Balochistan are having only seasonal flows. This is the reason why in persistent droughts, rivers and surface irrigation streams dry up rather quickly.

Wells/Tubewells: In the recent drought (1998-06), the shallow dugwells were worst affected, as the transmissibility of shallow aquifer is much less and lowering of water table had direct impact on drying of shallow dugwells. The deep tubewells were relatively less affected as with the lowering of water table farmers started deepening their wells. Therefore, the deep tubewell farmers adapt to the situation by lowering the tubewells having additional cost and more devastating impacts on the sustainability of groundwater during the drought. It had extremely adverse impacts on Karez irrigation systems. The drought did not have that detrimental impact on the Karez system rather than deepening the tubewells.

Minor Perennial Irrigation Schemes: As per definition of the IPD, the minor perennial irrigation schemes include surface perennial waters, springs and Karez systems. Both the surface perennial and springs were adversely affected by drought, where initially these schemes observed reduction in water supply and then some of these dried up. Karez systems were less affected by drought per say rather impacts were largely due to lowering of deep tubewells which are installed in the catchment and command of the Karez systems.

Karez Systems: For understanding the sustainability of Karez system it is essential to view it in a much longer perspective. The Karez systems were sustainable for millenniums and fulfilling the needs of human, livestock and nature. The life of tubewells in Balochistan is less than half a century. In the last 40 years, the deep tubewells have contributed in lowering of water table from less than 30 m to over 150 m in major part of the province. Further signs of negative impacts of mining of groundwater are now visible. Therefore, the role of Karez system can be understood only in longer term basis. Period of 40 years is nothing in the life of nations. Signs are clear that deep tubewells are going to evacuate aquifers quite rapidly. So if the life span of a tubewell does not come to an end in case of a drought, they shall dry up very quickly. Thus, wells/tubewells are generally useful for short-term usage and alter their surrounding environment very swiftly.

Storage and Delay-action Dams: The dams, although are more resistant to droughts, but certain conditions are necessary for their long-term sustainability: a) location; b) technical engineering details and know-how; and c) regular maintenance. This is essential in Balochistan, because of the arid environments and lack of vegetative cover which results into serious problems of watershed degradation. The primary 'generation' of small dams that have been constructed in the province or in the country during 1960-90 have lost major part of their live storage capacity. Even dams that have been designed and constructed using adequate engineering feasibilities have been suffered adversely by drought.

It is under these severe climatic changes and environmental degradation, the value of Karez systems can be assessed. In periods of drought, Karez are more resilient and do not dry up rapidly, as they have the capability of abstracting the aquifers slowly. In addition, Karez systems are constructed in harmony with human settlement patterns and water requirements for domestic and agriculture uses. In a drought situation, when the need for water is critical and every drop of groundwater needs to be accounted for, water from Karez is returned to the aquifer, in addition, the evaporation losses are minimal in comparison to the dams where extremely large quantities of water evaporate especially in shallow depths. Therefore, Karez systems prove stable in times of drought especially for securing water supply.

Lastly, the most vital point related to Karez is to recognize and understand that Karez systems are closely linked to the local communities and their abilities in planning and management of their own water resources. The management system is such that the water is distributed more equitably. As a result, water security and equity in water access and distribution are supporting the foundations of the local community and agriculture at large.

In brief, Karez system is not only an engineering and hydrological wonder, but also a social phenomenon that survived in the last millenniums despite climatic change, socio-economic development and environmental conditions, even though it has kept a low profile.

7. Issues and Challenges

The issues and challenges of Karez systems are:

- Karez systems provide ecosystem goods and services (water, staple food, fruits and vegetables); and promote social cohesion through participation of water users and cultural rituals. The system has survived in millenniums until recently in the last 40 years indiscriminate development of deep tubewells and subsidy on electric tariff resulted in assigning low priority to these stable systems in Balochistan. In the process of modernizing harvesting of groundwater the traditional systems were neglected.

- Karez irrigated farming is threatened by a number of factors: a) lowering of water table and mining of groundwater due to indiscriminate development of deep tubewells resulted initially in reduction of water supply and eventually drying the Karez; b) reduction in flow due to siltation of canals as a result of deferred maintenance; c) moving sand dunes affected the mother well and the vertical wells required for maintenance, d) migration of youth to nearby towns and decline of skilled technicians for managing the old systems and construction of new systems; e) lack of support from the public and private sectors in improving capacity of the skilled technicians through the use of appropriate technology.
- There is hardly any programme supported by the public-sector to improvise the traditional Karez systems, as there is hardly any research and development activity. In contrast, in Iran, where Karez systems are much more sustainable than Pakistan, the government of Iran has established "International Qanat Research Centre in Yazd" in collaboration with UNESCO.
- The current policy of investment in water sector development still emphasize for the development of tubewells, minor perennial irrigation schemes and canal development like the Kachhi canal. Hardly any study has been undertaken considering technical, institutional and economic dimensions of Karez systems and farming in arid zones of Balochistan.
- **Karez system is a relic form of harvesting groundwater for irrigated farming in the arid-zones and has been introduced in many other parts of the world. Most of the countries have given importance to sustaining the Karez systems but in Balochistan, these systems are facing relatively more abandonment due to lack of right focus in maintaining balance between expansion of tubewells and sustaining the Karez systems. The experiences from other parts of the world are hardly brought back to Balochistan.**

8. Way Forward

A Karez system has a profound influence on the lives of the water users. It allows those living in arid zones adjacent to a mountain watershed to create a large oasis in an otherwise stark environment. The UN and other organizations are encouraging the revitalization of traditional water harvesting and supply technologies in arid areas because experts are now of the opinion that Karez system is vital for sustainable water use in fragile environments. The options appropriate for Balochistan are:

- As some of the countries like Iran has declared the Karez system as ***'National Heritage'*** and started giving higher priority for sustaining this system of harvesting groundwater on longer term basis. Similarly, the governments of Pakistan and Balochistan may declare Karez system as ***'National Heritage'*** and initiate mass awareness campaigns and develop curriculum for schools and universities. ***A special corner in the National and Provincial Museums for "Water" may also include some of the information on Karez systems.***
- The UNESCO and United Nations University, Tokyo Japan are promoting studies on Karez systems through International Hydrological Programme that cover member states and the Traditional Technology in Dryland Programme that supports systematic studies. Similarly, Iran has established the International Qanat Research Centre at Yazd. ***Therefore, governments of Pakistan and Balochistan may initiate a modest Programme for initiating R&D for the Karez systems in Balochistan. The focus should be to conduct research in real-life situation initially to understand these systems and issues and constraints and then build technologies and processes for improving these systems.***
- ***Initiate a similar R&D programme for improving Karez irrigated farming with an objective to improve water productivity by introducing water efficient high value crops, fruits and vegetables.***
- ***Develop and enforce a programme of organizing the Karez communities and skilled technicians in the rural areas leading towards capacity building. Initially a Polytechnic Trade Institute may be established with satellites in the districts having major concentration of Karez systems (Panjgur, Turbat, Qilla Abdulla, Qilla Saifulla and Zoab).*** The purpose of this polytechnic should be to upgrade the skills of technicians in the

use of relatively modern tools for: a) assessment of water resources; b) siting the mother well; c) aligning the underground galleries, d) lining the sensitive reaches of underground galleries using pre-cast concrete or plastic tiles; e) digging of vertical wells and covering these to minimize the maintenance; f) operation and maintenance of Karez system.

- ***Creating awareness for the civil society at large in conveying the message that Karez systems are more sustainable and electric power based deep tubewells are going to be a disaster both in terms of groundwater and energy use in the province.*** Furthermore, the Karez system is going to support the challenge of poverty reduction as poor and rich are treated in more or less a similar manner.
- ***Initiate a study to collect all the written material available on Karez systems of Balochistan, as there is hardly any useful information available on the internet about Karez Systems of Balochistan.*** Efforts may also be made to translate the literature into English.
- ***Prepare the new generation to be able to understand that Karez systems are more sustainable as they were sustained for millenniums in the past and going to be much more sustainable in future compared to deep tubewells which in less than half a century started giving signs of non-sustainability. The new generation must understand, use, conserve and further build the Karez systems in Balochistan***. This would require including the curriculum of water in schools and universities. ***The school children may be exposed to the Karez and Sailaba systems in their relatively early age so they are not overwhelmed from the modern technology without considering the environmental consequences.***

The Policy Briefings is a Series of Issues, which will be prepared and circulated to the policy and decision makers in the province of Balochistan and in other provinces of the Country with an objective to synthesize and disseminate the studies outputs under the TA-4560 (PAK).

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The Policy Briefings are also based on the research work done by other national and international institutions with an objective to get benefit of the work done elsewhere. The comments and suggestions can be sent at the following address:

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The topic to be addressed in the next Issue of Policy Briefings is "Restructuring and Strengthening of Water Resources Planning, Development and Monitoring Directorate of Irrigation and Power Department, Balochistan". The topic includes: a) Introduction; b) Inadequacies of Existing Institution and Planning Activity; c) The Erstwhile Policy Vacuum; d) Essential Elements of Balochistan's IWRM Policy; e) Issues; f) Future Development of Water; g) Future Restructuring; and h) Strategy and Action Plan for Restructuring of WRPDM-IPD.