Pakistani Water: 4,500 Years of Manipulation

Septic tanks, bathrooms and fountains have been around for a long, long time

Vernon L. Scarborough

The country of Pakistan is a land of contrast, where Eastern contemplation graphically abuts Western pragmatism. The landscape, no less than the cultures themselves, is characterized by marked extremes. To the north, sharing a common border with Afghanistan, China and India, Pakistan contains the highest collection of mountain peaks in the world. To the south, along the great floodplain of the Indus River and near the turquoise waters of the Arabian Sea, Pakistan harbors some of the highest temperatures recorded for the planet.

Many of the great civilizations of the Old World affected and were affected by this major crossroads region. How native and foreign groups through time dealt with the environmental challenges this region poses is significantly linked to that most precious of human resources - water. Pakistan has nearly always been a blend of Western hydraulic technology within an Eastern aesthetic, producing water systems in harmony with the diversity of physical settings. In addition to the technical ingenuity apparent in these hydraulic works, the historical developments and cultural achievements that parallel the technology provide a necessary backdrop.

Some of the earliest experiments in high civilization found anywhere in the world were carried out along the slow-moving meanders of the Indus River. The Harappan Civilization, 2500-1700 B.C., depended on the Indus for its many resources. From two of the best understood ancient cities of the period, Harappa (southwest of Lahore) and Mohenjo-daro (near present-day Sukker), rise monumental citadels covering more than 19 acres and climbing to a height of 40 feet above an otherwise featureless floodplain. Elevated probably to prevent floodwaters from inundating the many structures on their summits, as well as for defensive measures, these silent sentinels suggest a glorious past.

Pakistan has drawn on its rich traditions to cope with a seemingly simple, actually complicated and most necessary resource.

Ordered by a gridiron of main streets and resting to the east of either citadel are the ancient remains of the residential quarter. At Mohenjo-daro, this area housed the bulk of a population estimated at over 40,000 by Walter Fairservis of the American Museum of Natural History. To support such populations, large granaries must have been located within the walls of the citadels. These surpluses were not simply a food source necessary to assure survival during lean periods, they were a clear statement by those in power the control they and their deities had over their constituency.

Despite the scale and complexity of Harappan society, there is little evidence for an intensive irrigation system. Agriculture was probably based on the annual floodwater cycle, with wheat and barley planted on the rich, newly deposited alluvium carried by Indus torrents from the steep slopes farther north. Today, some floodwater farmers still plant cotton and *sessamum* (sesame) at the onset of autumn's rising waters and harvest their investment near the time they sow their wheat and barley. The latter crops are harvested by April or May in part to avoid the stifling heat and humidity of the Indus floodplain.

Given the size and sophistication of a city such as Mohenjo-daro, it is tempting to conclude that much of its bureaucracy was developed to sustain a massive and well-maintained irrigation system. One look at present day Pakistan with more than 37,000 miles of canal length and the all-embracing power given the landed gentry, makes such an argument attractive. Still, there is little hard evidence to support the existence of an ancient, massive canal system. Except for the covered and brick-lined drainage channels through Mohenjo-daro, there is no trace of extensive canal-building. It is likely that the

V. Scarborough

The Great Bath at Mohenjo-daro

Indus' seasonal flooding would have played havoc with primitive irrigation schemes. The flood cycle of the Indus, like the Nile of Lower Egypt, brought water and nutrients in sufficient abundance to provide even large human populations with adequate agricultural yields.

The blessings of the seasonally turgid Indus with its nutrient-rich sediment load were also its bane. At Mohenjo-daro the water table has risen 30 feet since people first began living there some 4,500 years ago. Part of this rise is a result of recent irrigation schemes that have saturated the water table. This is clearly noticeable in the damage inflicted at the site by salty irrigation waters. Further, George Dales of the University of California at Berkeley has shown that the ancient fluvial deposits descend nearly 40 feet. The evidence within these deposits for human occupation suggests periodic attempts to elevate the city. Moreover, Sir Mortimer Wheeler, the don of Pakistani archeology, indicates that a mud-brick embankment or bund over 40 feet thick was placed outside the citadel in an early period of its history. Presumably constructed to hold back the force of the floodwaters and their ever-encroaching sediment load, it is now entirely buried and featureless on the vast plain.

Although the Harappans were unable to control the periodic fury of the Indus, they did incorporate hydraulic principles. The heavy architectural investment made in the administrative core of these cities, an investment far in excess of the community's needs, included water management techniques. Resting near the summit of the citadel at Mohenjo-daro is the Great Bath. Built of fired brick, as were most structures at the site, the feature was 40 feet by 23 feet and approximately 26 feet deep. It was entered by a set of inset stairs placed at either end and drained by a high corbel-vaulted passage debouching near the margins of the citadel. The floor of the Bath was defined by finely joined brick placed on edge with a layer of bitumen sealant sandwiched between an inner and outer course. Water was taken from nearby wells with bathrooms affording a degree of privacy. This feature and its location in the center of administrative and ceremonial activity illustrates the age-old importance of ritualized cleansing for peoples of the South Asian sub-continent.

Away from the citadel and within the urban core were the great houses surrounding courtyards, as well as the single-room, tenement residences. Much of the city was designed to channel torrential downpours into a network of lined drainage channels. Many elite dwellings contained private bathrooms with well water nearby. Latrines much like those of today were drained by earthenware pipes which in turn issued into soak pits or small ancient septic tanks excavated under the busy streets. Sometimes these pits consisted of little more than a buried and pierced ceramic jar. Such primitive engineering skills, however, helped alleviate one of the first great urban dilemmas - pollution.

The demise of the great Indus Valley civilization is still not well understood, but its presence did establish a foundation for cultures that came after. The movement of Indo-Aryan influences into Pakistan occurs shortly after this demise, in about 1700 B.C. Our earliest historic sources suggest the establishment of the city of Pushkalavati, the Lotus City, not far from present-day Peshawar and the Kabul River, the latter a part of the greater Indus drainage. Also, the great Hindu epic, the *Ramayama*, names both Taxila and Pushkalavati, the former resting near modern-day Islamabad. Both areas had permanent settlements from at least the beginning of the first millennium B.C.

Resting near the parched limestone of the Margala Hills, the Bhir Mound complex at Taxila was the focus of considerable excavation during the 1930s and 40s. Here, associated first with the Achaemenid dynasty of the far-flung Persian empire which ruled from the sixth to the fifth century B.C., urban life flourished. In contrast to the planning so evident in Harappan cities, the layout of Bhir Mound was haphazard and irregular. The water supply for the community was apparently outside the city and was drawn from the natural course of a nearby stream. Again, unlike Mohenjo-daro more than a millennium earlier, no special planning was involved in obtaining a readily accessible water supply. No wells have been found inside the city.

Street drainage was a more pressing concern, given the monsoon-like downpours that occasionally affected this region. However, any systematic scheme for drainage control is poorly documented in the archaeological remains. Surface drains in houses did exist, were constructed of limestone and issued into the street. Later in the history of the site, by the third century B.C., slate slabs were used in lining these gutters. Earthenware drainage pipes were sometimes incorporated and have even been found with spigot and faucet joints. Sewage was clearly separated from the other

Pakistan: ancient and modern places

effluent and discharged into soakpits not unlike those at Mohenjodaro.

Following the arrival of Alexander the Great to Taxila in 327 B.C., the subsequent appearance of Buddhism throughout the region, and the conquest of Taxila by the later Bactrian Greeks, the focus of urban activity shifted from Bhir Mound to neighboring Sirkap. Given the planning characterized in the architecture and street orientations of this city, it is curious that, apparently, little attention was given to water management. Additional survey and excavation is sure to reveal a better understanding of Taxila's environmental challenges, including the ancient exploitation of the water resource.

The subsequent appearance of Gandaran Buddhism and its influence on Pakistani art and architecture is second only to the spectacular achievements of the following Mughal period. Buddhism in Pakistan has a long and celebrated history, although sometimes a turbulent one. Various warrior kings maintained Buddhism as a state religion into the fifth century A.D. Stimulated in part by western merchants interested in oriental goods who followed the Silk Route into China via northern Pakistan, the region experienced a "golden age" under the tutelage of Kanishka, a Kushan ruler. The heartland of the religion for Pakistan was in Gandara or what is today roughly the North West Frontier Province. As early as the conversion to Buddhism of King Asoka, 272-231 B.C., of the Mauryan Empire, royal edicts engraved on boulders in northern Pakistan instructed the people to excavate wells and plant trees throughout this Delhi-based domain. The later Kushans were also shown to have invested heavily in irrigation canals, wells and reservoirs to increase agricultural production.

Monasteries and stupas lying in ruin dot the landscape of northern Pakistan, with most of the better-understood sanctuaries resting on craggy slopes in quiet isolated areas. One excavated and well-stabilized monastic retreat lies near Mardan. Takt-i-bahi exhibits the classic architectural plan of a Gandaran monastery. Resting 500 feet above the mustard fields and new winter wheat on the plain below, the setting resembles the semi-desert conditions of portions of the American Southwest. Even the carefully erected stone masonry walls remind one of the ancient Puebloan architects dating only a few hundred years later and precisely halfway around the world. (see also R.W. McColl's article in the Winter 1987 issue of *FOCUS*).

Water in these more elevated locations is difficult to obtain and may have been acquired by trekking down to wells and springs. Water was also collected from roof-tops and courtyards during the rainy season and conserved in tanks for use during dry periods. One such tank was defined in the monastery's main courtyard.

One of the principal seats of Gandaran Buddhism was in the Swat Valley of today's North West Frontier Province. This valley is renowned for its oranges and apples, though snow frosts the surrounding hills. The Hindu Kush mountains are the backdrop for this ancient Shangri-la. Water today as in the past comes from meltwater carried by the Swat River and its tributaries. Low earthen walls, or bunds, keep the spring flood in the fields. When sufficiently soaked, the fields are planted with a summer crop of rice. Winter wheat and clover are harvested in the spring. The latter are planted every other year or so to revitalize the nitrogen-deficient soils.

Little information is available concerning the extent of irrigation and agricultural terracing during the reign of Gandaran Buddhism. The idyllic accounts of some travellers, however, suggest that landscape modifications similar to today's terracing may have ben used to produce the lush valley. Still, there is another side to this apparent abundance. Today, according to ethnologist Charles Lindholm, the Swat Valley has one of the most dense populations for a rural agrarian society in Pakistan. With a density of nearly 1,943 people per square mile, natural resources have been stretched. The use of nearly every square foot of terraced mountain slope can be readily understood.

The terracing in the region today is primarily agricultural, though inhabi-

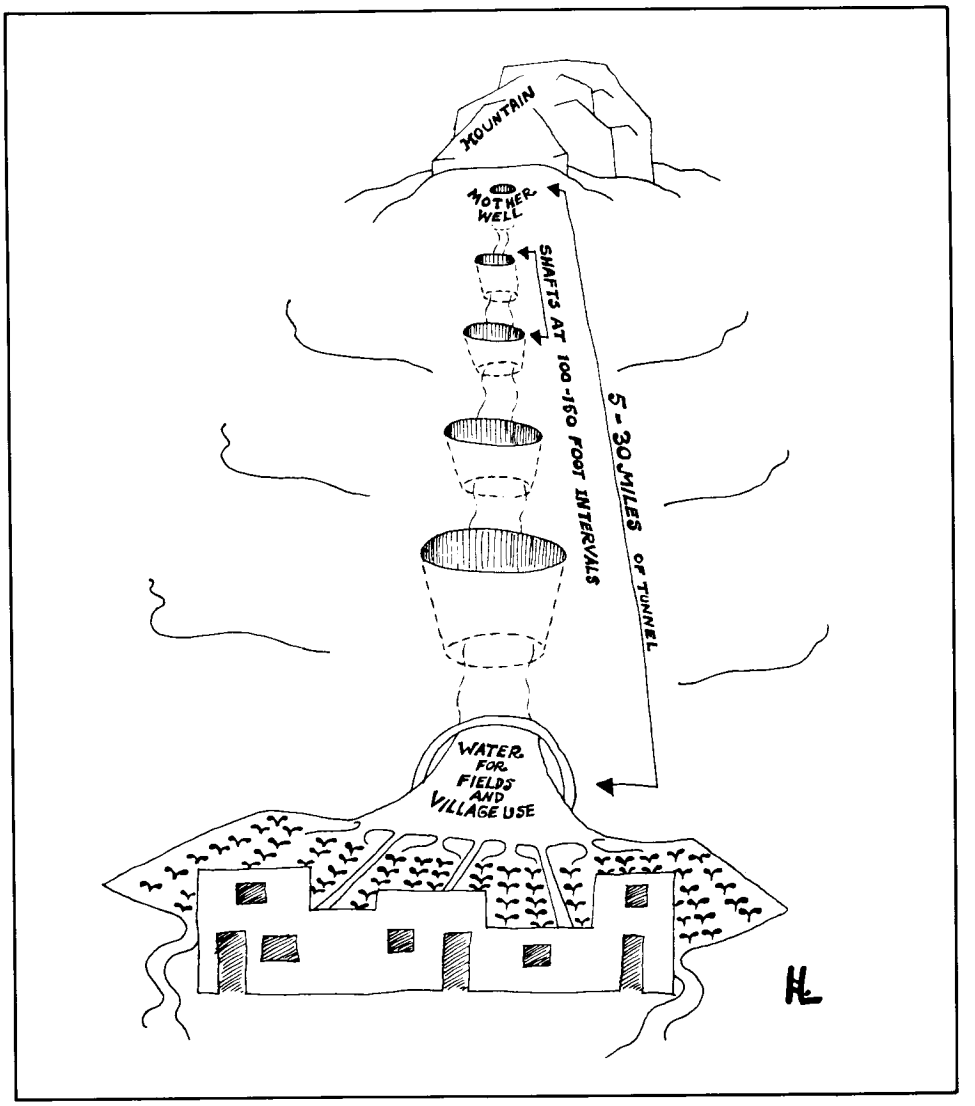
Four thousand years ago, latrines were drained by earthenware pipes which issued into soak pits or small septic tanks excavated beneath busy city streets.

tants have located their houses on residential terraces to shorten travel time to their fields. A stone wall or alignment is built parallel to the natural contours of the slope. Colluvium and alluvium collect behind the wall, eventually forming a level planting surface. Although canals irrigate many terraces, particularly those near the river's narrow floodplain, most fields at higher elevations are dependent on local rainfall and dry farming methods. At lower elevations water is diverted into impressive ditches lined with stone which run through villages and even under individual homes. In larger communities, water is quite contaminated for villagers living downslope and sharing the same canal course. When seen from above, a canal length appears as a braided network complementing the meanders of the Swat River.

Following the decline of Buddhism as a state religion, Islam forcibly introduced itself to the sub-continent by the eighth century A.D. Lahore

V. Scarborough

Takt-i-bahi monastery.



Karez system

together with Delhi evolved as eastern and western capitals of the Mughal Empire, though Hindu Rajas continued to hold local power. From 1526-1759 most of Pakistan was controlled by this mighty state. Today, Lahore is seen by most visitors as the seat of high culture for the country. This judgment is drawn from the spectacular monuments and objects of art produced during the Mughal reign, many of them focused on water.

Most renowned for his commissioning of the Taj Mahal, Emperor Shah Jehan was the architect king of the period. Although elaborate terracing and enclosed gardens were introduced two centuries earlier, the water-rich Shalamar Gardens of Lahore were constructed under the order of Shah Jehan in 1641. Three receding terraces embrace a rectangular area of 40 acres enclosed by a high wall. More than 400 symmetrically placed fountains grace the lavish setting which includes marbled pavilions and causeways connecting the tiered grounds. A canal was said to have brought water from a pure source more than 100 miles away.

Although irrigated farming in part supported the Empire, much of the hydraulic technology of the period was used to enhance the magnificence of the royal palace. The grace and tranquillity of these water settings was a symbol of heaven on earth and of the absolute power of the Empire in creating such an ambience. Royal palaces, usually within massively fortified redoubts, always contained gardens.

There were also royal baths, reflecting pools, and methods for cooling rooms constructed of white marble. Curtains of a sweet-smelling marsh grass called *khus-khus* were woven

V. Scarborough

Karez watered fields near Quetta

and draped across arched entranceways. Delicate earthenware pipes were hung above these doorways and were punctured with small holes, allowing drip water to moisten the braided mat. With a draft created by an open window inside the room a simple though elegant evaporative cooler was set in motion. The scent of the aerated plant fiber would further sweeten this opulent surrounding.

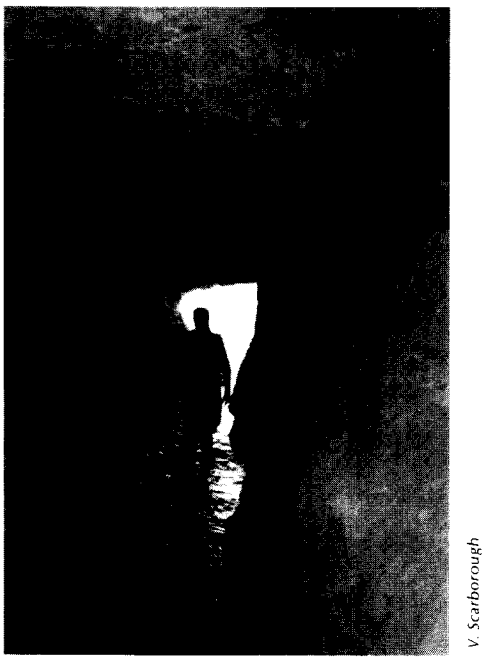
Much of Pakistan is generously watered, indeed an over-abundance of water is the usual condition. However, in the desert reaches of Baluchistan away from the Indus floodplain, near present-day Quetta, the rainfall averages less than 12 inches a year, the soils are poor, and the vegetation is scant. Here is found the *Karez*, one of the most unique and ancient water systems designed for utilitarian needs. Unlike many of the previously described systems (Swat excluded), hydraulic principles were not primarily designed to make life more comfortable for the privileged few.

The *karez* system was probably introduced to Pakistan by the Persians. The word itself is also Persian, though the Arabic word *qanat* is used in most Middle Eastern countries where the technique is still practiced. Although no archaeological evidence has been recovered to clearly demonstrate the advent of the *karez* system in Baluchistan, it is speculated that the technique was introduced to southeastern Afghanistan and western Baluchistan by the third century A.D. Baluchistan was integrated into the Persian Empire at an early date, although the region was somewhat peripheral to its dealings. The Bolan Pass immediately southeast of Quetta was a major conduit for later commercial exchange between the Indus Valley centers of Multan and Lahore and the Iranian Plateau.

A *karez* can be viewed as a horizontal well consisting of an underground tunnel channeling water from a deeply buried, water-bearing stratum of permeable rock to a low-lying oasis. These water-rich layers are usually found beneath soils at the rocky base of a mountain range. The amount of water in a *karez* system depends on precipitation and the size of the rainfall catchment recharging the aquifer. These hand-dug tunnels are punctuated by a series of vertical shafts situated at 100 to 165 foot intervals along the length of a *karez*. The depth of a shaft depends on the depth of the original or mother well, as well as on the elevation of the land surface above the tunnel, as it moves downslope toward village and fields. Although the deepest mother well, nearly 1,000 feet deep, is reportedly located in Iran at Gonabad near the Afghan border, most wells are about 65 to 330 feet deep. The gradient of the tunnel itself cannot be significantly altered, and for a short *karez* a maximum slope can be little more than one vertical yard down for every 1,640 yards laterally. If the gradient is too sharp, the *karez* may excite erosion which can damage or plug the flow of water. On the other hand, if the gradient is not steep enough, the water will intersect the downsloping surface of the landscape prematurely and issue too far away from the village and fields it is intended to service. Evaporation and seepage loss accelerate under these conditions.

Excavation is done with primitive digging tools by a class of craftsmen who specialize in this dangerous work. The only engineering equipment consists of a string-level which formerly involved a bead of water drawn to the middle of a taut line. Where pockets of sand or friable sediments are encountered, hoops or oval tiles are placed inside the tunnel as a lining to help prevent collapse. Generally, however, the passages are not reinforced and the *karez* requires periodic maintenance, a precarious task at best.

The *karez* system near Quetta was designed to support valley floor agriculture. In the early 1960s approximately two-thirds of the irrigated area was watered by the system. Today however tube-wells, which descend through a less conventional metal casing and use diesel engines to draw water from depths far greater than manual technology would otherwise permit, provide water for much of the irrigated land, though *karez*



V. Scarborough

Karez tunnel

V. Scarborough

Shalamar Gardens, Lahore

waters continue to maintain a considerable portion of the tenant farmer's yield. Crops grown by way of the *karez* system include wheat and barley, which are sown in the fall and harvested in the spring. Potatoes, peas, lentils, melons and sugar beets are planted in the spring and harvested in the autumn.

Although the water is for everyone, control over the *karez* has traditionally been held by powerful elite families and their feudal-like constituencies. Generally speaking, those families at higher elevations in the community are the most influential, because they have had the clout necessary to build homes where fresh potable water is assured. Further downslope the water becomes more polluted by household use and reuse before issuing into irrigation canals. To avoid water disputes between groups, Islamic law prevents the capture or even the encroachment of a *karez* water supply. *The Book of Qanats* was issued in the eleventh century and sets down standards to curb conflict. Still, disagreements occur and a local *jurga* or council of elders may be drawn upon for solving disputed water rights.

When visitors first arrive in Pakistan today, particularly to any small town or village within the broad reaches of the Indus, they are most struck by the extensiveness of the canals and ditches associated with agricultural production. Although people in Pakistan have been skillfully manipulating water for over four thousand years, today's irrigated landscape is surprisingly new-looking. Initiated under the British Raj by 1860, the Indus Irrigation Project now represents the largest irrigation system in the world, covering more than 24.7 million acres.

As impressive as the scheme has become, it is not without problems. With a population density of over 1,760 people per square mile (compared to 414 people per square mile in the U.S.A.), Pakistan has developed a worrisome dependency on the project. Serious problems resulting from siltation and salinization are threatening productivity. The water table has been rising at a rate of one foot per year in most areas along the Indus, resulting in waterlogged soils. These soils in turn prevent the necessary flushing of minerals and salts which ultimately burn and damage crops. Although the siltation of the canal system has contributed to the rising water table, it has also altered the gradient in making gravity-dependent water flow difficult even after major dredging operations.

In some areas, tube-wells have been installed to help drain away an elevated water table. This has had significant results, though the verdict is not yet in. Government-built tube-wells are excavated to a depth of as much as 230 feet and can discharge at a rate of 32 gallons a second. Nevertheless, the water must be consumed or discharged some distance from the field or affected canal area to prevent the reentry of seepage into the water table. This poses its own set of gradient problems.

Yet another consideration is the construction of dams across the many tributaries of the Upper Indus. In a resource-poor country, the harnessing of hydroelectric power within huge human-made reservoirs is an attractive alternative to imported oil. Unfortunately, the resulting seepage of water into adjacent soils raises groundwater levels to further jeopardize the farmer's chances.

Pakistan presents us with some of the world's most ancient, most modern and unique water harvesting techniques. Managing a number of very different environments, the country has drawn on its rich traditions to cope with a seemingly simple, actually complicated and most necessary resource. From the adroit Baluchi to Mughal elegance, the cultural manipulation of water has helped shape contemporary Pakistan. Mughal lords used hydraulic works as a symbol of authority and power, while the petty fiefdoms of North West Frontier Province and Baluchistan still use water today as a *physical* sign of who lives well and who does not. The interlacing of water and history travel the same braided course.

In many densely occupied zones of present day Pakistan, too much water is the dilemma. Throughout these varied environments and varied responses to water management, Pakistan has maintained a certain flexibility. European hydraulic engineers attempting to renovate or revitalize over-worked canal segments may view Pakistan as a frustrating and backward experience. However, the strength of the nation is in its heritage of resilience. Pakistan will do well to harness the water schemes of the past in applying the new technology of the present.

Further Reading

Allchin, Raymond and Bridget Allchin, 1982. *The Rise of Civilization in India and Pakistan.* Cambridge: Cambridge University Press.

Ambroggi, Robert P., 1977. "Underground Reservoirs to Control the Water Cycle," *Scientific American* 236:5, pp 21-27.

Cressey, George B., 1958. "Qanats, Karez, and Foggaras," *Geographical Review* 48, pp. 27-44.

English, Paul W., 1966. *City and Village in Iran: Settlement and Economy in the Kirman Basin.* Madison: University of Wisconsin Press.

Johnson, B.L.C., 1979. *Pakistan.* London: Heinemann.

Marshall, Sir John, 1960. *A Guide to Taxila.* Cambridge: Cambridge University Press, 4th edition.

Sehrai, Fidaullah, date unknown. *A Guide to Takht-i-Bahi.* Peshawar: Khyber Printers.

Wheeler, Sir Mortimer, 1968. *The Indus Civilization.* Cambridge: Cambridge University Press, 3rd edition.