Sustainable Rainwater Harvesting Techniques prevailing in Ancient India.

Abstract - Watershed management in India has been defined as rational utilization of land and water, and water resources for optimum, and sustained production with minimum hazards to natural resources. It is essentially related to water conservation.

Rainwater is the only source of water, but its distribution is neither uniform nor assured in all parts. India receives about 400 million hectare metres (mhm) of rain per year over an area of 329 m ha. In India around 83% of available fresh water is used for agriculture. Rainfall being the primary source of fresh water, the concept behind conserving water is to harvest it when it falls and wherever it falls. The importance of storing rainwater through different techniques can be understood by an example of the desert city of Jaisalmer in Rajasthan which is water self-sufficient despite experiencing meager rainfall as against Cherrapunji, which is blessed with the highest rainfall in the world, but still faces water shortage due to lack of water conservation methods.

The history of India tells us that floods, droughts or both were a perennial occurrence. If the overflow of rivers and streams in spate could be redirected and stored, the water could be used during drought. Even rainfall as low as 100 mm, if harvested properly, can meet the drinking water needs of the people.

India’s rich tradition of water harvesting systems dates back to Vedic times and the traditional methods of water harvesting need to be reviewed and successfully implemented in an economically viable and ecologically sustainable manner to meet the water demand of the present and future as with the increasing demand for water arising due to urbanization, increase in population, agriculture, greater electricity consumption especially thermal power, infrastructure growth and a depleting forest cover, the situation ahead can only be described as alarming. An uncertain monsoon, lack of adequate irrigation facilities and over exploitation of surface/groundwater have only compounded the problem.

The main focus of the paper would be to review the traditional rainwater harvesting methods practiced in ancient India and to understand the excellent systems of water harvesting and drainage developed at Dholavira, during the Indus valley civilization and Fatehpur Sikri developed by Emperor Akbar in medieval India. In the forts developed by the various rulers– Example Jaigad, the desert city of Jaisalmer in Rajasthan which is water self-sufficient despite experiencing meager rainfall as against Cherrapunji, which is blessed with the highest rainfall in the world, but still faces water shortage due to lack of water conservation methods.

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Key Words - Watershed management, floods, droughts, traditional water harvesting systems, conserving water,
II. TRADITIONAL WATER HARVESTING METHODS

The knowledge of hydrology is deep rooted in the science of ancient India. Our ancestors applied the knowledge in water resource engineering. They designed and constructed dams and a variety of water structures much earlier than the consciously believed Greek, Roman or other ancient civilizations. Every region of our country had its own water harvesting techniques, reflecting the geographical peculiarities and cultural uniqueness of different communities.

**Paar system**: Paar is a common water harvesting practice in the western Rajasthan region. It is a common place where the rainwater flows from the agar (catchment) and in the process percolates into the sandy soil. In order to access the rajani pani (percolated water) kuis or beris are dug in the agar (storage area). Kuis or beris are normally 5 metres (m) to 12 m deep. These structures are constructed through traditional masonry technology. Normally six to ten of them are constructed in a paar. However depending on the size of the paar the numbers of kuis or beris are decided. This is the most predominant form of rainwater harvesting in the region.

**Talab** - Talabs are reservoirs. They may be natural, such as the ponds (pokhariyan), are found at Tikamgarh in the Bundelkhand region. They can be human-made, such as the lakes in Udaipur. A reservoir area of less than five bighas is called a talai; a medium sized lake is called a bandhi or talab; bigger lakes are called协商 or samand. The pokhariyan serve irrigation and drinking purposes. When the water in these reservoirs dries up just a few days after the monsoon, the pond beds are cultivated with rice.

**Saza Kuva** - An open well with multiple owners (saza = partner), saza kuva is the most important source of irrigation in the Aravalli hills in Mewar, eastern Rajasthan. The soil dug out to make the well pit is used to construct a huge circular foundation or an elevated platform sloping away from the well. The first is built to accommodate the rehat, a traditional water lifting device; the sloping platform is for the chada, in which buffaloes are used to lift water. Saza kuva construction is generally taken up by a group of farmers with adjacent landholdings.

**Johads** - are small earthen check dams that capture and conserve rainwater, these improve percolation and groundwater recharge. There are some 3000 johads spread across more than 650 villages in Alwar district, Rajasthan. This has resulted in a general rise of the groundwater level by almost 6 metres and a 33 percent increase in the forest cover in the area. Five rivers that used to go dry immediately following the monsoon have now become perennial.

**Bandha** are found in the Mewar region of the Thar Desert. It is a stone check dam, constructed across a stream or gully, to capture monsoon runoff on a stretch of land. Submerged in water, the land becomes fertile as silt deposits on it and the soil retains substantial amounts of water.

**Baoris** are community wells, found in Rajasthan, that are used mainly for drinking. Most of them are very old and were built by banjaras (mobile trading communities) for their drinking water needs. They can hold water for a long time because of almost negligible water evaporation.

**Jhalaras** - were human-made tanks, found in Rajasthan and Gujrat, essentially meant for community use and for religious rites. Often rectangular in design, jhalaras have steps on three or four sides. Jhalars are ground water bodies which are built to ensure easy & regular supply of water to the surrounding areas, the jhalaras are rectangular in shape with steps on three or even on all the four sides of the tank the steps are built on a series of levels. The jhalaras collect subterranean seepage of a talab or a lake located upstream.

**Tobas** - Tobas is the local name given to a ground depression with a natural catchment area. A hard plot of land with low porosity, consisting of a depression and a natural catchment area was selected for the construction of tobas.

**Tankas** - (small tank) underground tanks are found traditionally in most Bikaner houses. They are built in the main house or in the courtyard. They are circular holes made in the ground, lined with fine polished lime, in which rainwater is collected. Tankas were often beautifully decorated with tiles, which helps to keep the water cool. The water is used only for drinking. The tanka system is also to be found in the pilgrim town of Dwarka where it has been in existence for centuries. It continues to be used in residential areas, temples, dhamramshalas and hotels.

**Khadin** - A khadin, also called a dhora, is an ingenious construction designed to harvest surface runoff water for agriculture. Its main feature is a very long (100-300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands. Sluices and spillways allow excess water to drain off. The khadin system is based on the principle of harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production.

**Bavadi** - Traditional stepwells are called vav or vavadi in Gujarat, or baolis or bavadis in Rajasthan and northern India. Built usually for strategic and/or philanthropical reasons, they are secular structures from which everyone could draw water.
Stepwell locations often suggested the way in which they would be used. When a stepwell was located within or at the edge of a village, it was mainly used for utilitarian purposes and as a cool place for social gatherings. When stepwells were located outside the village, on trade routes, they were often frequented as resting places. Many important stepwells are located on the major military and trade routes from Patan in the north to the sea coast of Saurashtra. When stepwells were used exclusively for irrigation, a sluice was constructed at the rim to receive the lifted water and lead it to a trough or pond, from where it ran through a drainage system and was channelled into the fields. Stepwells usually consist of two parts: a vertical shaft from which water is drawn and the surrounding inclined subterranean passageways, chambers and steps which provide access to the well. The galleries and chambers surrounding these wells were often carved profusely with elaborate detail and became cool, quiet retreats during the hot summers.

The Chand Baori stepwell is one of the most overlooked landmarks in the country, consists of 3,500 narrow steps over 13 storeys making it one of the deepest and largest stepwells in India. It is one of the oldest and most attractive landmarks in Rajasthan and also the most visually spectacular step well in India.

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The Sun Temple complex of Modhera, situated on the bank of the river Pushpavati, is under the supervision of Archaeological Survey of India. Surya Kund of Modhera is a large rectangular stepped water tank known as a finest example of geometry. The Adalaj Stepwell is a unique Hindu water building situated in the village of Adalaj near Ahmedabad. The Adalaj stepwell attracts a large number of tourists and were also venues for colorful festivals and sacred rituals.

The Queen’s Stepwell is situated in the town of Patan in Gujarat, Raniji Ki Baori is one of the noted stepwell situated in Bundi town in Rajasthan. Rajon Ki Baoli is a famous stepwell in India, located in Mehrauli Archaeological Park with 100 historically significant monuments. Gandhak ki Baoli and Rajon Ki Baoli are two stepwells located in Mehrauli Delhi. The Pushkarni Tank Hampi is an example of Chalukya architecture, the one in Hampi.

All these wells, tanks, stepwells, were attempts to store, harvest water for them and for the coming generations.

Munda is a small embankment built across any kind of drainage channel. Designed on a smaller scale, individual farmers could build it for limited use.

Bondha is a four-sided tank excavated below a Kata from which it receives water by percolation. In Meghalaya, the traditional water harvesting system of tapping flowing streams and spring water for use in irrigation is popular in the state. Umber and Mawlyndep and many other villages of Revoi district of Meghalaya collect flowing stream water through bamboo pads for domestic use. In Jowai district, the flowing stream water are stored in small cement plastered pond through bamboo which is used by the whole community, and the overflowing water is used in the catchments areas for farming.

Zabo system is practiced in some parts of the state which combines water conservation and forestry. The river/stream water is brought down by long channels through the hill slopes. In Assam, however, there are large water bodies like Brahmaputra and several other tributaries flowing through the state. Rain water are stored itself in the natural lakes, ponds and in the low lying areas. In some parts of the state, the ancient kings constructed big ponds to preserve rain water. In some places, the garhis also built to channelise river water to the agricultural field.

A garh is like big nala, where both the sides have big and long embankment and the middle side is left open to flow water. In the paddy field, the whole area is divided into small pieces in square size, creating small embankment, called Dara, where rain water is stored for cultivation. This is also a rain water harvesting techniques practiced in the state from the ancient time. These traditional techniques of rain water harvesting can be used in some other dry land areas in the country. However, to preserve and to stop evaporation planting of more trees is necessary, which is termed as natural shed on the water shed projects. In tribal dominated Chota Nagpur belt of Jharkhand, the traditional system of conserving water is Aharor surfaced irrigation tanks. It has been adapted to the gently sloping plains with the help of run-off diversion channel called pyne.

An ahar basically involves an earth filled check dam across the natural drainage joining uplands or harvesting the run-off. In Garhwal region, the water mills continue to meet the water needs of the remote isolated villages.
Working for appropriate techniques the growing water need of a growing population can be met if excess run off rainwater is properly harnessed. To conserve rain water, the Chola kings built a net work of tanks in Tamil Nadu which can still be seen. Such tanks can be seen in Andhra Pradesh and Karnataka also. Most of these tanks were used for irrigation purposes. Percolation tanks and nala-bunds have been constructed in different parts of Maharashtra. All this shows that rain water harvesting has been practiced for centuries, but the concept was abandoned after we went in for the big dams. Appropriate or indigenous technology can become handy in collecting and storing rain water.

India is a land having various religions, cultural and social rituals where water itself had many applications. Development of reliable sources of water like, storage reservoirs, ponds, lakes, irrigation canals etc. came to be regarded as an essential part of good governance. Emperors and Kings not only built various water bodies but also encouraged the village communities and individuals to build these on their own. Wide-ranging laws were made to regulate their construction and maintenance and for conservation and preservation of water and its proper distribution and use. Our ancient religious texts and epics give a good insight into the water storage and conservation systems prevailing in those days.

In our villages there are countless stories from mythology, folklore and songs extolling the glory of our sacred rivers and lakes. By all accounts, there was no water problem in those days and every household could meet its minimum water requirements through these rudimentary local water collection and management measures.

In India, the first major human settlements started in the Indus Valley (3000-1500 B.C.) in the north and western India. Evidence of water systems is found in different writings of this period. There are archaeological evidence of irrigation and drinking water supply systems from a large number of wells with brick lining. Dholavira, an important site of Indus Valley had several reservoirs to collect rain water. Similar evidences have been found at Mohanjodaro and Harappa. In Lothal (Gujarat) and Inamgaon (Maharashtra) and other places in north and western India, small bunds were built by the local people to store rain water for irrigation and drinking.

Water-harvesting techniques at Dholavira - Dholavira is a small village in the Kutch district, situated in a corner of an island, Khadir in the Great Rann of Kutch. It is one of the five biggest Harappan sites in the sub continent; the excavations have revealed an elaborate water system which is an example of advanced hydraulic engineering, achieved by the Harappans of Dholavira. The site is divided into three parts: the citadel, the middle city and lower city and archaeologists have identified a sequence of seven stages of its development. A fortification wall is seen running around the entire city. Dholavira shows a wide use of dressed stone in construction.

**Water System:** The site gives ample evidence of rainwater harvesting network, a system of tanks and ponds that supply water and even a sewage system way advanced for its times. The city was built between the seasonal rivulets of Mansar and Manhar. The water from these streams was accumulated with the help of dams from which water was let into the reservoirs. The rain water thus collected was stored in yet another reservoir that was carved out in the western half of the city. Huge stone drains are seen which were used to direct storm water to the western and northern section of the lower town that had been separated with the help of bunds. The site has a total of sixteen reservoirs built on eastern, western and southern sides which were internally linked. Rock cut reservoirs were part of a rather complex water system that made use of rainwater and partly from ground water which reveals an enormous, elaborate system of water harvest. Rock cut reservoirs had distillation chambers to provide purified water as well as channels to divert overflowing water. The rock cut well found in the eastern reservoir was at the eastern gate inside which was another rock-cut well which had a provision for drawing water manually and a drain with distillation chambers to carry this water to a tank, and from there through a drain from the tank to a “hamam”.

![Fig – 4 Water Reservoir at Dholavira](image-url)
Fig – 5 Water Reservoir at Dhoulavira

Water harvesting and Management techniques at Fathpur Sikri –

Mostly all the Indian cities are developed in and around major source of water, such as a river, lake or pond, which would not only act as a source of potable water, but also provide a barrier for security. Even the development of the town sikri and later Fathpur was also on the same lines. The small settlement of Sikri also had water in abundance before it developed as Fathpur Sikri and so was also the reason why Emperor Akbar choose this site for his new capital city Fathpur Sikri. In the year 1571-72 AD Emperor Akbar constructed the city of Fatehpur, the major elements of the town were planned not around the existing lake, but on the broad top of the ridge and on the plain towards the south of the ridge.

The lake of Fatehpur Sikri remained the major source of water supply to the city. Though it is formed by a natural depression in the ground between the Sikri ridge on the south and certain spurs in the north-west near the village of Rasulpur, it was regulated by the construction of two barrages, viz., the Terah Mori and the Bawan Mori. The Terah Mori barrage, situated exactly to the north of the lake, on the Agra-Bharatpur road comprises thirteen arches which contained wooden sluices to release the excess water. To the north east of it is constructed where the more heavily built barrage now popularly known as the Bawan Mori, as the name suggests once comprised fifty two sluices. This earthen barrage forms the limit of the lake towards the old township of Nagar. The excess water released from these barrages flowed into a rivulet which then passed on towards the east, crossing the Agra-Sikri road near the town of Kirauli.

This rivulet provided water to the area situated to the east of Fatehpur Sikri. The lake was fed through two sources – 1) channels drawing water from the Utangan River, now known as Khari Nadi, and 2) rain water. These barrages and dams which regulated the natural lake were constructed by Akbar in AD 1579. Later the demand of the potable water was satisfied by constructing 14 step wells and 60 wells. These step wells were fairly evenly located all around the medieval settlement of Fatehpur Sikri.

Apart from the major tanks in the palace complex, around six rectangular tanks were constructed to store water. Of these, five are located in an area reserved for pleasure resorts and gardens. The sixth water tank is located in the residential area reserved for the nobility on the north eastern spurs of the ridge. This tank, which has recently been discovered, is situated between the nobles’ quarters and the rows of excavated shops of the Bazar-i buzurg-u Sangin (the large stone market). This is a very large water tank constructed to meet the needs of the houses of the nobles, the market, as well as the sarai located near the Agra Gate.

A square water tank is situated on top of the ridge on the extreme west, at a distance mid-way between the old Chishti quarters and the Chor Khirki. Constructed with rubble stone, each side of this tank is provided with steps. In the centre is a square platform which is connected with a cause-way on all the four sides. The major objective behind construction of these tanks was Water harvesting. The major source of water for these

Fig – 6 Water Tanks in Fathpur Sikri
tanks was rainwater which was harnessed into them through slopes and channels.

Fig – 7 Layout of Faethpur Sikri

Similar harvesting of rainwater appears to have been resorted in the Jami Masjid Complex. The water falling on the floor of the Mosque as well as the Tomb of Shaikh Salim Chisti is collected in an underground covered water-tank constructed by the walling up of the vaults forming the courtyard of this mosque. Water from the ceiling of the mosque is also directed to the octagonal baoli and tank (jhalra) situated to the west of the Buland Darwaza.

Fig – 8 Layout of Fathpur Sikri

The real feat of hydraulic engineering is however revealed in the elaborate system of lifting the water from the ground level to the top of the ridge where the palace complex, the nobles' quarters and houses of the main civic population were located. This imperial system of water supply is divided into two sections - the Northern Water Works, situated near the Hathipol and the Southern Water Works, near the Hakim's Baths. These water works were apparently designed to meet the entire
need for water in the palace complex as well as the town of Fatehpur Sikri.

The Northern Water Works appear to be more elaborate and technically sophisticated. At the first stage, the subterranean water was raised through the construction of an octagonal baoli below the Hathipol. This baoli is shaped in the form of an irregular octagon, a chamfered square, with each of the principal sides measuring 15.45 metres. The chamfered sides of the octagon have lengths of 4.60 m. In the middle of this structure is an octagonal well with each side 2.90 m in length. To the north and south of the well are placed two octagonal chambers, the raised vaulted ceilings of which are visible as octagonal platforms from above. A 0.23 m wide water channel carried the water from this baoli to an artificial well situated to its west. This water channel runs on top of a 12.15 m long and 2.55 m broad aqueduct. The artificial well which acted as the second stage for lifting water is a rectangular structure with two vaulted chambers flanking the circular well on two sides. The well itself is 10.6 m deep and 3.96 m in diameter. From here a water channel (0.23 m in width) took the water to a second storage well, which is again flanked by two vaulted chambers. Between the two storage wells, the water was carried to an approximate distance of 10.50 m. The water brought to this second storage tank was then lifted to a large rectangular tank situated towards the south. A water channel then emptied the water into another rectangular trough constructed at the level of the floor of the Hathipol. Until this stage the water was raised to an approximate height of 30 metres from the ground level. Another branch of the water channel took the water through the northern walls of the bureaucratic establishments constructed below the hauz-i shirin.

Fig -10 Rain water Harvesting at Fathpur Sikri

Apart from the baolis, wells and tanks, a number of piers of the aqueducts survive around the city of Fatehpur which gives us some idea of how water was carried from one area to another. For example a series of such piers survive in the area below hauz-i shirin, on the slopes of the northern ridge. These piers carried the aqueducts which connected the northern works with the large water tank situated near the nobles' houses, as mentioned earlier. This massive tank is 28.10 m wide and 67.40 m long. Probably the entire needs of the eastern area were met through the water stored in this tank. It is also important to note that the individual residential structures, at Fatehpur Sikri had their own water storage tanks. A number of wells still survive in the south-west region of Fatehpur Sikri.

Rain water Harvesting Technique at Jaigadh Fort near Amber in Jaipur, Rajasthan, India

Another rain water harvesting technique was developed by Raja Jai Singh -II in year 1726 in Jaigadh Fort, near Amber in Jaipur, which is considered as One of the largest examples of traditional rainwater harvesting technique in India. Jaigarh Fort is situated on the Aravalli range and overlooks the Amber Fort and the Maota Lake. The fort was built by Raja Jai Singh II in 1726 to protect the Amber Fort and its palace complex and was named after him.
The fort, similar in structural design to the Amber Fort, is also known as Victory Fort. It has a length of 3 kilometres (1.9 mi) along the north–south direction and a width of 1 kilometre (0.62 mi). The palace complex (Laxmi Vilas, Lalit Mandir, Vilas Mandir and Aram Mandir) located, an armoury and a museum. Jaigarh Fort and Amber Fort are connected by subterranean passages and considered as one complex.

The Aram Mandir and the garden within its courtyard, on the northern side of the fort complex, has a triple arched entrance "The Awani Darwaza" which was refurbished in recent times to get fine views of the Sagar Lake (an artificial lake); water from this lake used to be transported to the fort in pouches loaded on elephant backs and also by humans carrying water pots. The triple arch gateway with fortification walls above it is painted red and yellow. It is oriented in an east–west direction and faces west. The architectural features are of Indo-Persian style with cyclopean walls built with dressed stone and plastered with lime mortar. There are two temples within the fort precincts, one is the Ram Harihar temple of the 10th century and the other one is the Kal Bhairav temple of 12th century vintage. The water supply facilities in the fort was met by creating water harvesting structures in the vicinity in the Aravalli catchment and conveying water through a canal on the west side of the fort over a 4 kilometres (2.5 mi) distance (seen at site) to be stored in three underground tanks below the central courtyard. The largest tank had a capacity of 6 million gallons of water.

**CONCLUSION**

This in short, is the history of our glorious tradition of water harvesting by the village Communities and individuals, Royal Families, Emperors, Kings. More importantly this reflects the ingenuity and wisdom of our forefathers who made harvesting of water and its management an integral part of the native culture and community life. This meant that these practices were perceived by the Kings and the commons and were considered as a sacred duty and by the communities as part of good local self-governance and social responsibility. This Water-Wisdom at all levels of society ensured adequate availability of water for all, which in turn, formed the basis for all round development and prosperity.

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