

Groundwater development and utilization has been of great interest from ancient times in arid and semi arid regions of Asia where the activities of man were controlled by the occurrence of water. From the dawn of history until comparatively recent times the source of water of the springs and streams had constituted a puzzling problem and had been the subject of much speculation and controversy. Mohenjo-Daro was a major urban center of the Indus civilization during the early Bronze Age (around 2450 BC). Recently, Angelakis and Zheng (2015) found that the city was receiving water from at least 700 wells. The design of these wells was varying from circular to pipal leaf shaped (Khan, 2014). Figure 6.1 shows the wells constructed in about 2600 BC, discovered at Lothal, an important Harappan site.



Figure 6.1: Wells discovered at Lothal, 2600 BC
(Source: <https://rainwaterharvesting.files.wordpress.com>)

The ancient western science of groundwater, which generally assumed that the water discharged by the springs could not be derived from the rainfall, was based on their belief that: (i) the rainfall was inadequate in quantity and (ii) the earth was too impervious to permit penetration of the rainwater far below the surface. In contrast to above wild theories, the ancient Indian literature contains the very valuable and advanced scientific discourse on ground water.

In Rig Veda, Sam Veda and Yajur Veda we get concepts of hydrological cycle and water use through wells etc., which clearly imply the use of groundwater. In the area of groundwater renowned astronomer, astrologer and mathematician, Varahmihira (AD. 505-587), author of

Vrhat Samhita, which is esteemed for its learning of many important branches of knowledge, in the 54th chapter entitled ‘Dakargalam’, deals with ground water exploration and exploitation with various surface features, that are used as hydrologic indicators to locate sources of ground water, at depths varying from 2.29 m to as much as 171.45 m (Prasad, 1980). The hydrologic indicators, described in this ancient Sanskrit work, include various plant species, their morphologic and physiographic features, termite mounds, geophysical characteristics, soils and rocks. All these indicators are nothing but the conspicuous responses to biological and geological materials in a microenvironment, consequential to high relative humidity in a ground water ecosystem, developed in an arid or semi arid region. Variation in the height of water table with place, hot and cold springs, groundwater utilization by means of wells, well construction methods and equipment are fully described in the Dakargalam (Jain et al., 2007).

The treatise on Dakargalam (science of underground water) by Manu is referred to in the Vrhat Samhita. By the latest his time must be (400BC-200BC). Varahmihira alludes that मनुना विरचितं दकार्गलम which clearly indicates Manu’s contribution to this science. This also indicates that the science was cultivated in India several centuries before Christ and that it was developed by indigenous people altogether independently. Varahmihira has utilized to a greater extent another treatise on the science of underground water and water table, written by ‘Saraswat’. Rather the farmer (Manu) appears to give a preference to the latter over the Manava Dakargalam (Vrhat Samhita, 54.99).

सारस्वतेन मुनिना दकार्गलं यत् कृतं तलवलोक्य ।

आर्याभिः कृतमेतद्वृत्तैरपि मानवं वक्ष्ये ॥Vr.S.54.99 ॥

As far as underground water and water table is concerned as a science, a brief survey of chapter 54 of the Vrhat Samhita designated as ‘Dakargalam’ is furnished below. Apart from the wider term ‘Dakargala’, there are two other technical terms शिरा and शिराविज्ञान used in this chapter (Verse 54.1, 54.61-62) viz.

धर्म्यं यशंस्यं च वदाम्यतोहं दकार्गलं येन जलोपलब्धिः ।

पुंसां यथाग्देषु शिरास्तथैव क्षितावपि प्रोन्नतनिम्न संस्था ॥ Vr.S.54.1 ॥

मरुदेशे भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।

ग्रीव करभागामिव भूतलसंस्थाः शिरा यान्ति ॥ Vr.S.54.62 ॥

The term शिरा implies arteries of water or streams and the शिराविज्ञान exactly conveys the meaning of water table. Verse 54.1 above tells us that at some places water table is higher and at others it is lower, resembling the veins in the human body. From Verse 54.2 we learn that water table is a complex function of rainwater.

एकेन वर्णेन रसेन चाम्भश्च्युतं नभस्तो वसुधाविशेषात् ।

ननारसत्वं बहुवर्णतां एवं परीक्ष्यं क्षितितुल्यमेव ॥ Vr.S.54.2 ॥

It means, the water which falls from the sky originally has the same colour and same taste, but assumes different colour and taste after coming down on the surface of the earth and after percolation. Figure 6.2 shows infiltration and percolation process for an unconfined aquifer leading to different zones of groundwater.

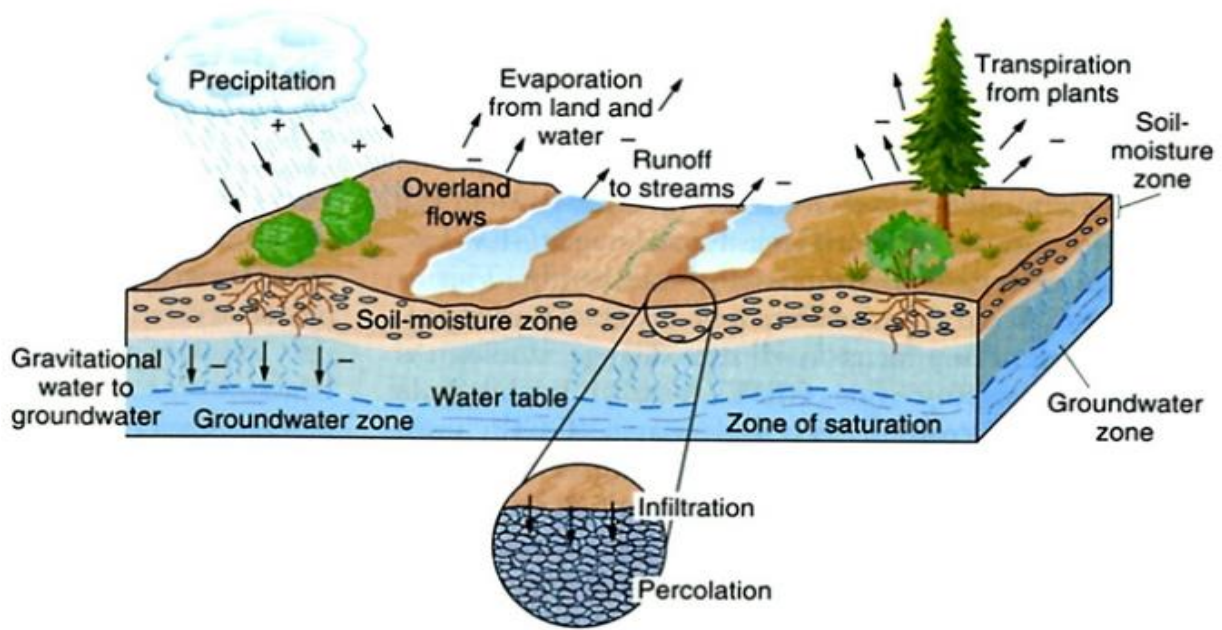


Figure 6.2: Unconfined aquifer showing different zones: uppermost soil moisture where precipitation infiltrates downward to the water table where all the open pore spaces are filled or saturated (Source: UNO, International programs)

In the later verses of Dakargalam, the modes of occurrence of sub-terrainian water and its depth at different places are given. Verse 54.3, 54.4 and 54.55 inform us that the sub-terrainian streams are rainfed in all the quarters and also apart from nine arteries, thousands more are present flowing to various directions as:

पुरुहूतानलयमनिऋतिवरुणपवनेन्दुशंकरा देवाः ।
विज्ञतव्याः क्रमशः प्राच्याघानां दिशां पतयः ॥ VR.S.54.3 ॥

दिक्पतिराज्जा च शिरा नवमी मध्ये महाशिशनाम्बी ।
एताभयोत्याः शतशो विनिः सूता नाममिः प्रथिताः ॥ Vr.S.54.4 ॥

पातालाटूर्ध्वाशिरा शुभा चतुर्दिक्षु संस्थितता याश्च ।
कोणदिगुत्था न शुभाः शिरानिमित्तान्यतो वक्ष्ये ॥ Vr.S.54.5 ॥

Rock or soil structure and depth of water table from the surface of the earth is described correctly in various verses. Verse 54.7 describes the various symptoms of occurrence of water along with pervious and impervious strata.

चिन्हमपि चार्धपुरुषे मण्डूकः पाण्डुरोश मृत पीता ।
पुटभेदकश्च तस्मन् पाषाणो भवति तोयमधः ॥ Vr.S.54.7 ॥

Meaning: on digging we will get yellow frog at a depth of half purusha (1 purusha = height of man with erected hand = 7.5 feet) then yellow soil, then rock and then ample amount of water.

Similarly, many other verses describe some 70 odd field situations or ecological spectra from which it would be possible to deduce the presence of underground springs. Actually the technique of underground water exploration as described by Varahmihira depends upon a close observation of naturally occurring specific signs in the terrain, comprising the flora, fauna, rocks, soils and minerals, whose state and variation can be logically or empirically linked up with the presence of underground springs in the vicinity.

One startling factor emphasized in details by Varahmihira is the role of termite knolls as indicator of underground water. Apart from the underground water exploration, some of the verses of the chapter deal with topics such as digging of wells, their alignment with reference to the prevailing winds, dealing with hard refractory stony strata, sharpening and tempering of stone-breaking chisels and their heat treatment, treating with herbs of water with objectionable taste, smell, protection of banks with timbering and stoning and planting with trees, and such other related matters.

Some thirty-three verses of the Varahsanhita deal with termite, standing alone by themselves or associated with vegetation, thirty with vegetational factors alone and the remaining using other factors to help in exploration.

जम्बूवृक्षस्य प्राग्वल्मीको यदि भवेत् समीपस्थः ।
तस्माददक्षिणपार्श्वे सलिलं पुरुषद्वेयं स्वादु ॥ Vr.S.54.9 ॥

उदगर्जुनस्य दृश्यो बल्मीको यदि ततोर्जुनाद्वस्तैः ।
त्रिभिरम्बु भवति पुरुषैस्त्रभिर्धसमन्वितैः पश्चात् ॥ Vr.S.54.12 ॥

Meaning: If there is a termite mound nearby to the east of a Jambu tree, plenty of sweet water, yielding for a longtime occurs at a depth of two purushas, at a distance of three hastas (cubit) to the south of the tree (54.9). Similarly, an Arjuna tree with a termite mound to the north shows water at a depth of 3.5 purushas at a distance of 3 hastas to the west.

The mound builder variety of the termites are responsible for the impressive soil structure called 'Ant-hills' in lay terms, but referred to as termite – knolls – mounds – spires, or – prominences by the scientists. These are familiar features of most tropical and subtropical landscape and are of interest to us in the technique of exploration of underground springs. Without exception, the water requirements of the insects are generally very high and they need to protect themselves against fatal desiccation by living and working within the climatically sealed environment of their nest or within earth-covered galleries. According to Rao et al. (1971) the atmosphere within the nest has to be maintained practically at saturation moisture level (99-100% relative humidity). It is a matter of common observation that whenever a termite nest or runway is damaged, the insects immediately rush to the breach and repair it with wet soil brought up from within the nest. From an overall consideration of the evidence it seems to be safe to conclude that, while normally the insects use every readily available near a source of water close to the ground surface, under conditions of severe climatic stress, they can and probably do descend to the water table, no matter how deep it may be. Hence, a well-developed, active, persistent colony of mould-building termites can be taken as an indication of underground springs in the proximity.

E.G.K. Rao (1979) observed the alignment of the termite knolls in the dry-jungle uplands of coastal Mysore as well as the Deccan Plateau area, and testified the verses of Vrhat Samhita

relating the same. Following verse of Vrhat Samhita suggests that the author was aware of this tendency of mould builders.

बल्मीकानां पक्कृत्यां यघेकोभयुच्छतः शिरा तदधः ॥ Vr.S.54.95 ॥

Meaning: If in a line of termite-moulds one is found to be raised up (taller), water vein is to be found within it.

Similarly, Verse 82 says that if a group of five termites are found in a place, and the middle one among them is found white, water should be declared in it at a depth of fifty five purushas (i.e. 7.5' X 55 = 412.5 feet).

It is a matter of common observation that many times territories are met with in close association with trees; and it is quite common sight to see termite mounds completely covered over with grass or vegetation. Very close observation is often necessary to detect the termitary. The ancient Indian scholar has exploited this association quite extensively in the exploration of underground springs as discussed below:

जम्बूस्त्रिवृता मौर्वी शिशुमारी सारिवा शिवा श्यामा ।
वीरुधयो वाराही ज्योतिष्मती गरुणवेगा च ॥ Vr.S.54.87 ॥

सूकरिकमाषपर्णीव्याघ्रपदाश्चेति यघहेर्निलये ।
वल्मीकादुत्तरतात्त्रीभिः करैस्त्रिपुरुषे तोयम ॥ Vr.S.54.88 ॥

Meaning: If Jambu, Trivrt, Maurva, Sisumari, Sariva, Siva, Syama, Varahi, Jyotismati, Garudavega, Sukarika, Masaparni, Vyaghra Pada trees and creepers are seen by a termite mound, there is water 3 hastas to its north at a depth of 3 purushas”.

The botanical names of the flora mentioned in the above verses are: Jambu (Eugenia Jambos, Engenia Jambolana), Trivrt (Ipomea turpethum), Maurvi (Sanservieraroxburgiana), Sisumari (?), Sariva (Hemidesmus indicus), Siva (Several Plants: Cucumis Utilissimus, Terminalia Chebula, Emblica officinalis, Cynodon dactylon), Syama (Ichnocarpus fructens – black creeper, Krsna Sariva, Datura metal, Agalala rox-burgiana, Panicum coloncum etc.), Sukarika (Lyccopodium imbricatum, I. Clovatum), Masaparni (Glycine debitis, G. Labialis).

Similarly, various other verses of the chapter 54 of Vraht Samhita are related to the underground water exploration with relation to combination of different symptoms, as below:

अतृणे सदृणा यस्मिन् सतृणे तृणवर्जिस्मिता महीयत्र ।
तस्मिन् शिरा प्रदिष्टा वक्तव्यं वा धनं वास्यिन ॥ Vr.S.54.52 ॥

Meaning: if in a grass less place, there is a patch of grass or in a grassy place, there is a grassless place, water or treasure is indicated.

कण्टक्यकण्टकानां व्यत्यासेम्भास्त्रिभिः करैः पश्चात् ।
खात्वा पुरुषत्रितयं त्रिभागयुक्तं धनं वा स्यात् ॥ Vr.S.54.53 ॥

Meaning: a flourishing thorny tree in the midst of non-thorny trees or vice-versa indicates water or treasure at a depth of 3 ¾ Purushas at a distance of 3 hastas to the west”.

यस्यामूष्मा धात्र्यां धूमो वा तत्र वारि नरयुगले ।
निर्देष्टव्या च शिरा महता तोयप्रवाहेण ॥ Vr.S.54.60 ॥

Meaning: where there is stream or smoke issuing from the ground, an abundant water vein will be struck at a depth of 2 Purushes. Varahamihira has also discussed the occurrence of underground water in the desert region. He further says that sub-terranean streams or water table in the desert region takes the shape of the neck of a camel and is at a great depth from the surface of the earth as:

मरुदेशे भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।
ग्रीवा करभाणाभिव भूतलसंस्थाः शिरा यान्ति ॥ Vr.S.54.62 ॥

Geological strata scheme of the modern artesian well fully corroborates this.

In the Verse 102 of the Vraht Samhita , it is described how water occurs in a mountainous region.

विभीतको वा मदयान्तिका वा यत्रास्ति तस्मिन् पुरुषत्रयेमभः ।
स्यात्पर्वतस्योपरि पर्वतोन्त्यस्तत्रापि मूले पुरुषत्रयेम्भः ॥ Vr.S.54.102 ॥

सशर्करा ताम्रमही कषायं क्षारं धरित्री कपिला करोति ।

आपाण्डुरायां लवणं प्रदिष्टं मृष्टं पयो नीलवसुधरायाम् ॥ Vr.S.54.104 ॥

Above verse (54.104) explains the relation of soil and water. It says that pebbly and sandy soil of copper colour makes water astringent. Brown-coloured soil gives rise to alkaline water, yellowish soil makes water briny and in blue soil underground water becomes pure and fresh.

In Ramayana we come across the knowledge of artesian wells. The verses VI,22.37-38 say that the water from deep earth comes out by force continuously through the hole created by arrow of Lord Rama as:

निपातितः शरो यत्र वज्राशनिसमप्रभः ॥ Rama., VI,22.36 ॥

तस्माद् व्रणमुखात् तोयमुत्पपात् रसातलात् ॥ Rama., VI,22.37 ॥

स बभूत् तदा कूपो व्रण इत्येव विश्रुतः ।

सततं चोत्थितं तोयं समुद्रस्येव दृश्यते ॥ Rama., VI,22.38 ॥

It clearly and very scientifically explains the artesian well flowing continuously with force. The Vayu Purana also refers to the various underground structures and topography such as lakes, barren tracts, dales, rocky rift valley between mountains अन्दद्धोणी (38.36). The chapter 38 of the Purana also speaks of a large number of hot springs in a mountainous region.

तथा ह्यनन्त तप्तानि सरंसि द्विज सत्तमाः ।

शैलकुक्ष्यन्तरस्थानि सहस्राणि शतानि च ॥ Vayu.38.78 ॥

The Gopath Brahmana was also acquainted with two types of springs or falls, namely hot and cold (II,8).

As mentioned in the previous chapter, in Markandeya Purana we come across a peculiar type of topography found in the Kimpurusavarsa and seven other countries where water bubbles up from the ground (55.21-22).

नवंस्वपि च वर्षेयु सप्त सप्तकुलाचलाः ।

रुकैकस्मिस्तथा देशे नद्यश्चाद्रि-विनिः सृता ॥ Markandeya.53.21 ॥

यानि किंपुरुषाघानि वर्षाण्यष्टौ द्विजोत्तम ।

तेषुदिभज्जानि तोयानि नैवं वार्यत्र भारते ॥ Markandeya.53.22 ॥

The above discussions reveal that chapter 54 of the Vrhat Samhita is a very important treatise on ground water exploration.

Epilogue:

Discussions and the references presented in the chapter show that there were well developed scientific concepts of groundwater occurrence, distribution, prospecting and utilization. It is for this reason that the people of Harappan civilization were able to dig the wells and able to utilize the groundwater. By means of hydrologic indicators such as physiographic features, termite mounds, geophysical characteristics, soils, flora, fauna, rocks and minerals etc., the presence of ground water was detected, which is fully scientific. Termite mounds were used as an important indicator of the groundwater by the ancient Indians. The presence and variation of these indicators have been linked up with the availability of underground springs in modern era too. Modern scientists have also established that the moisture within the mounds is kept practically at saturation level (99-100%) indicating the presence of underground spring in proximity. Well before many centuries of Christ, Indians were aware of underground water bearing structures, change in the direction of flow of ground water, high and low water tables at different places, hot and cold springs, ground water utilization by means of wells, well construction methods and equipment, underground water quality and even the artesian well schemes. This high level of knowledge of groundwater in those ancient times was developed by indigenous people of India altogether independently.

