

CHAPTER 6

GROUNDWATER

Groundwater development and utilization have 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.

The old testament of Bible contains numerous references to ground water, spring, and wells (Prasad, 1980). The most extraordinary work of ancient man for collecting groundwater are the 'Kanats' (also called Kariz, Kahriz, canaut, ghanat etc.). In the persions they are the infiltration galleries which are the structures inteded to collect groundwater from alluvial deposits and soft sedimentary rocks. Such Kanats were believed to be used first more then 2500 years ago in Iran.

The ancient western science of groundwater which generally assumed that the water discharged by the springs could not be derived from the rain, firstly because the rainfall was believed to be inadequate in quantity, and secondly because the earth was believed to be too impervious to permit penetration of the rain water far below the surface. In contrast to above wild theories the ancient Indian literature contains the most valuable and highly advanced scientific discourse on groundwater.

In Rigveda, Samveda, Yajurveda 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, Varahanihira (AD.505-587), author of Urhat Sanhita which is esteemed for its learning of many important branches of knowledge, in this the 54th chapter, entitled 'Dakargalam' deals with ground water exploration and exploitation with various surface features, which are most obvious, as hydrological 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 in biologic and geologic materials in a microenvironment, consequential to high relative humidity in a ground water ecosystem, developed in an arid or semi arid region.

The treatise on Dakargala (science of underground water) by Manu is referred to in the Urhat Sanhita. By the latest his time must be (400BC-200BC). Varahnihire alludes that मनुना विरचितं दकार्गलम, clearly indicates 'Manu's contribution to this science thus it is established that this science of geohydrology studied and cultivated in India several centuries before christ and that it was developed by indigeneous 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 dakargala (Urhat Sanhita, 54.99).

सारस्वतेन मुनिना दकार्गलं यत् कृतं तलवलोचय ।

आर्याभिः कृतमेतद्वृत्तैरपि मानवं वदये ॥ Ur.S.54.99 ॥

So far absolutely nothing is known about Saraswata and his work, though Varahmihira mentioned him. From this atleast one thing is certain that Sarasweta's work existed in that time.

Now so far as subject proper, the science of underground water and water table is concerned, a brief survey of chapter 54 of the Urhat Sanhita designated as 'Dakargalom' 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 यथागङ्गेषु शिरास्तथैव क्षितावपि प्रोन्नतनिम्न संस्थाः ॥ Ur.S.54.1 ॥

मह्द्वेशो भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।
पृथिवी करभाणामिव भूतलसंस्थाः शिरा यान्ति ॥ Ur.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 as 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 2 we learn that water table is a complex function of rainwater, viz.

एकेन वर्णेन रसेन चाम्भश्च्युतं नभस्तो वसुधाविशेषात् ।
ननारसत्वं बहुवर्णतां च गतं परीक्ष्यं क्षितितुल्यमेव ॥ Ur.S.54.2 ॥

i.e. 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. Then in the latter verses are given the modes of occurrence of sub-terranean water and its depth, at different places. Verse 3,4 and 5 inform us that the sub-terranean streams are rainfed in all the quarters, and also apart from nine arteries, thousands more are present flowing to various directions.

पुरुहूतानलयमनिऋतिवरुणपवनेन्दुशंकरा देवाः ।
विज्ञातव्याः क्रमशः प्राच्याघानां दिशां पतयः ॥ UR.S.54.3 ॥

दिव्यपतिराज्जा च शिरा नवमी मध्ये महाशिशनाम्नी ।
एताभ्योन्याः शतशो विनिः सूता नामभिः प्रथिताः ॥ Vr.S.54.4 ॥

पातालाटूर्ध्वाशिरा शुभा चतुर्दिक्षु संस्थिता याश्च ।
कोणदिग्मुत्था 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 7 describes the various symptoms of occurrence of water along with pervious and impervious strata.

चिन्हमपि चार्धपुरुषे मण्डूकः पाण्डुरोश्च मृत पीता ।
पुटभेदकश्च तस्मिन् पाषाणो भवति तोयमधः ॥ Vr.S.54.7 ॥

which means that 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 describes some 70 odd field situations or ecological spectra from which it should be possible to deduce the presence of underground springs.

Actually the technique of under ground 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 under ground springs in the vicinity.

One startling factor emphasized in detail 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 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.

जम्बूतृक्षस्य प्राग्बल्मीको यदि भवेत् समीपस्थः ।
तस्माद्दक्षिणपार्श्वे सलिलं पुष्पदेयं स्वाद् ॥ Vr.S.54.9 ॥

उद्यार्जुनस्य दूरयो बल्मीको यदि ततोर्जुनाद्वस्तैः ।
त्रिभिरम्बु भवति पुष्पैस्त्रिभिरर्घसमन्वितैः पश्चात् ॥ Vr.S.54.12 ॥

"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 the 'Ant-hills' in lay terms, but termite - knolls - mounds - spires, or - prominences by the scientists, which are familiar features of most tropical and subtropical landscape, and the once that 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 dessication by living and working within the climatically sealed environment of their nest or within earth-covered galleries. According to present level of research (Rao, et al. 1971) the atmosphere within the nest has to be maintained practically 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 over-all consideration of the evidence it seems to be safe to conclude that, while normally the insects use every readily available source of water close to the ground surface, under conditions of severe climatic stress, they can and they 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.

In the dry regions of Katanga province (Congo-Krishasa), the great termitaries of the macrotermes are seen clearly aligned on the slopes right down to the ooze level. (Kumara-Krishna etal. "Biology of Termites" Vol.II, P.190). 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 Urhat Sanhita relating the same. Following verse of Urahata Sanhita suggests that the Ancient Hindus were aware of this tendency of mould builders.

बलमीकानां पक्क्यां यद्येकोभ्युच्छतः शिरा तदधः ॥ Vr.S.54.95 ॥

"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 (desert region), 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 termitaries are met with in close association with trees; and it is quite common sight to see termite mounds inhabited by these insects completely covered over with grass or vegetation and very close observation is often necessary to detect the termitary. The ancient Hindus have exploited this association quite extensively in the exploration of underground springs. viz.

जम्बूस्त्रिवृता मौर्वी शिशुमारी सारिवा शिवा श्यामा ।
वस्त्रियो वाराही ज्योतिष्पती गरुणवेगा च ॥ Vr.S.54.87 ॥

सूकारिकमाषपर्णीत्याद्यपदारचेति यद्यहेर्निलये ।
वलमीकाद्दुस्तरतास्त्रीभिः करैस्त्रिपुष्पे तोयम् ॥ Vr.S.54.88 ॥

"If Jambu, Triurt, 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 names of the flora mentioned are given below with their botanical names:

Jambu (Eugenia Jambos, Engenia Jambolana), Triurta (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 (Lycopodium imbricatum, I.Clovatum), Masaparni (Glycine debitis, G.Labialis).

Likewise various other verses of the chapter are related to the underground water exploration with relation to combination of different symptoms.

अतूणे सतूणा यस्मिन् सतूणे तूणवर्जिस्मिता महीयत्र ।
तस्मिन् शिरा प्रदिष्टा वक्तव्यं वा धनं चास्मिन् ॥ VrS.54.52 ॥

i.e. 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.

कण्टकयकण्टकानां व्यत्यासेम्मास्त्रिभिः करैः पश्चात् ।
खात्वा पुष्पत्रितयं त्रिभागयुक्तं धनं वा स्यात् ॥ Vr.S.54.53 ॥

i.e. a flourishing thorny tree in the midst of non-thorny trees or vice-versa indicates water or treasure at a depth of 3 3/4 Purushas at a distance of 3 hastas to the west.

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

Where there is stream or smoke issuing from the ground, an

abundant water vein will be struck at a depth of 2 Purushes (54.60).

From the point of view of occurrence of sub-terranean water, Varahamihira has discussed the occurrence of underground water in the desert region. He 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 viz.

मृद्वेशे भवति शिरा यथा तथातः परं प्रवक्ष्यामि ।
ग्रीवा करभाणामिव भूतलसंस्थाः शिरा यान्ति ॥ Vr.S.54.62 ॥

Geological strata scheme of the modern artesian well fully corroborates this. In the Verse 102 is described how water occurs in a mountaneous region.

विभीतको वा मद्यान्तिका वा यत्रास्ति तस्मिन् पुरुषत्रयेभः ।
स्यात्पर्वतस्योपरि पर्वतोन्त्यस्तत्रापि मूले पुरुषत्रयेभः ॥ Vr.S.54.102 ॥

सशर्करा ताम्रमही कषायं द्वारं धरित्री कपिला करोति ।
आपाण्डुरायां लवणं प्रदिष्टं मृष्टं पयो नीलवसुन्धरायाम् ॥ Vr.S.54.104 ॥

Above Verse (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 under ground water become pure and fresh.

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

निपातितः शरो यत्र वज्राशनिसमप्रभः ॥ Ramayana,VI,22.36 ॥
तस्माद् वणमुखात् तोयमुत्पपात् रसातलात् ॥ Ramayana,VI,22.37 ॥

स बभूत् तदा कूपो वण इत्येव विश्रुतः ।
सततं चोत्थितं तोयं समुद्रस्येव दृश्यते ॥ Ramayana,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 अन्वद्रोणी (38.36). The chapter 38 also speaks of a large number of hot springs in a mountaineous region.

तथा ह्यनन्त तप्तानि सरांसि द्विज सत्तमाः ।

शैलकुदयन्तरस्थानि सस्त्राणि शतानि च ॥ Vayu.38.78 ॥

In Markandeya Purana we come across - Peculiar type of topography found "in the Kimpurusavarsa and seven other countries" when water bubbles up from the ground (55.21-22).

नवंस्वपि च वर्षेयु सप्त सप्तकुलाचलाः ।

स्कैकस्मिस्मस्तथा देशे नघश्चाद्रि-विनिः सुताः ॥ Markandeya.53.21 ॥

यानि किंपुस्वाघानि वर्षाण्यष्टौ द्विजोत्तम ।

तेषुविभज्जानि तोयानि नैवं वार्यत्र भारते ॥ Markandeya.53.22 ॥

the Gopathbrahmona was also acquainted with two types of springs or falls, namely hot and cold (II,8). शतोष्णाविहोत्सौ

All above literature reveal some knowledge about groundwater, but as discussed above, chapter 54 of the Urahat sanhita is the most important treatise on ground water exploration.

In Ancient days when the western knowledge about the occurrence of ground water was based on the wild theories as they were believing that rainfall being inadequate in quantity can not be the source of ground water, the Indians had the scientific concepts of its occurrence, distribution, prospecting and utilization. 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 being detected, which is fully scientific and presence and variation of these indicators have

been linked up with the availability of underground springs in modern era. Termite mounds were used as an important indicator of ground water. Modern scientists have also established that the moisture within the mounds is kept practically at saturation level (99-100%) and presence of underground spring in proximity is indicated. 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 ground water in those remote days was developed by indigeneous people of India altogether independently.