Teaching Materials -8, Management of Water Resources in Tank Cascade Systems

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Improving System Efficiencies and Water Productivity Project

Management of Water Resources in Tank Cascade Systems

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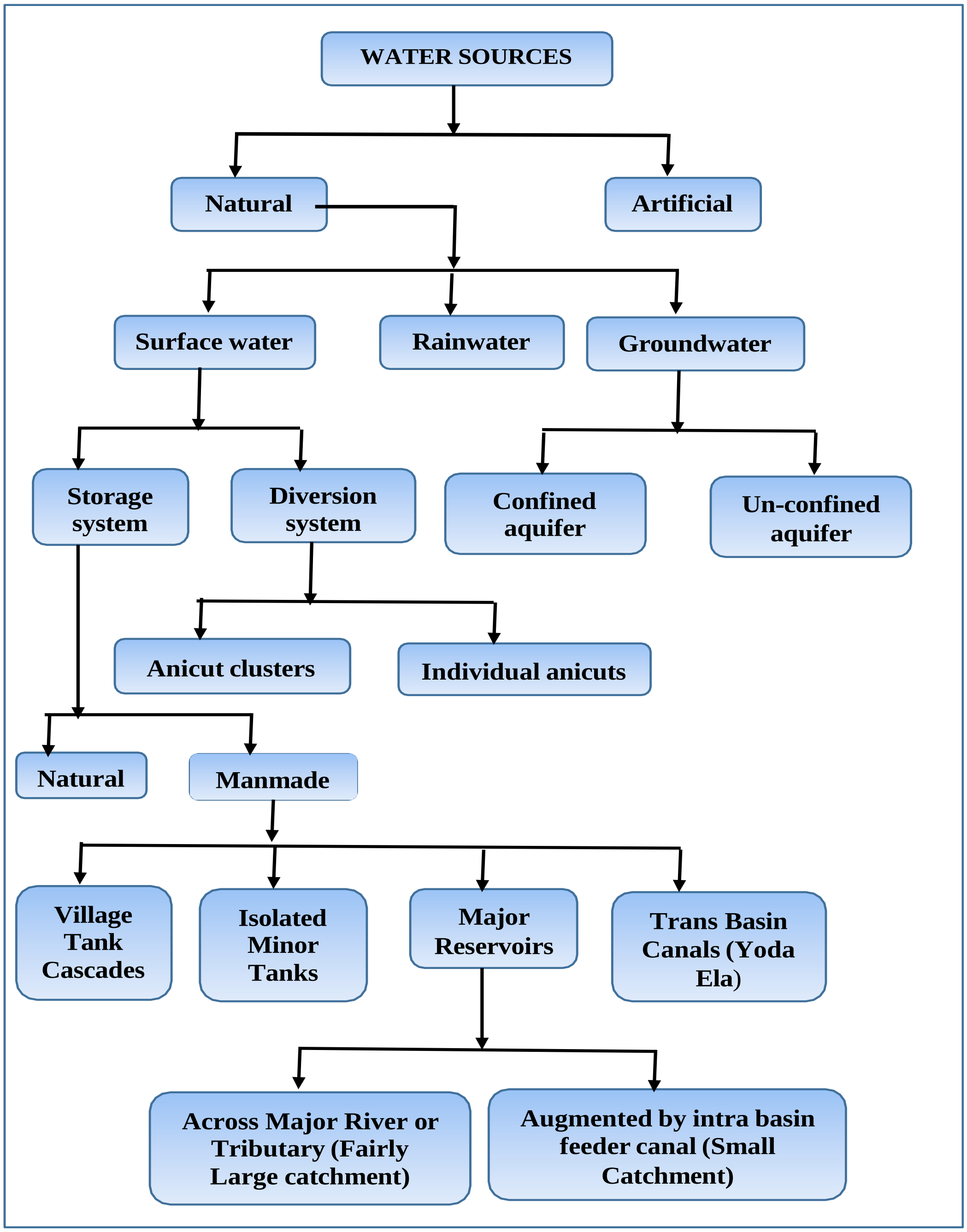
Content of the Lecture

1. Introduction

Water resource management for irrigation has been practiced in Sri Lanka on a priority basis since 500 BC, and it was treated as one of the main responsibilities of the rulers. According to the history of Sri Lanka, when the Aryans landed on Sri Lanka in 500 BC, they came with the knowledge of irrigation and water management as their main diet was rice[i]. In this era, land and water were the most important resources. The people living at that time selected places to settle where the rainfall was not very heavy, but were water was readily available: this was a good condition for cultivation. All villages in which they had chosen to live were near rivers and natural canals (*Ova*) and the terrain was generally flat, allowing for rice cultivation.

Integrated approach in irrigated agriculture in Sri Lanka has a great history with the origin of much more earlier than so called hydraulic civilization in Malwathu Oya basin, which continued up to the 13th century AD, developing from isolated small tanks (*Gamika Wawi*) to more elaborate irrigation network called Village Tank Cascade (*Ellangawa*) and culminated in intra-basin and trans-basin diversions to augment major reservoirs as well as village tanks. Examples are the Kalawewa-Yoda-Ela system and Elahera-Minneriya-Kantale System. At the same time, there was another type of irrigation systems introduced called "*Dana Wawi*" like Parakrama Samudra, Angammedilla anicut and Ambanganga, Madagalla tank, Deduruoya and Redeebendi Ela etc. Village Tank is a community cantered multifunctional eco-system and major reservoir is for flood control and production centred water body. The command areas in most of these village irrigation systems in miniature were limited to the poorly drained soils, which are suitable only for lowland rice cultivation, and water distribution in fairly large village tanks and major tanks (*Maha wawi*) were facilitated by parallel multi canal system operated with a water bifurcation as well as flow measuring device structure called "*Karahana*"(Dharmasena and Witharana, 2021[1]). Classification of the water resources in Sri Lanka is illustrated in Fig. 1.



Source: Dharmasena and Witharana, 2021

Fig. 1. Classification of the water resources in Sri Lanka

[1] Dharmasena, P.B. and Prabath Witharana, 2021. Regulation and Control of Water Usage in Irrigated Agriculture through Best Practices, A strategic paper submitted to the Office of the Prime Minister along with the National Water Resources Policy of Sri Lanka in June 2021

In areas where adequate rainfall is not assured, supplementary irrigation is provided through distributary channel systems from tanks and anicuts. These irrigation networks essentially designed for rice cultivation are divided into two main categories based on command area namely;

Minor irrigation systems: (Fig. 2)

- Command and area is less than 80 ha;
- Both tank and anicut systems are included under this category;
- Operation and maintenance works are carried out by the Department of Agrarian Development;
- Water management and cultivation decisions are made collectively with the Farmer Organization;
- Support for cultivation is provided through Agrarian Services Centers of DAD; and
- Water availability depends on the catchment area, rainfall, tank capacity and the size of command area.

Major irrigation systems: (Fig. 3)

- The system command area is larger than 80 ha;
- Systems include both tanks (reservoirs) and anicut schemes;
- These systems come under the jurisdiction of either the Irrigation Department or the Mahaweli Authority of Sri Lanka;
- Tanks and streams which are used for anicut systems depend on their own catchments for water in many systems;
- For some tanks, water is diverted from other catchments through trans-basin channels, by which water supply is more assured than the tanks which depend on their own catchments;
- Distribution channel systems are better equipped with control structures than in the minor irrigation schemes and controlled water management practices have been introduced; and
- Water is issued mostly on a pre-scheduled rotation

Fig. 2. A minor irrigation system

Fig. 3. Major Irrigation Reservoir - Kalawewa

2. Evolution of Irrigation Systems

The first man-made water resources were the small-scale reservoirs built in every village which stored water for irrigation from the heavy rains during the monsoons. It was a collective effort undertaken by the entire community of the particular village and was done on the basis of village planning. During the same periods the smaller tanks were built by individuals or groups. In group efforts, the group evolved its own rules and regulations for water management. These tanks were well established the dry zone of Sri Lanka during the first century BC.

Under village tank irrigation a three-fold system of land exploitation was practiced, namely, irrigated paddy field, rainfed *chena* cultivation (slash-and-burn system) and home-garden agroforestry.

During the period between the first and fifth centuries, irrigation systems were developed having large and central tanks serviced by distributary canals throughout the dry zone. Especially in the third century, reservoirs were built with greater storage capacity and the irrigation systems were developed so that the farmers were able to cultivate rice three times a year.

In the twelfth century during the reign of King Parakramabahu the Great, irrigation structures were constructed with expert knowledge and skills. In this era, systematic and effective systems were worked out with a strong and competent bureau for the maintenance of public works, particularly irrigation, agriculture and city building. Water management, which was regarded as a common resource belonging to the king, became the hub of the whole social organization in this period. The achievements in water management and irrigation during this period were at the initial level of their development.

After the twelfth century, there was a decline and most of the massive irrigation works, which were active earlier, were ignored and as a result, most of them fell to ruin. The reasons for this neglect of the water management systems are given as climatic changes, epidemic diseases, infertility of the soil, foreign invasions and famine (Manchnayake and Madduma Bandara, 1999)[2]. The reason for the ruin of the efficient water management systems in the past was the complete disorganization or weakening of the irrigation experts of that time. It was said to be a push-pull mechanism in which the wet zone began to pull the population from the dry zone where many factors conspired to push them.

Sri Lanka was under colonial rule since 1505 by the Portuguese, Dutch and British. In the Portuguese period (1505 – 1640), no attempts were made to reconstruct the irrigation works; however, during the Dutch period (1640 – 1795), a few irrigation works in maritime areas were restored. Some of these Dutch canals are still in use. Thereafter, in the early years under British rule (1815 – 1855), the maintenance of the irrigation network was totally neglected and some of them were destroyed. Later, the British rulers of Sri Lanka who governed during the period of 1855 – 1877 gave considerable attention to irrigation improvement. During that period, irrigation and water resource management were under the Public Works Department (PWD) and in 1900; the Irrigation Department was established to handle the task. After the establishment of the Irrigation Department,

[2] Manchanayake P. and Madduma Bandara, C. M., 1999. *Water Resources of Sri Lanka*, National Science Foundation, Colombo, Sri Lanka.

all ancient reservoirs and other irrigation networks were repaired and maintained (Weerasinghe and Navarathne, 2003)[3].

In 1930, after the establishment of the 'Donoughmore Constitution' under the leadership of the Hon. D. S. Senanayake, irrigation became the most important element of agriculture. The main objectives of this policy were to increase paddy production in the island and move more people to the lands in the dry zone from the wet zone. After restoring ancient irrigation tanks, the Hon. D. S. Senanayake started a number of colonization schemes and the large reservoir 'Senanayake Samudra' was constructed with a capacity of 950 MCM. A large number of reservoirs were developed after 1950 under the same policy, such as Udawalawe, Kirindioya, Galoya, etc. For the purpose of water management development, the country was categorized in four major regions in 1960, namely: Mahaweli project region, south-east dry-zone region, western wet-zone region and north-west dry-zone region.

Under the United Nations Development Programme (UNDP), the Food and Agriculture Organization (FAO) prepared a master plan to develop the water resources of the Mahaweli Ganga Basin and adjacent areas during the period of 1965 – 1968. Under this project, it was planned to irrigate an area of about 3 64 000 ha in the dry zone. Further, it aimed to restore water to nearby tanks or reservoirs that did not have enough water to irrigate the surrounding areas in either the *yala* or the *maha* season. The implementation period of the plan was estimated as around 30 years. The main objectives of this project were irrigation, hydro power generation and flood control. The Government of Sri Lanka accelerated the Mahaweli Development Programme with the aid of foreign countries in 1978. Under this programme six large reservoirs and three canals were constructed mainly for hydro power generation and irrigation (Weerasinghe and Navarathne, 2003).

In the South-east dry zone region the reservoirs Chandrika, Navakiri Ara, Unnichchai, Rugam reservoirs were built for irrigation purposes after the 1960s, and the existing reservoirs in the area such as Udawalawe, Lunugamvehera, Muruthawela, and Senanayake Samudra were restored. The Samanala Wewa reservoir, which was built by constructing a dam across the Walawe Ganga in the upper reach, failed as there was leakage at the dam site.

3. Small Irrigation Schemes

The first tanks were the numerous small tanks in the foothills near fields or terraces to catch the runoff water which was released as needed. Then a number of small dams and, bunds, were built, often in a series on the upper reaches of tributaries of the greater rives,

[3] Weerasinghe, K.D.N. and C.M.K. Navarathne, 2003. History of Hydraulic Civilization and Irrigation Systems Development in Sri Lanka, Institut Français de Pondichéry, P 43-61

thus retaining annual or inundator flow and discharging it as desired by small canals along the valley side. As time went on, larger dams were built submerging or rendering unnecessary smaller ones

As mentioned by Brohier (1934)[4], in pre-Christian times Ceylon attained the idea of controlling the waters of streams formed by nature to satisfy the many needs of the unfertile regions He illustrated the development of irrigation in Rajarata (Royal Country), where an old diversion channel to Nuwara Wewa was built before the Nachchaduwa tank, which had submerged its head work (Brohier, 1934).

The next step was revolutionary; a weir (anicut) was built much higher up the main river to obtain the head to flow and contribute to join the annual monsoon supplies in the great reservoir (*Yodhawewa*). This method, ambitious as well as scientific, had numerous advantages: it harnessed a greater volume of water than any local catchment area could yield; it put both monsoon and other rainfall to full use, and secured a resource in dry the period as well as an even supply in normal years. This method also lessened the problem of silt accumulation because the feeder canal could be cleared periodically and much more easily than the tanks.

The ancient irrigation system in Sri Lanka is a man-made water and soil conservation ecosystem that had evolved and developed in seven stages by a process similar to natural selection (Mendis, 2001)[5].

i. Rainfed agriculture
ii. Seasonal or temporary river diversion and inundation irrigation
iii. Permanent river diversion and channel irrigation
iv. Development of weirs and spillways on irrigation channels
v. Invention of the sluice (*Sorow wa*) with its access tower (*Bisokotuwa*)
vi. Construction of storage reservoirs equipped with sluices
vii. Damming a perennial river.

Remains of sluices were not found and it is logical to think that man had practiced pastoral after the early hunter-gatherer stage, had known rainfed agriculture and discovered the possibility of settled agriculture in river valleys, before he learned to construct storage reservoirs. Natural ponds and dug wells may have been used for domestic water supply, and even for some irrigation. The construction of storage reservoirs depended on the invention of the sluice.

[4] Brohier, R. L., 1934. *Ancient Irrigation Works in Ceylon, Part one,* Government Press, Ceylon
[5] Mendis, D. L. O., 2001. *Evolution and development of water and soil Conservation Ecosystem* A Sri Lanka Pugwash Group Publication.

The traditional terraced paddy field carved into the hill tops of the country also provides a profound technological background for river diversion and canal construction. Here, the perennial rivers flowing downhill slopes were conveyed along contour canals constructed at a suitable elevation. A new ecological unit, the cascade system, formed in this manner with a harmony of village tanks and paddy fields, is a distinct example of water conservation and an erosion control measure adopted by the Sri Lankan farmer. The revolution of this system may have occurred with the invention of the *Sorowwa* (valve pit) and the *Bisokotuwa*.

In many traditional systems, most of the poorly drained soils (Low Humic Gley - LHG) were incorporated within the distribution systems, and separate irrigation and drainage outlets to individual farmers or farmlands were not very essential as either groundwater or perch water table was very closure to the root zone when the tank is full of water. As most of the village tanks were having water depth of around 2 meters, it can be identified as a shallow wetland with less effective for wind velocity in the dry zone of Sri-Lanka. These systems could only be operated as community ventures (Collective Farm) and not as independent operations of individual farmers. Water distribution and drainage took place from farm to farm by using main and lateral slope properly identified in the downstream area. If the community decided on the cultivation calendar, individuals had no chance to deviate but to adhere to the community plan.

The next stage of development in design was the provision of individual irrigation and drainage outlets. This system was based on a continuous supply of irrigation water and therefore requires fair amount of community participation for the operation. However, the tail-enders of canals were always at a disadvantage since the head-enders could obtain a more or less unlimited supply of water. Given that the paddy plant does not suffer from over-irrigation and that the maintenance of standing water in the fields reduces weed problems, the head-enders were not concerned about the extent of their water consumption.

The most recent design in distributary irrigation systems was adopted in the 1970s under the Mahaweli Project. Here a tertiary distribution system based on field channels of uniform capacity serving a more or less similar number of farmers was utilized to practice a rotational or intermittent system of irrigation. This system was expected to alleviate the tail-ender problem and depended on total cooperation of the farmers in each field channel area for efficiency and equity in the distribution of water. This, however, has not fully eliminated the problems of the tail-enders. Another innovation tried out on an experimental basis was a piped distribution pilot system (System H - David Reservoir). This was designed as an automated system to enable individual farmers to obtain water as decided by the operator. The two most recent irrigation methods tried out in Sri Lanka are first, pipe born conduit system with control valve at each farm gate and second, an on-farm and on-demand system of drip or trickle irrigation to increase the efficiency of water use further (Dharmasena and Witharana, 2021[6]).

4. Tank Cascade Systems

The recurrent shortages of water for agriculture, animal husbandry and for domestic use, caused by droughts, and dry spells had always been a serious natural and economic setback to the rural communities in the dry zone areas of Sri Lanka since ancient times. This is indicated by many references to the drought hazard frequently found in the historical chronicles such as Mahawansa, Chulawansa etc. The ancient irrigation reservoirs and the hydraulic society that once flourished in these areas exhibited a remarkable human adaptation to the problems created by droughts, floods and seasonal water shortages. Irrigation planning between and in the tank cascade systems was another example showing the wisdom of our ancient irrigation skills. The drainage pattern formed in the undulating topographic formation in the dry zone landscape can be classified as dendritic drainage pattern. This ramifying nature of the drainage system has led to form clusters of small tanks found in series, which are connected to form a system known as 'tank cascades'.

Existence of small tanks in a cascade pattern is an advantageous feature in many ways. Surface water bodies spread over an area can maintain the groundwater level closer to the land surface at least in lower portions of the minor basins. It can be stipulated that absence of such a branched system of tanks could lead to rapid depletion of groundwater due to natural gradient of the drainage system. Therefore, in the absence of tank cascade systems natural vegetation seeing now would have not been in the same composition with deep-rooted large tree species found in the various positions along the catenary slope. Upper tanks in a tank cascade system act as buffer reservoirs to absorb flood-generating rainfall, which would otherwise bring the risk of breaching lower tanks. Similarly, these upper tanks are buffer reservoirs to supply water to the lower tanks when they are in short of water to save the crop. Since the tanks exist not in isolation but as clusters, and they are hydrologically inter-related, planning for individual tanks could create conflicts in water resource management among them. Sustainability of the traditional tank cascade systems had been maintained in the past simply not only from structural maintenance. Each and every component of the eco-system was given due consideration. The attention was paid not only on macro-land uses such as paddy land, settlement area, chena lands, tank bed etc. but also on micro-land uses such as *godawala* (upstream waterhole), *iswetiya* (Earth ridges at either side of the tank), *gasgommana* (upstream tree strip), *perahana* (upstream meadow), *kattakaduwa* (downstream reservation), *tisbambe* (buffer zone around the hamlet), *kiul-ela* (common drainage of the paddy field) etc. (Fig.4.).

[6] Dharmasena, P.B. and Prabath Witharana, 2021. Regulation and Control of Water Usage in Irrigated Agriculture through Best Practices, A strategic paper submitted to the Office of the Prime Minister along with the National Water Resources Policy of Sri Lanka in June 2021

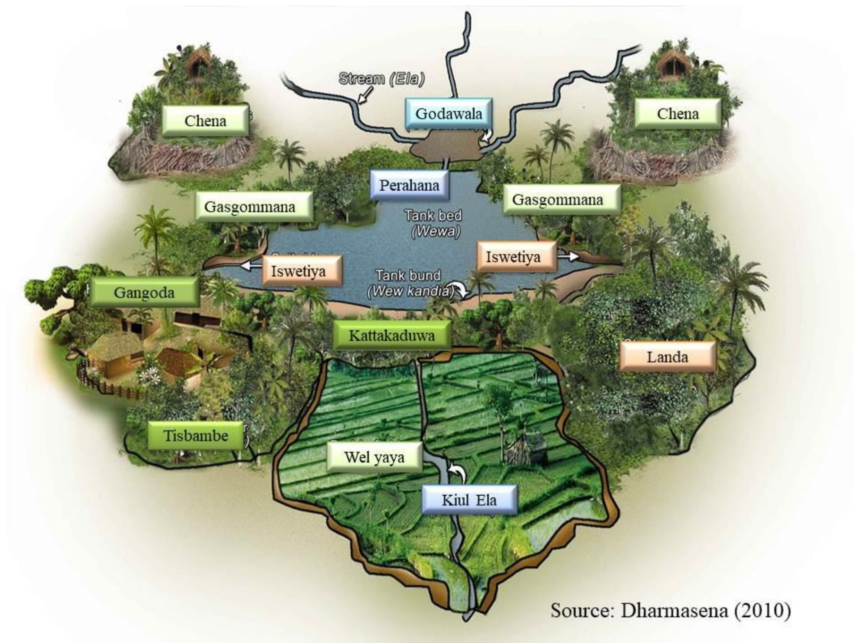


Fig. 4. Village Tank Ecosystem (Dharmasena, 2010)[7]

5. Water Management in Paddy Fields

Use of groundwater for irrigation was not a practice in ancient time. They have given the entire effort to innovate techniques for irrigation through surface water. Groundwater has been kept to maintain the vegetation around them and abstract in a very critical situation caused by drought. In responding drought situation people found water on river beds and in natural depressions, when digging down to a certain depth. These were temporary works. Once the drought was over, they neglected these water holes. However, they have used groundwater efficiently to protect their environment and in paddy farming. The people in the past kept a certain volume of water in the tank, which cannot be used for irrigation. The area called 'mada kaluwa' (presently known as dead storage) stored water below the irrigation sluice sill level to be available during dry season of the year for several purposes. They wanted to allow fish population to continue the life cycle, trees around to survive, cattle to drink and people to use for washing clothes and sometime bathing. If somebody comes up with an argument that our ancestors have never used groundwater for paddy cultivation, it cannot be accepted. They used groundwater for paddy farming without exploiting it. In the past farmers cultivated paddy only in poorly drained lands, where the groundwater table is very shallow during many months of the year. This field is known as *purana wela* (old paddy tract). If the groundwater table is at a

[7] Dharmasena, P.B. 2010. Essential components of traditional village tank systems. In: Proceedings of the National Conference on Cascade Irrigation Systems for Rural Sustainability. Central Environmental Authority, Sri Lanka, 9 December 2010.

depth less than 50cm, the surface soil is moist enough to raise the paddy crop. They supplied irrigation water only when they experienced a very dry *maha* season. This is one of the reasons that they could cultivate paddy in *yala* season from tank water remained after *maha* season.

Karahana – This water distributing device is said to be the oldest in the world used for controlling field level irrigation water. The device was made up of a wood log, which had two weir shape cuts of different size in depth and width. It diverted the flow in two or three directions with different discharges to feed two or three different extents of paddy fields (Fig. 5). *Gamarala* (village chief) or *WelVidane* had the control on it (Anuruddha, 1989)[8].

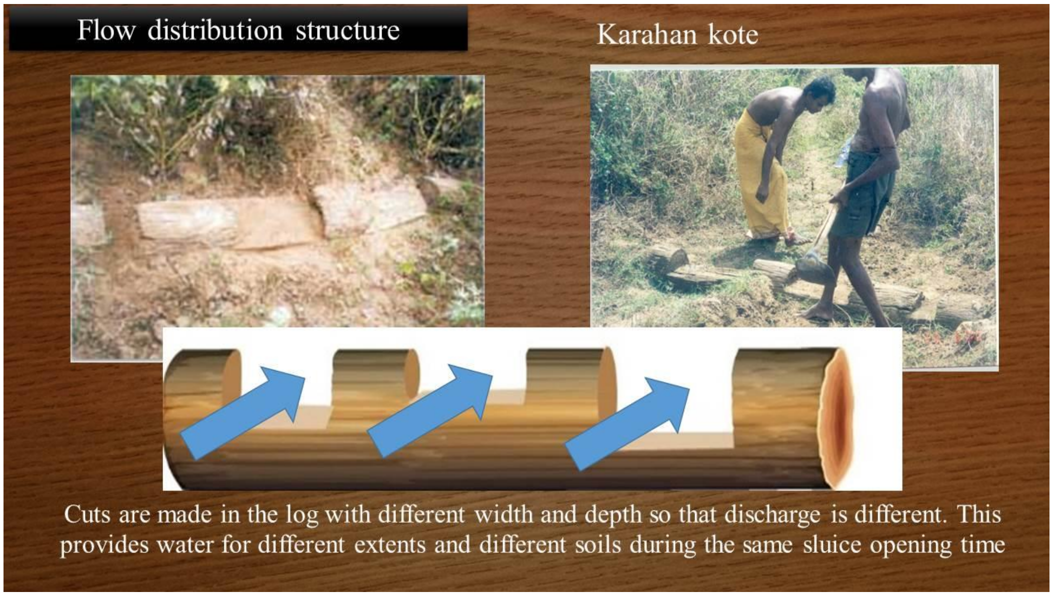


Fig. 5. Water distribution log – *Karahan kote*

[8] Anuruddha Seneviratne, 1989. *The Springs of Sinhala Cultivation*, RB 7 Inderpuri, New Delhi.