Southeast Asian Studies, Vol. 22, No. 2, September 1984

Intersocietal Transfer of Hydraulic Technology in Precolonial South Asia: Some Reflections Based on a Preliminary Investigation

R. A. L. H. GUNAWARDANA*

It is in Sri Lanka and South India that hydraulic civilization in South Asia reached its highest levels of development. Since the proximity of the two regions points to the possibility of mutual exchange of technology, they constitute two important areas for comparative study by students of ancient technology. While in certain parts of South India, like the Kāverī valley, irrigation activity appears to have been heavily dependent on canal systems, in most other areas within this region, water for agriculture is provided by a multitude of reservoirs of varying proportions which can be compared with the reservoir systems of the Dry Zone of Sri Lanka. The unusually large number of reservoirs found throughout Tamiḻnāḍ, Karṇṇāṭaka and Āndhra drew the attention of several writers who served in the British colonial administration. The observations made by Crole, the author of *The Chingleput District Gazetteer*, are representative of their impressions. "Almost every catchment basin, however small, still bears traces of having been bounded across," he wrote, "and in many instances this was done to secure a crop of paddy on a few acres of stony, ungenerous soil" [Crole 1879: 209–210]. Like many of his predecessors and contemporaries in British India, Crole was convinced that these remains of minor irrigation works, some of which were long abandoned, demonstrated "the solicitude of the monarchs for the extension of cultivation even on tracts not favoured by natural position or the quality of the soil" [*ibid.*: 45–46].

The assumption shared by many nineteenth-century writers, that all ancient irrigation works found in South India were products of royal initiative, has been uncritically accepted by students in even more recent times.[1] The great majority of these irrigation works represent only a rudimentary level of hydraulic technology and are on such a small scale that their construction was well within the capabilities of the cooperative effort of peasant communities. Further, archaeological research into the so-called megalithic burial sites, carried out during the past few decades, points to the strong possibility that the origin of the smaller irrigation reservoirs may have to be traced back into the remote past, well beyond the period of state formation. These burial sites are distributed over a wide area within peninsular India. The megalithic folk appear to have shared several cultural traits including acquaintance with iron tools, the use of a distinctive type of pottery called

* Department of History, University of Peradeniya, Peradeniya, Sri Lanka

1) See, for instance, Srinivasan [1968: 45–46].

Black and Red Ware and the domestication of the horse [Bridget & Raymond Allchin 1968: 223–232; Gururaja 1972; Parpola 1973].[2] At Hallur the stratum in which iron objects occurred has been assigned to the beginning of the first millennium B. C. [Bridget & Raymond Allchin 1968: 230]. Wheel-turned pottery and iron objects appear more frequently at sites datable to a time after the third century B. C. [Srinivasan & Bannerjee 1953: 108]. Srinivasan and Bannerjee observed that megalithic sites "have invariably been found to occur on rocky high grounds, which are themselves unfit for cultivation, in close juxtaposition to a hillock and an irrigation tank, but in very close proximity to arable land" [*ibid.*: 109]. These two archaeologists have claimed that the close association between megalithic sites, hillocks and irrigation works was so significant that it was possible for them to predict with a high degree of accuracy the presence of megalithic sites simply by picking out on a one-inch map places where both irrigation reservoirs and hillocks were marked [*loc. cit.*].[3]

The most widely accepted theory on the origin of irrigation in Sri Lanka has been that it was introduced by Aryan immigrants from the northwestern parts of India.[4] Elements of a second theory may be detected in the short Presidential Address that R. L. Brohier delivered before the Engineering Association of Ceylon. Brohier presented an analytical scheme of the stages of the development of irrigation on the island. His views were based on the assumption that the earliest immigrants to the island were nomadic wanderers who gradually took to the domestication of plants. And, since the land on which they settled was dry and barren, "they were compelled to devise artificial means for storing the monsoon rains" in "simple ponds." Brohier cited two small reservoirs, located near the Mōdaragam Āru, close to the Vilpattu Sanctuary, as examples of such primitive attempts at irrigation [Brohier 1956: 28–37]. The implications of Brohier's views were that the irrigation systems of Sri Lanka were of purely local origin and that cross-cultural transmission of ideas was not significant in the process of their development. However, in the light of archaeological evidence from South India, it appears that both the theories on the origin of irrigation in Sri Lanka have to be re-examined.

In its seventh *maṇḍala* the *Ṛgveda* mentions "artificial waterways" (*khaṇtrimā āpaḥ*) while in the later 10th *maṇḍala* it refers to the use of stone wheels, to which wooden pails were attached with leather straps, as devices for lift irrigation [Müller 1862–1874 (7.49.2; 10.6.7)]. However, the earliest hymns in the Vedic texts do not suggest that reservoir irrigation was known to their composers. In Sri Lanka, irrigation developed primarily as a prerequisite for the cultivation of rice. Information on supplementary crops is also available in the early historical records. People in straitened circumstances who could

2) For details of this culture, see Srinivasan & Bannerjee [1953: 103–115].

3) The fact that megalithic sites were almost always found near ancient reservoirs was first noticed by Hunt [1924: 140–156]. Gururaja Rao [1972: 298–299] also believed that reservoir irrigation was a technology introduced to South India by the megalithic folk.

4) See, for instance, Paranavitana [1959: pt. 1, 218–219].

not afford rice had to be content with "lesser grains" (*kudhānya*) like millet (Pāli *koṅgu*, probably *Echinochloa colona* or *Echinochloa crusgalli*) [Geiger 1958 (32.30)]. Leguminous plants like *rājamāsa* (*Vigna cylindrica L.*), *kālamāsa* (*Phaseolus mungo* or *Dolichos biflorus*) and *muṅg* (*Phaseolus radiatus*) as well as oil-producing plants like *tila* (*Sesamum indicum*) are mentioned in both literary and inscriptional sources [*ibid.* (29.12); *Epigraphia Zeylanica* Vol. 3: 181–185; Saranatissa 1920: pt. 2, 87, 131].[5] However, unlike rice, these crops were not raised on irrigated land. It is particularly significant that not a single distinct reference is to be found in the early historical records of Sri Lanka to either barley or wheat, popular crops in the northwestern parts of India which are mentioned in the Vedic sources. Evidence suggesting that rice was an item in the diet has been found in a neolithic context at Baidipur in Orissa and in later phases of Lothal and Rangpur, which were two of the southernmost outposts of the Harappan culture [Rao 1963].[6] Further evidence has been collected from Phases II to IV (c. 1600–1200 B. C.) at Navdatoli [Mittre 1961: 15–17].[7] It is particularly noteworthy that rice has been found at the megalithic site of Hallur in Karṇṇāṭaka in the strata in which the earliest iron objects were found, as also at several other later iron age sites in Tamiḻnāḍ.[8]

The culture of the megalith-makers was not limited to Peninsular India. The Allchins have reported what they termed iron age graves in the extreme south and the coastal parts of Sri Lanka [Bridget & Raymond Allchin 1968: 223]. While a comprehensive study of the megalithic sites in Sri Lanka has not been undertaken so far, explorative work by the Archaeological Survey has brought to light several sites some of which, like those at Gurugalhinna and Kirimäṭiyāhinna in the Anurādhapura District, are in close proximity to minor-scale irrigation works.[9] It is noteworthy that remains of rice have been found at certain megalithic sites in Sri Lanka [Deraniyagala 1972: 159].[10] Megalithic folk appear to have been among the earliest migrants from India to Sri Lanka and it seems likely that they brought with them several cultural traits including the use of iron, the domestication of the rice plant and, if we are to accept the implications of the observations made by Srinivasan and Bannerjee, a rudimentary irrigation technology including the art of constructing small-

5) Though it is not mentioned in early literary and epigraphic records, it is certain that *kurakkan* (*Eleusine coracana*) was an important item in the diet. Seeds provisionally identified as *kurakkan* have been found in Stratum IIIa at Kitulgala for which a C^{14} dating of 11750±390 YBP had been proposed [Wijepala 1980: 327–328].

6) See note on plant remains by S. S. Ghosh and K. Lal [Rao 1963: 168].

7) See also Allchin [1971: 323–329].

8) See Bridget & Raymond Allchin [1968: 265–266].

9) Author's field notes, 15 April 1977. For information on the distribution of these sites, see map (Fig. 1) in Begley *et al.* [1981: 52]. It has to be noted, however, that the information presented in this map is incomplete.

10) The information is based on a personal communication from R.H. de Silva, the Commissioner of the Archaeological Survey of Sri Lanka at the time. See Deraniyagala [1972].

scale reservoirs. Excavations at Bellan-bäñdi-pälässa revealed that, even as late as the ninth century A. D., the culture of the people who practised irrigation was still expanding into areas originally occupied by "the Balangoda culture" [Deraniyagala & Kennedy 1972: 44]. An earthwork embankment, "nearly 20 m. wide at its base and about 0.75 km. long" had been built, creating a reservoir "which would have contained at least 20 hectares of water" on the site of what had been a burial ground of people belonging to a mesolithic culture [*ibid.*: 23]. However, the exact relationship between irrigation and the culture represented by iron-age burials in Sri Lanka has not been established yet through evidence from excavations. At Pomparippu, for instance, the reservoir at the site "definitely was a late feature" [Begley *et al.* 1981: 65].

The pace of change in ancient irrigation technology was extremely slow. No doubt certain refinements and modifications were introduced from time to time. The poets of the Sangam collection were aware of the practice of "deepening reservoirs" (*kuḻantoṭṭu vaḻam perukkip*) or desilting operations, for in the *Paṭṭiṉappālai* the semi-mythical hero Karikāla is credited with such activities [Chelliah 1962: 46]. However, small-scale village reservoirs were in existence for several centuries before the huge artificial lakes like Minneri and Kāverīpākkam were built under the initiative of kings. It appears that this crucial transition took place in Sri Lanka several centuries earlier than in South India. As the present writer has pointed out elsewhere, the construction of the Minneri reservoir in the third century marks the beginning of a new stage in the development of hydraulic technology in South Asia [Gunawardana 1981]. In 1931 the capacity of this reservoir, which is best described as an artificial lake, was estimated to be more than 87 million cubic metres [Brown 1931: 42]. According to the chronicles, the next four centuries witnessed the construction of 66 irrigation works, including 11 other artificial lakes like Minneri, and six major canal projects involving diversion of resources on a massive scale. It has been estimated, for instance, that the embankments of the Padaviya reservoir contain about 453,000 cubic metres of earthwork [Manamperi 1955: 53]. The invention of the cistern sluice, which seems to have come into use some time before the second century A. D.,[11] was an essential technological prerequisite for the construction of reservoirs on such a scale. It would seem that these four centuries of intensive hydraulic enterprise were accompanied by further progress in hydraulic technology. The *Samantapāsādikā*, which was translated from Sinhala into Pāli in the fifth century, refers to both sluices (*udaka-niddhamana-tumba*) and spillways or waste-weirs (*udaka-nibbāhana*). This work reflects the awareness of the fact that waste-weirs were essential for the safety of reservoirs [Takakusu & Nagai 1969: 344]. As Parker and Blair observed, natural rock formations were selected to form the foundation of the embankments of large reservoirs like Mahāgalla and Kavuḍuluväva [Blair 1934: 34; Parker 1878]. That the site was carefully selected to minimize the construction work on the dams

11) For a discussion on the date of this invention, see Gunawardana [1978: 71–73].

is evident from a number of reservoirs like the Minneri. An embankment only about a kilometre in length was necessary to create this gigantic reservoir. The canal which conveyed water from the Kalā reservoir to Anurādhapura, which is 87 kilometres long, reveals the high degree of skill attained in the techniques of surveying and levelling. For 27 kilometres of its course, this canal was laid out at the remarkable gradient of about 10 centimetres per kilometre. It is also possible to suggest that the experience and observations accumulated during many centuries of irrigation activity helped the engineers of the Sri Lankan tradition to gain a knowledge of the behavioural characteristics of liquids and their practical implications. The erosive effect of wave action on earthwork embankments is mentioned in the *Samantapāsādikā* [Takakusu & Nagai 1969: 344]. The Sri Lankan engineers sought to counteract wave-action by covering the waterface of the embankment with a layer of rough stone boulders. The designers of the larger Sri Lankan reservoirs were aware of the relationship between head and pressure of water. By placing their sluices at various levels in the embankments, and thereby controlling the effective head, they succeeded in releasing water from their massive reservoirs at a pressure which would not damage the earthwork of the embankments.

An inscription found at Tāḷaguṇḍa in the Shimoga District of Karṇṇātaka, which has been assigned by Kielhorn to the first half of the sixth century, records the construction of a "large reservoir" (*taḍākaṃ mahat*) in the reign of the Kadamba king Kakusthavarman [*Epigraphia Indica* Vol. 8: 33, line 14]. In Tamiḻnāḍ, however, it is only after the rise of the power of the Pallavas in the seventh century that the construction of large-scale reservoirs appears to have been undertaken. Minakshi and Srinivasan have prepared lists of irrigation works which may be assigned to this dynasty [Minakshi 1938: 94–102; Srinivasan 1968: 32–34]. One of the earliest of the new, large type of reservoir built in Tamiḻnāḍ is to be found in North Arcot District, at Mahendravāḍi in the area between Arkonam and Walajapet. Writing at the end of the last century, A. F. Cox, the author of the *Manual of the North Arcot District*, described it as "a fine tank" with a dam that had been built to a remarkable height. Though he appears to have been mistaken in supposing that originally it was larger than the Kāverīpākkam reservoir, he was correct in assuming that it would have irrigated fields lying a considerable distance away [Cox 1895: 438–439]. The Mahendravāḍi inscription, which helps us to identify the reservoir as the Mahendrataṭāka, further states that there was a city called Mahendrapura close to the reservoir [*Epigraphia Indica* Vol. 4: 153]. Hultzsch was probably correct in suggesting that the reservoir and the city were named thus because they were founded by Mahendravarman I in the first half of the seventh century [*ibid.*: 152]. It has been suggested that the reservoir called Parameśvarataṭāka, in the village of Kūram, Chingleput District, was constructed by the Pallava ruler Parameśvaravarman who lived in the second half of the seventh century.[12) An inscription from this village records that

12) See, for instance, Minakshi [1938: 97].

he "dug a reservoir" [*South Indian Inscriptions* Vol. 1: 154]. The Tīraiyanēri reservoir, which is located about 20 kilometres east of Kāñcī, had already been built by the first half of the eighth century, for it is mentioned in the Kaśākuḍi copper plates of Nandivarman Pallavamalla [*ibid.* Vol. 2: pt. 3, 352, line 116]. It is a reservoir of extensive proportions, provided with two waste-weirs which have stilt-like stone pillars enabling control of the water-head at full supply level. The waterface of the embankment is covered with fairly large, uncut, naturally rounded boulders. The reservoir is very much silted up today.[13]

It is possible to suggest that at least three other large reservoirs were constructed in the time of the Pallavas or their successors, the Gaṅga-Pallavas. One of these is the reservoir at Uttaramallūr (Uttaramērūr). Today it is bisected by a road and its bed appears to be silted. Yet it still has an estimated capacity of 27.1 million cubic metres and is said to irrigate about 2,200 hectares.[14] Ten epigraphs found at the Vaikuṇṭhaperumāl temple at Uttaramallūr record transactions pertaining to this reservoir [*Madras Reports* 1898 (Nos. 11, 42, 61, 65, 69, 74, 80, 84, 85, 90)]. It was known as Vayiramegataṭāka at that time. Three of these records were indited in the reign of a ruler called Dantivikramavarman (var. Dantivarman, Dantipōttaraśar), who has been identified with the ruler of Kāñcī who paid tribute to the Rāṣṭrakūṭa king Govinda III in about A. D. 804 [*Epigraphia Indica* Vol. 4: 181–182; Vol. 5: 159].[15] It is clear from these records that the reservoir was operational in this king's reign and that it was being maintained by a committee of the rural assembly of the locality.[16]

The largest reservoir in the district of North Arcot is Kāverīpākkam, which is second only to Chembarampākkam in the whole of Tamilnāḍ. It is situated to the north of the road from Kāñcīpuram to Walajapet, only a few kilometres from the latter town. It has an elegantly built dam which is more than seven kilometres long and is curved, with the apex of the curve projecting into the reservoir. Arch dams or dams with a convex waterface offer greater resistance to the pressure of water in the reservoir. However, it is not possible to determine whether the designer responsible for this dam was aware of this principle or was merely following the line of a natural rock formation which would afford a firmer foundation for his dam. Since the dam does not follow a regular curve, the latter possibility seems to be more likely. The reservoir draws on a catchment-area of about 127 square kilometres. At its full capacity, it has a water-head of 9.3 metres above the sill of the lowest sluice and covers an area of about 15.5 square kilometres. Its estimated capacity is about 39.6 million cubic metres. The reservoir irrigates rice fields belonging to 14 villages, amounting to 2,550 hectares about 1,010 hectares of which are cultivated twice a year. Unlike many other reservoirs in the area examined by the author, Kāverīpākkam has a good reserve of water even in April, and

13) The description is based on the author's field notes dated 6 April 1976.

14) Author's field notes dated 6 April 1976.

15) See also Venkayya [1903: 204].

16) See inscriptions Nos. 61, 74, 80 and also 69 [*Madras Reports* 1898].

wave action was evident. To counteract erosion of the embankment by such wave action its waterface was covered with a layer of rough stone boulders, some of which were quite large.[17] The present capacity of Kāverīpākkam may not be representative of its proportions in Pallava times. The yield from the catchment-area of the reservoir was supplemented with water from the Pālār which used to be diverted by means of temporary *korambu* or sand dams. The construction of a permanent *anicut* on the Pālār in 1857 would have significantly added to the resources of the reservoir [Cox 1895: 194].

An inscription found at Tiruppāṟkaḍal, close to Kāverīpākkam, helps us to form an idea about the date of the construction of the reservoir. It records that the committee which supervised irrigation reservoirs was confronted with the task of finding funds to pay the labourers who removed silt in "the big reservoir." They decided to draw on an endowment which had been created with the gold donated by a royal official to finance feasts for Brāhmaṇas. The record is dated in the 12th regnal year (A. D. 917) of Parāntaka I, the Cōḻa ruler [*Madras Reports* 1904 (No. 693); Venkayya 1903: 206, n. 1]. Venkayya has suggested that "the big reservoir" should be identified with the Kāverīpākkam, and that it was already in existence in the reign of Parāntaka I [Venkayya 1903: 206, n. 1]. Venkayya and Minakshi may be correct in suggesting that this reservoir, located in the area around Kāñcīpuram, was built by the later Pallavas [*ibid.*: 106, n. 1; Minakshi 1938: 99].

17) Author's field notes dated 7 April 1976.

Another large reservoir which may be assigned to Pallava times is to be found at Māmaṇḍūr in North Arcot, only about eight kilometres southwest of Kāñcīpuram. Cox noted that it had a greater head of water than the Kāverīpākkam reservoir though the area it covered was not as extensive [Cox 1895: 305]. A record indited in the Pallava Grantha script was discovered in its vicinity [Venkayya 1903: 206]. Two later inscriptions from the Cōḻa period, found near the reservoir, reveal that its name was Citramēgataṭāka [*South Indian Inscriptions* Vol. 4, No. 137: line 11; No. 138: line 2]. Minakshi has suggested that it was built by Mahendravarman who bore the title Citrākarapuli [Minakshi 1938: 96].

While hydraulic activities under Pallava and Gaṅga-Pallava rule led to the creation of several large reservoirs in the area around Kāñcīpuram, it seems likely that similar activities occurred in roughly the same period in the southern parts of Tamiḻnāḍ which was under Pāṇḍya rule. Nakkan Puḷḷan, a feudatory under the Pāṇḍya ruler Māṟañjaḍaiyan, claims in an inscription found at Rāmanāthapuram, that he improved the reservoir at this site [*South Indian Inscriptions* Vol. 14, No. 26: 23]. Sathianathaiar has identified this ruler with Neḍuñjeḍaiyan and assigned his reign to the period between A. D. 765 and 815 [Sathianathaiar 1955: 156–157]. An inscription by the same ruler was discovered at Mānūr, close to one of the largest reservoirs in the Tinnevelly District [*South Indian Inscriptions* Vol. 14, No. 37: 28–29]. This reservoir, which is about 10 kilometres north of the town Tirunelvēli, was in a very neglected state when the present writer visited it in 1976. Some traces of the riprap which covered the waterface of its large embankment could be detected even then. A record set up by Iruppaikkuḍi Kiḻavan, a feudatory of a king named Śrī Vallabha, is a good indicator of the role that provincial political leaders played in irrigation activity. In this record Kiḻavan lists more than 10 reservoirs which he either constructed or enlarged [*ibid.* Vol. 14, No. 144: 74–75; *Madras Reports* 1929–1930: pt. 2, para 73]. If Śrī Vallabha should be identified with Śrī Māra Śrī Vallabha, as Srinivasan has assumed [Srinivasan 1968: 35], the inscription points to the extensive hydraulic activities that were taking place in the ninth century in that part of South India which is the closest to the shores of Sri Lanka.

An important question which confronts us when we consider the chronological sequence of hydraulic enterprise in Sri Lanka and South India is whether Sri Lankan hydraulic technology, which had previously reached a high point of development, wielded an influence on the irrigation activities of the Pallavas and the Pāṇḍyas. Movements of merchants, monks and migrants provided avenues for close cultural links between South India and Sri Lanka throughout this period. Pallava influence on Sri Lankan culture is evident from sculptures like the famous "Man and Horse" at Isurumuniya and from several Sanskrit inscriptions indited in the Pallava Grantha script.[18] When Mānavamma, a Sri Lankan noble, captured the throne of Anurādhapura at the end of the seventh century with the help of troops provided by the Pallava ruler, political relations between the two kingdoms probably became very close [Geiger 1925 (47): 4–61]. The relations between the Pāṇḍya kingdom and Sri Lanka were sometimes hostile, as when Śrī Māra Śrī Vallabha invaded Sri Lanka in the time of Sena I [*ibid.* (51): 27–45].[19] Sena's successor, who shared his name, joined South Indian powers who were hostile to the Pāṇḍyas to attack Madurai and to place Varaguṇa II on the throne [*loc. cit.*].[20] It would seem that this event helped to place the relations between the Pāṇḍya and the Sri Lankan kingdoms on a closer footing.

The following observations on certain similarities between irrigation technology in South India and Sri Lanka are intended only to serve as a rough guide to further investigation, and it has to be emphasized that the fieldwork on which they are based can by no means be described as comprehensive. It emerged from these preliminary investigations that the irrigation reservoirs of South India and Sri Lanka shared certain basic features. While all these reservoirs were created by constructing earth dams, certain refinements in methods of construction which were introduced in Sri Lanka appear to have been adopted later in South India as well. In both these regions one can often observe that reservoir embankments follow irregular lines, probably suggesting that the designers tried to utilize natural rock formations to serve as foundations for their earthworks.

18) See Paranavitana [1953: 167–190] and *Epigraphia Zeylanica* [Vol. 3: 158–161; Vol. 4: 151–160, 242–246; Vol. 5: 162–169].

19) See also the Sinnamannūr inscription of Śrī Māra Śrī Vallabha [*South Indian Inscriptions* Vol. 3: pt. 3, 461].

20) See also *Epigraphia Zeylanica* [Vol. 2: 25, 38].

It has already been pointed out that, as early as in the fifth centuryA. D., Sri Lankans were aware of the fact that wave-action had an erosive effect on earthwork embankments. They had also recognized that waste-weirs were an essential element for the safety of reservoirs. As in Sri Lanka, in South India the waterface of the embankment was protected with a layer of riprap to counteract the effects of wave-action. The first reference to a waste-weir in a South Indian inscription is to be found at Taṇḍalam, which is situated about seven kilometres from Arkonam, in North Arcot District. According to this record, assigned by Hultzsch to the ninth century, "the Great Pallava King" (*Pallava mahārāya*) had a waste-weir (*kaliṅgu*) constructed for the reservoir at the site.[21] All the large reservoirs mentioned above have waste-weirs. In fact, some of the reservoirs attributed to the Pallavas, like Teṉṉēri, are provided with more than one waste-weir. The similarities noted above, when considered in the light of information on the relative chronology of irrigation enterprises in these two regions, are suggestive of a transfer of hydraulic technology from Sri Lanka to South India. However, since the possibility that at least some of these features may have been the result of independent development cannot be ruled out, further investigation is necessary before such a conclusion can be drawn.

In early times, prior to the appearance of large reservoirs in the kingdoms of the Pallavas and the Pāṇḍyas, it appears that simple methods were used to lead water from the reservoirs to the fields. Apart from cutting the embankment and then rebuilding it between the monsoons, two other main methods can be detected. One was the *ēṟṟam*, or the water-lever, which is called *shaduf* in West Asia and the other was the use of *kūḍai*, or bailing pails. It is probably the use of the *ēṟṟam* which is mentioned in the *Maṇimēkalai* when it speaks of *entiravāvi*, "reservoirs with machines" and *entirakkiṇaṟu*, "wells with machines" [Saminataiyar 1965: 211, 326]. The commentary on this work explains that these machines made it possible to transfer water into or out of the reservoir as and when necessary.[22] The *Maduraikāñci* describes how people of the Pāṇḍya kingdom irrigated their fields from reservoirs with water-levers and pails (see *Pattupāṭṭu* [Chelliah 1962: 237]). The "machines" were probably the same as the *jalayantra* mentioned in the Udayendiram plates of Nandivarman and the Utkal inscription of Rājendra Cōḻa [*South Indian Inscriptions* Vol. 2: pt. 3, 368; Vol.

21) *Ērikkaliṅgum aṇḍattu (ḷ) ōr...* [*Epigraphia Indica* Vol. 7: 26]. The term *kaliṅgu* has been translated by some scholars as "sluice" and it appears that in certain writings on South Indian irrigation the term "sluice" is used indiscriminately to connote "waste-weirs" as well. The following excerpt is one such example: "Sluices are also used for surplus vents. They are usually constructed on the tank bund to permit the flow of surplus water and keep the tank intact from bursting owing to overfulness of water" [Minakshi 1938: 104–105]. See also Srinivasan [1968: 183]. The term *kaliṅgu* is best rendered as "waste-weir" and distinguished from the sluices proper. See *Tamil Lexicon* [Vol. 2: 782].

22) *Vēṇḍum poḻutu nīrai niṟaittaṟkum vēṇḍāmpolutu pōkkutaṟkum uriya yantiraṅkaḷaiyuḍaiya nīrtilai* [Saminataiyar 1965: 326].

3: pt. 1, 15]. At Ukkal, the water-levers were used on "the upper side" of the reservoir. Such early methods of irrigation remained in use even after more suitable devices had been introduced. An undated inscription found at Vēppambaṭṭu in Chingleput District invokes curses on those who would cut the embankments of the reservoir [*Madras Reports* 1947–1948 (No. 92)] and the use of pails for bailing water was prohibited at a reservoir built by Rājamānya Rājaśrī Mullārirāyar [*Annual Reports* No. 280]. An inscription from Taṇṇīrkulam in Chingleput District records that the *mahājanas* of the village agreed not to draw water from the reservoir with water-levers or bailing pails [*Madras Reports* 1944–1945 (No. 17)]. Though the exact date of the inscription is not clear, it carries the implication that some individuals preferred older methods of irrigation, even after better methods had been introduced. The use of the water-lever to draw water from even large reservoirs has continued into modern times, as noted by the present writer at the massive Chembarampākkam reservoir. This reservoir is fitted with modern sluices but, on its upper side, the water-lever is still in use. Both the water-lever and a bailing device worked by three men were being used to lift water from the channels onto the fields. However, such devices are, by themselves, inadequate to regulate the outflow of water from the larger reservoirs, and it is reasonable to assume that the engineers who began to design such massive reservoirs were already aware of some form of sluice mechanism. There is clear evidence to suggest that sluices which could be opened at will were in use by the time of Kampakavarman, a ruler of the later Pallava dynasty. An inscription dated in the reign of this ruler records a donation of 1,000 *khāḍi*[23] of rice which was entrusted to the committee in charge of the supervision of irrigation reservoirs in the rural assembly at Ukkal with the proviso that interest on it, calculated to be 500 *khāḍi* per year, was to be used for the maintenance of the reservoir at this village. The assembly decided that it would "close the reservoir" each year to collect the interest, the implication being that irrigation water would not be released from the reservoir if the interest on seed-paddy loaned out to cultivators was not duly paid (*Verikaṭṭi ikuttuvippomāṇom*...[*South Indian Inscriptions* Vol. 3: pt. 1, 9]). Corroborative evidence on reservoirs equipped with sluices is to be found in an inscription from Guḍimallam, dated in the 49th year of the later Pallava ruler Dantikavarman who, as noted earlier, probably lived in the ninth century. If we accept the chronology proposed by Nilakanta Sastri [Nilakanta Sastri 1955: 163], the inscription has to be assigned to A. D. 844. It records that a field named Nandikuṇḍil, irrigated by the reservoir Tūmbaṇēri, was donated for the maintenance of another reservoir called Vellēri. The income from the field was to be used "to dig pits" in the Vellēri reservoir and to deposit the earth thus removed from the reservoir on its embankment [*Epigraphia Indica* Vol. 11: 225]. Venkayya noted that the name Tūmbaṇēri meant "reservoir with sluice" [Venkayya 1903: 205]. The term *tūmbu* may

23) *Khāḍi* was a measure equivalent to 16 *droṇa* = 64 *āḍhaka* = 4096 *prastha*. Apte [1978: 321] suggests that 1 *āḍhaka* was "nearly 7 lbs. 11 ozs." (i.e. 3,494 grammes).

be taken as a variant of *tūmpu* for which the *Tamil Lexicon* gives, among others, the meanings "a sluice" and "vent in a sluice" [*Tamil Lexicon* Vol. 4: 2018]. In the Tamil epic *Cīvakacintāmaṇi* the term *tūmpu* occurs in association with *kuḷam* (reservoir) and both terms are used as metaphors. In this context the term "reservoir" alludes to the human body and "sluices" to it orifices [Sōmasundaram 1959: pt. 2, 1560, *V.* 2760]. Gnanamurthy, who has made a detailed study of this literary work, assigns its composition to the end of the ninth century or the beginning of the tenth [Gnanamurthy 1966: 12].

The term *tūmbu* and its variants occur in several later inscriptions from the Tamiḻnāḍ area. An inscription from Paraṉūr in South Arcot, dated in the 24th regnal year of the Cōḻa ruler Rājakesarīvarman, records an endowment created by a donation of land in order to maintain the sluice (*tūmbaḍai*) at the Puttēri reservoir in proper repair [*Madras Reports* 1935–1936 (No. 62)]. According to another inscription found at Ēlambākkam in Chingleput District, issued in the 39th year of Kulottunga Cōḻa (A. D. 1109), a certain Uyyavandān constructed a sluice (*tūmbu*) [*Madras Reports* 1947–1948 (No. 45)]. Similarly, an undated Vaṭṭeluṭṭu inscription from Viṉṉapaḷḷi in Coimbatore District records that a lady named Kōvaḍikāmi set up a stone *tūmbu* [*Madras Reports* 1935–1936 (No. 107)].

It is interesting to note that the term used in these records bears a close resemblance to *tumba*, the term used in the fifth-century Sri Lankan writings to denote the same hydraulic device [Takakusu & Nagai 1969: 344]. This similarity led the writer to expect that the cistern sluice developed previously in Sri Lanka may have influenced the development of hydraulic technology in South India. However, the field data collected by the present writer in South India did not contain any instances of the Sri Lankan cistern sluice being incorporated into the reservoirs built by the Pallavas or the Pāṇḍyas. At the major reservoirs from Pallava times examined by the author, no remains of old sluices could be found as they had been replaced with modern devices. In this context, some of the old sluices which are still to be found at reservoirs in the Rāmanāthapuram and Tinnevelly Districts of Tamiḻnāḍ are of particular interest. Of all the districts in Tamiḻnāḍ, these two are the closest to the shores of Sri Lanka, and inscriptions of the Pāṇḍya dynasty have been found in both these districts. Remains of old sluices were examined at six of the reservoirs in these two districts. Of these reservoirs Mānūrkulam is to the north of Tirunelvēli while Śevilippēri (Sivalappēri) is to the northeast of this town. The Nānguṉēri and Vijayanārāyanam reservoirs are in the Nānguṉēri *taluk* of Tinnevelly District. The fifth reservoir is located immediately to the south of the town of Rāmnāḍ in Rāmanāthapuram District while the sixth is situated by the road to Madurai, about five kilometres north of Rāmnāḍ.[24] The sluices at all these reservoirs represent variations on a specific and highly distinctive type of sluice mechanism.

A feature common to all the sluices at these

24) The following descriptions are based on author's field notes (April 1976).

six reservoirs which distinguishes them from the cistern sluices of Sri Lanka is that the inlets of the sluice barrels and the regulating mechanisms are located not in the embankment but on the beds of the reservoirs. In fact, the regulating mechanism is located at such a considerable distance from the embankment that access to it would have been possible only by boat. This characteristic feature of South Indian sluices may provide at least part of the explanation for a practice mentioned in several epigraphic records. It is evident from these records that boats were maintained at reservoirs [*Madras Reports* 1902/1903 (Nos. 342, 343); *South Indian Inscriptions* Vol. 3: pt. 1, 15]. While such boats were also used for desilting operations, they were essential to gain access to the sluices and to regulate the outflow of water from the reservoirs. It is likely that there were strong reasons which made the designers opt for this specific form of layout despite the resulting inconvenience in the operation of the sluices. The further away from the embankment the regulating mechanism was installed, the more difficult it would have been for water-thieves to surreptitiously operate it, particularly if the boat was removed when not in use. In Sri Lanka the location of the cistern sluice in the waterface of the embankment created a serious problem since the stability of the embankment was always in danger of being undermined by seepage of water from the cistern. Though the engineers who built these reservoirs directed much effort at preventing such seepage, it is very common to find at many breached reservoirs that the breach occurred at the very place where a sluice had been located. The need to protect embankments from seepage may have been a compelling reason for the South Indian engineers' decision in favour of this type of sluice.

At five of the reservoirs mentioned above the site of each sluice is marked by two well-cut stone columns (Plate 1) which can be easily detected from a distance. At the reservoir to the north of Rāmnāḍ bricks are substituted for stone, but the other features of the sluice are basically the same. The craftsmen who produced the stone columns took great pains to give the columns an elegant appearance. Those at the Mānūr reservoir

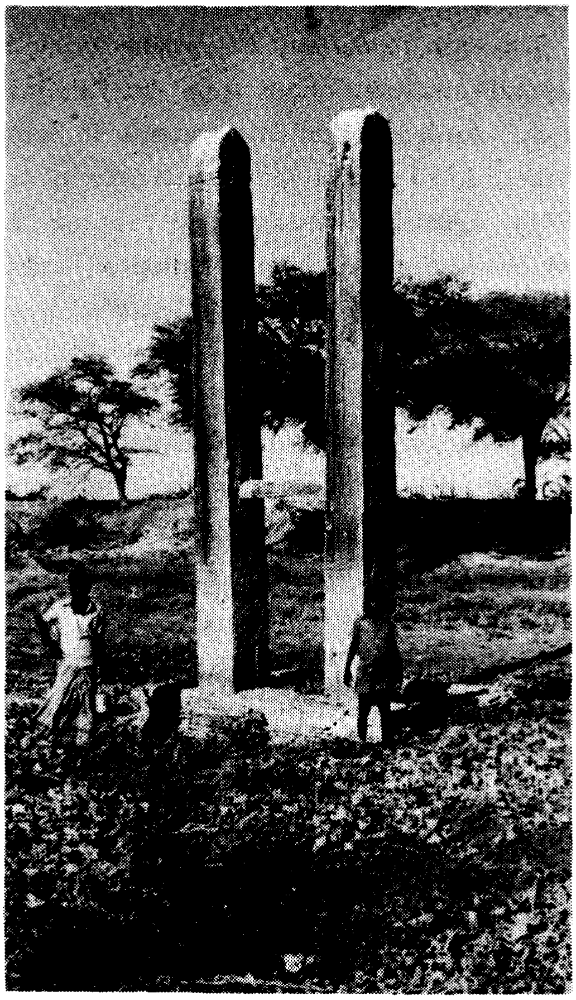


Plate 1 Stone Columns of the Sluice at the Reservoir to the South of Rāmnāḍ

are ornamented with intricately carved designs. These sets of columns are of varying height, depending on the depth of each reservoir at full supply level and the specific location of each sluice. At the reservoir to the south of Rāmnāḍ, one set of columns is about six metres tall while another group, located on higher ground, is shorter. At one of the sluices at the Vijayanārāyanam reservoir, the columns measured 40.5 by 33 centimetres in cross-section and appeared to be about six metres tall. More detailed measurements were obtained at another sluice at the same reservoir. It had shorter columns which were 44 by 23 centimetres in cross-section and 238 centimetres high from ground level.

Of the two sluices at the Vijayanārāyanam reservoir mentioned above, the columns at the bigger sluice were erected 140 centimetres apart while at the other sluice they were 132 centimetres apart. At one of the sluices of the Mānūr reservoir the columns were 145 centimetres apart and mortices had been cut into the inner sides. A stone slab, about 145 centimetres long, 51 centimetres wide, and 28 centimetres thick, with tenons to fit the mortices, was found by the Mānūr sluice. The slab had a circular aperture, 14 centimetres in diameter, located in the middle.

Originally there were three such slabs mounted on the columns, more or less equidistant. The lowest, which was still in place, was level with the bed of the reservoir. It would seem that a cylindrical pole, lowered through the apertures in the series of stone slabs, formed an important element in the sluice mechanism. Since no remains of such poles have been preserved at any of the sluices mentioned above, it seems most likely that they were made of wood.

On examining the sluices mentioned above, it was found that usually there is a rectangular enclosure, built of stone or brick, at the base of each set of columns. At the Mānūr sluice the inside measurements of the enclosure were 400 by 152 centimetres. Its exact height could not be determined due to the presence of a hardened layer of silt on its floor, but it appeared to be over one metre. The outlet conduits, which had been laid in the bed of the reservoir and across the base of its embankments, connected the enclosure with the channels outside. On examining the sluice at the reservoir to the north of Rāmnāḍ, it became clear that the sill of the sluice was above the outlet conduit. Presumably, the primary function of the enclosure was to minimize the risk of the sluice being clogged by silt and debris, but it is likely that the enclosure had to be regularly cleaned to maintain the sluice in good working order.

The sluice found at the reservoir to the north of Rāmnāḍ is of particular importance since it provides additional information which enables us to understand the manner in which the sluice mechanism functioned. Stone slabs, each with a circular aperture, had been mounted on a brick structure which incorporated the columns as well as an enclosure the inner sides of which measured 120 centimetres square. On the walls of the enclosure, in between the columns, is a recess about 50 centimetres wide and 60 centimetres deep (Plate 2) which is divided into two sections by a horizontally placed stone slab with two apertures. Below this slab the width of the recess narrows to about 35.5 centimetres. One of the apertures in the

Plate 2 Sluice at the Reservoir to the North of Rāmnāḍ: The Sluice Mechanism

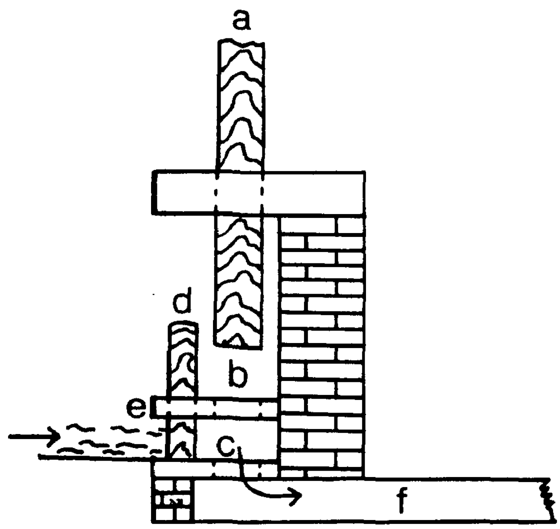


Fig. 1 Sluice at the Reservoir to the North of Rāmnāḍ. The drawing demonstrates the layout of the sluices mechanism. The outlet conduit (f) is placed below the sill of the sluice. The outflow of water could be regulated by lowering the piston (a) through the circular apertures (b, c) till it rested on the floor of the outlet conduit. When the level of water in the reservoir fell below point e, a wooden slab (d) lowered through the rectangular aperture of the stone slab (e) could be used as an alternative regulating device.

stone slab is circular, 22 centimetres in diameter, and is in line with the circular apertures on the slabs mounted above it on the two columns. The second aperture is rectangular and measures 35.5 by 15 centimetres. Looking down through the circular aperture it was possible to observe that there was yet another circular aperture of about the same size on the floor of the enclosure. Through this lowest aperture water could flow from the enclosure to the outlet conduit below it (Fig. 1f). By lowering a cylindrical pole of matching cross-section through these circular apertures, it would be possible to stop the flow of water into the outlet conduit. Thus the sluice would remain closed as long as the pole remained lowered and would permit the passage of water when it was raised above the lowermost aperture (Figs. 2 and 3). The fact that the pole passed through the apertures in a series of three slabs mounted on the columns would ensure that it was in close alignment with the lowermost aperture.

It will have been evident from the preceding description that these sluices were operated with a "plugging device" or what may be termed a piston-valve. The efficiency of the piston-valve would depend on the precision with which the dimensions of the piston matched those of the aperture. Raising the piston would not have been an easy task unless

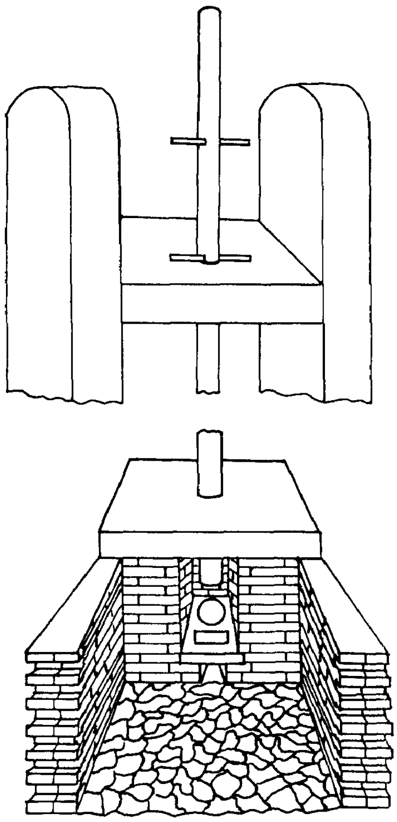


Fig. 2 Conjectural Drawing Demonstrating the Operation of Piston Sluices: Open Position

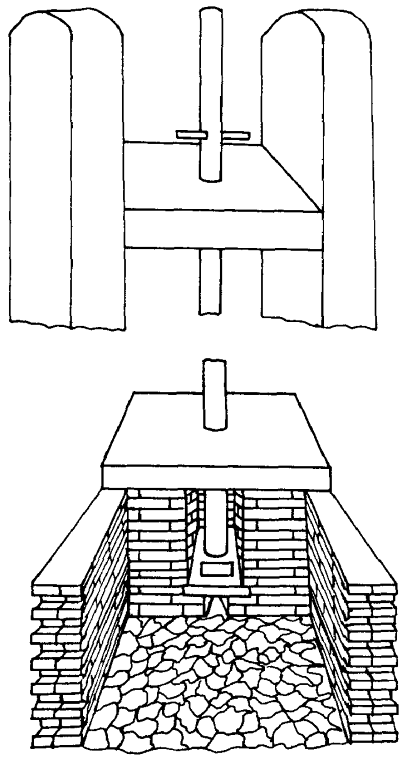


Fig. 3 Conjectural Drawing Demonstrating the Operation of Piston Sluices: Closed Position

its shaft had horizontally bored holes. Batons passed through such holes would have facilitated the operation of the pistons, and by resting such a baton on one of the upper stone slabs it would have been possible for the operators to keep the piston in a raised position and thus allow the sluice to remain open. It is possible to suggest that the stone slabs mounted on the columns not only kept the pistons in proper alignment but also facilitated the task of keeping the sluice open (Fig. 2). When the level of water in the reservoir fell below that of the slab with the additional rectangular aperture, it is likely that the piston was kept raised, and that the outflow of water was regulated with a slab of wood inserted through the rectangular aperture (Fig. 1d).

An obvious disadvantage of the piston sluice was that the volume of water it could handle was relatively low. Of the sluices examined by the author the one at the reservoir to the north of Rāmnāḍ had the largest piston. However, the area of its outlet aperture amounted to only about 410.5 square centimetres, which is quite meagre when compared with the measurements of the outlets of sluices at Sri Lankan reservoirs such as Nāccadūva (2,475 square centimetres), Vāhalkaḍa (4,400 square centimetres) and Nuvaravava (Northern Low Level Sluice: 9,900 square centimetres). Any increase in the size of the outlet apertures of South Indian sluices had to be accompanied by a corresponding increase in the size of the piston. The larger and heavier the piston, the more formidable would be the task of operating it. Thus there appears to have been an almost invariable upper limit on the volume of water that each piston-valve could regulate.

One might suggest that the builders of some of the larger South Indian reservoirs were aware of this disadvantage and that they tried to circumvent it. One of the means they adopted was to mount two piston-valves side by side within each sluice. Three stone slabs, 141 centimetres long, 39 centimetres wide and 27 centimetres thick, were mounted on the stone columns at one of the sluices at the Vijayanārāyanam reservoir. These slabs had not one but two circular apertures, each slightly less than 13 centimetres in diameter and 15 centimetres apart (Plate 3). Similar slabs with two circular apertures were mounted on the columns of a smaller sluice at the same reservoir. It is evident from these arrangements that the engineer who designed the Vijayanārāyanam reservoir placed two piston-valves in each of these sluices. However, it is worth noting that he utilized pistons of a convenient and not very large size, and that, even with this novel arrangement, the total area of the outlets in each sluice could not have been very much more than 250 square centimetres. Another solution to the problem was to increase the total number of sluices at each reservoir. An eighth-century inscription from Kāmevahaḷḷi refers to a reservoir with eight sluices [*Epigraphia Carnatica* Vol. 10, No. 11: 2–3]. Once a certain number of sluices are installed in a reservoir, the resultant complex of conventions and institutional arrangements regarding the distribution of water tend to discourage changes in that number. This may explain why, even after new and efficient types of sluices were introduced in modern times, certain South Indian reservoirs continued to have many more sluices than Sri Lankan reservoirs of comparative proportions. The Ālampākkam reservoir, which now irrigates only about 25 hectares, has four sluices. There are eight sluices at Chembarampākkam, 10 at Kāverīpākkam, 13 at Uttaramallūr and 23 at Vīranām.

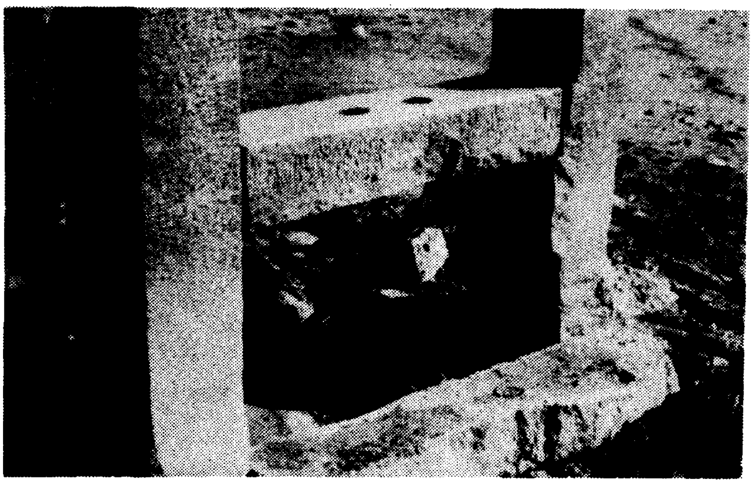


Plate 3 Detail from the Sluice with the Shorter Columns at the Vijayanārāyanam Reservoir. Note the two apertures on the horizontal slab.

The piston sluices described above are all from the southern part of Tamiḻnāḍ. Further investigations, more comprehensive than those the author could undertake, would be necessary before any definite conclusions could be drawn on the distribution of this type of sluice. However, it seems likely that at some time in the past the piston sluice was widely known in Tamilnāḍ, for a similar type of sluice it to be found even beyond the northwestern borders of this region, at places like Mysore and Hoskote in Karṇṇāṭaka State. The Hoskote reservoir is situated about 25 kilometres from Bangalore, on the road to Kolar. Its sluices are of particular interest since they are still in use, albeit with some modifications. The one examined by the writer has four stone columns, about 30 by 35.5 centimetres in cross-section, all connected at the top with cross-beams so that they form parts of a single structure (Plate 4). Another feature which distinguishes this sluice from those found in the southern part of Tamilnāḍ is that it is located much closer to the embankment of the reservoir. In fact, a pathway formed of stone slabs supported on brick-built columns links the sluice with the embankment. In spite of these differences, it is easy to recognize in the Hoskote sluice a variation on the same basic type of piston sluice observed in Rāmanāthapuram and Tinnevelly Districts. Two sets of stone slabs are mounted on the four columns of the Hoskote sluice and, as at Mānūr and Rāmnāḍ, each slab has a circular aperture in the centre. Thus it appears that two sluice-valves were fitted within the Hoskote sluice, not side by side as at Vijayanārāyanam, but one in front of the other.

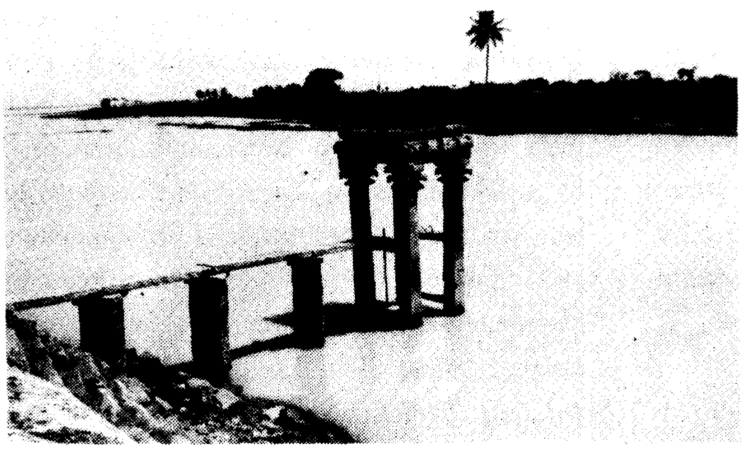


Plate 4 Sluice at the Hoskote Reservoir. Note the stone slabs placed on brick-built columns which provide access to the sluice from the embankment.

My preliminary investigations point to the hypothesis that the piston sluice enjoyed wide popularity in South India. It was probably the most common device used to regulate the distribution of water from large irrigation reservoirs. Inscriptions of the Pāṇḍya rulers have been found at five of the villages where reservoirs with piston sluices are located. An inscription from the time of Māṟañjaḍaiyan (Neḍuñjeḍaiyan) found at Rāmnāḍ, records that one of his feudatories, named Nakkan Puḷḷan, began constructing a reservoir at the site and that it was completed by his son [*South Indian Inscriptions* Vol. 14, No. 26: 23]. It is possible that the inscription refers to the reservoir to the south of the present town. Another inscription of Māṟañjaḍaiyan has been found at Mānūr [*ibid.* Vol. 14, No. 37: 28–29]. It is also likely that Śaḍaiya Māṟan, whose inscriptions are found at Vijayanārāyanam and Śevilippēri, should be identified with the same ruler [*ibid.* Vol. 14, No. 67: 45–46; Vol. 14, No. 71: 47]. The last three inscriptions do not refer to the reservoirs at the sites. The earliest reference to the Vijayanārāyanam reservoir, which was called Manōmayaṉēri at the time, is from the 12th year of a king named Jaṭāvarman Śrī Vallabha [*ibid.* Vol. 14, No. 231: 134–135]. One possibility is that this ruler was the same as Śrī Māra Śrī Vallabha who ruled from 815 to 862. However, it seems more likely that he was a contemporary of Jaṭāvarman Sundara Pāṇḍya (1251–1268) and Jaṭāvarman Vīra Pāṇḍya (1253–1275) and that he was one of the five brother kings who are said to have ruled at the time [Cordier 1926: 331].[25] It is noteworthy that, according to the Vijayanārāyanam inscription, the reservoir was constructed much earlier. In fact, Nambi Śankaran, the local administrator who issued the inscription, states that he found the reservoir breached and that he completed the repairs to it [*South Indian Inscriptions* Vol. 14, No. 231: 134–135].

It is fairly reasonable to assume that a certain type of sluice had come into use by the time the large reservoirs mentioned above were constructed in those parts of Tamilnāḍ which were ruled by the Pallavas and the Pāṇḍyas. It is further likely that the area under Koṅgu rule also witnessed progress in irrigation activity during the same period. One of the earliest inscriptional references to *tūmbu* comes from a Koṅgu record from Rāmevahaḷḷi [*Epigraphia Carnatica* Vol. 10: 2–3]. Unfortunately, the information from inscriptional and literary sources from South India is not specific enough to enable us to determine whether it was the piston sluice described above that was in use in these early times. In this respect, evidence from certain literary works preserved in Sri Lanka is particularly useful. The Sudhīna Jātaka in the Theravāda collection of stories about the previous incarnations of the Buddha contains a mnemonic verse which includes the phrase *imaṃ nikkhaṃ sukuṇḍalaṃ* [Fausboll 1963: 358–359]. In the Theravāda canon, the term *nikkha* generally denoted "a golden ornament for the breast or neck" or "a ring" while the term *kuṇḍala* was used in the sense of "an earring."[26] However, the *Jātakaṭṭhakathā*, the exegetical work on the mnemonic verses in the Jātaka collection, gives a different explanation. The author of this commentary states that he composed it at the request of three monks, Atthadassi, Buddhamitta and Buddhadeva [Fausboll 1962: 1]. In his *Papañcasūdanī* Buddhaghosa refers to a monk named Buddhamitta, who lived at Mayūrapaṭṭana in India, as the person who prevailed upon him to undertake this work [Dhammakittissiri 1926: 1029]. It has been suggested that Mayūrapaṭṭana was in South India.[27] If the monks known by the name Buddhamitta, mentioned in the *Papañcasūdanī* and the *Jātakaṭṭhakathā* were identical, it would imply that the latter work was composed by a contemporary of Buddhaghosa and that he was probably living in South India. Malalasekera believed that both these references were to the same monk, and he in fact suggested that the *Jātakaṭṭhakathā* was written by Buddhaghosa [Malalasekera 1960: 309]. However, this identification is by no means certain. It can be argued that religious ideas held by the author of the *Jātakaṭṭhakathā*, such as his belief in Maitreya,

25) Marco Polo speaks of five brother kings in his description of the Pāṇḍya kingdom: "You must know that in this province there are five kings, who are own brothers" [Cordier 1926: 331].

26) See Rhys Davids & Stede [1959: 220, 353].

27) See Buddhadatta [1960: 173–174].

suggest that he was distinct from Buddhaghosa and probably a later writer.[28] It is interesting to note that this commentator explains the term *nikkha* as a sluice (*udakaniddhamanaṃ*). He further explains *sukuṇḍalaṃ*, the last word in the phrase from the mnemonic verse, as *musala-pavesana-kuṇḍalena samannāgataṃ* [Fausboll 1963: 358–359]. *Musala* is a common term in both Pāli and Sanskrit which denotes "pestle," and the whole phrase may be translated as "fitted with a ring (i.e. circular aperture) through which the pestle was inserted." The description leaves little doubt that the sluice the commentator had in mind was of the piston-valve type. It is evident that the piston was referred to as "the pestle," and certainly the resemblance would have been striking. In the Sinhala gloss on the *Jātakaṭṭhakathā*, which has been assigned to the time of the Polonnaruva kingdom, the term *rajamohol*, which literally means "royal pestle" or "king's pestle," was used to denote the piston while the term *bisōkoṭu*, which means "queen's enclosure," was used to denote the circular aperture (*kuṇḍala*) of the sluice-valve.[29] It would thus appear that the term *bisōkoṭuva*, which in more recent times, came to be applied to the cistern of Sri Lankan sluices, originally denoted the valve-apertures of the piston sluices. Several etymological explanations of the term have been given by modern writers, but it is clear from the Sinhala gloss on the *Jātakaṭṭhakathā*, where it occurs for the first time, that the origin of the word has probably to be traced to the sexual metaphors of peasant humour.

The testimony of the *Jātakaṭṭhakathā* strongly attests to the antiquity of the piston sluice, and one might suggest that it was the type of sluice known in the time of the Pallavas and the Pāṇḍyas. It is possible that the piston sluice came into use long before the large reservoirs were built. In fact, its low capacity, mentioned earlier, suggests that it was originally used in smaller reservoirs. In this connection, it is noteworthy that the *Çilappadikāram*, one of the later works in the Śangam cycle, contains the terms *mataku* and *ō* which, in subsequent times, came to denote "sluice" [Sāminātaiyyar 1968: 204, 275]. Nilakanta Sastri has assigned this work to a time slightly later than the fifth century [Nilakanta Sastri 1955: 112]. It is most interesting to note that the evidence in the Sinhala gloss on the *Jātakaṭṭhakathā*, implies that the South Indian sluice was known to Sri Lankans. The *Pūjāvaliya*, a Sinhala book on Buddhism of a popular nature written in the thirteenth century, also contains a reference to piston sluices [Saddhātissa 1930: 417]. The Buddhists of Sri Lanka maintained close relations with South Indian centres of Buddhism, and it is but to be expected that the knowledge they thereby acquired about irrigation practices in that area would be reflected in their writings. Perhaps the implications of this evidence extend further. There is at least one inscription from the tenth century which seems to suggest that the piston sluice was something more than hearsay to Sri Lankans. The phrase *mohol nañgā* occurs in the Vessagiri inscription where Mahinda IV spec-

28) See Fausboll [1964: 594–596].

29) *Jātakaṭṭhakathā Granthipadavarṇṇanā*, published under the title *Jātaka Aṭuvā Gāṭapadaya* [Heṭṭiāracci & Rammañḍala 1960: pt. 2, 94].

ifies in detail the arrangements he instituted for the distribution of water from the Tissa reservoir at Anurādhapura [*Epigraphia Zeylanica* Vol. 1: 33]. The phrase was left untranslated by Wickremasinghe who published this inscription. He appears to have assumed that it was a proper name. The term *naṅgä* occurs in the sense of "raising" in the tenth-century work called *Dhampiyā Aṭuvā Gäṭapadaya* [Jayatilaka 1932: 260]. The phrase *mohol naṅgä* may be translated as "having raised the piston." This rendering is in accord with the meaning of the rest of the passage which may be translated as follows: "Having raised the piston, water should be allowed to flow without interruption until the top of the stone erected near the inlet of the sluice to mark the water-level of four *riyan* becomes visible."[30] If this interpretation is correct, it would imply that a piston sluice was in operation at this particular reservoir in the tenth century. However, if there was such a transfer of technology, its effect appears to have been limited. Columned sluices of the type found in South India have not been reported in Sri Lanka. On the other hand, the cistern sluice was clearly the most popular type of sluice on the island.

The question of whether the Sri Lankan cistern sluice exerted an influence on the development of South Indian irrigation was one which the writer had in mind during the course of his fieldwork in South India. No sluices of the cistern type were found at any of the Pallava and Pāṇḍya reservoirs examined by the author or, with one exception, at any of the many later reservoirs examined during several successive visits. It was a very exciting experience to discover a cistern-type sluice at one reservoir which may be assigned to the period of Cōḻa rule. This reservoir is located not far from the large and ornate temple at Gaṅgaikoṇḍacōḻapuram, the new city built by Rājendra I. By the time this city was built Rājendra had evidently completed the conquest of the northern plains of Sri Lanka, which had been invaded earlier in the time of his father Rājarāja I. The reservoir, which is called Poṇṇēri at present, is rather neglected, but it irrigates about 637 hectares. The author first noticed the sluice in April 1976 and made two subsequent visits to the site to gather field data. The cistern is visible from the road which connects Gaṅgaikoṇḍa-cōḻapuram with Jayakoṇḍacōḻapuram (Plate 5). According to the villagers, an attempt was made to dismantle the old sluice in 1973 when a new sluice was installed, but, fortunately for students of history, this proved too formidable a task and it was decided to merely block its inlets.

Unlike the piston sluices described in the preceding paragraphs, this sluice is built into the embankment of the reservoir, and, in this respect as well as the basic aspects of design, it is similar to the cistern sluices of Sri Lanka. At none of the Sri Lankan sluices has the valve-mechanism been well preserved, and the information these sluices provide is not adequate to form an idea of the actual manner in which the valves functioned. The information from the Poṇṇēri reservoir is particularly useful since the entire structure of the

30) *Mohol naṅgä radsoro pereṭä satara riyanak diyaṭ hinduvū diyakaṭā pahaṇ munduna (pä) nenatāk ḍahak nätivä diya pavatvanu...* [*Epigrahia Zeylanica* Vol. 1: 33, lines 17–18].

Plate 5 The Cistern Sluice at the Poṇṇēri Reservoir

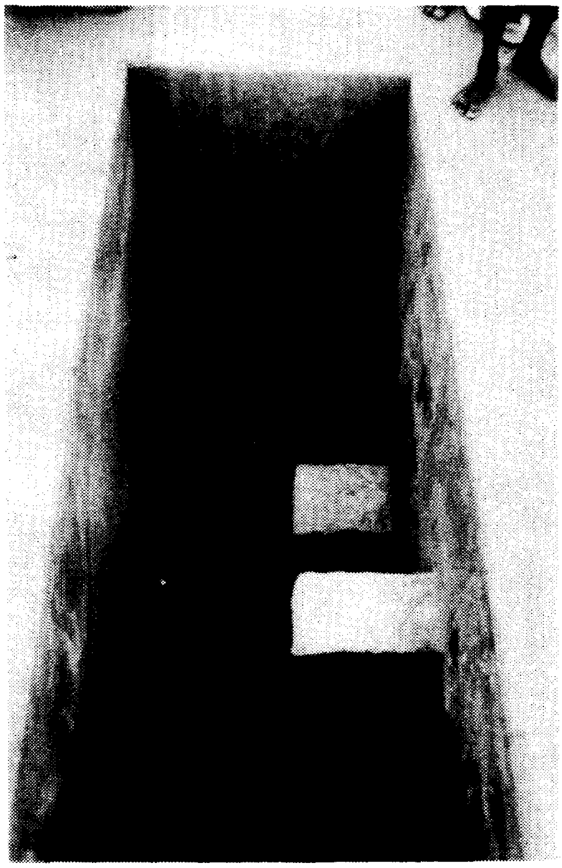
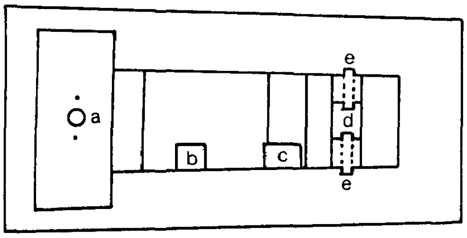


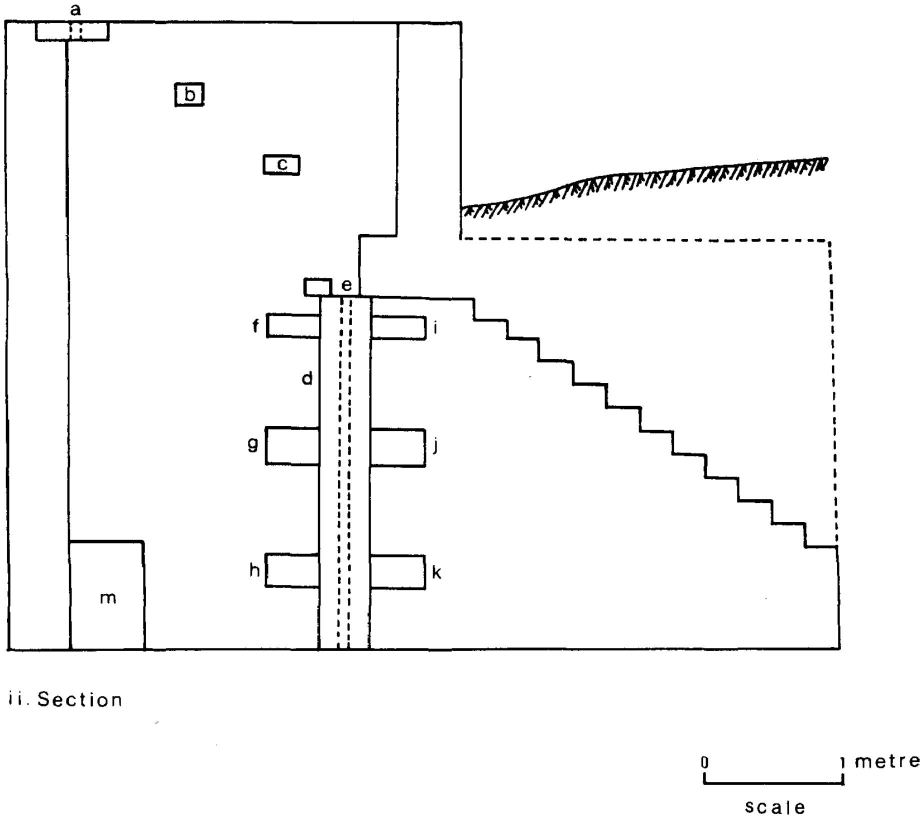
Plate 6 The Interior of the Poṇṇēri Sluice

sluice was constructed of brick and stone and has been fairly well preserved.

The cistern consists of a brick wall, rectangular in plan and of varying width, measuring about 45 centimetres at certain places (Plate 6). The longer side is about 297 centimetres. The shorter sides are not of the same length. The side facing the reservoir measures 80 centimetres. While the opposite side is only 63.5 centimetres. The depth of the cistern is about 450 centimetres. Up to a height of about 245 centimetres from the sill the inside walls of the cistern are faced with stone while, above this level, they are covered with a thick layer of a type of plaster. On reaching the floor of the cistern, it becomes clear that it extends much further into the embankment of the reservoir than is evident to a person looking down from the top of the wall (See Fig. 4.ii). Thus the length of the floor is about 5.5 metres, about double the length of the longer side of the top of the cistern. At the inlet end of the floor of the sluice is what appears to have been a block of stone, 53 centimetres wide and 81 centimetres deep, connecting the two longer walls of the cistern. It shows signs of having been covered with concrete in more recent times, probably in 1973, and hence the inlet is not functioning at present. The main element in the regulating mechanism housed inside the cistern is a pillar of stone, about 38 by 23 centimetres in cross-section and about 1.86 metres high (Fig. 4d) which is held in place by six cross-



i. Plan



ii. Section

Fig. 4 Plan (i) and Section (ii) of the Cistern Sluice at the Poṇṇēri Reservoir

beams (Fig. 4f–k). Grooves about 7.5 centimetres wide have been cut on either side of the pillar and there are corresponding grooves in the stone slabs built into the walls of the cistern (Fig. 4e). By inserting two sets of stone slabs through these grooves, it would have been possible to close the sluice. Access to this regulating mechanism was provided by two steps (Fig. 4b, c) which lead down from the top of the cistern. On moving along the floor of the cistern, beyond the regulating mechanism and towards the outlet, one notices that the roof gradually diminishes in height and the outlet aperture is only 76 centimetres high.

In several ways, the sluice at the Poṇṇērī reservoir marks a radical departure from the other sluices at the South Indian reservoirs mentioned above. The use of a cistern type device, the location of the regulating mechanism within the embankment rather than on the bed of the reservoir and the higher capacity of the outlet conduit are features which reveal kinship with the cistern sluices of Sri Lanka. The location of the gantry midway across the floor of the sluice reminds one of the plan of the sluice found at the Māduru Oya reservoir in Sri Lanka.[31] Since no remains of such gantries, which were made of wood, have been preserved in Sri Lanka, the information provided by the Poṇṇēri sluice about the manner in which the outflow of water was regulated with slabs inserted into vertical grooves is particularly useful in helping us to understand how the cistern sluices functioned.

The construction of the Poṇṇēri reservoir probably has to be dated in the time of the foundation of Gaṅgaikoṇḍacōḻapuram, which Rājendra intended to be his capital. In his history of the Cōḻas, Sadāsiva Maṇḍārattār identifies Poṇṇēri with the Cōḻagaṅgam reservoir mentioned in the Tiruvālaṅgādu inscription of this king [Sadāsiva 1974: 557; *South Indian Inscriptions* Vol. 3: pt. 3, 400, lines 246–247]. If this was indeed the case, it is to be expected that the Cōḻas, who had brought the northern plains of Sri Lanka under their control, had acquired a close acquaintance with the system of irrigation which was at the height of its development on the island. It should not be surprising to find that the irrigation engineers working for Rājendra would attempt to incorporate some of the irrigation devices which were in use in Sri Lanka. Further exploration would be necessary before it would be possible to make a detailed assessment of the influence of the cistern sluice on South Indian irrigation. Even in the case of the Poṇṇēri sluice, it has to be emphasized that the cistern sluice was not borrowed *in toto*, but certain noteworthy modifications were made. The cistern is much smaller than those found in Sri Lanka, and, as pointed out earlier, its lower parts were designed differently. In Sri Lankan sluices, it is the longer sides which are parallel to the embankments while, at Poṇṇēri, the longer sides are at right angles to the embankment. The sluice was probably the work of a South Indian, rather than Sri Lankan, technologist. Evidently, a further modification was introduced, probably at a later time. On the inlet end of the cistern, a stone slab with a single circular aperture was built into the top of the wall in such a manner that it would be possible to lower a piston through it. Most probably the block on the floor of the cistern which had been recently covered, originally housed the circular valve-aperture into which the piston was lowered (Fig. 4a, m). Thus it appears that the cistern was modified to house a piston-valve sluice. The piston-valve served the same function as was originally served by the slabs inserted through the grooves in the gantry. The modifications in the inlet of the cistern to accommodate the piston-valve would have radically reduced the water-handling capacity of the sluice, far below the level which can be inferred from the size of the outlet orifice. It is most unlikely that the original designer would have incorporated two types of valves with different handling capacities within the same sluice. Hence it is tempting to suggest that the insertion of a piston-valve within a cistern sluice represented

31) This sluice was excavated by Mr. D. Fernando. The author is grateful to Mr. K. A. Tilakaratna for making it possible to examine this sluice.

an attempt on the part of the people of the locality to revert to an irrigation technology they were more conversant with or, in other words, that it amounted to a rejection of the "imported technology" of the period of Cōḻa rule.

It will have been evident from the preceding discussion that the migration of megalithic folk probably constituted an important factor in the diffusion of hydraulic technology in proto-historic times. The widespread reliance on reservoir systems of irrigation and the preponderance of minor-scale reservoirs in both South India and Sri Lanka reflect the deep impact of these proto-historic contacts. The transition from the initial phase of irrigation activity represented by minor-scale reservoirs to the mature phase, which saw the appearance of large-scale irrigation works, took place in Sri Lanka earlier than in South India. This raises the possibility of a reverse flow of technology from Sri Lanka to South India in the time of the Pallava and Pāṇḍya kingdoms when a similar transition took place in this region. A folk-tale concerning the Kashmiriān king Jayāpīḍa perhaps reflects the fact that Sri Lankan irrigation technology was held in high regard even in the northernmost regions of India. According to this story, preserved in the *Rājataraṅgiṇī*, Jayāpīḍa sent an envoy to Laṅkā to bring back five *rākṣasas* and, with their help, had a lake and several other works constructed within his kingdom [Stein 1961: 167, *taraṅga* 4, *vv.* 503–509]. It is possible that some of the similarities between the structural elements of large reservoirs in South India and Sri Lanka represent the results of the influences of Sri Lankan hydraulic technology. Similarly, as noted above, the influence of certain aspects of South Indian technology can be traced in Sri Lanka. It is important to note, however, that the development of hydraulic technology in these two regions cannot be explained merely in terms of diffusion. In fact, in historical times, the intersocietal transfer of technology between South India and Sri Lanka does not appear to have been as extensive as one would be led to expect by the proximity of the two regions.

Large-scale irrigation activity had demographic implications. The construction of a large irrigation work was tantamount to the creation of preconditions for a future concentration of population in that particular region.[32] Since population resources were perhaps the primary determinant in the political struggles of those times, it is not very likely that kings would have encouraged the transfer of hydraulic technology to neighbouring kingdoms. The Sinhalese chronicle *Pūjāvaliya* contains a legend about King Gajabāhu who is said to have become wrathful on being informed that people from his kingdom went to work on the Kāvērī. According to this legend, he invaded South India to bring them back and then issued a proclamation forbidding Sri Lankans to go to work on the Kāvērī [Suravīra 1961: 93]. Though the historicity of this invasion is open to question, it seems likely that the legend reflects the opposition of Sri Lankan rulers to their subjects going to work on South Indian irrigation projects. It is quite possible that, especially the more capable irrigation tech-

32) For a discussion on the influence of demographic considerations on irrigation activity, see Gunawardana [1981].

nologists, were discouraged, if not actually prevented, from offering their services to the neighbouring kingdoms. This may partly explain the limitations on the diffusion of the Sri Lankan sluice technology. While certain elements of hydraulic technology, like the use of riprap which would be evident even to a casual observer, could be easily borrowed, the services of an expert were essential for the construction of a cistern sluice. It is significant that the only cistern-type sluice found so far in South India dates from a time when the northern plains of Sri Lanka had come under Cōḻa dominance. It is further noteworthy that even the sluice at Poṇṇēri appears to be the work of a South Indian, rather than Sri Lankan, technologist. Institutionalized arrangements for water-management, entrenched in tradition for many centuries, may have discouraged the acceptance of an innovation like the cistern sluice which would radically alter the pattern of water distribution. In addition to political rivalry and such institutional factors, it seems likely that what one might term "user preference" was another important factor which militated against the expansion of hydraulic technology in medieval South Asia. The sluices of the cistern and the piston types represent two different approaches to the problem of releasing water from reservoirs. The piston-type sluice had a lower water-handling capacity, but the fact that it did not release large quantities of water at high pressure was in another sense an advantage: it minimized the threat to the stability of the embankment. Further, the peasants of medieval Tamiḻnāḍ had become accustomed to the piston sluice which had been in use for centuries, and it is clear from the later modifications to the Poṇṇēri sluice that those who operated it preferred the piston-type to the cistern-type sluice. Similarly, though there appear to have been attempts to introduce the piston-type sluice to Sri Lanka, it does not seem to have gained acceptance: the cistern sluice was clearly the preferred type. Needham refers to an analogous situation when he discusses the water-raising machines of the Chinese which, he noted, "failed to travel because the custom of other cultures was to employ different types of machines, no less efficient" [Needham 1954: 241]. It appears that the development of hydraulic technology in South India and Sri Lanka, while sharing a common heritage, followed essentially independent paths of development as regards this crucial element of technology on which the reservoir systems were based.

The preceding study of irrigation technology in South India and Sri Lanka helps to bring out the complex nature of the movement of ideas and technologies, and it focuses our attention on certain limitations on the explanatory value of diffusionism in the study of the history of technology in precolonial South Asia. Hydraulic engineering is a highly specialized branch of technology in the history of which advocates of diffusionism could expect to find ample support for their theoretical positions. However, it is evident from our study that, while the development of certain aspects of hydraulic technology may be correctly explained in terms of the penetration of influences from one cultural area to another, such expansion of influences does not conform to a model of an outward flow from a single centre as conceived by classical protagonists of diffusionism.[33] It appears likely that, while the influence of South Indian irrigation technology spread to Sri Lanka in proto-historic times, there was a reverse flow, from Sri Lanka to South India, in historical times. It would seem that "interaction," rather than "diffusion," is a suitable term to describe this process. The multidirectional movement of ideas and technologies across cultural and political boundaries in pre-colonial South Asia has to be distinguished from, even contrasted to, the patterns of expansion of technology that emerged after the industrial revolution. The impressive advances in hydraulic technology made in Sri Lanka, as represented by the appearance of large-scale, interlinked reservoir systems, antedated similar developments in South India, but did not lead to the transposition of this entire technology to the neighbouring region, with which Sri Lanka shared several cultural features. Our examination of the sluice mechanisms in the two regions reveals how these closely linked cultures in similar physical environments arrived at two distinct technological solutions to the same basic problem. Each culture, it would appear, borrowed certain elements of hydraulic technology from the other, but, with regard to a crucial element of this technology, preserved its own way of doing things, rejecting attempts at introducing an analogous method from the neighbouring culture. Theirs was a highly selective approach: if the leaders in hydraulic technology were reluctant to share their know-how, it would appear that the would-be recipients were no less reluctant to accept everything that came their way.[34]

33) One of the earliest examples of this approach is to be found in Terrien de Lacouperie [1894].

34) The research work on which this paper is based was supported by the National Science Council of Sri Lanka, the Indian Council of Historical Research and the Japanese Ministry of Education. The assistance extended by these institutions, the facilities extended by the Archaeological Survey of Tamiḻnāḍ and its Director, Dr. R. Nagaswamy, and the generous hospitality readily extended by Prof. Shelton Kodikara, Deputy High Commissioner for Sri Lanka in Madras, and Mrs. Kodikara during several visits by the author to South India are gratefully acknowledged. The author wishes to thank Messrs. J. G. Mahawatta, W. P. Sugathapala and M. A. Navaratne for assistance in the preparation of illustrations.

References

Allchin, Bridget; and Allchin, Raymond. 1968. *The Birth of Indian Civilization.* Harmondsworth.

Allchin, F. R. 1971. Early Cultivated Plants in India and Pakistan. In *The Domestication of and Exploitation of Plants and Animals,* edited by Peter J. Ucko and G. W. Dimbleby. Aldine.

Apte, V. S. 1978. *The Practical Sanskrit English Dictionary.* Kyoto.

Begley, V.; Lukacs, J. R.; and Kennedy, K. A. R. 1981. Excavations of Iron Age Burials at Pomparippu. *Ancient Ceylon.* No. 4.

Blair, D. 1934. Report on Kavudulla Reservoir. In *Ancient Irrigation Works in Ceylon,* quoted by R. L. Brohier. Vol. 1. Colombo.

Brohier, R. L. 1956. Presidential Address. *Transactions of the Engineering Association of Ceylon.*

Brown, W. 1931. Irrigation in Ceylon. *Transactions of the Engineering Association of Ceylon.*

Buddhadatta, Polvattē. 1960. *Pāli Sāhityaya.* Vol. 1. Ambalangoda: Ananda Book

Company.

Chelliah, J. V., ed. 1962. *Pattupāṭṭu.* Madras.

Cordier, H., ed. 1926. *The Book of Ser Marco Polo.* Vol. 2. London.

Cox, A. F. 1895. *Manual of the North Arcot District.* Revised by H. A. Stuart. Vol. 2. Madras.

Crole, C. S. 1879. *The Chingleput District Gazetteer.* Madras.

de Lacouperie, Terrien. 1894. *The Western Origin of Chinese Civilization.* London.

Deraniyagala, S. 1972. The Citadel of Anuradhapura 1969: Excavations in the Gedige Area. *Ancient Ceylon.* No. 2.

Deraniyagala, S.; and Kennedy, K. A. R. 1972. Bellan-bäñdi Pälässa 1970: A Mesolithic Burial Site in Ceylon. *Ancient Ceylon.* No. 2.

Dhammakittissiri Dhammārāma, ed. 1926. *Papañcasūdanī.* Vol. 2. Colombo: The Royal Asiatic Society.

Fausboll, V., ed. 1962–1964. *The Jātaka.* Vols. 1 (1962), 4 (1963), 6 (1964). London: Pali Text Society.

Geiger, Wilhelm, ed. 1925. *Cūlavaṃsa.* London: Pali Text Society.

Geiger, Wilhelm. 1958. *Mahāvaṃsa.* London: Pali Text Society.

Gnanamurthy, T. E. 1966. *A Critical Study of the Çīvakaçintāmaṇi.* Coimbatore.

Gunawardana, R. A. L. H. 1978. Hydraulic Engineering in Ancient Sri Lanka: The Cistern Sluices. In *Studies in South Asian Culture, Vol. VII: Senarat Paranavitana Commemoration Volume,* edited by P. L. Prematilleke *et al.* Leiden: E. J. Brill.

———. 1981. Total Power or Shared Power? A Study of the Hydraulic State and Its Transformations in Sri Lanka from the Third to the Ninth Century A.D. Paper presented to the Symposium on the Evolution of Political Organization, Intercongress, International Union of Anthropological and Ethnological Sciences, Amsterdam, April 1981.

Gururaja Rao, B. K. 1972. *Megalithic Culture in South India.* Mysore.

Heṭṭiāracci, D. E.; and Rammañḍala, M. Sri, eds. 1960. *Jātaka Aṭuvā Gāṭapadaya.* Colombo.

Hunt, E. H. 1924. Hyderabad Cairns and Their Significance. *Journal of the Royal Anthropological Institute* 24.

Jayatilaka, D. B., ed. 1932. *Dhampiyā Aṭuvā Gaṭapadaya.* Colombo.

Malalasekera, G. P. 1960. *Dictionary of Pali Proper Names.* Vol. 2. London: Pali Text Society.

Manamperi, H. de S. 1955. The Padaviya Reservoir Project. *Transactions of the Engineering Association of Ceylon.*

Minakshi, C. 1938. *Administration and Social Life under the Pallavas.* Madras.

Mittre, Vishnu. 1961. Plant Economy in Ancient Navdatoli and Maheshwar. *Technical Reports on Archaeological Remains.* Poona.

Müller, Max, ed. 1862–1874. *Ṛgveda Sanhitā, the Sacred Hymn of the Brahmans.* London: W. H. Allen and Company.

Needham, Joseph. 1954. *Science and Civilization in China.* Vol. 1. Cambridge: University Press.

Nilakanta Sastri, K. A. 1955. *A History of South India.* Madras.

Paranavitana, S. 1953. The Sculpture of Man and Horse near Tisāväva at Anurādhapurā. *Artibus Asiae* 16 (3): 167–190.

———. 1959. *The University of Ceylon History of Ceylon.* Vol. 1. Colombo.

Parker, H. 1878. Report on Māgalleväva. Communication addressed to the Director of Public Works, dated 23 July 1878, the Sri Lanka National Archives, File No. 72/547.

Parpola, Asko. 1973. *South Indian Megaliths.* Madras.

Rao, S. R. 1963. Excavations at Rangpur. *Ancient India.* Vols. 18 and 19.

Rhys Davids, T. W.; and Stede, William. 1959. *The Pali Text Society's Pali-English Dictionary.* London.

Sadāsiva Maṇḍārattār, T. V. 1974. *Piṟkālaççoḻar Varalāru.* Annamalai.

Saddhātissa, B., ed. 1930. *Pūjāvaliya.* Colombo.

Saminataiyar, V., edited together with commentary. 1965. *Maṇimēkalai.* Madras.

Sāminātaiyyar, S., ed. 1968. *Çilappadikāram.* Madras.

Saranatissa, ed. 1920. *Rasavāhinī.* Colombo.

Sathianathaiar, R. 1955. The First Pandya Empire. In *The Age of Imperial Kanauj*, edited by R. C. Majumdar and A. D. Pusalker. Bombay: Bhāratīya Vidya Bhavan.

Sōmasundaram, P. V., ed. 1959. *Çīvakaçintāmaṇi*. Madras.

Srinivasan, K. R.; and Bannerjee, N. R. 1953. Survey of South Indian Megaliths. *Ancient India*. No. 9.

Srinivasan, T. M. 1968. Irrigation and Water Supply in South India up to 1300 A.D. M. Litt. Dissertation. Madras University.

Stein, M. A., ed. 1961. *Kalhaṇa's Rājataraṅginī*. Vol. 1. Delhi: Motilal Banarsidass.

Suravīra, A. V., ed. 1961. *Pūjāvaliya*. Colombo: M. D. Gunasena.

Takakusu, J.; and Nagai, M., eds. 1969. *Samantapāsādikā*. Vol. 2. London: Pali Text Society.

Venkayya, V. 1903. Irrigation in South India in Ancient Times. *Annual Report of the Archaeological Survey of India*.

Wijepala, W. H. 1980. Mesolithic Stone Technology of Sri Lanka. M.A. Dissertation. University of Peradeniya.

Annual Reports on Indian Epigraphy. 1950–1951. No. 280. Delhi.

Epigraphia Carnatica. 1952. Vol. 10.

Epigraphia Indica. Vols. 4, 5, 7, 8. 11.

Epigraphia Zeylanica. Vols. 1, 2, 3, 4, 5.

Madras Reports on Epigraphy. 1898. Nos. 11, 42, 61, 65, 69, 74, 80, 84, 85, 90.

———. 1902/1903. Nos. 342, 343.

———. 1904. No. 693.

———. 1929–1930.

———. 1935–1936. Nos. 62, 107.

———. 1944–1945. Appendix B: No. 17.

———. 1947–1948. Nos. 45, 92.

South Indian Inscriptions. Vols. 1, 2, 3, 4 (137, 138), 14 (26, 37, 67, 71, 144, 231).

Tamil Lexicon. Vols. 2 and 4. Madras: The University of Madras.