AUGMENTING GROUNDWATER RECHARGE THROUGH RENOVATION OF PONDS - A MODEL STUDY IN VADAKARAPATHI PANCHAYAT, PALAKKAD DISTRICT

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b. Further progress of excavation in the northern part. The depth of excavation has reached about 7 m from the original floor level of the pond. The dark layer in the bottom part of the trench shows weathered rock. Water is being pumped out of the trench using a tractor mounted heavy duty pump.

18 View of the trench looking south from the northern edge. Partly weathered rock is exposed in the trench. Fractures are visible. The presence of a hard rock barrier in the centre of the trench has limited the progress of excavation. Workers are in action to ensure that continuous dewatering is carried out and the water level does not rise.

19 Photograph showing a long view of the trench excavation that is in progress. Note the slumping of the cutting on the valley floor (lower bottom) due to heavy seepage of water. Water is being bailed out on a continuous basis. The hard rock in the centre is adding to the undulations in the trench.

20 The trench being manually cleaned such that all debris and mud are removed. The fresh rock- migmatite- is exposed in the trench.

21 a. The irregular surface of trench is being levelled with plain cement concrete (PCC) to give a smooth surface before anchoring the LDPE sheet. The thickness of the PCC layer can vary from place to place but the average thickness provided is 20 cm.

b. The LDPE sheet is anchored into the PCC by providing another 20 cm thick covering. This layer acts as an impervious barrier at the bottom. The width and thickness of the PCC layer is indicated with the graduated levelling staff.

22 The LDPE sheet is being lowered into the trench before its anchoring into the PCC layer.

23 The view from the upper part of the trench. The trench floor is levelled with PCC over which the LDPE sheet of 500 gsm is spread. Over this layer and the LDPE sheet, another 20 cm thick PCC is applied. Note that only half of the trench is covered with the LDPE sheet such that the entire length of the sheet is embedded in the PCC to act as impervious barrier. The PCC layer on the pond side acts as one layer while at the bund side, the sheet is embedded. This will prevent the seepage out of the bottom of the bund. In order to ensure continuity, the sheets are folded together with sufficient overlap.

24 Embedding the LDPE sheet in the sector where the rock is exposed as a barrier in the trench.

25 Completing the work of laying LDPE sheet in the trench with a PCC layer over it.

26 In order to the measure the water level in the pond above the trench bottom, a piezometer has to be installed. For this purpose perforated PVC pipe is inserted. The photograph shows inserting a 110 mm dia interconnected PVC pipes to act as a piezometer for recording the water level. The bottom horizontal pipe is perforated all through to permit entry of groundwater into it. End cap is provided to prevent entry of mud into the pipe. The water level in the vertical pipe is recorded.

27 The entire trench length up to the road level is covered with LDPE sheet. This acts as the impervious layer arresting any seepage through the bund. It also strengthens and adds stability to the bund. After laying the sheet, the trench is filled with loose excavated earth. Care is taken to ensure angular fractions of large dimensions like boulders are not coming in direct contact with the sheet. Dropping them from a height can damage the sheet. So the process of refilling is done slowly and with care.

28 a. The trench is filled up and the LDPE sheet covered with excavated earth. The slope of the bund is maintained at about 1 in 2 to prevent slumping. Additionally the freshly covered face of the bund will be provided with a grass cover.

b. Another view of the completed bund without grass cover. Note the small mount in the foreground with a PVC pipe in the centre. This is to record the ground water level in the pond. Total height of the pipe is 7.6 m.

29 a. Considering the water scarcity and considerable lowering of water table to below the pond floor in dry period, a smaller sized pond 20m x 15 m x 2m was excavated instead of desilting the entire pond.

b. Further, the new excavation was extended on one side having a dimension of 15 m x 10 m x 4 m. In this pond, water was seen at a depth of 2 m at the time of excavation. This became a source of water for the local population during the summer of 2017. This additionally excavated structure enhances the percolation rate into the surrounding aquifer ensuring the recharge component.

30 a & b. View of the Pond with water up to the overflow level marked by the masonry step visible in water over which a flat stone is placed for washing clothes. The elevated grass covered part is the bund in which LDPE sheet has been embedded.

31 a & b. View of the pond with the bund and overflow section. Over flow water is channelized by the side of the pump house and led to the southern part to be released into the valley. The over flow which was initiated on 23.07.2018 after heavy rains continued till the first week of November 2018.

32 a, b &c. Photographs of selected open irrigation wells where water level has come nearly up to the surface. Well –a is 13m, well-b is 15.7 m and well-c is 9m

33 Location of observation wells upstream and downstream of Mariamman kovil pond

1.0 Introduction

Water is one of the most precious gifts of nature. All through the history, civilizations have thrived in regions of abundant water supply. The amount of water available to meet the competing demands of growing population is diminishing day by day while the quality is deteriorating at an alarming rate. The general perception of this precious and replenishable resource has changed from an infinite to finite status. Providing access to adequate water and sanitation at the local level is a growing challenge to a state like Kerala that experiences rapid changes in landuse, unsustainable exploitation of limited natural resources, high density of population with unplanned migration, poor strategy for waste management all of which lead to a progressive depletion and degradation of fresh water resources (Mathai J, 2000). Water scarcity and the tensions it causes especially in demanding for the development of deeper sources and wider network for distribution, competing claims to trans-boundary water resources are seldom accompanied by an obligation to use water efficiently for the benefit of this and future generation (IRC, 1995). The demand for water in Kerala is primarily for protected water supply, irrigation and hydel power generation. Industries and recreational sectors also demand their due share. Before water resources can be managed effectively and in a sustainable way, it is essential to know what resources of surface water and ground water exist and how readily accessible they are. If these resources are to be sustainable, steps must be taken to ensure conservation and protection of both quality and quantity. Thus the need for appropriate integrated studies is all the more important in view of the burgeoning population, wide spread drought and aridity, scant fiscal resources and vagaries of nature in the light of the projected climate change.

Kerala state, situated in the humid tropics, has a unique terrain set up. It can be divided into three broad physiographic zones parallel to the coastline. The highland region broadly falling in the Western slopes of the Western Ghats is characterized by relatively flat erosional plateau surfaces flanked by debris mantled steep slopes giving a step like aspect. Most of the rivers in Kerala originate from this zone. The middle zone or the midlands comprises of laterite capped residual mounts and flat bottomed valleys. The lowlands that abut against the sea are more or less an alluvial plain with a number of backwaters. The annual average rainfall in the state is about 300 mm, but shows a wide variation from south to north as well as form low land to highland. There are forty-one west flowing and three east flowing rivers draining the state. The gross yield from rainfall for the entire state is estimated around 115 km3/year. The runoff through all the rivers to the sea is estimated at 77.9 km3 per annum. The annual replenishable ground water resource is estimated as 7.5 km3 (Central Groundwater Board, 1992). Considering the interstate and other related problems, the total utilizable water resource of the state is only around 50 km3 per annum. It is estimated that by 2021 AD, Kerala would require about 47 km3 of water per annum to meet the entire demands.

1.1 Urgency for Groundwater recharge

Major source of the supply of fresh water is located underground and there is plenty of it, several times more than the total fresh water in lakes and rivers (L'vovich, 1979). Statistics show that generally there should not be any water scarcity anywhere, provided there is a proper distribution system without any wastage, with recycling facilities and no pollution. However experiences are on the contrary. In order to combat the ever-increasing demand for water; larger water projects, deeper tube wells and wider network of distribution system are provided. This has led to falling water tables and unprecedented drying up of sources. Therefore, it is suggested that instead of continuously reaching out for more water, the challenge is to do more with the available resource by conserving, recycling and preventing it from pollutants always keeping in mind that water is a finite resource.

The ensuing drought experienced during the past few years in many parts of the country and the state has generated considerable interest, as never before, on water conservation especially rainwater. Lamentations on wasteful use, over exploitation by multinationals depriving weaker sections, unplanned landuse practises etc. are reaching hysterical proportions. Drinking water, the most sensitive demand for water, is now chosen as the focus of concern by all, from highest authority to the common man, often fuelled by consistent media hype. While appreciating the campaign efforts in creating awareness on conserving water, the scientific basis of the suggested solutions need a revisit. Should we create additional facilities to store bulk of the rainfall through open structures or can we direct this to the existing underground reservoirs? The success of water supply programmes depends solely on the capacity to harness rainwater locally to the maximum and direct it to the aquifers. Ground water recharge appears to be the only corrective measure to ensure sustenance of the sources. Some of the water related environmental problems are dealt in detail by James (1997).

The natural process of recharge, though a continuous process, is slow and presently inadequate to compensate for the overexploitation and to sustain the yield from source region of the aquifers. Additional replenishment of the ground water reservoirs can be achieved only by augmenting the infiltration of rainwater or surface water into the underground formations. Artificial ground water recharge includes all those practises of increasing the amount of water that enters the ground water reservoir. Advantages of groundwater storage as compared to surface storage are a) no loss of evaporation, b) virtually no construction cost in preparing the reservoir for storage and c) the land above the underground reservoir can be put to different uses. Artificial recharge may be induced by various methods depending on the rainfall, local topographic, geologic and soil conditions.

1.2 Climate change and its impacts on water

The global concern on changing climate and the need for preparedness to mitigate the adverse impacts is a challenge faced by the community even at local levels. It has been projected that the western coastal region of the country is likely to be drought prone even though there is a 10% increase in precipitation. The reduction in number of rainy days and the untimely rainfall pattern can impose undue strain especially on the agrarian society. The slight increase in temperature as evident from recent studies is likely to affect the crops and animals in a large way. The crop tolerence to the higher level of temperature as well as the comfort level of humans and animals can be ensured to some extent by providing a microclimate dominantly controlled by moisture retention in the soil, vegetative cover to absorb the solar energy and by providing water bodies for enhancing water storage. All this calls for a concentrated effort to harvest entire rainfall and enhance groundwater availability in the region taking the micro watershed as the unit of water conservation. There is a need to understand the existing hydrological regime in each watershed to suggest appropriate methods of water conservation.

1.3 Selection of study area

As a follow up of the International Year of Water Co-operation, State level Committee meeting was convened by the Hon'ble Chief Minister on 22.07.2013 to discuss the modalities for the sustainable development of water resources of the state. In this meeting a presentation made by the Scientists of National Centre for Earth Science Studies (NCESS) highlights some of the success stories of rainwater harvesting and ground water recharge especially from Palakkad district. It was suggested that similar works could be taken up in conjunction with renovation of ponds in the district. As a follow up, Additional Chief Secretary, Water Resources convened a meeting on 04.09.2013 for discussing the issues in connection with taking up entire Palakkad district as a Pilot project for repair, rennovation and restoration of water bodies. Major activity involves taking an inventory of ponds in the district and preparing DPR for follow up activities. In this meeting it was suggested that NCESS should carry out a study in a Grama Panchayat in Palakkad district where acute water scarcity is felt and to demonstrate viable models for water conservation in the area. In this context, as suggested by some of the members, Vadakarapathy Panchayat was selected for the study of water conservation by enhancing water retention in the existing ponds. In this region having a common border with adjacent Tamilnadu state, the rainfall is only one third of the State's average and scarcity of water is a prime concern. The presence of large sized ponds, declining water table in the region, the gramma panchayat falling in the over exploited Chittur Block and its disposition at a higher elevation etc calls for an in-depth study of the region to suggest site specific rainwater harvesting and groundwater recharge measures to enhance water availability in the region.

2.0 Objectives of the Project

The overall objective of this study is to develop an alternate model for enhancing water availability in a water starved region of Kerala with the watershed as the unit of intervention. This objective is proposed to be achieved through a sequential study process as given below

1. Identification of Hydro-geomorphic units in each micro-watershed and mapping them on large scale.
2. Selection of one micro watershed with acute water scarcity for detailed study. Document the existing hydrological regime and fluctuation in water level. The current system of water source development and its utilisation for different agricultural practises as well as drinking.
3. Suggest methods for harvesting rainfall and augmenting groundwater recharge for the sustainability of the existing sources especially ponds.
4. Involve the local community in the planning of the model structure
5. Execution of one model structures in conjunction with large ponds for water harvesting/conservation.
6. Monitoring the water levels in the vicinity for one complete season to ascertain its success and for replication in similar terrain.

3.0 General features of the study area

Vadakarapathy Panchayat falls in Chittur block of Palakkad district and is located on the eastern part having a common boundary with Tamilnadu State (Fig. 1). The Gramma Panchayat is divided into 17 wards and covers an area of 49.51 sq.km falling in two villages viz. Ozhalapathy on the east and Vadakarapathy on the west. The area in general falls in the Palghat gap region with elevation ranging from 140m to 230 m. The general slope is towards west drained by the low order streams draining either to Varattar on the south or Walayar on the north, the two prominent rivers in the area (Figure 2).

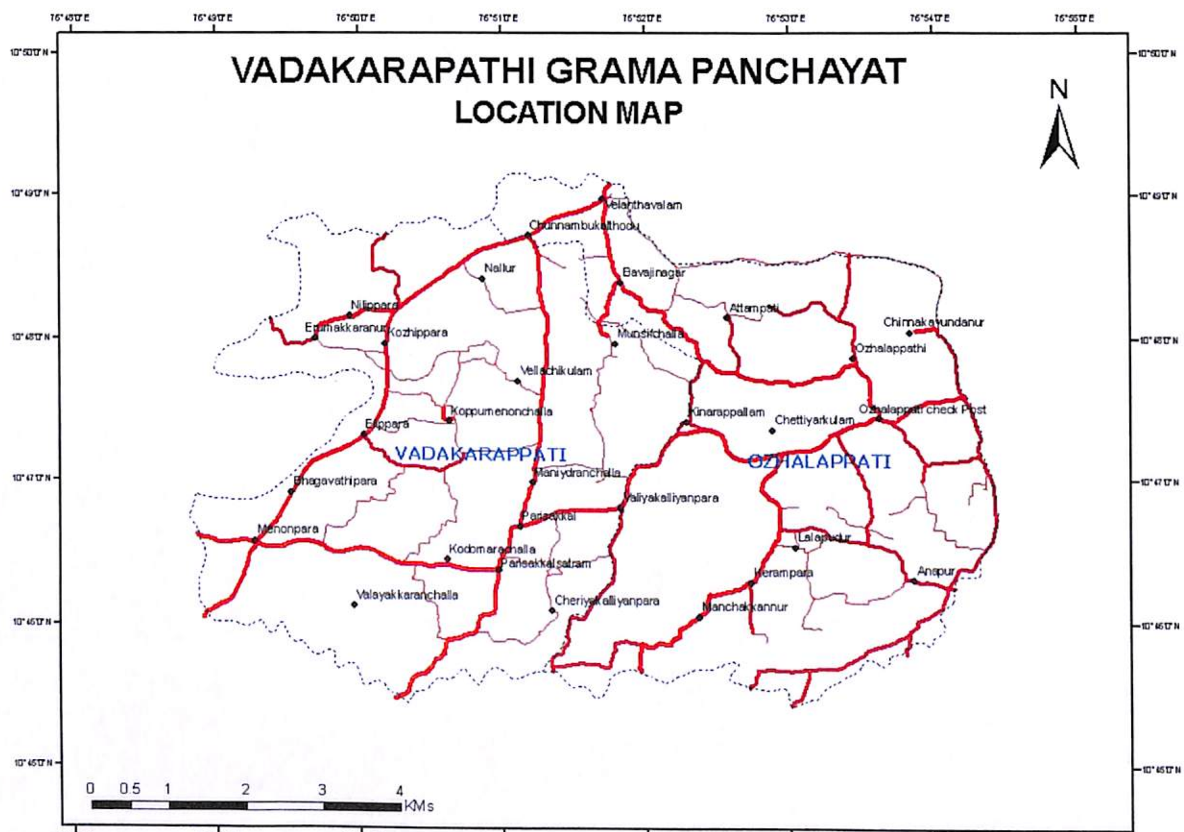


Figure 1: Location map of Vadakarapathy Gramma Panchayat. The eastern boundary is the Inter-state border with Tamilnadu.

3.1 Geology

Banded gneisses with quartzo-feldspathic leucocratic bands and dark mafic bands mostly biotite and hornblende forms the dominant rock type of the area. The rocks exhibit folded attitude in both regional and outcrop scale. In general the rocks are polyphasedly deformed. The general strike of foliation is east-west with steep dips. The rocks are fractured to a great extent close to the surface. Deep seated fracture zones are rare. In the weathered zones especially in the valleys, a thin discontinuous Kankar bed is seen in well sections. The valley region is covered mostly by a thin layer of recent unconsolidated sediments.

Figure 2: Out crops of banded gneiss in the area indicating polyphase deformation. Note the discordant mafic bands are further disrupted by felsic bands of later generation.

3.2 Land form and slope

The area in general has a denudational topography and can be classified as a dissected pediment-inselberg complex. The generalised landform of the area is given in Figure.3 Elevated ridges/mounts, shown with deep red colour, often expose hard basement with shallow weathering profile. These are mostly runoff zones. The side slopes, shown in orange colour, are gentle to moderately sloping zones with minor undulations. Much of the side slopes are terraced for cultivation. The lower elevation, shown in yellow colour, is occupied by broad flat bottom valleys mostly with a ill-defined channel to facilitate storm water flow. The altitudinal variation across the Panchayath is shown as shaded relief in figure 4. The eastern part has an elevation exceeding 220 m amsl with isolated mounts above 240 m. Though the overall slope is towards west, the area has a distinct southerly and northerly slope with the central part forming a ridge. The lowest part of the Panchayath is seen in the southwest part where the elevation is below 130 m amsl. Though the shape of the contour lines indicates a higher degree of dissection leading to an erosional topography, the variation in elevation is limited to about 100 m only

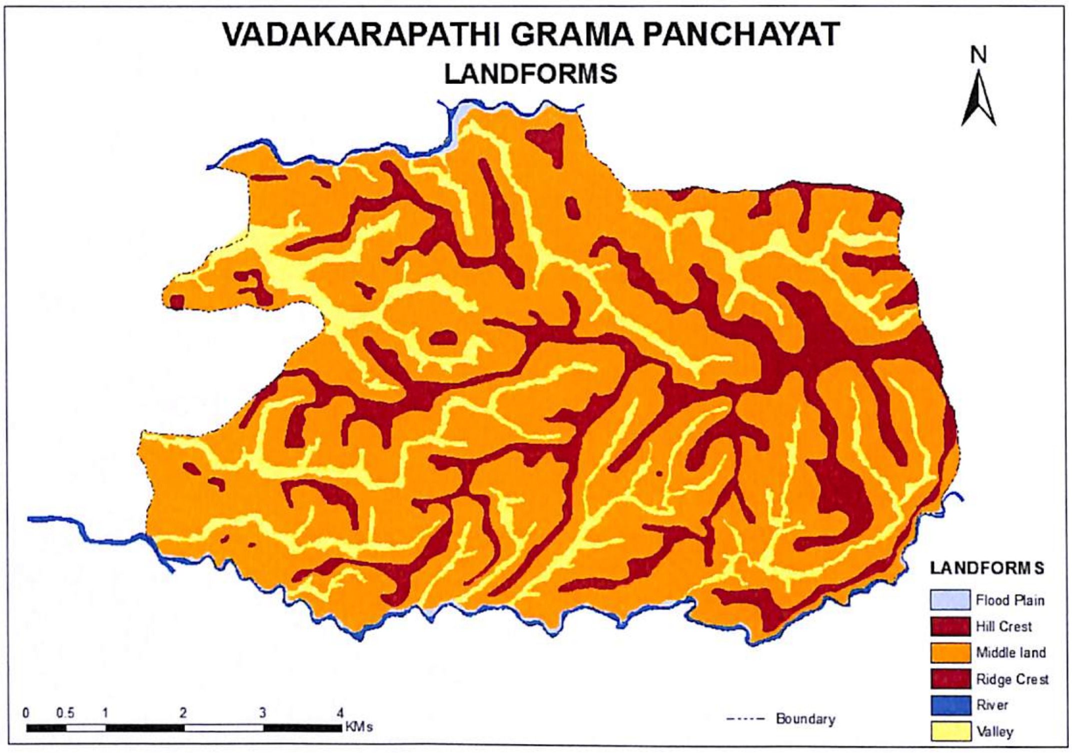


Figure 3: Generalised landform in the Vadakarapathy Panchayath area dividing the region into three broad units.

3.3 Soil

Rocky outcrops occupy the elevated region. The soil in this area is limited to pockets. It is mostly well drained pebbly/gravelly loam. The gentle to moderately sloping side slopes are covered by well drained gravelly/ sandy loam. Rock out crops is also seen in pockets. The broad flat bottom valleys are covered with shallow well drained loamy soil. The thickness of the overburden can be as deep as 5-6 m. In some of the flat valleys on the eastern side dark clay loam similar to black cotton soil is noticed. The heavy texture of the soil make it water stressed during the non-rainy period. In the valleys on western side brownish coloured silty clay loam dominates. The benchmark soils identified by the Soil Survey Organisation of Kerala Government in the area are Agali series, Anuppur series and Bhavaji Nagar series.

Agali series is a member of fine-loamy, mixed, isohyperthermic. Agali soils have yellowish red to reddish brown, moderately alkaline, sandy clay loam to clay loam A horizon and dark reddish brown to red, moderately alkaline, gravelly clay loam to gravelly clay B horizons. These type of soils are seen in the elevated rocky region. Anuppur soils have very dark brown to dark brown, moderately alkaline, clay A horizon and very dark brown to very dark greyish brown. These soils are formed in the valleys over a gneissic basement. Bhavoji nagar soils have brown to brownish yellow, neutral; loam to clay A horizon and reddish brown to yellowish red, slightly acid to moderately alkaline. The lowest part of the horizon has gravelly clay texture. This soil is common to the gentle sloping areas. Water stress in summer is a common feature of both these series.

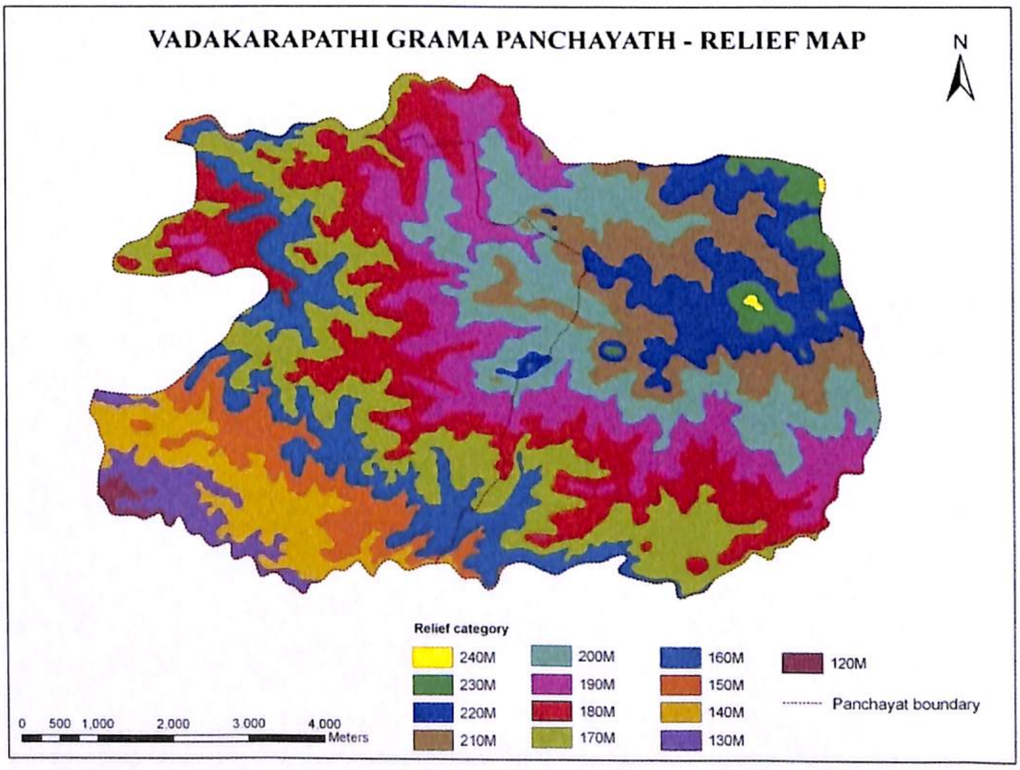


Figure 4: Shaded relief of Vadakarapathy Panchayat area indicating the altitudinal variation with a general slope to the west

3.4 Climate and Rainfall

The climate of the region is humid tropical with a very severe hot season. The hot season from March to May is followed by the southwest monsoon season from June to September. October and November form the northeast monsoon season. During dry weather, hot winds blow through Palghat gap from the plains of Coimbatore. The mean annual temperature is 27.33°C. The district experiences the maximum temperature in summer compared to other districts in the state. The maximum temperature recorded at Palakkad was 43°C.

Vadakarapathy Panchayath, by its location in the eastern part of the Palghat gap region, is a low rainfall zone when compared to the western parts of the district. The rainfall data from Kozhinjampara station, located about 10 km away, for a period of twenty seven years indicate that the average annual rainfall recorded is 1200.2 mm (Table 1). Bulk of the rainfall ie.776 mm is received during SW monsoon while 224.3 mm is received during NE monsoon and 145 mm as pre-monsoon. The year wise rainfall variability is large and data indicates a dependable rainfall of about 800 mm only. There are periods when the SW monsoon has totally failed in this region creating a drought like situation.

Table 1 Summary of rainfall, average temperature-maximum and minimum recorded at Kozhinjampara for the period 1976-2003 and the rainfall recorded at Ahalia campus during 2017

Sl No	Month	Average Rain fall (mm)	Av. Minimum Temperature C	Av. Maximum Temperature C	Rainfall at Ahalia campus during 2017
1	January	2.3	21.3	30.1	nil
2	February	7.1	22.3	34.5	trace
3	March	23.7	23.8	36.3	13.8
4	April	63.8	25.1	35.6	12.1
5	May	81.2	24.7	33.8	118.2
6	June	222.7	23.3	30.2	182.9

7	July	282.4	22.8	29.2	190.3
8	August	195.8	23.0	29.7	105.2
9	September	75.1	23.1	30.9	287.3
10	October	130.1	23.2	30.8	10.3
11	November	94.2	22.6	31.0	22.6
12	December	21.8	21.6	31.2	0.3
	Total for the year	1200.2			943.0

The rainfall recorded at Ahalia campus located at about 10 km west of Ozhalapathy is given in the last column. This area that normally receives about 1300 mm rainfall annually has received only 943mm rainfall during 2017 indicating a 28% deficiency during the year. The rainfall during 2017 at Ozhalapathy has been meagre limited few days of showers. Local enquiry indicates that the area experienced mostly drizzles without any heavy showers. There has not been any significant increase in the water levels in the wells.

3.5 Water resources

The Panchayath is bordered on the north by the Walayar river and on the south by Varattar river. Both these rivers are non-perennial. Walayar dam on the upper reaches of the river makes the river bed dry most of the time. The benefit of the irrigation canal is accrued to the adjacent Panchayaths which are at a lower elevation. Varattar river, that mostly exposes a rocky river bed, is provided with check dams at close intervals such that the water collected is available to the plots in the immediate vicinity. A number of ephemeral streams are seen in the valleys that conduct water during the rainy season from the central part of the Panchayath flow to the rivers. The general topography of the area is such that the drainage is directed to the two sides promoting runoff. Hence surface water sources are limited. This region falls in the Chittur block that is designated as an overexploited region by CGWB implying that the groundwater levels are depleting rapidly.

There are many large sized ponds in the area, mainly as private holdings to irrigate the adjacent agricultural lands. These ponds are dugout depressions mostly confined to the valley region. The dugout material is used as a bund to prevent outflow from the depressed land. The current practise is to lead the rainwater into the large sized ponds in the area and to use this water for irrigating the crops. However retention of water in the ponds is negated by the presence of pebble rich layer over the hard basement in the valleys. The clay rich layers at the surface especially in the paddy fields favour overland flow there by retarding the possibility of groundwater recharge. As a result almost all these ponds dry up even before the onset of summer. The location of the ponds is given in figure 5. The large scale Survey of India Topographic maps indicate about 58 large ponds in this area. Open wells and bore wells are other water sources in the Panchayath that tap the phreatic aquifer. The number of bore wells is many and the yield is not sustained in the long term. Even though the area falls in the overexploited zone, there is a tendency to deepen both these type of wells with the hope to draw more water. The open wells that normally occupy about two Ares land have been excavated to about 10-15 m depth with the bottom half almost entirely in fractured rock basement.

3.6 Landuse

Landuse of the Panchayath is shown in figure 6. Area under dry crops constitutes 42.1% of the total area. Coconut occupies 28.8% while wet crops like paddy cover 16.6%. 6.9% of the area is under settlement. The balance 5.6% is uncultivable waste and others. The eastern part of the area shows mostly coconut and dry crops. A significant change in landuse pattern in the eastern part has been brought in by the proliferation of bore wells in the region. The dry land farming is slowly being replaced by coconut cultivation. However sustenance of coconut or other agriculture practises that need more water depends on the yield of bore wells.

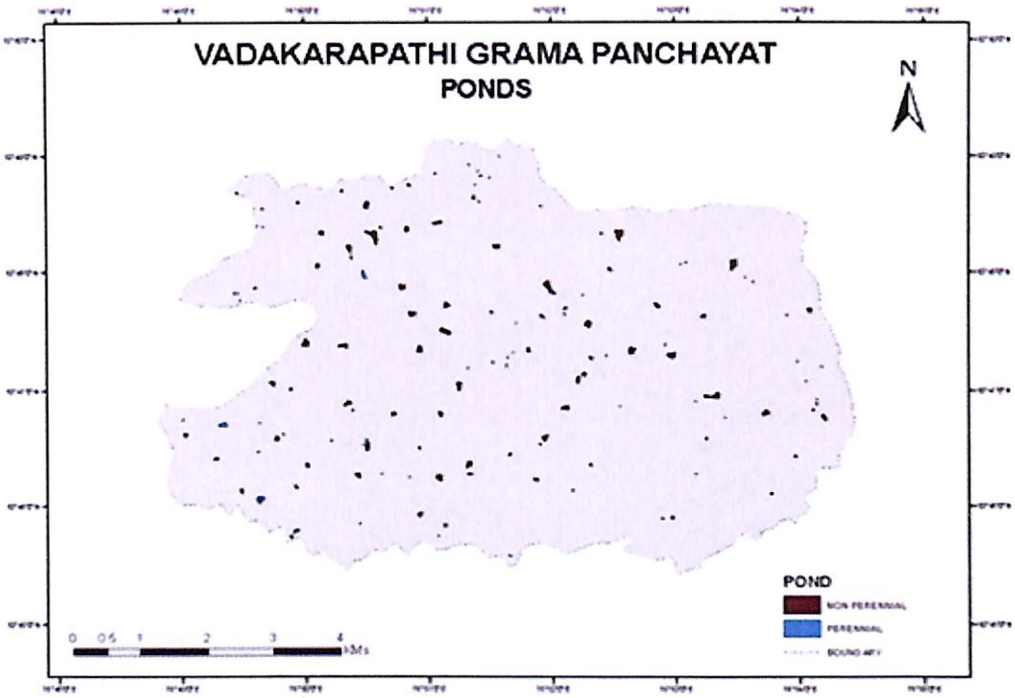


Figure 5: Location of ponds in Vadakarapathy Panchayat. The larger sized ponds are in colour while the smaller ones are given as dots. Almost all of them dry in summer

As such the yield of wells is dwindling probably due to indiscriminate mining of water. The significant deviation from traditional farming practises to wet land farming will also need support from external sources of water. In the western part, dry crops are grown seasonally. The valleys are covered with paddy and banana and other mixed crops. The area also produces large quantity of vegetables through the efforts of VFPCK. This again calls for provision for larger quantity of water which can be achieved only through *insitu* conservation of water. Unlike other parts in the state, this region has a clustered settlement pattern. The drinking water needs are catered mainly through piped water supply. However, the supply is irregular and in summer months there is over dependence on tanker supply.

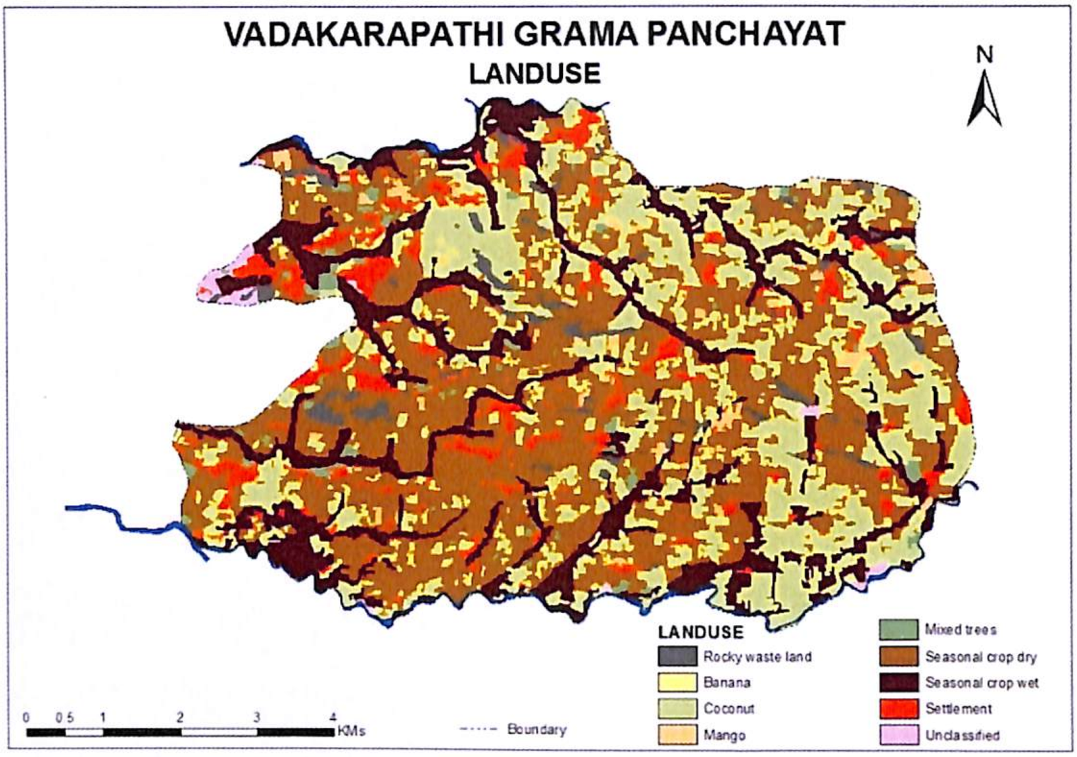


Figure 6: Landuse map of the Panchayath indicating dominance of dry crops especially in the western part. The dominance of coconut in the eastern part is a recent phenomenon especially after the proliferation of bore wells in the region.

4.0 Watersheds in Vadakarapathi Panchayat

Watershed based water conservation and recharge is presently advocated as an effective means to tide over the water crisis on account of indiscriminate withdrawal. The river basin can be subdivided into sub-basins and further into micro-watersheds such that activities can be prioritised with a broad aim to harvest every drop of water. Experience has shown that the micro-watersheds are unit areas that are amenable to treatment and the activities inside such a unit directly benefit the resident population without adversely affecting the adjacent watersheds. Before undertaking any artificial conservation/recharge project, it is a basic prerequisite to identify the watersheds, demarcate its geographical area, characterize them in terms of landform, soil, drainage, landuse etc. The spatial distribution of the watersheds in Vadakarapathy Panchayat is given in figure 7. The overall boundary of each watershed is first demarcated from large scale topographical maps of 1:25,000 scale.

Subsequently, critical segments are checked based on field traverses and boundary of the micro-watersheds is precisely demarcated. The area is divided into eight micro-watersheds. There is a narrow linear zone fringing Varattar that forms an inter flow region which is separated as unnamed. The area under each watershed with its prominent landform and number of ponds is given in table 2 below.

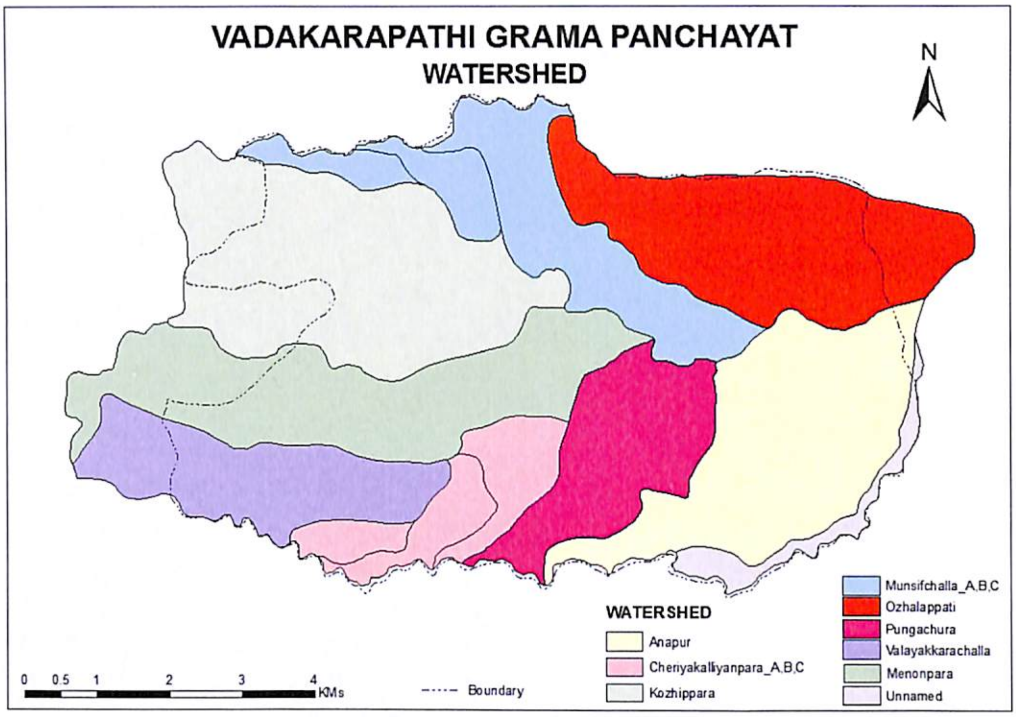


Figure 7: Distribution of micro-watersheds in Vadakarapathy GP

Table 2: Micro-watersheds in Vadakarapathy Gramma Panchayath

Sl No	Name of Micro-Watershed	Catchment Area-Km^2	Area under Hill crest	Area under Side Slope	Area under Valley	Ponds	
						Large	Small
1	Anappur	8.60	2.15	5.68	0.77	3	15
2	Pungachira	4.83	0.93	3.35	0.55	6	6
3	Cheriyakalliyanpara	3.65	0.75	2.34	0.56	7	3
4	Valayakkaranchalla	3.76	0.31	3.04	0.41	8	3
5	Menonpara	6.47	1.22	4.38	0.87	10	14
6	Kozhippara	7.97	1.35	5.21	1.41	11	15
7	Munsifchalla	6.69	1.09	4.72	0.88	7	19
8	Ozhalapathy	6.82	1.27	4.74	0.81	6	8

The watersheds listed in the table from one to five ie. Anapur to Menonpara drain to the south to Varattar. Kozhippara, Munsifchalla and Ozhalapathy watersheds drain to the north and west with their streams leading to Walayar. Anappur watershed and Ozhalapathy watershed are located on the extreme eastern part bordering Tamilnadu and draining the most elevated portions of GP. The rainfall in these two regions is relatively lower than other parts of the Panchayat. Hence either of the watersheds is suitable for demonstrating this experiment on artificial recharge. Considering the fact that Ozhalapathy region has lesser number of ponds, this watershed was selected for the study and field experiment.

4.1 Ozhalapathy Watershed

Ozhalapathy watershed (Figure 6) is located on the northeastern part of the Gramma Panchayath. Overall slope of the watershed is towards west. Highest elevation of 267 m amsl is seen in the eastern part near Virappakaundanur while the lowest elevation of 192 m amsl is seen to the east of Velanthavalam. The variation in elevation in the watershed between the ridge and valley is limited to a few meters only. The degree of dissection is low such that the overall slope is gentle towards west. The elevated parts and isolated mounts especially in the catchment region expose rock outcrops. Depth of weathering increases towards the valley. Deeply weathered sections exceeding 4 m are seen in the lower slopes and valley. The valleys are generally covered with a 1-2 m thick alluvial cover. The watershed is drained by the seasonal stream that occupies the central valley portion and joins the Walayar river near Velanthavalam. The total area of the watershed is 835.5 ha out of which the eastern 153.1 ha falls in the adjacent Tamilnadu state. Six large and eight small ponds are located within the watershed. Chinnakaundanur, Mariammankovil and Attampati ponds are the larger ponds. Besides these, 121 large dug wells, mostly rectangular in shape, are seen that cater to the irrigation and drinking water needs. Traverses in the watershed have indicated more than 50 bore wells. Water availability in all these sources depend on the rainfall and most of them nearly dries up in summer. This has led to a tendency of deepening the open wells in an effort to draw more water. Reports from local people also indicate that there is a steady decline in the yield of bore wells. Coconut with some intercrops is the dominant landuse covering an area of 298.2 ha located mostly in the lower slopes and valley. Dry land farming is seen in the upper slopes in an area of 216.7 ha. Paddy and other water dependent seasonal crops cover 99.8 ha while 60.7 ha is used for mixed trees mostly mango. 10.7 ha is rocky and 38.5 ha is under settlement.

4.2 Selection of the site

'In situ' precipitation will be available almost at every location but may or may not be adequate to cause artificial recharge. The runoff going unutilized through the ephemeral streams can be arrested through simple recharge structures at appropriate locations. Considering the terrain conditions of the Vadakarapathy region with gentle/moderate slope, existence of a well-developed flat bottom valley where there is convergence of rainwater, basement rock at shallow level, weathered mantle of moderate thickness overlain by a thin soil cover and the presence of fractures and veins in the gneisses; the better methods of conservation is limited to sub-surface dykes. Subsurface dyke is a structure that is built in an aquifer with the intention of obstructing the natural flow of ground water, thereby raising the ground water level and increasing the amount of water stored in the aquifer. This method is increasingly being popularized by CGWB and through the efforts of However, the excess overland flow is not arrested by this structure which needs a structure for the collection of rain water. Hence the present experiment aims at augmentation of recharge by maintaining elevated water level in the existing ponds that normally dries in January such that sufficient resident time is made available for effecting percolation of collected water to the surrounding shallow aquifer. The selected watershed has three large ponds. The lower Attampati pond is lined with random ruble all around. Construction of Sub-surface dyke in this site would require demolition of the RR construction and hence it was not selected. The Chinnakaundanur pond is in private possession. The Mariammankovil pond is the largest, common to all, located in the central part of the watershed and in close proximity to the Ozhalapathy hamlet. After detailed discussion with local persons including elected representatives of the Gramma Panchayat, Mariammankovil pond was selected for the experiment.

5.0 Mariammankovil pond

Mariammankovil pond is located in the central part of Ozhalapathy watershed (Fig 8). The pond covers an area of 1.1 ha with an average depth of nearly 3 m from surface. The bund of the pond is oriented NS and is made of the excavated material from the pond. A motorable road is made over the bund. The floor of the pond is nearly flat with a thin cover of alluvium resting on weathered rock. In the central part of the pond, weathered rock is exposed. The northern flank has a deeply weathered section while the southern flank exposes rock. The presence of deep trenches in the plot down slope side of the bund for conducting water indicates a high rate of seepage from the pond through the bund. Surface flow in the two valley sections on the upstream is channelized into the pond through pipe culverts. The runoff from the settlement area of Ozhalapathy is also channelized into the pond through an open channel. Drinking water supply schemes have been implemented in the area with the pond as the source. But they have failed as the source dries up in dry period when the demand for water is high.

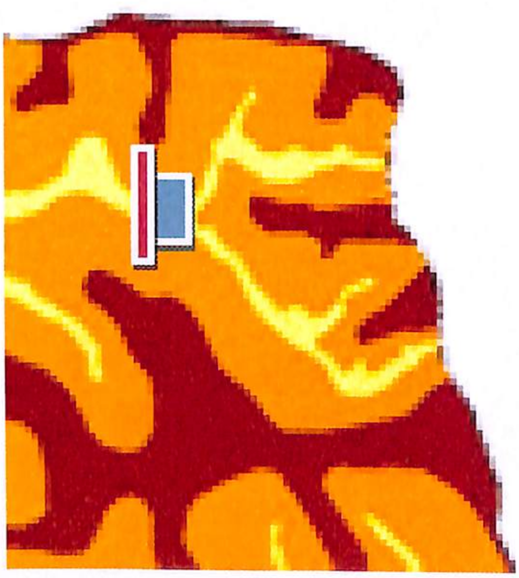


Figure.8: Upper part of Ozhalapathy watershed in the Kerala side is given in the figure on the left. Dark red shows the elevated parts, yellow are the valley and orange depicts side slopes. The runoff from the two valley portions are collected in the pond (blue rectangle). The bund on the lower part is shown in red.

The photographs given in figure 9 indicate the site condition of Mariamman pond when it was nearly dry in March 2015 and December 2016. The year 2014 was a normal rainfall year with the pond reaching to its full capacity. In spite of the normal rain it is seen that the pond had dried up in March 2015. The monsoon of 2015 and 2016 was poor that made the pond dry in the month of December itself. It is clear that even though the pond collects water to its full level during rainy season, bulk of it seeps out and is rendered dry.

Figure 9: Photographs of the pond in two seasons. The photograph on the left is taken in February, 2015 when the pond had little water in the deeper part of the floor. On the right is the photograph taken during December, 2016 when the pond bed is exposed with some grass cover.

5.1 Catchment Characteristics

The free draining upper catchment of Mariammankovil pond covers an area of about 280 ha forming the upper most part of Ozhalapathy watershed. A minor part of upper catchment of the watershed lies in the adjacent state of Tamilnadu. The altitude in the upper most part is about 260m amsl while in the floor of the pond it is about 210 m amsl. The outer fringe zone (deep brown on figure 8) represents elevated parts of the catchment. These elevated segments are mostly low level hillocks occasionally exposing rocky knobs. Generally these elevated segments are covered with weathered basement rock with limited soil cover. Vegetation cover over this region is limited such that it is mostly not prime agricultural land. The low level hillocks are flanked by gently sloping side slopes. These side slopes (depicted in orange colour in figure 8) are mostly terraced and brought under coconut and dry land agriculture. This unit is mostly covered by 3-5 m thick weathered rock overlain with moderate sandy soil cover. The depth of weathering is non-uniform such that basement rock exposures are sporadically noticed. Two prominent valley segments are seen in the watershed occupying the central part (marked with yellow colour in figure 8). They are narrow zones whose width varies from 50 to 100 m. The surface of the valley is covered with alluvial soil. The relative proportion of clay and sand and the thickness of this soil layer vary from plot to plot. Much of it has been detached and transported from the elevated region. The soil rests on a deeply weathered basement rock. The depth of weathering may exceed 10 m in places. The upper section of the weathered basement rock is loose and friable that can easily be removed by shovels. In some places large voids are seen in this layer. The partly weathered section below the friable zone is hard and is not easily detached by simple mechanical means. A thin of calcareous rich layer represented by kankar is seen below the loose and friable zone. Deep weathering is seen in places with closely spaced planes of discontinuity in the basement and also along the pegmatite veins. In general the elevated low level hillocks and ridges can be said to be runoff zones with little or nil groundwater potential. The side slopes with terraced nature and having moderately thick weathered zone do act as temporary recharge zones. However the valleys and its adjacent terraces act as the aquifers in the area. From the well data, it can be seen that the top 2 m is sandy alluvium with a high potential to store water. The lower completely weathered zone of about 4 m thickness also acts as a potential aquifer. The partly weathered zone has only limited water holding capacity while in the hard rock water availability is limited, mostly held in the fracture zones. Interconnecting fractures and shear zones serve as potential zones for development of bore wells. It is seen that bore well density in the area is very high with about one bore well per hectare. As a result, of over pumping the shallow weathered zone, the only productive zone, the water level in the catchment is drastically lowered. In dry period, the yield from most of these bore wells is limited to less than an hour of pumping.

5.2 Water holding capacity

The pond occupies an area of 1.1 ha or 11000 m^2. The excavated flat bottom of the pond is about 3 m below the overflow level. The total volume of water that can be held directly within the pond as surface storage is 33,000 m^3. In addition, the quantity that can be stored as groundwater is also to be computed. The sub-surface storage largely depends on the porosity of the materials. Based on long term studies, Freeze and Cherry (1979) has provided the values of porosity of different litho-units. (Table 3). Gravel and sand have a minimum porosity of 25%. The porosity in fractured crystalline rocks varies from nil to 10%. Porosity in the weathered rock can vary such that the friable layers tending to fine sand while the poorly weathered rock tending fractured rock. Likewise, column three of the table provides estimates on the hydraulic conductivity of different materials in m/day. The values for clay are very low such that the layer practically holds all the water without releasing it. With increasing grain size the hydraulic conductivity also increases such that the gravelly layers can permit a flow up to a kilo meter per day. The fourth column provides the specific yield (the ratio of water that drains from a saturated stratum under gravity the volume of the whole rock) of different materials. The loose materials in the study have a specific yield in the range of 18 to 27. The upper catchment of the pond has about 2-3 m thick alluvial cover along the valley section having a specific yield of about 21. The side slopes and the valley support about 4 m thick completely weathered zone that is similar to the silty layer. The silty layer has a specific yield of 18 while the weathered crystalline rocks have a specific yield of 10.

Considering the gentle slope of the terrain, the zone of influence of the pond when completely filled is at least about 200 m along the flanks and 400 m along the valley. This means that when the pond is in filled condition, the subsurface is provided with sufficient resident time to be saturated at least up to the zone of influence. The total area falling in the zone of influence of the pond is 20 ha (taking 200 m width on the flanks and 100 m width for the pond). Hence the total volume of material that can be saturated completely amounts to about 1.6 million cu.m (2.5m for alluvium, 4m for completely weathered rock and 1.5 for partly weathered rock). Assigning the relevant specific yield coefficients (21 to the alluvial layer and 18 to the completely weathered layer and 10 to partly weathered rock), the total water that can safely be drawn as groundwater from the zone of influence of the pond amounts to about two lakh seventy nine thousand cu.m. This is more than eight times the open storage potential of the pond. Thus the present water conservation strategy at this site can result in a total storage of 3.12 lakh cu.m of water. Considering that rainfall for recharge will continue till the end of November month and no rains till June 20th, the water conserved in the zone of influence has to cater to the need for 200 days. So the water availability per day amounts to 1560 cu.m or roughly 1.5 million lpd.

Table 3: Porosity, hydraulic conductivity and specific yield of different aquifer materials in the catchment (modified after Freeze and Cherry, 1977)

Material	Porosity %	Hydraulic conductivity m/day	Specific yield
Clay	40-70	<0.01	02
Silt	35-50	0.01-0.1	18
Fine sand	25-50	1-5	21
Coarse sand	25-40	20-100	27
Gravel	25-40	100-1000	23
Weathered X'llines	10-25	1-5	10
Fractured X'lline	0-10	-	-

5.3 Recharge from rainfall

In the absence of canal network or other source of water in the catchment area, the only source of water is rainfall. The long term rainfall data indicates that the region receives about 1200 mm of rainfall in a year. All this water cannot recharge the area. Only the water that falls during the monsoon period percolates down recharging the substrate. The sporadic showers in other seasons and part of rain even during the monsoon are evaporated back. The water needed for crops and trees also need to be considered. It can be safely stated that only 40% of the annual precipitation percolates down and rendered available as groundwater at the end of the rainy period ie

November. The balance 60% amounting to about 700 mm partly flows out as overland flow and partly is used for maintaining the normal ecological functions chiefly evapo-transpiration. The free draining catchment of the pond is 280 ha. The dependable portion that is assumed to percolate down is 40% of the annual rainfall or 480 mm. The total volume of water that percolates down in the catchment amounts to 1.34 million cu.m. Considering the depth of completely weathered zone and alluvial cover of about 6.5 m with a porosity of at least 25%, the normal average rainfall is not sufficient to fully recharge the phreatic aquifer in Ozhalapathy catchment. In periods of less than average rainfall the region will face acute water scarcity. At a time when water demand is high due to cultivation practises that consume more water and the farmers are competing with each other to draw more and more water through their closely spaced bore wells, rapid drawdown is to be expected in the region. Targeted water conservation efforts through percolation ponds and sub-surface dykes can only ensure availability of ground water in the area enhancing the recharge from 40% to at least 70% and still allowing 30% for evaporation.

5.4 Strategy for water conservation in Mariammankovil pond

Considering the dimensions of the pond covering an area of 11000 m^2 and an average depth of 3 m, Mariammankovil pond can directly store 0.33 lakh cu.m of water. However, the quantity it can store indirectly is eight times more, when the substrate in the upper catchment in its zone of influence is fully is saturated. Saturating the upper catchment and maintaining the water level needs retention of water level in the pond for a longer period. One of the methods to achieve this is by constructing a sub-surface dyke. Construction of a sub-surface dyke along the bund of the pond can arrest the seepage of water through the bund and maintain elevated water table conditions in the area (Fig.10). This requires formation of a trench up to the hard basement rock and providing an impervious layer in the trench from the basement rock up to the top of the bund such that no water seeps out of the pond through the porous bund. The seepage out of the pond will be limited to the two flanks where the rock depth is shallow as well as with reduced porosity. This aspect was considered while planning the field experiment. Cursory examination of the local geology reveals that the southern flank of the pond exposes hard rock at surface while the northern flank has slightly deep weathering. Rock exposures are also seen in the floor of the pond. Hence it was inferred that the hard basement rock is at shallow levels not exceeding 6 m from surface. The pond is already excavated by three meters. So excavation of additional three meters depth can reach the hard rock. However, arriving at the quantity to be excavated for preparing estimates, depth to the basement rock at the base of the bund all along was to be estimated. This is mainly done through pitting at different places. An electrical resistivity survey is yet another method that gives a near accurate picture of the basement. The roughness of the basement can also be deciphered through this method.

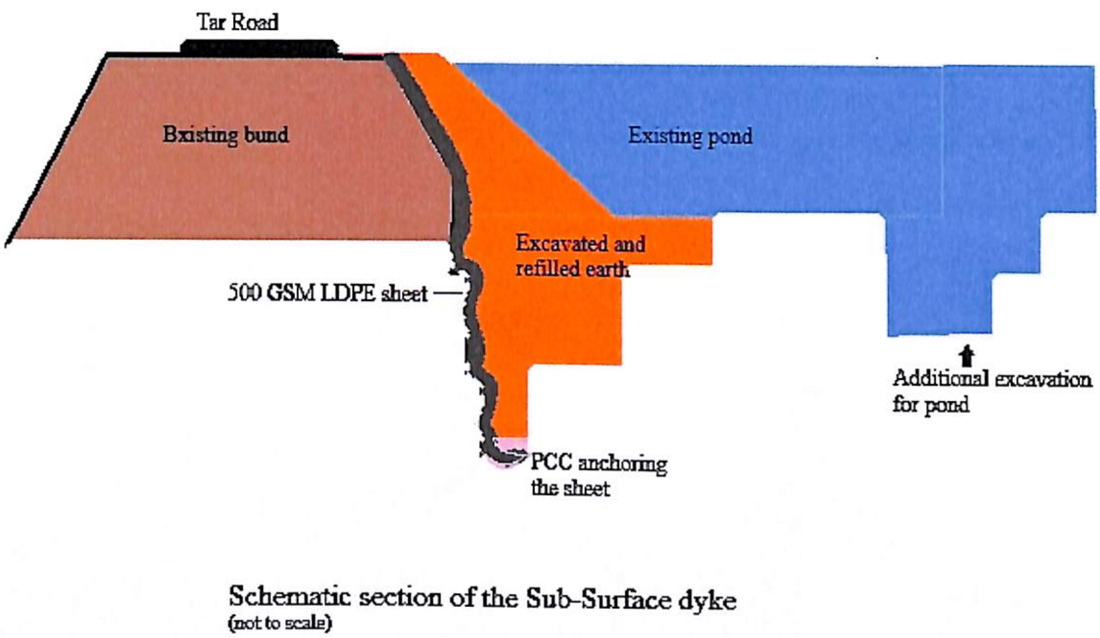


Figure 10: Sectional view of a typical Sub-surface dyke.

The Eastern edge of the existing bund is trimmed. The trench is taken in three different depths: 0-2 m, 2-5 m and 5-8 m. The top 2 m is taken with a width of 12 m. The middle segment from 2-5 m depth is provided 7 m width and the bottom 3 m is given 2 m width. The trench wall on the bund side is given two small benches of 0.5 m for stability and for laying the LDPE sheet. Desiltation of the bottom of pond was replaced by providing a smaller pond within the bigger pond. This additional excavation is taken away from the dyke trench. This inner pond serves as an intake point as well as a structure to enhance percolation into the surrounding aquifer.

6.0 Estimation of depth to basement

Two methods were employed at Mariammankovil pond site for the estimation of depth to bed rock. One was running an electrical resistivity survey with closely spaced electrodes along the line of the proposed trench. The other method is by pitting at few points along the line where the trench of the dyke is to be taken. Based on the depth arrived and on the surface geological inputs, design of the sub-surface dyke, quantity to be excavated etc. are arrived at.

6.1 Electrical resistivity surveys

Mineral grains comprised of soils and rocks are essentially nonconductive, except in some exotic materials such as metallic ores, so the resistivity of soils and rocks is governed primarily by the amount of pore water, its resistivity, and the arrangement of the pores. To the extent that differences of lithology are accompanied by differences of resistivity, resistivity surveys can be useful in detecting bodies of anomalous materials or in estimating the depths of bedrock surfaces. Surface electrical resistivity surveying, based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivities and distribution of the surrounding soils and rocks, was utilised to arrive at the depth to bed rock/thickness of overburden. The electrical resistivity method has some inherent limitations that affect the resolution and accuracy that may be expected from it. Like all methods using measurements of a potential field, the value of a measurement obtained at any location represents a weighted average of the effects produced over a large volume of material, with the nearby portions contributing most heavily. This tends to produce smooth curves, which do not lend themselves to high resolution for interpretations. Another feature common to all potential field geophysical methods is that a particular distribution of potential at the ground surface does not generally have a unique interpretation. Hence the local geological information on the depth to water table and depth to hard rock, taken from nearby dug wells were used to validate the data for the site.

6.2 Multi-function digital DC resistivity/IP meter- WDJD-4

The WDJD-4 multi-function digital DC resistivity/IP Meter is a new generation instrument with 32 single-chip and 24 bit A/D technology. It can carry out Resistivity and IP survey at the same time. This system can be widely used for metal and non-metal mineral resources exploration, geotechnical investigations, as well as in hydrogeology and engineering geological prospecting, such as searching for groundwater, investigating dam base, studying flood protection levee for incipient faults and conducting geothermal survey. It can conduct not only general electrical resistivity/IP survey but also multi-electrode 2D Resistivity imaging. It features high accuracy, fast sounding speed, mass memory capability and easy operation, in association with flexible multi-electrode converter. Its self-check function can even locate each converter. WDJD-4 system can connect many multi-electrode converters in series to compose cascade connection by communication cable. The measured data of WDJD-4 can be processed by other multi-electrode resistivity software, which makes the interpretation more convenient.

6.3 Methodology

There are mainly three types array, Schlumberger, Wenner and Dipole-Dipole array used for ground investigation.

(a) Schlumberger array:

The Schlumberger array (Figure 11 a) consists of four collinear electrodes. The outer two electrodes are current (source) electrodes and the inner two electrodes are the potential (receiver) electrodes. The potential electrodes are installed at the centre of the electrode array with a small separation, typically less than one fifth of the spacing between the current electrodes. The current electrodes are increased to a greater separation during the survey while the potential electrodes remain in the same position until the observed voltage becomes too small to measure.

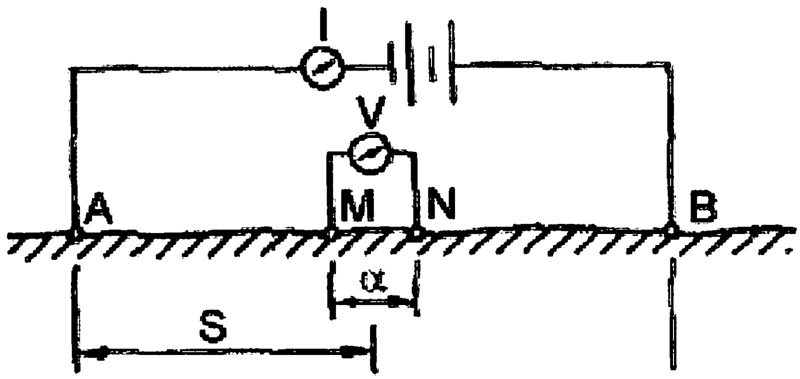


Figure 11a: Schlumberger array configuration

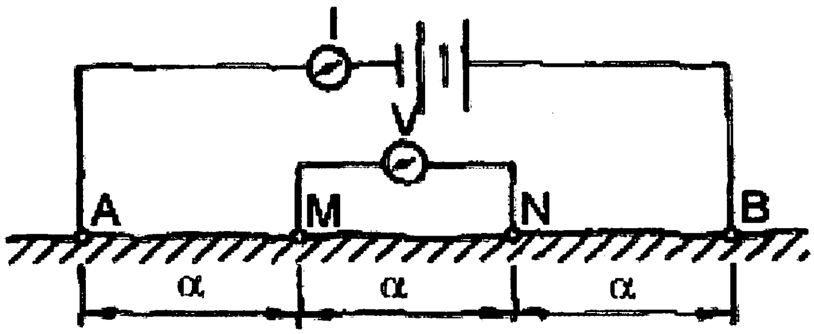


Figure 11b: Wenner array configuration

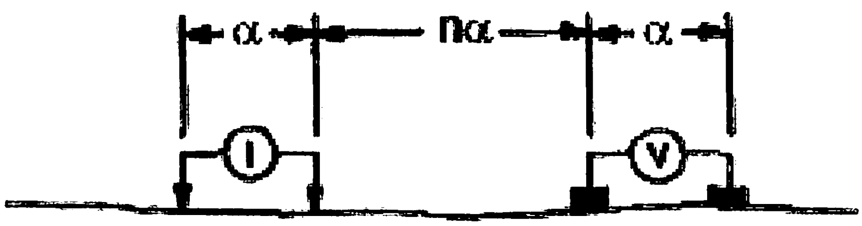


Figure 11c: Dipole – Dipole configuration

(b) Wenner array

In Wenner array the electrode configuration (figure 11 b), in which four electrodes are deployed in a line, with equal spacing between the two potential electrodes, and between each current electrodes and its nearest potential electrode. Its geometric factor (*K*g) is $2\pi a$, where *a* is electrode spacing .The Wenner array has five variations, three referred to as the tri potential method with α, β, and γ configurations

(c) Dipole – dipole

The Dipole-Dipole array is a type of electrode configuration for a Direct Current Resistivity Survey and is defined by its electrode array geometry. The dipole-dipole array (figure 11 c) is one member of a family of arrays using dipoles (closely spaced electrode pairs) to measure the curvature of the potential field. This array is especially useful for measuring lateral resistivity changes and has been increasingly used in geotechnical applications

6.4 The 2D Electrical Resistivity Imaging

The electrical resistivity profiles were laid at the base of the bund in the pond aligned parallel to the bund. The maximum length of the profile was depending on the electrode separation; 60 electrode was using with a WDZJ-4 switcher box (Figure 12) i.e., the profile length achieved is 150m when the electrode separation is 2.5m and the same is only 90m for the electrode separation of 1.5m. Since the profile was taken on a level surface application of elevation correction was not attempted. In order to nullify the contact resistance, if any, at the electrodes, Grounding Resistance (Rg) was initially measured for the set of electrodes by setting the desirable maximum limit of Rg to 5 K. Ohms considering the requirement of improving the signal to noise ratio. On switching on for Rg measurements the instrument automatically highlight the electrode number where the Rg is higher than 5 K. Ohms. For such electrodes, corrective measures have to be taken to improve the ground contact by tight pegging of the electrode and/or by pouring saline water. After ensuring that all the electrodes are well grounded without contact resistance beyond the desirable limit, the switcher box is connected and measurement mode initiated. The instrument is facilitated to measure Wenner, Schlumberger & Dipole-Dipole array. The instrument generates the resistivity data for various combinations and layers and is stored in the WDJD-4 mainframe which could be transferred to an external computer facility. The data so gathered is interpreted using a RES2DINV Software. In order to do the interpretation using this software, the data gathered and stored is converted to a compatible format using WDAFC.EXE program and subsequently interpreted. The depth of Penetration of digital electrical resistivity imaging is shown in the figure 13.

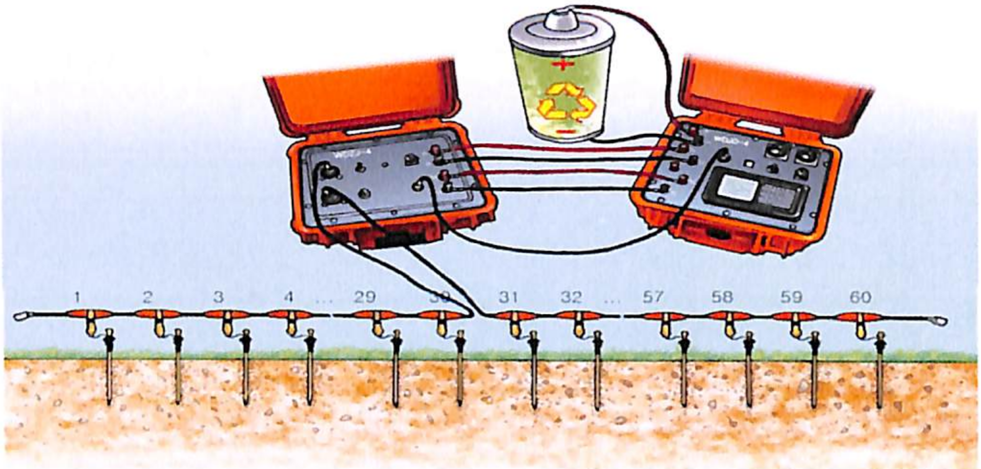
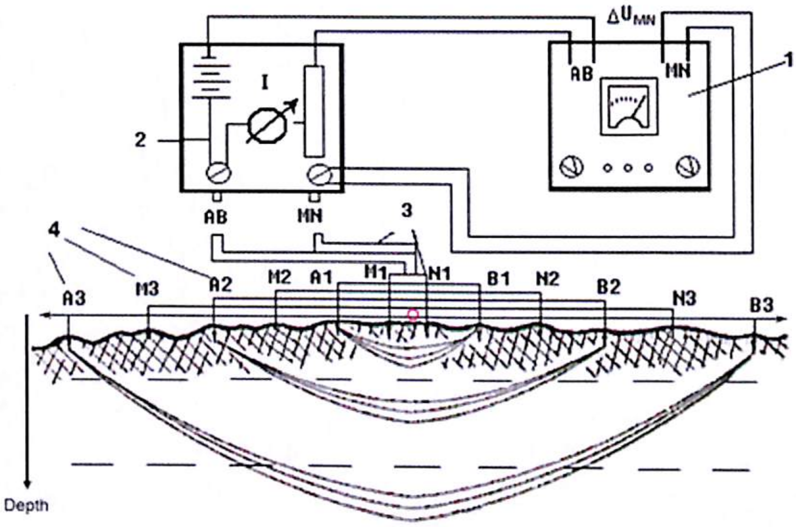


Figure 12: Survey Layout sketch for 2D ERT of WGMD-4 Model



a) A, B Current Electrodes; b) M, N Potential Electrodes, c) O is Mid-point

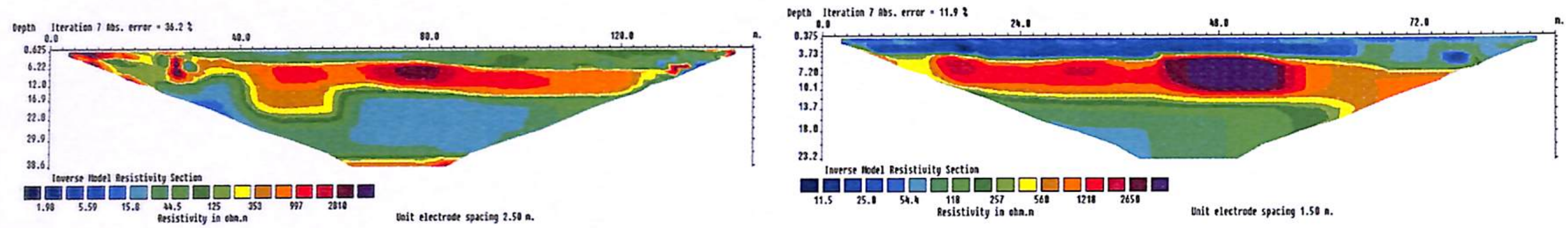
Figure 13: Model for depth of Penetration of Electrical Resistivity Imaging

The figure 14 shows the 2D true resistivity model using all the three arrays separately. This profile is laid along the base of the bund in the N - S direction. The top layer of the pond indicates low resistivity values on account of the presence of some amount of soil moisture. In general, the resistivity section covering up to a depth of 4m indicate low resistivity values except for the southern part indicating high resistivity zone. Between 4m and 6 m a steep increase in resistivity is seen indicating the presence of a sharp contact between the overburden and hard basement. The picture is clear in the image with 1.5 m electrode separation. However in the northern part high resistivity values are not clear indicating deeper depth of weathering. In the image with an electrode separation of 2.5m, lower resistivity values are obtained at depth indicating the presence of water probably along some preferred plains of discontinuity. Dipole-dipole array indicates moderate values up to about 30 m depth below pond bottom. Further at depth, high resistivity values are observed. It can be safely concluded that the thickness of overburden in the site is about 5 m only. There is a transition zone of 2 m from 5m to 7m which probably corresponds to the basement rock that has undergone partial weathering. Hard basement is to be observed below 7m depth. Three high resistance zones along the profile seen from the Dipole array could probably indicate the presence of un-weathered boulders/patches at shallow depth.

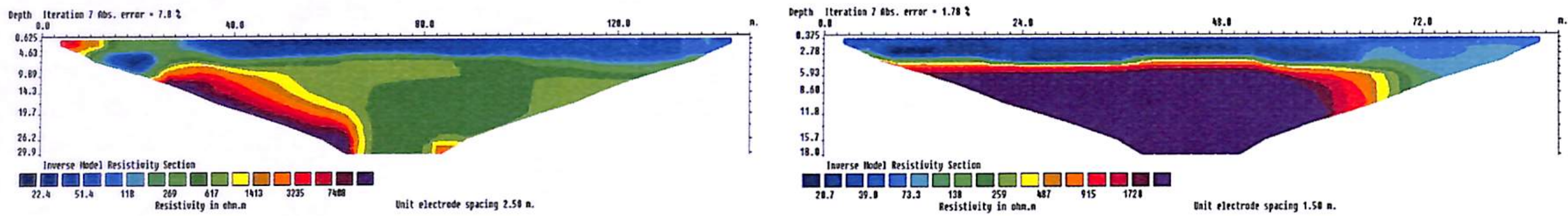
6.5 Pitting

Three pits were taken along the trench, one on the southern side, second one in the centre and third one on the northern side. The depth to hard rock in the pit on the southern side was 4 m. The pit on the central part indicated a shallow depth of 5 m while the pit on the northern side indicated a depth of 6 m to the hard but weathered strata. Hard basement was not obtained in the pit. Another aspect that was noticed while pitting was the presence of water table at a depth of about 5 m from the pond floor. This indicates the area is not completely dry during the month of January and has certain groundwater potential. It also means that certain amount of pumping of water is required to erect the dyke during the construction stage which has to be taken into consideration while making estimates.

Dipole-Dipole Array



Schlumberger Array



Wenner Array

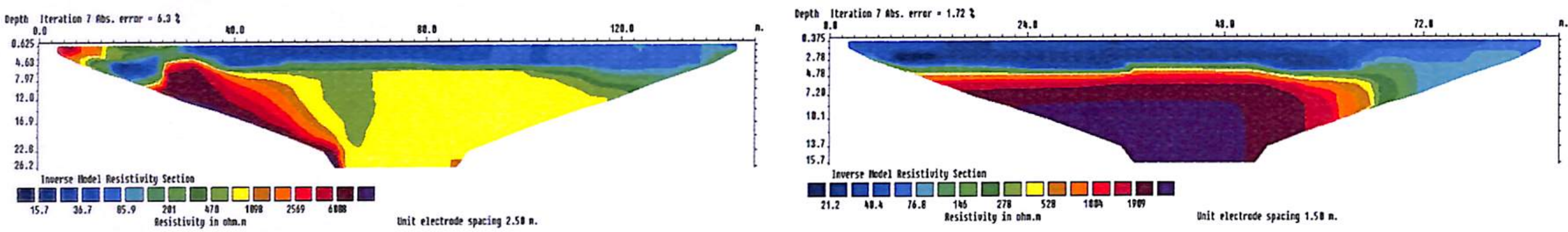


Figure: 14 2D images in different arrays at a separation of 2.5 and 1.5 m. Note the high resistance layer at a depth of 5m-7m

6.6 Estimated depth to basement

The depth to basement by the two methods mentioned above is in close agreement but not very precise. The data indicates that the depth to basement rock is not uniform all along the trench. The southern part has shallow basement conditions at about 4 m. In the middle section there is a slightly deeper zone of weathering while in the northern part the depth to hard rock can exceed 7 m. The electrical resistivity data also indicates the presence of a high resistivity layer in the centre with lower values on either side. This indicates that depth of weathering in the centre is shallow and the value of 5 m obtained while pitting may be correct for that point only. The presence of water at shallow levels has also affected the precision in deciphering the depth to hard rock basement. Taking clues from the data the average depth to which the trench has to be taken is estimated as 7 m from the floor level of the pond. However in the southern most part, the depth to hard rock will be about 4 m only as indicated in the pit. It must be emphasised that during the actual construction stage, the depth of the trench on which a dyke can be made can vary slightly depending on other factors like stability of the strata, capacity of the machinery and escalation of cost of excavation with depth. The configuration of the upper surface of the hard basement on which the trench is to be limited will be uneven as the depth of weathering is not uniform everywhere.

7.0 Planning stage of Sub-Surface dyke

Terrain parameters, climatic conditions and the landuse practises in Ozhalapathy region calls for greater amount of water storage and maintenance of elevated water table conditions in the area. This aspect merits higher attention as the traditional water conservation structures like pond are progressively neglected and there is a proliferation of bore wells with periodic increase in depth of recent ones.

7.1 The pond and surroundings

The description of the pond is given earlier in section 5.0. The pond is developed by excavation of a flat bottom valley and depositing the loose material on the western side to form the bund. The bund is nearly 6 m wide at the top and with a well laid metalled road that permit fairly frequent vehicular traffic between Ozhalapathy and adjacent hamlets like Tenampathi and Chinnakaundanur. The upper road level on the bund top is 4 m above the pond floor level. Steps are provided on the southern side that serve as entry point into the pond. There are ten steps each having a height of 30 cm. Over flow section which starts from the top of the upper most step is provided on the southern side in the form of an open channel of about 2 m width. This channel crosses the road through a cause way such that the overflow water is led into the lower valley to the west. Pipe inlets are provided to the pond from three sides to bring in the surface flow, if any, from the upper catchment. The plots in the upper part in the immediate vicinity are relatively flat land at an elevation of 4-5 m from the pond bottom. They are mostly agricultural fields with seasonal crops like banana. Some of the plots to the north and east are under coconut. On either side of the pond are two defunct water supply schemes with bore well as the source. Settlement is mostly in the elevated part on the southern side-Ozhalapathy hamlet- and slightly away on the north western side-Tenamapathy hamlet. There are few large rectangular energised wells both upstream and downstream mainly used for irrigation. Surprisingly few of them additionally fed by bore wells developed indiscriminately in the area.

The pond is mainly kept to augment the water availability in the region. There are no intake structures inside the pond either for irrigation or drinking water. The village people use the water for their normal domestic purposes like washing, bathing and for cattle. The pond also serves as a source for certain rituals related to Mariamman temple. In the absence of settlement in the immediate vicinity of the pond or any intake structures, keeping the water level in the pond up to the overflow level will not affect the normal activities of the local people. Hence design of the structure is accordingly made.

7.2 Work Execution

Dyke is planned all along the bund of the pond. Length of the bund with the road by the side of the pond is 130 m. However there should be sufficient overlap on either side such that the rock the seepage is arrested. The depth to hard basement is more than 6 m on the northern side. Hence greater length should be given to the dyke on the northern side. However, the reluctance of the plot owner in making deep excavation in his plot was a constraint by which the dyke could not be extended north as desired. On the southern side, hard rock is exposed on the road and hence the overlap may be limited. Measurements were taken in the field with such overlap. The length of the trench on which the dyke has to be constructed is measured as 160 m. The depth is estimated as 6 m from the pond floor. It can reach to greater depth too if the hard strata is not met. Excavation to a depth exceeding 6 m can be achieved only in three stages. It needs a 12 m wider zone of initial excavation to a depth of 2m followed by 7m wide zone up to a depth from 2 to 5m and finally a 2 m wide trench till the rock depth. During excavation, seepage of water into the trench is to be expected. Such seepage should not be allowed to accumulate. It can destabilise the side cutting resulting in slope failure. Continuous pumping of water is to be ensured during the excavation. Once the excavation is completed and hard rock exposed in trench, it has be cleaned free of all debris. This is done mostly manually. After the debris is cleared and fresh rock exposed, the trench is levelled with cement concrete to get a smoother and even surface for laying LDPE sheet. The LDPE sheet of 500GSM acts as a flexible impervious layer arresting the seepage through the bund. The bottom of the sheet is anchored on to the trench with a mixture of cement concrete. The sheet is rolled on to the bund side of the trench. The LDPE sheets usually come in 7-8 m width and 40-50 m length. In order to cover the entire length of the trench, sufficient overlap with lapping of adjacent sheets is given. The sheets are loosely placed on the wall of the trench. Care is to be taken to remove all the sharp edges on the bund face. Subsequently the trench is filled with the finer clay/silty material dugout from the site. The coarse material used for the filling the part of the trench away from the LDPE sheet. The excavated part is completely. The sheet on the bund needs a covering of earth on a slope not steeper than 1 in 2. This exposed part is to be covered with grass for the stability of the freshly covered part. Additionally, a smaller sized in-well kind of structure has to be provided within the pond away from the trench. This is to act as an extraction structure as well as to ensure percolation to the surrounding aquifer so as to maintain elevated water table conditions in the vicinity. The entire list of work components is given in the table below.

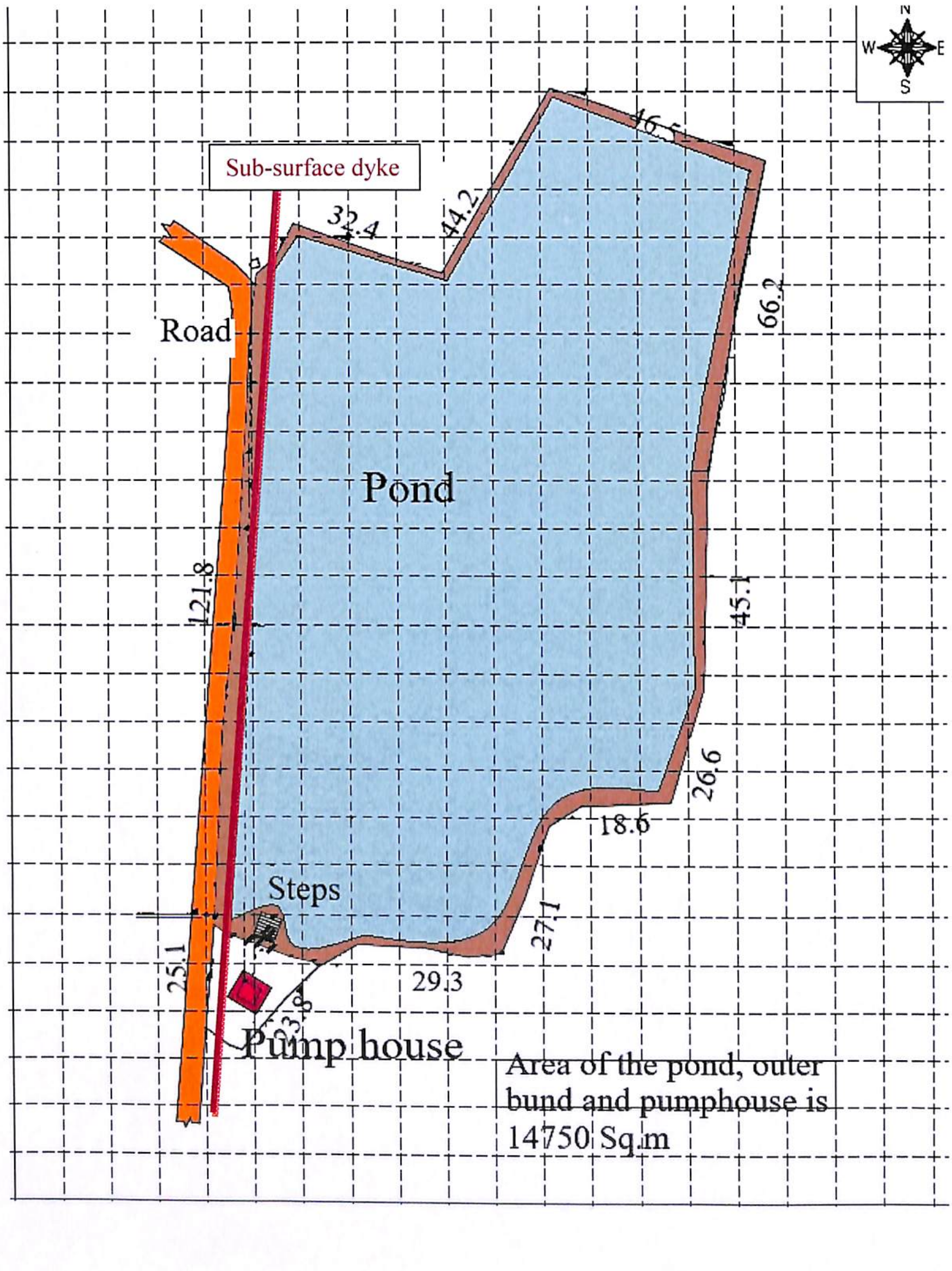
7.3 Work components

1. Engaging man mazdoor for site clearance
2. Trimming the western bund of the pond to provide a regular shape and smooth surface
3. Bailing out water from the excavation of trench. This activity cannot be stopped from the excavation till the dyke is completed. In case the dewatering is stopped and water level is allowed to rise it may destabilize the excavated banks of the dike.
4. Earth work excavation in Ordinary soil & depositing the soil on the bank with initial lead up to 50m including neat banking. The excavation is to reach the hard rock for the dyke. The initial width of excavation is fixed as 12 m to prevent slumping at the bottom. At the lower part liquid mud is to be expected. The length of excavation towards bottom part can vary as a hard stratum is expected at varying depth all along. It may be required to remove some of the hard material to provide a smooth surface at the bottom. All loose rock boulders need removal before the fixing of film.

5. LDPE film (500 Microns) is used as impervious membrane to arrest the lateral seepage. The film is to be fitted loosely to prevent damage.
6. Cement concrete 1:3:6 using 20mm broken stone is used for levelling the bottom and fixing the film. The quantity used for filling can vary depending on the irregularity of the trench bottom.
7. Once the film is fixed at the bottom it can be rolled up to the surface. Sufficient overlap with interlocking of films may be provided.
8. The trench has to be refilled filled with excavated material and compacted carefully without damaging the LDPE film
9. The LDPE film needs to be covered with earth such that it is not directly exposed.
10. Shaping and Grass cover to be provided to the layer of earth covering the LDPE sheet such that it is not exposed outside and is held in position.
11. The existing overflow structure to be slightly modified by deepening and widening it to let out excess water from the pond.
12. Excavation for a smaller sized pond within the pond reaching to the hard strata. The dimension is fixed as 20 m x 40 m for a depth of 2 m and further 20 m x 20 m to a depth of 3 m.
13. Shaping of this inner pond

8.0 Construction of the Sub-surface dyke

Initial level of the pond was taken prior to excavation. The shape of the pond and the road over the bund are clear from the figure given modified from the CAD drawing.



The construction of the sub surface dyke is done in stages as explained here with the help of field photographs.

Figure: 15

Photograph showing the initial excavation for the trench. Far end is the northern end while the closer edge is the southern part. To start with, the bund is trimmed to free it from all vegetation including the roots. A smooth surface is made carefully with the existing slope. The base of the bund is cut with steep angle such that the sides are maintained without slope failure. At a depth of about 4 m from the pond floor water table is met. The excavated material is mostly overburden that is the product of complete weathering.

Figure: 16

Another view of the trench excavation in progress prior to the intersection with water table.

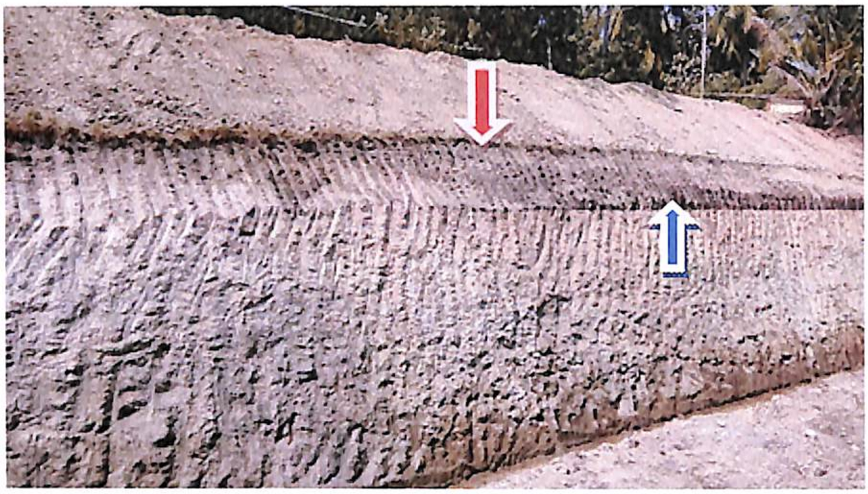


Figure: 17a. Photograph showing the upper cross section of the trench. The red arrow above points to the dark line indicating present floor of the pond. The horizontal dark line indicated by blue arrow below shows a 75 cm thick clay deposit above the original pond floor that accumulated over a period of time. In the extreme bottom of the excavation weathered rock is starts appearing.

Figure: 17b.

Further progress of excavation in the northern part. The depth of excavation has reached about 7 m from the original floor level of the pond. The dark layer in the bottom part of the trench shows weathered rock. Water is being pumped out of the trench using a tractor mounted heavy duty pump.

Figure: 18
View of the trench looking south from the northern edge. Partly weathered rock is exposed in the trench. Fractures are visible. The presence of a hard rock barrier in the centre of the trench has limited the progress of excavation. Workers are in action to ensure that continuous dewatering is carried out and the water level does not rise.

Figure: 19
Photograph showing a long view of the trench excavation that is in progress. Note the slumping of the cutting on the valley floor (lower bottom) due to heavy seepage of water. Water is being bailed out on a continuous basis. The hard rock in the centre is adding to the undulations in the trench.

Figure: 20
The trench being manually cleaned such that all debris and mud are removed. The fresh rock- migmatite- is exposed in the trench.

Figure: 21 a & b

a) The irregular surface of trench is being levelled with plain cement concrete (PCC) to give a smooth surface before anchoring the LDPE sheet. The thickness of the PCC layer can vary from place to place but the average thickness provided is 20 cm.
b) The LDPE sheet is anchored into the PCC by providing another 20 cm thick covering. This layer acts as an impervious barrier at the bottom. The width and thickness of the PCC layer is indicated with the graduated levelling staff.

Figure: 22
The LDPE sheet is being lowered into the trench before its anchoring into the PCC layer.

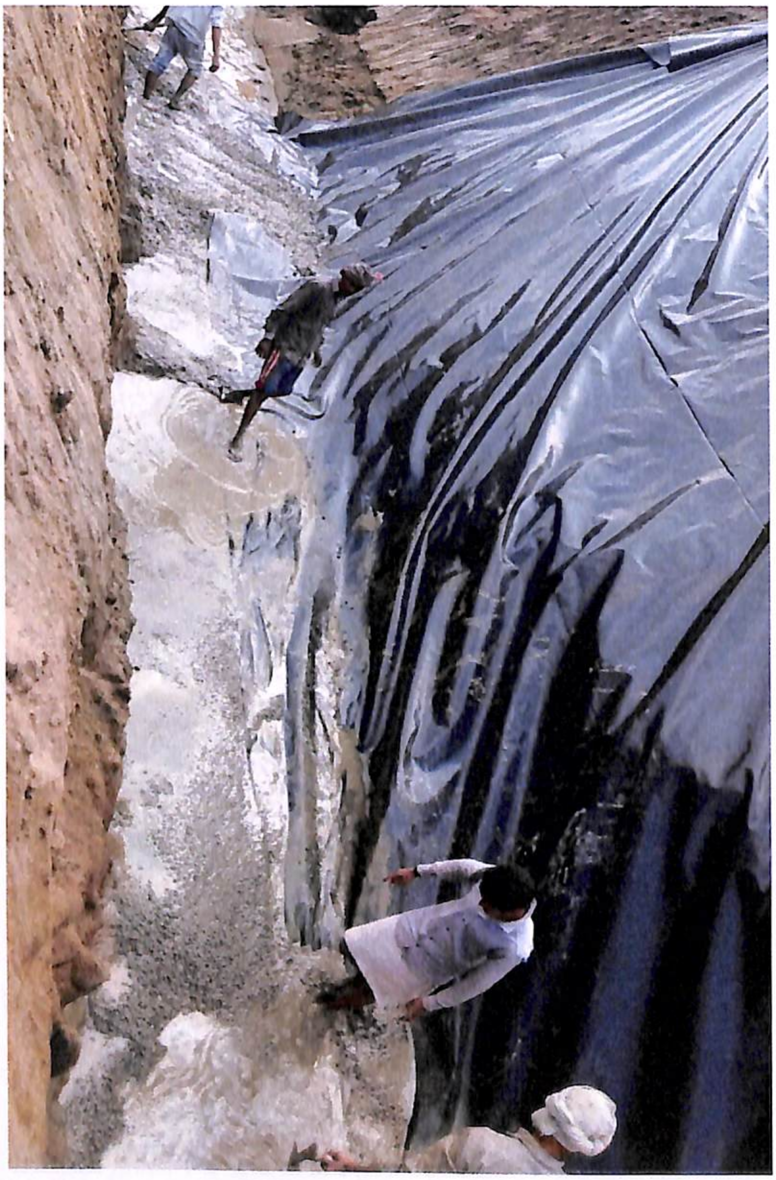


Figure: 23
The view from the upper part of the trench. The trench floor is levelled with PCC over which the LDPE sheet of 500 gsm is spread. Over this layer and the LDPE sheet, another 20 cm thick PCC is applied. Note that only half of the trench is covered with the LDPE sheet such that the entire length of the sheet is embedded in the PCC to act as impervious barrier. The PCC layer on the pond side acts as one layer while at the bund side, the sheet is embedded. This will prevent the seepage out of the bottom of the bund. In order to ensure continuity, the sheets are folded together with sufficient overlap.

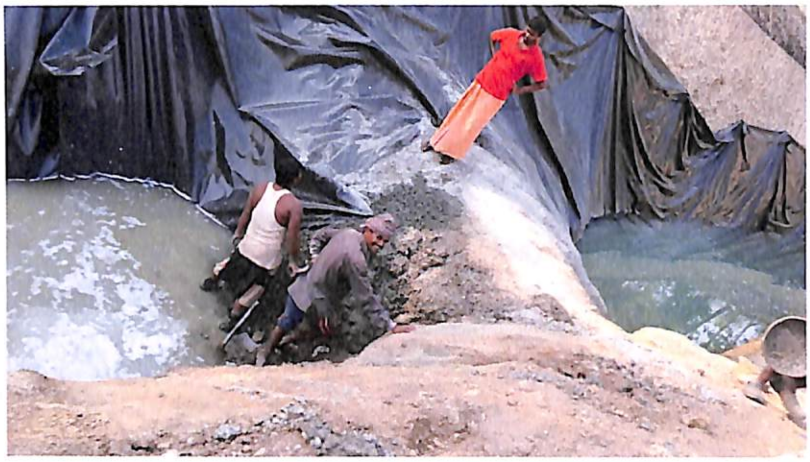


Figure: 24
Embedding the LDPE sheet in the sector where the rock is exposed as a barrier in the trench.

Figure: 25
Completing the work of laying LDPE sheet in the trench with a PCC layer over it.

Figure: 26
In order to the measure the water level in the pond above the trench bottom, a piezometer has to be installed. For this purpose perforated PVC pipe is inserted. The photograph shows inserting a 110 mm dia interconnected PVC pipes to act as a piezometer for recording the water level. The bottom horizontal pipe is perforated all through to permit entry of groundwater into it. End cap is provided to prevent entry of mud into the pipe. The water level in the vertical pipe is recorded.

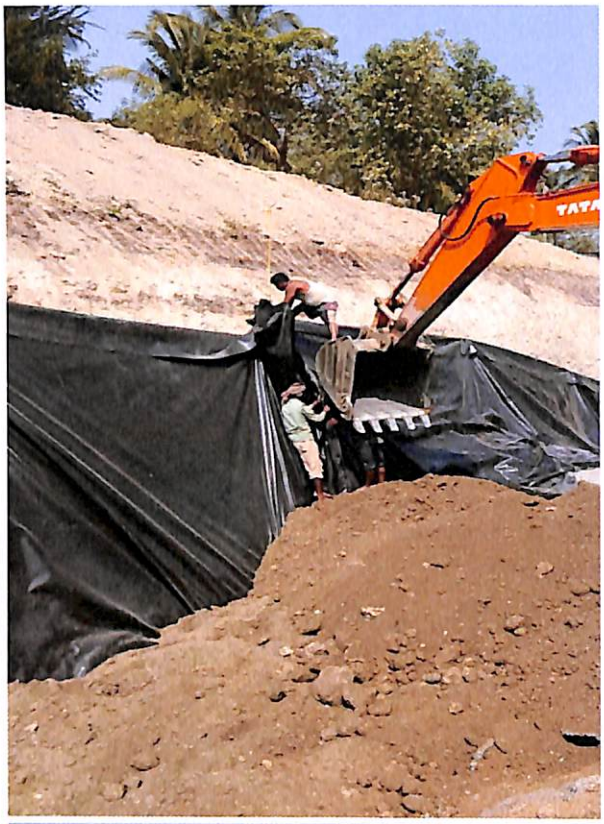


Figure: 27

The entire trench length up to the road level is covered with LDPE sheet. This acts as the impervious layer arresting any seepage through the bund. It also strengthens and adds stability to the bund. After laying the sheet, the trench is filled with loose excavated earth. Care is taken to ensure angular fractions of large dimensions like boulders are not coming in direct contact with the sheet. Dropping them from a height can damage the sheet. So the process of refilling is done slowly and with care.

Figure: 28 a and b

a) The trench is filled up and the LDPE sheet covered with excavated earth. The slope of the bund is maintained at about 1 in 2 to prevent slumping. Additionally the freshly covered face of the bund will be provided with a grass cover.
b) Another view of the completed bund without grass cover. Note the small mount in the foreground with a PVC pipe in the centre. This is to record the ground water level in the pond. Total height of the pipe is 7.6 m.

Figure: 29 a and b

a) Considering the water scarcity and considerable lowering of water table to below the pond floor in dry period, a smaller sized pond 20m x 15 m x 2m was excavated instead of desilting the entire pond.

b) Further, the new excavation was extended on one side having a dimension of 15 m x 10 m x 4 m. In this pond, water was seen at a depth of 2 m at the time of excavation. This became a source of water for the local population during the summer of 2017. This additionally excavated structure enhances the percolation rate into the surrounding aquifer ensuring the recharge component.

Figure 30 a & b

View of the Pond with water up to the overflow level marked by the masonry step visible in water over which a flat stone is placed for washing clothes. The elevated grass covered part is the bund in which LDPE sheet has been embedded.

Figure 31 a & b
View of the pond with the bund and overflow section. Over flow water is channelized by the side of the pump house and led to the southern part to be released into the valley. The over flow which was initiated on 23.07.2018 after heavy rains continued till the first week of November 2018.

Figure 32 a, b &c
Photographs of selected open irrigation wells where water level has come nearly up to the surface. Well –a is 13m, well-b is 15.7 m and well-c is 9m

9.0 Monitoring water level after construction of Dyke

The water level in the vicinity of the pond after the construction of water level was monitored for more than one monsoon season. The construction work was completed in the summer of 2017. The influence of the water conservation structure, the sub-surface dyke, in the groundwater regime of the area can be established only through the monitoring of the wells in the surroundings. The bore wells are encased and not amenable for measurement. Hence open wells were selected for the purpose. The location of the wells is depicted in the satellite imagery of the area given below. Wells numbered W4 to W7 are on the downstream while others are in the upstream side. W13 is the measurement in the pond.

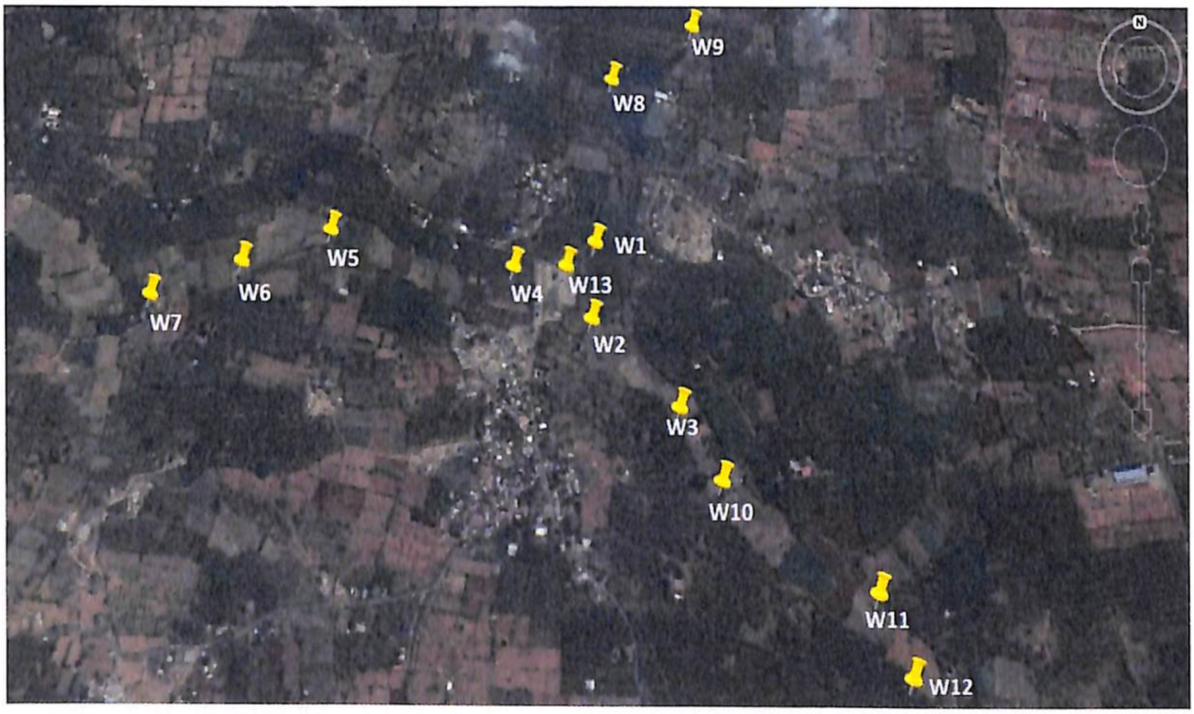


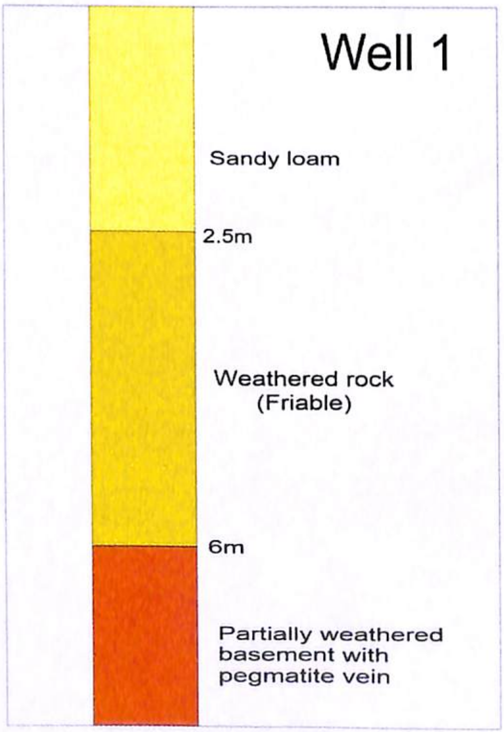
Figure 33: Location of observation wells upstream and downstream of Mariamman kovil pond

Some of these wells are pumping wells hence the water level data taken immediately after pumping can be slightly distorted on account drawal of water. In addition, there are cases where the bore wells feed open wells. Water levels were recorded periodically. The locational details of these wells, the sub-surface lithology and water level data at the time of observation are given below against each well.

Well No: 01

Location:	Lat 10^0 48' 06.6" N; Long 76^0 53' 31.0" E
Landform	Lower terrace
Elevation:	215 m amsl
Ownership:	Private- Unni's
Total depth	8.7 m bgl

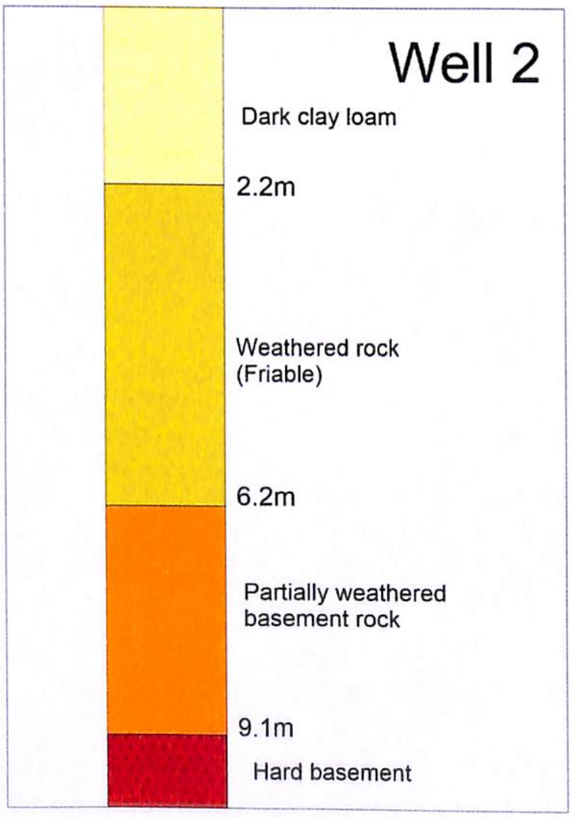
Date	Depth to Water table	Date	Depth to Water table
8.12.2016	4.8	16.03.2018	5.8
02.03.2017	4.9	07.06.2018	4.0
25.08.2017	5.1	07.07.2018	1.7
27.09.2017	4.1	30.08.2018	0.3
06.11.2017	4.3	27.12.2018	1.2



Well No: 02

Location:	Lat 10^0 48' 01.24" N; Long 76^0 53' 30.69" E
Landform	valley well bottom exposes hard rock
Elevation:	214 m amsl
Ownership:	Private- Ramesan
Total depth.	9.2 m bgl

Date	Depth to Water table	Date	Depth to Water table
8.12.2016	6.8	16.03.2018	7.1
02.03.2017	6.6	07.06.2018	6.5
25.08.2017	6.5	07.07.2018	2.8
27.09.2017	6.0	30.08.2018	0.1
06.11.2017	6.3	27.12.2018	0.9



Well No 3

Location: Lat 10^0 47’ 55.25” N; Long 76^0 53’ 36.68” E

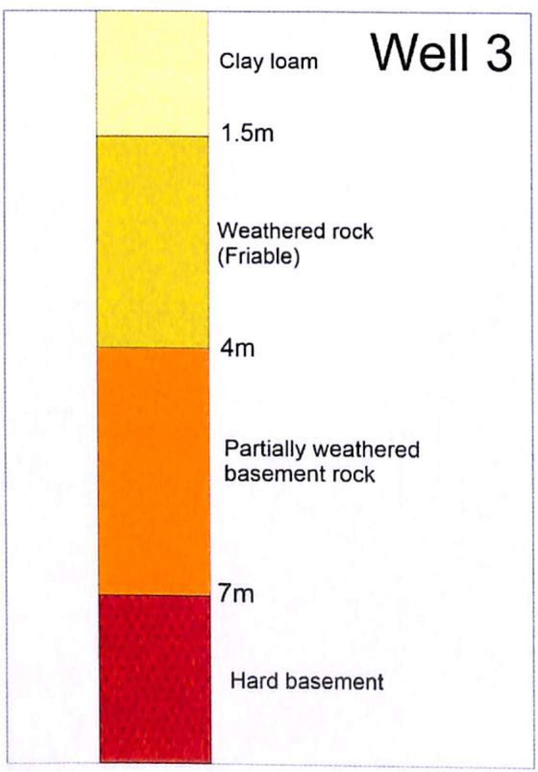
Elevation: 219 m amsl

Landform: Lower terrace

Ownership: Private- Ramesan

Total depth: 9.5 m bgl

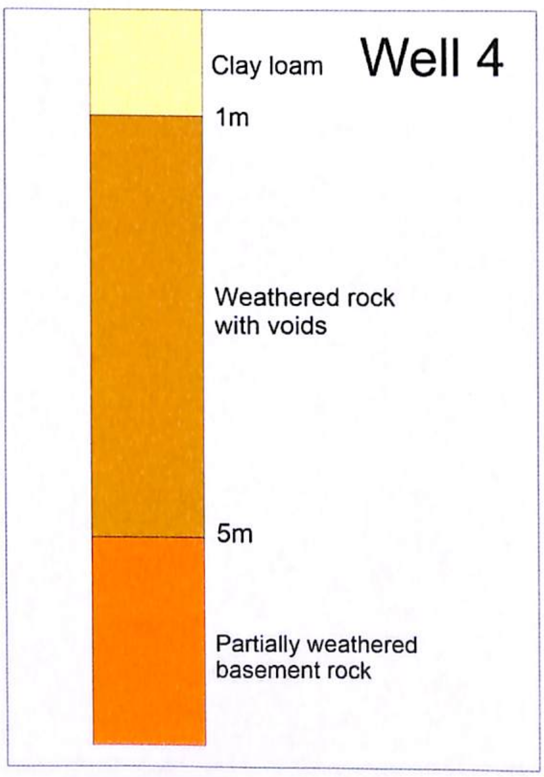
Date	Depth to Water table	Date	Depth to Water table
8.12.2016	8.1	16.03.2018	9.0
02.03.2017	8.0	07.06.2018	8.1
25.08.2017	7.1 (well being filled from a bore well)	07.07.2018	6.2
27.09.2017	7.0	30.08.2018	0.2
06.11.2017	8.2	27.12.2018	3.4



Well No 4

Location:	Lat 10^0 48' 04.94" N; Long 76^0 53' 25.06" E
Elevation:	211 m amsl
Landform	valley side
Ownership:	Private- Divakaran
Total depth	6.0 m bgl

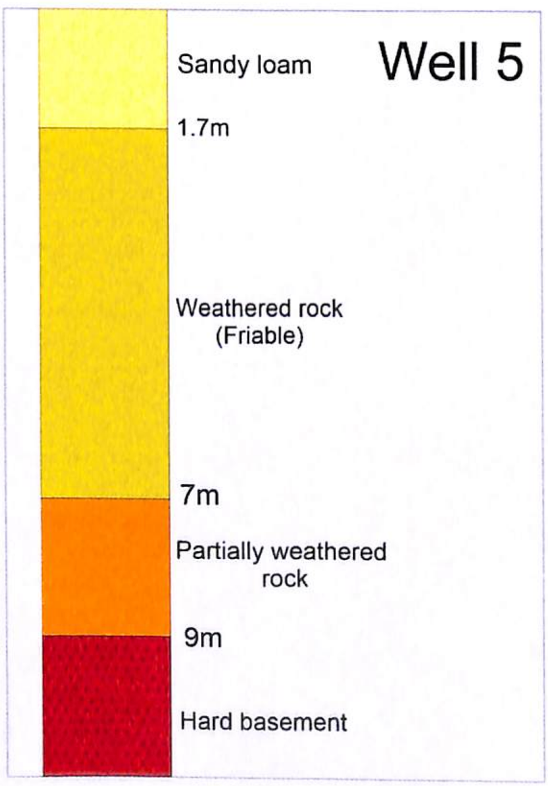
Date	Depth to Water table	Date	Depth to Water table
8.12.2016	4.4	16.03.2018	5.9 (deepened)
02.03.2017	5.5	07.06.2018	4.6
25.08.2017	5.6	06.07.2018	2.0
27.09.2017	4.4	30.08.2018	0.1
06.11.2017	4.2	27.12.2018	0.5



Well No 5

Location:	Lat 10^0 48' 07.56" N; Long 76^0 53' 11.56" E
Elevation:	209 m amsl
Landform	Lower terrace-valley
Ownership:	Private- Swamiappan
Total depth	10.6 m bgl

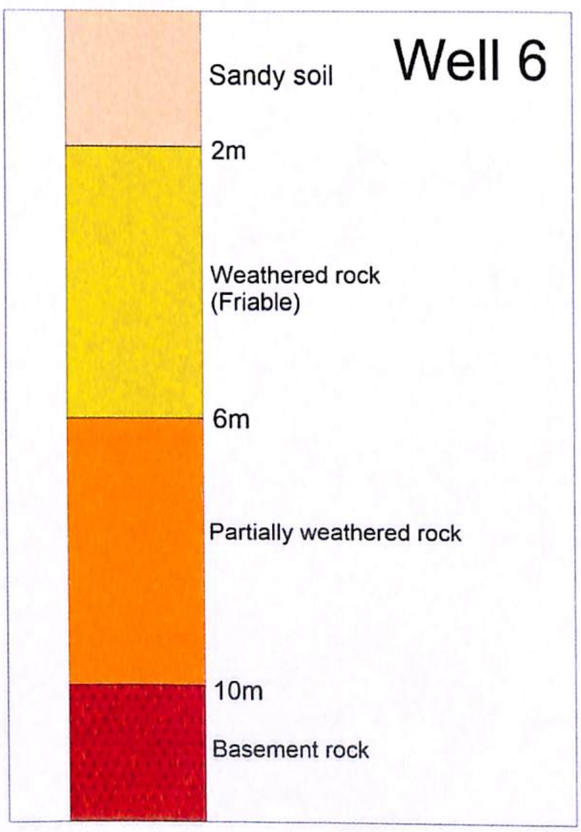
Date	Depth to Water table	Date	Depth to Water table
8.12.2016	8.7	16.03.2018	10.2
02.03.2017	9.2	07.06.2018	8.8
25.08.2017	9.6	06.07.2018	7.6
27.09.2017	8.3	30.08.2018	0.2
06.11.2017	9.3	27.12.2018	0.7



Well No 6

Location: Lat 10^0 48' 05.32" N; Long 76^0 53' 05.26" E
Elevation: 207 m amsl
Landform terrace edge - valley
Ownership: Private-Kuppuswamy
Total depth 11.2 m bgl

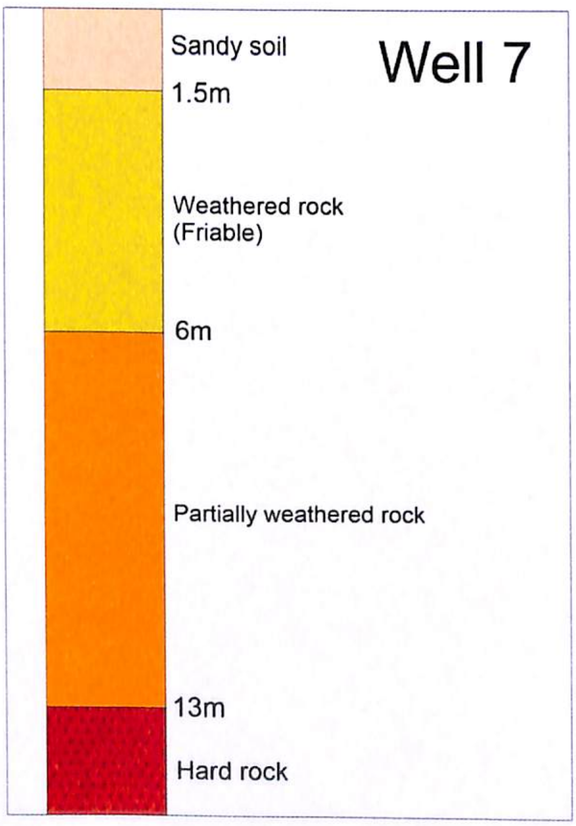
Date	Depth to Water table	Date	Depth to Water table
02.03.2017	7.9	07.06.2018	8.2
25.08.2017	8.2	06.07.2018	5.1
27.09.2017	7.8	30.08.2018	0.1
06.11.2017	8.4	27.12.2018	1.0
16.03.2018	dry		



Well No 7

Location:	Lat 10^0 48' 03.01" N; Long 76^0 52' 58.93" E
Elevation:	204 m amsl
Landform	valley
Ownership:	Private-Premanand
Total depth	16.4 m

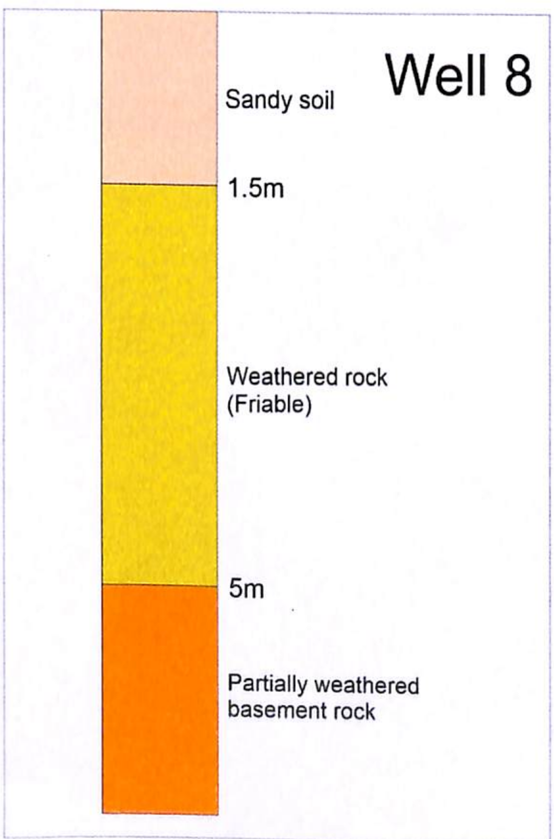
Date	Depth to Water table	Date	Depth to Water table
02.03.2017	14.5	07.06.2018	15.1
25.08.2017	15.1	06.07.2018	10.4
27.09.2017	14.6	30.08.2018	0.2
06.11.2017	15.3	27.12.2018	0.7
16.03.2018	15.9		



Well No 8

Location:	Lat 10^0 48' 19.13" N; Long 76^0 53' 32.40" E
Elevation:	218 m
Landform	Flat terrace
Ownership:	Private-Thomas
Total depth:	5.6 m.

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	dry	07.06.2018	dry
25.08.2017	dry	30.08.2018	0.6
27.09.2017	dry	27.12.2018	1.3
06.11.2017	dry		
16.03.2018	dry		



Well No 9

Location: Lat 10^0 48' 23.44" N; Long 76^0 53' 38.81" E

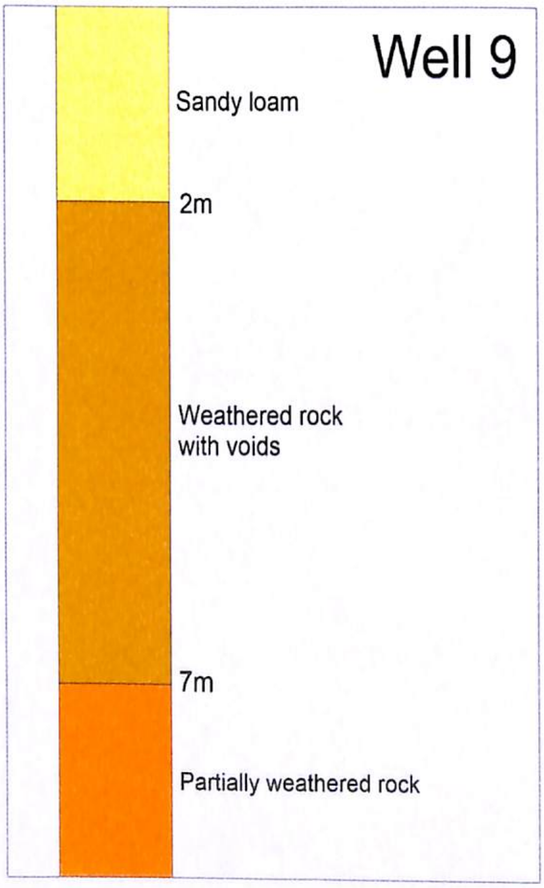
Elevation: 223 m amsl

Landform Flat terrace

Ownership: Private-Thomas

Total depth 12.3 m

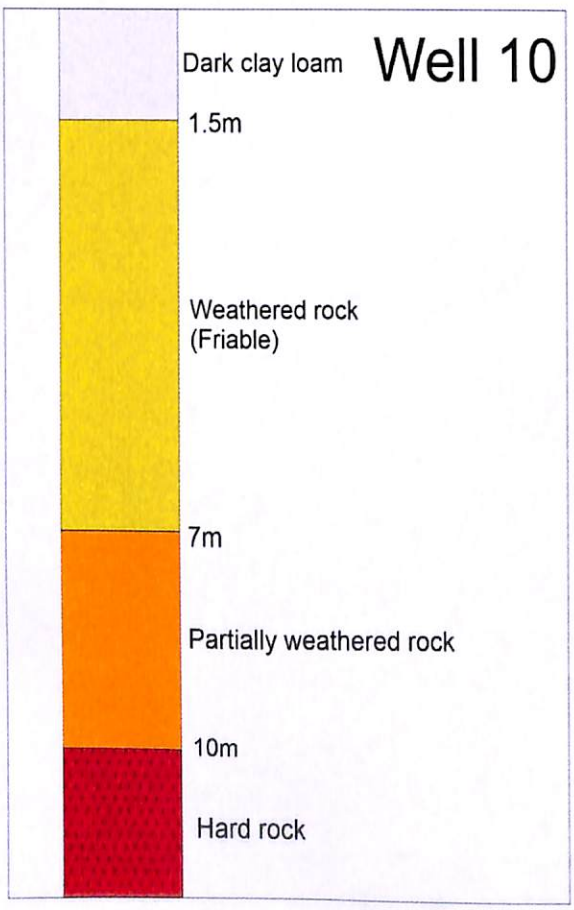
Date	Depth to Water table	Date	Depth to Water table
02.03.2017	dry	07.06.2018	dry
25.08.2017	dry	30.08.2018	1.5
27.09.2017	dry	27.12.2018	3.0
06.11.2017	dry		
16.03.2018	dry		



Well No 10

Location:	Lat 10^0 47'50.65" N; Long 76^0 53' 39.32" E
Elevation:	221 m amsl
Landform	Valley edge
Ownership:	Private-Krishnaraj
Total depth	10.2 - Well deepened to 16.5 m in May, 2017

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	9.1	07.06.2018	16.0
25.08.2017	16.1	06.07.2018	12.9
27.09.2017	14.8	30.08.2018	0.5
06.11.2017	15.0	27.12.2018	1.6
16.03.2018	15.8		



Well No 11

Location: Lat 10^0 47' 44.18" N; Long 76^0 53' 48.95" E

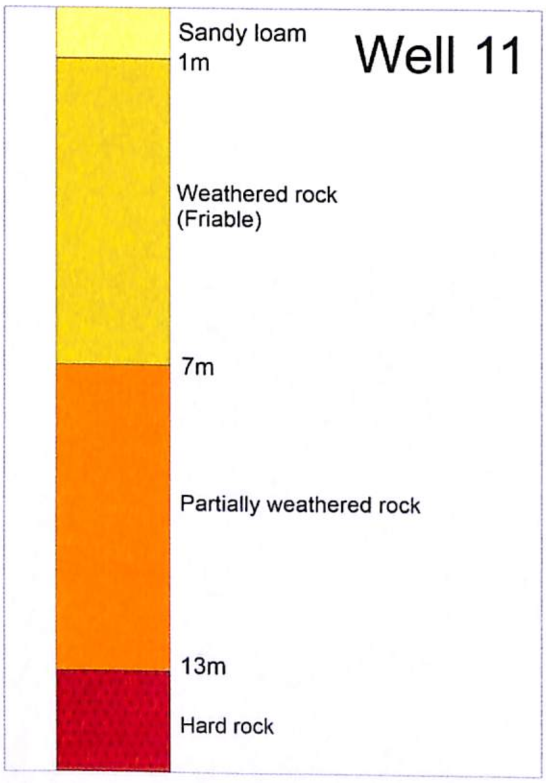
Elevation: 226 m

Landform flat land

Ownership: Private- Karuppuswamy Koundar

Total depth 12.5 m- well deepened to 15.7 m in March 18

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	11.1	07.06.2018	dry
25.08.2017	11.8	19.06.2018	15.5
27.09.2017	11.5	07.07.2018	12.2
06.11.2017	11.7	30.08.2018	0.6
16.03.2018	dry	27.12.2018	1.2



Well No 12

Location: Lat 10^0 47' 39.49" N; Long 76^0 53' 50.51" E

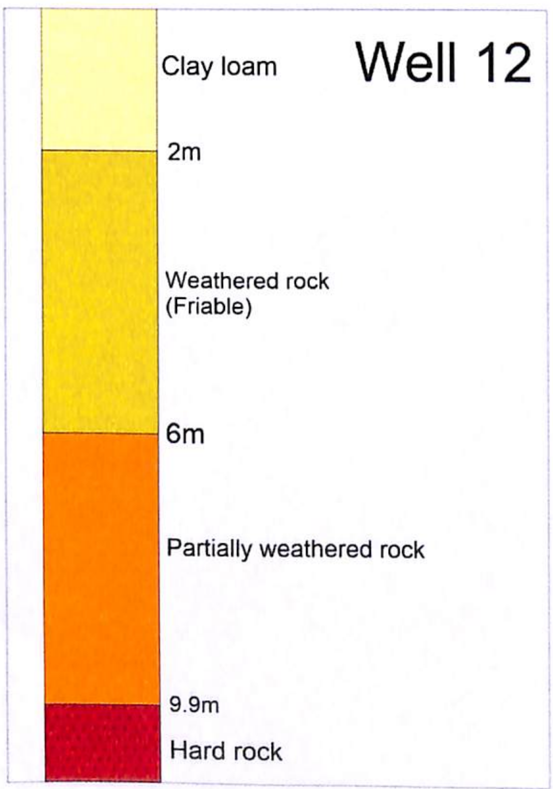
Elevation: 228m

Landform valley edge south side

Ownership: Kumaraswamy Koundar

Total depth 13 m bgl

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	12.1	07.06.2018	12.8
25.08.2017	12.7	07.07.2018	11.8
27.09.2017	12.4	30.08.2018	0.5
06.11.2017	12.2	27.12.2018	1.4
16.03.2018	12.5		



Well No 13

Location: Lat 10^{0} 48’ 04.96” N; Long 76^{0} 53’ 28.87” E

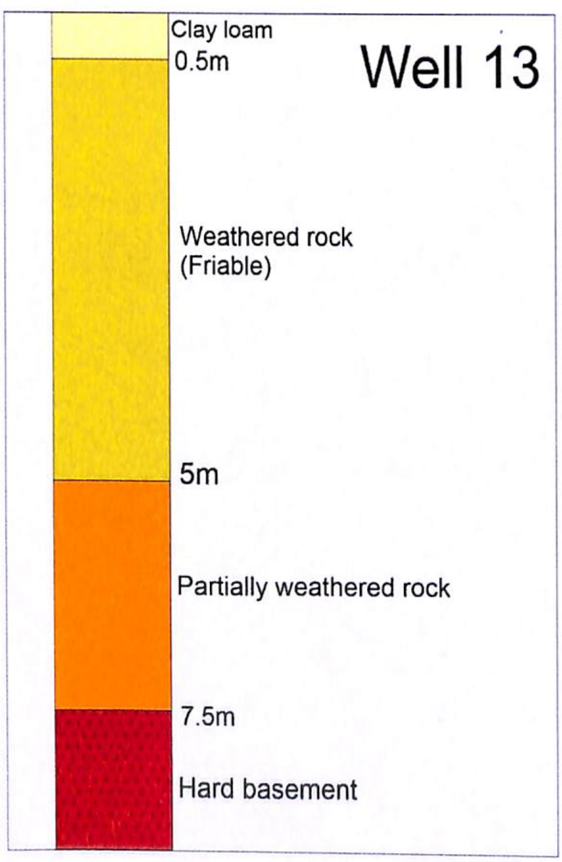
Elevation: 211 m

Landform Valley –pond floor

Ownership: Public-Mariamman kovil Pond

Total depth: 6 m from pond floor

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	4 m (below pond floor level)	07.06.2018	3.6 m
25.08.2017	4.4 m	19.06.2018	1.2 m
27.09.2017	3.0 m	07.07.2018	0.9 m
06.11.2017	3.7 m	12.07.2018	+0.75 m
16.03.2018	5.1 m	30.08.2018	+3.4 m
		27.12.2018	+2.7 m



Top-View of the floor of the pond in June 2018
Bottom- A view of the deepened part of the pond when constructed in 2017.

Pond overflowed on 23.07.2018. The over flow continued from the pond and peaked on 16.08.2018 when the water level above the over flow point (cemented steps) was 1.5 m. Over flow from the pond continued till the middle of November, 2018. On 30.08.2018, the water level stood at 0.4 m above the overflow point while it was 0.3 m on 14.10.2018.

Pipe piezometer (Perforated pipe inserted in the trench taken for the dyke)

Location:	Lat 10^0 48' 04.96" N; Long 76^0 53' 28.87" E
Elevation:	211 m
Landform	Valley –pond floor
Ownership:	Public-Mariamman kovil
Total depth	7.6 m from top edge of pipe inserted on the bund.

Date	Depth to Water table	Date	Depth to Water table
02.03.2017	5.6 m	07.06.2018	4.85
25.08.2017	5.9 m	19.06.2018	3.05
27.09.2017	4.45 m	07.07.2018	2.7
06.11.2017	5.05 m	12.07.2018	1.3
16.03.2018	6.35 m	30.08.2018	Pipe submerged
		27.12.2018	Pipe submerged

Arrow points to the head of the pipe piezometer from where measurements are taken

Composite table showing the variation in water level (bgl) in the observation wells

Well no	02/3/17	25/8/17	29/9/17	06/11/17	16/3/18	07/6/18	7/7/18	30/8/18	27/12/18
1	4.9	5.1	4.1	4.3	5.8	4.0	1.7	0.3	1.2
2	6.6	6.5	6.0	6.3	7.1	6.5	2.8	0.1	0.9
3	8.0	7.1	7.0	8.2	9.0	8.1	6.2	0.2	3.4
4	5.5	5.6	4.4	4.2	5.9	4.6	2.0	0.1	0.5
5	9.2	9.6	8.3	9.3	10.2	8.8	7.6	0.2	0.7
6	7.9	8.2	7.8	8.4	11.2	8.2	5.1	0.1	1.0
7	14.5	15.1	14.6	15.3	15.9	15.1	10.4	0.5	0.7
8	5.6	5.6	5.6	5.6	5.6	5.6	4.0	0.6	1.3
9	10.8	10.8	10.8	10.8	10.8	10.8	8.9	1.5	3.0
10	15.0	16.1	14.8	15.0	15.8	16.0	12.9	0.5	1.6
11	11.1	11.8	11.5	11.7	15.7	15.7	12.2	0.6	1.2
12	12.1	12.7	12.4	12.2	12.5	12.8	11.8	1.0	1.4
13	7.0	7.4	6.0	6.7	8.1	6.6	3.9	+0.4	0.3
14	5.6	5.9	4.5	5.1	6.4	4.9	2.7	+1.5	+0.8

Variation in water level from the previous observation

Well no	25/8/17	29/9/17	6/11/17	16/3/18	7/6/18	7/7/18	30/8/18	27/12/18
Wells located upstream of pond								
1	+0.2	-1.0	+0.2	+1.5	-1.8	-2.3	-1.4	0.9
2	-0.1	-0.5	+0.3	+0.8	-0.6	-3.7	-2.7	0.8
3	-0.9	-0.1	+1.2	+0.8	-0.9	-1.9	-6.2	3.2
10	+1.1	-1.3	+0.2	+0.8	+0.2	-3.1	-12.4	1.1
11	+0.7	-0.3	+0.2	+4.0	0	-3.5	-11.6	0.6
12	+0.6	-0.3	-0.2	+0.3	+0.3	-1.0	-10.8	0.4
Wells located downstream of pond								
4	+0.1	-1.2	-0.2	+1.7	-1.3	-2.6	-1.9	0.4
5	+0.4	-1.3	+1.0	+0.9	-1.4	-1.2	-7.4	0.5
6	+0.3	-0.4	+0.6	+2.8	-3.0	-3.1	-5.0	0.9
7	+0.6	-0.5	+0.7	+0.6	-0.8	-4.7	-9.9	0.2
Wells located on the northern flank of the pond								
8	0	0	0	0	0	-1.4	-3.4	0.7
9	0	0	0	0	0	-1.9	-6.9	1.5
Pond and Piezometer levels								
13	+0.4	-1.4	+0.7	+1.4	-1.5	-2.7	-4.3	0.7
14	+0.3	-1.4	+0.6	+1.3	-1.5	-2.2	-4.2	0.7

The table above shows that maximum filling was observed during August 2018 when peak values in water levels are seen. It is reported by the local people that the pond started to overflow from the end of July. The peak flow level was reported to be about 1 m above the overflow level marked by the top of the steps. The water level in all the water bodies including the observation wells were close to the surface during the first two weeks in the month of August, 2018 when the rainfall was at peak. Subsequent reduction in rainfall saw a slight decline in water level recorded on 30.08.2018. During the period from the first week of November to the end of December, 2018, the area did not receive any rainfall. The farmers had also started pumping to irrigate their fields. Despite this fact only a steady gentle decline in water level is seen in the subsequent period but not a sudden decline. The decline in water level from the overflow level of the pond is limited to only 45 cm in a period of 50 days (from 07.11.2018 to 27.12.2018) which means that the average decline in water level is only about 1 cm/day. The evaporation rate in this area can be taken as 0.4 cm per day during this period. Then the reduction is water level is limited to 0.6 cm which is less than a cm /day. The depth to the floor of the pond is 3 m from the over flow level. Hence at the time of observation at the end of the month, the pond was supporting a water column of 2.55 m from its floor level. Water level falling at the rate of 1 cm/day, the total reduction in water level till the end of May would only be 150 m. The pond would still support 1 m water column in addition to the water retained as groundwater below the floor.

The observations taken on 27.12.2018 in most of the wells show a reduction in water level of less than a meter from the peak value on 30.08.2018. Well no 3 shows a greater decline of 3.4 m during this period mainly due excess pumping for irrigation. Another aspect that was observed was the condition of the plot on the downstream side of the bund. This plot is normally in a marshy condition when the pond is filled up. It will continue till the water level in the pond reduces to all most its floor level. Deep trenches are provided in this plot to drain out water from the plot. However, during this year when the pond was in full level, the adjacent plot was not rendered in a marsh like condition though surface wetness was maintained.

10.0 Conclusion

The model study carried out in Vadakarapathy Gramma-panchayat falling in Chittur block, which has been categorised as overexploited for ground water availability and development in ground water resource assessment (2013), has indicated that harvesting rainwater and retaining it in the ponds in the area augments groundwater recharge in the region.

Through the initial part of the study the entire Gramma-panchayat area was divided into eight micro-watersheds and each watershed was evaluated in terms of landform, landuse, geology, soil and available water resources. This has resulted in the identification of Mariammankovil pond falling in Ozhalapathy watershed for implementation of the model recharge structure. The sub-surface dyke installed along the retaining bund of the pond has prevented the normal seepage through the earthen wall of the bund. This resulted in maintaining water level in the pond to its maximum water level for at least four months. The excavation in the form of an in well or pond within the floor of the main pond and reaching to the hard rock has enhanced recharge through all the layers of the earth's column laterally. The longer residence period of water in the pond has assisted in augmenting groundwater recharge in the area.

The wells, mostly pumping, located both upstream and downstream of the pond was monitored before and after intervention. It is seen that during the monsoon of 2017 which was far below normal, the area responded marginally only. During this period, there was no overland flow, the water level in the pond remained below the floor level and the observation wells showed only a marginal increase. The monsoon of 2018 produced excess rainfall-150%- which caused overland flow in the watershed, a part of which was channelized to the pond. The pond did over flow from end of July to the first week of November maintaining elevated water table conditions. The reduction in water table in the monitoring wells after the cessation of rains in the area is limited to less than one metre while the water level in the pond lowered only by 0.7 m in four months. The structure has also helped in reducing the surface flow on the downstream side of the pond.

The hydrogeological survey conducted in the end of December 2018 has indicated that the total depletion in water level in a period of 50 days was only 45 cm from the over flow level in the pond after it was in the spate condition. This means that the average daily lowering is about 1 cm only including evaporation loss. It is presumed that the available surface water in the pond and the groundwater stored in surrounding aquifer would cater to the requirements of local population and agriculture activities till the onset of next monsoon. Water usage shall be restricted in case of sudden fall in water table or anticipated delay in receipt of subsequent rains.

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