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MANAGEMENT OF WATER RESOURCE FOR AN OPEN PIT MINE

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मधुक्कराई लाइमस्टोन खदान में जलीय स्त्रेतों के प्रबन्धन हेतु एक जलभूवैज्ञानिक अध्ययन किया गया। यह खान कौरियार जलसायबान (watershed) में अवस्थित है। यह अनुमान लगाया गया है कि इस खुली खदान में जल-बहाव की चरम सीमा लगभग 1750 लीटर प्रति सेकेण्ड है। भूमिगत जल फ्रियाटिक (Phreatic) अवस्था में सामान्य भू-सतह से ग्रीष्म काल में 29 मीटर की गहराई में और मानसून काल के बाद 21 मीटर की गहराई में मिलता है। भावी योजना के अनुसार इस खदान को आगामी 20 वर्षों में सामान्य भू-सतह से अधिकतम 80 मीटर तक गहरा किया जाना है। ऐसा अनुमान है कि उस समय इस खदान से चरम परिस्थितियों में लगभग 85 लीटर प्रति सेकेण्ड जल का निष्कासन करना पड़ेगा। चरम मानसून काल में सम्प (Sump) में जमा होने वाले पृष्ठीय एवं भू-जल की अनुमानित मात्रा को ध्यान में रख कर यह अनुशंसा की गयी है कि भू-जल स्तर के नीचे चार 40 अश्व शक्ति वाले अवगाहन-क्षम पम्प (Submersible Pump), जिनकी जल-निष्कासन क्षमता 180 लीटर प्रति मिनट हो, स्थापित किए जायें। अन्य मौसमों में ऐसे तीन पम्प ही खान के लिए पर्याप्त होंगे। बरसात के समय सम्प की जल संग्रहण क्षमता कम-से-कम 17000 घन लीटर होनी चाहिए।

खान में जमा जल (Pit water) में कॉलीफार्म की उच्च मात्रा पाई गई और यह जल देखने से ही दूषित लगा। अतः, यदि इस जल को पीने के काम लाना है तो इसका शुद्धीकरण आवश्यक हैं। इस खनन क्षेत्र में विभिन्न कार्यों के लिए जल की वार्षिक आवश्यकता 573683 किलो लीटर आंकी गयी है, जिसे सम्प्रति भू-जल संसाधनों से प्राप्त किया जा रहा है। प्रभावी नियंत्रण लागू कर इस खान से बिना भू-जल को क्षति पहुँचाए लाइमस्टोन का खनन किया जा सकता है।

INTRODUCTION

The Madukkarai limestone mine is a captive mine of M/s Associated Cement Company (ACC) covering an area of about 167.91 hectares (ha) under the Mining Lease (ML), which includes a forest area of about 5.99 ha, for which the lease renewal is not granted so far. The ML area falls under the village areas of Madukkarai and Kurichi in Madukkarai block of Coimbatore district in Tamilnadu (Fig. 1). Besides the above mining lease area, M/s ACC has also got surface rights over 71.59 ha of land, for areas to cover compensatory afforestation in respect of Walayar mine and keeping safety zones along the mine site and about 82.69 ha of land to accommodate the approach roads, cement works, colony etc. The above three areas are contiguous and are located in the same villages of Madukkarai and Kurichi.

Thus the total area of about 322.19 ha of land falls between the latitude 10^0 54' to 10^0 56' and longitude 76^0 56' to 76^0 59' and located on Survey of India toposheet No. 58 B/13. The area marked by undulating terrain with ridges in between. The hill Dharmalingam Malai is located on the south western side of the lease area. The village Madukkarai located about 1.5 km further south of the ML area, is accessible from Coimbatore through the National Highway (NH-47). This distance from Coimbatore is about 15 km. In fact this NH-47 passes right through the mining lease area, separating a portion of the ML area, into road side east and the road side west sections. The cement plant is located about 1.5 km east of the road, adjoining Podanur-Palghat BG railway line of the southern railway. Presently working is going on quarry located west side of the road and the cement plant is at about 3.5 km from quarry. A key plan showing the mining area is illustrated in Fig. 2.

At present, bottom bench of the open pit has reached up to the groundwater level of the area. As per the future demand of the limestone, the open pit mine has to be deepended below groundwater level for exploitation of limestone. Therefore, proposed mining activities will necessitate storage of groundwater in the sump and thereby arrangement of pumping of storage water out of the open pit. In addition to handling of groundwater, there is a need for considering peak quantity of rain storm water which will accumulate in the open pit and subsequently

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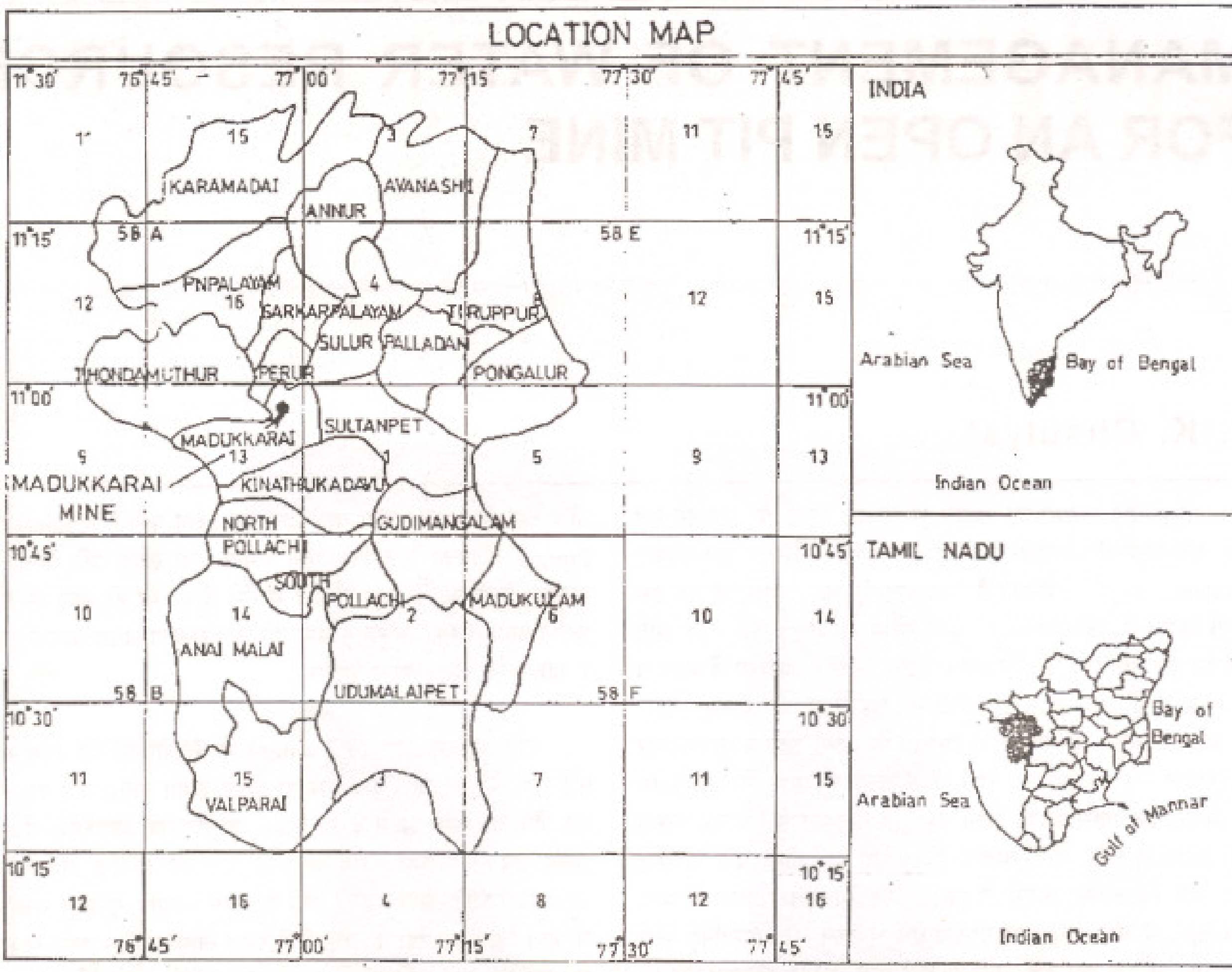

Fig. 1 : Location map of Madukkarai limestone mine

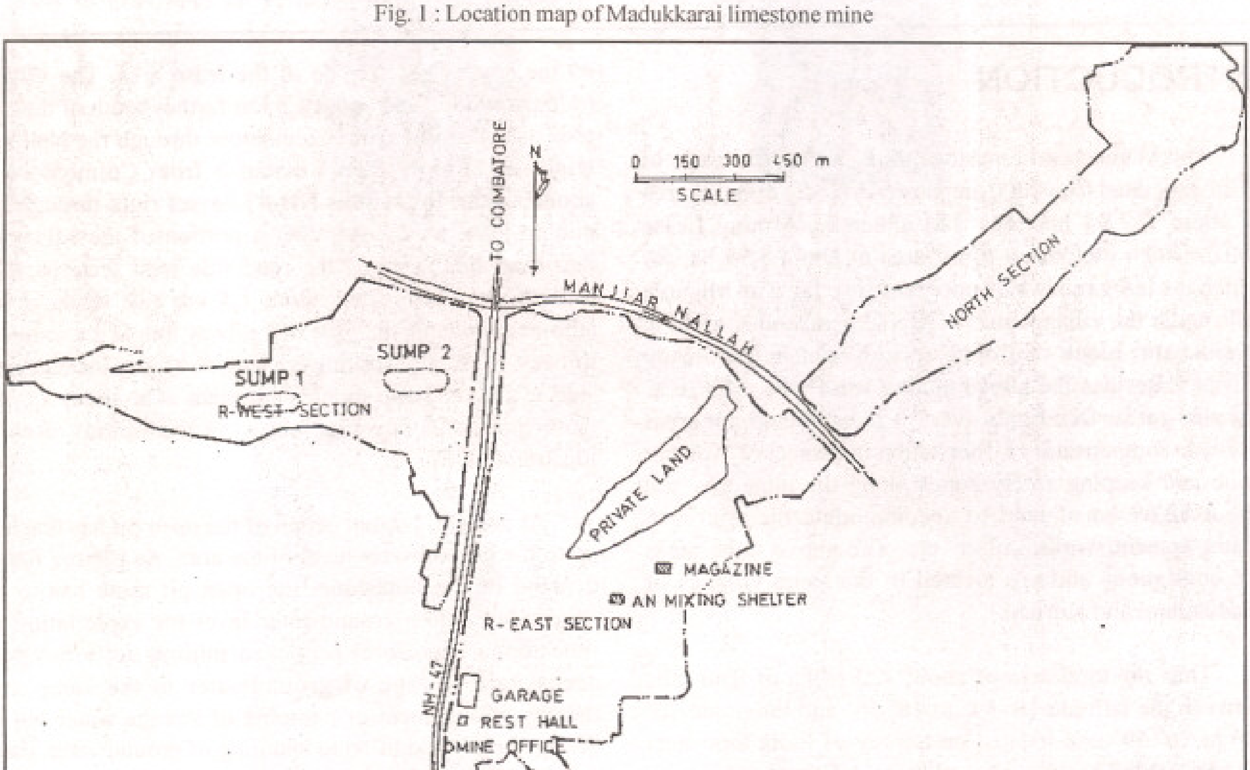

Fig. 2 : Key plan of Madukkarai limestone mine

pumping arrangement has to be made for safe exploitation of limestone from the mine.

Therefore, considering the above facts, a hydrogeological study has been carried out for the limestone mine. The broad objectives of the study were to quantify the water availability with deepening of the pit vis-à-vis estimation of pumping requirement, analysis of physico-chemical properties of pit water to evaluate of it's potability and finally to prepare a water resource management strategy for the mining area. The paper described the findings of the study in brief.

METHODOLOGY

To attain the above objectives following methodologies have been adopted:

- Supporting data regarding drainage pattern, recharge zones, rainfall, ground and surface water resources, water balance status and other details of Madukkarai block have been collected from various agencies like Central Groundwater Board, Chennai; Anna University, Chennai; Tamilnadu Water Supply and Drainage Board, Coimbatore; Public Works Division (Groundwater), Coimbatore; Agricultural University, Coimbatore; Indian Bureau of Mines, Nagpur; Madukkarai Limestone Mine, Madukkarai etc.

- Rainfall pattern and its intensity has been analysed to evaluate the runoff characteristic. Long term water levels were collected for correlation of rainfall with water level fluctuations and analysis of pre and post monsoon water level fluctuations following Adamovski and Homory (1983), Weeks and Boughton (1987) and Soliman et al. (1997).

- Geological structure and strategraphic sequences have been analysed from bore hole data and geological cross sections of the mine as per the methodology described by Karaguzal et al. (1999), Chaulya et al. (2000) and Chakraborty et al. (2001).

- Aquifer parameters have been determined by pumping test in the pit and groundwater modelling has been carried out based on field study data and supporting data to estimate the availability of groundwater and requirement of pump capacity based on following references Rao and Rao (1985), Brawson and Istok, (1992), Kresic (1997), Singh et al. (1999), Bell and Maud (2000) and Umar and Ahmad (2001).

- Water resource potential of the area has been calculated based on rainfall, runoff, evaporation, infiltration, drainage, landuse, soil characteristics, geology, geomorphology, terrain features, slope, lineament density, etc. The references followed for this purpose were Bradon (1986), Lyle (1987) Karanth (1990), Tolman (1993), Abu-Taleb (1999) and Feng et al. (2000).

- Water balance study has been carried out based on analysis of water resource availability and demand in open pit mine following Brawner (1986), Basu and Basu (1999), Berger (2000) and Reddy et al. (2000).

- Physico-chemical properties of pit water have been analysed as per the standard method of analysis to evaluate its potability (Down and Stocks, 1977; Dominico and Schwart, 1990; AWWA, 1992; Lee et al., 2001).

- Finally, water management strategy has been formulated based on techno-economical feasibility and recharge potential of the area following the experience of various case studies (ASCE, 1972; Aral, 1995; Abu-Taleb, 1999; El Ouali et al., 1999; Graniel et al., 1999; Yang et al., 1999; Farah et al., 2000; Reddy et al., 2000).

TOPOGRAPHY

The area under mining lease of Madukkarai limestone mine is undulating with intermittent ridge/ hillocks. The general slope of this area is west to east. The lowest contour passing through the area is 370 mRL (Reduced Level) and highest is at 465 mRL. Based on the limestone deposition and topographical features, this area is divided into 5 sections. The road side west section and the road side east section where the NH-47 running in north-south direction separates the lease area. The road side west section has got a gentle slope towards east i.e. towards NH-47. Beyond the southern limits of this section, the hill range called Dharmalingam Malai exists. The highest peak of its range adjoining the ML area is 615 mRL. The hill range falls under the reserve forest area, covered with fairly dense scrub. A portion of this hill slope, along it's northern flank, of area about 5.99 ha, adjacent to the presently working quarry in the area for which renewal of mining lease has not been granted so far. However, this portion of the area is covered with only open scrub.

A seasonal nallah called Munjiar nallah runs almost parallel to the northern boundary limit of this section. Presently active quarrying operations up to 45 m depth are in progress in this section alone. The quarry workings in this section stretch for about 1.5 km, in east-west direction, perpendicular to NH-47, with a maximum width of 400 m. The depth extensions of limestone proved in this area is below 100 m from the ground level. The waste dumps have been built up for a maximum height of about 15 m at the south-east and north-east corners of this section. Present waste dumping is also under progress at the middle portion along the northern boundary of this section. The roadside east section covers with old and abandoned quarries, partly covering the cuttings along the hillock slope up to a height of 400 m RL i.e. about 25 m below the ground level. This area stretches in north-south direction parallel to the national highway NH-47, for a length about 1.4 km, with a maximum width of 450 m. Because of the nearness to this national highway, presently no quarrying operations are being undertaken in this area. Here the grade is also poor and not amenable for mechanised mining.

A high tension (HT) power feeder line also passes through this area at its north-western corner. In this section also, the Munjiar nallah runs parallel to the northern boundary limits. Limestone, being produced from roadside west section, is transported by road through trucks to the cement plant located further east of NH-47. A hillock, of maximum height 455 mRL, separates the roadside east section and the north section. Also there exists a strip of private cultivated land of maximum width about 200 m, separating these two sections. In the northern section, the limestone deposit is thin, the width of which ranges from 20 to 50 m, with a steep dip and stretches north-east to south-west direction. Reserves in this section are almost exhausted. In this area there exists a narrow (about 50 m maximum width) abandoned quarry, which extends in length over 1.35 km and a maximum depth of about 15 m. In this section, at its south western extremity, the worker's colony, school and canteen are existing.

This quarry further extends in north-east direction and enters into Kurichi section. The Munjiar nallah cutting across the ML area, bifurcates this into northern section and Kurichi sections. Kurichi section, located along the foot-hill of a hillock (extending to a maximum height of 400 mRL), the limestone deposit further extends in south-west to north-east direction, but narrows down substantially at the middle portion (less than 5 m) and again widens to about 50 m at the north-eastern extremity. In this section also, there exists narrow abandoned quarry of length of over 1.7 km, worked to a maximum depth of about 15 m. Both northern and Kurichi sections are not being worked at present because of the narrow limestone bed and high cost in developmental work. The narrow portion of the quarry in north section is being used for dumping of flotation rejects generated from the cement mill. A HT power line, feeding to cement plant, passes adjoining to the northern edges of these quarries. Two more HT power lines, running parallel, with in 250 m from each other, are also passing across the Kurichi section of the ML area. In Kurichi section, along the foot of the hillock range, located within 200 m north of the ML area, there lies the residential houses of this village. The south bed section is located at the south eastern extremity of the ML area. In this area also, there are old and abandoned workings, worked to a depth of about 20 m (maximum), stretching over a length of 950 m in north-west to south-east direction, with a maximum width of 150 m. Presently, this quarry is being used for storage of water for the plant. This area also covers the present workers colonies, officers bungalows etc. In between the north and south sections, there exists another seasonal nallah, which is not a prominent one.

LAND USE

The total ML area is about 167.91 ha of land which includes forest area of 5.99 ha for which mining lease renewal was not granted so far. This area under mining lease is classified as government waste land (144.71 ha), ACC owned land (17.21 ha) and forest land (5.99 ha). The present status of land use within the existing mining lease area, excluding the forest land which is not renewed so far is given in Table 1.

Table 1 : Present land use status of Madukkarai mining lease area

Type of area	Area (ha)	Area (%)
Active quarry area	21.20	13.3
Old quarries used for storage of water	15.50	9.6
Old quarries used for filling the flotation rejects	4.25	2.6
Unused old and abandoned quarries	22.75	14.1
Mine waste dumps	7.50	4.6
Barrier left for HT powerline	7.00	4.3
Barrier left for NH 47	13.50	8.3
Colony, office buildings and roads	20.00	12.4
Area covered by barren hillock - in roadside east section	13.00	8.0
- in Kurichi section	15.00	9.3
Parking place for private trucks	2.75	1.7
Balance virgin area	19.47	11.8
TOTAL	161.47	100%

Apart from the above area M/s. ACC have got surface rights over 154.28 ha of Rayatwari land adjoining the ML area held for the purpose of other than mining i.e. as safety zones for blasting, mill reject dumps, compensatory afforestation for Walayar mines, approach roads and office buildings, colony and for the cement plant. Hence, the total area under the core zone, constitute about 322.20 ha. The existing land use pattern in this area is given in Table 2. From the data it can be seen that the land disturbed by the quarries constitutes only about 20% of the total land under the core zone.

Table 2 : Existing land use pattern of the area

Type of land	Area (ha)
Present working quarry	21.50
Old and abandoned quarries	42.50
Mine waste dumps	7.50
Compensatory afforestation for Walayar mine	65.50
Colony and cement plant	71.75
Undisturbed forest area (not renewed)	4.00
Old quarry with in this forest area (not renewed)	2.00
Safety zone for blasting, green barriers, virgin area of ML, approach roads, mine office etc.	71.45
Social afforestation	36.00
TOTAL	322.20

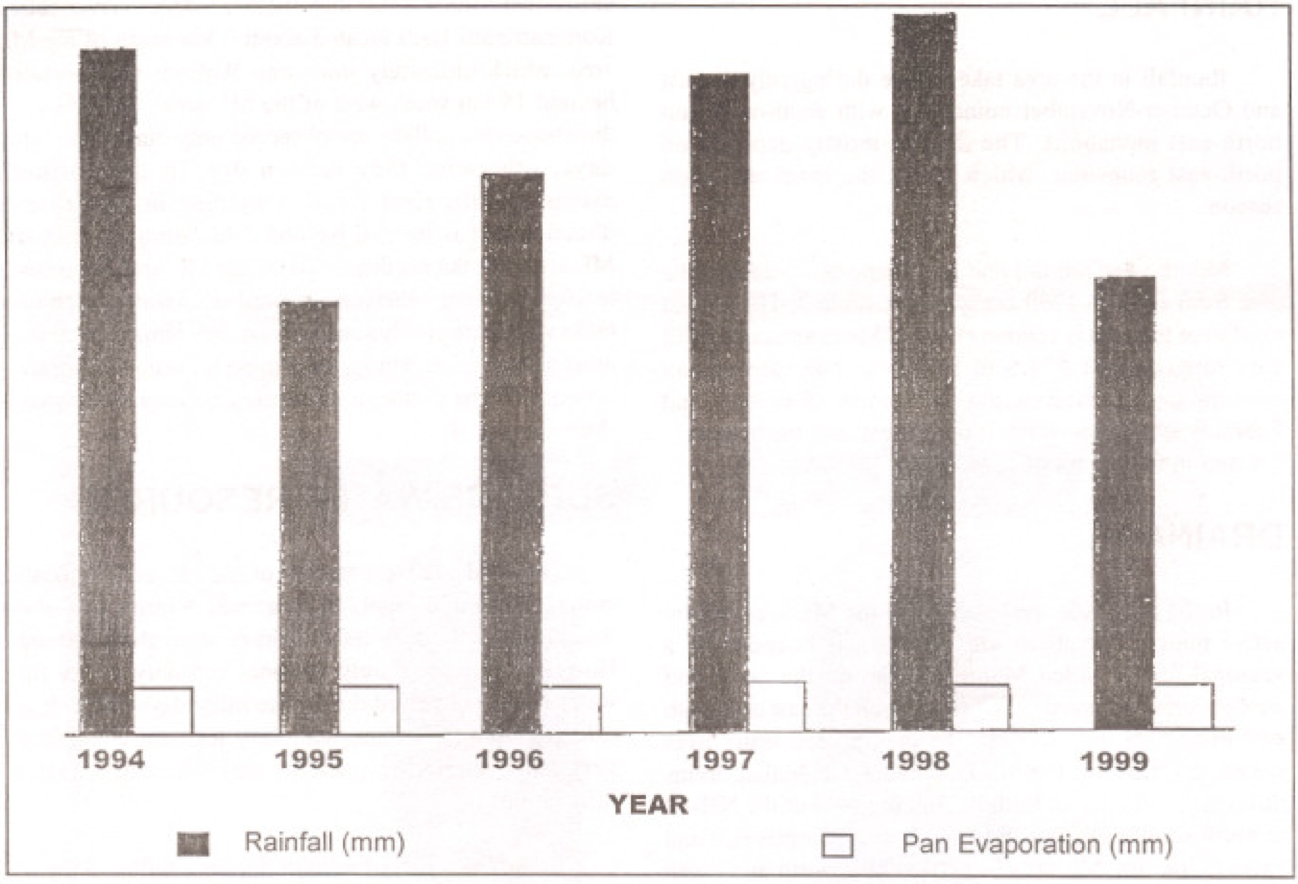

Fig. 3 : Variation of annual rainfall and pan evaporation

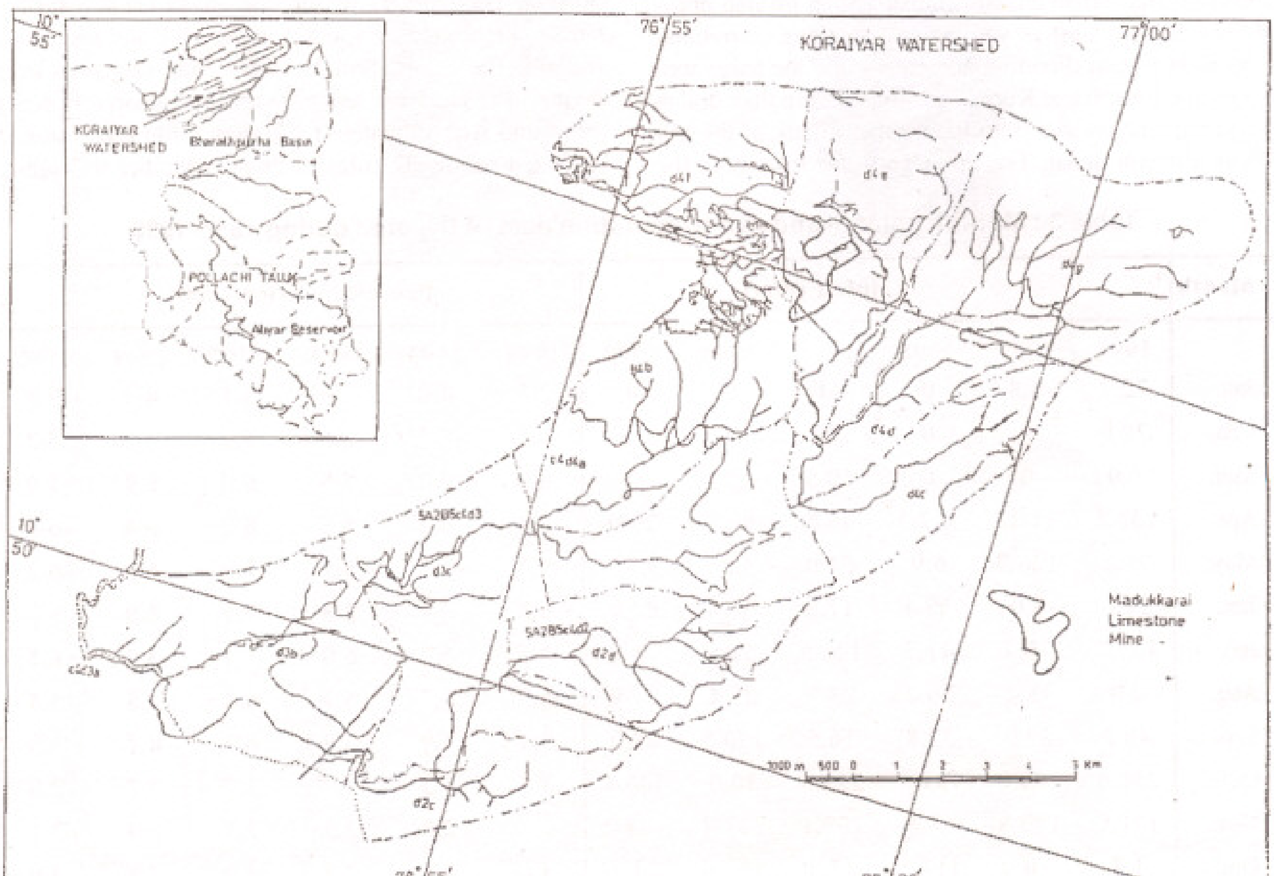

Fig. 4 : Drainage map of Koraiyar watershed

RAINFALL

Rainfall in the area takes place during July-August and October-November coinciding with south-west and north-east monsoons. The district mostly depends on north-east monsoon, which forms the main monsoon season.

Month-wise rainfall and pan evaporation data of the area from 1994 to 1999 are given in Table 3. The annual rainfall of the area is vagrant (Fig. 3). Mean annual rainfall data ranged from 573.5 to 949 mm. The rate of pan evaporation observed during the months of January and February is 3.0 mm which is the lowest, and the highest is 7.9 mm in the month of June.

DRAINAGE

In the road side west section of the ML area, where active mining operations are in vogue, is bounded by a seasonal nallah called Munjiar nallah on the north and another small seasonal nallah flowing on the east and south east of the ML boundaries. The precipitated water over the eastern flank of the hill Dharmalingam Malai, drains through the dry nallah initially running west of the NH-47 in north-south direction and later diverts towards east and extends into the ML area in between the north and south sections. As stated earlier, this nallah is not so prominent. The other dry nallah called Munjiar nallah located north of the roadside west as well as east sections, is running from west to east direction and enters into the lease area between the north and Kurichi sections. This nallah drains the precipitated water from the northern flank of the hill Dharmalingam malai. The drainage water from both the above two nallahs enter into another seasonal river called Kummattipatti Nadi located about 7 km south of the ML area, which ultimately joins into Walayar river, located beyond 15 km south west of the ML area. Water flow in the above two nallahs are observed only during the rainy days, otherwise they remain dry. In the northern extensions, the river Noyil is running in west to east direction and is located beyond 5 km distance from the ML area. On the northern side of the ML area, between 2 to 10 km radious, there are a number of water catchment tanks which are purely seasonal and they remain dry during most of the period. Madukkarai mine is located in Koraiyar watershed. The drainage and watershed map of the area is shown in Fig. 4.

SURFACE WATER RESOURCE

The roadside west section of the ML area is located at the toe end of a small hill range which forms part of the watershed for the seasonal nallahs running along this area. However, they are purely seasonal and only a very little water flow is observed during the rainy days alone. It is a calc-granulite hill range, with very less soil cover and a very thin vegetation growth, which restricts rate of infiltration.

Runoff as a part of rainfall does not infiltrate the soil and flow over the soil surface to natural drains existing in the area. The more easily the rain enters the soil surface and the more storage (pores) in the soil, the less water available for runoff (Strack, 1998). Silty clay soils as in the present case, have less pore space compared to sandy loams and will ultimately have slow infiltration rates. A vegetated soil tends to retain its permeability throughout

Table 3 : Monthly rainfall and pan evaporation data of the area during 1994-1999

Month	Rainfall (mm)						Pan evaporation (mm)					
	1994	1995	1996	1997	1998	1999	1994	1995	1996	1997	1998	1999
Jan.	72.7	3.8	0	2.0	0	0	3.8	4.0	3.0	5.1	4.2	3.8
Feb.	29.0	0	0	0	0	3.0	4.7	5.5	6.5	5.4	5.3	5.2
Mar.	6.0	0	0	10.5	0	0	6.8	7.2	7.9	6.6	6.8	5.9
Apr.	138.3	111.2	167.5	29.5	96.0	29.0	5.4	6.4	5.6	6.0	6.4	6.2
May	31.1	126.2	6.9	54.0	52.5	33.0	6.7	5.2	6.7	7.8	5.5	6.2
Jun.	28.0	8.0	56.4	17.0	57.8	24.0	6.8	6.1	5.8	7.9	6.9	6.2
Jul.	125.8	36.7	47.7	121.5	51.5	25.8	5.5	5.7	6.0	5.4	5.4	6.1
Aug.	2.0	48.8	36.2	24.5	25.4	21.9	5.9	5.7	5.7	5.8	4.8	5.7
Sep.	48.9	29.0	52.8	16.5	170.5	28.0	6.4	5.9	5.2	6.3	4.7	5.9
Oct.	256.6	100.0	197.6	259.0	30.0	306.1	3.5	4.5	3.7	3.7	4.7	2.9
Nov.	171.9	109.8	61.4	299.1	303.7	104.2	2.8	2.8	3.5	2.5	2.9	3.1
Dec.	1.8	0	117.2	37.3	161.6	23.2	3.6	4.8	2.8	3.9	2.8	3.0
Annual	912.1	573.5	743.7	870.9	949	598.2	61.9	63.8	62.4	66.4	60.4	60.2

a rain storm, until the pores are completely filled with water. It is necessary to know the heaviest amount of water that can be expected to accumulate in the open pit during a rain storm. This information is needed to ensure that pumping arrangement can be made and dump is designed to cope up with the amount of runoff water including structures groundwater. The peak rate of runoff for the quarry area is estimated as follows:

Approximate watershed area 22 ha or 54.36 acres (say 55 acres). The value of curve number 'CN' is 70 for mining areas as developed by USDA soil conservation service (Lyle, 1987) for determining peak rate of runoff for watershed up to 2000 acres, for an area where only grasses can be grown having slow rate of infiltration and transmission (as is the present case). For CN 70, with moderate slopes, for watershed area of 125 acres, the peak discharge in cfs/inch of runoff, from the graphs, provided by Lyle (1987), is estimated as 45 cubic feet/second/inch. For this area, the maximum rainfall on any rainy day recorded for the years 1984 to 1993 was 112.5 mm i.e. 4.4 inches per day. Therefore, the runoff depth for 4.4 inches rainfall, and for the curve number 70, the depth of runoff is 1.4 inches, as per the chart provided by Lyle (1987).

Therefore, the estimated peak rate of runoff = 45 X 1.4 cubic feet/sec. = 63 cubic feet/sec. = 1.78 cubic metre/second = 1780 l/second.

The contour plan of the area depicts that almost the entire quantity of the other precipitated water over the remaining portion of the leasehold area drains towards north and north east. The precipitated water over the remaining portion of the leasehold area, as well as the runoff from the adjoining hill area, mainly drains towards the seasonal nallahs called Munjiar nallah and the other nallah flowing along the National Highway. Since the adjoining hill area, which is the watershed, is not significantly disturbed by the mining activity, the runoff discharged from this area will be duly collected in a garland drain and diverted into the seasonal nallahs existing in the area. Based on the above details, it can be stated that the overall effect of mining on the surface water resources is very little.

PUMPING TEST

Pumping test is the most accurate, reliable and commonly used method to evaluate the hydraulic parameters of an aquifer, efficiency of a well, safer operational rates of pumping and selection of suitable pump (Kresic, 1997). The methodology of a pumping test is dependent on its application (Drawson and Istok, 1992).

A 24-hour well pumping test in a confined aquifer was conducted in order to determine its hydrogeological parameters with exploratory drilling in the area. The results of the pumping tests carried out near the mine are given in Table 4. The lithological logs of exploratory borewells, constructed at Madukkarai, indicate the varying thickness and discharge capacity as indicated in Table 5. Groundwater modelling has been carried out based on pumping test data and field conditions, like topography, open pit configurations, hydrogeology, aquifer characteristics, etc. following Kresic (1997).

Table 4 : Aquifer parameters of few exploratory wells located near the mine

Parameters	Location	
	Madukkarai	Sundarapuram
Depth drilled (m)	51.81	290.16
Length of casing (m)	1.0	6.73
Rock type	Crystalline limestone and biotic gneiss	Charanockite biotic gneiss and crystalline limestone
Static water level (m)	15.44	9.7
Discharge during drilling (lps)	0.75	4.35
Duration of pumping (min.)	3000	300
Discharge (lps)	8.33	1.16
Drawdown (m)	0.46	35.6
Specific capacity (lpm/m)	17.28	0.032
Transmissivity (m^2/d)	1146.5	1.367
Storativity	$2.84X10^{-2}$	———
Total available drawdown (m)	2.78	———
Safe pumping rate in (lps/d)	80.3	———
Condition of the aquifer	Unconfined aquifer with delayed gravity drainage	Unconfined aquifer with delayed drainage

Table 5 : Characteristic of different lithology

Lithology	Thickness (m)	Discharge (lps)
Soil	1.52	1.19
Limestone massive	27.43	4.98
Limestone fractured	9.14	6.25
Limestone fractured with quartz veins	13.71	6.88

GROUNDWATER RESOURCE

The water table occurs in phreatic conditions below 29.0 m depth in summer and below 21.0 m depth in post-monsoon season from the general ground level. As per the future plan of the mine, it is further proposed to deepen the opencast workings to a maximum depth of about 80 m from the ground level during the next 20 years of production period. Hence, during this proposed opencast workings, due to excavation at greater depth, the groundwater table may be depressed below the working level. At this stage, the maximum quantity of groundwater to be pumped out of the quarry during peak time is estimated to be about 85 litres per second.

An approximate influence zone was worked out with the available aquifer parameters. By assuming maximum excavation depth to be about 80 m, hydraulic conductivity of 10 m per day and specific yield 0.1, the radius of influence zone works out to be about 5 km. Therefore, an area of radious about 5 km of the quarry should be closely monitored to assess any change in the hydrological regime of the area.

PUMPING ARRANGEMENT

Pumping arrangement should be done for discharging maximum quantity of both surface and groundwater which will be accumulated in the sump during peak monsoon period. Maximum quantity of water that would accumulate during peak period is estimated as per the following procedure:

A) <u>Surface water quantity</u>

Surface runoff into the quarry per second (as estimated earlier) = 1780 l/sec

Considering duration of storm as 20 min., (as per the guideline by the Ministry of Environment & Forests, Government of India) the total quantity of surface runoff becomes = 1780 x 60 x 20 l
= 2136000 l

Rainfall during 48 hours other than storm (considering 10 % of peak rainfall = 213600 l

Total quality of surface water = 2349600 l

B) <u>Groundwater quantity</u>

The quantity of groundwater accumulation per second (as calculated earlier) = 85 l/sec

Total quantity of groundwater accumulation for a duration 48 hours (2 days) = 85 x 60 x 60 x 48 l
= 14688000 l

Total quantity of water accumulation in the sump during peak rainfall for a period of 48 hours = (2349600 +14688000) l
= 17037600 l

Therefore, total capacity of pump required for the mine (based on 48 hours duration) = 17037600/ (40x60)
= 5916 l/min.

Number of 40 HP submersible pump required for the mine (considering discharge capacity of 1800 l/min. for each pump) = 5916/1800 Nos.
= 4 Nos.

Total sump capacity required for storing water for a duration of 48 hours = 17037600 l
= 17038 m^3

Based on the above estimation it can be safely concluded that during monsoon season four numbers of 40 HP submersible pumps having 1800 l/min. discharge capacity is required for future mining operations below the groundwater level. However, during all other season only three numbers of 40 HP submersible pumps would be sufficient for the mine. The total sump capacity should be minimum of 17000 m^3 for storage of water during rainy season. The locations of sump(s) and pump(s) would depend upon the mine design at different stages of future mining operations.

LOCATION OF SUMPS

Under the present scenario the pit area between RW-17 and RW-14 (Sump 1) and between RW-8 and RW-4 (Sump 2) can be used as the sumps for accumulation of pit water and surface runoff water. The location of proposed sumps and pumps are demarcated in Fig. 2. Two 40 HP submersible pumps can be installed at each sump (at present there is one pump at each place, therefore only 2 pumps, one at each place needs to be added). In future when the mine will be deepened below 360 mRL at other places of working these two sumps will have to be developed first i.e., these areas will have to be worked out first so that mine as well as rain water keep on accumulating at these places due to the lower RL value. This pattern of working will have to be followed at each successive stages of mining.

WATER QUALITY

Pit water sample has been collected and analysed as per IS: 10500. Analysis report of the water sample was found to have high coliform content and facially contaminated (Table 6). If this water is to be used for drinking purpose, it needs proper treatment. Other physico-chemical parameters, as per the tolerance limits for drinking water (IS: 10500) are well within the limits.

Table 6 : Drinking water quality of Madukkarai pit water

Sl. No.	Parameters	Value	IS:10500
1.	pH	7.5	6.5-8.5
2.	Colour, Hazen Units	Colourless	—
3.	Temperature (°C)	23.0	—
4.	Total Suspended Solids	432	—
5.	Total Dissolved Solids	1059	500
6.	Total Volatile Solids	BDL	—
7.	Dissolved Oxygen	7.8	—
8.	BOD (5 days at 20°C)	1.6	—
9.	COD	3.7	—
10.	Oil and Grease	BDL	—
11.	Chloride (as CL^-)	30	250
12.	Phenolic compound (C_6H_5OH)	BDL	0.001
13.	Cyanide (as CN^-)	BDL	0.05
14.	Sulphides (as S^-)	0.003	—
15.	Sulphate (as SO_4^{--})	105.0	150
16.	Total Nitrogen (as N)	3.8	—
17.	Fluorides (as F)	0.72	0.6-1.2
18.	Pesticides	Absent	Absent
19.	Insecticides	Absent	Absent
20.	Total Residual Chlorine	0.08	0.2
21.	Boron (as B)	BDL	—
22.	Barium (as Ba)	BDL	—
23.	Arsenic (as As)	BDL	0.05
24.	Cadmium (as Cd)	BDL	0.01
25.	Lead (as Pb)	0.012	0.1
26.	Copper (as Cu)	0.15	0.05
27.	Chromium (as Cr^{+6})	0.05	0.05
28.	Mercury (as Hg)	BDL	0.001
29.	Nickel (as Ni)	BDL	—
30.	Selenium (as Se)	BDL	0.01
31.	Silver (as Ag)	BDL	—
32.	Zinc (as Zn)	0.009	5
33.	Iron (as Fe)	0.03	0.3
34.	Calcium (as Ca)	70.8	75
35.	Magnesium (as Mg)	24.8	30
36.	Coliform Organism (MPN/100 ml)	45	Absent

Note : All parameters expressed in mg/l except pH, Temp. & Colour
IS : 10500 - Specification for drinking water.
BDL - Below Detection Limit.

WATER DEMAND

The maximum requirement of water for industrial use, drinking, colony, afforestation, water spray and the cement plant is estimated to be about 573683 kl/year (Table 7). The water demand is being met with by tapping the groundwater resources. There are in all 8 bore wells, 3 located in roadside east section, 2 in south section, 1 in Kurichi section and balance 2 located in the colony area.

Table 7 : Requirement of water for different purposes in the mine

Purpose	Quantity (kl/year)
Processing and cooling	29,04,77
Domestic	19,93,90
Others (forestry etc.)	8,38,16
Total	**57,36,83**

GROUNDWATER RECHARGE

A portion or occasionally all of the rain water sinks into the ground, a portion may runoff and a portion or all may be evaporated (Linsley et al., 1975; Kashef, 1987; EI Ouali et al., 1999; Bell and Maud, 2000). Influent seepage i.e. feeding of water underground from the rainfall which reaches the water table causes the groundwater increment from the rainfall. Rainfall in this area is usually of short duration and between the storms. Field capacity may be so reduced that rain can not completely replenish the water depleted by transpiration and evaporation. Whenever such deficiency exists there will be no contribution to the groundwater table from the rainfall. Influent seepage, from whatsoever source, must pass through the zones of suspended water, including capillary fringe, unless the water table stands at ground surface, which is not the present case. Influent seepage through cracks and fractures and in clayey soil is more erratic than the seepage through granular material (Strack, 1998). Hence, the rate of seepage through the quarried portion of limestone, where there is a chance of widening of the existing cracks by blasting, is more compared to the seepage through the virgin area which consists of clayey soil.

Under the artificial recharge, the term water spreading is applied to all operations by which water is distributed over permeable formations or supplied to temporary streams during the dry period (Marsity, 1986). In this, the surface water courses are allowed to spread in more areas by creating impoundments or by construction of check dams to retard the flood water flow. This increases the rate of recharge over the total surface area, over which the water is allowed to spread (Soliman et al., 1997). However, silt occurrence at the back of dams may retard influent seepage. In the other "Basic method", the areas surrounded by dykes are either harrowed or natural vegetation is not disturbed or the shallow water sheet is maintained over the dyked area for circulation (Maidment, 1993). It was found that in the areas of same soil type, basins with undisturbed vegetations retain 1.7 times more water than furrows plots and 1.3 times more water than basins cleared of vegetation and harrowed (Tolman, 1993). The advantage of this water hold underground is that it is not subjected to evaporation or surface pollution and also it avoids expenditure on building huge and costly dams across the river for its surface storage. Where the surface and sub-surface strata are low permeable in nature, resulting in the influent seepage from the surface to be less and satisfactory spreading areas are not available, as in the present case, the only method of surface recharge is by feeding water down the existing wells (Todd, 1995). It is essential that clear water be fed down the wells, as the water containing undesirable elements will clog the well casings and will not permit increasing of the groundwater table (Freeze and Cherry, 1979).

Thus, as explained above increase in groundwater recharge rate to the water table taking advantage of rainfall can be achieved in two ways (Marsity, 1986; Soliman et al., 1997):

i) Natural influent seepage from streams, lakes and ponds.
ii) Artificial influent seepage from irrigation, reservoirs, spreading operations including feeding water down the wells.

However, percolating water may carry adverse substances i.e. nitrates to the water table (Dominico and Schwart, 1990). Percolation is also frequently the path in which ambient atmospheric pollution reaches the groundwater and for its assessment, the groundwater recharge rate together with the cleaning capacity of the soil passages are the important qualities (Coates, 1981). Further, because of the frictional resistance offered by water bearing material to the seepage flow of water; from the intake, at the surface level to the discharge area at the groundwater table; rate of recharge will be affected (Fetter, 1994). Hence, it is preferred to have artificial influence seepage from reservoirs and feeding the water through bore wells drilled from the bottom of the reservoirs. Artificial recharge can be accomplished by (a) draining surface water to the wells and spreading it over areas underlined by permeable material, (b) temporary storing it in leaky reservoirs from which it may circulate to the water table or (c) storing it relatively tight reservoirs from which it is released as fast as it can seep into the stream belts below the reservoirs (soliman et al., 1997). For this, it is proposed to convert the deep and reworked portions of the old quarries at the northern extremity of roadside east section, southern extremity of north section, northern extremity of Kurichi section and south bed sections, where bore wells from the bottom of the quarries are already located. Further, in the presently working roadside west section, after the abandonment of mining operations, it is proposed to drill large diameter bore wells at every 100 m intervals from the bottom of the quarry. This will increase the rate of groundwater recharge at the micro level. The massive afforestation programme proposed on virgin barren area will also increase the rate of recharge of the groundwater.

With regards to the surface water system, a permanent drain with cement is proposed at the foothill, which collects the precipitated water over the water catchment area and discharge it into the seasonal nallahs flowing within the area, there will be no adverse effect on the surface water resources. Check dams will also be erected on these nallahs, which will allow infiltration rather than runoff of the precipitated water.

CONCLUSIONS AND RECOMMENDATIONS

From the above information it can be safely concluded that the mine can be deepened with a recommended pumping capacity and mining operations could continue without hindrance. It is proposed to increase the depth and area of sump(s) while working on the lower benches. An extra pump is recommended to handle runoff during rainy season. Therefore, mining can be carried out in lower benches with some additional pumping capacity as estimated earlier. Location of sumps and pumps are also indicated.

To enhance groundwater resource of the mining area, various recharging methods both for ground and surface water systems are recommended. Most of the recommended measures are being implemented by the mine management. Therefore, it may be safely concluded that the mine can be deepened with a recommended pumping capacity and mining operation could continue without hindrance.

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