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GROUNDWATER INDUCED INUNDATION IN THE PANDARETHU MINES OF MALABAR CEMENTS LIMITED

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ABSTRACT

This paper is concerned with detailed investigations which were carried out in the Pandarethu mines of Malabar Cements Limited to obtain quantitative estimates of groundwater induced inundation in the mine pit. A number of profiles and vertical electric soundings were carried out and the general characterisation of the subsurface geologic condition were identified. A few exploratory bore holes were also drilled to confirm these results. A few long duration aquifer performance tests were carried out to obtain estimates of the formation properties. Data on rainfall, base flow and water table fluctuations within the mine area were monitored. The information obtained through these investigations were used to quantify the likely inundation in the mine pit. The results indicate that the expected inundation is about 3.0 million litres per day.

1.0 INTRODUCTION

Malabar Cements Limited is a Government of Kerala undertaking and is engaged in manufacture of portland cement. The cement factory of the company has a production capacity of about 4.2 lakh tonnes of cement annually. The factory is located by the side of Walayar railway station, adjacent to National Highway No. 47, midway between Palghat and Coimbatore, and about 25 km from either towns. The limestone required for the factory is being mined from the reserves available in the Pandarethu hills.

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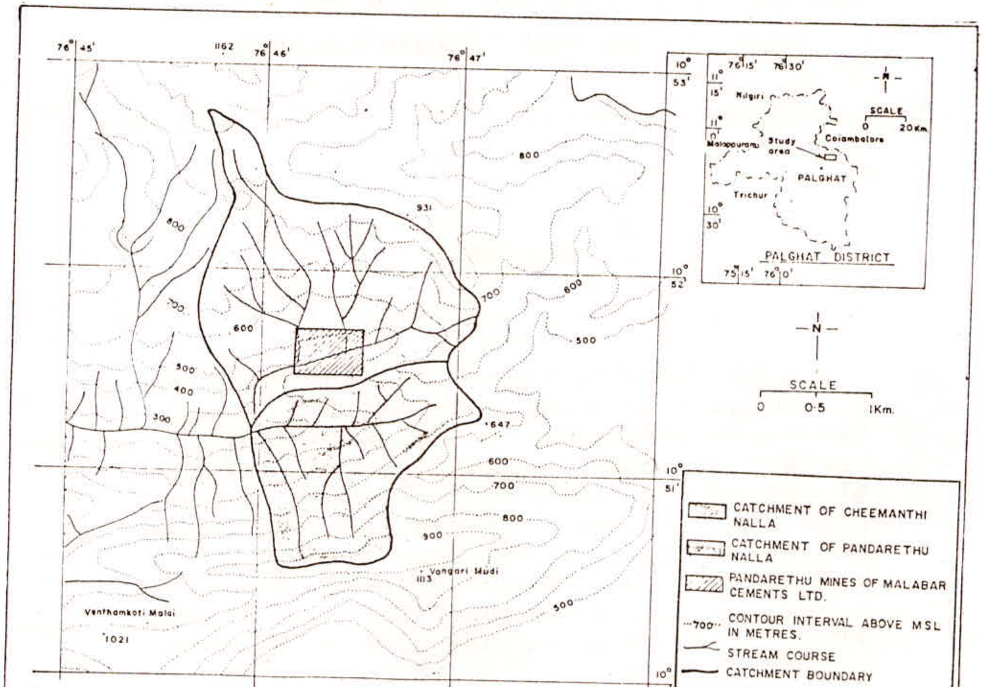

Figure.1

LOCATION MAP OF THE PANDARETHU MINES OF MALABAR CEMENTS WITH REFERENCE TO THE CATCHMENT AREAS OF CHEEMANTHI NALLA AND PANDARETHU NALLA

The location map of the Pandarethu mines with reference to the catchment areas of Cheemanthi nalla and Pandarethu nalla is shown in Fig 1. The Cheemanthi nalla drains over the mine area and ultimately joins the Pandarethu nalla. The Pandarethu nalla drains into the Malampuzha reservoir. The geological map of Pandarethu mines is given in Fig 2.

Open cast mining method has been adopted to exploit the limestone deposit at Pandarethu. The successive bench levels at which mining operations are carried out have a height difference of 9.0 metres. The bed of the Cheemanthi nalla which drains over the limestone deposit has an RL of about 430 metres. The mining operations will ultimately extend to about 100 metres below the bed of Cheemanthi nalla. Till now the mining operations have been limited to deposits available above the bed level of the Cheemanthi nalla. Consequently the mining operations have been free from problems due to inundation. However, such problems may be encountered when the mining operations extends to deposits below the bed level of Cheemanthi nalla. The surface flow in Cheemanthi nalla, direct precipitation over the mine area and the groundwater inflow in to the mine pit are the three likely sources of inundation. A scheme

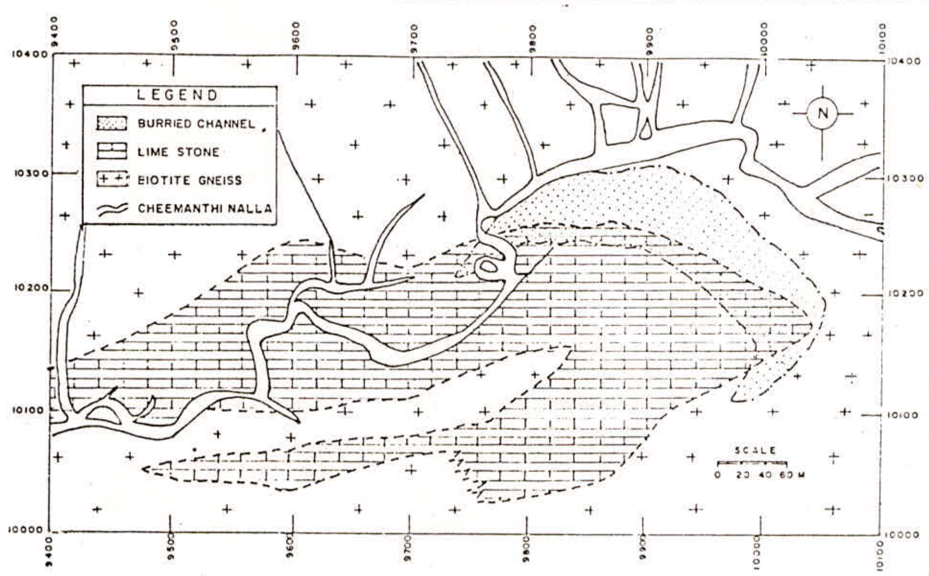

Figure 2:
GEOLOGICAL MAP OF THE PANDARETHU MINES OF MALABAR CEMENTS LTD.

to overcome inundation due to surface flows in the Cheemanthi nalla has been already taken up by Malabar Cements Limited, through construction of a diversion canal, which will direct the flows from upstream of the mine back into the Cheemanthi nalla downstream of the mine. Schemes for tackling the inundation problem due to groundwater inflow in the mine pit are yet to be drawn up because of lack of relevant data on the groundwater conditions in the mine and adjacent areas. Malabar Cements Limited has therefore approached the Groundwater Division of CWRDM with a request to examine this problem in depth through necessary investigations. This study derives it genesis from the above request.

2.0 OBJECTIVES OF THE STUDY

The following objectives were aimed to be achieved in this study.

- Obtain information on the subsurface geologic conditions within the mining area and in areas adjacent to it and thereby identify the saturated subsurface geological formations which may contribute to inundation of the mine from groundwater inflow.

- Obtain information on water storage and water transmission properties of the identified saturated strata.

- Obtain quantitative estimation of inundation in the mine pit caused by groundwater inflow and runoff due to direct rainfall in the mine area.

- Formulate relevant recommendations for tackling the groundwater induced inundation of the mine pit.

3.0 RAINFALL IN THE STUDY AREA AND DISCHARGE IN THE CHEEMANTHI NALLA

Malabar Cements Limited has been maintaining a raingauge station from which daily rainfall is being recorded. The mean annual rainfall is 2000 mm. The maximum daily rainfall in the mine can be about 75 mm. Rainfall is confined mainly during the months of June to November. The rest of the periods are practically dry. During the monsoon periods the total number of rainy days will be typically 80 to 90. The average daily rainfall in the mine area can be estimated to be 25 mm.

Malabar Cements Limited have also earlier recorded the daily discharges in the Cheemanthi nalla. These results show that the maximum expected flow in the Cheemanthi nalla during the monsoon period is about 100 million litres per day. The Cheemanthi nalla also carries a base flow during the non-monsoon periods which is contributed by spring discharges in the upper catchments and subsurface flow in to the nalla course mainly from the northern side of the nalla. Typically the base flow which is maximum after the end of the south west monsoon is about 2.0 million litres per day and it reduces to 0.5 million litres per day just before the onset of south-west monsoon. The Groundwater Division of CWRDM has monitored the discharge in the Cheemanthi nalla during the period June 1986 to May,1987. The Hydrograph of discharges in the Cheemanthi nalla as obtained from this record is given in Fig 3. The rainfall histogram for the same period is also given in Fig 3.for better clarity. A plot of the water table hydrograph recorded at one of the tube wells in the burried channel portion (about which details will be given in Section 5) is also given in Fig 3 to further enhance the clarity of results. The direct co-relation between rainfall, discharge and water table fluctuations is evident from the results presented in Fig 3.

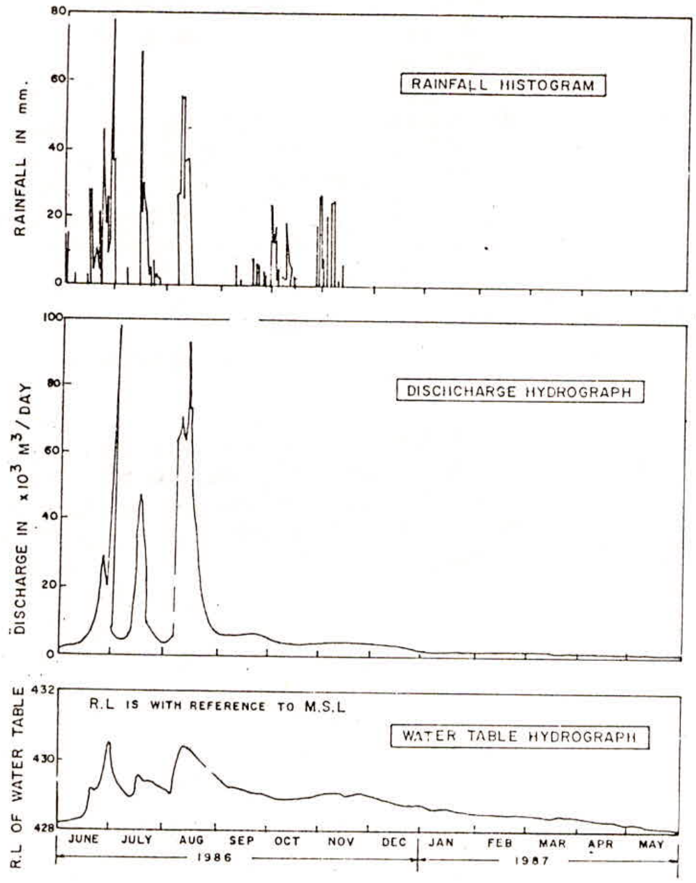

Figure. 3
RAINFALL HISTOGRAM, DISCHARGE HYDROGRAPH AND WATER TABLE HYDROGRAPH IN THE PANDARETHU MINES

4.0 GEOPHYSICAL INVESTIGATIONS

The geophysical investigations were aimed at identifying the subsurface geologic conditions in the mine area and areas adjacent to it. The resistivity methods of geophysical surveys were adopted. The ABEM Terrameter SAS 300 was used for the investigations. Profiling along a number of alignments and vertical electric soundings at station points in these alignments were carried out Wenner configuration of electrode was used for all the profiles. The profiling in each alignment was done by keeping the distances between the electrodes as 10, 20, 30 and 40 metres. Both Wenner and Schlumberger configuration of electrodes was used for the vertical electrical soundings. The study area can be conveniently catagorised under two major portions, namely the burried channel and the limestone terrain as shown in Fig 2. The data generated through the geophysical investigations and the interpretations of the data are discussed separately for these two portions in this section.

In the burried channel portion profiling was done along five alignments. Five vertical electrical soundings were also carried out. Data from vertical electric soundings and the interpreted and geoelectric section is given in Fig 4. The following results emerge from the analysis of the data from the geophysical investigations.

- The subsurface geologic formation in the burried channel is essentially composed of three distinct layers.
- The topmost layer shows a low resistivity of about 100 ohm metres and extends to a depth of about 20 metres. This top layer can be saturated and unconsolidated sediments of sands derived through river transportation.

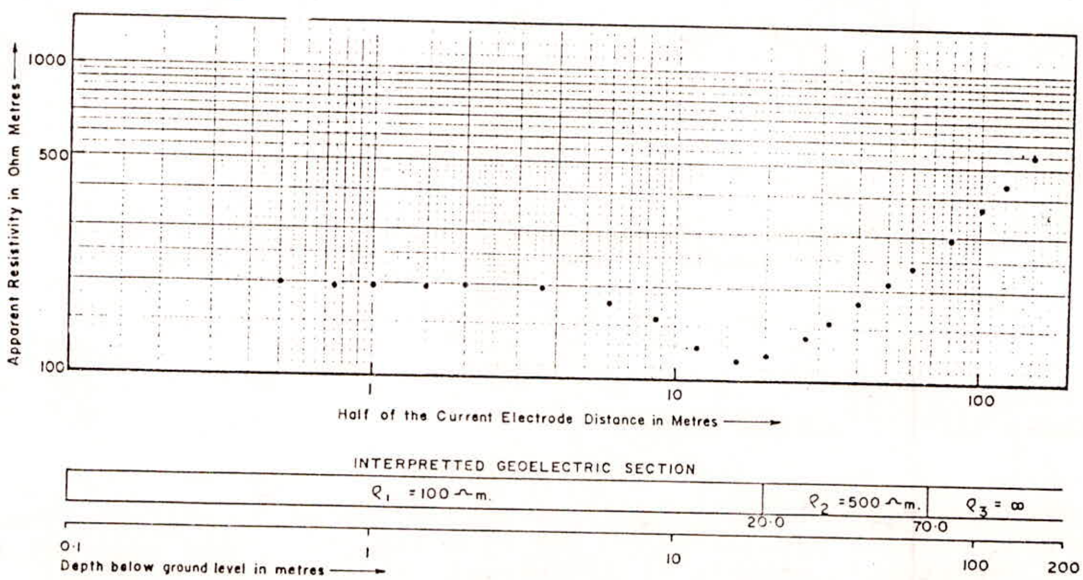

Figure. 4

VERTICAL ELECTRIC SOUNDING AND INTERPRETTED GEOELECTRIC SECTION FOR A TYPICAL STATION POINT IN THE BURRIED CHANNEL PORTION IN PANDARETHU MINES

- The middle layer shows a medium range of resistivity of about 500 ohm metres and occurs in the depth horizons between 20 metres and 70 metres below ground level. This middle layer can be a saturated and partially consolidated sediments of sand as well as other bouldery type of formations derived through river transportation.

- The bottom layer shows a very high resistivity value (tending towards) and occurs at a depth of about 70 metres below ground level and beyond. This layer can be the hard garnet biotite gneiss which is the country rock sarrounding the mine area. The top of this rock formation is approximately at a RL of about 360 metres.

In the limestone terrain profiling was done along six alignments. Typical profiling data obtained along one such alignment is given in Fig 5. Eight vertical electric soundings were also carried out. The following results emerge from the analysis of the data from the geophysical investigations.

- The subsurface geologic formation in the limestone terrain is essentially composed of three layers.

- The topmost layer shows a low resistivity of about 50 ohm metres and extends to a depth of about 5.0 metres below ground level. This layer can be a saturated unconsolidated sediments of sand and clay materials derived through river transportation.

- The middle layer shows a medium ranger of resistivity of about 450 ohm metres and occurs in the depth horizons between 5 metres and 25 metres below ground level. This middle layer can be saturated and semiconsolidated sediments of sand and bouldery type of formations derived through river transportation.

- The bottom layer shows a very high resistivity value (tending towards) and occurs at a depth of about 25 metres below ground level and beyond. This layer can be hard consolidated limestone formation is approximately at an RL of about 400 metres.

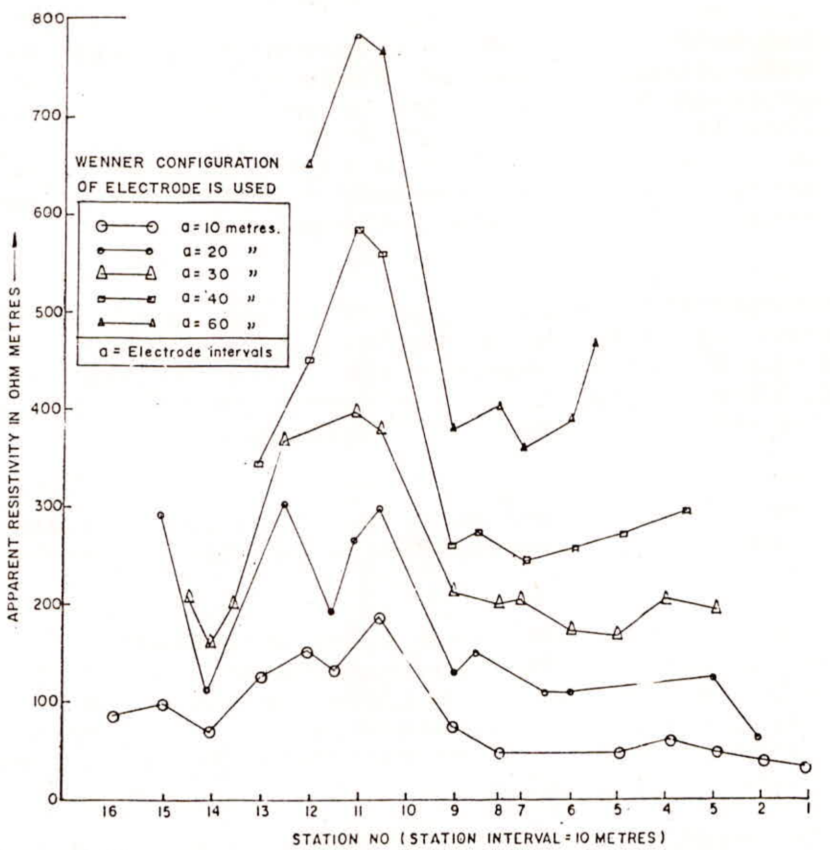

Figure 5 PROFILING DATA ALONG A TYPICAL ALIGNMENT IN THE LIMESTONE TERRAIN IN PANDARETHU MINES

The data generated through profiling were used to identify the valley fill portions above the limestone formation. The areas having low apparent resistivity values were taken into account for this purpose. The thickness of the valley fill materials is about 25 to 30 metres, and the valley fill is also in continuation with the burried channel. Thus the subsurface flow in the burried channel also drains through the valley fills below the bed of the Cheemanthi nalla.

5.0 HYDROGEOLOGICAL INVESTIGATIONS

A few exploratory bore holes were drilled in the Pandarethu mines to confirm the subsurface geologic information derived from the geophysical investigations discussed in the previous section. Four bore holes were drilled in the burried channel portion using calyx rig. Well assemblies using slotted and blind casing pipes were subsequently lowered in each of the four drilled holes. The annular space between the well assembly and the drilled holes were packed with gravel. All the four wells were developed using a compressor till clear water was obtained. The results of geo-electric sections obtained through the analysis of geophysical data, and the litholog obtained during actual drilling co-relate well. Three bore holes were drilled in the limestone terrain. The top overburden portions in these three bore holes were cased with a blind casing pipe and the lower portions in the limestone formation were left naked. The results of geoelectric sections obtained through the analysis of geophysical data and the litholog obtained during actual drilling co-relate well. The bore wells constructed in the limestone terrain show that the limestone below the overburden is generally hard, compact and totally dry.

Two long duration aquifer performance tests were conducted in the tube wells constructed in the burried channel portion. The record of the time drawdown data obtained during one of these tests is given in Fig 6. These data were analysed using conventional type curve analysis methods and the permeability of the aquifer formations in the burried channel portion was estimated to be about 1.0 to 2.0 metres per day.

The aquifer formations in the burried channel were found to be under water table conditions. The tube wells constructed in this terrain were used to record the periodic depth to water table below the measuring point in each of them. The reduced levels of measuring points in all the four tube wells were related to the common datum of mean sea level. The reduced levels of the water table in these four tube wells were then obtained. A record of the reduced levels of water table recorded in one of the tube wells during the course of these investigations is given in Fig 3. The results indicate that there is a natural subsurface flow within the burried channel in a general east-west direction. This subsurface flow further extends into the valley fills overlying the limestone bed below the Cheemanthi nalla. The gradient at which this subsurface flow occurs in the burried channel portion can be obtained from the records of the reduced levels of water table in the tube wells and the distances between these wells. This gradient has been estimated to be about 0.01 to 0.02.

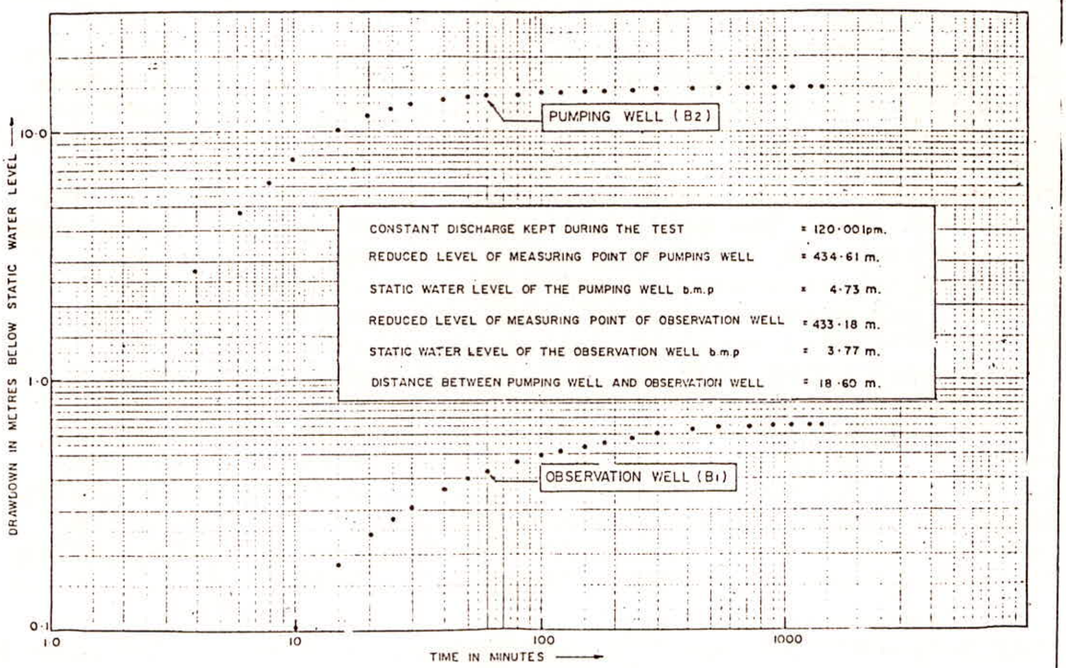

Figure 6
TIME DRAWDOWN DATA DURING ONE OF THE AQUIFER PERFORMANCE TESTS CARRIED OUT IN THE BURRIED CHANNEL PORTION

6.0 ESTIMATION OF INUNDATION

The results presented in the earlier sections indicate that the inundation in the mine pit can be expected to be contributed by

- Subsurface flow in the burried channel and along the valley fill below the bed of the Cheemanthi nalla.
- Base flow in the Cheemanthi nalla.
- Static groundwater storage in the valley fill below the bed of the Cheemanthi nalla and portions of the burried channel which will be excavated as the mining progresses.
- Direct rainfall within the catchment of the mine pit below the offtake of the diversion canal under construction along the northern boundary of the mine pit and above the barrage under construction in the western end of the mine pit.

The exploratory bore holes drilled in the limestone terrain have indicated that the limestone deposits below the valley fills are practically dry and the inundation in the mine pit can be only due to the four components mentioned above.

The results obtained from the section 5, show that the gradient at which the subsurface flow occurs in the general east-west direction within the burried channel portion is about 0.01 to 0.02. The permeability of the aquifer formation in the burried channel has been estimated to be about 1.0 to 2.0 metres per day. It has also been found that the subsurface flow in the burried channel is confined within the width of about 70 metres and a saturated depth of about 70 metres. Based on the above data, the component of subsurface flow within the burried channel can be estimated to be about 0.1 million litre per day (mld). This flow which is now confined within the burried channel and the valley fills can be expected to be transformed as seepage into the mine pit once these formations are progressively excavated during the course of progress in the mining operations.

Results reported in section 3 have shown that the base flow in Cheemanthi nalla is maximum in January when it is about 2.0 mld and is minimum by the end of April when it is about 0.5 mld. Hence it can be estimated that the two components of base flow and subsurface flow put together will range from a maximum of about 2.1 mld immediately after the cessation of the north-east monsoon to a minimum of about 0.6 mld just prior to the onset of the south-west monsoon. The larger value of 2.1 mld can be therefore safely taken as the expected inundation in the mine pit due to those two components put together.

The valley fills below the bed of the Cheemanthi nalla and portions of the burried channel which will be excavated as the mining progresses are saturated with water. The geometry of these formations can be defined by an average length of about 1000 metres, an average width of about 50 metres and an average thickness of about 30 metres. The specific yield of these formations can be assumed to be about 0.1. Hence, the total static groundwater storage can be estimated to be about 150 million litres. This amount has to be drained off by the time of all these formations are excavated and the limestone deposit below them exposed.

The surface flow component due to the rainfall within the mine pit below the offtake point of the diversion canal can be estimated using the results presented in section 3. The total catchment area has a spread of 0.25 sq. km. The average daily rainfall during the monsoon period is about 25 mm. It can be assumed that the runoff is about 40 per cent of the direct rainfall. Hence it can be estimated that the inundation in the mine pit due to direct rainfall is about 2.5 million litres per day.

7.0 RECOMMENDATIONS

The computations presented in the earlier sections indicate that a conservative estimate of the expected inundation in the mine pit is about 3.0 million litres per day. It is recommended that the inundation water may be collected in a sump located in the western end of the mine pit through a channel running along the northern periphery of the mine pit. The bed levels of the channel and the sump will progressively decrease as the mining progress. The water collected in the sump can be pumped out over the barrage under construction in the western end of the mine pit and into the down stream course of the Cheemanthi nalla. Adequate number of pumps with required capacity may be installed for this purpose to take care of pumping out about 3.0 million litres per day.

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