MINISTRY OF WORKS AND PUBLIC UTILITIES
GOVERNMENT OF MALAYSIA

DEVELOPMENT OF PRODUCTION WELLS IN KEDAH & PERLIS INTERIM REPORT

GROUNDWATER DEVELOPMENT CONSULTANTS (INTL) LTD
Cambridge, England

in association with
JURUTERA KONSULTANT (S.E.A.) SDN BHD
Kuala Lumpur

Drilling and backup services:
SYARIKAT TIMOR (INLAND DEEPWELLING) SDN BHD
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SUMMARY

This interim report describes the present status of the project based on progress to the end of March 1982, discusses findings and recommendations and includes a forward planning section covering the work programme, staff and costs.

Present Status

Equipment procurement has been a prolonged activity but all major items were received by the end of March. The second drilling rig arrived at the beginning of December and was commissioned by mid-month.

In total, 77 wells have been drilled of which 60 are in north Kedah, 12 on Langkawi island and 5 in Perlis. After 14½ rig months, or 45% of the total allocated, 43% of the required total meterage has been achieved. In order to maximise yield, wells have been drilled 40% deeper, on average, than assumed in the Agreement and 17 have been completed at 8 inch instead of 6 inch diameter.

For north Kedah, 74 wells were originally allocated by JKR but only 60 have been drilled due mainly to the occurrence of brackish water and/or very low yielding formations in some areas. Although the yields from some wells have yet to be confirmed by pumping tests, the total yield for the 60 wells, based on 16 hours operation per day, is expected to be about 3.4 mgd. Recommended maximum well yields range from about 5 gpm for hand pump supplies up to 270 gpm for the highest yielding wells.

Implementation proposals for the north Kedah wells have been formulated and engineering designs are in progress. Based on designs submitted by the Consultants, JKR Kedah have prepared and issued tender documents for a group of three wells at Kg Kubor Panjang, Pendang District. They have also installed hand pumps in 10 wells.

Water treatment recommendations have been made and outline designs prepared for a standardised range of plant sizes. These cover simple treatment for hand pump wells and plant required for powered pump wells and well groups yielding up to 1000 gpm as at Bukit Jambul, Pendang district. A separate report on this work has been submitted recently.

Well construction on Langkawi island started in February. Drilling in the Singa formation, aimed at assessing development potential, is nearing completion. During drilling, yields in the range 15-30 gpm were indicated at three wells. All others were either dry or suitable only for hand pumps. Sites for development of a wellfield in the Sungei Melaka alluvial basin were selected in October 1981. Construction of necessary access roads and hardstandings in this padi area has been completed for only 10 of the 23 well sites owing to difficulties with some of the landowners.

Hydrogeological investigations for site selection in southern Perlis have resulted in cancellation of 13 wells provisionally located by JKR in areas which have proved to contain brackish to saline water. These, and a further three cancelled because of low yield potential, are to be reallocated to other areas where good potential is confirmed by initial drilling. Some may be drilled in new areas of good potential to be identified by the Consultants. Well drilling started in March. Pumping tests have yet to be carried out but, during drilling, yields in the range 100 to 500 gpm were indicated.

A trainee drilling technician has been assigned to the project from JKR Kedah since December. One from JKR Perlis and two from the Geological Survey are expected to be assigned shortly. The Geological Survey will also be assigning a geologist for hydrogeological training. All trainees are expected to work with the Consultants for the remainder of the project.

Findings and Recommendations

The concept of the project as envisaged in the Terms of Reference is the provision of reticulated supplies to 250 drought affected communities outside the existing water supply network by drilling 250 wells, ie one per community. As the project has developed, this concept has changed in various ways.

For north Kedah, JKR allocated 74 wells to serve 425 kampongs, an average of about 6 kampongs per well. Under the original concept, relatively low well yields would have been adequate but with this high ratio of kampongs per well, the highest possible yields had to be sought. Many of the kampongs are within areas served by the existing water supply network. Where feasible and desirable, wells have been located close to pipeline routes to allow groundwater supplies to be connected into the network. Similarly, wells have been grouped together in some areas to avoid the higher engineering costs which would be associated with individual wells. This has proved particularly relevant for water treatment which needs to be more extensive than could have been forseen from water quality data available for wells drilled before this project.

For Perlis, JKR's aim for the majority of the 50 wells allocated is to boost supplies in the existing distribution network by groundwater supplies from groups of wells. As in north Kedah, maximum attainable yields are desired.

The need for high yields has resulted in wells being drilled deeper than originally envisaged and completed at 8 instead of 6 inch diameter where necessary to allow abstraction of maximum potential yield. Additionally, the implementation of relatively high yielding wells, often in groups, is a different scale of development from isolated, relatively low yielding wells. Greater effort must be put into assessment of long term reliability of the resource in terms of both quantity and quality so that capital investment is not wasted. This factor, together with the need for extensive investigations prior to site selection, has increased the hydrogeological workload.

Assessment of geological formations in terms of development potential for rural water supplies is summarised below :

Formation	Area	Assessment
Semanggol sandstones	Padang Terap, N. Kedah	Suitable with careful development
Kubang Pasu shales	Kubang Pasu, N. Kedah and Perlis	Little potential
Mahang metashales/ sandstones	Pendang, N. Kedah	Promising but likely to be variable
Chuping limestone	Perlis	Promising but presents drilling and development problems
Setul limestone	West Perlis	Promising but limited by access
Singa formation	Langkawi	Poor to moderate potential
Marine alluvium	Coastal Kedah and Perlis	No potential

Brackish to saline water bearing marine alluvium occurs in a coastal strip up to 12 miles wide through north Kedah and into Perlis. Project investigations indicate that formations overlain by this alluvium are also likely to contain brackish/saline water. Intrusion of such water into fresh groundwater areas has occurred at Bukit Keriang and Kodiang in north Kedah. The Arau wellfield in Perlis lies adjacent to the area of marine alluvium and could suffer brackish water intrusion with time. Monitoring of water quality and investigations to try and quantify the risk are recommended.

Generally the groundwater from the sandstone and shale areas drilled in north Kedah is of an aggressive bicarbonate type. Typical features are low pH and total dissolved solids, high carbon dioxide and iron, no dissolved oxygen. Iron and manganese concentrations are very variable, ranging from 0.1 to 2.5 mg/l and 0 to 4 mg/l respectively. At Bukit Jambul, wells penetrated a high yielding metalliferous hydrothermal fracture zone in Silurian rocks. Water sample analysis indicated the presence of lead, copper, zinc and arsenic. The arsenic levels detected are a cause of concern for drinking water supplies.

Proposed water treatment process selection is based on well head values for iron, manganese, pH and carbon dioxide. The variation in these parameters results in 5 treatment processes for hand pump supplies and 13 for powered pump supplies. Some of these are very similar, varying only by the amount of pH correction required. Adopted standards for powered pump supplies are pH > 6.5, iron and manganese 0.3 mg/l. These levels lie between the World Health Organisation highest desirable and maximum permissable limits. For hand pump supplies it has been assumed that iron and manganese contents of 1.0 and 0.5 mg/l, the WHO maximum permissable levels, will be acceptable. Field tests at Bukit Jambul have proved a treatment process which will remove arsenic but only to slightly higher levels than recommended by WHO; further tests for alternative forms of treatment are recommended.

The total estimated yield of 3.4 mgd from the 60 wells of average depth 43 m in north Kedah compares favourably with the estimate made at Inception of 2.0 mgd (after adjustment for comparable operating hours) from 74 wells averaging 30 m deep. According to estimates by the Statistics Department, the total 1980 population for the 425 water short kampongs was 107000. Total water demand is as tabulated overleaf :

Year	Estimated Population	Per capita demand (gcd)	Total demand (mgd)
1980	107000	25	2.68
1985	121000	30	3.63
1990	136000	40	5.44
1995	154000	45	6.93

The total estimated yield would meet total demand up to 1985 and about half the 1995 demand.

Forward Planning

Based on the available balance of 17½ rig months plus one additional rig month requested to make up for slow progress due to equipment and materials shortages earlier in the project, a total of 200 wells averaging 40 m deep is believed to be achievable by the end of the project. This would give a total meterage drilled of 8000 compared with 7500 required under the Agreement. The distribution of wells is expected to be as follows :

North Kedah	60	
Perlis	50	
Langkawi island	38	
Central Kedah	38-42	(estimated requirement)
South Kedah	14-10	(estimated requirement 27-35)
	200	

The estimated requirements for central and south Kedah are based on the number of kampongs to be supplied as advised by JKR. For south Kedah, Baling district is excluded as no kampongs have been specified. Several additional wells have been requested on Langkawi island. These are not included in the above listing as their construction will be dependent on the results of preliminary investigation.

All drilling is planned to be completed by mid January 1983. This is 3½ months later than envisaged in the Agreement mainly due to tbe arrival of the second drilling rig being 4 months later than originally assumed. The timing could be affected by delays on Langkawi island if completion of access roads and hardstandings in the Sungei Melaka basin cannot continue in the near future and also by wet ground conditions which are currently making rig movements onto and off sites extremely difficult. It is hoped to complete well testing, preparation of engineering designs and the final report by the end of February 1983, one month later than in the Agreement.

To cover the necessary extension of the drilling period, foreign professional staff and non-professional local staff inputs need to be increased. Additional Groundwater Engineer/Hydrogeologist staff inputs are also requested because of the workload for these personnel. Some adjustments to local professional staff are proposed which lead to a slight saving in man-months.

Total costs have been reassessed resulting in an estimated increase of about 10% in local currency costs and a slight decrease in foreign currency costs. Overall costs are increased by 4½ to 7½% depending on the exchange rate used in calculation. About one third of this increase is in well construction costs.

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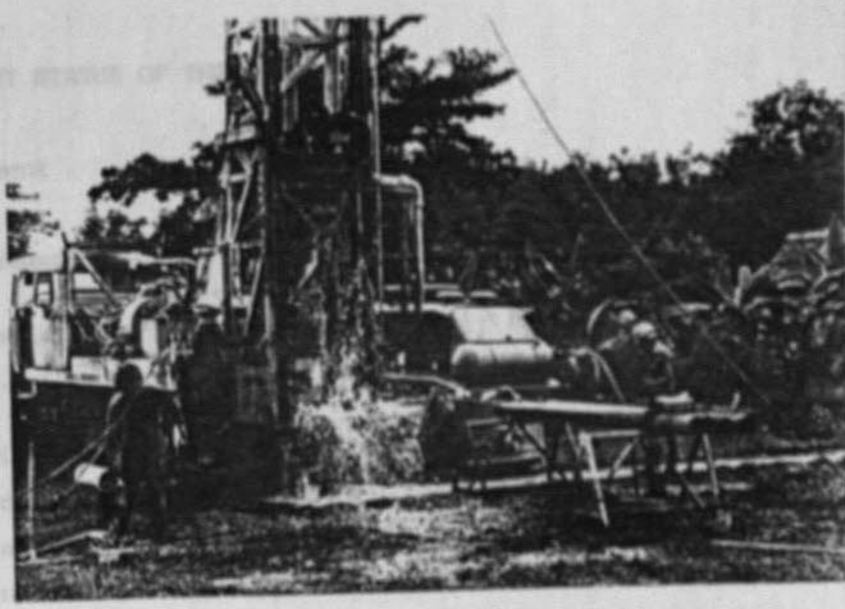
1.0 INTRODUCTION

During discussions on the Inception Report, JKR requested the Consultants to produce an Interim Report in March 1982. It was subsequently agreed with the project coordinator that the report should cover progress to the end of March 1982 and would therefore be prepared during April.

The purpose of the report is to give details of progress and findings at approximately the mid-point of the project. At the end of March, 14½ of the 32 rig months allocated to the project had been used. Drilling had been completed in north Kedah and commenced in both Langkawi island and Perlis. On the engineering side, implementation plans for the north Kedah wells had been formulated, water treatment recommendations made and engineering designs commenced.

The report is divided into three main sections covering present status of the project, findings and recommendations, and forward planning. The present status section covers equipment and materials, well site selection, well construction and testing, water supply engineering and training. Under the findings and recommendations section, changes in the concept of the project which have evolved as the work progressed are discussed and their effects described. The section also covers the hydrogeology of north Kedah, Perlis and Langkawi island, well design, water quality and water supply engineering aspects. Water treatment is the subject of a separate report submitted in mid-April. Information extracted from that report is reproduced in section 3.5.2. The forwarding planning section covers revisions to the work programme, staffing and costs. At the anticipated Steering Committee meeting to discuss this report it is hoped that, in addition to technical discussions, specific consideration can be given to the content of the forward planning section and agreements be reached.



DRILLING OPERATIONS USING THE BOMAG RIG
(separate air compressor and pipe rack)

CASING INSTALLATION USING THE INGERSOLL-RANG RIG
(air compressor and pipe rack mounted on rig)

2.0 PRESENT STATUS OF THE PROJECT

2.1 Equipment

2.1.1 Procurement

Procurement periods for major items of project equipment are illustrated in Figure 2.1.

The second drilling rig, an Ingersoll-Rand TH-55HP, and ancillary equipment were delivered on 4 December. Commissioning was completed on 16 December. A subsidiary agreement for supply of spare parts for a three year period has been set up and initial supplies to be held on site obtained.

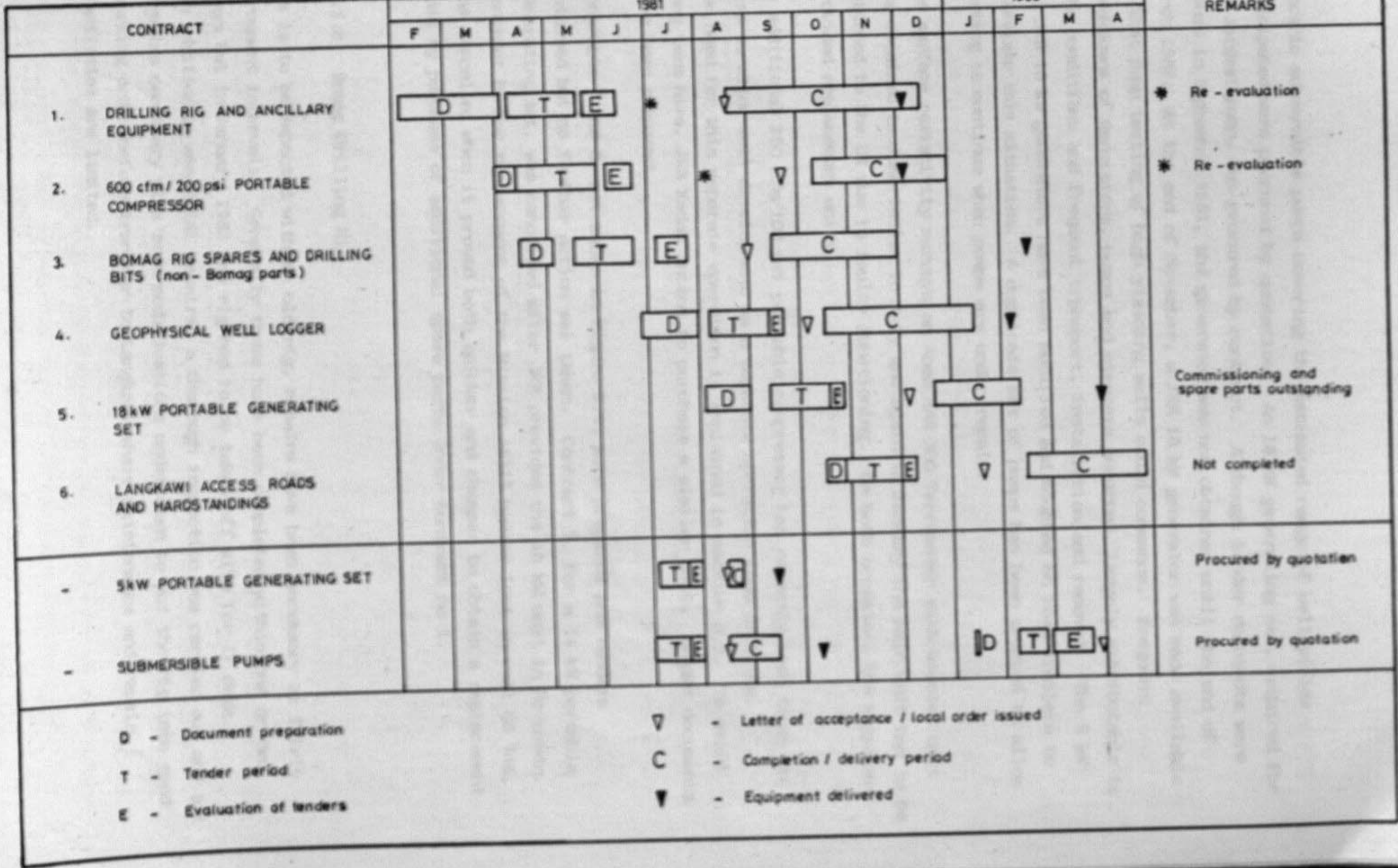
The ancillary portable compressor for the Bomag rig, an Ingersoll-Rand 750 cfm/250 psi unit, was delivered on 2 December. From 18 June onwards a hired 600 cfm/125 psi unit had been available but previously drilling operations were hampered by lack of a suitable ancillary compressor.

Procurement of non-Bomag spare parts and drilling bits for the Bomag rig took 9 months from issue of tender documents to delivery. Delays to the work were alleviated by procuring some drilling bits by quotation soon after drilling commenced. Spare parts required from Bomag were procured over the period April to December 1981.

The SIE T450 geophysical well logger was delivered early in February. Previously the project had the use of a similar unit on loan from JPT. Whilst drilling is proceeding concurrently on the mainland and Langkawi island, two loggers are desirable. As the loan of the JPT unit cannot be continued until the end of the Langkawi work as previously hoped, procurement of a second logging unit is in progress. The SIE T450 is capable of a range of logging functions, all of which will be needed for the alluvial wells on Langkawi. For the mainland, a caliper logger will give the minimum information required and therefore, to keep costs down, such a single function unit has been requested.

According to the Terms of Reference, JKR were expected to have available three electric submersible pumps and two generators. Of these only one pump, without cable or starter, was available. A 5 KW portable generator and three

FIGURE 2.1 EQUIPMENT PROCUREMENT



electric submersible pumps covering the estimated range of well yields anticipated were procured by quotation. An 18 kW generating set, required for the largest pump, was procured by contract. Although tender documents were issued in September 1981, the generator was not obtained until the end of March 1982. At the end of November, a JKR 18 kW generator was made available so that pump testing of high yielding wells could commence. Frequent breakdowns of generators, pumps and starters occurred, largely attributable to site conditions and frequent transport, installation and removal. The 5 kW and JKR 18 kW generators have been modified and mounted on road trailers to alleviate this situation. A duplicate set of pumps has been ordered to allow testing to continue when pumps are under repair.

For surface resistivity surveys an Abem SAS 300 Terrameter with booster unit was obtained in June 1981. In July and again in January the main unit had to be returned to the UK due to faulty functioning. On both occasions the suppliers provided replacement units.

An additional 250 cfm/100 psi portable compressor has recently been taken on hire to allow well development as a separate operation from drilling. The need for this separate operation is explained in section 3.3. To avoid long term hire, JKR Kedah intend to purchase a similar unit. Tender documents have been prepared.

Contracts 7 and 8, not shown in Figure 2.1, were prepared and tenders obtained but no further action was taken. Contract 7, for a 14 kW portable generating set, was cancelled after JKR provided the 18 kW unit in November. Contract 8, for replacement of the Mission A6315 hammer lost in well GS 745, was cancelled when it proved both quicker and cheaper to obtain a replacement unit by purchase of additional spare parts under contract no 1.

2.1.2 Bomag Drilling Rig

As is to be expected with an old rig, repairs have been necessary at fairly frequent intervals. Generally these have been completed within one or two days but in January 1982 the rig had to be taken off site for 17 days. In addition to essential repairs, a thorough inspection was carried out and all repairs necessary plus some modifications undertaken to put the rig into good working order before transfer to Langkawi where maintenance and repair facilities are limited.

The loss of the downhole hammer mentioned above occurred on 28 October during withdrawal of the drill string. It is believed that withdrawal was impeded by a small obstruction which put extra strain on the connection to the drill pipe which then parted owing to age and wear of the threads. A total of 8 days drilling time was lost due to recovery operations which unfortunately were unsuccessful. The replacement hammer was not available until February. In the meantime drilling was unavoidably slower.

2.2 Materials

There have been a number of changes to materials originally allowed for in the Agreement. The main change has been the use of 8 inch diameter casing for high yielding wells which was proposed and accepted at Inception stage. High yielding wells drilled up to the end of August, when the first delivery of 8 inch casing was received, had to be left incomplete and the rig returned to complete them at a later stage. Flush jointed 8 and 6 inch casing has been used for wells where the overall diameter of socket jointed casing would have been too large to suit the construction method or well design. uPVC top caps have been replaced by steel as these are less susceptible to damage and will not deteriorate through prolonged exposure to sunlight as would uPVC caps. Canvas baskets and seals were introduced to seal the annular spaces between blank and slotted casing and between cased and uncased hole sections.

For several months in the second half of 1981, supplies of uPVC materials were barely adequate to meet day to day requirements. Adequate stocks are now available and no further difficulties in obtaining supplies are anticipated.

2.3 Drilling Site Selection

2.3.1 General

Studies of existing data, field survey, geophysical survey and interpretation, photogeological interpretation, accessibility and engineering considerations all contribute to drilling site selection. The body of existing data from previous work is continuously augmented by new data from project surveys and drilling allowing re-evaluation as work proceeds. Photogeological interpretation has proved a very useful tool in locating geological weaknesses such as fractures and joints but field surveys have been of limited value in many areas due to lack of formation outcrop.

Geophysical survey has proved particularly useful in identifying saline groundwater areas but definition is reduced in zones of intermediate quality. Generally the value of survey data has been limited by complicated subsurface geology and consequent difficulties in interpretation.

Accessibility poses a constraint to optimal site selection from hydrogeological considerations though access to drilling areas is generally good. Private land and sites requiring access construction have been avoided wherever possible. In most cases clearance of access to sites has been expedited by helpful District Officers and penghulus.

Site selection has been completed in north Kedah and Langkawi island and is well advanced in Perlis. Selection in central and south Kedah has not started.

2.3.2 North Kedah

JKR initially allocated 74 wells distributed over 16 areas of north Kedah. Over 80 potential sites were selected of which 60 have been drilled. The well locations are shown on map KP/1 (inside back cover). The extra sites were selected to allow flexibility as drilling proceeded and for some rejections where access permission could not be obtained. Geophysical survey during the selection process included 139 soundings and 29 km of profiling.

Fewer wells were drilled than originally allocated as investigations indicated that in some areas brackish groundwater and/or very low yielding formations would be encountered. Additional factors were poor results from initial drilling in some areas and progress on surface water works in others.

Some of the proposed drilling areas were found to have low potential for groundwater supplies. These include parts of Kubang Pasu, Pokok Sena area and southern Yan. As these areas suffer particularly from water shortages it was agreed with JKR Kedah that wells would be drilled to try to alleviate this situation to some degree. Half of the dry or hand pump wells occur in these areas.

2.3.3 Perlis

The 50 wells allocated to Perlis were distributed by JKR to 22 proposed areas shown on Figure 2.2. Site selection procedures including 26 resistivity soundings and 20 km of profiling have been carried out for 34 wells with the following results :

a) 16 sites in southern Perlis cancelled, 13 owing to poor water quality and 3 because of low potential;

b) 15 sites recommended of which 5 have been drilled;

c) 3 sites near Kodiang dependant on results from monitoring quality at existing wells in Kodiang.

The cancelled sites are to be reallocated to other areas where indicated good potential is confirmed by initial drilling. Some may be reallocated to new areas to be selected by the Consultants. Study of existing data to identify possible new areas has started. This will be followed up by field investigations prior to submission of recommendations.

2.3.4 Langkawi Island

Project objectives on Langkawi island cover the development of a wellfield in the Sungei Melaka alluvial basin and an investigatory drilling programme in the Carboniferous Singa formation to assess its potential as a source for water supplies.

For the Sungei Melaka wellfield, sites for 23 production wells were selected in October 1981. Selection was based on field survey, information from 22 existing boreholes and piezometers, results of seismic surveys by the Geological Survey of Malaysia and theoretical consideration of well interference, effects on river flows, effects of aquifer boundaries and saline intrusion. A minimum spacing of 500 metres was adopted in order to avoid excessive drawdowns due to well interference and to balance abstractions against vertical recharge. All wells have been sited at least 100 m from river channels to minimise the effects of pumping on river flows. The selected site positions are shown in Figure 2.3.

FIGURE 2-2 PERLIS DRILLING AREAS

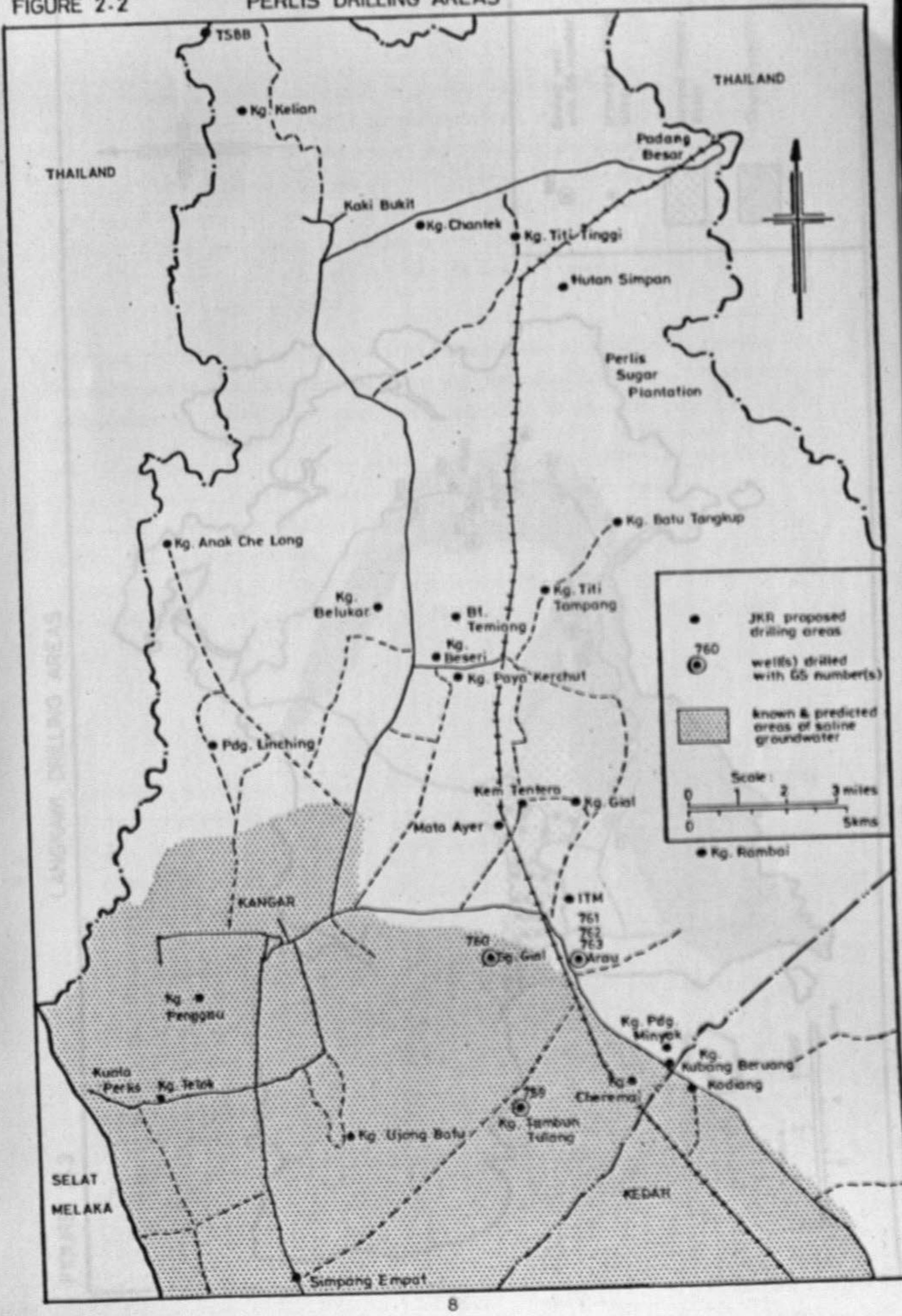
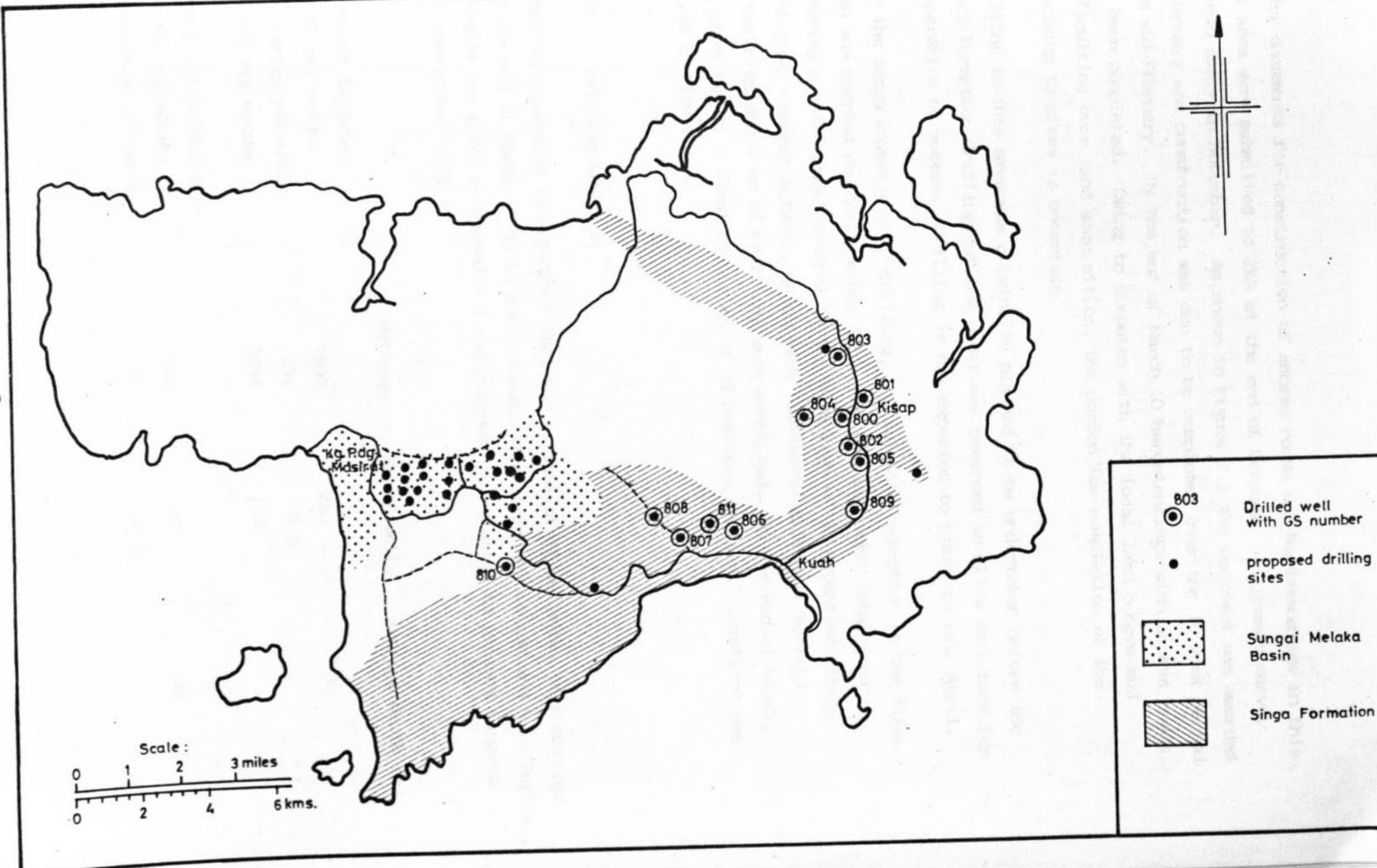


FIGURE 2.3

LANGKAWI DRILLING AREAS



Tender documents for construction of access roads and hardstandings in this padi area were submitted to JKR at the end of October. Alignment survey started early in November. As shown in Figure 2.1 the contract was awarded in January and construction was due to be completed over the 10 week period from mid-February. By the end of March 10 hardstandings with access roads had been completed. Owing to disputes with the local land owners and difficulties over land acquisition, the period for completion of the remaining 13 sites is uncertain.

Drilling in this area was originally planned to be undertaken before the Singa formation drilling but the order was reversed to allow more time for preparation of access. Drilling is now expected to start in late April.

For the Singa investigatory drilling, initial site selection in the Kisap area was carried out in December 1981. In February additional studies covering a wider area resulted in the selection of 31 potential sites. During geophysical surveys, which were limited by difficult terrain, 7 soundings and 5 km of profiling were completed. By the end of March, 12 sites out of a final selection of 15 had been drilled. Locations are given in Figure 2.3.

2.4 Well Construction

Drilling commenced in mid-April 1981 and a total of 77 wells had been drilled by the end of March : 60 in north Kedah, 12 on Langkawi island and 5 in Perlis . Details are given in Appendix A and progress in relation to project targets is summarised below :

	Meterage	No of wells	Average depth (m)
Project targets :			
- 32 rig months	7500	250	30
- average per month	234	7.8	
- 14½ rig months	3398	113	
Progress to 31.3.82 :			
- 14½ rig months	3216	77	42
- average per month	222	5.3	

The number of wells drilled is substantially less than the project target as the depths drilled average 40% greater than originally planned. Comparison of meterage target and achievement shows that drilling progress is slightly less than one month behind programme.

Shortages of equipment and materials during the early stages of the project, particularly drilling bits and 8 inch uPVC casing, meant that many of the wells drilled had to be left incomplete until outstanding items became available. Thus the drilling rig had to be returned to such wells often having to ream out to larger diameter before installation of permanent casing. The condition of some holes had deteriorated since the time of drilling and this slowed completion progress. Some wells drilled in difficult ground conditions took particularly long periods to complete owing to equipment and materials limitations. Progress was also affected by lack of drilling and well completion experience of the contractor's personnel at the start of the project. These problems have now been largely overcome.

Additional constraints on well drilling and completion have arisen recently with identification of the need to develop wells for longer periods and to place cement grout in the bore wall/casing annulus above the basket type seals.

2.5 Well Testing

Pumping tests were not started until late September when necessary equipment was first available. By the end of March the testing backlog had been reduced to 19 wells - 10 in north Kedah, 3 in Perlis and 6 in Langkawi. Priority is being given to completion of the north Kedah wells.

The test programme for wells normally consists of four steps at increasing discharges each of 150 minutes duration with the last step extended to a short constant rate test of 360 minutes. Step duration was increased from 100 to 150 minutes at an early stage to allow more time for steady state conditions to be reached or approached. In many cases steady state is not reached. Water levels are monitored throughout each test including the recovery period after pumping stops. Electrolytic conductivity measurements, a simple indicator of water quality, together with rate of discharge checks, are made regularly throughout the pumping period. Towards the end of the tests, a Hach portable laboratory is used for well head chemical analysis including unstable parameters. At the same time water samples are taken for detailed laboratory analysis at Jabatan Kimia, Penang.

Maximum recommended well yields are assessed from analysis of pumping test results. These are shown in Appendix A together with apparent yields during drilling and development. The relationship varies substantially from well to well but, on average, recommended maximum yields are about 70% of apparent yields during drilling.

2.6 Water Supply Engineering

2.6.1 Consultant Action

Table 2.1 lists the north Kedah well yields and implementation proposals based on discussions with JKR Kedah. In summary, 8 wells are proposed for hand pump supplies and 40 for powered pump supplies of which about half will be grouped for treatment purposes. Implementation is not recommended for 4 low yielding wells. Treatment processes listed in the table are discussed in section 3.5.

Designs and specifications for well group GS 701, 702, 703 at Kg Kubor Panjang, Pendang district were prepared by Jurutera Konsultant and submitted to JKR Kedah in February. The treatment process was amended by the Water Treatment Specialist early in March. Survey and designs for other wells are in progress and are planned to be submitted during April and May.

In March, the Water Treatment Specialist defined the water treatment processes required for the north Kedah well waters. These include 5 treatment processes for hand pump wells and 13 for powered pump wells. The number of different treatment processes required reflects the variability of water quality.
In addition to the water treatment recommendations called for in the Terms of Reference, the Water Treatment Specialist prepared outline designs for a standardised range of plant sizes suitable for the north Kedah wells. This work has been embodied in a report to JKR and is being followed by Jurutera Konsultant in preparation of designs.

2.6.2 JKR Action

Hand pumps have been installed in 10 of the north Kedah wells (GS 720, 703, 711, 713, 716, 721, 730, 733, 738 and 743). At GS 716 a prototype treatment plant for hand pump supplies is in operation.

Table 2.1 Implementation Proposals for North Kedah Wells

Well no	Yield[1] (gpm)	Type of Supply Indicated	Treatment Process	Implementation Proposals
Kota Setar district :				
717	Dry	-	-	-
716	(4)	Hand pump	HP4	Local supply
719	(5)	Hand pump	HP5	Local supply
721	(5)	Hand pump	HP2	Local supply
722	(1)	-	-	-
718	25	Powered pump	PP11	Local supply envisaged
720	25	Powered pump	PP6	Pump to Gajah Mati reservoir
723	(140)	Powered pump		Awaiting pumping test results. Possibly group supply with 724.
Yan district :				
752	Dry	-	-	-
Pendang district :				
700	Dry	-	-	-
751	Dry	-	-	-
739	(5)	Hand pump	HP5	Local supply
740	(5)	Hand pump	HP4	Local supply
750	(5)	Hand pump	HP5	Local supply
704	26	Powered pump	PP3	Gravitate to JKR main and local supply to Kg Kepala Bukit.
742	11	Powered pump	PP2	Local supply to Kg. Padang Pusing and vicinity.
701	42)			
702	15)	Group supply	PP6	Gravitate to JKR main
703	45)			
737	14)	Mechanical pump,	PP4	
738	100)	possibly group	PP9	Under consideration
741	26)	supply	PP6 (group PP9)	
743	46)			
744	153)			
745	270)	Group supply	PP11[2]	Pump to Bukit Jambul reservoir
746	270)			
747	270)			
748	159)	Group supply	PP12	Gravitate to Guar Chempedak reservoir and local supply
749	84)			

Table 2.1 Implementation Proposals for North Kedah Wells (continued)

Well no	Yield[(1)] (gpm)	Type of Supply Indicated	Treatment Process	Implementation Proposals
Padang Terap district :				
726	5	Hand pump	HP5	Local supply
730	(4)	Hand pump	HP5	Implementation not recommended[(3)]
724	(240)	Powered pump		Awaiting pumping test results. Possibly group supply with 724
725	(110)	Powered pump		Awaiting pump test results Local supply envisaged
733	30	Powered pump	PP5	Local supply to Kg Nako area
734	26	Powered pump	PP6	Local supply to Kg Baharu Pokok Machang
735	96	Powered pump	PP6	Local supply to Kg Alor Nibong and vicinity
736	39	Powered pump	PP6	Local supply to Kg Baharu Bukit Tembaga Selatan
705	23)			Local supply between
706	23)	Group supply		Kuala Nerang
707	(73))			and Padang Sanai
727	(305))	Group supply		Awaiting pumping test results.
728	(140))			Local supply envisaged
729	(200))			Awaiting pump test results.
731	(195))	Group supply		Local supply
732	33)			envisaged.
Kubang Pasu district :				
755	Dry	-	-	-
756	Dry	-	-	-
758	Dry	-	-	-
710	7	Hand pump		Local supply
711	3	Hand pump	-	) Implementation not recommended.
713	2	Hand pump	-	) Yield too small.
708	17	Powered pump	PP6	Local supply envisaged
709	29	Powered pump	PP7	Local supply envisaged
712	57	Powered pump	PP4	Local supply envisaged
714	272	Powered pump	PP6	Gravitate to JKR main
715	117	Powered pump	PP4	Local supply envisaged
757	11	Powered pump	PP6	Under consideration
753	11)	Group supply		Local supply envisaged
754	(42))			

Notes

1. Yields in brackets are apparent yields during drilling. For powered pump and and group supplies pumping test results are awaited prior to stating maximum recommended yields.
2. A modified treatment process may be required to ensure adequate arsenic removal.
3. Well 730 is located in Kg. Musa. About 1½ km to the west is well 729 which had an apparent yield during drilling of 200 gpm. It appears preferable to serve Kg. Musa from well 729 and to abandon 730.

Tender documents for the three well group at Kg Kubor Panjang have been prepared and issued. Closing dates for the equipment and civil works contracts are 4th and 15th May respectively. Tender drawings prepared by JKR Kedah from the outline designs provided by the Consultants are reproduced in Appendix B.

2.7 Training

The first trainee, Lee Hooi Huat, was assigned to the project by JKR Kedah on 1 December for training on drilling operations and equipment maintenance. After 4 months working with the Ingersoll-Rand rig team under the supervision of the Master Driller, he is familiar with rig operation and maintenance and has some knowledge of well development. At the end of April, after further operational experience to gain confidence, he will be transferred to Langkawi for experience of alluvial drilling with the Bomag rig.

It is understood that JKR headquarters propose to set up a drilling organisation to take over the rigs when this project is completed. As an introduction for personnel to be assigned to this organisation, a three day programme of lectures and site visits was held at the beginning of March. Topics covered included rotary well drilling methods, surface resistivity survey, geophysical well logging and test pumping of wells. The programme was attended by three JKR engineers. Further training is expected to be requested.

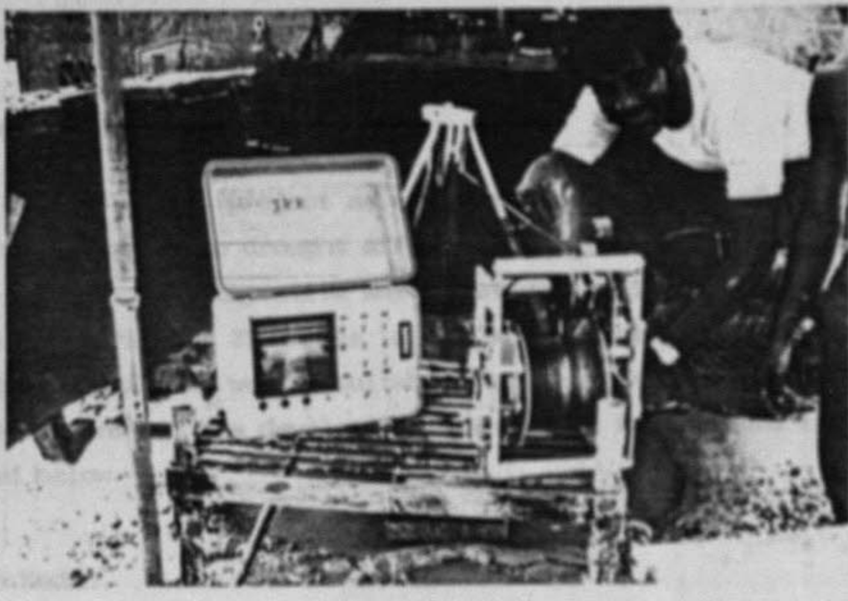
JKR Perlis are assigning a trainee from mid-April for training on drilling operations under the supervision of the Master Driller.

A geologist from the Geological Survey of Malaysia is to be assigned to the project from the beginning of May until the completion of all work. He will be expected to spend about 7 months on the mainland and 2 on Langkawi island working under the supervision of the project hydrogeologists. Training is expected to cover the following aspects :

- site selection including field geology, photogeology, resistivity surveys and accessibility and engineering considerations
- methods and equipment for hard rock drilling with air and alluvial drilling with mud
- logging of drilling samples and grain size analysis of aquifer material

- geophysical borehole logging
- elements of well design
- pumping tests and analysis of results
- well head chemical analysis
- piezometry
- piezometer construction
- infiltration tests
- hydrometry including river flow and level gauging

The Geological Survey also intend to assign two technicians for training on drilling rig operations. To ensure that adequate attention can be given to each trainee, one will work under the supervision of the Master Driller on mainland drilling, the other on Langkawi island under the supervision of the Drilling Engineer.



THE SIE T450 GEOPHYSICAL WELL LOGGER

DEVELOPMENT BY AIRLIFT AT GS 763, ARAU

3.0 FINDINGS AND RECOMMENDATIONS

3.1 Concept of the Project

The original concept of the project as envisaged in the Terms of Reference was to supply groundwater to drought affected villages outside the existing water supply network. The objective was to provide reticulated supplies to 250 communities by drilling 250 wells ie one per community. Where groundwater resources locally available were unsuitable, hand pump supplies were to be designed. As the project has developed, this concept has changed in various ways discussed below.

3.1.1 North Kedah

JKR specified 425 kampongs grouped in 16 areas of north Kedah and gave a preliminary allocation of 74 wells to serve these kampongs ie an average of about 6 kampongs per well. Thus the concept of one well per community could not be applied. The area enclosed by the kampong groups is well over 300 square miles or about 25% of the total area of north Kedah. Hydrogeological investigations leading to well site selection had to cover this extensive area and be aimed at producing the highest possible well yields. Under the original concept, hydrogeological investigations would have been local to the kampongs to be served with the aim of drilling wells in their immediate vicinity. Relatively low yields would have been adequate.

The existing water supply network passes through 8 of the drilling areas and extensions through other areas are either under construction or planned. In selecting well sites each area has been considered separately and existing and planned pipelines taken into account. Where feasible and desirable, as agreed with the project coordinator, wells have been sited close to pipeline routes to allow groundwater supplies to be connected into the network or kept away from pipelines with the intention of setting up separate local treatment plants and distribution systems. Similarly, wells have been grouped together in some areas to avoid the higher engineering costs which would be associated with individual wells.

This has proved particularly relevant for water treatment which needs to be more extensive than could have been forseen from water quality data available for wells drilled before this project. A notable case is the 5 well group at Bukit Jambul, Pendang district where treatment needs to include arsenic removal in addition to iron and manganese removal and pH correction as are commonly required for other wells.

3.1.2 Perlis

The allocation of wells provided by JKR Perlis called for 50 wells distributed over 22 areas. Many of these are groups of 2-4 wells intended to be pumped into the existing distribution network. Hydrogeological investigations in southern Perlis have resulted in cancellation of 13 wells owing to the likelihood of encountering brackish/saline water and probable cancellation of a further three. As instructed by JKR Perlis these wells are to be reallocated to other areas where initial drilling confirms expected good yields and to some new, potentially good areas to be identified by the Consultants. Thus, as in north Kedah, large areas require investigation.

3.1.3 Effects of Concept Changes

One of the effects has been the need to obtain maximum yield from each well. At the Inception stage 8 inch diameter wells were introduced in addition to the 6 inch wells allowed for in the Agreement. Where the groundwater resources permit, yields in excess of those possible from 6 inch wells can therefore be achieved. Early drilling results showed that higher yields could be achieved by drilling deeper than the average well depth of 30 metres envisaged in the Agreement. The potential for increased yield from extra depth varies from site to site but an increase to about 40 metres on average has been shown to be worthwhile. Thus wells are being drilled deeper and in some cases being completed to larger diameters than originally envisaged.

A further effect has been an increase in the hydrogeological workload resulting from the need for extensive investigations prior to site selection in north Kedah and Perlis. Additionally, the implementation of relatively high yielding wells, often in groups, is a different scale of development from isolated, relatively low yielding wells. Greater effort must be put into assessment of long term reliability of the resource in terms of both quantity and quality so that capital investment is not wasted. Possible problems are illustrated by the rapid deterioration of water quality in existing developments at Bukit Keriang and Kodiang in north Kedah. In consequence of these changes in the scope of work, time has not been available for the preparation of well completion reports for the mainland wells. A proposal for overcoming this problem is given in section 4.2. Appendix C contains a sample completion report to show the standard planned.

3.2 Hydrogeology

3.2.1 North Kedah

Whilst in detail the hydrogeology of North Kedah can be described as complicated, certain generalisations can be made.

In Padang Terap area the Semanggol formation of Triassic age is encountered. This formation is composed dominantly of sequences of sandstones, siltstones and shales and has been subject to moderate regional tectonics resulting in fracturing. The formation has no primary permeability and aquifer zones are related solely to zones of secondary permeability due to fracturing. These zones exhibit non-uniform variation with depth as well as laterally. Yields indicated from drilling results are given in Table 3.1. It is concluded that with careful development the hydrogeology of the Semanggol formation can support the concept of rural groundwater supply projects.

Table 3.1 Project Well Yields Indicated During Drilling

Formation	Yield during drilling (gpm)[1] Range	Average	No of wells
Recent - Melaka basin alluvium	ND	ND[2]	-
Permo-Triassic - Chuping limestones	5 - 500	177	7
Triassic - Semanggol sandstones	7 - 305	98	24
Carboniferous :			
- Kubang Pasu/Singa shales	0 - 27	6	18
- Kubang Pasu/Singa sandstones	5 - 190	48	16
Silurian - Mahang meta shales/sandstones	43 - 500	221	7
Ordovician - Setul limestone	ND	ND	-

Notes : ND - no data

1. Maximum safe long term operational yields are generally about 70% of these values
2. Predicted yield 158 gpm

The Kubang Pasu formation of Carboniferous age occurs in the northern and western areas. This formation, stratigraphically underlying the Semanggol, is composed dominantly of shale sequences with minor quartzitic sandstones. Whether fractured or unfractured the relatively incompetent shales possess no primary and very little secondary permeability. Relatively thin sandstone bands within the shale sequences exhibit moderate permeabilities where sufficiently fractured. Such situations are however in many cases difficult to locate and develop. Unless hand pump supplies only are required (see Table 3.1), further development of rural groundwater supplies in areas underlain by the Kubang Pasu shales is not recommended.

A relatively small area of the Silurian age Mahang formation, dominantly meta-shales and sandstones, has been encountered south of Pendang. Where fractured these rocks possess moderate permeabilities. Wells drilled under this project have given the yields shown in Table 3.1. The hydrogeology of the Mahang found in North Kedah appears to be more promising than that indicated by previous investigations in south Kedah. The suitability of the formation for development of rural groundwater projects is likely to be variable.

One very important factor in the hydrogeology of Kedah is the existence of Recent deposits of brackish/saline water bearing marine alluvium covering a large part of the western area (see Map KP/1). Drilling in such areas cannot be recommended. As a result of information from this project, the theory that fresh groundwater aquifers could occur beneath the brackish water bearing alluvium now seems much less likely. It should generally be expected that formations overlain by the marine alluvium, if aquifers, are likely to contain brackish/saline water. The intrusion of such water into originally fresh groundwater areas has occurred over a period of time at both Bukit Keriang and at Kodiang. Care must be exercised in the development of any groundwater source in or adjacent to areas overlain by marine alluvium such as at Bukit Jambul where previously recommended abstraction rates may have to be reduced in view of information gained from recent events and studies.

3.2.2 Perlis

Generally the hydrogeology of Perlis can be described as related to four main formations.

The Kubang Pasu/Singa formation of Carboniferous age covers a large part of the state. Its properties are very similar to those described for north Kedah and therefore the same comments can be made. Although not yet drilled during this project, existing data indicates even less promising hydrogeological conditions. Fracturing is less apparent and, where encountered, secondary infilling by calcite or quartz has greatly reduced the already limited permeability. It is unlikely that drilling can be recommended in any areas underlain by the Kubang Pasu shales.

The Chuping limestone formation of Permo-Triassic age is of limited and scattered outcrop but due to karst processes can be highly permeable. Such a karst (cavernous) formation, although providing high yielding wells, presents practical difficulties during well drilling and development. The regional hydrogeology of the Chuping limestones may be subject to review as information from recent drilling shows the existence of a shale sequence overlying the limestone which in turn overlies the Kubang Pasu shales. With careful development the Chuping limestones appear most promising for the development of rural groundwater supplies.

For the Ordovician age Setul limestone there is little quantitative hydrogeological information but indications are that, although probably not as good as the Chuping limestone, it could provide useful groundwater supplies. The outcrop in west Perlis is quite mountainous and access will be a major limitation.

Extending from north Kedah, a large part of Southern Perlis is covered by Recent deposits of marine alluvium. As in north Kedah there is no potential for groundwater development in this alluvium. Recent project investigations and drilling have cast strong doubt on the possibility of developable fresh groundwater limestone aquifers beneath the alluvium. Furthermore it is likely that the Arau wellfield, abstracting fresh groundwater from a Chuping limestone aquifer lying adjacent to the area of marine alluvium, could suffer by intrusion of brackish water. Monitoring of water quality with time should be undertaken and investigations to try and quantify the risk have been recommended. In the meantime, the potential for abstraction at Arau has been increased by the drilling of new wells. However if saline intrusion is positively identified then abstractions would have to be decreased rather than increased.

3.2.3 Langkawi Island

At the Inception stage, two formations were selected for drilling - the Carboniferous age Singa formation and the Recent alluvium in the Sungei Melaka basin.

The Singa formation consists primarily of low yielding shaley strata but contains thin steeply dipping beds of more resistant metashales, siltstones and sandstones. As on the mainland, drilling results indicate that these thin beds can give moderate yields typically in the range 20-40 gpm if sufficiently fractured. However, suitable drilling sites are difficult to locate due to the restricted thickness of the beds, steep dips and particularly, access limitations.

Two main areas with relatively better potential are apparent; the Kisap area has the best potential and access conditions within the rubber plantation are more favourable than elsewhere. A second area extending north east from the golf course has also been identified although access is much restricted. Borehole yields in this area appear to be generally lower than those in the Kisap area. Overall, the formation has poor to moderate development potential.

Project well drilling and testing has not yet commenced in the Sungei Melaka basin. Preliminary analysis of hydrogeological conditions is based on existing data largely derived from Geological Survey of Malaysia work and initial project surveys. The alluvium, up to 30 m thick, is composed of clays, sands and gravels in varying proportions and mixtures. Evidence suggests that it is more sandy and therefore probably more permeable in the northern and western parts of the basin. The most favourable aquifer conditions are believed to exist in the Padang Saga area. Available hydrogeological data would indicate that enough groundwater is available in the basin to meet the required demand of 2.3 mgd by 1985 with some possible intensification if aquifer conditions prove favourable.

3.3 Well Design

Well designs outlined in the Inception report have in general been followed but several significant variations have evolved.

Initially well design was limited by the equipment and materials available. Now, in most cases, instead of drilling at small diameters and then reaming out to suit appropriate casing size for potential yield, wells are drilled at 9⅝ inch to rock head. The rock is drilled with 9⅝ inch rock bit or 8/8½ inch hammer bit if the rock is hard. The 9⅝ inch rock section being weaker usually requires lining with perforated or slotted casing whilst the hammer-drilled section can usually be left unlined.

Hole condition as well as lithological zoning is checked by geophysical logging to aid well design, particularly optimum casing and seal positions.

The overall diameter of 8 inch uPVC casing sockets proved to be a problem for insertion through 10 inch temporary casing and hole diameters possible below and therefore threaded flush joints were developed to allow more clearance. Well design and construction is now simplified as the standard 9⅝ inch hole can accommodate either 6 inch socket jointed or 8 inch flush jointed casing. Some 6 inch flush jointed uPVC casing is used in particular circumstances such as when the casing string has to be installed through 8 inch temporary casing. Flexibility is also available for two string casing designs as the 6 inch flush can been inserted through 8 inch uPVC casing.

Types of well annulus seals have progressed from push-tight socket seals to steel and canvas basket type seals and specially shaped rubber seals. With the advent of water chemistry data indicating highly corrosive waters, cement plugs are now placed in and above the basket type seals. After placing cement, a minimum waiting time of 24 hours and preferably at least 48 hours is necessary to allow the cement to set before well development commences. To avoid the drilling rig being idle for this waiting period with consequent delays to the drilling programme, a separate compressor for well development has been obtained thereby releasing the rig to move on to the next site as soon as construction is completed.

The original project design depth was 30 metres. Drilling results have shown higher well yields can be achieved from deeper wells. An optimum well design depth of 40 metres has been adapted.

Typical well design features are illustrated in Figure 3.1. Approximately 70% of completed wells are lined with 6 inch casing and 30% with 8 inch casing. Typically, for the average 42 metre deep well, about 30 metres is lined with casing, of which 12 metres is perforated or slotted, and the bottom 12 metres is left unlined.

3.4 Water Quality

Water quality data has been obtained from well head chemical analysis during pumping tests and from fuller laboratory analysis of samples collected at the same time. The data for north Kedah are summarised in Table 3.2.

Generally the groundwater from the sandstone and shale areas drilled is of an aggressive bicarbonate type. Typical features are low pH and total dissolved solids, high carbon dioxide and iron, no dissolved oxygen. High iron content is due to the ability of this aggressive water to take iron into solution from the laterite, sandstones and shales contacted by it. Both iron and manganese concentrations are very variable, ranging from 0.1 to 25 mg/l and 0 to 4 mg/l respectively.

During water sampling, some exposure of samples to atmosphere is unavoidable resulting in loss of carbon dioxide and therefore concentrations measured can be taken to be low. Associated effects are raising of pH and lowering of alkalinity due to changes in carbonate equilibria. Limited oxygenation also occurs allowing oxidation of ferrous iron in solution to form ferric hydroxide which precipitates out of solution. This reaction is associated with lowering of pH and alkalinity. Manganese precipitation also occurs. Well head values for these parameters are unaffected as analysis takes place immediately after sampling but changes occur in the time between sampling and laboratory analysis. Well head values are therefore relied upon.

At Bukit Jambul, wells penetrated a high yielding metalliferous hydrothermal fracture zone in Silurian rocks. Water sample analysis indicated the presence of lead, copper, zinc and arsenic. The levels of arsenic detected are a cause of concern in drinking water supplies.

FIGURE 3.1 TYPICAL WELL DESIGN FEATURES

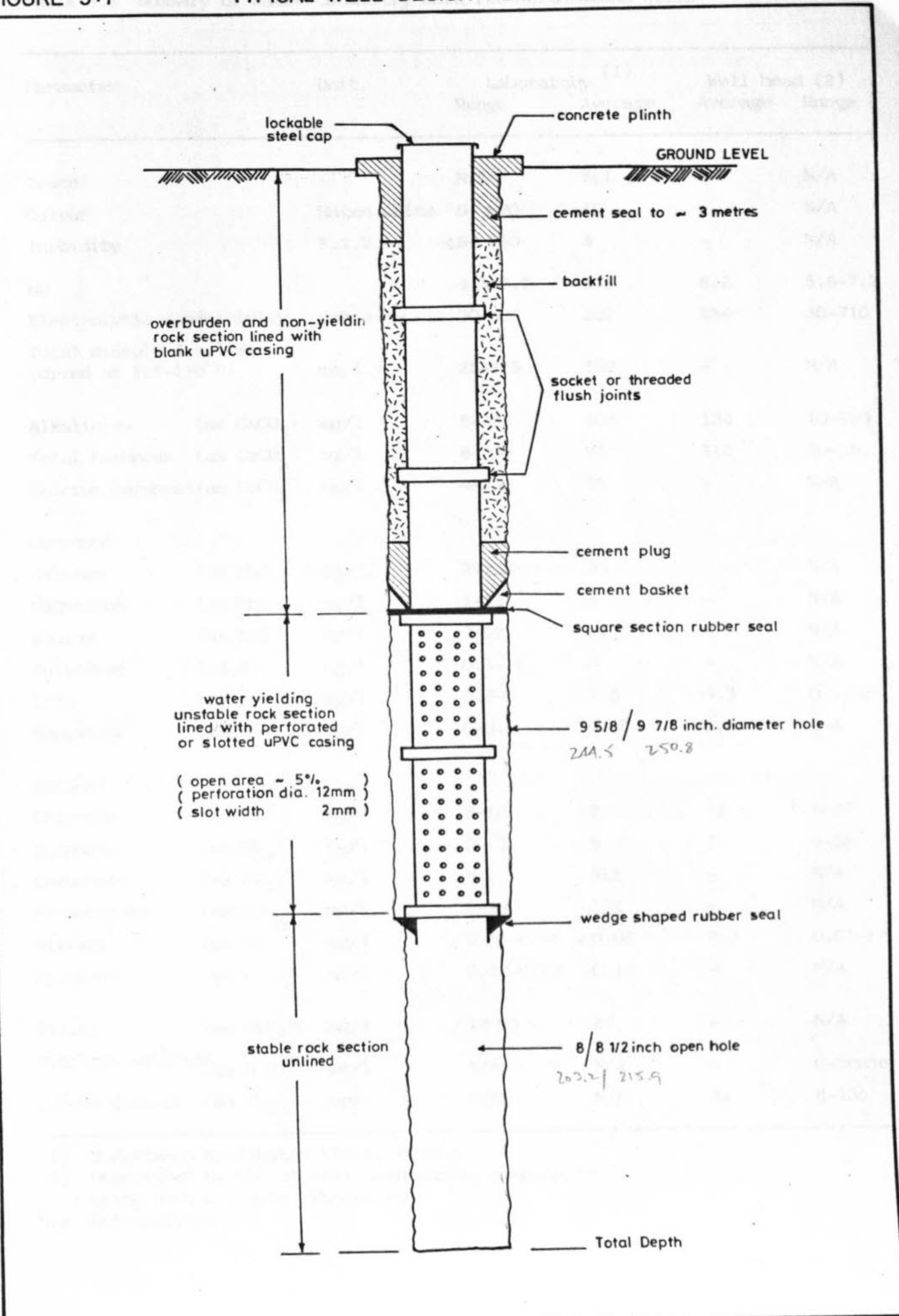


Table 3.2 Summary of Water Chemistry Data for North Kedah Wells

Parameter		Unit	Laboratory (1) Range	Laboratory (1) Average	Well head (2) Average	Well head (2) Range
Taste		-	Nil	Nil	-	N/A
Colour		Hazen units	5- > 70	10	-	N/A
Turbidity		F.T.U	< 5- 150	5	-	N/A
pH			4.5-7.7	6.2	6.2	5.6-7.2
Electrolytic conductivity		umhos/cm	30-600	222	234	30-710
Total dissolved solids (dried at 105-110 ^{o}C)		mg/l	25-375	152	-	N/A
Alkalinity	(as $CaCO_3$)	mg/l	5-295	108	134	10-330
Total hardness	(as $CaCO_3$)	mg/l	8-300	92	112	20-250
Calcium hardness	(as $CaCO_3$)	mg/l	4-290	75	-	N/A
Cations:						
Calcium	(as Ca)	mg/l	2-116	30	-	N/A
Magnesium	(as Mn)	mg/l	1-12	8	-	N/A
Sodium	(as Na)	mg/l	3-62	11	-	N/A
Potassium	(as K)	mg/l	0.3-12	3	-	N/A
Iron	(as Fe)	mg/l	0.2-8	1.5	4.3	0.1-25
Manganese	(as Mn)	mg/l	0-0.4	0.05	0.6	0-4
Anions:						
Chloride	(as Cl)	mg/l	2-16	7	15	5-25
Sulphate	(as SO_4)	mg/l	0-15	5	7	0-36
Carbonate	(as CO_3)	mg/l	Nil	Nil	-	N/A
Bicarbonate	(as HCO_3)	mg/l	6-360	132	-	N/A
Nitrate	(as N)	mg/l	< 0.05-0.55	< 0.05	2.2	0.01-12
Fluoride	(as F)	mg/l	0.03-0.20	0.13	-	N/A
Silica	(as SiO_2)	mg/l	12-75	27	-	N/A
Hydrogen sulphide	(as H_2S)	mg/l	N/A	N/A	-	0-trace
Carbon dioxide	(as CO_2)	mg/l	N/A	N/A	51	8-136

(1) Undertaken by Jabatan Kimia, Penang.
(2) Undertaken by GDC at well head during pumping test, using Hach portable laboratory
N/A Not analysed

Water quality data for wells drilled before this project are sparse but indicate that pH values in the range 5.3 - 7.8 and iron concentrations of 0.1 - 0.6 mg/l were to be expected. Similar pH values have been found but iron concentrations are generally very much higher.

Available data on water in the limestone formations currently being drilled in Perlis indicate generally higher values for pH, hardness and chloride than found in the sandstone and shale formations.

3.5 Water Supply Engineering

3.5.1 Population, Water Demand and Levels of Supply

Population data for the 425 water short kampongs in North Kedah originally listed by the JKR as those to be supplied with groundwater have been estimated from the 1980 population census by the Department of Statistics. The census block data do not generally allow identification of individual kampong populations and therefore population data provided are mostly for kampong groups.

In many cases groundwater from the north Kedah wells will be fed into the surface water distribution system and will not therefore be supplied solely to the JKR listed kampongs or be the sole source of water for them. Assessment of the levels of supply achievable as envisaged in the Terms of Reference is not applicable in these circumstances. However where groundwater supplies are planned to have their own separate distribution systems such assessment is possible and will be undertaken.

A very generalised indication of levels of supply achievable can be obtained by comparing total water demand for all listed kampongs with the total supply anticipated from the 60 north Kedah wells. The total 1980 population as estimated by the Statistics Department is 107000. This has been forecast forward at 2½% annual growth rate to 1995 and total water demand calculated from the per capita demands agreed at the Inception stage. The results are given in Table 3.3.

Table 3.3 Water Demand and Available Groundwater Supplies

Year	Estimated Population	Water Demand (gal) Per capita gcd	Total mgd	Available supply (Total 3.4 mgd) gcd
1980	107 000	25	2.675	(32)
1985	121 000	30	3.630	28
1990	136 000	40	5.440	25
1995	154 000	45	6.930	22

The total available supply is derived from the maximum recommended well yields for 16 hours operation per day. For wells where pumping test data are not yet available, 70% of the yield during drilling is assumed. On this basis the total available supply is 3.4 mgd which is expressed in terms of gallons per capita per day in Table 3.3. The values indicate that estimated demand will exceed available supply from 1985.

3.5.2 Water Treatment

The engineering aspects of the project are substantially the same as discussed and agreed at the Inception stage with the major exception of water treatment. The water quality data now available for north Kedah are much more comprehensive than from previous work and show that iron concentrations in particular are usually much higher than originally anticipated. Generally more treatment is required and treatment processes need to be varied from well to well to suit the wide variation in water quality.

The Water Treatment Specialist's recent report covers raw water quality, treatment tests, treatment process recommendations and outline designs for a standardised range of plant sizes for both hand and powered pump supplies. Recommendations on water treatment presented below are drawn from his report.

Where the well yield is less than 10 gpm water will be supplied by means of a hand pump for which normal output is taken as 5 gpm. The philosophy has been adopted that electricity will not be available and that iron and manganese contents of 1.0 and 0.5 mg/l respectively will be acceptable. Process selection is based on well head values for iron, manganese and pH.

Where the iron plus manganese concentrations exceed 5 mg/l, abandonment of the well is recommended as treatment is judged to be too complicated and costly. A logic diagram for process selection is given in Figure 3.2 together with the treatment processes required.

Powered pumps are planned where well yield exceeds 10 gpm. The treated water quality standards adopted are compared with World Health Organisation standards below.

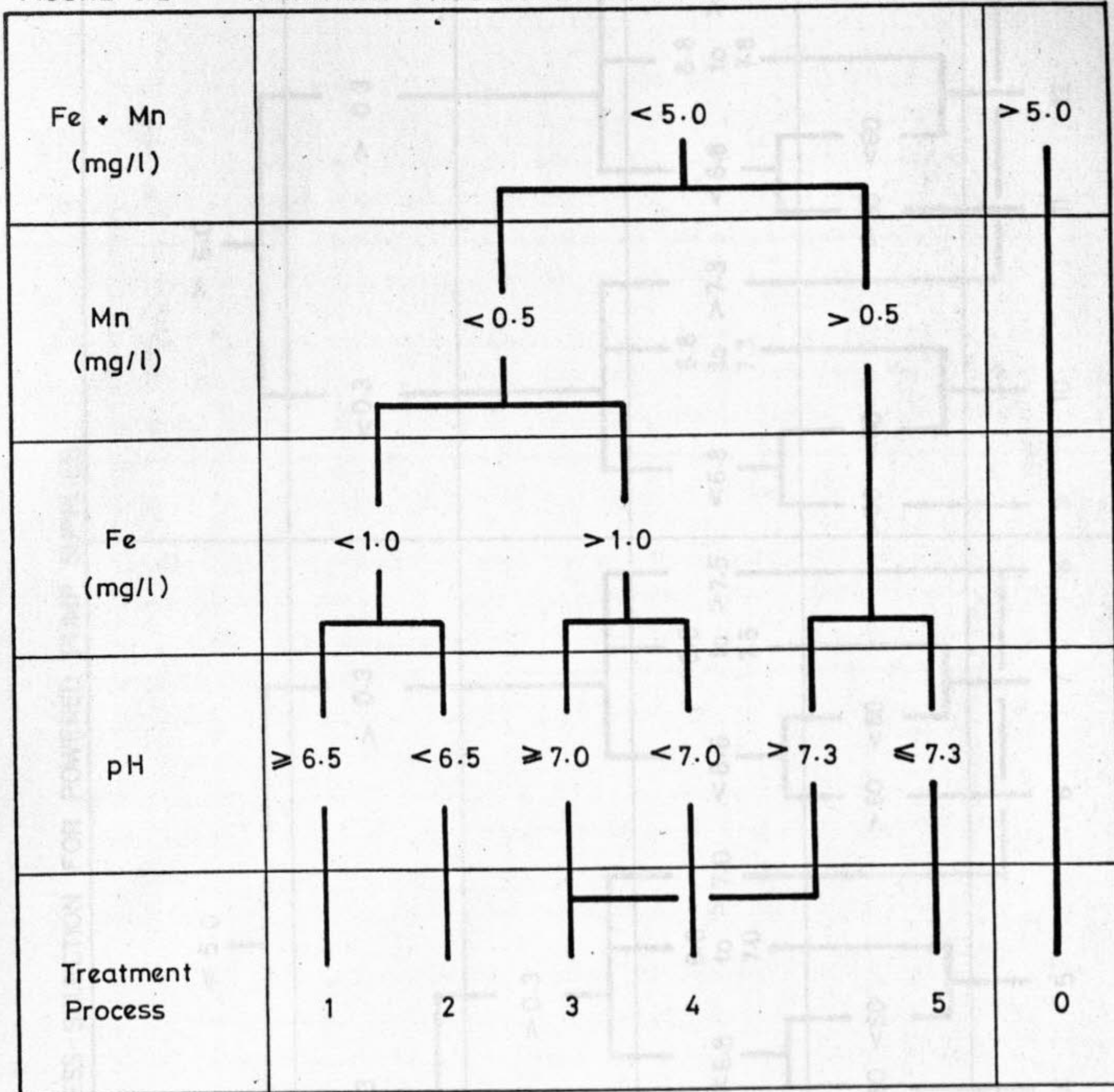
		WHO standard		Standard adopted
		Permissable	Desirable	
Iron (Fe)	mg/l	1.0	0.1	0.3
Manganese (Mn)	mg/l	0.5	0.05	0.3
pH		6.5-9.2	7.0-8.5	>6.5

Process selection is based on well head values for iron, manganese and pH plus carbon dioxide (CO_2) values calculated from well head alkalinity and pH. Figure 3.3. shows a logic diagram for process selection; treatment processes are given in Table 3.4.

Table 3.4 Treatment Processes for Powered Pump Supplies

PP1		Chlorination
PP2	(pH)	pH Correction, Chlorination
PP3	(pH)	Aeration/pH Correction, Chlorination
PP4	(Fe)	Aeration/pH Correction, Filtration, Chlorination
PP5	(Fe)	Weir, pH Correction, Filtration, Chlorination
PP6	(Mn)	Aeration/pH Correction, Filtration, Chlorination
PP7	(Mn)	Weir, pH Correction, Filtration, Chlorination
PP8	(Fe, Mn)	Weir, Filtration, Chlorination
PP9	(Fe)	Aeration, pH Correction, Flocculation, Sedimentation, Filtration, Chlorination
PP10	(Fe)	Weir Aeration, pH Correction, Flocculation, Sedimentation, Filtration, Chlorination
PP11	(Mn)	Aeration, pH Correction, Flocculation, Sedimentation, Filtration, Chlorination
PP12	(Mn)	Weir Aeration, pH Correction, Flocculation, Sedimentation, Filtration, Chlorination
PP13	(Fe, Mn)	Weir Aeration, Flocculation, Sedimentation, Filtration, Chlorination

FIGURE 3.2 TREATMENT PROCESS SELECTION FOR HAND PUMP SUPPLIES



Treatment Processes:

HP 0 – Abandon source

HP 1 – Chlorination alone

HP 2 – Aeration, pH correction, chlorination

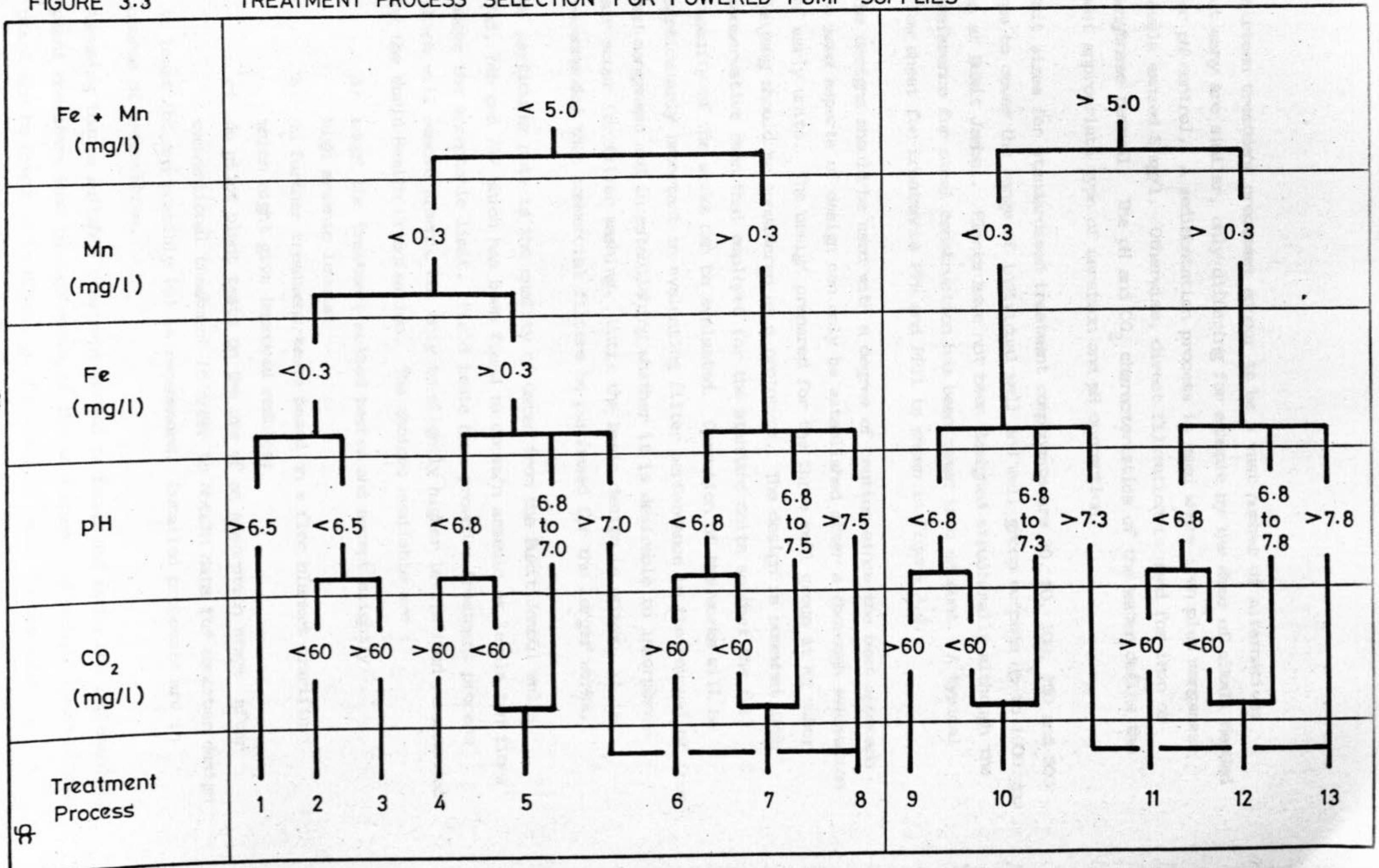
HP 3 – Filtration, chlorination

HP 4 – Aeration, pH correction, filtration, chlorination

HP 5 – Aeration, large pH correction, filtration, chlorination

gc

FIGURE 3.3 TREATMENT PROCESS SELECTION FOR POWERED PUMP SUPPLIES



Thirteen treatment processes appear to be a vast number of alternatives but many are similar, only differing for example by the dose of alkali needed for pH control. A sedimentation process is used where iron plus manganese levels exceed 5 mg/l. Otherwise, direct filtration is used for iron or manganese removal. The pH and CO_2 characteristics of the water define the most appropriate type of aeration and pH correction.

Unit sizes for standardised treatment components are 20, 50, 100, 250 and 500 gpm to cover the range of individual well and well group outputs up to 1000 gpm as at Bukit Jambul. Plants have not been designed structurally although the preference for steel construction has been taken into account. A typical flow sheet for treatments PP9 and PP11 is shown in Figure 3.4.

The designs should be used with a degree of caution since the best approach to some aspects of design can only be established after a thorough evaluation of early units. The design prepared for the three well group at Kg Kubor Panjang should be considered as a prototype. The design is somewhat less conservative than that employed for the standard units so that the full capacity of the works can be evaluated. Operation of the works will be particularly important in evaluating filter performance in the removal of iron and manganese and in establishing whether it is desirable to incorporate air scour for filter washing. Until the basic design is proven, it is recommended that commercial filters be purchased for the larger works.

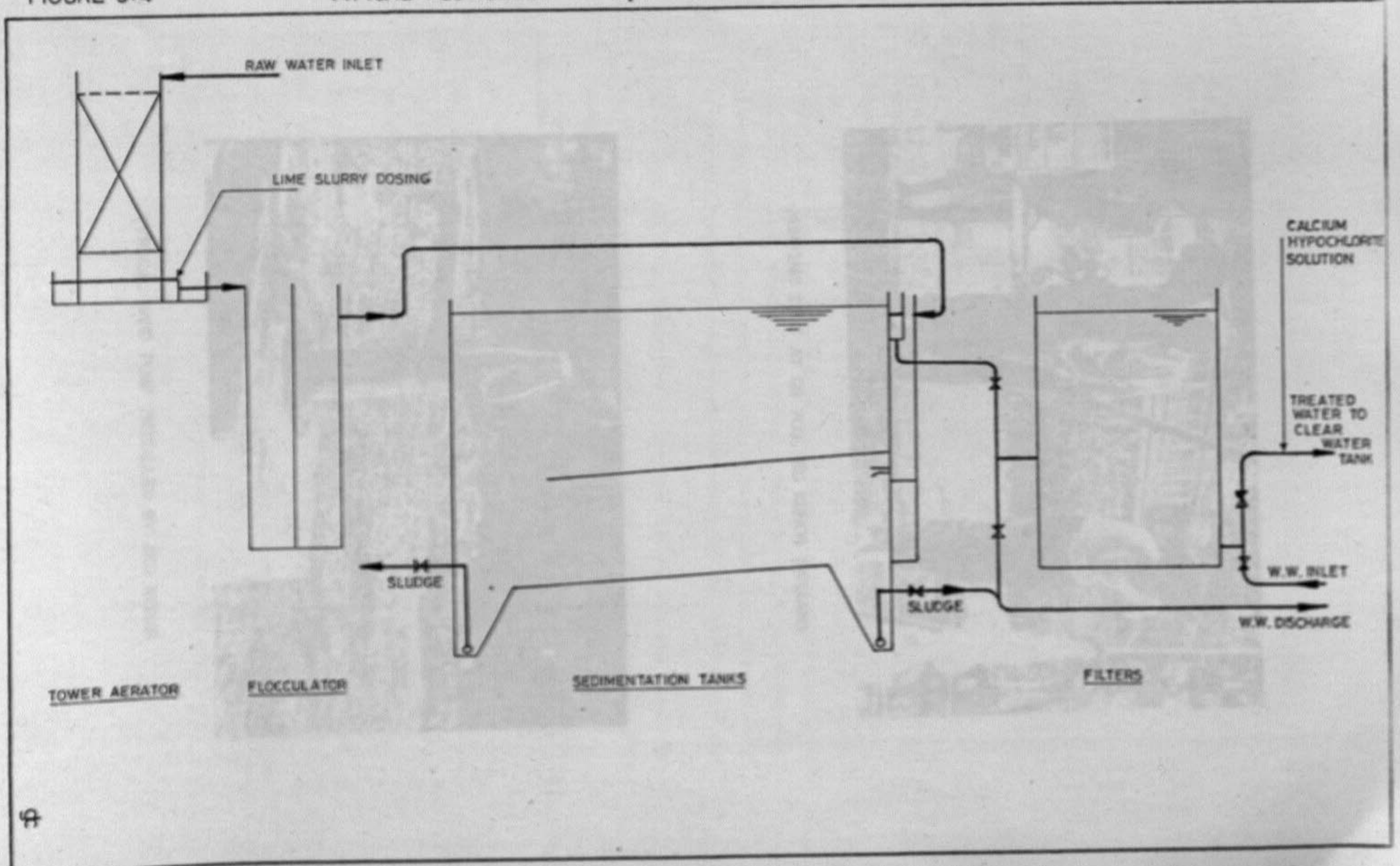
Of particular note is the quality of water from the Bukit Jambul wells 745, 746 and 747 which has been found to contain arsenic at levels ten times above the acceptable limit. Field tests have proved a treatment process which will remove arsenic but only to slightly higher levels then recommended by the World Health Organisation. The choices available are :

a) adopt the treatment method tested and accept slightly high arsenic levels;
b) do further treatment tests based on a floc blanket clarifier which might give improved results;
c) do pilot plant tests on the use of an adsorption stage after conventional treatment in order to obtain data for absorber design

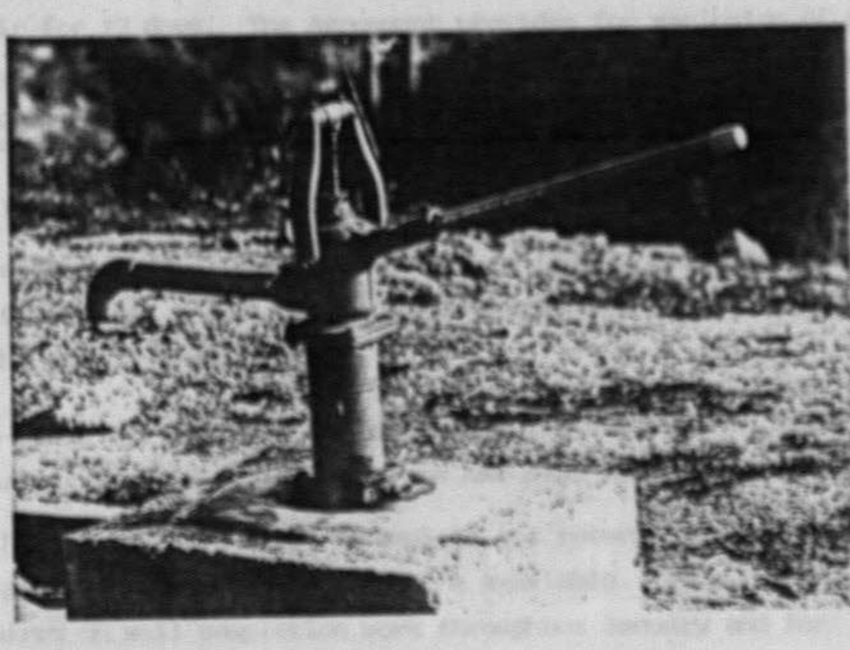
At least (b) and possibly (c) is recommeded. Detailed proposals are in course of preparation.

Assuming that a suitable treatment method is found and works are implemented, plant operators must be made aware of the seriousness of maloperation of the plant and be prepared to discharge all water to waste in the event of unsatisfactory operation.

FIGURE 3.4 TYPICAL FLOWSHEET PP 9, PP 11 TREATMENT



PUMPING TEST AT GS 703, KG KUBOR PANJANG



TYPICAL HAND PUMP INSTALLED BY JKR KEDAH

4.0 FORWARD PLANNING

4.1 Work Programme

4.1.1 Assessment of rig months

The progress statement on well construction (section 2.4) is related to usage of 14½ rig months. This was assessed as follows :

a) Bomag rig (11 months)

As soon as rehabilitation was completed, the rig was moved to the first site (7 April 1981). The JKR ancillary compressor for use with the rig was not available until 12 April. This compressor was found to be unsuitable and attempts to drill were abandoned pending the availability of an alternative. The arrival of a compressor hired by JKR from the Muda project allowed drilling to proceed on 16 April. This date is taken as the start of the 32 rig months.

In January 1982, as described in section 2.1.2, the rig was under repair for 17 days. The Agreement provides for exclusion of such periods from the 32 rig months. Taking this period as ½ month, 11 months were used by the Bomag rig up to the end of March 1982.

b) Ingersoll-Rand rig (3½ months)

The rig was delivered on 4 December and commissioning was completed on 16 December. This rig was therefore in full use for 3½ months to the end of March.

On the above basis the remaining allocation is 17½ rig months. However, as mentioned earlier in this report, progress has been adversely affected by :

a) having to leave wells incomplete and return the rig later when equipment and materials needed were available. Both rigs were required on well completion work throughout January and for parts of December and February.

b) loss of the A6315 downhole hammer and consequent reduction in drilling rates until a replacement was obtained over 2 months later. Eight days drilling time was also lost in unsuccessful recovery operations.

These causes of delay are not readily quantifiable in terms of drilling time effectively lost but one rig month is believed to be a conservative estimate. Government is therefore requested to approve an extension of one rig month.

4.1.2 Numbers and Distribution of Wells

Assuming Government approval of the requested one rig month extension, the completion of 200 wells averaging 40 metres in depth (total meterage 8000 m) appears feasible. This would require mainland drilling at the rate of 7 wells per month and Langkawi drilling at the rates estimated in the Inception report. During March these rates were achieved.

The anticipated distribution of wells is as follows :

North Kedah	60	
Perlis	50	
Langkawi	38	
Central Kedah	38-42	(estimated requirement)
South Kedah	14-10	(estimated requirement 27-35)
	200	

The estimated requirements for central and south Kedah are based on the number of kampongs to be supplied as advised by JKR. For south Kedah, Baling district is excluded as no kampongs have been specified.

The above total for Langkawi excludes additional wells requested by Y.A.B, Menteri Besar, Kedah to serve the new cement factory, Tanjong Rhu tourist development area and the Langkawi Country Club. Groundwater development potential is poor at all three locations but there are possiblities of obtaining water from alluvial areas within 5 miles of each location. It has been agreed with JKR Kedah that, prior to drilling any wells, preliminary investigation will be carried out by constructing jetted piezometers. Prospects for the cement factory are poor as saline water may be encountered or could be drawn in with time.

4.1.3 Drilling Programme

The order of drilling in the main project areas is as proposed at Inception but timings now vary. On estimated future progress rates, Langkawi drilling would be completed in August. The Bomag rig would then join the Ingersoll-Rand rig in Perlis to complete the 50 wells there in September. Thereafter the two rigs would move to central followed by south Kedah, completing all drilling in January 1983.

This planning may be affected by difficulties on Langkawi. Delays in construction of access roads and hardstandings in the Sungei Melaka basin may mean that the rig has to be withdrawn after drilling all accessible sites and returned at a later date. A further factor is that, at the time of writing, access to sites is proving extremely difficult owing to wet conditions; this also applies to some of the mainland sites.

4.1.4 Other Activities

Efforts will be made to reduce the current backlog of pumping tests so that, in future, tests can be undertaken shortly after the completion of well construction.

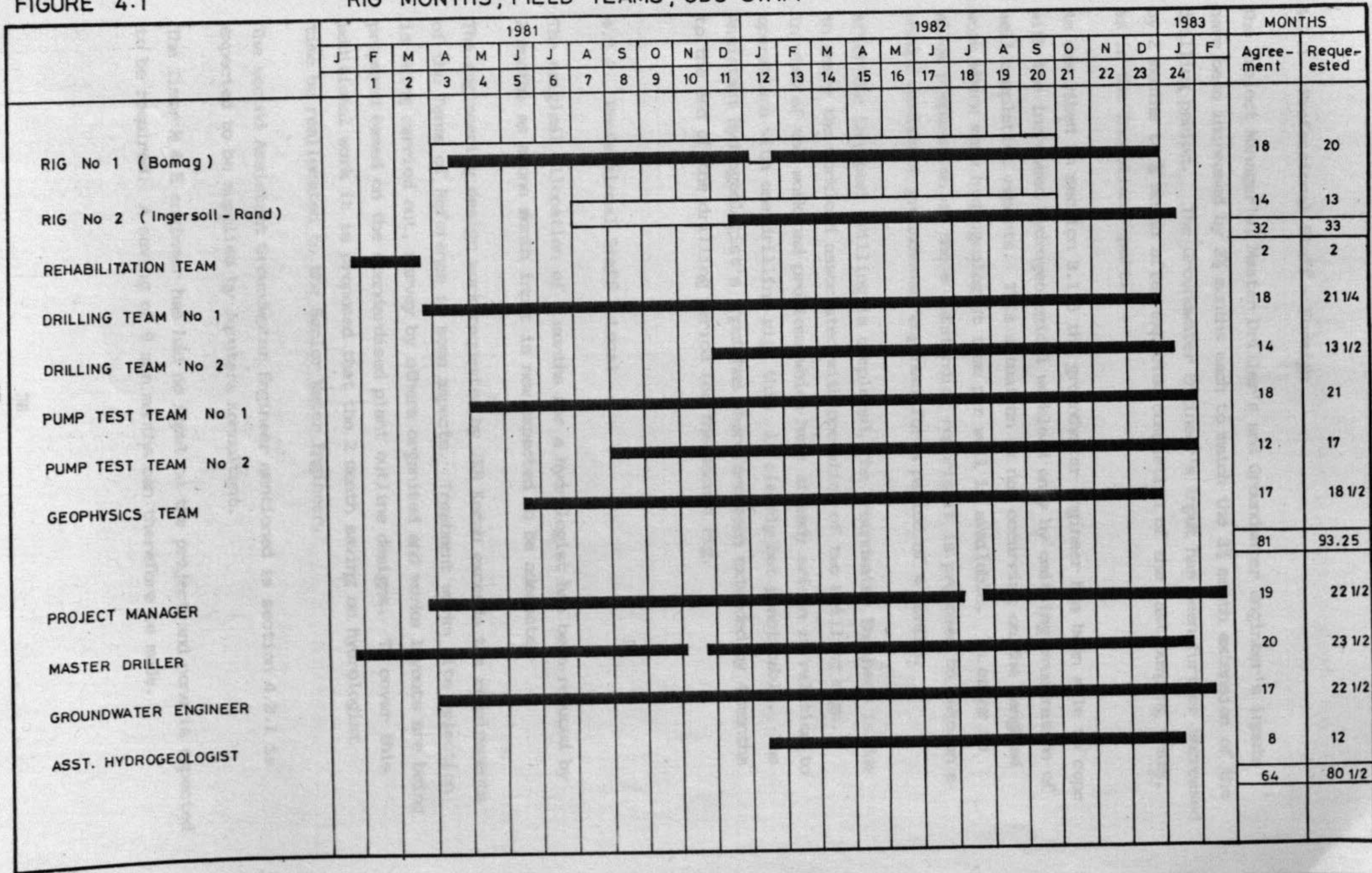
As stated earlier in this report, engineering designs for all the north Kedah wells are planned to be submitted by the end of May. For other areas, survey and design are planned to be undertaken as drilling and testing data become available.

Although it appears possible to complete drilling and testing within the 24 month project period, the completion of engineering designs is likely to require a further month, as will preparation of the final report. The aim is therefore to complete these by the end of February 1983.

4.2 Staff

Figure 4.1 illustrates the anticipated drilling periods for the two rigs compared with the periods given in the Agreement. The period for rig no 1 (Bomag) is shown as ending ½ month before rig no 2 to allow some gradual reduction in levels of activity. The figure also shows the periods for the field teams and main GDC inputs as these are closely related to the drilling period.

FIGURE 4.1 RIG MONTHS, FIELD TEAMS, GDC STAFF



4.2.1 Professional Staff - Foreign

The Project Manager's, Master Driller's and Groundwater Engineer's inputs have been increased by 3½ months each to match the 3½ month extension of the drilling period. The Groundwater Engineer's input has been further increased by 2 months to ½ month after expected completion of the last pumping tests, as in the Inception report.

As described in section 3.1.3 the groundwater engineer has been able to cope with the increased hydrogeological workload only by omitting preparation of well completion reports. This situation is not occurring on the Langkawi work where more hydrogeologist time per well is available. In order to allow preparation of these outstanding reports it is proposed to take on a second assistant groundwater engineer for a period of 4 months.

After the Langkawi drilling is completed, the Groundwater Engineer is due to carry the workload associated with operation of two drilling rigs. In view of the workload problems which have already arisen in relation to operations with one drilling rig, this is clearly not practicable. The Assistant Hydrogeologist's input has therefore been extended by 4 months to the end of the drilling period for the second rig.

4.2.2 Professional Staff - Local

The original allocation of 3 months for a hydrologist has been reduced by 2 months as a one month input is now expected to be adequate.

The engineering design work requested by JKR Kedah exceeds the requirements of the Terms of Reference in some aspects. Treatment works site selection is being carried out, survey by others organised and works layouts are being prepared based on the standardised plant outline designs. To cover this additional work it is proposed that the 2 month saving on hydrologist time be reallocated to the Senior Water Engineer.

The second Assistant Groundwater Engineer mentioned is section 4.2.1 is expected to be supplied by Jurutera Konsultant.

The Timor M & E engineer has had no input on the project and none is expected to be required. A saving of 9 man months can therefore be made.

The net change in the local professional staff schedule is a reduction of 5 man months.

4.2.3 Non-professional Staff

All office staff inputs have been extended to suit the extended drilling period. Details are shown in Figure 4.2.

The drilling team months (Figure 4.1) total 34¾. The excess of 1¾ team months over the total rig months is made up as follows :

a) Drilling team no 1 was set up at the end of the two month rehabilitation period for the Bomag rig in anticipation of immediate commencement of drilling. Delays in receipt of spare parts from Bomag and compressor problems mentioned earlier meant that the drilling period did not start for ¾ rig month. A further ½ rig month is accounted for by Bomag rig repairs in January 1982.

b) Drilling team no 2 was set up at the beginning of December 1981 for rig commissioning. The drilling period started in mid-December (½ rig month).

Pump test team months have been extended to ½ month beyond the end of drilling operations to carry out pumping tests on the last wells drilled. The geophysics team input is extended by 1½ months as resistivity surveys for site selection are expected to continue almost to the end of the drilling period.

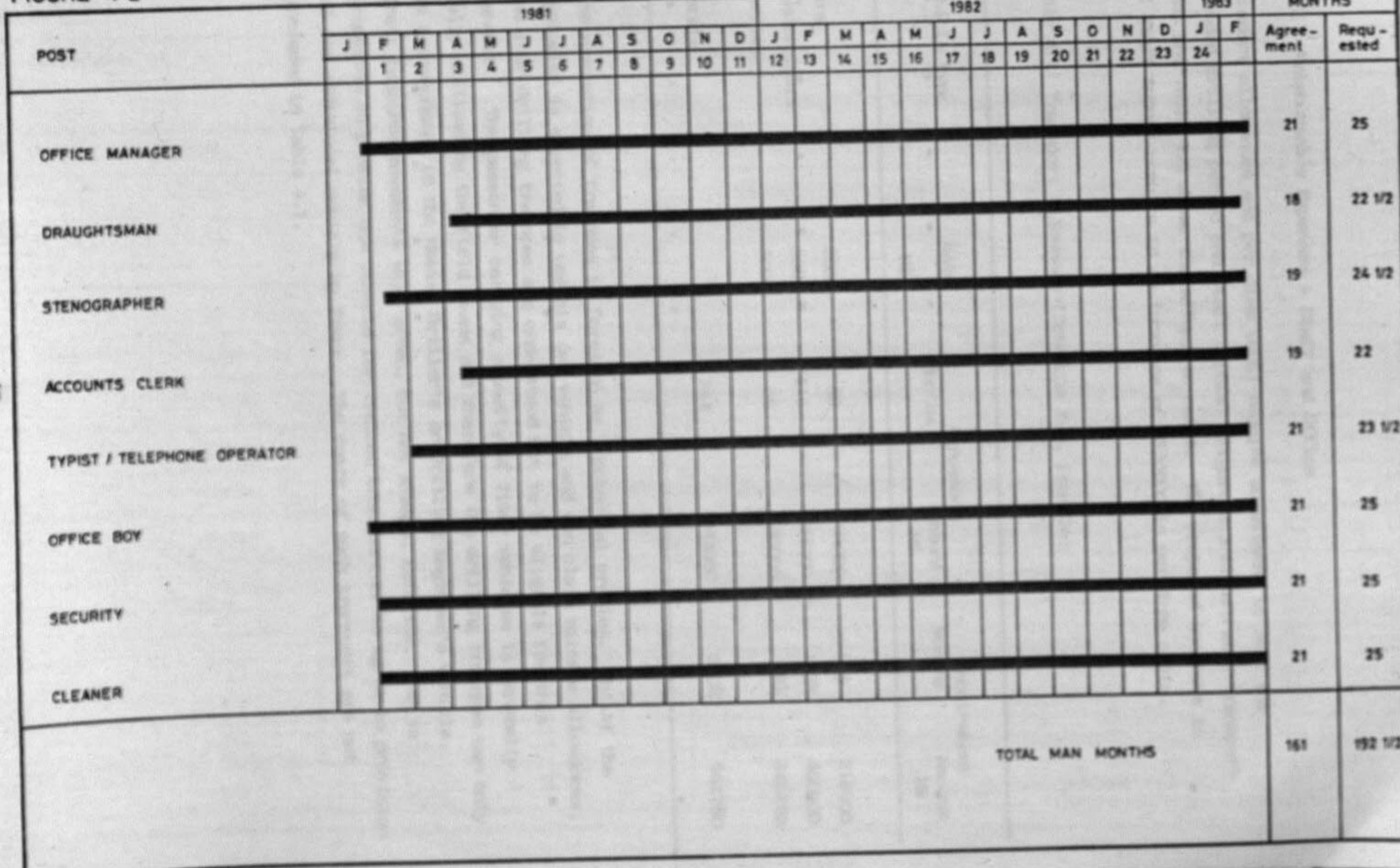
4.3 Costs

4.3.1 Staff Costs

Detailed staff costs are not presented here but totals for Schedules E-2, E-3, E-4 and E-5 are given in the summary of costs (Table 4.4). The totals are calculated from the adjusted inputs given in section 4.2 at the rates stated in the Agreement.

FIGURE 4.2

NON-PROFESSIONAL STAFF - OFFICE



4.3.2 Reimbursable Expenses - Staff and Office

Transport allowances and per diem (GDC) require adjustment to suit the extended drilling period and staff inputs. Figure 4.3 illustrates transport needs and Table 4.1 shows the effect on costs. The proposed increase in GDC staff inputs results in an increase of M$20000 in per diem costs.

Table 4.1 Transport allowance (Schedule E-6, item 2b)

Vehicle type	Rate M$	Agreement Months	Agreement Amount M$	Requirement Months	Requirement Amount M$
Cars	2000	82	164000	108	216000
Landcruisers	3000	116	348000	133½	400500
Lorries	5000	66	330000	69¼	346250
Totals		264	842000	310¾	962750

Transportation of trainees is foreseen as a potential problem. Whilst the geologist is expected to use his own vehicle and can claim mileage allowances, the four drilling trainees are understood not to be eligible for this benefit. The passenger carrying capacity of Timor vehicles is generally fully utilised by the field teams and therefore the drilling trainees can only be accommodated in the Master Driller's or Drilling Engineer's vehicle. Their required movements will often, but not always, coincide. JKR is requested to provide one vehicle for trainee transport or to agree to provision of one additional vehicle by Timor. The costs of such transport are not included in Table 4.1.

FIGURE 4.3 TRANSPORT REQUIREMENTS

VEHICLE		MONTHS Agreement	MONTHS Requested
GDC & JK :	- Car	20	23 1/2
	- Car	19	23 1/4
	- Car	17	22 3/4
	- Car	8	13 1/2
TIMOR :	- Car	18	25
	Totals :	82	108
GDC :	- Landcruiser	19	20
TIMOR :	- Landcruiser	18	21 3/4
	- Pickup	17	21 1/2
	- Pickup	17	20 3/4
	- Pickup	17	18 1/2
	- Pickup	14	17
	- Landrover (2)	14	14
	Totals :	116	133 1/2
TIMOR	- Lorry	18	20 3/4
	- Lorry	18	21
	- Lorry	15	14
	- Lorry	15	13 1/2
	Totals	66	69 1/4

Office electricity and water charges are expected to exceed the amount allocated by about M$9000. However this increase can be offset against the allocation for telephone, telex and radio telephone where savings in excess of M$9000 are expected. Charges against other items are expected to be in line with the original allocations.

The increases in transport and per diem costs amount to M$140750 which can be met from the contingency sum of M$250000 leaving a balance of M$109250.

4.3.3 Reimbursable Expenses - Well Construction

Well construction costs for the 200 wells envisaged are expected to exceed the allocation in Schedule E-7. The main reasons for increased costs may be summarised as follows :

a) under allocation for rig repairs, maintenance, drilling bits, spare parts, Revert and sundry items (items 1, 14 and 27);

b) the need for 8" instead of 6" casing in high yielding wells (items 2, 3, 4);

c) the need for canvas baskets and seals in the well designs (additional item 29).

Details of estimated quantities and costs, together with those given in the Agreement, are presented in Tables 4.2 and 4.3. The percentage increase in Schedule E-7 costs depends upon the exchange rate used in calculation but lies in the range 5-7½%.

4.3.4 Summary of Costs

The summary of costs in Schedule E-1 of the Agreement is reproduced in Table 4.4 together with the adjusted costs now estimated. Local currency costs are increased by $421427 or about 10% of the original total. Foreign currency costs are reduced slightly. The overall increase in cost is 4½-7½% depending upon the exchange rate used in calculation. About one third of this increase is in well construction costs.

Table 4.2 Estimated Reimbursable Expenses - Well Construction - Local Currency (Schedule E-7)

Item	Description	Unit	Rate	Agreement Quantity	Agreement Amount	Estimated (200 wells) Quantity	Estimated (200 wells) Amount	Remarks
1	Rig repairs, maintenance, drilling bits and spares	-	-	-	185000	-	395000	All expenditure in local currency, part budget in foreign currency
2	6" uPVC pipe	lin.ft	15.18	20550	311949	14800	224664	
	8" uPVC pipe	"	16.92	-	-	5500	93060	Rate approved by JKR
	10" uPVC pipe	"	28.00	-	-	200	5600	Formal approval of rate awaited
	12" uPVC pipe	"	39.03	-	-	200	7806	Formal approval of rate awaited
	Item 2 totals :			20550	311949	20700	331130	
3	6" double end sockets	no	18.98	1250	23725	970	18411	
	8" double end sockets	"	77.55	-	-	155	12020	Rate approved by JKR
	8" to 6" reducer	"	122.20	-	-	30	3666	Formal approval of rate awaited
	10" double end sockets	"	147.88	-	-	10	1479	Formal approval of rate awaited
	12" double end sockets	"	155.10	-	-	10	1551	Formal approval of rate awaited
	Flush joint for 6" pipe	"	29.38	-	-	230	6757	Formal approval of rate awaited
	Flush joint for 8" pipe	"	35.25	-	-	310	10928	Formal approval of rate awaited
	Item 3 totals :			1250	23725	1715	54812	
4	6" top and bottom caps	well	120.75	250	30188	-	-	
	6" steel top cap	no	120.75/2	-	-	140	8453	
	6" bottom cap	"	120.75/2	-	-	60	3623	
	8" steel top cap	"	88.12	-	-	60	5287	Formal approval of rate awaited
	8" bottom cap	"	88.12	-	-	20	1762	Rate approved by JKR
	10" steel top cap	"	117.50	-	-	12	1410	Formal approval of rate awaited
	12" steel top cap	"	146.88	-	-	6	881	Formal approval of rate awaited
	Item 4 totals :			250	30188	298	21416	
	Amounts carried forward :				550862		802358	

Table 4.2 Estimated Reimbursable Expenses - Well Construction - Local Currency (Schedule E-7) (continued)

Item	Description	Unit	Rate	Agreement Quantity	Agreement Amount	Estimated (200 wells) Quantity	Estimated (200 wells) Amount	Remarks
	Brought forward				550862		802358	
5	Locking device	well	52.33	250	13083	200	10466	
6	6" uPVC slotted pipe	lin.ft	29.17	6500	189605	2300	67091	
	8" uPVC slotted pipe	"	27.49	-	-	1050	28865	Rate approved by JKR
	Slotting of 6" uPVC pipe by Syk. Timor	"	13.99	-	-	3400	47566	Pipe cost included under item 2
	Slotting of 8" uPVC pipe by Syk. Timor	"	10.57	-	-	1200	12684	Pipe cost included under item 2
	Item 6 totals :			6500	189605	7950	156206	
7	6" stainless steel screen	lin.ft	138.57	1000	138570	1050	145499	
8	Ditto, female socket	no	255.30	50	12765	6	1532	
9	Ditto, male socket	no	220.80	50	11040	6	1325	
10	Cement etc for seal, plinth	well	70.00	250	17500	200	14000	
11	Sand	cu.yd	18.80	1500	28200	500	9400	
12	Laterite	cu.yd	7.52	4000	30080	1000	7520	
13	Gravel packing	lin.ft	8.50	2000	17000	2000	17000	Assumes none required for Langkawi alluvial wells
14	Revert	bag	166.75	50	8338	215	35851	Additional requirement notified in Inception report
	Carried forward				1017043		1201157	

Table 4.2 Estimated Reimbursable Expenses - Well Construction - Local Currency (Schedule E-7) (continued)

Item	Description	Unit	Rate	Agreement		Estimated (200 wells)		Remarks
				Quantity	Amount	Quantity	Amount	
	Brought forward				1017043		1201157	
15	Pumping tests	hrs	9.36	8000	74880	5000	46800	
16	Fuel and lubricants	-	-	-	30000	-	30000	
17	Repairs, spares for Government plant	-	-	-	30000	-	30000	
18	Water analysis	well	200	250	50000	200	33000	Assumes average cost $165/well
20	Borehole geophysical equipment	-	-	-	-	-	67000	Budget in foreign currency
23	Survey equipment	-	-	-	-	-	2000	Budget in foreign currency
25	Jetted piezometers	no	3000	15	45000	19	55000	
26	Langkawi shipment	-	-	-	30000	-	30000	
27	Sundry items	-	-	-	15000	-	100000	Need for increased budget notified in Inception report
28	Insurance	-	-	-	30000	-	30000	
29a	Canvas baskets and seals, type 1	-	88.13	-	-	150	13220	Formal approval of rate awaited
29b	Canvas baskets and seals, type 2	-	104.58	-	-	150	15687	Formal approval of rate awaited
	Totals				1321923		1653864	

Table 4.3 Estimated Reimbursable Expenses - Well Construction - Foreign Currency (Schedule E-7)

Item	Description	Agreement		Estimated (200 wells)		Remarks
		Quantity	Amount	Quantity	Amount	
1	Rig repairs, maintenance, drilling bits and spares	-	36000	-	-	All expenditure in local currency
19	Surface geophysical equipment	-	8000	-	8500	
20	Borehole geophysical equipment	-	14000	-	-	All expenditure in local currency
21	Portable chemical testing equipment	-	1500	-	1500	
22	Dipmeters	-	500	-	500	
23	Survey equipment	-	1000	-	500	
24	Bacteriological testing equipment	-	500	-	-	
	Totals		61500		11000	

Table 4.4 Summary of Costs

Item	Agreement M$	Agreement £	Estimated Costs M$	Estimated Costs £
STAFF COSTS				
E-2 Professional Staff (GDC)		211 986		259 672
E-3 Professional Staff				
(JK)	312 955		326 295	
(Timor)	45 540		-	
Non-professional Staff :				
E-4 Office	132 230		159 030	
E-5 Field	736 370		831 256	
Sub-totals	1227 095	211 986	1316 581	259 672
ESTIMATED REIMBURSABLE EXPENSES				
E-6 Staff and Office	1666 815	35 644	1666 815	35 644
E-7 Well Construction	1321 923	61 500	1653 864	11 000
Sub-totals	2988 738	97 144		46 644
TOTALS :	4215 833	309 130	4637 260	306 316

APPENDIX A

SUMMARY OF DRILLED WELL DATA

Table A.1 - Summary of Drilled Well Data

Well Number	Kampong/District	Total Depth (1) (m)	uPVC Casing diameter (in)	Apparent Yield (2) (gpm)	Recommended Yield (3) (gpm)	Formation (4)	Work Outstanding (5)
KEDAH Area KU/1							
GS 700	Kepala Bukit/Pendang	61.5	6	1	0	Shale (C)	-
GS 701	Kubor Panjang/Pendang	30.5	6	40	42	Sandstone (T)	-
GS 702	Kubor Panjang/Pendang	42.1	6	11	15	Sandstone (T)	-
GS 703	Kubor Panjang/Pendang	30.1	6	73	45	Sandstone (T)	-
GS 704	Kepala Bukit/Pendang	34.5	6	93	26	Sandstone (C)	-
Area KU/2							
GS 705	Kg. Sari/Padang Terap	39.0	6	73	23	Sandstone (T)	-
GS 706	Pdg. Terap/Padang Terap	31.0	8	105	23	Sandstone (T)	-
GS 707	Tanjong/Padang Terap	26.9	6	73		Sandstone (T)	3,4
Area KU/3							
GS 708	Palas/Kubang Pasu	40.2	6	27	17	Sandstone (C)	-
GS 709	Malau/Kubang Pasu	29.9	6	27	29	Shale (C)	-
GS 710	Tanjong/Kubang Pasu	35.0	6	7	Hand	Sandstone/Shale (C)	-
GS 711	Natoi/Kubang Pasu	23.8	6	3	Hand	Shale/Sandstone (C)	-
GS 712	Lubok Batu/Kubang Pasu	33.9	6	62	57	Sandstone (C)	3
GS 713	Salit/Kubang Pasu	29.9	6	2	Hand	Shale (C)	-
Area KU/4							
GS 714	Lubok Batu/Kubang Pasu	60.6	8	190	272	Sandstone (C)	-
GS 715	Kelubi Dalam/Kubang Pasu	60.5	6	105	117	Sandstone (C)	3, 6

Table A.1 - Summary of Drilled Well Data (continued)

Well Number	Kampong/District	Total Depth (1) (m)	uPVC Casing diameter	Apparent Yield (2) (gpm)	Recommended Yield (3) (gpm)	Formation (4)		Work Outstanding (5)
KEDAH Area KU/5								
GS 716	Pokok Sena/Kota Setar	29.3	6	12	Hand	Shale	(C)	-
GS 717	Pokok Sena/Kota Setar	59.3	6	0	0	Shale	(C)	-
GS 718	Panchor/Kota Setar	59.5	6	25		Sandstone/Shale	(C)	3,4,5
GS 719	Kedondong/Kota Setar	50.3	6	10	Hand	Sandstone	(C)	-
GS 720	Gajah Mati/Kota Setar	32.6	6	42	25	Sandstone	(C)	-
GS 721	Pokok Sena/Kota Setar	30.9	6	20	Hand	Shales/Siltstone/Cherts	(C)	-
Area KU/11								
GS 722	Bukit Lada/Kota Setar	30.8	6	1	0	Sandstone	(C)	-
GS 723	Bukit/Padang Terap	56.5	8	140		Sandstone/Shale	(T)	-
GS 723A	Bukit/Padang Terap	50.0	6	135		Sandstone/Shale	(T)	3,4
GS 724	Kubang Kenyeng/Padang Terap	41.7	8	240		Sandstone/Shale	(T)	4
Area KU/15								
GS 725	Lamdin/Padang Terap	51.8	6	110		Sandstone/Shale	(T)	4
GS 726	Pong Selatan/Padang Terap	49.8	6	15	Hand	Sandstone/Silt-stone	(T)	-
GS 727	Lebai Saman/Padang Terap	39.6	8	305		Siltstone/Shale	(T)	4,5
GS 728	Datok/Padang Terap	39.5	6	140		Siltstone/Shale	(T)	4,5
Area KU/13								
GS 729	Musa-K.Tekai/Padang Terap	50.7	8	200		Sandstone/Shale	(T)	4
GS 730	Musa/Padang Terap	51.4	6	7	Hand	Sandstone/Shale	(T)	-
GS 731	Tong Pelu/Padang Terap	42.9	8	195		Sandstone/Shale	(T)	4,5
GS 732	Banggol Pong/Padang Terap	40.0	8	30	33	Sandstone/Shale	(T)	-

Table A.1 - Summary of Drilled Well Data (continued)

Well Number	Kampong/District	Total Depth (1) (m)	uPVC Casing diameter (in)	Apparent Yield (2) (gpm)	Recommended Yield (3) (gpm)	Formation (4)		Work Outstanding (5)
KEDAH Area KU/8								
GS 733	Naka/Padang Terap	39.5	6	34	30	Siltstone/ Sandstone	(T)	-
GS 734	Bt. Tampoi/Padang Terap	48.9	6	44	26	Siltstone/Shales/ Sandstone	(T)	-
GS 735	Nai Teh/Padang Terap	48.9	8	230	96	Sandstone	(T)	-
GS 736	Bt. Tembaga/Padang Terap	36.9	6	50	39	Cherts	(T)	-
Area KU/14								
GS 737	Nangka/Pendang	39.8	6	25	14	Sandstone	(C)	-
GS 738	Pokok Asam/Pendang	50.6	6	50	100	Shales/Sandstone	(C)	-
GS 739	Pdg. Durian/Pendang	50.2	8	135	Hand	Siltstone/Shale/ Sandstone	(T)	-
GS 740	Titi Akar/Pendang	45.6	6	20	Hand	Silicified Shale	(T)	-
GS 741	China/Pendang	39.9	6	60	26	Siltstone/Shale/ Sandstone	(T)	-
Area KU/10								
GS 742	Pdg. Pusing/Pendang	35.7	6	7	11	Sandstone/Shale	(C)	-
Area KU/17								
GS 743	Bukit Jambul/Pendang	44.5	6	43	46	Meta-shale	(S)	-
GS 744	Bukit Jambul/Pendang	50.4	6	93	153	Meta-shale/ sandstone	(S)	-
GS 745	Bukit Jambul/Pendang	48.7	8	600	270	Meta-sandstone/ shale	(S)	-
GS 746	Bukit Jambul/Pendang	51.0	8	350	270	Meta-shale/ sandstone	(S)	-
GS 747	Bukit Jambil/Pendang	47.6	8	300	270	Meta-shale/ sandstone	(S)	-
GS 748	Pokok Tai/Pendang	35.6	6	170	159	Meta-sandstone/ shale	(S)	-
GS 749	Pokok Tai/Pendang	42.9	6	95	84	Meta-sandstone/ shale	(S)	-

Table A.1 - Summary of Drilled Well Data (continued)

Well Number	Kampong/District	Total Depth (1) (m)	uPVC Casing diameter (in)	Apparent Yield (2) (gpm)	Recommended Yield (2) (gpm)	Formation (4)		Work Outstanding (5)
KEDAH Area KU/10								
GS 750	Paya Mengkuang/Pendang	44.7	6	7	Hand	Shale	(C)	-
GS 751	Paya Mak Isun/Pendang	29.6	-	0	0	Shale	(C)	-
Area KU/9								
GS 752	Acheh/Yen	42.0	-	1	0	Colluvium	(R)	-
Area KU/12								
GS 753	Rumput Minyak/Kubang Pasu	38.8	6	42	11	Shale/Sandstone	(C)	-
GS 754	Tunjang Quarry/Kubang Pasu	51.0	6	42		Shale/Sandstone	(C)	3,4
GS 755	Tunjang Quarry/Kubang Pasu	51.6	-	0	0	Shale/Sandstone	(C)	-
Area KU/6								
GS 756	Kodiang/Kubang Pasu	97.9	-	5	0	Limestone	(P)	-
GS 757	Kodiang/Kubang Pasu	40.2	6	30	11	Sandstone	(T)	-
Area KU/7								
GS 758	Masjid/Kubang Pasu	39.1	-	0	0	Siltstone	(C)	-
PERLIS Area A1/11C								
GS 759	Tambun Tulang/Mukim Arau	39.7	-	100	0	Limestone	(P)	-
Area A1/11A								
GS 760	Behor/Mukim Arau	43.4	8	250	0	Shale/Limestone	(P)	-

Table A.1 - Summary of Drilled Well Data (continued)

Well Number	Kampong/District	Total Depth (1) (m)	uPVC Casing diameter (in)	Apparent Yield (2) (gpm)	Recommended Yield (3) (gpm)	Formation (4)		Work Outstanding (5)
PERLIS								
Area A1/11D								
GS 761	Arau/Mukim Arau	38.10	8	500		Limestone	(P)	3,4,6
GS 762	Arau/Mukim Arau	49.2	8	100		Limestone	(P)	3,4,6
GS 763	Arau/Mukim Arau	42.0	8	135		Limestone	(P)	3,4,6
LANGKAWI								
GS 800	Kisap	29.5	-	0	0	Clay/Colluvium	(R)	7
GS 801	Kisap	33.0	-	0	0	Clay/Colluvium	(R)	7
GS 802	Kisap	42.4	-	0	0	Clay/Siltstone	(R)	-
GS 803	Belanga Pechah	30.9	6	5		Siltstone/Shale	(C)	4,5,6
GS 804	Kisap	36.6	6	5		Siltstone/Shale	(C)	4,5,6
GS 805	Kisap	8.5	-	0	0	Clay/Boulders	(R)	7
GS 806	Dendang	38.1	6	5		Sandstone/Shale	(C)	4,5,6
GS 807	Kelibang	33.3	6	15		Shale	(C)	4,5,6
GS 808	Kelibang	37.2	6	20		Siltstone	(C)	4,5,6
GS 809	Kisap	36.4	6	30		Siltstone/Shale	(C)	4,5,6
GS 810	Bayas	39.8	-	0	0	Shale	(C)	-
GS 811	Kelibang	30.7	-	0	0	Siltstone/Shale	(C)	-

Notes

1. Total meterage = 3216
   No of wells = 77
   Average well depth = 42 m

2. Yield observed during drilling and development of well.
   Average = 79 gpm

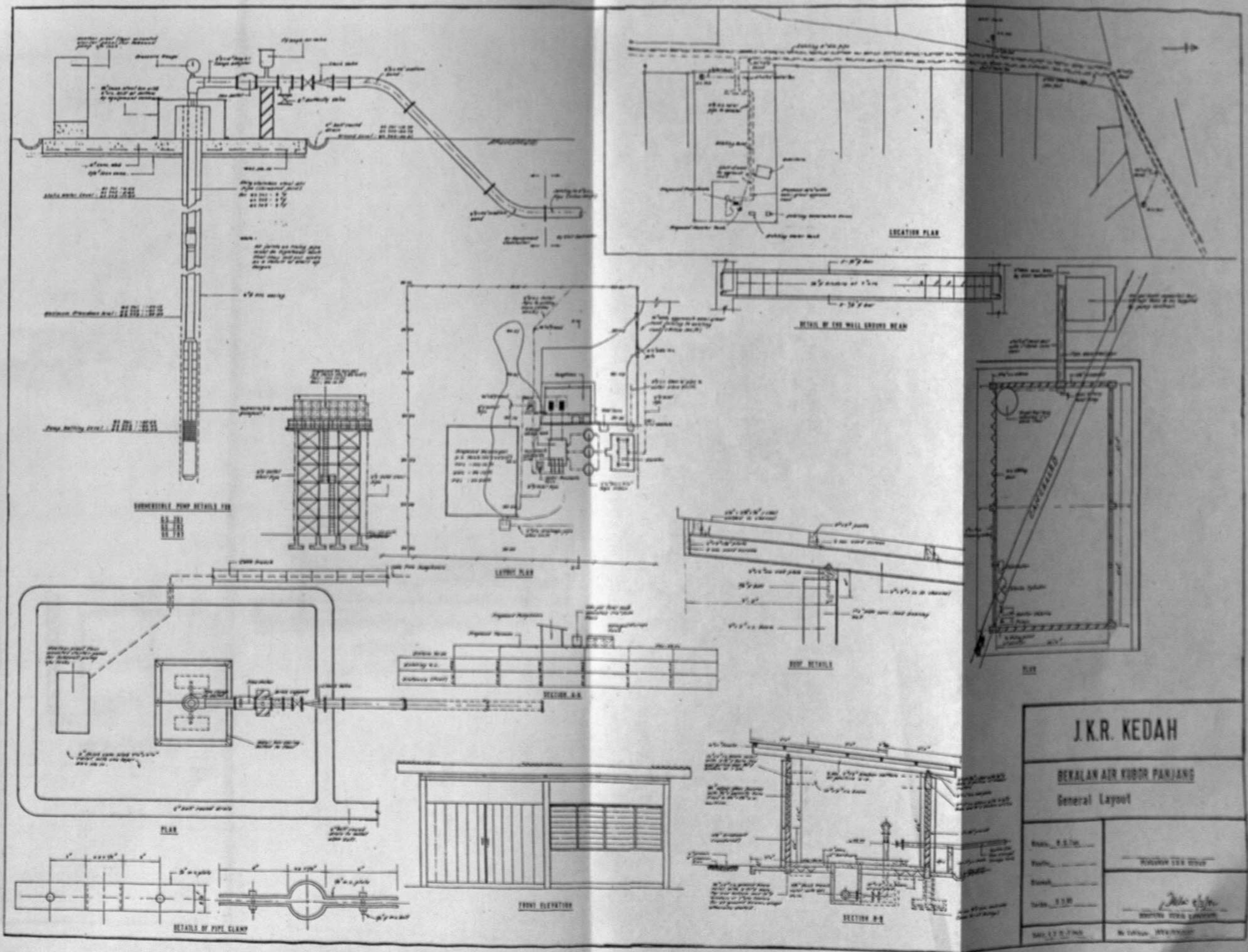
3. Recommended maximum well yield for pumping 16 hours/day
   (Hand = hand pump i.e. $\leqslant$ 5 gpm)

4. R - Recent
   P - Permo-Triassic
   T - Triassic
   C - Carboniferous
   S - Silurian
   O - Ordovician

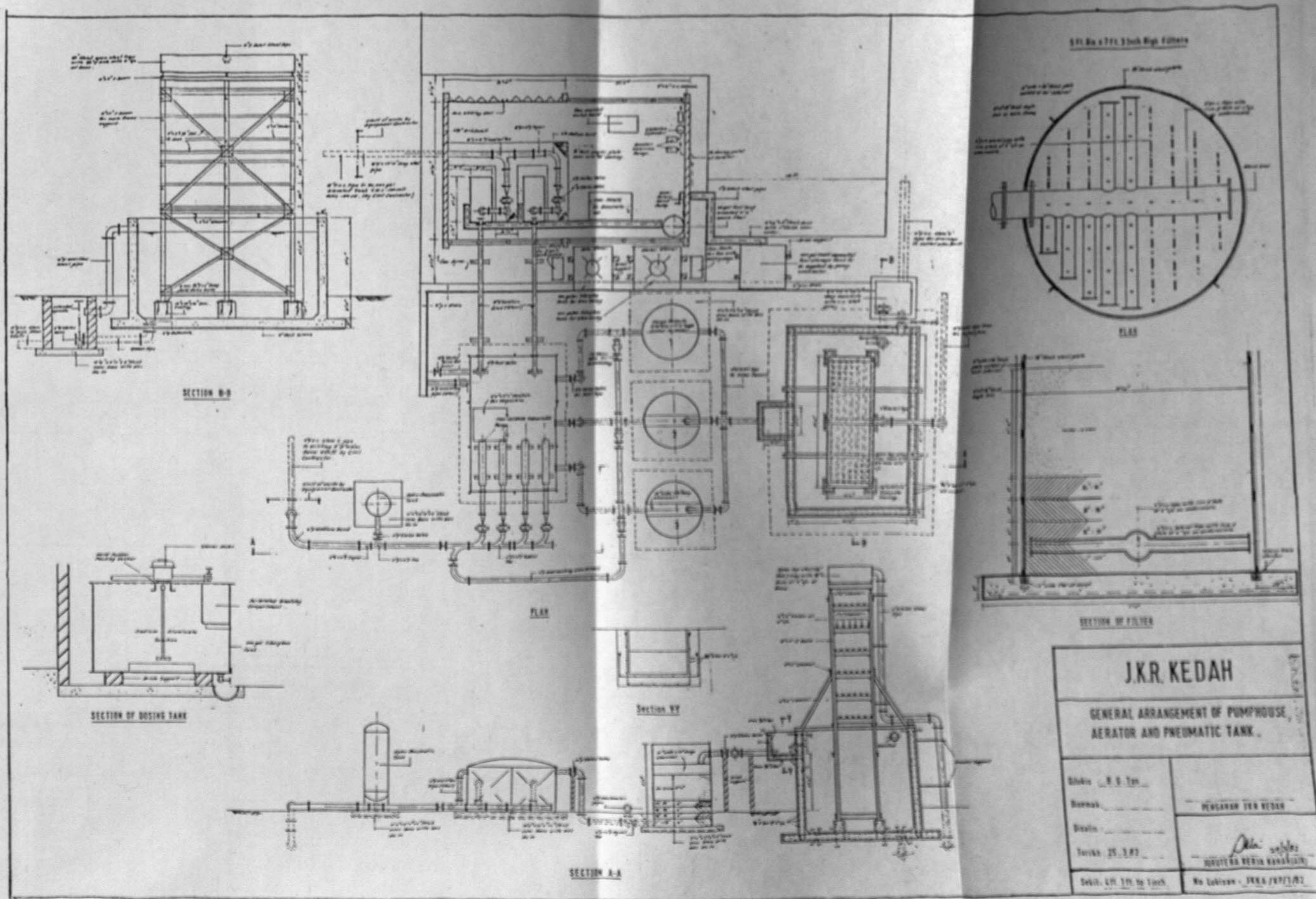
5. Work outstanding
   1 - Reaming out to larger diameter
   2 - Installation of casing/screen string
   3 - Developing
   4 - Pumping Test
   5 - Geophysical logging
   6 - Seal and concrete plinth
   7 - Results inconclusive, further drilling under consideration

APPENDIX B

JKR TENDER DRAWINGS FOR 3 WELL GROUP AT KG KUBOR PANJANG



SUBMERSIBLE PUMP DETAILS FOR
LAYOUT PLAN
LOCATION PLAN
DETAIL OF END WALL GROUND BEAM
ROOF DETAILS
PLAN
SECTION A-A
FRONT ELEVATION
DETAILS OF PIPE CLAMP
SECTION B-B
J.K.R. KEDAH
BEKALAN AIR KUBOR PANJANG
General Layout


SECTION B-B
PLAN
SECTION OF FILTER
SECTION OF DOSING TANK
Section YY
SECTION A-A
J.K.R. KEDAH
GENERAL ARRANGEMENT OF PUMPHOUSE, AERATOR AND PNEUMATIC TANK.
PENGARAH JKR KEDAH
Tarikh: 25.3.82

APPENDIX C

SAMPLE WELL COMPLETION REPORT

MINISTRY OF WORKS AND PUBLIC UTILITIES
GOVERNMENT OF MALAYSIA

DEVELOPMENT OF PRODUCTION WELLS IN KEDAH AND PERLIS

COMPLETION REPORT FOR WELL GS 702

GROUNDWATER DEVELOPMENT CONSULTANTS (INTERNATIONAL) LTD.
Cambridge, England
in association with JURUTERA KONSULTANT (S.E.A) SDN BHD
Kuala Lumpur

Drilling and backup services :
SYARIKAT TIMOR (INLAND DEEPWELLING) SDN BHD
Alor Setar

COMPLETION REPORT FOR WELL GS 702 (KU/1/3)

1. GENERAL

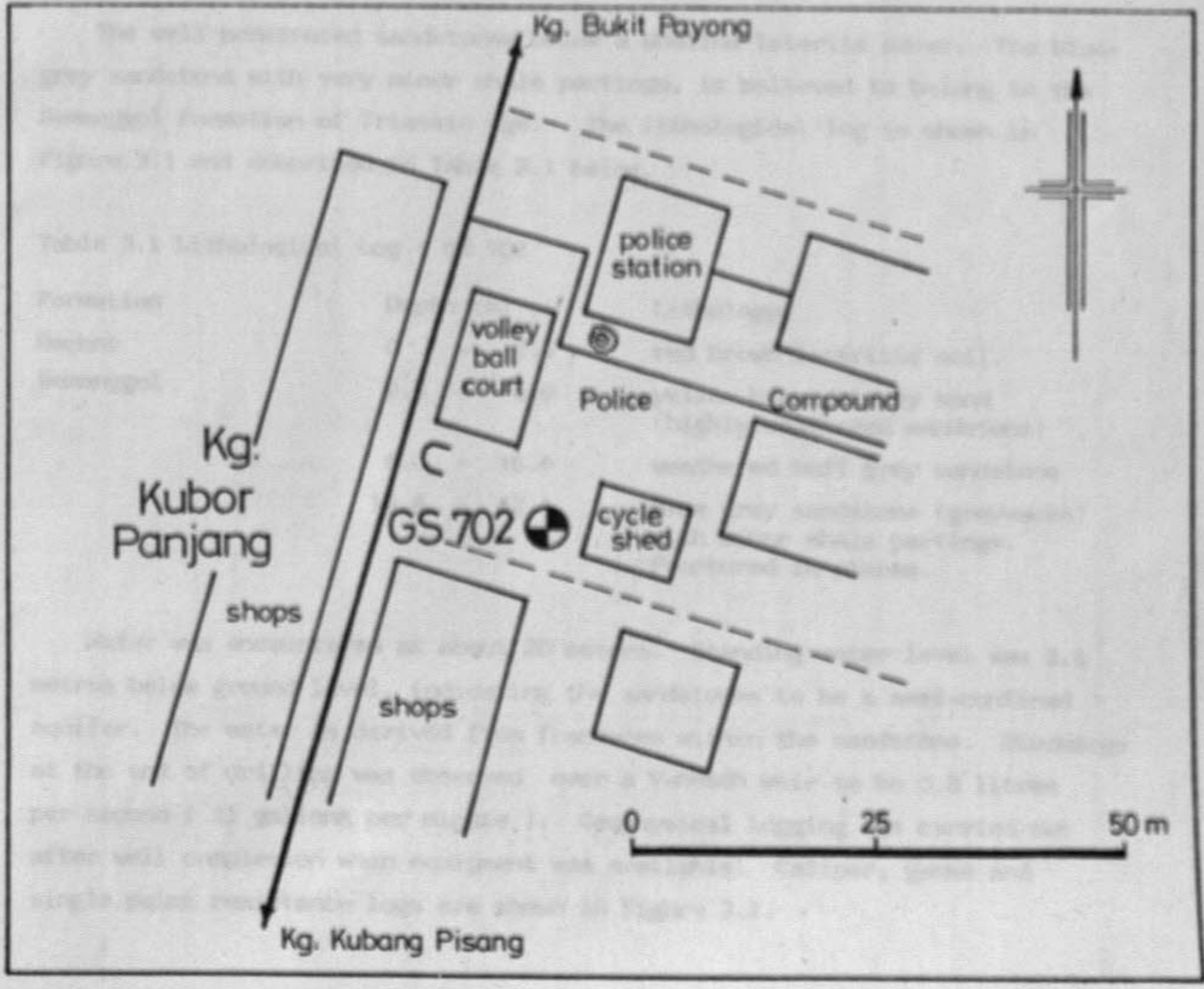
Location	State	:	Kedah
	District	:	Pendang
	Mukim	:	Rambai
	Kampong	:	Kubor Panjang
	Map Sheet	:	Sungai Petani, 16 (1:63,360 scale)
	Airphoto	:	125, F241 L26N (1:25,000 scale, 1974/75)
Coordinates	MRSO	:	28560 E, 67381 N
	Geographic	:	100°33'17" E, 6°05' 16" N
Elevations	Ground surface	:	8.78m
	Top of Plinth	:	9.47m
	Top of casing	:	9.21m

Drilling period : 29th April to 4th May, 1981

Total depth : 42.1m

Water producing formation : Semanggol (Triassic) sandstone

Figure 1.1 LOCATION PLAN



2. CONSTRUCTION

The borehole was drilled at 5⅞ inch diameter to 35.95 metres by the rotary air-flush method. The top 20.80 metres was then reamed out, by the same method to 7⅞ inch diameter. Blank 6 inch class E uPVC casing was installed to 20.80 metres. A 7-9/16 inch O.D. socket was fitted to the bottom of the casing to act as a seal between the 7⅞ and 5⅞ inch holes. Drilling at 5⅞ inch was continued through the casing to a depth of 42.07 m.

Slow drilling progress was due to inadequate air capacity as well as formation hardness. Increase in penetration rate at the bottom of the hole is solely a reflection of increased air capacity when two compressors were utilised. The well was cleaned by air-lift development and completed with a 0.6 m square x 0.45 m deep concrete plinth set to 0.13 metres below ground level, and a numbered lockable steel cap. There is no cement seal in borehole casing annulus. Final well construction is shown in Figure 3.1.

3. HYDROGEOLOGY

The well penetrated sandstones below a shallow laterite cover. The blue-grey sandstone with very minor shale partings, is believed to belong to the Semanggol formation of Triassic age. The lithological log is shown in Figure 3.1 and described in Table 3.1 below.

Table 3.1 Lithological Log : GS 702

Formation	Depth (m)	Lithology
Recent	0 - 2.5	red brown lateritic soil.
Semanggol	2.5 - 6.0	yellow brown clayey sand (highly weathered sandstone)
	6.0 - 16.6	weathered buff grey sandstone
	16.6 - 42.1	blue grey sandstone (greywacke) with minor shale partings. Fractured in places.

Water was encountered at about 20 metres. Standing water level was 2.6 metres below ground level, indicating the sandstones to be a semi-confined aquifer. The water is derived from fractures within the sandstone. Discharge at the end of drilling was observed over a V-notch weir to be 0.8 litres per second (11 gallons per minute). Geophysical logging was carried out after well completion when equipment was available. Caliper, gamma and single point resistance logs are shown in Figure 3.2.

FIGURE 3-1 COMPOSITE WELL LOG - GS 702

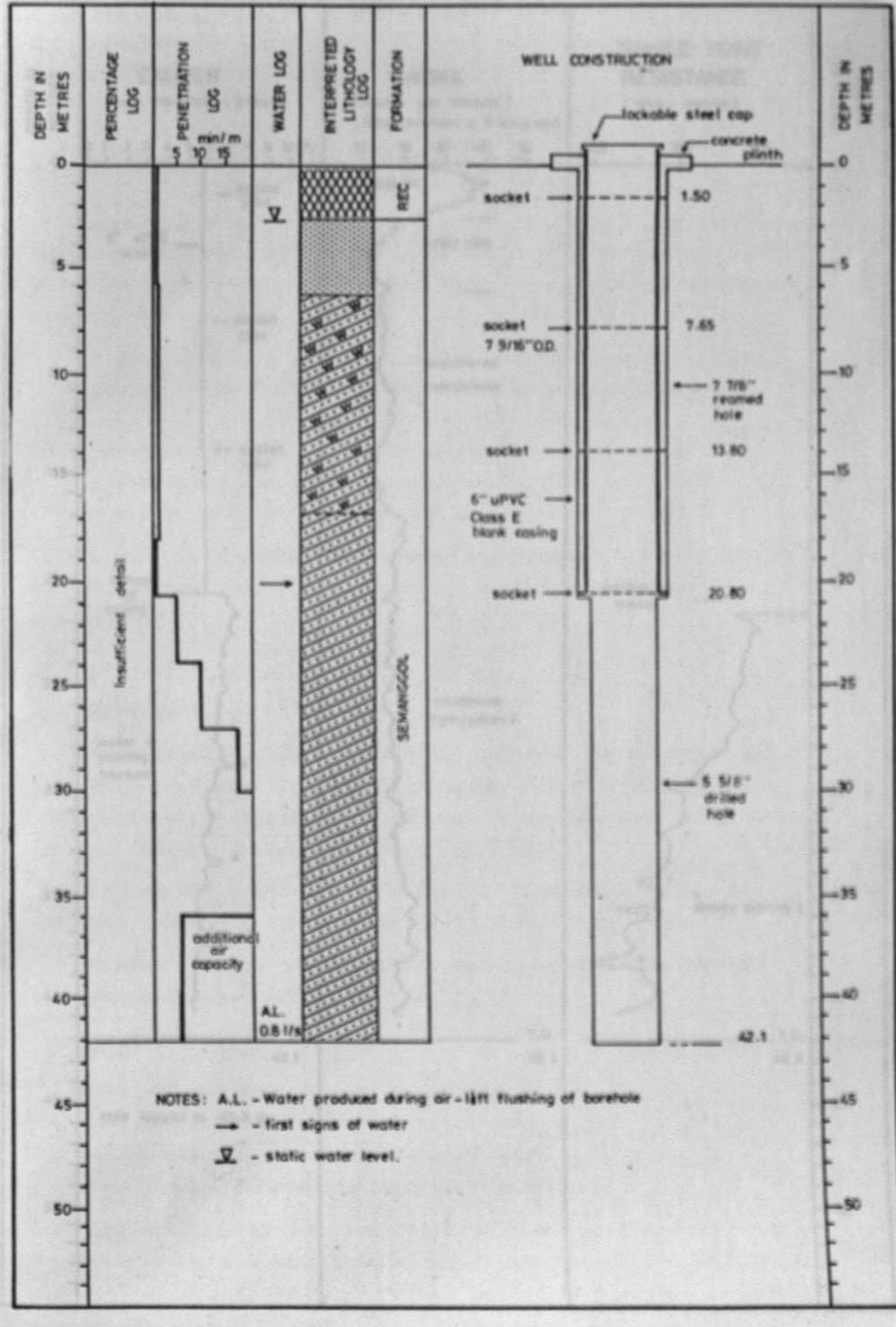
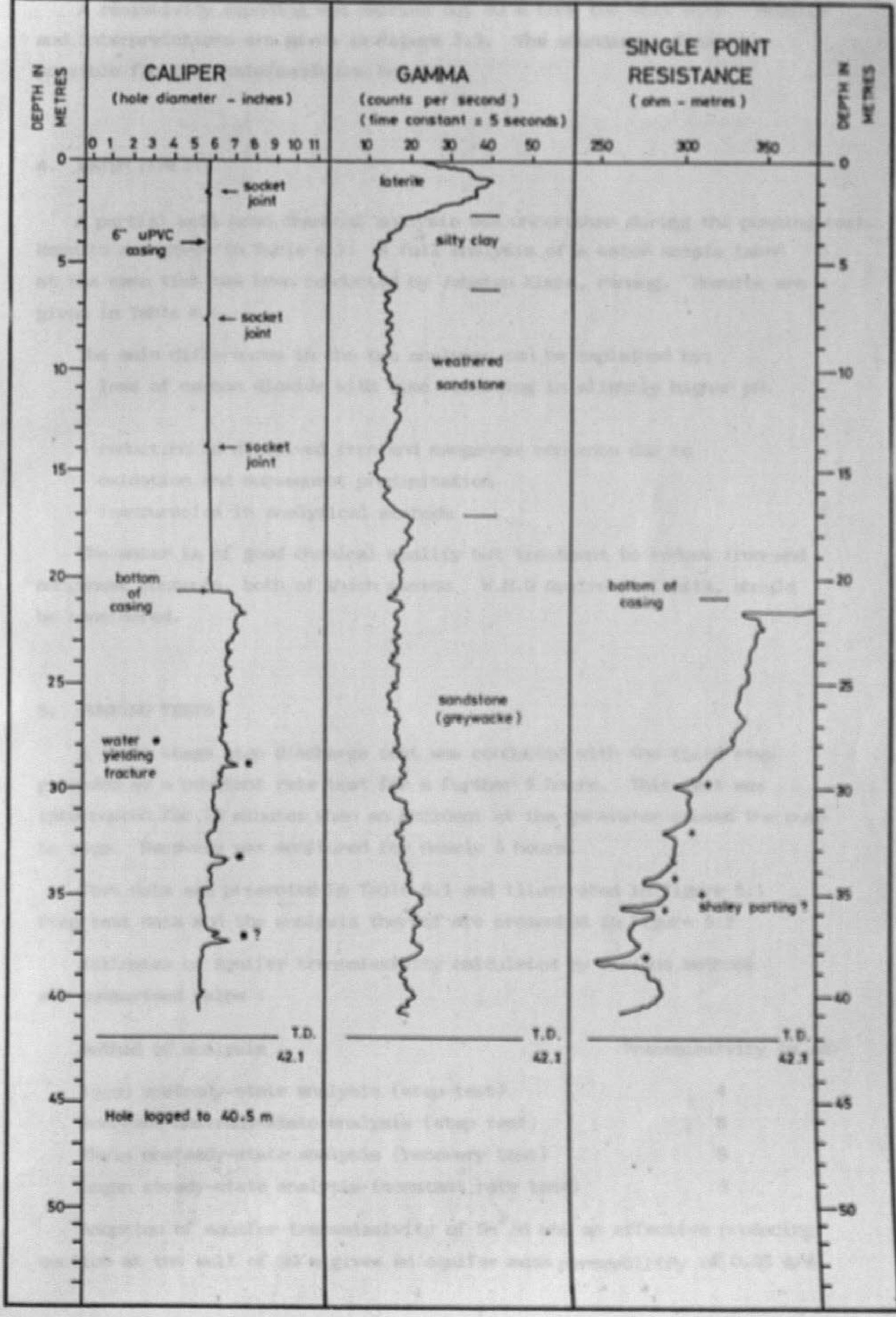


FIGURE 3·2 GEOPHYSICAL LOGS - GS 702



A resistivity sounding was carried out 50 m from the well site. Results and interpretations are given in Figure 3.3. The sounding indicated a possible faulted shale/sandstone boundary.

4. WATER QUALITY

A partial well head chemical analysis was undertaken during the pumping test. Results are given in Table 4.1. A full analysis of a water sample taken at the same time has been conducted by Jabatan Kimia, Penang. Results are given in Table 4.1.

The main differences in the two analyses can be explained by:

- loss of carbon dioxide with time resulting in slightly higher pH.
- reduction in dissolved iron and manganese contents due to oxidation and subsequent precipitation
- inaccuracies in analytical methods

The water is of good chemical quality but treatment to reduce iron and manganese contents, both of which exceed W.H.O desirable limits, should be considered.

5. PUMPING TESTS

A three stage step discharge test was conducted with the third step extended as a constant rate test for a further 5 hours. This test was interrupted for 20 minutes when an accident at the generator caused the pump to stop. Recovery was monitored for nearly 5 hours.

Test data are presented in Table 5.1 and illustrated in Figure 5.1 Step test data and the analysis thereof are presented in Figure 5.2

Estimates of aquifer transmissivity calculated by various methods are summarised below :

Method of analysis	Transmissivity (m^2/d)
Jacob unsteady-state analysis (step test)	4
Brereton unsteady-state analysis (step test)	5
Theis unsteady-state analysis (recovery test)	5
Logan steady-state analysis (constant rate test)	5

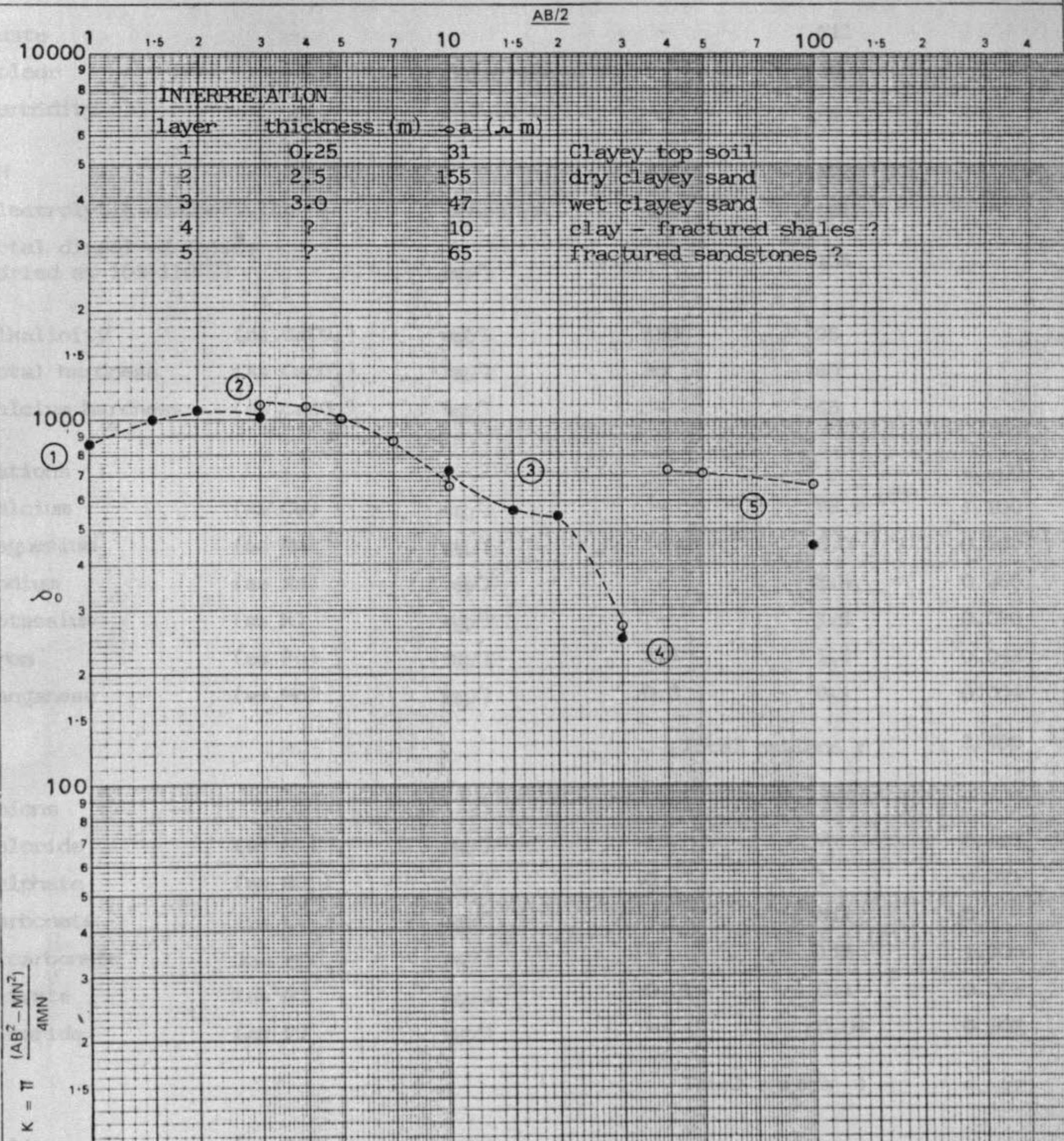
Adoption of aquifer transmissivity of $5m^2/d$ and an effective producing section at the well of 20 m gives an aquifer mass permeability of 0.25 m/d.

FIGURE 3.3 ELECTRICAL SOUNDING NO: ESK 15

Location: Kubor Panjang - near Police Station Date: 6.7.81

Centre point: 50 m from borehole GS 702 on bearing 342°

Alignment: 186° Equipment: Abem Terrameter SAS Electrode configuration: Schlumberger Operator:



MN/2	AB/2	R ohms	K	ρ0 (K x R)
0.25	1	14.85	5.9	88
0.25	1.5	7.44	13.7	102
0.25	2	4.36	24.7	108
0.25	3	1.863	56.2	105
0.75	3	6.51	17.7	115
0.75	4	3.50	32.3	113
0.75	5	2.09	51.2	107
0.75	7	0.871	101.4	88
0.75	10	0.319	208.3	66
2.5	10	1.215	58.9	72
2.5	15	0.416	137.4	57
2.5	20	0.215	247.4	53
2.5	30	0.0442	561.6	25
7.5	30	0.152	176.7	27
7.5	40	0.223	323.3	72
7.5	50	0.1362	511.8	70
7.5	70		1014	
7.5	100	0.0312	2083	65
25	100	0.0755	589.0	44
25	150		1374	
25	200		2474	
25	300		5616	
75	300		1767	
75	400		3233	
75	500		5118	

Table 4.1. Chemical Analyses of Water from GS 702

			Well head (1)	Laboratory (2)	
Taste			-	Nil	
Colour		Hazen units	-	10	
Turbidity		F.T.U.	-	< 5	
pH			6.0	6.2	
Electrolytic conductivity		umhos/cm	195	185	
Total dissolved solids (dried at 105-110^{o}C)		mg/l	-	105	
Alkalinity	(as $CaCO_3$)	mg/l	130	95	
Total hardness	(as $CaCO_3$)	mg/l	80	80	
Calcium hardness	(as $CaCO_3$)	mg/l	-	55	
Cations :					meq/l
Calcium	(as Ca)	mg/l	-	22.0 (3)	1.100
Magnesium	(as Mn)	mg/l	-	6.0	0.500
Sodium	(as Na)	mg/l	-	8.4	0.365
Potassium	(as K)	mg/l	-	3.5	0.090
Iron	(as Fe)	mg/l	5.5	1.2	0.043
Manganese	(as Mn)	mg/l	0.3	0.1	0.004
				Total cations :	2.102
Anions :					
Chloride	(as Cl)	mg/l	15	7	0.197
Sulphate	(as SO_4)	mg/l	8	1	0.021
Carbonate	(as CO_3)	mg/l	-	Nil	0
Bicarbonate	(as HCO_3)	mg/l	-	116 (3)	1.900
Nitrate	(as N)	mg/l	0.01	0.1	0.002
Fluoride	(as F)	mg/l	-	0.04	0.002
				Total anions :	2.122
Silica	(as SiO_2)	mg/l	-	24	
Hydrogen sulphide	(as H_2S)	mg/l	Nil	-	
Carbon dioxide	(as CO_2)	mg/l	46	-	

(1) Undertaken by GDC, at well head, during pumping test, using Hach Kit.
(2) Undertaken by Jabatan Kimia, Penang.
(3) Corrected from Jabatan Kimia analyses reported, assuming alkalinity and hardness values correct.

TABLE 5.1

PUMPING TEST DATA FOR WELL GS 702

Pump: Grundfos 25-5B electric submersible set at 37 metres
Method of discharge measurement: Orifice plate
Method of water level measurement: Electric contact gauge
Datum for water level measurement: 0.31mfrom top of concrete plinth
0.75m from ground level

TIME hr.min	ELAPSED TIME min.	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm	TIME hr.min	ELAPSED TIME min.	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm
30 September 1981 STEP 1					30 September 1981 STEP 2				
6.20	0.0	3.40	0.00	12.4	8.50	0.0	16.45	13.05	15.4
6.20½	0.5	7.42	4.02	12.4	8.50½	0.5	16.78	13.38	15.4
6.21	1.0	7.79	4.39	12.4	8.51	1.0	17.19	13.79	15.4
6.21½	1.5	8.33	4.93	12.4	8.51½	1.5	17.48	14.08	15.4
6.22	2.0	8.80	5.40	12.4	8.52	2.0	17.76	14.36	15.4
6.22½	2.5	9.25	5.85	12.4	8.52½	2.5	18.03	14.04	15.4
6.23	3.0	9.70	6.30	12.4	8.53	3.0	18.23	14.83	15.4
6.23½	3.5	9.94	6.54	12.4	8.53½	3.5	18.38	14.98	15.4
6.24	4.0	10.24	6.84	12.4	8.54	4.0	18.55	15.15	15.4
6.24½	4.5	10.69	7.29	12.4	8:54½	4.5	18.72	15.32	15.4
6.25	5.0	10.80	7.40	12.4	8.55	5.0	18.88	15.48	15.4
6.26	6.0	11.25	7.85	12.4	8.56	6.0	19.08	15.68	15.4
6.27	7.0	11.58	8.18	12.4	8.57	7.0	19.75	15.85	15.4
6.28	8.0	11.85	8.48	12.4	8.58	8.0	19.39	15.99	15.4
6.29	9.0	12.10	8.70	12.4	8.59	9.0	19.65	16.25	15.4
6.30	10.0	12.40	9.00	12.4	9.00	10.0	19.78	16.38	15.4
6.35	15.0	13.27	9.87	12.4	9.05	15.0	20.29	16.89	15.4
6.40	20.0	13.72	10.32	12.4	9.10	20.0	20.61	17.21	15.4
6.45	25.0	14.10	10.70	12.4	9.15	25.0	20.81	17.44	15.4
6.50	30.0	14.43	11.03	12.4	9.20	30.0	20.87	17.47	15.4
7.00	40.0	14.74	11.34	12.4	9.30	40.0	21.20	17.80	15.4
7.10	50.0	14.96	11.56	12.4	9.40	50.0	21.38	17.98	15.4
7.20	60.0	15.15	11.75	12.4	9.50	60.0	21.63	18.23	15.4
7.30	70.0	15.30	11.92	12.4	10.00	70.0	21.77	18.37	15.4
7.40	80.0	15.49	12.09	12.4	10.10	80.0	21.84	18.44	15.4
7.50	90.0	15.77	12.37	12.4	10.20	90.0	22.04	18.64	15.4
8.00	100.0	16.20	12.80	12.4	10.30	100.0	22.07	18.67	15.4
8.10	110.0	16.40	13.02	12.4	10.40	110.0	22.08	18.68	15.4
8.20	120.0	16.41	13.01	12.4	10.50	120.0	22.18	18.78	15.4
8.30	130.0	16.45	13.05	12.4	11.00	130.0	22.10	18.70	15.4
8.40	140.0	16.45	13.05	12.4	11.10	140.0	22.14	18.74	15.4
8.50	150.0	16.45	13.05	12.4	11.20	150.0	22.34	18.74	15.4

TIME hr.min	ELAPSED TIME min.	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm
STEP 3				
11.20	0.0	22.34	18.94	18.0
11.20½	0.5	-	-	-
11.21	1.0	-	-	-
11.21½	1.5	22.72	19.32	18.0
11.22	2.0	22.93	19.53	18.0
11.22½	2.5	23.29	19.89	18.0
11.23	3.0	23.34	19.94	18.0
11.23½	3.5	23.50	20.10	18.0
11.24	4.0	23.64	20.24	18.0
11.24½	4.5	23.79	20.39	18.0
11.25	5.0	23.93	20.53	18.0
11.26	6.0	24.18	20.78	18.0
11.27	7.0	24.45	21.05	18.0
11.28	8.0	24.67	21.27	18.0
11.29	9.0	24.79	21.39	18.0
11.30	10.0	25.05	21.65	18.0
11.35	15.0	25.32	21.92	18.0
11.40	20.0	25.66	22.26	18.0
11.45	25.0	25.81	22.41	18.0
11.50	30.0	26.06	22.66	18.0
12.00	40.0	26.24	22.84	18.0
12.10	50.0	26.46	23.06	18.0
12.20	60.0	26.24	22.84	18.0
12.30	70.0	26.54	23.14	18.0
12.40	80.0	26.62	23.22	18.0
12.50	90.0	26.56	23.16	18.0
13.00	100.0	26.74	23.34	18.0
13.10	110.0	26.86	23.46	18.0
13.20	120.0	26.87	23.47	18.0
13.30	130.0	26.88	23.48	18.0
13.40	140.0	26.87	23.47	18.0
13.50	150.0	26.66	23.26	18.0
14.00	160.0	26.58	23.18	18.0
14.10	170.0	26.70	23.30	18.0
14.20	180.0	26.92	23.52	18.0
14.30	190.0	26.79	23.39	18.0
14.40	200.0	26.70	23.30	18.0

TIME hr,min	ELAPSED TIME min	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm
STEP 3 continued				
15.05	225	15.10	11.70	18.0
15.10	230	19.65	16.25	18.0
15.15	235	20.20	16.80	18.0
15.16	236	20.39	16.99	18.0
15.17	237	20.55	17.15	18.0
15.18	238	20.65	17.25	18.0
15.19	239	20.73	17.33	18.0
15.20	240	20.75	17.35	18.0
15.21	241	20.79	17.39	18.0
15.22	242	21,26	17.16	18.0
15.23	243	21.78	18.38	18.0
15.24	244	22.07	18.67	18.0
15.25	245	22.30	18.90	18.0
15.26	246	22.46	19.07	18.0
15.27	247	22.56	19.16	18.0
15.28	248	22.66	19.26	18.0
15.29	249	22.76	19.36	18.0
15.30	250	22.78	19.38	18.0
15.35	255	23.60	20.20	18.0
15.40	260	23.86	20.46	18.0
15.45	265	24.30	20.90	18.0
15.50	270	24.64	21.24	18.0
15.55	275	24.76	21.36	18.0
16.00	280	25.03	21.63	18.0
16.05	285	25.01	21.61	18.0
16.10	290	25.12	21.72	18.0
16.15	295	25.18	21.78	18.0
16.20	300	25.35	21.95	18.0
16.25	305	25.34	21.94	18.0
16.30	310	25.36	21.96	18.0
16.35	315	25.31	21.91	18.0
16.40	320	25.50	22.10	18.0
16.45	325	25.51	22.11	18.0
16.50	330	25.40	22.00	18.0
16.55	335	25.68	22.70	18.0
17.00	340	25.78	22.78	18.0
17.05	345	25.71	22.31	18.0

TIME hr.min	ELAPSED TIME min.	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm	TIME hr.min	ELAPSED TIME min.	WATER LEVEL m	DRAW-DOWN m	DIS-CHARGE gpm
STEP 3 continued									
17.10	350	25.63	22.23	18.0					
17.15	355	25.61	22.21	18.0					
17.20	360	25.60	22.20	18.0					
17.30	370	25.58	22.18	18.0					
17.35	375	25.68	22.24	18.0					
17.40	380	25.83	22.43	18.0					
17.45	385	25.90	22.50	18.0					
17.50	390	25.82	22.42	18.0					
17.55	395	25.77	22.51	18.0					
18.00	400	25.74	22.54	18.0					
18.05	405	25.72	22.32	18.0					
18.10	410	25.70	22.30	18.0					
18.15	415	25.69	22.29	18.0					
18.20	420	25.71	22.31	18.0					
18.25	425	25.84	22.40	18.0					
18.30	430	25.92	22.52	18.0					
18.35	435	25.91	22.51	18.0					
18.40	440	-	-	-					
18.45	445	-	-	-					
18.50	450	-	-	-					
18.55	455	25.77	22.37	18.0					
19.00	460	25.76	22.36	18.0					

TIME hr. min	ELAPSED TIME t'	WATER LEVEL m	RESIDUAL DRAWDOWN m	TOTAL * TIME t	t/t'
30.9.81 RECOVERY TEST					
19.00	0.0	25.76	22.36	692.7	∞
19.00½	0.5	25.70	20.30	693.2	1386
19.01	1.0	22.25	18.85	693.7	694
19.01½	1.5	20.40	17.00	694.2	463
19.02	2.0	18.53	15.13	694.7	347
19.02½	2.5	17.05	13.65	695.2	278
19.03	3.0	15.84	12.44	695.7	232
19.03½	3.5	14.70	11.30	696.2	199
19.04	4.0	13.75	10.35	696.7	174
19.04½	4.5	13.05	9.65	697.2	155
19.05	5.0	12.38	8.98	697.7	140
19.06	6.0	11.42	8.02	698.7	116
19.07	7.0	10.71	7.31	699.7	100
19.08	8.0	10.25	6.85	700.7	88
19.09	9.0	9.85	6.45	701.7	78
19.10	10.0	9.58	6.18	702.7	70
19.15	15.0	8.66	5.26	707.7	47
19.20	20.0	8.07	4.67	712.7	36
19.25	25.0	7.62	4.22	717.7	29
19.30	30.0	7.25	3.85	722.7	24
19.40	40.0	6.65	3.25	732.7	18
19.50	50.0	6.20	2.80	742.7	15
20.00	60.0	5.81	2.41	752.7	13
20.10	70.0	5.53	2.13	762.7	11
20.20	80.0	5.27	1.87	772.7	9.7
20.30	90.0	5.06	1.66	782.7	8.7
20.40	100.0	4.90	1.50	792.7	7.9
21.10	130.0	4.45	1.05	822.7	6.3
21.40	160.0	4.17	0.77	852.7	5.3
22.10	190.0	3.98	0.58	882.7	4.7
22.40	220.0	3.83	0.43	912.7	4.2
23.10	250.0	3.74	0.34	942.7	3.8
23.40	280.0	3.66	0.26	972.7	3.5

*Note : Total time t is the adjusted time from the start of testing, derived by dividing the total quantity of water abstracted by the constant rate discharge.

FIGURE 5.1

PUMPING TEST DATA PLOT GS 702

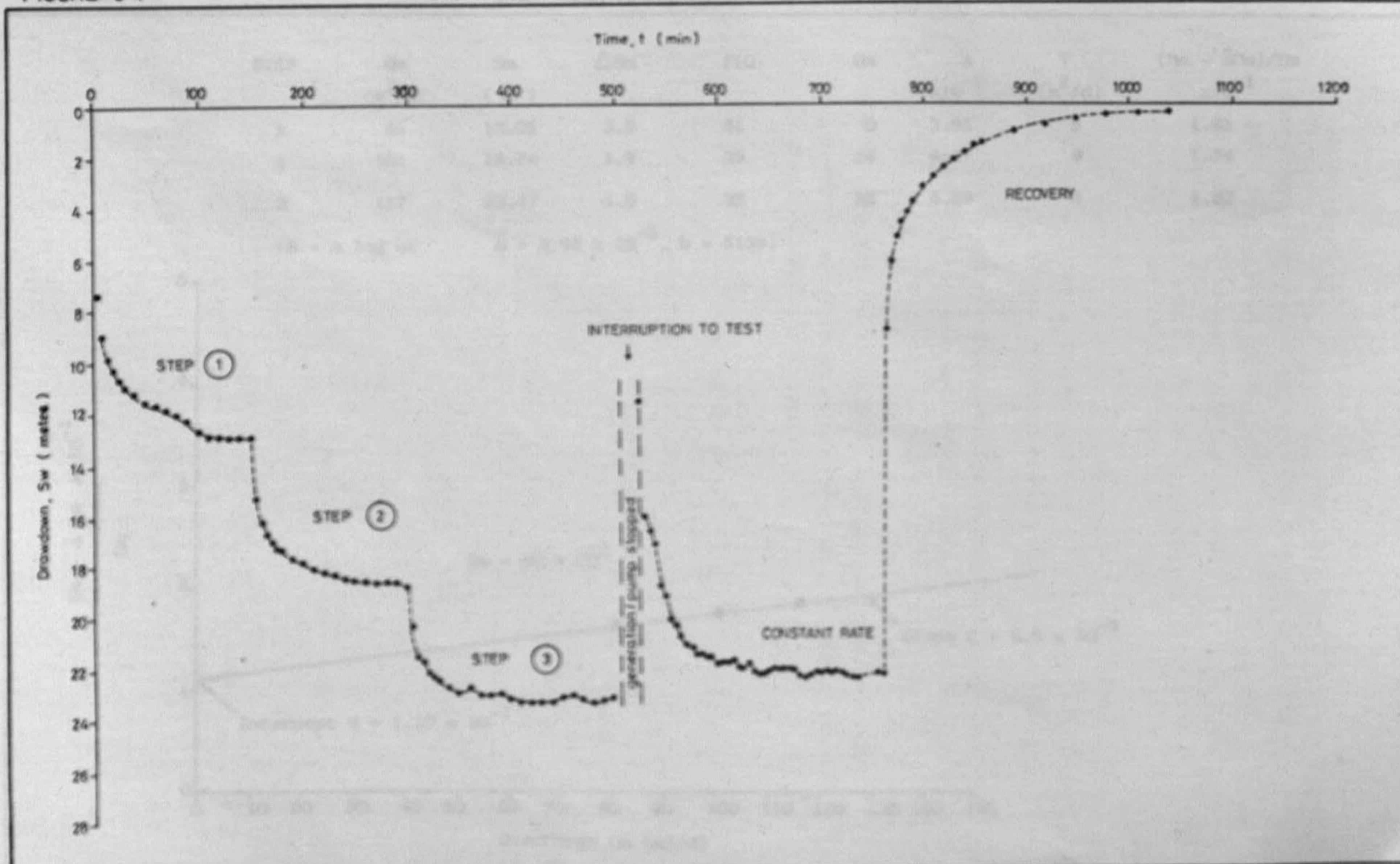
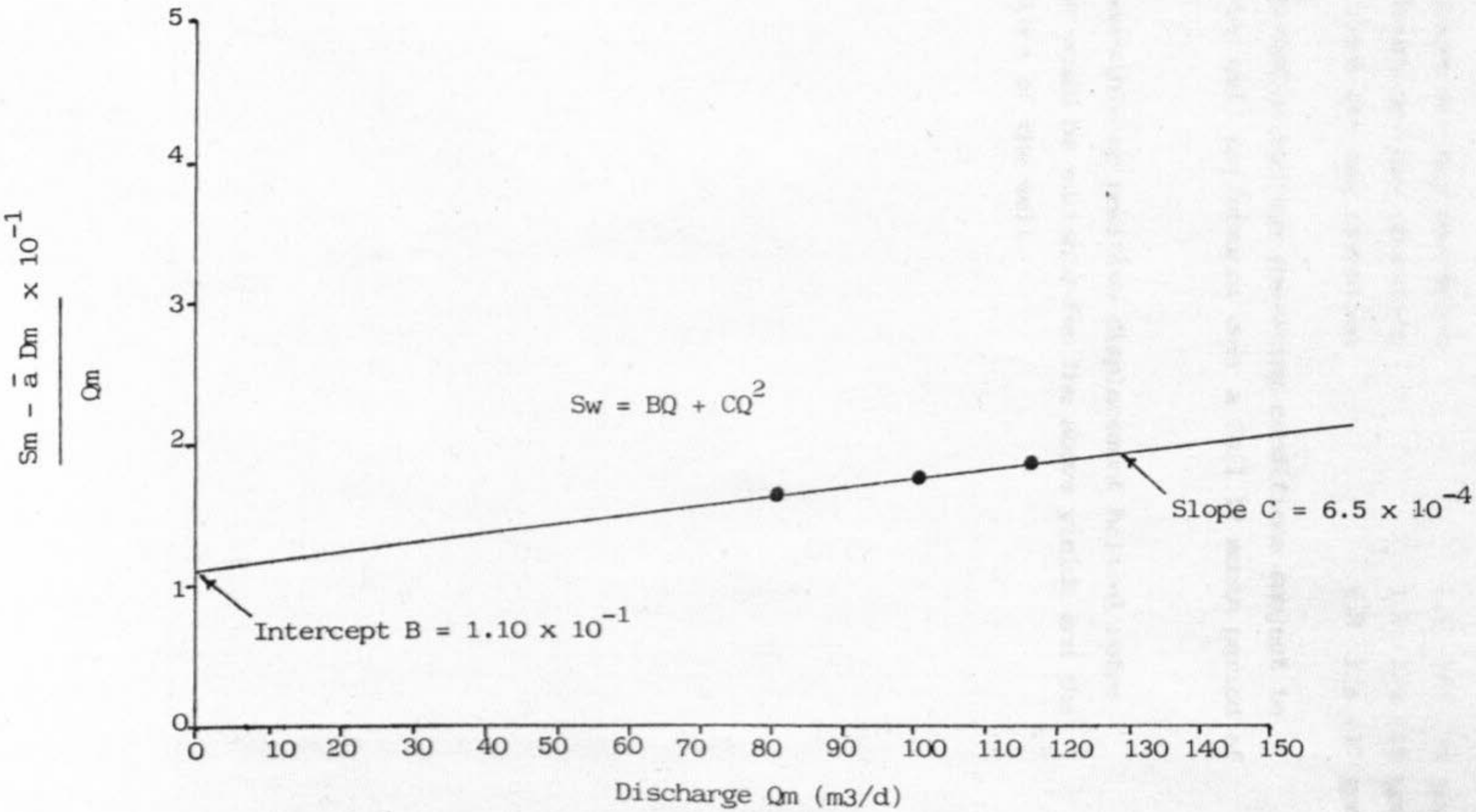


FIGURE 5.2

STEP TEST ANALYSIS GS 702

STEP	Qm (m^3/d)	Sm (m)	ΔSm	f(Q)	Dm	a $\times 10^{-2}$	T (m^2/d)	$(Sm - \bar{a}Dm)/Qm$ $\times 10^{-1}$
1	81	13.05	3.2	81	0	3.95	5	1.61
2	101	18.74	1.9	39	24	4.87	4	1.74
3	117	23.47	1.5	32	38	4.69	4	1.85

($B = a \log bt$ $\quad \bar{a} = 3.95 \times 10^{-2}$, $b = 5159$)



6. RECOMMENDED OPERATION

Maximum pumping water level (below ground level)	34 m
Pump inlet setting depth (below ground level)	36 m
Estimated lowest dry season static water level (below ground level) (max. P.W.L. - lowest S.W.L → max. W.L. drawdown, used in calculation of max. pumping rate).	7 m
Pumping rate at 24 hours per day operation	1.1 l/s (14 gpm)
Pumping rate at 16 hours per day operation	1.2 l/s (15 gpm)
Pumping rate at 8 hours per day operation	1.3 l/s (17 gpm)

These should be regarded as maximum operating conditions subject to review after observing well performance over a full 12 month period of operation.

Either electric submersible or positive displacement helical rotor type (eg Mono) pumps would be suitable for the above yields and the dimensional limitations of the well.


THAILAND
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PADANG TERAP
KOTA SETAR
PENDANG
YAN
CENTRAL KEDAH
SELAT MELAKA
Changlun
Kodiang
Jitra
Bukit Kerang
ALOR SETAR
Langgar
Pokok Sena
Kuala Nerang
Padang Sanai
Kubur Panjang
Simpang Empat
Kota Sarang Semut
Pendang
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DEMETER HOUSE, STATION ROAD, CAMBRIDGE, ENGLAND
DATE : APRIL 1982
SCALE : 1" = 2 MILES
SHEET : KP/1