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# DEVELOPMENT OF PRODUCTION WELLS IN KEDAH & PERLIS INCEPTION REPORT

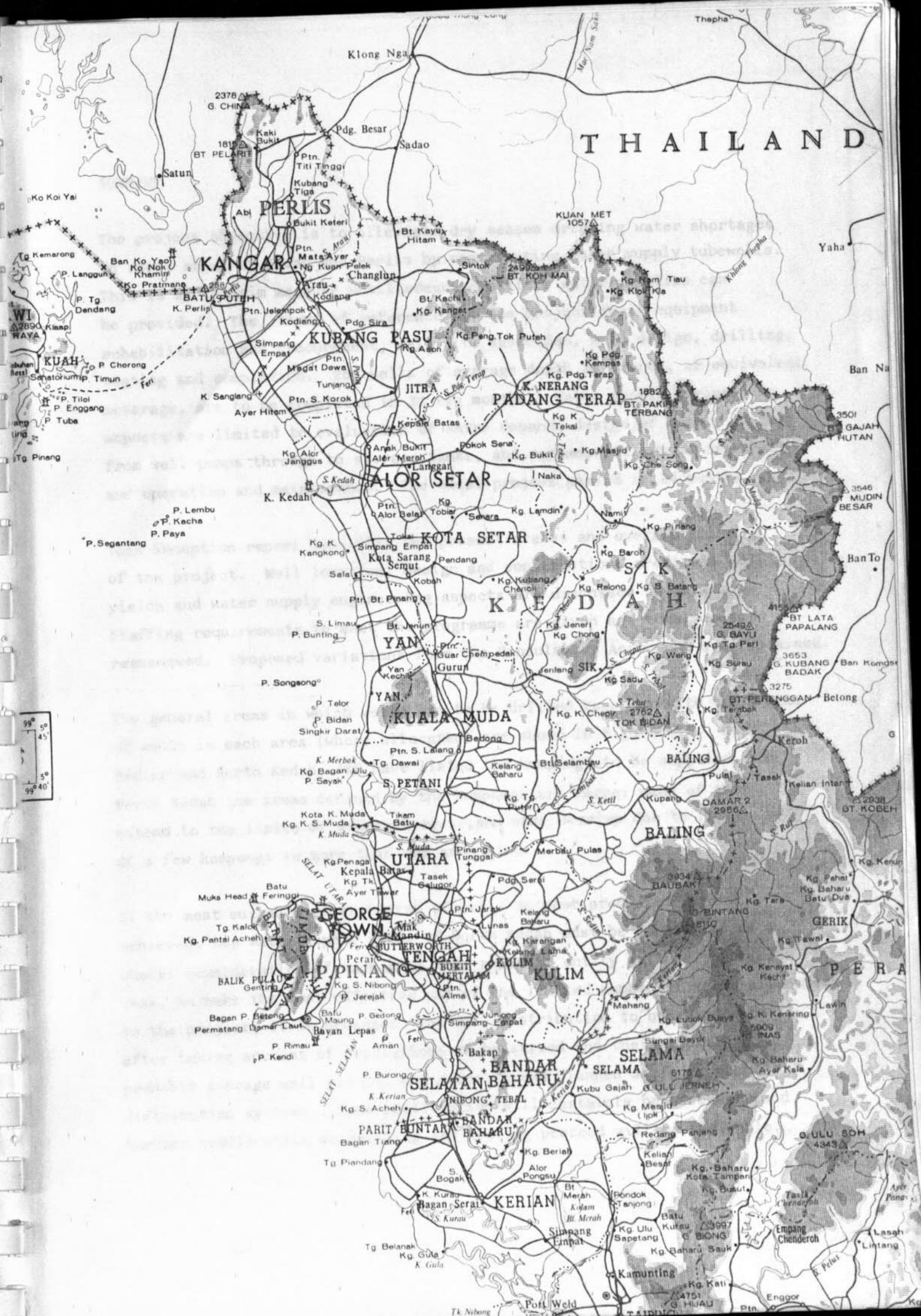
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GROUNDWATER DEVELOPMENT CONSULTANTS (INTL) LTD  
Cambridge, England

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

MAY 1981



THAILAND

PERLIS

KANGAR

KUBANG PASU

JITRA

K. NERANG  
PADANG TERAP

ALOR SETAR

KOTA SETAR

KEDAH

YAN

KUALA MUDA

S. PETANI

UTARA

GEORGE TOWN

P. PINANG

BANDAR SELATAN  
BAHARU

PARIT BONTAR

BUTTERWORTH

TENGAH

BUKIT MERTALAM

KULIM

BALING

BALING

SELAMA

KERIAN

SELATAN BAHARU

BANDAR BAHARU

KAMUNTING

PERAK

GULU SOH



## SUMMARY

The project objective is to alleviate dry season drinking water shortages in rural areas of Kedah and Perlis by constructing water supply tubewells. This is an interim measure until adequate surface water supplies can be provided. The terms of reference for the project cover equipment rehabilitation and procurement, well site selection, well design, drilling, testing and completion. 250 wells of average depth 30 metres, or equivalent meterage, are to be completed in 32 rig months. Water supply engineering aspects are limited to evaluation of water demand, design of supply systems from well pumps through to storage tanks, and recommendations on treatment and operation and maintenance. The total project period is 24 months.

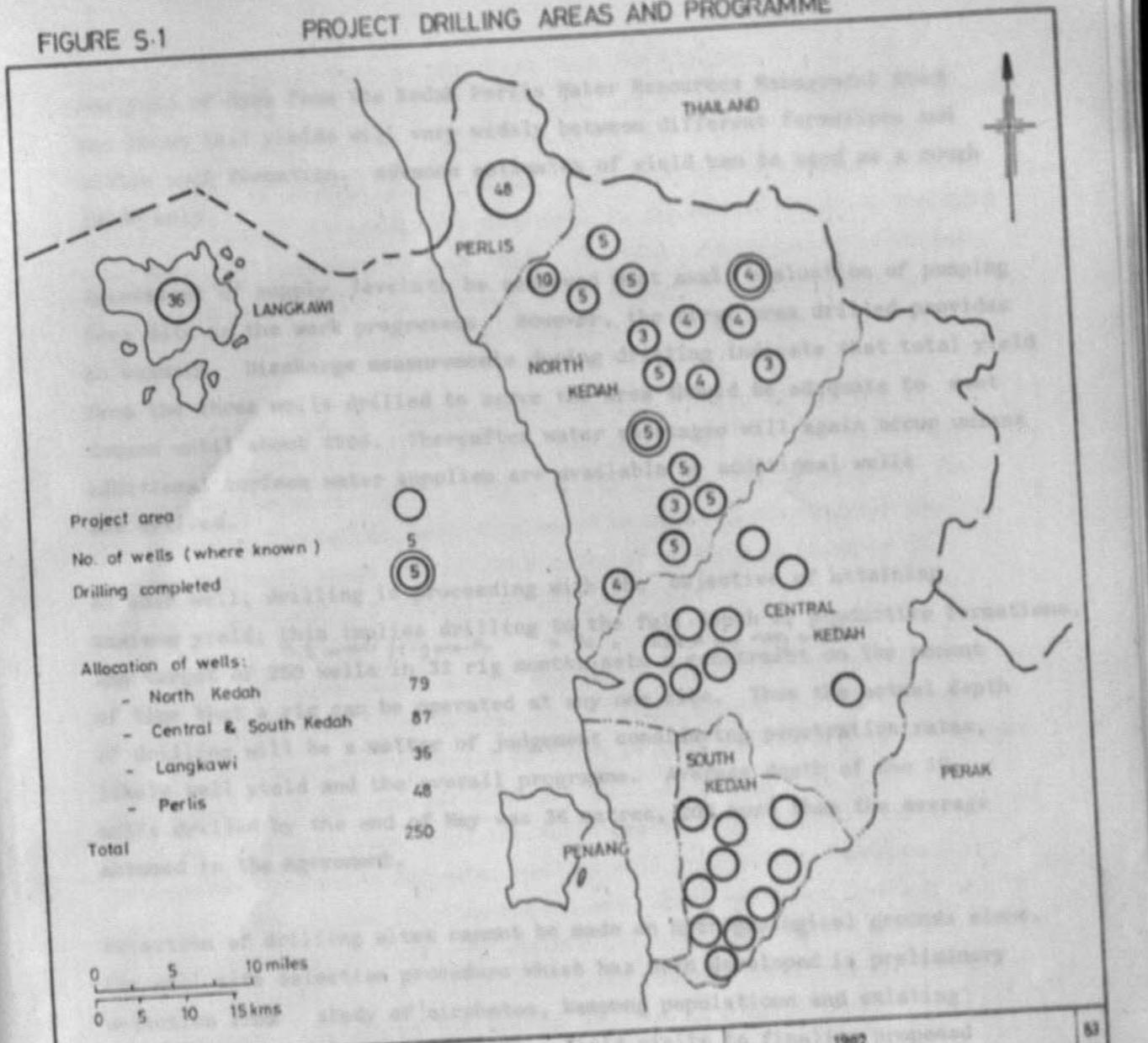
This inception report describes the present status and overall planning of the project. Well location, design and construction, predicted well yields and water supply engineering aspects are discussed in detail. Staffing requirements to meet the programme are given and total costs reassessed. Proposed variations from the Consultancy Agreement are explained.

The general areas in which wells are to be drilled together with the number of wells in each area (where allocated) are shown in Figure S.1. For Perlis and North Kedah, JKR have listed the kampongs to be supplied. In North Kedah the areas defined by the kampongs are large; many of them extend to the limits of adjacent areas and some overlap due to inclusion of a few kampongs in more than one area list.

If the most suitable distribution of wells to meet predicted demand is to be achieved, the water supply needs of North Kedah must be considered as a whole; consideration of each area as a separate entity will be inadequate. Thus, to make the most effective use of the limited number of wells allocated to the project, it is proposed that well distribution to be reassessed after taking account of populations to be served and their locations, probable average well yields, and existing and planned surface water distribution systems. Some reallocation will certainly be necessary and further reallocation as drilling and testing proceed will be desirable.

FIGURE 5-1

PROJECT DRILLING AREAS AND PROGRAMME



ACTIVITY	1981												1982												53
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
RIG No. 1	Rehabilitation	█																							
	Well Construction & Testing																								
	- North Kedah	█																							
- Perlis													█												
- Central & South Kedah													█												
RIG No. 2	Procurement	█																							
	Well Construction & Testing																								
	- Langkawi	█																							
- Perlis													█												
- Central & South Kedah													█												
Water Supply System Designs	█																								
Reports	█																								

Legend:  As shown in Consultancy Agreement      **█** Actual and planned

Analysis of data from the Kedah Perlis Water Resources Management Study has shown that yields will vary widely between different formations and within each formation. Advance estimates of yield can be used as a rough guide only.

Assessment of supply levels to be achieved must await evaluation of pumping test data as the work progresses. However, the first area drilled provides an example. Discharge measurements during drilling indicate that total yield from the three wells drilled to serve the area should be adequate to meet demand until about 1990. Thereafter water shortages will again occur unless additional surface water supplies are available or additional wells are drilled.

At each well, drilling is proceeding with the objective of attaining maximum yield; this implies drilling to the full depth of productive formations. The target of 250 wells in 32 rig months <sup>2.3 wells / rig month</sup>  $\times 30 = 224.4$  <sup>224.4 wells / rig month</sup> sets a constraint on the amount of time that a rig can be operated at any one site. Thus the actual depth of drilling will be a matter of judgement considering penetration rates, likely well yield and the overall programme. Average depth of the 10 wells drilled by the end of May was 36 metres, 20% more than the average assumed in the Agreement.

Selection of drilling sites cannot be made on hydrogeological grounds alone. The well site selection procedure which has been developed is preliminary selection from study of airphotos, kampong populations and existing or planned water supply pipelines, field visits to finalise proposed sites, clearance of access to sites through the relevant District Office, and finally, approval of sites by JKR. From late June, site selection is expected to be aided by geophysical survey.

The overall programme for the project is also shown in Figure S.1. Well drilling started in April after rehabilitation of the Government owned Bomag drilling rig. Completion of drilling is scheduled for the end of November 1982, two months later than envisaged in the Agreement. This is unavoidable as the second drilling rig is not likely to be delivered and commissioned before the end of November 1981. Provided that the rig is available then, completion of the project is not expected to be delayed.

Drilling on Langkawi will be the first task for the second rig. There, unlike the mainland, the project objectives are to identify potential ground-water resources and to drill production wells for a supply of 2.3 mgd. The Langkawi investigation programme, which includes development of a groundwater model for resource evaluation, is planned to start in September 1981 and to be completed in June 1982. Thirteen investigation boreholes and 23 production wells are expected to be required. These would be drilled over the six month period December 1981 to May 1982.

The Bomag rig is due to complete the North Kedah wells at the end of January 1982 when it would be transferred to Perlis. At the end of May it would be joined by rig No. 2 to complete all the Perlis wells by the end of June. Thereafter, both rigs would be moved south to drill the Central and South Kedah wells. This order of working is proposed to minimise logistical and supervisory difficulties.

Preparation of water supply system designs is planned to be completed at the end of December 1982. For estimation of future demand, JKR have stated that the planning horizon should be taken as 1995 for which year the target supply rate is 45 gallons per head per day. As supply from tubewells is to be an interim measure only, the World Health Organisation 'maximum permissible' standards for water quality will be applied. Treatment is expected to be limited to chlorination and, where necessary, reduction of iron and manganese levels by aeration or oxidation and filtration. Package treatment plants and prefabricated pressed steel storage tanks are proposed. Control of the systems will be at a basic level.

The project programme ends in January 1983 when the final report is due to be submitted.

Resulting mainly from extension of the drilling period, staff inputs proposed are increased from those shown in the Agreement. The changes are summarised below :

		Agreement	Proposed
Professional staff - foreign	man months	84.25	97.25
Professional staff - local	man months	105	107
Non-professional staff - office	man months	161	182
- field	team months	81	88

The staffing adjustments and necessary minor revision of reimbursable items for well construction result in overall cost increases of M\$ 152 851 and £ 35 511, which amount to about 5½% of the original total cost.

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## 1. INTRODUCTION

THAILAND

### 1.1 Background

During the five month dry season from December to April, traditional sources of water in Kedah and Perlis are depleted. Drinking water shortages are experienced by rural communities dependent on shallow well supplies and by some communities at the extremities of existing reticulation systems. JKR Kedah and Perlis have to mount drought relief measures by transporting drinking water to these communities. In order to alleviate these water shortages, this project for drilling 250 water supply tubewells has been commissioned.

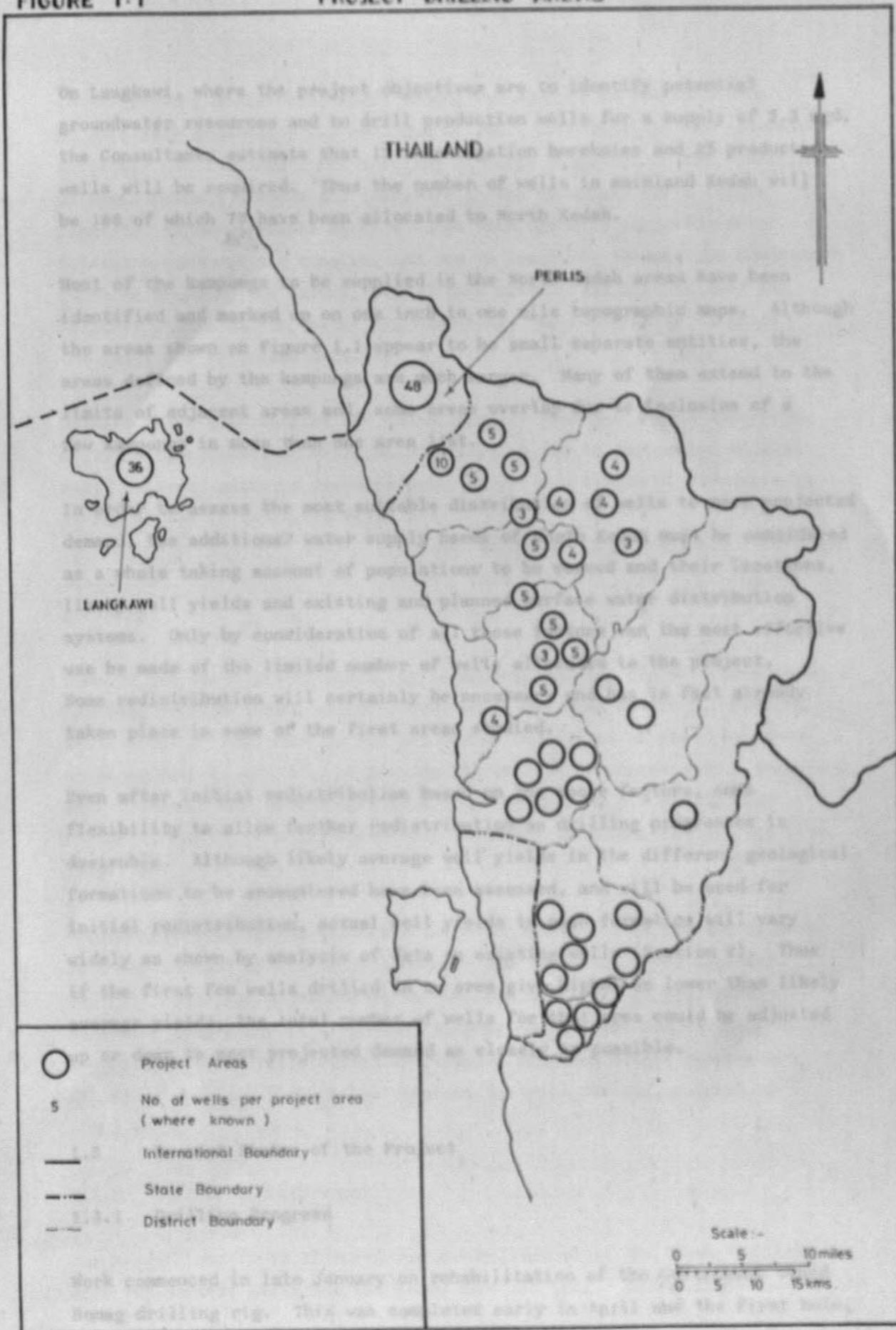
The terms of reference for the project, reproduced as Appendix A of this report, cover equipment rehabilitation and procurement, site selection, well design, drilling, testing and completion to the wellhead. Water supply engineering aspects are limited to design of the supply systems from the well pumps through to storage tanks including recommendations on treatment. Additional requirements include evaluation of water demand and recommendations for operation and maintenance. 250 wells of average depth 30 metres, or equivalent meterage, are to be completed within 32 rig months. The total project period is 24 months.

### 1.2 Distribution of Wells

The nominal allocation of wells to the two states is 200 in Kedah (including Langkawi) and 50 in Perlis. For mainland Kedah, JKR have allocated the general areas in which wells are to be drilled, as shown in Figure 1.1. In North Kedah only, an order of priority has been assigned together with the number of wells, ranging from 3 to 10, to be drilled in each area. Lists of the kampongs to be supplied with groundwater have also been provided. For Central and South Kedah, only the general areas of drilling are known. JKR Perlis have assigned 48 wells to serve 39 areas, generally one well per area. Kampongs to be supplied have been stated.

FIGURE 1-1

PROJECT DRILLING AREAS



On Langkawi, where the project objectives are to identify potential groundwater resources and to drill production wells for a supply of 2.3 mgd, the Consultants estimate that 13 investigation boreholes and 23 production wells will be required. Thus the number of wells in mainland Kedah will be 166 of which 79 have been allocated to North Kedah.

Most of the kampongs to be supplied in the North Kedah areas have been identified and marked up on one inch to one mile topographic maps. Although the areas shown on Figure 1.1 appear to be small separate entities, the areas defined by the kampongs are much larger. Many of them extend to the limits of adjacent areas and, some areas overlap due to inclusion of a few kampongs in more than one area list.

In order to assess the most suitable distribution of wells to meet projected demand, the additional water supply needs of North Kedah must be considered as a whole taking account of populations to be served and their locations, likely well yields and existing and planned surface water distribution systems. Only by consideration of all these factors can the most effective use be made of the limited number of wells allocated to the project. Some redistribution will certainly be necessary and has in fact already taken place in some of the first areas studied.

Even after initial redistribution based on the above factors, some flexibility to allow further redistribution as drilling progresses is desirable. Although likely average well yields in the different geological formations to be encountered have been assessed, and will be used for initial redistribution, actual well yields in each formation will vary widely as shown by analysis of data on existing wells (Section 2). Thus if the first few wells drilled in an area give higher or lower than likely average yields, the total number of wells for that area could be adjusted up or down to meet projected demand as closely as possible.

### 1.3 Present Status of the Project

#### 1.3.1 Drilling Progress

Work commenced in late January on rehabilitation of the Government owned Bomag drilling rig. This was completed early in April and the first hole,

and replacement of parts required, prices and delivery were requested in the Pendang district of North Kedah, was spudded on the 12th when an ancillary compressor was provided by JKR. Unfortunately the compressor available was inadequate for drilling at large diameters or for operation of down-the-hole hammers and therefore it was exchanged for a larger capacity, higher pressure machine hired from the MADA project. After several breakdowns and repairs, and due to inability to make the compressor function properly and safely, use of this machine was discontinued and reliance placed solely on the rig compressor, the capacity of which is too small for efficient drilling.

Despite these difficulties and those normally associated with commencing drilling operations, 10 wells were drilled in the 50 day period to 31st May. Progress achieved compared with the project target of 250 wells in 32 rig months is tabulated below :

	No. of wells	Days per well	Meterage
Target	12.8	3.9	385
Achieved	10	5	366

Some of the wells are of necessity incomplete and the rig will have to be returned to them once a suitable compressor has been obtained. Pumping tests have not been carried out yet but an indication of yield has been obtained during drilling by passing the airlift discharge over a measuring weir. These flows have ranged from 1 to 105 gallons per minute (gpm). Excluding the first well, where only 1 gpm was obtained, the average flow is 52 gpm.

Groundwater studies and well site selection commenced at the end of March with the arrival of the Project Manager and the Groundwater Engineer. The site selection procedure which has been developed is preliminary selection from study of airphotos, kampong populations and existing water supply pipelines; field visits to finalise proposed sites; clearance of access to sites through the relevant District Office; approval of sites by JKR.

### 1.3.2 Equipment Procurement

The major items to be procured for rehabilitation of the Bomag drilling rig were replacement parts for the power take off unit. After inspection of the

unit and assessment of parts required, prices and delivery were requested from Bomag and after receipt of their quotation and approval to purchase from JKR, an order was placed on 26th February. The parts were not received until 25th March which prevented completion of rehabilitation by the end of March as originally planned.

Quotations for surface geophysical equipment were obtained during April. The terms of reference require the Consultant to prepare tender documents for supply of an additional drilling rig and ancillary equipment. The documents were finalised, in conjunction with JKR, during March and submitted to JKR with a list of recommended tenderers on 4th April. The documents were issued during April to 13 tenderers and the tender closing date set at 19th May. Eight bids were received though one of these was rejected due to late delivery. The tenders were handed over to the Consultant on 23rd May for evaluation.

In order to obtain a suitable ancillary compressor for the Bomag drilling rig, a specification and bill of quantities for supply and delivery of a new 600 cfm/200 psi compressor was prepared by the Consultant and submitted to JKR on 12th April. The tender documents were completed and issued to 13 tenderers by JKR and the closing date set at 30th May. Six bids were received.

As an interim measure, pending delivery of the new compressor, arrangements have been made to hire a 600 cfm/125 psi machine. This is the highest operating pressure readily available in Malaysia, though not ideal, it will partially overcome drilling difficulties.

Initial supplies of drilling bits to supplement those already held by JKR were ordered in mid April and received by the end of the month. Replacement 3½ inch drill pipe for the Bomag rig was found to be necessary owing to excessive thread wear and damage on the existing pipe. An order was placed towards the end of May.

Long term spares and drilling bit requirements for the Bomag rig were assessed during April. Approval to purchase those spare parts which can only be supplied by Bomag was obtained at the end of April. The documents for the remaining spare parts and for drilling bits were submitted to JKR in mid-May and have since been issued. The closing date for receipt of tenders is 23rd June.

Miscellaneous items such as stores shelving, workbench, pipe stands, bit breakers, jetting tools and hand tools have been fabricated or purchased locally. Various modifications to the Bomag rig including the addition of a loading arm have been made to improve performance.

Quotations for surface geophysical equipment were obtained during April and May and JKR approval to purchase granted on 30th May. Delivery is expected in the second half of June. Details and costs of borehole logging equipment have been obtained. Owing to cost, this equipment will have to be purchased by contract.

The Government owned Grundfos submersible pump has been sent to the local agents in Kuala Lumpur for inspection and repair as necessary. Procurement of additional test pumps was delayed pending full assessment of the required and available range of discharge and head and of diameter limitations. Two sizes of submersible pump will be necessary for the mainland well testing. As this will be carried out concurrently by two teams, a total of three pumps is desirable to allow for possible breakdown and for flexibility of operation. Centrifugal pumps will be suitable for testing the Langkawi production wells. Procurement proposals will be discussed with JKR as soon as possible.

Portable chemical testing equipment, dipmeters and survey equipment will be purchased shortly. As an interim measure one electrolytic conductivity meter and one dipmeter have been brought out from GDC head office.

### 1.3.3 Materials

Initial supplies of 6 inch uPVC casing and wire would screen plus fittings have been obtained. Delivery of 6 inch slotted uPVC pipe was delayed as the supplier encountered difficulties in carrying out the slotting operation to the required specification.

Cement baskets and packers have been designed and prototypes fabricated locally. The well caps, originally to have been in uPVC, have been changed to a more robust steel cap which will be less susceptible to damage.

#### 1.4 Report Format

All aspects of well drilling on the mainland, from data collection through to well completion and testing, are described in Section 2. Langkawi island investigations and production well drilling are discussed in Section 3, the programme for Langkawi is also presented and described. In Section 5, the overall programme is presented, staff requirements to meet the programme are discussed and a reassessment of costs is given.

1:50 000 scale maps have been provided by the Geological Survey of Malaysia (GSM); coverage is incomplete for the north-eastern area but mapping is currently being prepared by GSM. Aerial photography at 1:50 000 scale (1974/5) has been obtained.

Groundwater exploration in Kedah and Perlis has occurred in two major phases. In 1957-60 an extensive series of rather unconnected groundwater investigations were carried out under the auspices of USM. The work included electrical resistivity and seismic surveys together with a drilling programme of some 120 boreholes. A summary of borehole and pumping test data has been obtained; site coordinates are omitted.

Little investigation appears to have been carried out during the 1965-75 period. Reports by Wong Tee Shin of GSM dated 1977 and 1978 deal with groundwater potential of Langkawi and the Tiangying Felde plantation in North Perlis. At about the same time Ang Nam Siat also of GSM investigated the coastal plain west of Alor Setar.

The most detailed study to date on groundwater resources in Kedah and Perlis is the recent Kedah-Perlis Water Resources Management Study (1979/80). Some 120 boreholes were drilled during the investigation and the results are included in the Final Report dated January 1981. These data which include electrical resistivity surveys, borehole logs, pumping tests and chemical analysis form the main groundwater data base for the present discussion. The drilling was carried out using GSM's Dowag 411 drilling rig.

## 2. MAINLAND PRODUCTION WELLS

### 2.1 Data Collection and Evaluation

A data base of maps, reports, aerial photographs, population and groundwater information has been assembled.

Topographic maps at 1:63 360 scale have been ordered through JKR Kedah; photocopies have been obtained for immediate use. Geological maps at 1:63 360 scale have been provided by the Geological Survey of Malaysia (GSM); coverage is incomplete for the north-eastern area but mapping is currently being prepared by GSM. Aerial photography at 1:25 000 scale (1974/5) has been obtained.

Groundwater exploration in Kedah and Perlis has occurred in two major phases. In 1957-58 an extensive series of rather unconnected groundwater investigations were carried out under the auspices of UNDP. The work included electrical resistivity and seismic surveys together with a drilling programme of some 200 boreholes. A summary of borehole and pumping test data has been obtained; site coordinates are awaited.

Little investigation appears to have been carried out during the 1958-76 period. Reports by Chong Foo Shin of GSM dated 1977 and 1978 deal with groundwater potential of Langkawi and the Chuping Felda plantation in North Perlis. At about the same time Ang Num Kiat also of GSM investigated the coastal plain west of Alor Setar.

The most detailed study to date on groundwater resources in Kedah and Perlis is the recent Kedah-Perlis Water Resources Management Study (KPWRMS). Some 109 boreholes were drilled during the investigation and the results are included in the Final Report dated January 1981. These data which include electrical resistivity surveys, borehole logs, pumping tests and chemical analysis form the main groundwater data base for the present discussion. The drilling was carried out using GSM's Bomag 411 drilling rig.

Mud flush with clay cutters were used in the upper clay zones and air flush with percussion hammer below to depths of up to 82m. The average borehole depth was 37 m. A total recommended exploitation of 4.2 mgd was said to be obtained from 4018 m of drilling.

The main emphasis of the groundwater survey part of KPWRMS has been the provision of domestic water supplies. A summary showing the various recommended uses of the wells is shown in Table 2.1.

Table 2.1 Recommended use of KPWRMS wells

Use	Number
Direct connection to existing JKR network	18
Direct connection to future JKR network	18
Use on individual rural water supply schemes	32
Special use for agricultural, fishery, tourist or industrial purposes	<u>10</u>
Total production wells	78
Observation boreholes for geological purposes	16
Abandoned, dry, collapsed or brackish	<u>15</u>
Total	109

The KPWRMS provides a large volume of rather unsystematic data, little of which was analysed in terms of groundwater potential or site selection and well design criteria. Average well yields in the major geological formations have been derived but such values mean little without some adjustment for well depth and drawdown.

The Final Report includes a table of classified results a summary of which is given in Table 2.2. The failed wells include wells abandoned due to very poor or no yield, collapsed boreholes and those producing brackish water. The observation boreholes for geological purposes are also included as failures. The reason for their inclusion is not clear and it is possible that because of low yield the wells were converted into observation boreholes.

Table 2.2 Classification of KPWRMS Drilling Programme

Formation	No. of wells	% failure	Production minimum	(gpd): average	maximum
Limestones	22	41	2 500	115 000	240 000
Silurian	8	25	2 500	33 000	60 000
Carboniferous	29	17	2 500	16 000	62 000
Triassic	27	19	2 000	59 000	216 000
Granite/alluvium	23	44	12 000	47 000	168 000
Total	109	29		51 000	

Evaluation of the data base will include compilation of a geological map of Kedah and Perlis using existing geological mapping and borehole data and showing the location of all known boreholes. This map is expected to provide a valuable aid to site selection.

Evaluation will also be undertaken of the KPWRMS drilling and pumping test data. Although providing sketch maps for each borehole location, showing electrical resistivity traverses and fracture traces at many of them, KPWRMS made no attempt to analyse drilling results in relation to geological and geophysical features. Although such a study may not produce conclusive findings, several valuable criteria for site selection such as open fracture lineations may result. This study will be carried out progressively with the present drilling programme.

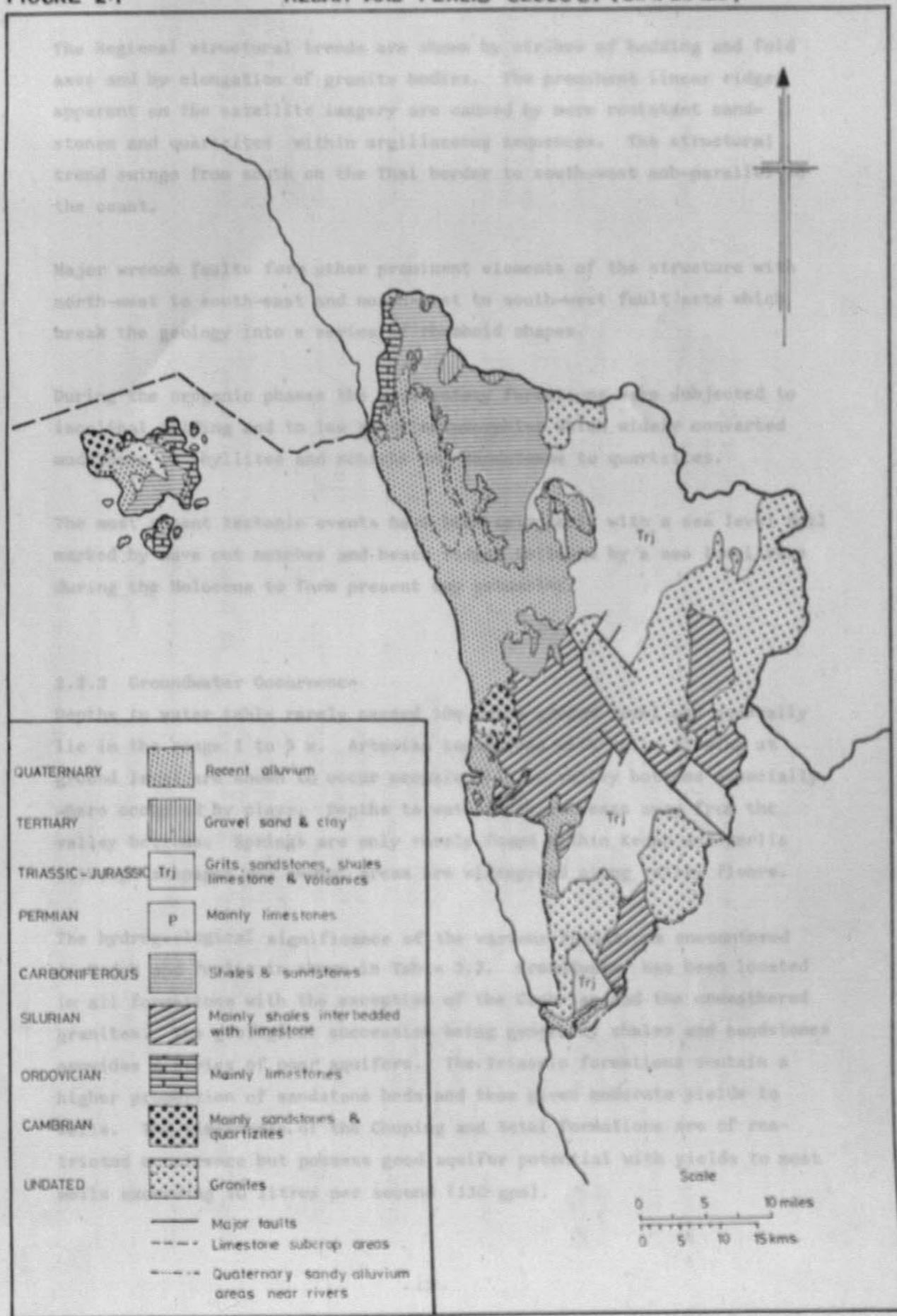
## 2.2 Hydrogeology

### 2.2.1 Geology

A north-west to south-east geological section across Kedah and Perlis shows the components of the Malayan geosyncline. In the north-west, in the Langkawi islands and in Perlis, the succession of thick deltaic deposits and shelly limestones were laid down in the shallow seas of a continental shelf. In Kedah and parts of Perlis the sequence is quite different comprising carbonaceous, siliceous and pyritic fine grained sediments which originated in deep waters. These beds are considered to have originated on a submarine ridge which was alternatively raised and depressed through geological time. A geological map of Kedah and Perlis is presented in Figure 2.1.

FIGURE 2-1

KEDAH AND PERLIS GEOLOGY (SIMPLIFIED)



The Regional structural trends are shown by strikes of bedding and fold axes and by elongation of granite bodies. The prominent linear ridges apparent on the satellite imagery are caused by more resistant sandstones and quartzites within argillaceous sequences. The structural trend swings from south on the Thai border to south-west sub-parallel to the coast.

Major wrench faults form other prominent elements of the structure with north-west to south-east and north-east to south-west fault sets which break the geology into a series of rhomboid shapes.

During the orogenic phases the sedimentary formations were subjected to isoclinal folding and to low grade metamorphism which widely converted mudstones to phyllites and schists and sandstones to quartzites.

The most recent tectonic events have been epirogenic with a sea level fall marked by wave cut notches and beach ridges followed by a sea level rise during the Holocene to form present day estuaries.

#### 2.2.2 Groundwater Occurrence

Depths to water table rarely exceed 10m below ground level and generally lie in the range 1 to 5 m. Artesian conditions with wells flowing at ground level are known to occur occasionally in valley bottoms especially where occupied by clays. Depths to watertable increase away from the valley bottoms. Springs are only rarely found within Kedah and Perlis although seepages and swampy areas are widespread along valley floors.

The hydrogeological significance of the various formations encountered in Kedah and Perlis is shown in Table 2.3. Groundwater has been located in all formations with the exception of the Cambrian and the unweathered granites. The geological succession being generally shales and sandstones provides a series of poor aquifers. The Triassic formations contain a higher proportion of sandstone beds and thus gives moderate yields to wells. The limestones of the Chuping and Setul formations are of restricted occurrence but possess good aquifer potential with yields to most wells exceeding 10 litres per second (130 gpm).

Table 2.3 Hydrogeological Significance of Geological Formations

Age	Formation Name	Lithology	Thickness (m)	Distribution	Hydrogeological Significance
Quaternary		Clays and sands of marine, estuarine fluvial and colluvial origin	up to 10	Coastal plain, estuaries, alluvial flood plain	Generally poor aquifer containing brackish to saline groundwater
Tertiary	Bukit Arang Coal beds	Semi consolidated gravel sand and clay with lignite	180	North Kedah and Perlis along border with Thailand	Good aquifer
Triassic	Semanggol formation, Kodiang formation	Sandstones with shales, limestones, siltstones and chert	?	Mountains of NE Kedah and North Kulim district	Moderate aquifer
Permian	Chuping formation	Massive, finely crystalline limestones with shale intercalations	600	Central Perlis and Pulau Langkawi	Good aquifer, secondary permeability developed
Carboniferous	Singa formation Kubang Pasu formation	Sandstones and shales with calcareous shales	?	Perlis and Kubang Pasu District of Kedah	Poor aquifer
Devonian		Red mudstones			Not known
Silurian	Sungai Petani formation, Mahang formation Baling formation	Shales with limestones, and sandstones, metamorphosed	1500	Kuala Muda, Baling and Kulim districts of Kedah	Poor aquifer

Table 2.3 Hydrogeological Significance of Geological Formations (continued)

Age	Formation Name	Lithology	Thickness (m)	Distribution	Hydrogeological Significance
Ordovician	Setul formation (possibly equivalent to Sg. Petani formation)	Dark grey crystalline limestone becoming argillaceous upwards	1500	West Perlis and Pulau Langkawi	Moderate aquifer, secondary permeability developed
Cambrian	Machinchang formation, Jerai formation	Schists quartzites and conglomerates	2000	West Pulau Langkawi and Gunung Jerai	Not known, formation well indurated
Triassic-Jurassic	Kulim granite, Bitang granite	Granites		Extensive in West and South Kedah	Poor aquifer

The consolidated and indurated nature of the formations means that the dominant mode of groundwater occurrence is within zones of secondary permeability such as joints and fractures and, within limestones, solution features. It is considered that intergranular groundwater flow is generally insignificant except within the unconsolidated quaternary formations and possibly the Tertiary beds.

### 2.2.3 Aquifer Characteristics and Well Yields

The KPWRMS report provides transmissivity values for some 42 wells. Unfortunately it is not clear from the report whether these results were obtained from pumping well or observation well data. Mention is made of observation wells for geological control but only pumping well data is presented (in graphical form). A useful check on the transmissivity values is provided by the Logan steady state approximation which has been used to re-analyse the KPWRMS data. No allowance has been made for well losses and in most cases steady state had not been achieved by the end of the pumping tests. In general the Logan approximation values are greater than the KPWRMS values suggesting that some allowance was made for unsteady state conditions. However, in view of the uncertainty involved in the KPWRMS method of analysis, reliance is placed here on the Logan values. Table 2.4 presents a summary of the calculations.

Table 2.4 Aquifer Transmissivity Values

Formation	No. of Tests	Transmissivity (m <sup>2</sup> /d)			Permeability (m/d)
		Minimum	Maximum	Geometric mean	
Ordovician	1	-	-	37	1.5
Silurian	3	26	69	43	1.5
Carboniferous	15	2.8	95	20	1.0
Triassic sandstones	16	14	160	78	3.0
Permo-Triassic limestones	6	84	630	220	9.0
Alluvium/weathered granite	1	-	-	23	?

Clearly the Permo-Triassic limestones have the highest transmissivity with the Silurian, Carboniferous and Triassic sandstones all of moderate potential, the Triassic sandstones being the best of these three formations. It should be emphasised that the tests were probably carried out on the higher yielding wells only and that no allowance has been made for any failed or low yielding boreholes.

In order to convert the transmissivity values into well yields it is necessary to make two additional assumptions, firstly that only the better yielding wells were tested and that all other wells drilled but not tested would have a lower yield, and secondly that a drawdown of 20 m can be obtained in all boreholes. The second assumption may not be strictly realistic in a fractured aquifer where one fracture close to water table provides the total yield but it does allow a basis for comparison. Well yields at 20 m drawdown have been calculated using the specific capacity measured at the end of KPWRMS step tests. The KPWRMS specific capacity values, obtained from short step tests, are likely to be higher than those which would be determined from longer term tests. Well yield probabilities shown in Figure 2.2 may therefore be optimistic in terms of long term 'safe' pumping rates.

From Figure 2.2 it may be seen that 50 percent of boreholes drilled in Triassic sandstones should produce a yield of 4 litres per second (53 gpm). The corresponding yields for the Permo-Triassic limestones, Silurian shales and the Carboniferous shales and sandstones are 9, 3 and 1 litres per second (119, 39 and 13 gpm) respectively. It is of interest to note that the distributions of yield values in the Permo-Triassic limestones and Carboniferous shales are similar whereas the Triassic and Silurian distributions appear to have a greater spread.

Tables 2.5, 2.6 and 2.7 list the allocated drilling areas (identified by kampong, main kampong or mukim), together with the formations to be drilled, numbers of wells and estimated safe yields. The number of wells to be drilled in each area may be adjusted as drilling progresses and more information is gained.



Table 2.5 Prognostic Supply Potential, North Kedah

Drilling area	Formation	Average yield (30 m well) (gpm)	No. of wells (1)	Total yield (gpd) (2)
Kubor Panjang	Carboniferous	15 1.14	2	36 000
	Triassic	30 2.27	3	108 000
Pdg. Sanai	Triassic	30	4	144 000
Binjal	Carboniferous	15	5	90 000
Wang Tepus	Carboniferous	15	3	54 000
Pokok Sena	Carboniferous	15	5	90 000
Kodiang	Carboniferous	15	5	90 000
	Permo-Triassic	125 9.48	5	750 000
Changloon	Carboniferous	15	5	90 000
Padang Temak	Triassic	30	4	144 000
Guar Chempedak	Silurian/Cambrian	20	4	96 000
Padang Pusing	Carboniferous	15	3	54 000
Kg. Bukit	Triassic	30	4	144 000
Gelong	Carboniferous	15	5	90 000
Kg. Peng Besar	Triassic	30	4	144 000
Kg. Pokok Asam	Triassic	30	5	180 000
Kg. Mesjid Lama	Triassic	30	3	108 000
Kg. Jeneri	Granite	40	5	240 000
Kg Whatt	Silurian	20	5	120 000

Note: 1. Allocated by JKR Kedah, total 79  
 2. For 20 hours pumping per day

Notes: 1. Estimated by SBC, total 97  
 2. For 20 hours pumping per day

Table 2.7 Prognostic Supply Potential, Perlis

Table 2.6 Prognostic Supply Potential, Central and South Kedah

Drilling Area	Formation	Average yield (30m well) (gpm)	No. of wells (1)	Total yield (gpd) (2)
Kg. Tambun Tulang	Permo-Triassic	125	2	300 000
Serdang	Triassic	30	5	180 000
Selama	Silurian	20	5	120 000
Kg. S. Puntis	Triassic	30	5	180 000
Kg. S. Taka	Silurian	20	5	120 000
Junjong	Granite	40	4	230 000
Mahang	Silurian	20	5	144 000
Kulim	Granite	40	5	230 000
Kelang Lama	Granite	40	2	192 000
Kg. Kubang Gajah	Triassic	30	2	72 000
Lunas	Triassic	30	5	180 000
Kg. Sedim	Silurian	20	5	120 000
Ladang United Petani	Silurian	20	5	120 000
Ladang Vengadasalam	Silurian	20	4	96 000
Selembu	Silurian	20	5	120 000
K. Kupang	Granite	40	2	96 000
Kg. Bok Kelang	Silurian	20	2	48 000
Ladang Sungkap Para	Silurian	20	4	96 000
Bedong	Silurian	20	4	96 000
Semeling	Granite	40	4	192 000
Kg. Begia	Granite	40	2	96 000
Paya Kerohit	Silurian	20	2	48 000
Padang Lembu	Silurian	20	5	120 000
Bt. Tok Panjang	Ordovician	55	1	55 000
Kg. Belukar	Carboniferous	15	1	15 000
Anak Che Long	Ordovician	55	1	55 000

- Notes: 1. Estimated by GDC, total 87  
 2. For 20 hours pumping per day

Table 2.7 Prognostic Supply Potential, Perlis (continued)

Drilling Area	Formation	Average yield (30m well) (gpm)	No. of wells (1)	Total yield (gpd) (2)
Simpang Empat	Ordovician	55	2	132 000
Kg. Tambun Tulang	Permo-Triassic	125	2	300 000
Arau	Permo-Triassic	125	3	450 000
Kg. Telok	Ordovician	55	2	132 000
Kg. Tebok	Carboniferous	15	1	18 000
Kg. Surau	Carboniferous	15	1	18 000
Kg. Santan	Carboniferous	15	1	18 000
Kg. A. Redah	Carboniferous	15	1	18 000
Kg. Panggau	Ordovician	55	1	66 000
Kg. Behor Mengkuang	Carboniferous	15	1	18 000
Kg. Kubang Gajah	Carboniferous	15	2	36 000
Kg. Gial	Permo-Triassic	125	1	150 000
Kg. Kerisek	Carboniferous	15	1	18 000
Kg. Mata Ayer	Carboniferous	15	1	18 000
Kg. Ulu Pauh	Carboniferous	15	1	18 000
Kg. Rambai	Carboniferous	15	1	18 000
Kg. Guar Nangka	Carboniferous	15	1	18 000
Kg. Kok Kelang	Carboniferous	15	1	18 000
Kg. Chuping				
Balek Bukit	Permo-Triassic	125	1	150 000
Bt. Jelutong	Carboniferous	15	1	18 000
Kg. Panggas	Carboniferous	15	1	18 000
Paya Kerchit	Permo-Triassic	125	2	300 000
Kg. Tanjong	Permo-Triassic	125	1	150 000
Bt. Tok Panjang	Ordovician	55	1	66 000
Kg. Belukar	Carboniferous	15	1	18 000
Anak Che Long	Ordovician	55	1	66 000

Table 2.7 Prognostic Supply Potential, Perlis (continued)

Well depths will vary according to subsurface conditions. The yield estimates are average values based on analysis of KPMNS well yields.

They are more conservative than yields implied by Figure 2.3 as allowances are made for long term pumping plus a possible decrease in permeability with depth in fractured rocks.

Relationship between yield and drawdown. For these estimates are for 30 m deep wells; well depths in the KPMNS study ranged from

Drilling Area	Formation	Average yield (30m well) (gpm)	No. of wells (1)	Total yield (gpd) (2)
Batu Hampar	Permo-Triassic	125	2	300 000
Kg. Guar Panji	Carboniferous	15	1	18 000
Kg. Titi Tampang	Permo-Triassic	125	1	150 000
Kg. Kubang Tiga	Carboniferous	15	1	18 000
Kg. S. Buloh	Carboniferous	15	1	18 000
Belukar Sering	Carboniferous	15	1	18 000
Kg. Tasoh	Carboniferous	15	1	18 000
Kg. Titi Tinggi Hilir	Carboniferous	15	1	18 000
Kg. Titi Tinggi Ulu	Carboniferous	15	1	18 000
Kg. Chantek	Carboniferous	15	1	18 000
Kg. Kelian	Ordovician	55	2	132 000
Bt. Rongit	Ordovician	55	1	66 000
Bt. Rongit	Cambrian	15	1	18 000

Notes: 1. Allocated by JKR Perlis, total 48  
 2. For 20 hours pumping per day

Using the yield probabilities in Figure 2.3 for the Triassic, Permo-Triassic, Silurian and Carboniferous formations, the number of boreholes giving yields in five selected ranges has been estimated (Table 2.8). The estimates are based on the assumption that a long-term drawdown of 20 m can be attained in each borehole. The average hand pump yield from a depth of 20 m is taken as 0.4 l/s (160 gpd); 0.2 l/s (80 gpd) is taken as the minimum mechanical pump yield. It is apparent from Table 2.8 that if the present project's drilling success rate is comparable to that of KPMNS, then probably 5 percent of the boreholes drilled in formations considered are likely to produce insufficient water for a hand pump.

About 80 percent of the boreholes drilled in these formations should

Well depths will vary according to subsurface conditions. The yield estimates are average values based on analysis of KPWRMS well yields. They are more conservative than yields implied by Figure 2.2 as allowance has been made for long term pumping plus a possible reduction in permeability with depth in fractured rocks which gives a non-linear relationship between yield and drawdown. Furthermore, these estimates are for 30 m deep wells; well depths in the KPWRMS study ranged from 6 to 82 m, average 38 m.

Actual well yields may vary considerably from those indicated in Tables 2.5, 2.6 and 2.7 as shown in Table 2.8.

Table 2.8 Analysis of KPWRMS Well Yields

Formation	No of wells	Yield range (gpm)	Average yield (gpm)
Triassic	29	20-140	30
Permo-Triassic	19	10-150	125
Carboniferous	31	0-70	15
Silurian	8	0-40	20
Ordovician	3	15-150	55
Cambrian	-	-	15
Granite	19	10-100	40

Using the yield probabilities in Figure 2.2 for the Triassic, Permo-Triassic, Silurian and Carboniferous formations, the number of boreholes giving yields in five selected ranges has been estimated (Table 2.9). The estimates are based on the assumption that a longterm drawdown of 20 m can be attained in each borehole. The average hand pump yield from a depth of 20 m is taken as 0.1 l/s (1.3 gpm); 0.5 l/s (6.6 gpm) is taken as the minimum mechanical pump yield. It is apparent from Table 2.9 that if the present project's drilling success rate is comparable to that of KPWRMS, then possibly 5 percent of the boreholes drilled in formations considered are likely to produce insufficient water for a hand pump.

About 80 percent of the boreholes drilled in these formations should produce sufficient water for a mechanical pump to be considered.

Table 2.9 Estimated Well Yields

Formation	No. of boreholes	No. of boreholes yielding: (l/s)				
		<0.1	0.1-0.5	0.5-2.5	2.5-10.0	10.0-20.0
Triassic sandstones	44	-	3	13	18	6
Permo-Triassic limestones	18	-	1	3	5	9
Carboniferous shales	57	7	14	18	12	6
Silurian shales	58	1	4	17	22	10
Total	177	8	22	51	57	32
%age of total	100%	5%	12%	29%	32%	18%

### 2.3 Site Selection

Selection of drilling sites is rarely determined by solely hydrogeological factors. Such factors as ease of access of rig to the site, and ease of procurement of permission to drill frequently constrain the choice of site. In addition consideration has to be given to the conflict that a well may only produce sufficient for a hand pump in which case a central position within a village would be advantageous or the well may produce sufficient for a mechanical pump in which case some location near a pipeline (existing or proposed) or possible storage tank location would be preferred. The actual location can be decided only after consideration of these factors in the light of the hydrogeological conditions.

The present working hypothesis for locating wells in consolidated formations is that :

- some formations yield more water than others, for example yields in the Triassic sandstone are generally better than in the Carboniferous shales; this is a lithological control
- higher yielding wells are located near to fractures, faults and joints which are obscured by alluvium or laterite on the ground but which are apparent on aerial photography as linear positive and negative features and can be detected below the

overburden by constant separation resistivity traverses;

this is a structural control.

Other considerations are that groundwater levels are closer to ground level along valleys than below hills and that coarse alluvium overlying the formation could produce an additional, though possibly seasonal, supply to the well.

There are several unknown factors concerned with selecting drilling sites near photo lineaments. Although various studies have shown that there is a correlation between the number of lineaments intersecting near a well site and the yield of the well, there is little evidence to show how far the site can be from the lineaments before low well yields are experienced.

However, it is suspected that the width of the zones of fracturing is at least between 10 and 100 metres wide. Another unknown factor is whether some lineament directions yield more water than others. Lineaments originating as tension fractures would be expected to be more open than those caused by compression; the tension fractures may however be those more susceptible to later infilling.

Evidence from the drilling carried out in April and May 1981 indicates that sandstones produce better yields than fractured shales and that fractured siltstones produce as well as fractured sandstones. These results are from drilling operations only and require to be confirmed by pumping tests.

Site selection is expected to be aided by resistivity surveys. Initial surveys, both soundings and constant separation traverses, would be made at already drilled and preferably tested wells so that preliminary calibration can be carried out. Resistivity surveys could then become an integral part of site selection. It may however become apparent with experience gained that insufficient resistivity contrast exists in some formations for the tool to be of value; in this event, surveys will be restricted to appropriate locations only. The KPWRMS apparently drilled on both resistive and conductive features, site selection being controlled by photo lineaments.

## Penetration Rate

Resistivity surveys for this project will include depth sounding to establish layering followed by constant separation traverses at a distance selected from the depth sounding. If time allows, a grid of measurements will be established which will allow contouring of the derived transversal resistance (thickness x resistance) values.

The procedure for site selection will thus involve the following operations

- desk study of geological maps, existing groundwater data and aerial photographs. Lithological and structural interpretation will be made on the photographs using the stereoscope and any photo lineaments will be identified
- site visit and field checking of any formation outcrops and existing boreholes and wells. Frequently photo lineaments are not visible in the field but any confusion with such features as fences can be cleared at this stage.

Possibly the most useful hydrogeological activity will be the process of continual analysis of the data. This process should allow the most significant fracture directions (in terms of groundwater potential) to be identified and also the better yielding lithologies. An assessment of all data towards the completion of the drilling activities should provide useful criteria for future site selection.

## 2.4 Well Design and Construction

### 2.4.1 Aids to Well Design

During drilling, four sources of information will be used to assess the formations penetrated in order to select suitable well designs:

- drilling cuttings
- penetration rate
- water show
- geophysical logging

#### Drilling cuttings

Samples of the formations being drilled will be collected at 1 to 3 metre intervals and analysed. The percentages of various cutting sizes and shapes will be recorded together with the percentages of the different rock types. This record will form the percentage log, which is a direct record of the samples as collected, and at this stage makes no allowance for the mixing of samples in the hole.

## Penetration Rate

Rate of drilling progress will be recorded at 1 to 3 metre intervals. This, after allowing for qualifying conditions such as method of drilling, size of bit etc, provides useful indirect information on the formations penetrated. In fractured formations a reduction in penetration rate usually indicates a decrease in the degree of fracturing.

## Water Show

This is the water produced whilst air drilling in saturated aquifers. The water can be channelled into a ditch and directed over a rectangular or V-notch plate weir. Measurements of flow over such weirs give good estimates of the discharge during drilling. During air-drilling, discharge will increase, to some degree, with increase in depth of submergence of the drill bit below the water level, but significant increases in discharge will usually indicate the interception of water yielding fractures. When drilling continues without any increase in discharge then this usually indicates that the rock penetrated does not contain any water yielding fractures. This information, together with reduction in penetration rate and the absence of water-seepage stained fracture faces in the drilling cuttings, provides the most obvious guide for deciding on final well depth. Measurements of electrical conductivity of the water show during drilling will usually be taken to provide information on water quality distribution in the formations penetrated.

## Geophysical logging

Geophysical borehole logging tools can provide useful additional information for assessment of formations penetrated. The following tools are considered most suitable for this project :

- electric logger (resistivity and spontaneous potential)

This helps to define bed thickness and location of permeable alluvial aquifers and will indicate changes in water quality with depth.

- gamma ray logger

This is the best tool for defining shaley and clayey horizons which are generally poor aquifers and can be used in cased boreholes.

Table 2.10 Available Drilling Bit and Casing Diameters (continued)

Item	Description	Diameter
- caliper	This records borehole diameter and therefore gives a positive indication of the location, intensity and size of water yielding fractures and cavities.	100
- electrical conductivity/temperature logger	This defines variation in water quality with depth and, correlated with the caliper log, confirms inflow from fractures	191

#### 2.4.2 Depth and Diameter Limitations

Depth of drilling envisaged in the Agreement is expected to average 30 m per borehole. At each hole drilling will proceed with the objective of attaining maximum well yield. In an aquifer whose total thickness probably exceeds 30 m this objective implies maximum depth. The requirement of 250 boreholes within a period of 32 rig months sets a constraint on the amount of time that the rig can be operated at any one site. Thus the actual depth of drilling will be a matter of judgement considering penetration rates, likely well yield and the overall programme.

At present, well sizes are restricted by the materials and equipment available; drilling bit and casing diameters are given in Table 2.10.

Table 2.10 Available Drilling Bit and Casing Diameters

Item	Description	Diameter		
		Inches	mm	
Drilling bits:	Drag bits	5 $\frac{5}{8}$	143	
		7 $\frac{3}{4}$	197	
		9	229	
	Rock bits	13	330	
		5 $\frac{5}{8}$	143	
		7 $\frac{7}{8}$	194	
		9 $\frac{7}{8}$	251	
		13	330	
		Button bits	5	127
			5 $\frac{1}{2}$	140
8	203			
		8 $\frac{1}{2}$	216	

Table 2.10 Available Drilling Bit and Casing Diameters (continued)

Item	Description		Diameter	
			Inches	mm
Casing	uPVC class E (plain and slotted)	ID	5½	146
		OD	6½	168
	socket	OD	7½	191
	steel, temporary	ID	10	255
		OD	10½	273

A significant restriction is the internal diameter of the 6 inch uPVC class E pipe. Nominal casing diameters for other materials normally refer to the internal diameter but, in the case of uPVC casing, the internal diameter is less than the nominal diameter. Thus pumps normally suitable for 6 inch boreholes cannot be used in the project wells since the tolerance between overall pump diameter and casing internal diameter is reduced beyond safe limits.

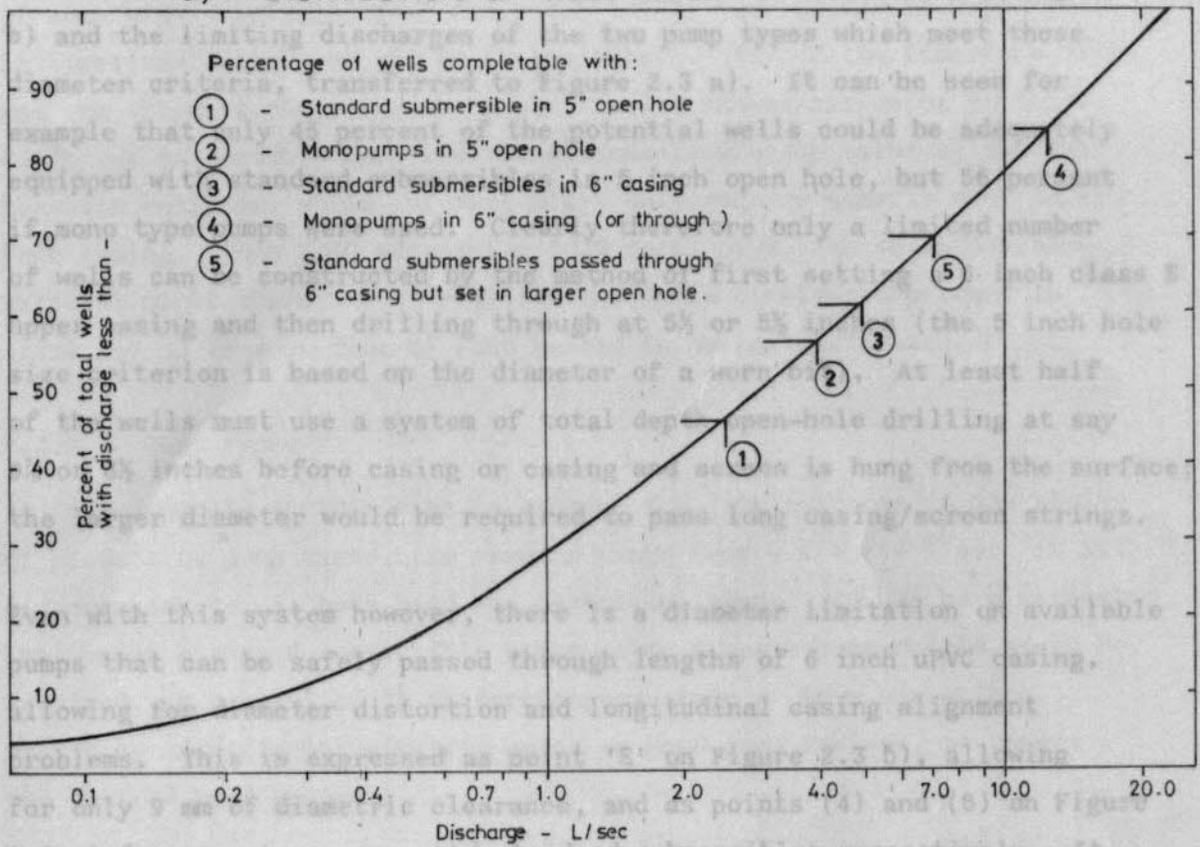
It is of interest to study the range of available pump types and diameters and compare them with the casing and choice of hole completion diameters available to the project, over the probable discharge spectrum that might be achieved. Figure 2.3 a) shows the probable percentage occurrence of wells with discharges less than the value on the horizontal scale, based on Figure 2.2 and Table 2.9. It can be seen that 50 percent of wells can be expected to be in the range 0.8 to 9.0 l/sec, but 25 percent may be in each of the upper and low ranges with extreme discharges of 0.1 and 24.0 l/sec.

Figure 2.3 b) shows the discharge capacity and respective maximum overall diameters of a group of manufacturer's standard electrical submersible units (Sumo, Pleuger and Grundfos) together with the sizes of mono-type positive displacement, shaft-driven borehole pumps. Now, in setting a submersible near the bottom of an open-hole or cased well, an absolute minimum clearance of 15 mm between the two diameters is essential for water passage and an even greater clearance ( of up to 50 mm) is desirable to allow for jamming and borehole alignment. A reduced clearance of say 9 mm might be acceptable for passing a pump through a short upper casing into a larger open hole below.

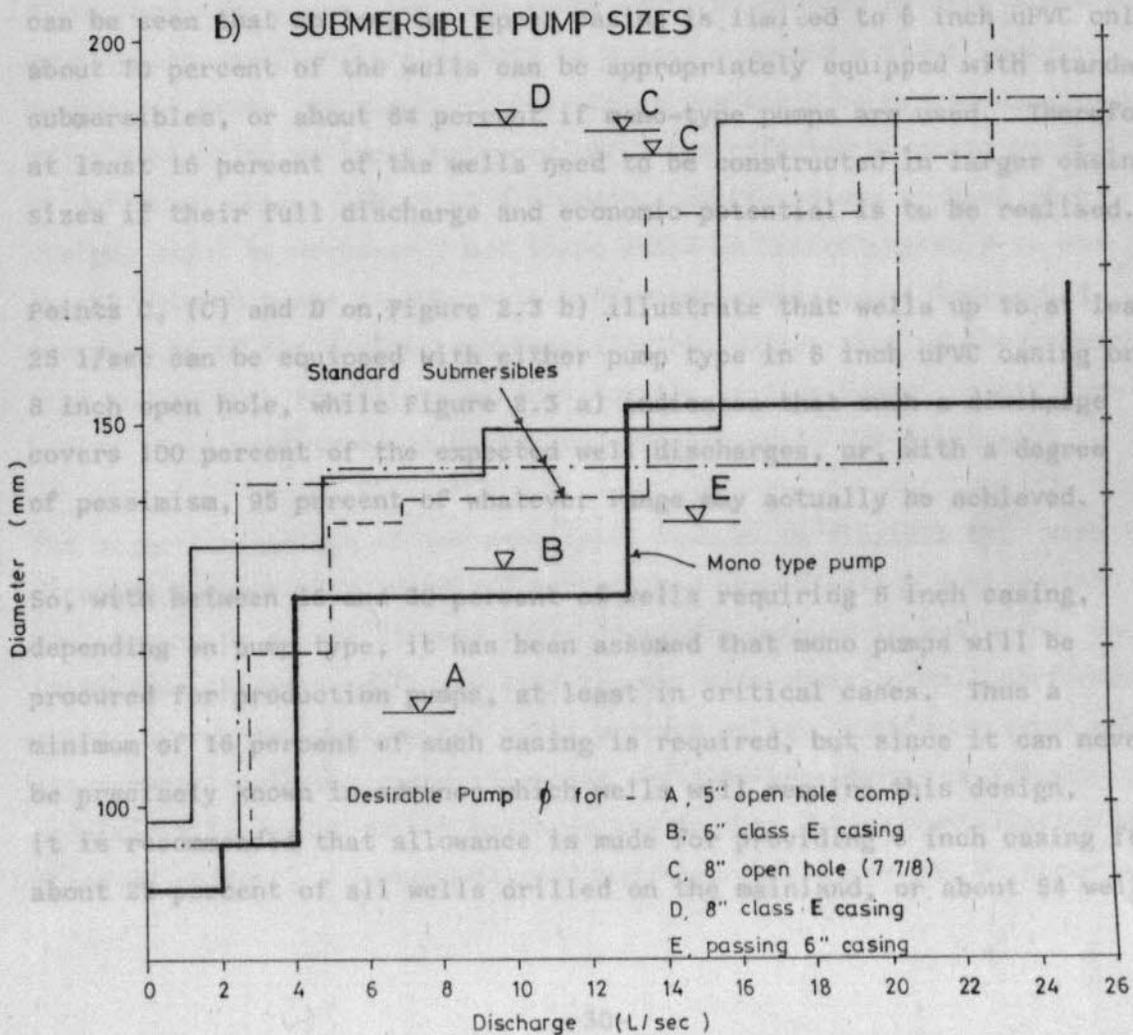
FIGURE 2.3

WELL AND PUMP DIAMETERS

a) DISTRIBUTION OF WELL SIZES



b) SUBMERSIBLE PUMP SIZES



Thus the recommended maximum pump diameters for 6 inch class E uPVC casing and for various open hole completion sizes have been marked onto Figure 2.3 b) and the limiting discharges of the two pump types which meet those diameter criteria, transferred to Figure 2.3 a). It can be seen for example that only 45 percent of the potential wells could be adequately equipped with standard submersibles in 5 inch open hole, but 56 percent if mono type pumps were used. Clearly therefore only a limited number of wells can be constructed by the method of first setting a 6 inch class E upper casing and then drilling through at  $5\frac{1}{4}$  or  $5\frac{3}{4}$  inches (the 5 inch hole size criterion is based on the diameter of a worn bit). At least half of the wells must use a system of total depth open-hole drilling at say  $9\frac{1}{2}$  or  $8\frac{1}{2}$  inches before casing or casing and screen is hung from the surface; the larger diameter would be required to pass long casing/screen strings.

Even with this system however, there is a diameter limitation on available pumps that can be safely passed through lengths of 6 inch uPVC casing, allowing for diameter distortion and longitudinal casing alignment problems. This is expressed as point 'E' on Figure 2.3 b), allowing for only 9 mm of diametric clearance, and as points (4) and (5) on Figure 2.3 a) for mono-type pumps and standard submersibles respectively. It can be seen that so long as upper casing is limited to 6 inch uPVC only about 70 percent of the wells can be appropriately equipped with standard submersibles, or about 84 percent if mono-type pumps are used. Therefore at least 16 percent of the wells need to be constructed in larger casing sizes if their full discharge and economic potential is to be realised.

Points C, (C) and D on Figure 2.3 b) illustrate that wells up to at least 25 l/sec can be equipped with either pump type in 8 inch uPVC casing or 8 inch open hole, while Figure 2.3 a) indicates that such a discharge covers 100 percent of the expected well discharges, or, with a degree of pessimism, 95 percent of whatever range may actually be achieved.

So, with between 16 and 30 percent of wells requiring 8 inch casing, depending on pump type, it has been assumed that mono pumps will be procured for production pumps, at least in critical cases. Thus a minimum of 16 percent of such casing is required, but since it can never be precisely known in advance which wells will require this design, it is recommended that allowance is made for providing 8 inch casing for about 25 percent of all wells drilled on the mainland, or about 54 wells.

Of such high-discharge wells above 8.5 l/sec, some 10 can be expected in limestone formations and 44 in the others. All of the limestone wells and one third of the remainder might require casing/screening to total depth due to unstable hard rock conditions leading to eventual partial borehole collapse, while the rest might only require some 10 m of upper hole casing. Some 1040 metres (or 3410 feet) of 8 inch casing/screen material might therefore be required and it is considered prudent to allow for up to 4000 feet of such casing in overall estimates.

#### 2.4.3 Pump Types

It is worthwhile at this time to examine the implications in the choice of production pump types. To cover a range from 0.1 to 24 l/sec, it will be necessary to use both hand and mechanical pumps. It has been estimated that using standard submersible pumps, some 9 basic pump models would be required, in a total of 25 different pump stage or trim variations, driven by 16 different electric motor or hand gear designs, to cover the desired head range,

Using mono type pumps, the same range could be covered by only 5 basic models, the smallest serving both as a hand pump and a low-discharge mechanical pump. No stage or trim variations would be required, output adjustment being entirely by speed variation effected by drive pulleys of different sizes. About 13 different electric motors or hand gear designs might be necessary, but these would be interchangeable to some extent between pumps to cope with performance variation. They would moreover be of the ordinary surface electric rather than of the submersible type and so more readily maintained locally in Alor Setar, rather than having to be sent to Kuala Lumpur or even Singapore for overhaul.

The biggest advantage of the mono types however is flexibility. With standard submersibles, detailed performance specification must go into procurement to ensure 25 pump types correctly matched to wells and, once installed, there is no flexibility to cope with changing well performances except by exchanging complete units between wells. With mono types only approximate performance specification would be necessary for 5 basic models, whilst exact output matching can be done during installation by speed adjustment. Subsequent well performance changes can be coped with

by further speed adjustment at the minor end, or at the major end by exchanging surface electric motors only between units.

There are certain operational advantages also for the mono types. They are less susceptible to damage from overpumping and drawing in air which can overheat or result in bearing damage with submersibles. They are not prone to cable damage which can result from vibrational movement of pumps installed in open-hole and similarly are less prone to jamming damage should partial collapse of open-hole material occur, requiring pump pull out and hole cleaning.

These advantages, on top of the fact that they are generally slimmer overall for a given discharge in the pertinent range, makes them worthwhile considering for production pumps.

#### 2.4.4 Well Designs

Project well designs need to be varied not only according to yield, but also to take account of the presence of saturated alluvial aquifer at shallow depth and of unstable fissured rock or caving shales in the hard rock yielding horizons. Standard designs to cope with these variations are illustrated in Figure 2.4; these fall into three discharge ranges, 0.1 to 2.5 l/s (1.3 to 33 gpm), 2.5 to 8.5 l/s (33 to 113 gpm) and 8.5 to 24.0 l/s (113 to 320 gpm). Wells in the range 0.1 to 0.4 l/s (1.3 to 5.2 gpm) would be equipped with hand pumps.

All wells will be spudded with 5 $\frac{1}{8}$  inch roller or drag bits through the alluvial overburden to establish rock head. Sampling during this operation will establish the existence of potential yielding horizons in the alluvium which might provide additional well yield. Airlifting tests in drill pipe will establish the magnitude of such yield. The hole will then be reamed out to 12 $\frac{1}{4}$  or 13 inches to such depth necessary and temporary 10 inch steel conductor casing set.

Drilling will continue through this at diameters between 7 $\frac{7}{8}$  and 9 $\frac{1}{8}$  inches until stable hard rock is proven, the smaller diameters being used only where stable rock is expected at shallow depths; the depth drilled in this way will subsequently be cased or screened.

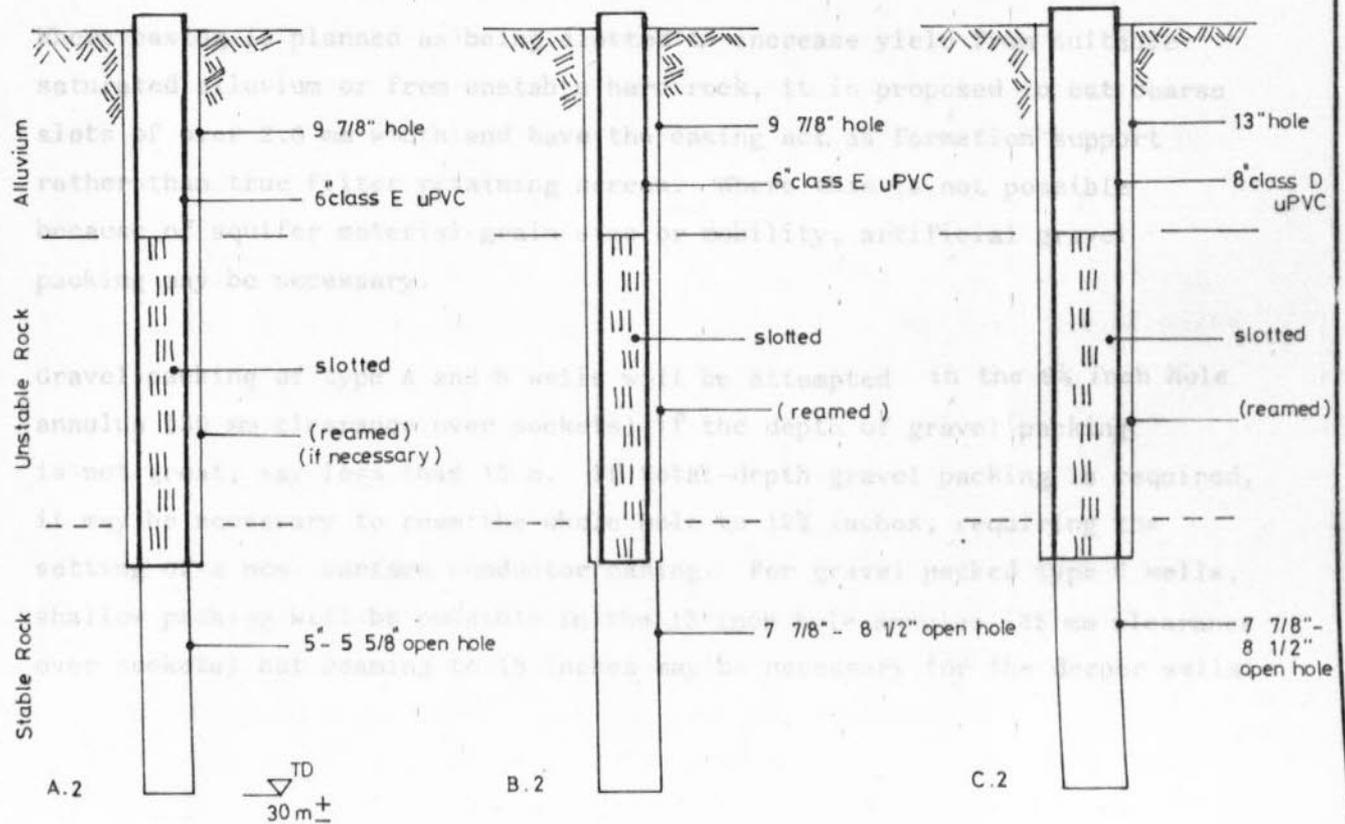
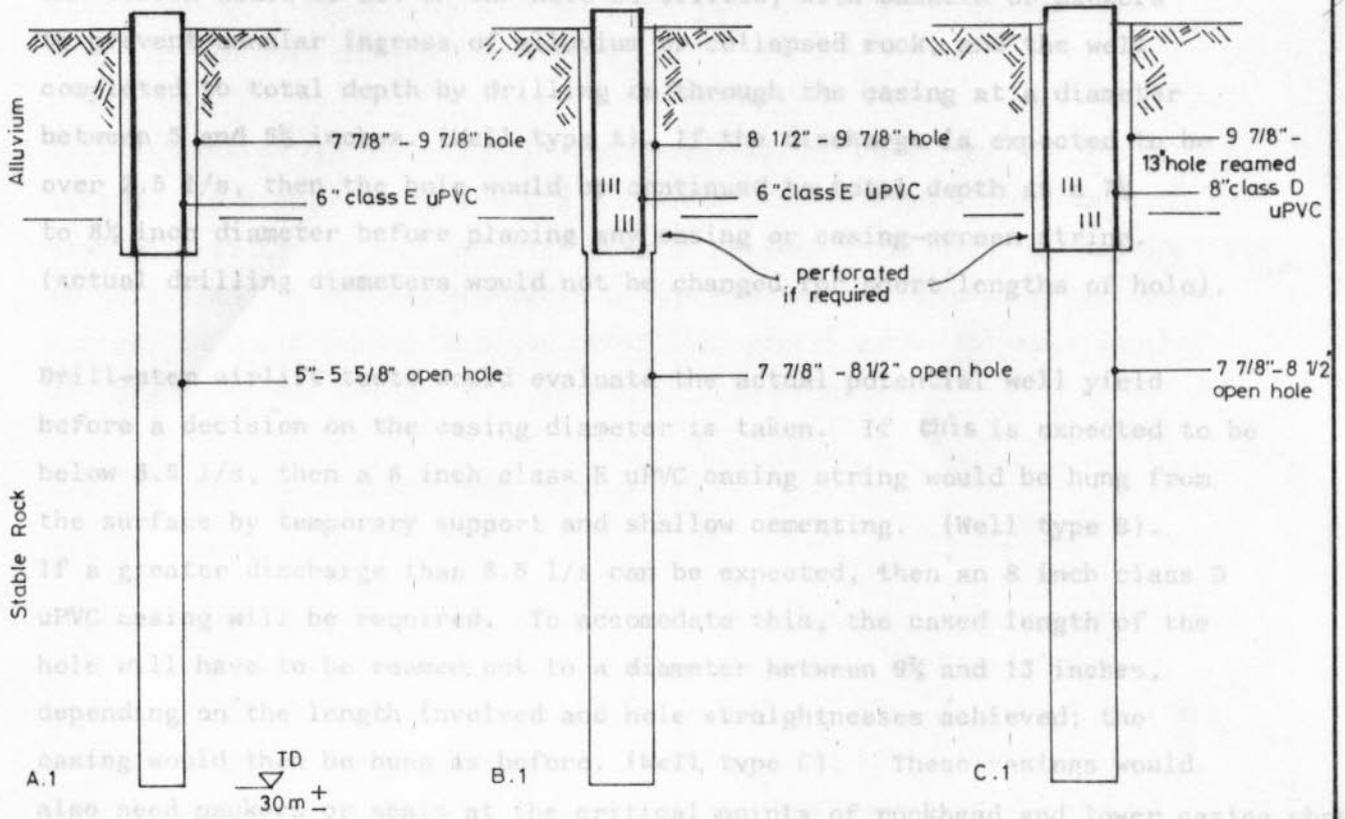
FIGURE 2.4

MAINLAND WELL DESIGNS

**WELL TYPE A**  
yield 0.1 to 2.5 l/s  
(1.3 to 33 gpm)

**WELL TYPE B**  
yield 2.5 to 8.5 l/s  
(33 to 113 gpm)

**WELL TYPE C**  
yield 8.5 to 24 l/s  
(113 to 320 gpm)



1 mm = 1" horizontally

Having reached stable hard rock, a decision would then be made on how to continue, related to likely well discharge. If a discharge below 2.5 l/s is expected, then a length of 6 inch class E uPVC casing or casing and screen would be set in the hole so drilled, with baskets or packers to prevent annular ingress of alluvium or collapsed rock, and the well completed to total depth by drilling on through the casing at a diameter between 5 and 5½ inches. (Well type A). If the discharge is expected to be over 2.5 l/s, then the hole would be continued to total depth at a 7½ to 8½ inch diameter before placing any casing or casing-screen string. (actual drilling diameters would not be changed for short lengths of hole).

Drill-stem airlift tests would evaluate the actual potential well yield before a decision on the casing diameter is taken. If this is expected to be below 8.5 l/s, then a 6 inch class E uPVC casing string would be hung from the surface by temporary support and shallow cementing. (Well type B). If a greater discharge than 8.5 l/s can be expected, then an 8 inch class D uPVC casing will be required. To accommodate this, the cased length of the hole will have to be reamed out to a diameter between 9½ and 13 inches, depending on the length involved and hole straightnesses achieved; the casing would then be hung as before. (Well type C). These casings would also need packers or seals at the critical points of rockhead and lower casing shoe.

Where casing is planned as being slotted to increase yield from suitable saturated alluvium or from unstable hard rock, it is proposed to cut coarse slots of over 2.0 mm width and have the casing act as formation support rather than true filter retaining screen. Where this is not possible because of aquifer material grain size or mobility, artificial gravel packing may be necessary.

Gravel packing of type A and B wells will be attempted in the 9½ inch hole annulus (30 mm clearance over sockets) if the depth of gravel packing is not great, say less than 15 m. If total-depth gravel packing is required, it may be necessary to ream the whole hole to 12½ inches, requiring the setting of a new surface conductor casing. For gravel packed type C wells, shallow packing will be possible in the 13 inch hole annulus (45 mm clearance over sockets) but reaming to 15 inches may be necessary for the deeper wells.

Development methods will include airlift pumping and backwashing, jetting (without airlifting) and surging with surge block, taking care not to collapse casing.

Gravel packs when installed will be surmounted by a short clay seal. The upper 2 metres of casing will in any case be cement sealed and a concrete plinth cast around the exposed casing, all after withdrawal of temporary steel casing. A steel cap with bolt and padlock security device will complete the well as shown in Figure 2.5.

This discussion has essentially considered slotted casing as the basic screen. However, some wire-wound stainless steel screen with 1 mm slots is available to the project and will be used, either in a telescope application or in a standard string, hopefully in the mode of the natural gravel pack system, to avoid having to place artificial gravel packs to large depths. The degree of use however will depend on circumstances.

## 2.5 Well Development and Testing

### 2.5.1 Development

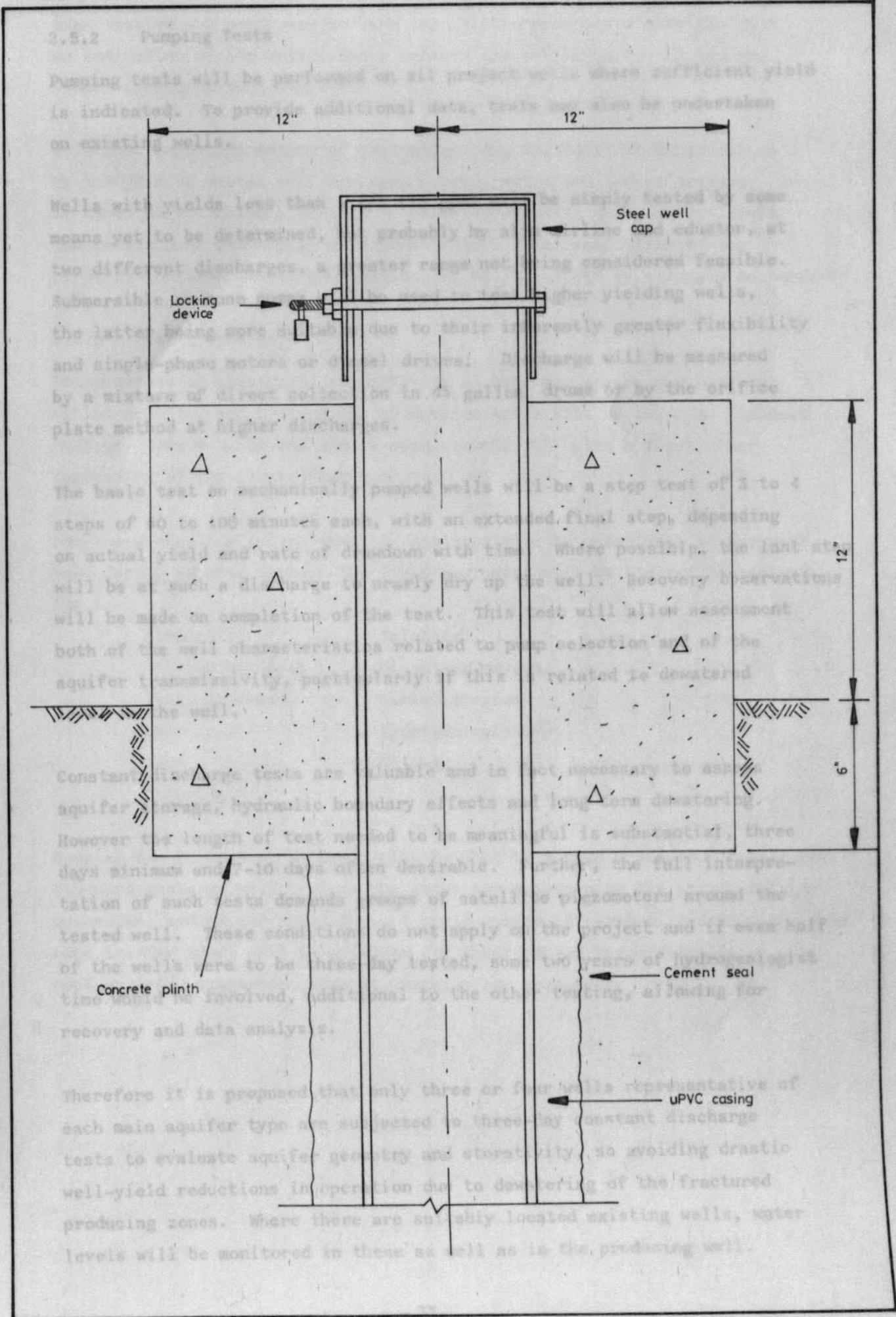
In hard rock aquifers rotary air flush or down-the-hole hammer air drilling will be employed. Providing sufficient air capacity (volume/pressure preferably 600-750 cfm/200-250 psi) is available, this method of drilling results in development and cleaning of the well whilst drilling. Thus only a few hours may be required for further development at the end of drilling. Development of fractured hard rock formation will be by airlift methods using the drill pipe and borehole sides or where necessary a separate eductor pipe and airline. Observation of airlift discharge during development will aid the assessment of well yield and the planning of the pumping test programme.

In some weaker rock aquifers or in limestone aquifers subject to drilling fluid circulation loss, rotary foam drilling will be employed. Development will again be generally by airlift methods but time spent on development will be inversely proportional to well yield, ie the poorer the aquifer the longer time required to clean/develop the hole.

In alluvial aquifers where water or foam drilling fluid is inadequate to support the well sides during drilling and construction, biodegradable mud (eg Revert) will be used. Development will have to be undertaken through the installed screen/slotted pipe. Development methods will include airlift pumping and backwashing, jetting (whilst airlifting) and surging with surge block, taking care not to collapse casings.

FIGURE 2.5

WELL HEAD COMPLETION DETAILS



## 2.5.2 Pumping Tests

Pumping tests will be performed on all project wells where sufficient yield is indicated. To provide additional data, tests may also be undertaken on existing wells.

Wells with yields less than 1 l/s (13 gpm) will be simply tested by some means yet to be determined, but probably by slim airline and eductor, at two different discharges, a greater range not being considered feasible. Submersible or mono pumps will be used to test higher yielding wells, the latter being more suitable due to their inherently greater flexibility and single-phase motors or diesel drives. Discharge will be measured by a mixture of direct collection in 45 gallon drums or by the orifice plate method at higher discharges.

The basic test on mechanically pumped wells will be a step test of 3 to 4 steps of 60 to 100 minutes each, with an extended final step, depending on actual yield and rate of drawdown with time. Where possible, the last step will be at such a discharge to nearly dry up the well. Recovery observations will be made on completion of the test. This test will allow assessment both of the well characteristics related to pump selection and of the aquifer transmissivity, particularly if this is related to dewatered level in the well.

Constant discharge tests are valuable and in fact necessary to assess aquifer storage, hydraulic boundary effects and long term dewatering. However the length of test needed to be meaningful is substantial, three days minimum and 7-10 days often desirable. Further, the full interpretation of such tests demands groups of satellite piezometers around the tested well. These conditions do not apply on the project and if even half of the wells were to be three-day tested, some two years of hydrogeologist time would be involved, additional to the other testing, allowing for recovery and data analysis.

Therefore it is proposed that only three or four wells representative of each main aquifer type are subjected to three-day constant discharge tests to evaluate aquifer geometry and storativity, so avoiding drastic well-yield reductions in operation due to dewatering of the fractured producing zones. Where there are suitably located existing wells, water levels will be monitored in these as well as in the producing well.

Even shallow dug wells can be used for this purpose since they can give an indication of the relationship between the shallow alluvial and the deeper fractured rock aquifers.

A further important method of evaluating long term aquifer behaviour is by analysis of annual well hydrograph data, which are few at present. It is hoped to establish a network of observation wells whose water levels can be measured monthly or more frequently. After completion of the project, continuation of such monitoring by JKR or GSM is strongly recommended.

### 2.5.3 Water Chemistry

Measurements of electrical conductivity at hand dug wells, springs and whilst drilling and testing the production wells will be taken as standard routine. These quick and simple measurements will give a first order impression of the groundwater quality.

For the production wells, chemical analyses will be undertaken at the well head during pumping tests. The field equipment will be limited to analysis for :

Alkalinity	Sulphate
Calcium hardness	Dissolved oxygen
Total hardness	Carbon dioxide
pH	Hydrogen sulphide
Iron	Nitrate
Chloride	

Samples for laboratory analysis will be sent to Penang Chemistry Department. Standard analyses will include the above parameters plus the anions calcium, magnesium, sodium and potassium. A small number of samples, possibly one from each aquifer type, will be selected for analysis for trace elements such as lead, manganese, arsenic, cadmium and mercury.

### 3. LANGKAWI ISLAND INVESTIGATIONS AND PRODUCTION WELLS

The project objectives for Langkawi are:

- identify potential groundwater resources to provide a surplus over a long term demand of 5 mgd
- locate well sites to supply 5 mgd
- develop wells for a 2.3 mgd first stage supply to meet the 1985 demand

#### 3.1 Hydrogeology

The geological succession and structure of Langkawi Island has been mapped in some detail by Jones. The geological map (1:63 360 scale) shows a succession of limestones and clastic rocks of Upper Cambrian to Permian age partly disturbed by Mesozoic granite intrusion. A simplified geological map is presented in Figure 3.1 and the hydrogeological significance of the various formations is shown in Table 3.1.

The sandy alluvium of the Sungai Melaka basin is likely to provide an aquifer of moderate permeability although its thickness is rather limited. Recovery tests and estimations of permeability using grain size analysis from 10 exploratory boreholes made by GSM indicate permeabilities in the range 1 to 200 m/day, averaging 25 m/day. Nine seismic spreads and information from 15 exploratory boreholes indicate that the aquifer becomes more arenaceous downstream and that saturated thickness increases from 17 to 25 m (total thickness about 30 m).

Zones of high permeability occur within the limestones of both the Setul and Chuping formations. Development of solution cavities can be seen in both formations; the extent of such development below ground level is a matter of some conjecture.

The Machinchang formation consists of conglomerates, grits, quartzites, subgraywackes, flags and shales. A similar though less arenaceous lithology is also found in the Singa formation outcropping around the granite in the eastern and southern parts of the island.

**FIGURE 3.1** Hydrogeological significance LANGKAWI: GEOLOGY

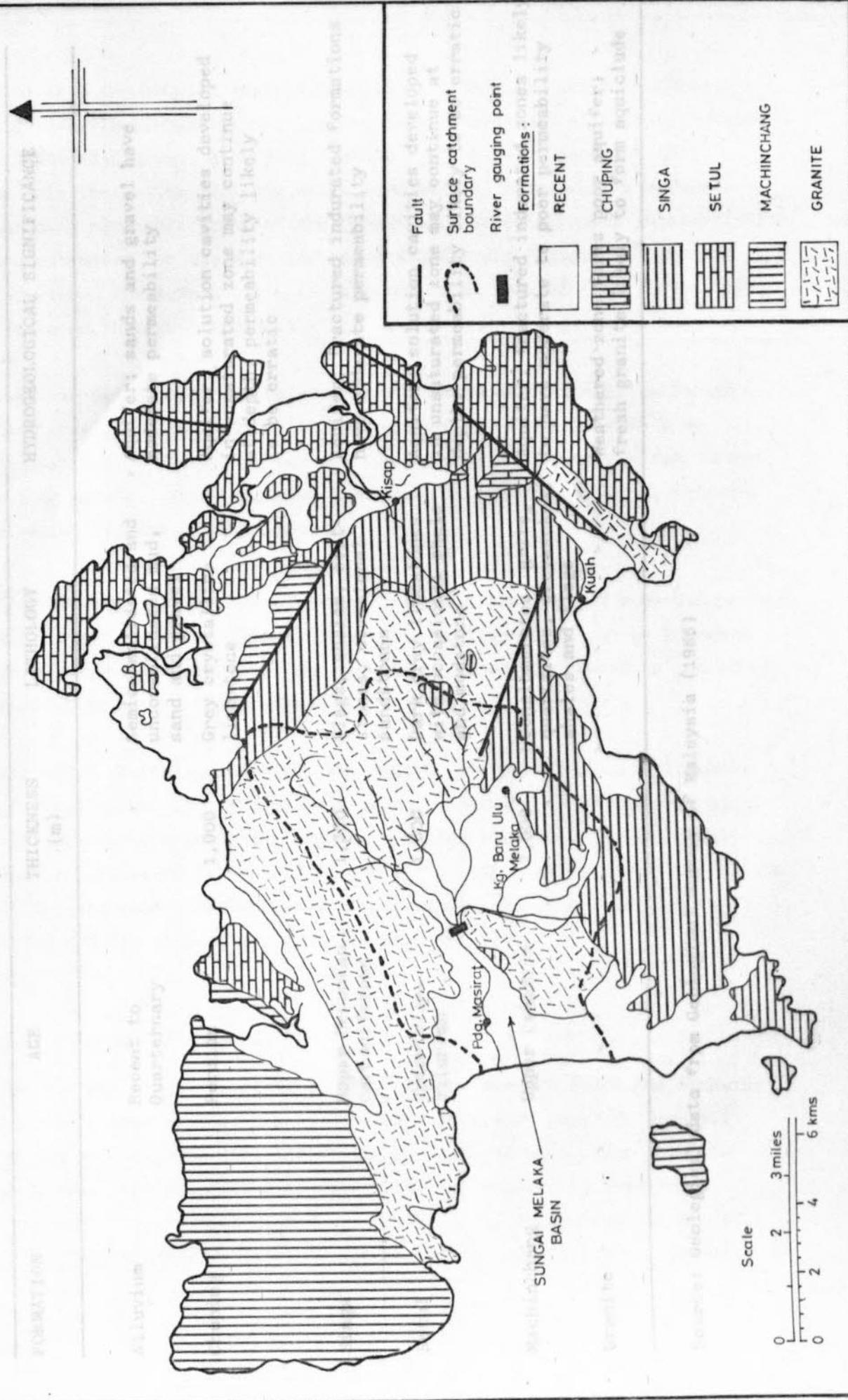


Table 3.1 Hydrogeological Significance of Geological Formations on Langkawi

FORMATION	AGE	THICKNESS (m)	LITHOLOGY	HYDROGEOLOGICAL SIGNIFICANCE
Alluvium	Recent to Quaternary		Semiconsolidated and unconsolidated mud, sand and gravel	Aquifer: sands and gravel have moderate permeability
Chuping	Permian	1,000	Grey crystalline limestone	Aquifer: solution cavities developed in unsaturated zone may continue at depth; permeability likely to be erratic
Singa	Upper Devonian - Carboniferous	1,350	Flags, shales, silt- stones, occasional sandstones	Aquifer: fractured indurated formations have moderate permeability
Setul	Ordovician - Silurian	1,500	Dark grey limestones with occasional shale and mudstone	Aquifer: solution cavities developed in unsaturated zone may continue at depth; permeability likely to be erratic
Machinchang	Upper Cambrian	2,000	Conglomerates, grits, quartzites, greywackes, shales and flags	Aquifer: fractured indurated zones likely to have moderate to poor permeability
Granite				Weathered zone forms poor aquifer; fresh granite likely to form aquiclude

Source: Geological data from Geological Survey of Malaysia (1966)

Data from the pumping tests conducted by KPWRMS and shown in Table 3.2 indicate permeabilities in the Singa shales and siltstones between 0.6 and 13.0 m/day, averaging 3 m/day. It is to be expected that, as only the better yielding wells were tested, these values reflect the more permeable parts of the formation. Somewhat lower permeabilities are estimated for the more indurated Machinchang formation. In both formations the permeability is expected to be derived from secondarily developed fractures and joints.

The intruded granite can be considered impermeable at depth although fractures and joints within 50 m of ground level may provide some permeability. Weathering reduces the formation to quartz grains within a clay matrix. Where the clay has been removed an aquifer of moderate permeability can be developed.

The GSM survey indicates a seaward hydraulic gradient of some 0.5 percent within the Sg. Melaka basin. A similar configuration can be expected throughout the island with the watertable generally providing a subdued reflection of the topography.

Sea water generally underlies the coastal strip particularly in areas of tidal estuaries. The central granite, forming an impermeable plug, will provide a barrier to complete seawater invasion. If the Ghyben-Herzberg relation is applied in the Sg. Melaka area the present location of the sea water/freshwater interface can be expected to intersect fresh granite at some 500 m inland from the sea.

### 3.2 Groundwater Resource

The average annual rainfall of 2520 mm provides the source of recharge to groundwater on the island. A large proportion runs off directly to the sea but some will infiltrate through the soil cover into the aquifers. The proportion of direct surface runoff will vary from catchment to catchment depending on soil type, vegetation and relief. A possible average would be 30 percent of the rainfall (ie 760 mm).

Table 3.2 Pumping Tests on Langkawi Island

Borehole No.	Location	Total depth (m)	Depth to SWL (m)	Discharge (l/s)	Drawdown (m)	Permeability (m/d)	Formation
491	Nyior Chabang	33	3.4	1.5	4.5	1.9	Alluvium/w. granite
492	Pg Masirat	36	4.1	5.3	13.7	2.2	Alluvium/carb. shale
564	Golf Club	24	2.0	0.5	15.0	0.6	Carb./siltstone
570	Kisap	24	5.2	7.9	8.6	13.0	Carb/shale
571	Mahsuri School	40.5	3.3	4.7	25.0	1.0	Carb/shale
574	Kisap	34	4.1	7.2	18.0	2.3	Carb/shale
576	Batu Dua Kisap	31	10.9	5.3	13.7	3.3	Carb/siltstone

Source: Kedah Perlis Water Resources Management Study

Abbreviations: SWL = standing water level

w = weathered

Carb = Carboniferous (Singa formation)

Infiltration will be discharged from the groundwater system as base flow to rivers, subsurface outflow to the sea, abstraction by wells and evapotranspiration. The Sg. Melaka is the only river with perennial baseflow; the remainder including the Sg. Kok, Sg. Chenang and Sg. Kisap dry up in drought periods between December and March. This suggests that the Sg. Melaka basin has the largest volume of groundwater storage.

There are a few springs on the island of which two appear to have some deepseated water contribution. The paucity of springs particularly in the limestone areas leads to the suggestion that subsurface outflow may occur into estuaries or as diffuse subsea seepage.

The volume of water currently abstracted from wells is small and probably does not exceed  $0.5 \text{ Mm}^3/\text{year}$ . The areas of high water table and of deep rooted vegetation suggest that evapotranspiration losses will be higher. If a possibly conservative estimate of 10 percent infiltration is made then the groundwater resource would amount to  $80 \text{ Mm}^3$  over the  $330 \text{ km}^2$  island.

This resource should be utilised initially in the catchment of highest permeability, greatest aquifer thickness, largest area and for which some data is presently available. The Sg. Melaka catchment covers some  $77.6 \text{ km}^2$  with some  $27 \text{ km}^2$  of alluvial sediments. GSM have carried out some preliminary investigations including seismic survey and exploratory drilling. The catchment should thus form the focus of further investigations. As discussed previously the Singa, Machinchang and limestone formations possess groundwater potential.

The Singa formation as indicated by the KPWRMS has a lower permeability than the alluvium and the thickness of the saturated fractured zone may be limited to a depth of 30 to 40 m. The area of outcrop is however fairly extensive, reasonably accessible and where the aquifer base is above sea level the formation has a moderate groundwater potential. Accordingly it is concluded that the Singa formation should be the next priority for investigation.

The limestones and the Machinchang formations are not recommended for further investigation in the present study for the following reasons:

- difficulty of access to the steep sided hills
- likely high failure rate in attempting to encounter permeable zones within the limestones
- possibility that the limestone and the Machinchang formations are underlain by saline water

### 3.3 Sungai Melaka Basin

The preliminary investigation by GSM included topographic levelling and water level measurements which allowed the construction of water table contours shown in Figure 3.2.

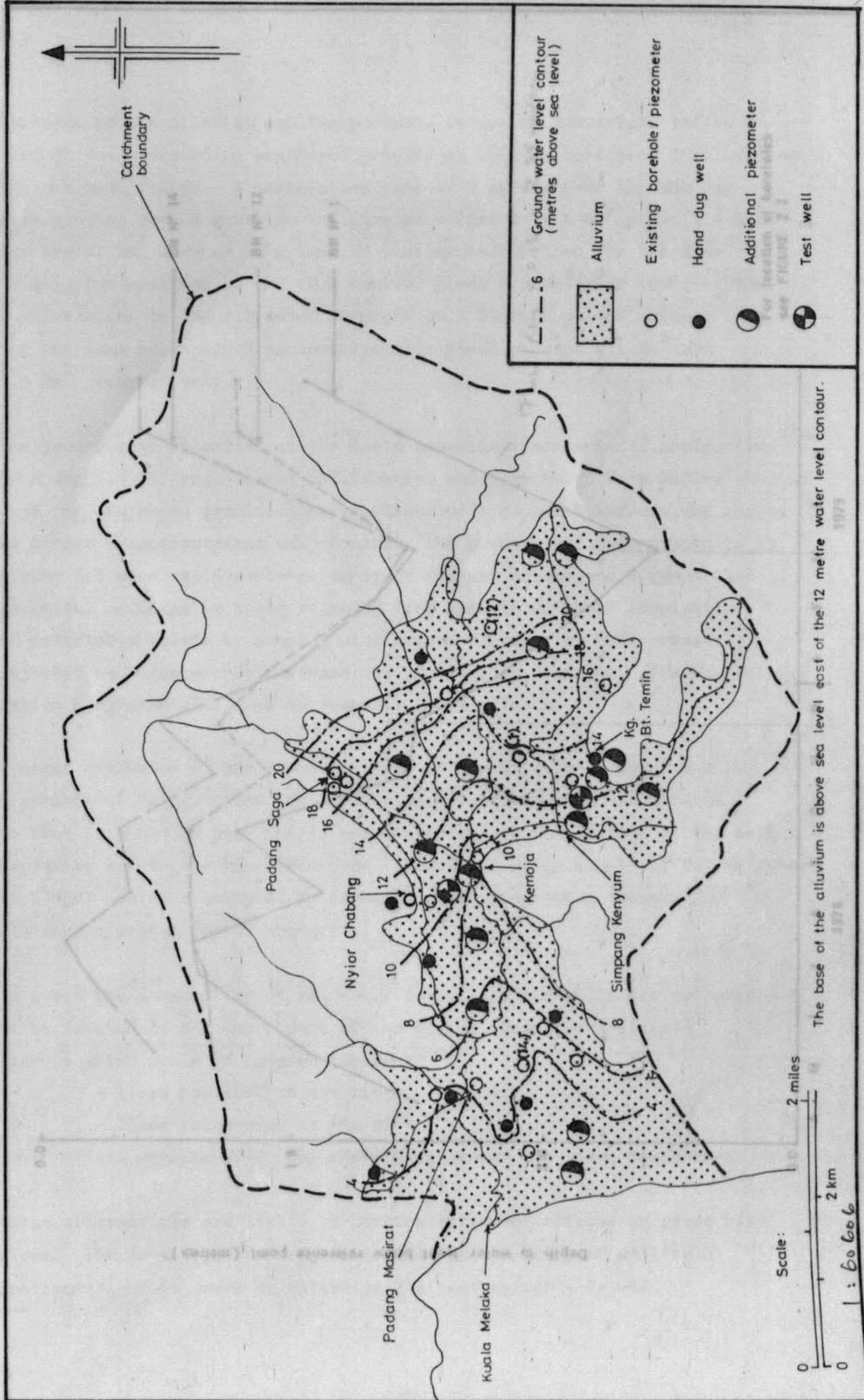
Hydrographs prepared from water level data for the period April 1978 to June 1979 are shown in Figure 3.3.

Surrounding and underlying the 27 km<sup>2</sup> of alluvium is granite, the upper zone of which is weathered. At some 4.5 km upstream from Kuala Melaka the granite outcrops on each side of the basin are only 750m apart, forming a possible constriction to groundwater flow. The water table contours however suggest that the constriction may not be total and that some flow occurs through the weathered granites. The contours also indicate that groundwater contributes to river flows within the basin. Field observation shows that groundwater levels are above river levels thus confirming this indication.

Subsurface throughflow upstream of the constriction formed by the granite outcrops has been estimated by applying the Darcy equation at the 12m contour. Using an estimated transmissivity of 500m<sup>2</sup>/day, 0.5 percent hydraulic gradient and a width of alluvium of 2.5 km, a subsurface throughflow estimate of 2.3 Mm<sup>3</sup>/year (1.4 mgd) was obtained. As the baseflow in the Sungai Melaka at the gauging site near the constriction is of the same order, it is likely that most of the subsurface throughflow discharges as river baseflow with little direct subsurface flow to the sea. Thus abstraction of groundwater within the basin will directly affect river baseflow.

FIGURE 3.2

SUNGAI MELAKA BASIN S. MELAKA BASIN



BOREHOLE HYDROGRAPHS - S. MELAKA BASIN

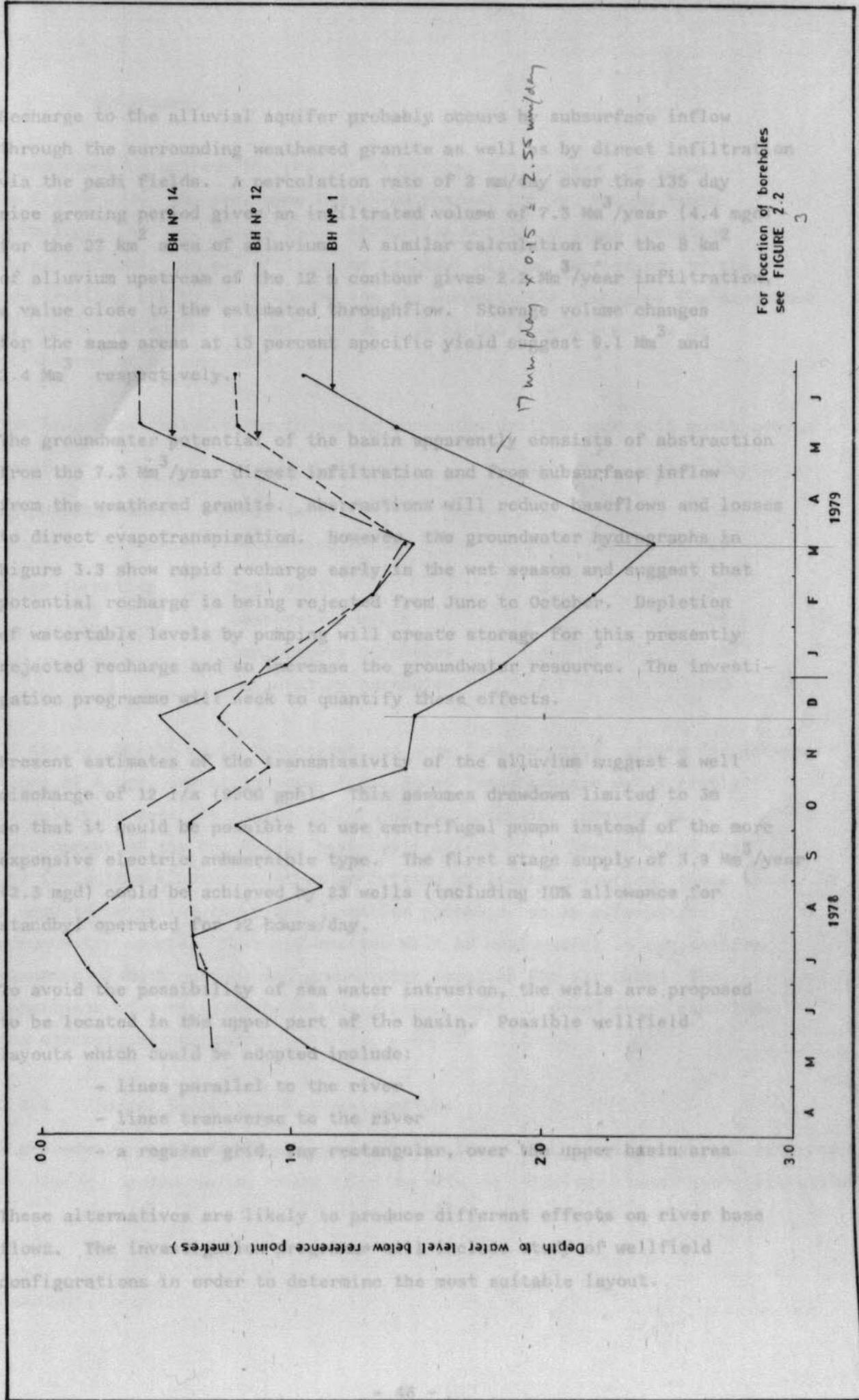


FIGURE 3.3

Recharge to the alluvial aquifer probably occurs by subsurface inflow through the surrounding weathered granite as well as by direct infiltration via the padi fields. A percolation rate of 2 mm/day over the 135 day rice growing period gives an infiltrated volume of  $7.3 \text{ Mm}^3/\text{year}$  (4.4 mgd) for the  $27 \text{ km}^2$  area of alluvium. A similar calculation for the  $8 \text{ km}^2$  of alluvium upstream of the 12 m contour gives  $2.2 \text{ Mm}^3/\text{year}$  infiltration, a value close to the estimated throughflow. Storage volume changes for the same areas at 15 percent specific yield suggest  $9.1 \text{ Mm}^3$  and  $2.4 \text{ Mm}^3$  respectively.

The groundwater potential of the basin apparently consists of abstraction from the  $7.3 \text{ Mm}^3/\text{year}$  direct infiltration and from subsurface inflow from the weathered granite. Abstractions will reduce baseflows and losses to direct evapotranspiration. However, the groundwater hydrographs in Figure 3.3 show rapid recharge early in the wet season and suggest that potential recharge is being rejected from June to October. Depletion of watertable levels by pumping will create storage for this presently rejected recharge and so increase the groundwater resource. The investigation programme will seek to quantify these effects.

Present estimates of the transmissivity of the alluvium suggest a well discharge of 12 l/s (9500 gph). This assumes drawdown limited to 3m so that it would be possible to use centrifugal pumps instead of the more expensive electric submersible type. The first stage supply of  $3.9 \text{ Mm}^3/\text{year}$  (2.3 mgd) could be achieved by 23 wells (including 10% allowance for standby) operated for 12 hours/day.

To avoid the possibility of sea water intrusion, the wells are proposed to be located in the upper part of the basin. Possible wellfield layouts which could be adopted include:

- lines parallel to the river
- lines transverse to the river

- a regular grid, say rectangular, over the upper basin area

These alternatives are likely to produce different effects on river base flows. The investigation programme will include study of wellfield configurations in order to determine the most suitable layout.

3.4 Programme

A programme to achieve the project objectives for Langkawi is shown in Figure 3.4. The programme has three phases: the Sg. Melaka basin investigations, Sg. Melaka basin production wells and Singa formation investigations. As all drilling on Langkawi will be carried out by the new drilling rig to be purchased for the project, the timing of the programme is controlled by the rig delivery date which has been assumed to be at the end of October 1981.

The programme includes the following boreholes drilled over a 5½ month period

Location	Description	No.	Approx. depth (m)
Sg. Melaka basin	Test wells	2	35
	Production wells	23	25
Singa formation	Test wells	2	35
	Observation wells	2	35
	Exploratory boreholes	6	35
	Exploratory boreholes	1	100

If the Sg. Melaka basin investigations show that potential exists for abstractions of 5 mgd, investigations of the Singa formation are not strictly necessary to meet the stated objectives for Langkawi. However as development of the Sg. Melaka basin will affect river baseflow and thus any irrigation schemes or other activities utilising riverflow, there is a need to establish the Singa formation potential as an alternative groundwater source. This information will be most useful in conjunctive planning of both surface and groundwater supplies for all uses. The importance of such planning at the present level of development cannot be too strongly emphasised.

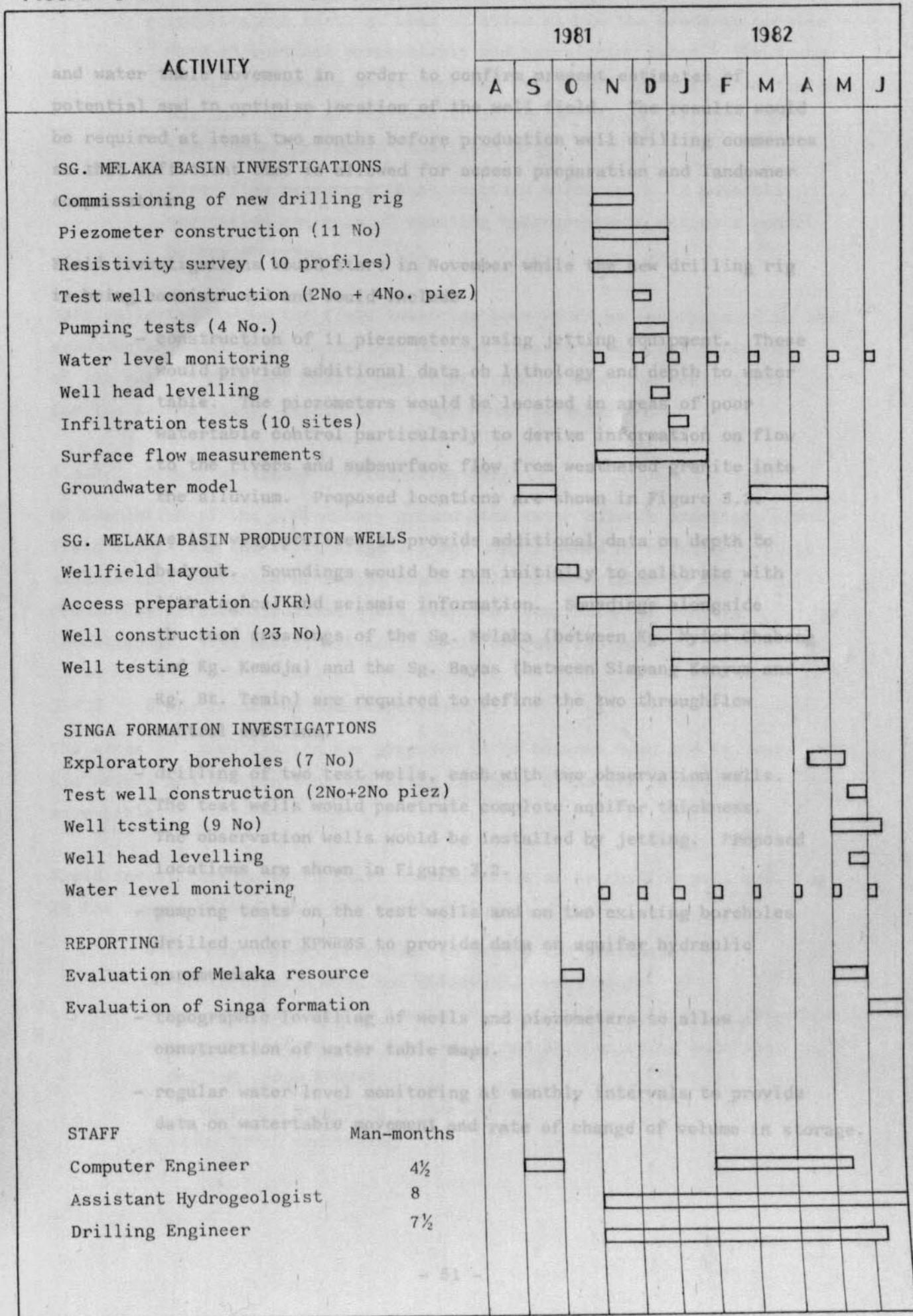
3.4.1 Sungai Melaka Basin Investigations

A groundwater water-balance exercise preliminary to the main model, is required on the Sg. Melaka basin, using existing data on lithology, water table elevation

STAFF	Man-months
Computer Engineer	4½
Assistant Hydrogeologist	8
Drilling Engineer	7½

FIGURE 3.4

LANGKAWI ISLAND PROGRAMME



- infiltration tests at some 10 sites within the basin to provide data on vertical permeability and percolation rates. The tests and water table movement in order to confirm present estimates of potential and to optimise location of the well field. The results would be required at least two months before production well drilling commences so that sufficient time is allowed for access preparation and landowner compensation.

Field investigations would start in November while the new drilling rig is being commissioned and would include :

- construction of 11 piezometers using jetting equipment. These would provide additional data on lithology and depth to water table. The piezometers would be located in areas of poor watertable control particularly to derive information on flow to the rivers and subsurface flow from weathered granite into the alluvium. Proposed locations are shown in Figure 3.2.
- resistivity profiles to provide additional data on depth to bedrock. Soundings would be run initially to calibrate with lithological and seismic information. Soundings alongside the road crossings of the Sg. Melaka (between Kg. Nyior Chabang and Kg. Kemoja) and the Sg. Bayas (between Simpang Kenyum and Kg. Bt. Temin) are required to define the two throughflow control sections.
- drilling of two test wells, each with two observation wells. The test wells would penetrate complete aquifer thickness. The observation wells would be installed by jetting. Proposed locations are shown in Figure 3.2.
- pumping tests on the test wells and on two existing boreholes drilled under KPWRMS to provide data on aquifer hydraulic parameters.
- topographic levelling of wells and piezometers to allow interface construction of water table maps.
- regular water level monitoring at monthly intervals to provide data on watertable movement and rate of change of volume in storage.

3.4.1 Sungai Melaka Well Design

- infiltration tests at some 10 sites within the basin to provide data on vertical permeability and percolation rates. The tests should preferably be carried out on flooded and unflooded fields, but the timing of the investigations may allow infiltration tests under unflooded conditions only.

- river flow measurements at selected sites, plus if possible, regression analysis of existing hydrographs to estimate contributory storage.

Data collected during the field investigations would be incorporated in the groundwater model which would then be used to assess the full potential of the basin. Provided that a supply of 5 mgd is feasible, well sites for the second stage supply of 2.7 mgd would be selected.

### 3.4.2 Sungai Melaka Basin Production Wells

On completion of the preliminary groundwater water balance exercise, a well-field layout for the first stage 2.3 mgd supply would be prepared. It is assumed that provision of access roads would be undertaken by JKR. Production well construction would start on completion of the two investigation test wells; all wells would be pump tested.

### 3.4.3 Singa Formation Investigations

The areas of investigation are proposed to be between Kuah and Kg. Baru Ulu Melaka and between Kuah and Kisap as these areas are reasonably accessible.

Field investigations would start on completion of production well drilling in the Sungai Melaka basin and would include :

- six exploratory boreholes to define the piezometry
- two test wells with one observation well each
- one deep borehole to locate the fresh water/salt water interface
- pumping tests on the test wells and on 7 existing boreholes drilled under KPWRMS
- topographic levelling of boreholes
- water level monitoring

## 3.5 Sungei Melaka Well Designs

For 12 l/sec wells envisaged for the Langkawi Water Supply units in a true alluvial aquifer with shallow watertables, a simple form of washing or bailing-in a string of 4 inch well screen and casing and connecting this directly to a centrifugal pump would normally suffice. However, there is a problem of accurately identifying and locating screenable material in the heterogeneous alluvium and for this reason, for the test wells at least, a drilled well construction with adequate formation sampling is necessary. It is therefore proposed to use such a form of construction. However, a number of piezometers required will be constructed by the washing-in or bailing techniques and the experience with these may be useful in deciding upon a drilled or a washed-in form of construction for future production wells.

Thus test and early production wells will be drilled with direct rotary mud flush techniques. To avoid subsequent development problems, degradable mud (Revert) will be used if possible.

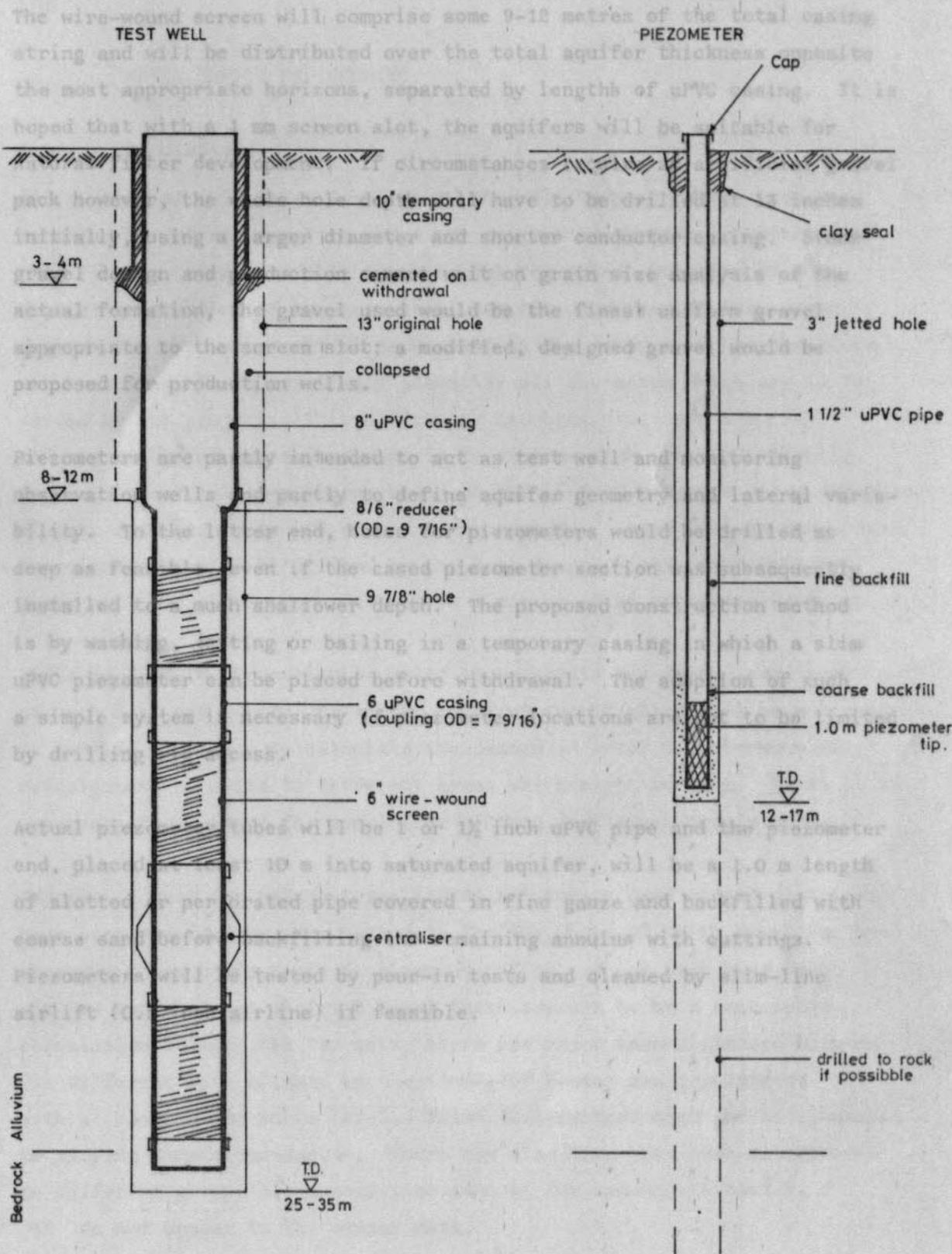
Submersible pumps for 12 l/s require 8 inch casing and mono-type pumps 6 inch casing. However, drawdowns are expected to be relatively small and it may be possible to utilise much cheaper, surface-mounted centrifugal pumps, in pits if necessary. These could be direct-coupled to well casing (steel) for production wells, but in uPVC casing will require a suction main with non-return valve. The size of this valve requires 8 inch casing to below its setting level at least, but the rest of the well could be 6 inch or even 4 inch.

Piezometers need only be a 1½ inch uPVC pipe in a 3 inch jetted hole. Proposed details of both constructions are shown on Figure 3.5.

For the wells, general procedure will be as follows; drill at 13 inch diameter to pump chamber depth and install 10 inch temporary steel casing; drill through to bedrock at 9⅞ inches; carry out geophysical logs and place 8/6 inch casing/screen string with centralisers; wash out well and perform initial development before pulling temporary steel casing, leaving one joint in place; complete development by airlift/jetting with polyphosphate additives for mud-cake removal; cement top section through temporary casing as it is finally pulled.

FIGURE 3.5

S. MELAKA BASIN - WELL AND PIEZOMETER DESIGN



Note:

Temporary casing may have to be jacked depending on rig capacity to pull.

The wire-wound screen will comprise some 9-12 metres of the total casing string and will be distributed over the total aquifer thickness opposite the most appropriate horizons, separated by lengths of uPVC casing. It is hoped that with a 1 mm screen slot, the aquifers will be suitable for natural filter development. If circumstances require an artificial gravel pack however, the whole hole depth will have to be drilled at 13 inches initially, using a larger diameter and shorter conductor casing. Since gravel design and production cannot wait on grain size analysis of the actual formation, the gravel used would be the finest uniform gravel not appropriate to the screen slot; a modified, designed gravel would be proposed for production wells.

Piezometers are partly intended to act as test well and monitoring observation wells and partly to define aquifer geometry and lateral variability. To the latter end, holes for piezometers would be drilled as deep as feasible, even if the cased piezometer section was subsequently installed to a much shallower depth. The proposed construction method is by washing, jetting or bailing in a temporary casing in which a slim uPVC piezometer can be placed before withdrawal. The adoption of such a simple system is necessary if piezometer locations are not to be limited by drilling rig access.

Actual piezometer tubes will be 1 or 1½ inch uPVC pipe and the piezometer end, placed at least 10 m into saturated aquifer, will be a 1.0 m length of slotted or perforated pipe covered in fine gauze and backfilled with coarse sand before backfilling the remaining annulus with cuttings. Piezometers will be tested by pour-in tests and cleaned by slim-line airlift (0.5 inch airline) if feasible.

There are major inconsistencies between the different sets of data on the number of houses and population, both at kampung and subje level. These discrepancies might be attributable to varying census boundaries. There may also have been name alterations to different groups of kampungs, as some of the kampungs listed by JKR do not appear in the census data.

In order to resolve the problem we will as a matter of urgency supply JKR with a list of the kampungs where the data already given is insufficient so that the information can be obtained from individual kampung Penghulus.

#### 4. WATER SUPPLY ENGINEERING

##### 4.1 Population

At the time of this Inception Report, the only kampongs which have been detailed by JKR for supplies under the project are groups in North Kedah. This list has been carefully examined but the actual location of a considerable number of kampongs still remains uncertain as they are not recorded on the topographical maps covering the areas. It has therefore not been possible to positively indentify all the areas which are to be served by the project. This difficulty has been discussed with JKR and the method of approach agreed is to examine each area individually, define a practical supply area based on the list of kampongs given and then discuss each area with JKR as the work proceeds. There will be many cases where the area will be defined by physical geographical restraints but there will be others where it will be a matter of an arbitrary decision.

It is part of the Consultant's brief to ascertain the demand requirements of each area and advise JKR of the level of supply which will be achieved. It is also necessary to calculate the demand in order to determine any reassignment of wells to different areas which might be made. Hence it is necessary to estimate the population of each individual supply area.

Population data for Padang Terap (1976) and Kubang Pasu (1978) districts have been provided by JKR; 1978 data for the whole of North Kedah has been obtained through the State Development Office. These data have been studied and while at district level there appears to be a reasonable correlation between the two sets, there are major inconsistencies between the different sets of data on the number of houses and population, both at kampong and mukim level. These discrepancies might be attributable to varying census boundaries. There may also have been name alterations to different groups of kampongs, as some of the kampongs listed by JKR do not appear in the census data.

In order to resolve the problem we will as a matter of urgency supply JKR with a list of the kampongs where the data already given is insufficient so that the information can be obtained from individual kampong Penghulus.

If this is not immediately available, the Penghulu should initiate a house count; the Consultant would then estimate the population on an average house occupancy. As has already been discussed with JKR, a population growth rate of 2.5 percent per annum will be applied to the derived populations to determine future population levels.

#### 4.2 Demand Planning

In planning future demands, it has already been discussed and agreed with JKR that a planning horizon for the project be taken as the year 1995.

Recent reports for the area have suggested the following per capita demand figures in gallons per capita per day including losses.

	1978	1980	1985	1990	1995	2000
a) Kedah/Perlis Water Resources Management Study (Yusoff Ibrahim Setar and Renardet Engineering) Jan 81						
Small Towns	20	-	-	30	-	35
Rural Areas	15	-	-	25	-	30
b) Alor Setar Water Supply (Sepakat Setia Perunding Sdn Bhd)	-	28	35	44	55	-

After discussion with JKR it has been agreed that the following figures, including losses, be adopted :

- 1980 - 25 g/c/d
- 1985 - 30 g/c/d
- 1990 - 40 g/c/d
- 1995 - 45 g/c/d
- 2000 - 45 g/c/d

Thus 45 g/c/d would seem to be the target supply, applied to 1995 population levels which, at 2.5 percent annual growth, might be 1.413 times current levels.

In order to calculate well outputs to supply this demand, it has been proposed to assume 20 hours of daily pumping and the provision of one day's storage capacity in separated systems. In order to size distribution mains etcetera, it is proposed not to allow any peaking factor to correlate with variations in seasonal demand, but to adopt a factor of 2.0 to calculate daily peaks in distribution systems.

The scheme location and the site of the reservoir would be plotted on the

#### 4.3 Well-head Engineering

The present project is intended as an immediate short term programme to alleviate the water supply situation in Kedah and Perlis during periods of drought. It is envisaged only as an interim measure until surface sources to serve the whole area are developed. The planning horizon has been taken as 1995 but the intention is to develop surface sources well before that date. Large service reservoirs will form part of the final scheme and it is intended that the project's wells would be linked to these reservoirs and retained as a standby facility.

##### 4.3.1 General

The terms of reference for the water supply engineering part of the project are to :

- Design the well pumps, well head system, storage tanks and size of the pumping mains .

- Identify the sites for and define TWL and BWL of storage tanks

- Identify the need for any additional forwarding or booster stations

- Identify the need for treatment and define alternatives or most suitable methods of treatment.

In order to carry out these duties each item must be examined individually but each scheme must be designed in outline since each component is interdependent. The level of the service reservoir for example is dependent upon the size, population and elevation of the zone to be served and the design of the pumping system is dependent upon the level of the service reservoir in relation to the level of the well.

After agreement with JKR of the areas to be supplied, the method of approach will be to plan a scheme in outline, examine the critical zones within the area and hence fix the level of the service reservoir. The design of the pumps, well-heads and tanks could then be carried out and the need for additional boosting if any, determined.

The scheme location and the site of the reservoir would be plotted on the available topographical maps at a scale of 1" = 1 mile. A diagrammatic sketch of the scheme would be included as well as relevant details of reservoir levels and capacity, size of pumping mains and treatment required. Individual components of the schemes would be related to a series of standard designs. A preliminary schedule of typical details which will be supplied is given in Section 4.7.

From the demand figures, a percentage of deficiency or excess in relation to present demand and estimated consumption in 1995 would be calculated.

#### 4.3.2 Well Pumps

The types of pump available for selection are :

- Centrifugal pumps
- Submersible pumps
- Line-shaft pumps

Centrifugal pumps have been successfully used in many parts of the world for water extraction from shallow wells. They are of simple, robust construction and maintenance is simple. However they are severely limited by the fact that they can only cope with a maximum practical suction head of about 25 feet (7.6 metres). The general standing water level of the wells in the Kedah/Perlis area is about 15 feet (4.6 m) and the estimated dewatering in the dry season is of a similar magnitude; well operating drawdown could add another 35 feet (10 + m). The suction required in Kedah/Perlis is therefore outside the range of centrifugal pumps and they need not to be considered further for the mainland.

On Langkawi however, there is a possibility of reasonable well yields being obtained from shallow watertables at low drawdowns in some alluvial wells and so this type of pump will be considered, set in pump pits if necessary and feasible.

Submersible pumps are used extensively as well pumps both in Malaysia and elsewhere. They are relatively reliable, easy to install and they can tolerate some misalignment of the well-casing. The manufacturing range covers most applications. Maintenance however is relatively complicated in that a rig or shear-legs are required to extract the pump from the wells. Pump maintenance is not normally carried out in the field and the unit must be returned to the workshop, often to the supplier's specialist workshop.

The capacity of submersibles is restricted by impeller diameters but the delivery head can be varied considerably by incorporating additional stages. The restriction on the pump impeller size also reduces the efficiency, below that of a surface mounted pump, especially in the lower discharge ranges considered. A major drawback is the high pump speed generally adopted (2900 rpm) to achieve adequate output. This makes components prone to wear in the presence of faults or of abrasive material in the water. Further, being electric drives and fixed-speed machines, their range of capacity is small and many models are required to cover a large range of heads and discharge. These points and other factors are discussed in Section 2.4.

Where mains electricity is available, the well-head can be very simple and need not even be covered. However when mains electricity is not available, a diesel generator unit must be supplied to provide the power and this factor must be taken into consideration in any cost comparison with other types of pump. Further, for all but the smallest discharge units, the type of power required is 3-phase, not normally available and expensive when it is, in small diesel generator sets under 5 kW.

Line-shaft pumps are probably not as extensively used in the water industry as submersibles but they have wide application at high discharges and in the oil industry.

Moreover, where on-site electric generation is required for submersibles, their overall cost advantage, at equal discharge, disappears. It is clear therefore that there are situations where the screw pumps will have both economic and operational advantages.

## FIGURE 4.1 THE MONO-TYPE PUMP

They require reasonable well verticality but in the present context of relatively shallow wells, this is not a problem. They are more difficult to install and remove than submersibles, but once installed and aligned, will give long reliable service.

The prime movers for line-shaft pumps can be electric motors or petrol or diesel engines, the latter giving speed-variation ability which greatly extends the range within which a single model of pump can operate, reducing the number of models required. Maintenance is relatively simple with surface prime movers and except for major overhauls when the pump has to be removed, can be carried out on site. The well-head housing will be smaller than that required for a diesel generator. In general however, standard line-shaft pumps are not cost effective in the range of heads and flows being considered for the present scheme, being particularly appropriate to discharges over 20 l/s (267 gpm).

Nevertheless there is an interesting variant of the line-shaft pump, the mono-type pump which is suitable for the present application of low discharges and is also slimmer than comparable submersibles for the same discharge— a pertinent factor in this case. This particular pump is a positive displacement unit with a helical metal rotor turning inside a fixed helically shaped body. The rotor is the only rotating part of the pump and it is therefore very reliable. The Consultant has particular experience of this type of pump in a large rural water supply scheme in Ethiopia, where it is performing very satisfactorily. The smaller versions are also ideal for use as hand pumps, while the larger versions are suitable for use with a whole range of mechanical prime movers. Figure 4.1 illustrates the principles of the mono type pump and the range of driving options.

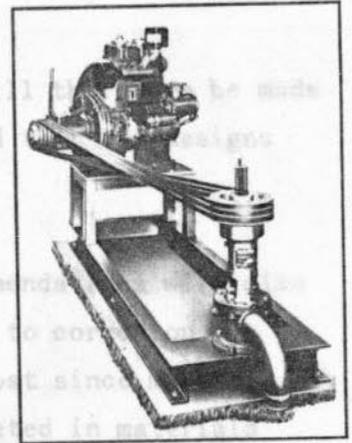
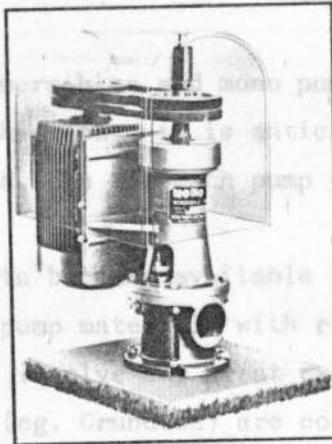
Experience elsewhere has indicated that for the head and output envisaged, submersibles should be cheaper than mono type pumps where mains electricity is available. However in the cases considered in Section 2.4 where a mono can get significantly more discharge from a diameter-limiting borehole than a submersible, the cost per unit of water from the mono may well be less than that from the submersible. Moreover, where on-site electric generation is required for submersibles, their overall cost advantage, at equal discharge, disappears. It is clear therefore that there are situations where the mono pumps will have both economic and operational advantages.

# FIGURE 4.1 THE MONO TYPE PUMP

engine drive and later converted to electric motors when power became available.

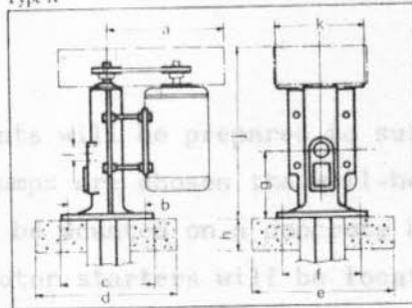
Cost of water supply is a major factor in the design of pumps. Some pumps will be made during the project, but at the same time anticipated designs of well-head will be required.

When water quality data is available, the pump should be selected on the basis of water quality data. The pump should be selected on the basis of water quality data. The pump should be selected on the basis of water quality data.

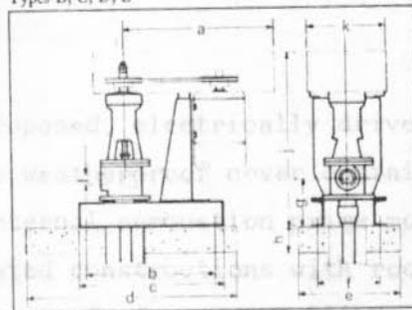


## Drive arrangements

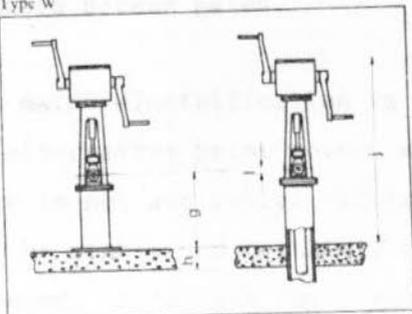
Type A



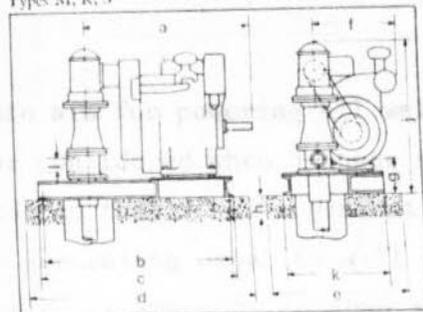
Types B, C, D, E



Type W



Types M, R, S



They could be initially installed with hand pumps then adapted for direct engine drive and later converted to electric motors when power became available.

Cost evaluations of both submersibles and mono pumps will therefore be made during the project, but at this stage it is anticipated that two designs of well-head will be required, one for each pump type.

When fuller water quality data becomes available recommendations will also be made concerning suitable pump materials with regard to corrosion resistance. This should not involve any great extra cost since many of the small submersible pumps (eg. Grundfos) are constructed in materials such as stainless steel as standard.

Chlorides 8 - 210 ppm

pH 5.3 - 7.8

#### 4.3.3 Well-heads

No tests were carried out for manganese or toxic metals.

Standard designs of well-head arrangements will be prepared to suit the type of pump selected. Where submersible pumps are chosen the well-head with the associated pipework and valves will be mounted on a concrete base without specific weather protection. Motor starters will be located within a small adjoining cubicle or, where available, in the chlorine house. All buildings will be of basic construction to the standards already indicated by JKR, ie timber framed, plywood infilled and asbestos cement roofing.

> 0.3 < 1 ppm, aeration only, giving 0.1 to 0.3 ppm after settlement  
< 0.3 ppm no treatment

Where vertical spindle mono-pumps are proposed, electrically driven versions would be provided with a simple weatherproof cover containing both motor and starter/control gear. Internal combustion prime movers will have to be housed in substantial ventilated constructions with room to remove and service engines plus removable roofs for pump pulling. Each well-head will be fenced with 6 foot high security fencing with lockable access gates.

However in view of the expense and the complications involved in running Full mains electrification is the ultimate aim for powering all wells and alternative prime movers will only be considered when 3-phase mains power is not available. It is not considered that on-site generation will be viable and certainly no stand-by generating capacity will be proposed. Extensive improvement to supplies in kampongs in some areas is

planned and these plans together with the present electricity supply situation will be investigated to form the basis of decisions.

#### 4.4 Treatment

##### 4.4.1 Iron

A summary of water quality to be expected within the area is tabulated in the KPWRMS Final Report Vol. 2 - Basic Data - Appendix II.

Twelve of the 22 wells analysed are within the project area. The results of the analyses were :

Iron	0.1 - 0.6	ppm
Chlorides	8 - 218	ppm
pH	5.3 - 7.8	

No tests were carried out for manganese or toxic metals.

The WHO standards for water quality give a desirable iron quality of 0.1 ppm and a maximum permissible quality of 1 ppm. The present well system is an interim measure. We would normally propose that the following standards for treatment for iron removal be adopted :

- > 1 ppm, oxidation + filtration, giving 0.1 to 0.3 ppm.
- > 0.3 < 1 ppm, aeration only, giving 0.1 to 0.3 ppm after settlement
- < 0.3 ppm no treatment

##### 4.4.3 Chlorination

It should be noted however that the intermediate range, where only aeration is proposed, is not an entirely satisfactory situation in that complaints will probably still be received from consumers regarding taste, appearance and staining. Some of the suspended iron will deposit out in the service reservoir but much will carry into the mains. The only satisfactory method of removal is by filtration.

Chlorine gas is the most efficient method of adding chlorine and is the However in view of the expense and the complications involved in running and maintaining small isolated treatment facilities and in view of the fact that the wells are an interim measure, the above maximum standard should be accepted and we will base our design on it accordingly.

In the unlikely event of the iron content being greater than 1 ppm then treatment would be required. We would recommend a 'package' treatment plant as illustrated in Figure 4.2. Package treatment plants are specially designed for this purpose and if required can be later dismantled and removed to other sites. Package plants with single filtration units dealing with flows up to 80 gpm ( 6 l/s ) are readily available and extra units can be added to deal with higher flows.

The treatment would be to raise the pH of the water to a value of 8 or 9 by the addition of alkali. The iron would then be oxidised by chlorine and passed through a filter containing sand and a catalyst.

#### 4.4.2 Manganese

Manganese is often associated with iron in water but tests for it do not appear to have been carried out under the KPWRMS. The WHO desirable level for manganese is below 0.05 mg/l with 0.5 mg/l as the maximum permissible (1 mg/l = 1 ppm). As in the case of iron we recommend that the 'maximum permissible' standard be adopted.

The treatment for manganese is more difficult than for iron, but the principle is the same, and as manganese is often associated with iron, the same treatment plant should reduce the manganese to acceptable levels.

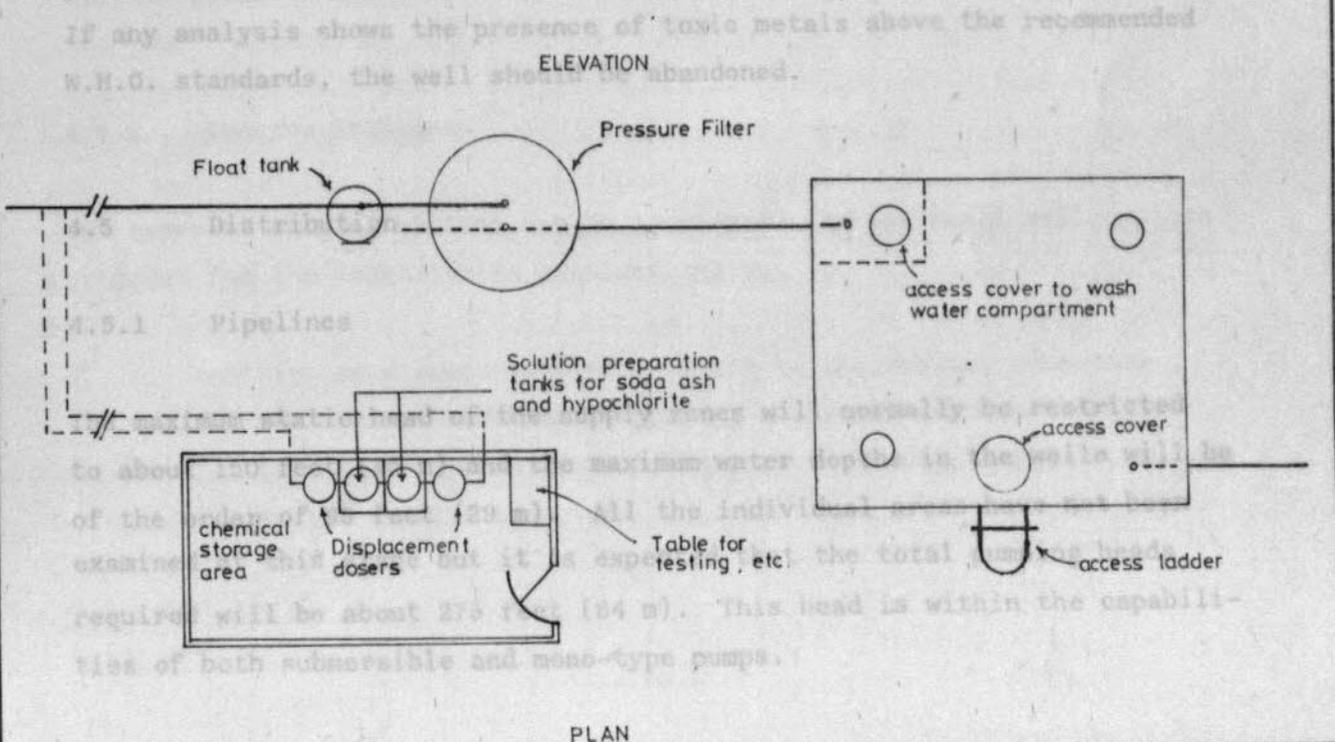
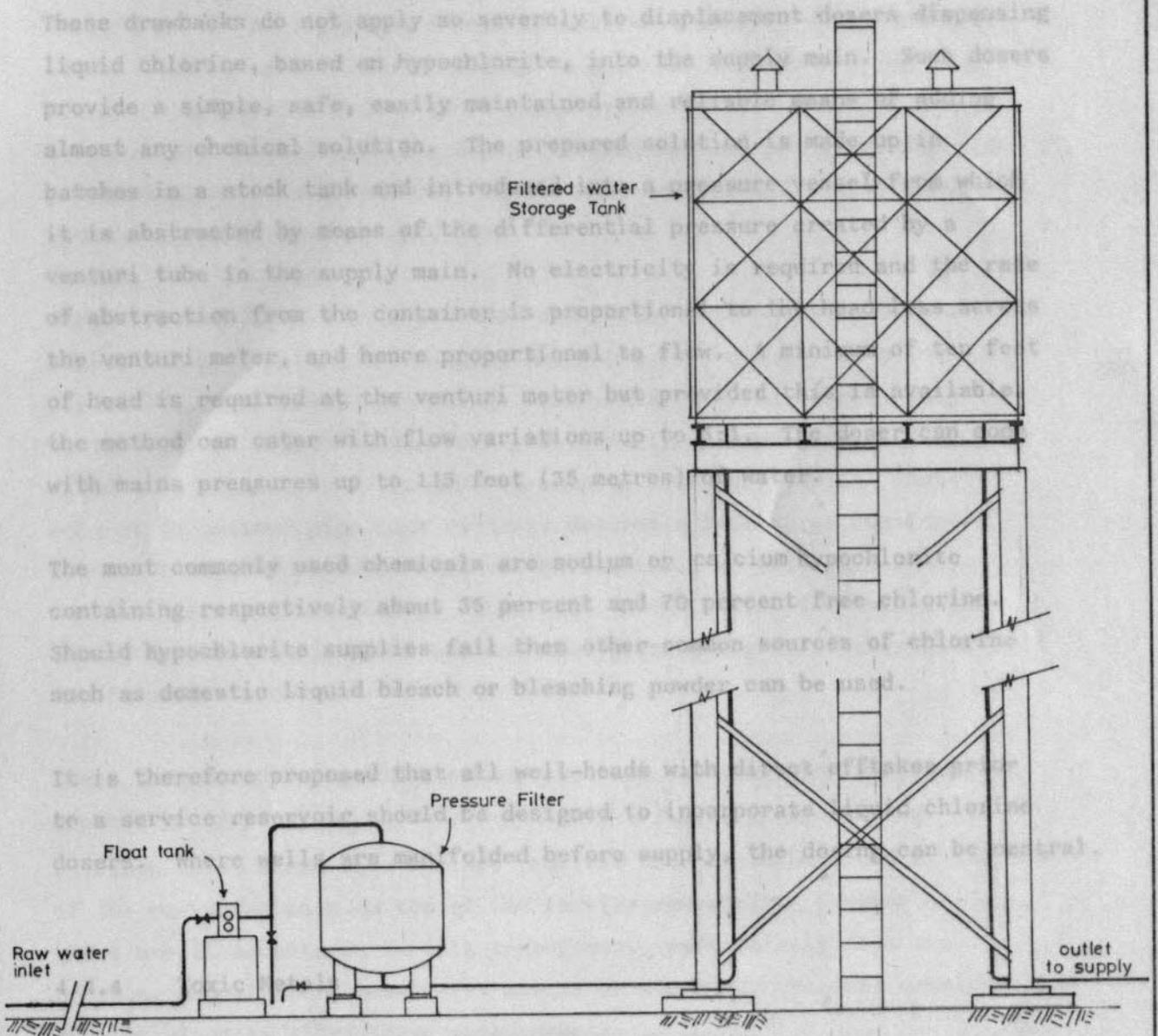
#### 4.4.3 Chlorination

Chlorination of all borehole supplies is recommended as standard practice. Chlorine can be supplied by two methods :

- Chlorine gas
- Hypochlorite solution

Chlorine gas is the most efficient method of adding chlorine and is the standard method used in large installations. It has drawbacks however in that it needs to be operated by skilled personnel conversant with the safety procedures required. It also requires a supply of high pressure water plus electricity for installations designed to give an output proportional to flow.

FIGURE 4-2 TYPICAL ARRANGEMENT OF AUTOMATIC WASH FILTRATION PLANT



These drawbacks do not apply so severely to displacement dosers dispensing liquid chlorine, based on hypochlorite, into the supply main. Such dosers provide a simple, safe, easily maintained and reliable means of adding almost any chemical solution. The prepared solution is made up in batches in a stock tank and introduced into a pressure vessel from which it is abstracted by means of the differential pressure created by a venturi tube in the supply main. No electricity is required and the rate of abstraction from the container is proportional to the head loss across the venturi meter, and hence proportional to flow. A minimum of ten feet of head is required at the venturi meter but provided this is available, the method can cater with flow variations up to 3:1. The doser can cope with mains pressures up to 115 feet (35 metres) of water.

The most commonly used chemicals are sodium or calcium hypochlorite containing respectively about 35 percent and 70 percent free chlorine. Should hypochlorite supplies fail then other common sources of chlorine such as domestic liquid bleach or bleaching powder can be used.

It is therefore proposed that all well-heads with direct offtakes prior to a service reservoir should be designed to incorporate liquid chlorine dosers. Where wells are manifolded before supply, the dosing can be central

#### 4.4.4 Toxic Metals

If any analysis shows the presence of toxic metals above the recommended W.H.O. standards, the well should be abandoned.

#### 4.5 Distribution

##### 4.5.1 Pipelines

The maximum static head of the supply zones will normally be restricted to about 150 feet (46 m) and the maximum water depths in the wells will be of the order of 95 feet (29 m). All the individual areas have not been examined at this stage but it is expected that the total pumping heads required will be about 275 feet (84 m). This head is within the capabilities of both submersible and mono-type pumps.

Small diameter A.C. pipes are readily available locally up to 300 feet (90 m) working head (Class C) and up to 400 feet (120 m) working head (Class D) to special order. When surge pressures are included it might be necessary to utilise Class D pipe in some systems but generally Class C pressure pipes should suffice. In the smaller sizes, the same pressure ratings are available in uPVC pipe.

Surge pressures could be a problem, especially with positive displacement pumps, but by limiting the pumping main to a low velocity of below 3 feet per second, pressure surges can be restricted to a low value. Each system will of course be examined individually. Pumping mains will be sized on a least-cost evaluation of pumping costs and capital costs subject to maximum pipe line velocity desirable from surge considerations. A minimum residual head of 40 feet (12.2 m) will be assumed for the distribution systems. This head is sufficient for future two-storey development in the areas and also gives a degree of flexibility for future extension.

It is considered therefore that in general intermediate booster stations. There is some advantage in breaking pressure for treatment purposes, especially if aeration is involved, but this involves re-pumping. To overcome this, where aerators are required they could be sited at the end of the raw water main on top of the service reservoir. However, there are disadvantages in this arrangement, particularly from the cleaning aspect where reservoirs are to be elevated. Further consideration will be given to alternative arrangements.

#### 4.5.2 Booster Stations

Two types of pumping systems can be considered for the small well systems proposed for the Kedah/Perlis mainland region:

- a) High head pumps supplying direct to the service reservoir
- b) Low/medium head pumps supplying a central suction tank

from which the water is boosted by centrifugal pumps to the service reservoir.

In both systems it is preferable to combine the raw water mains into one pipeline for ease of chlorination. In case b) the raw water mains would be combined and the water chlorinated before the suction tanks. System b) is obviously a more costly solution but the reasons why it is sometimes adopted are :

- Pumps cannot cope with the total head required
- Pressures are beyond pressure range of pipes available
- Surge pressure can be reduced by having an intermediate tank
- Greater flexibility in treatment plant layout.

The first three points do not apply in the present case and the fourth point has been considered and classed as non-pertinent because of the simple types of treatment envisaged.

It is considered therefore that in general intermediate booster stations will not be required on the mainland. If they are considered necessary however for any reason, suitable designs will be prepared.

On Langkawi, the situation is different in that about 23 wells will be situated within a defined wellfield feeding a central source. In this case there could be a benefit in having a forwarding station. The advantages and disadvantages of alternative systems from both operational and constructional aspects will be studied during the contract period and recommendations made. The situation is complicated in that centrifugal pumps are proposed for the Langkawi wells but these will be chosen for their suction capabilities and pumps with good suction capability are unlikely to have the total head ability to command the whole island. Booster arrangements will therefore most likely be required.

#### 4.5.3 Service Reservoirs

It is proposed to provide storage reservoirs with one day's consumption storage at each kampong or group of kampongs. As far as possible within

a zone each reservoir should have the same or similar top water level (TWL) for future interlinking of systems. The economics of siting a ground reservoir on adjacent high ground with distribution to each kampong group, will be compared to the economics of individual elevated tanks and the most appropriate arrangement selected.

Where treatment plants are necessary, the plant must be adjacent to the reservoir and at an elevation to give sufficient head for backwashing. It is likely then that in these cases the reservoir itself will be elevated.

In view of the speed of construction required and the interim nature of the project we propose to base our designs on the use of prefabricated, pressed steel bolted tanks. All tanks will be designed with two compartments for cleaning. A series of standard designs will be prepared and presented. The most appropriate methods for corrosion protection for the steel tanks will be evaluated during the design period and recommendations made. Reservoirs will be equipped with large, easily visible indicators with a clear line of sight to the wells where possible.

In siting of reservoirs, due regard will be given to possible methods of connection to a future mains distribution network. Each zone will be examined and an estimate made of the distribution pipe friction losses at maximum flow between the critical areas of the supply zone and the reservoir site. The level of the service reservoir will then be selected to maintain a residual head of not less than 40 feet at the highest point within the supply zone during peak flow conditions. In order to minimise leakage in the distribution system, reservoirs will where possible, be sited to ensure that maximum pressures are not more than 200 feet. The selected reservoir site will be located on the available 1" - 1 mile topographical maps and approximate levels obtained by altimeter. All detailed survey work will be undertaken by JKR.

#### 4.6 Operation and Maintenance

The schemes are planned to have as much routine maintenance carried out as is possible. Only for the major work such as the removal of the tanks will maintenance have to be performed in the workshop. Nevertheless a permanent travelling supervisor's maintenance group should

be set up with the intention of visiting each site in turn and checking that routine maintenance is being carried out satisfactorily.

It is intended that the control of schemes will be at a basic level and any scheme will be as self-sufficient as possible. The control system will be entirely manual except for low water level cut offs for the well pumps. Well pumps will be started and stopped manually at the well head and there will be no automatic operation of the well pumps from the reservoir water level. Nor will there be control valves on the delivery mains to prevent the reservoirs from overflowing.

The reservoirs will normally contain one day's storage and it will be the operators objective to fill the reservoir some time during each working day. It is intended that the system should operate on a 20 hour daily pumping cycle where necessary to meet demand. In order to determine the water level of the service reservoirs from a distance, it is suggested that large diameter indicators operated by floats be installed. Several proven designs which can be observed and correctly interpreted over distances up to about 1 mile are available. These simple devices could considerably cut down the amount of travelling required between sites.

The system will be designed for operation by relatively unskilled operators. The chlorine system proposed is safe and operators need not be conversant with chlorine gas procedures. The hypochlorite stock solution for chlorination is safe to handle but has to be made up every day. This frequently could be a drawback on an automatic system but where the operators must visit each site every day in any case to control the pumps, this method of working is considered to be acceptable. A minimum of two operators will be required to work a group of well systems. The number of systems which can be operated by one team is dependent on how far the systems are apart and exact manning levels will have to be decided during the design stage. Each operator should be equipped with a motor cycle for travelling.

#### POPULATION AND WATER DEMAND

We understand that it would be JKR policy to appoint operators from outside the area and not to appoint them from kampongs being served. We agree with this policy as local operators tend to favour their own village in times of inadequate supply.

The schemes are planned to have as much routine maintenance carried out on site as possible. Only for the major overhauls such as the removal of the borehole pumps will maintenance have to be performed in the workshop. Nevertheless a permanent travelling supervisor's maintenance group should be set up with the intention of visiting each site in turn and checking that routine maintenance is being carried out satisfactorily.

This group would also have to check that pump performances were remaining appropriate to the wells and that no abuses were occurring due to wells drawing down and letting pumps draw air. The group in fact would be responsible for all monitoring records.

4.7 Typical Details of Area Design Data

Information presented herein is to be taken as illustrative only at this stage. Neither well testing nor water sampling nor detailed ground inspection has been carried out. Similarly, the engineering design is only preliminary. The present section is included only to show the level of information which will be presented. Flows and populations etcetera still have to be verified.

AREA: KU/1 (A)  
 SITE: MUKIM RAMBAI

BRIEF DESCRIPTION OF SCHEME :

The scheme is located approximately East of Alor Setar and has Kg. Kubor Panjang as a major kampong within the area. JKR are presently laying a 10 inch dia. main alongside the metalled road which passes through the area.

Three boreholes, KU/1/2, KU/1/3 and KU/1/4, will serve the area. Water will be extracted from the three boreholes and pumped into a storage tank of approximately 150,000 gallons capacity. Chlorination will be provided before the water enters the storage tank.

POPULATION AND WATER DEMAND :

The kampongs to be served together with the present and estimated future population are listed overleaf :

KAMPONG	POPULATION IN 1981	POPULATION IN 1995
Kg. Kubang Pisang	410	579
Kg. Pak Pom	308	435
Kg. Bt. Nyah	400 *	565
Kg. Paya Besar	79	112
Kg. Huma Besar	152	215
Kg. Pondok	400 *	565
(Kg. Simpang Perupok)	244	345
(Kg. Kubor Panjang)	1004	1419
Kg. Bt. Berangan	143	202
Kg. Huma	59	83
Kg. Perupok	300	424
Kg. Banggul	240	339
Kg. Pokok Pauh	400 *	565
Kg. Kayu Bangun	400 *	565
Kg. Jangga	48	68
<b>TOTAL</b>	<b>4587</b>	<b>6481</b>

\* Estimated Populations

Water Demand in 1981 = 4587 x 25 g/c/d = 114,675 gpd

Water Demand in 1995 = 6481 x 45 g/c/d = 291,645 gpd

BOREHOLE YIELDS (subject to pump tests):

KU1/2 = 40 gpm

KU1/3 = 20 gpm

KU1/4 = 50 gpm

Total = 110 gpm

Estimated daily output = 110 x 60 x 20 = 132,000 gpd

∴ Level of supply (1995) = 20.4 g/c/d = 45.2 %

be required to meet the 1994 demand based on total population. If Kg. Kubor Panjang and Kg. Simpang Perupok are omitted, one would be adequate. For 1995 demand, the numbers are 4 and 2 respectively.

## RECOMMENDED PUMP TYPES :

See copies of attached well reports (not included).

## TREATMENT :

Chlorination prior to entry into elevated storage tank. Iron borderline and no treatment recommended. (illustration only, water sampling and analysis not carried out yet).

## COMMENTS:

Figures 4.3 and 4.4 show the location and outline details of the scheme which will provide an excess of capacity/demand of 15.1 % in 1981 but a deficiency of 54.8 % in 1995. Deficit would occur from 1985.

The proposed scheme envisages that the service tank will be interconnected with the 10 inch distribution main being laid nearby by JKR at present and that future connections to the surrounding kampongs will be made from this main. Tank level is thus set from the main pressure.

The demand figures are based on total population in the supply zone including Kg. Kubor Panjang and Kg. Simpang Perupok which are not on the original JKR supply list. If these are omitted because of adequate present supplies, then the demand projections reduce and excess-deficiency percentages become :

- 1981, excess capacity/demand, 58.1 %
- 1990, deficit first occurs
- 1995, deficit capacity/demand, 37.8%

There are two options available if deficits in supply are to be avoided:

- provide additional water from surface sources
- drill additional wells

Using the average yield of the wells already drilled, a further 3 would be required to meet the 1994 demand based on total population. If Kg. Kubor Panjang and Kg. Simpang Perupok are omitted, one would be adequate. For 1995 demand, the numbers are 4 and 2 respectively.

FIGURE 4.3

LOCATION OF KU/1(A) SCHEME

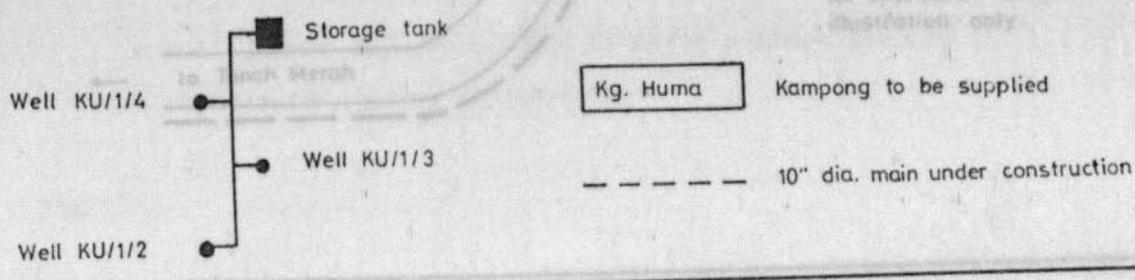
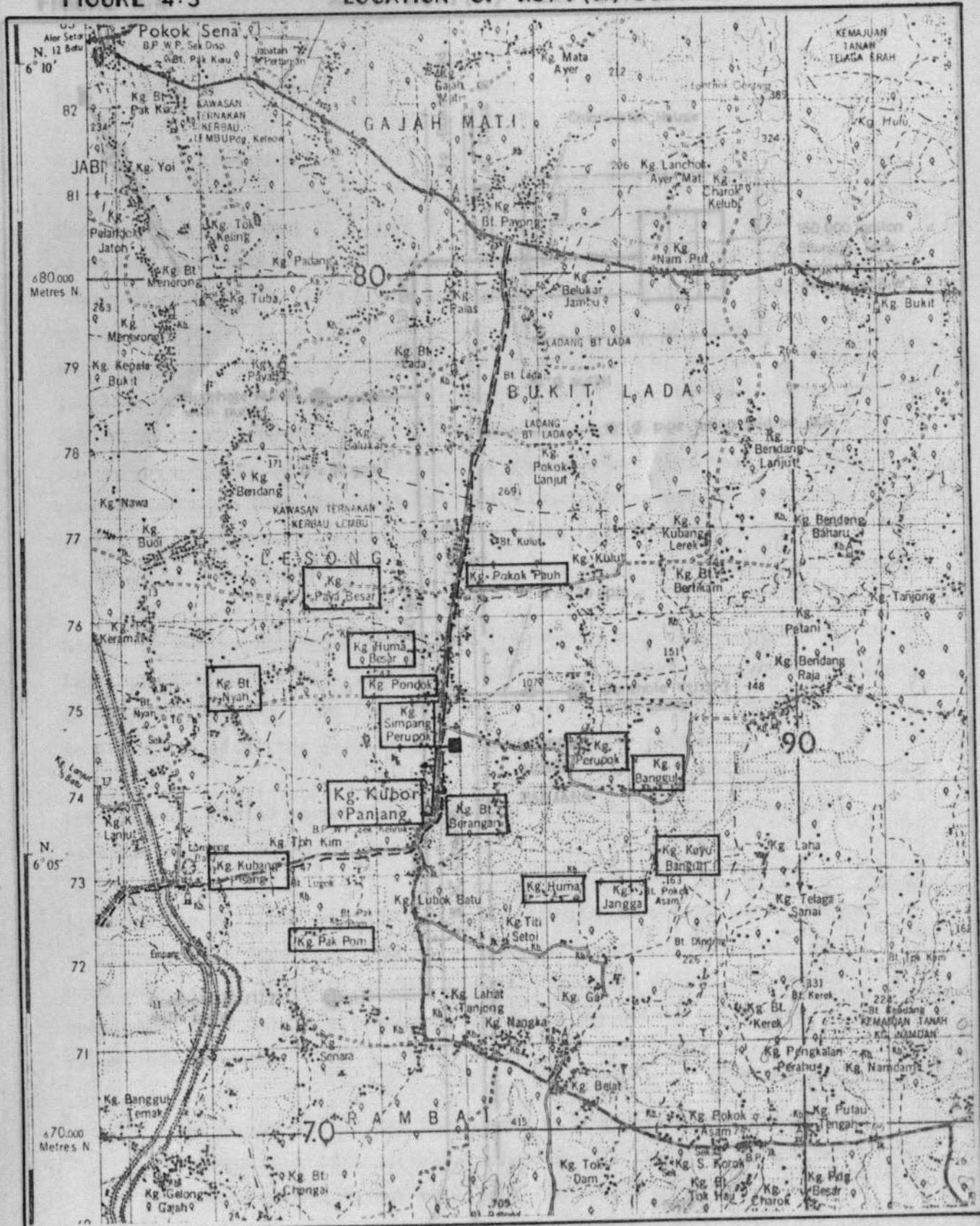
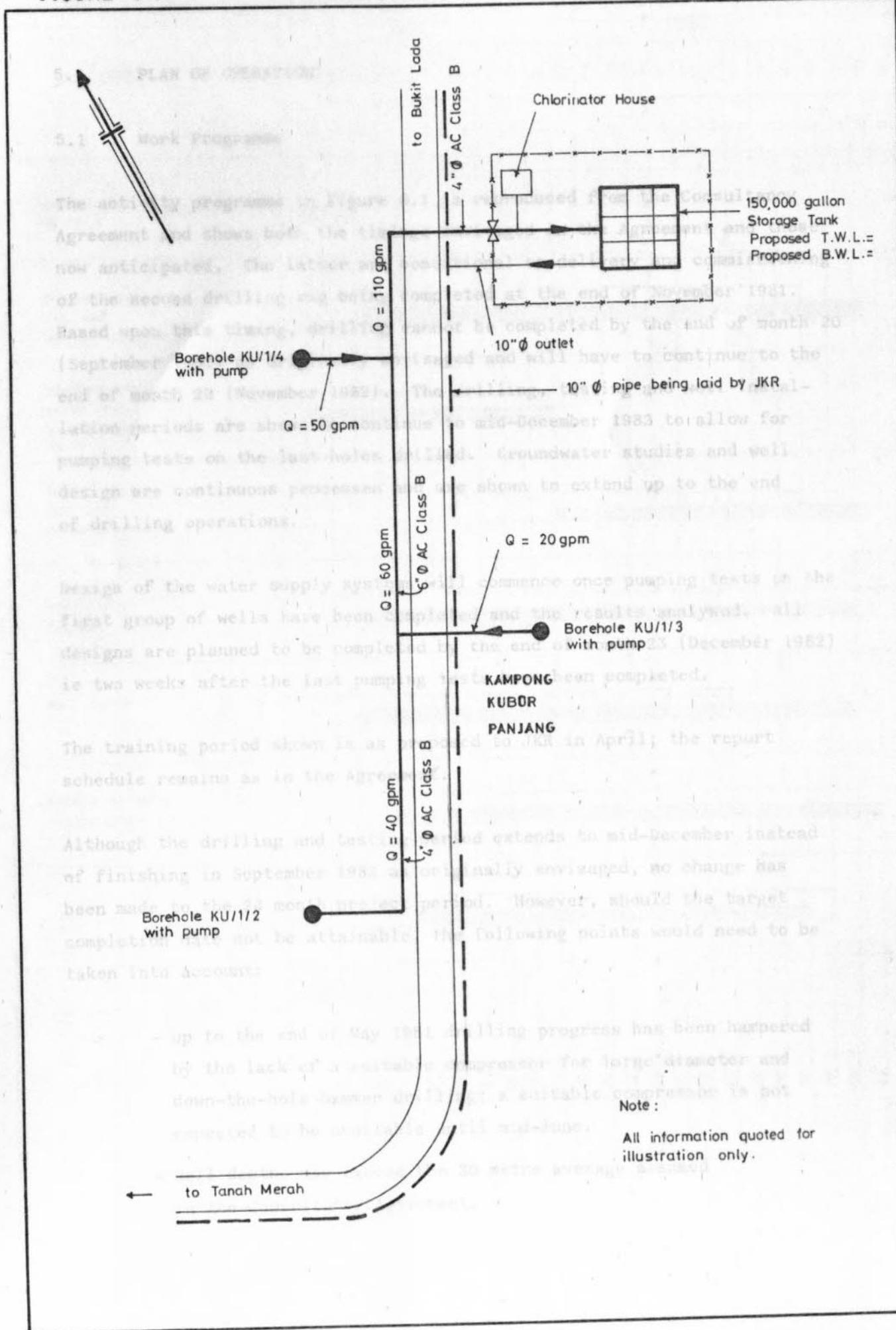


FIGURE 4.4

AREA KU/1(A) WELL SUPPLY



## 5. ACTIVITY PLAN OF OPERATION

## 5.1 Work Programme

The activity programme in Figure 5.1 is reproduced from the Consultancy Agreement and shows both the timings envisaged in the Agreement and those now anticipated. The latter are conditional on delivery and commissioning of the second drilling rig being completed at the end of November 1981. Based upon this timing, drilling cannot be completed by the end of month 20 (September 1982) as originally envisaged and will have to continue to the end of month 22 (November 1982). The drilling, testing and well installation periods are shown to continue to mid-December 1982 to allow for pumping tests on the last holes drilled. Groundwater studies and well design are continuous processes and are shown to extend up to the end of drilling operations.

Design of the water supply systems will commence once pumping tests on the first group of wells have been completed and the results analysed. All designs are planned to be completed by the end of month 23 (December 1982) i.e. two weeks after the last pumping tests have been completed.

The training period shown is as proposed to JKR in April; the report schedule remains as in the Agreement.

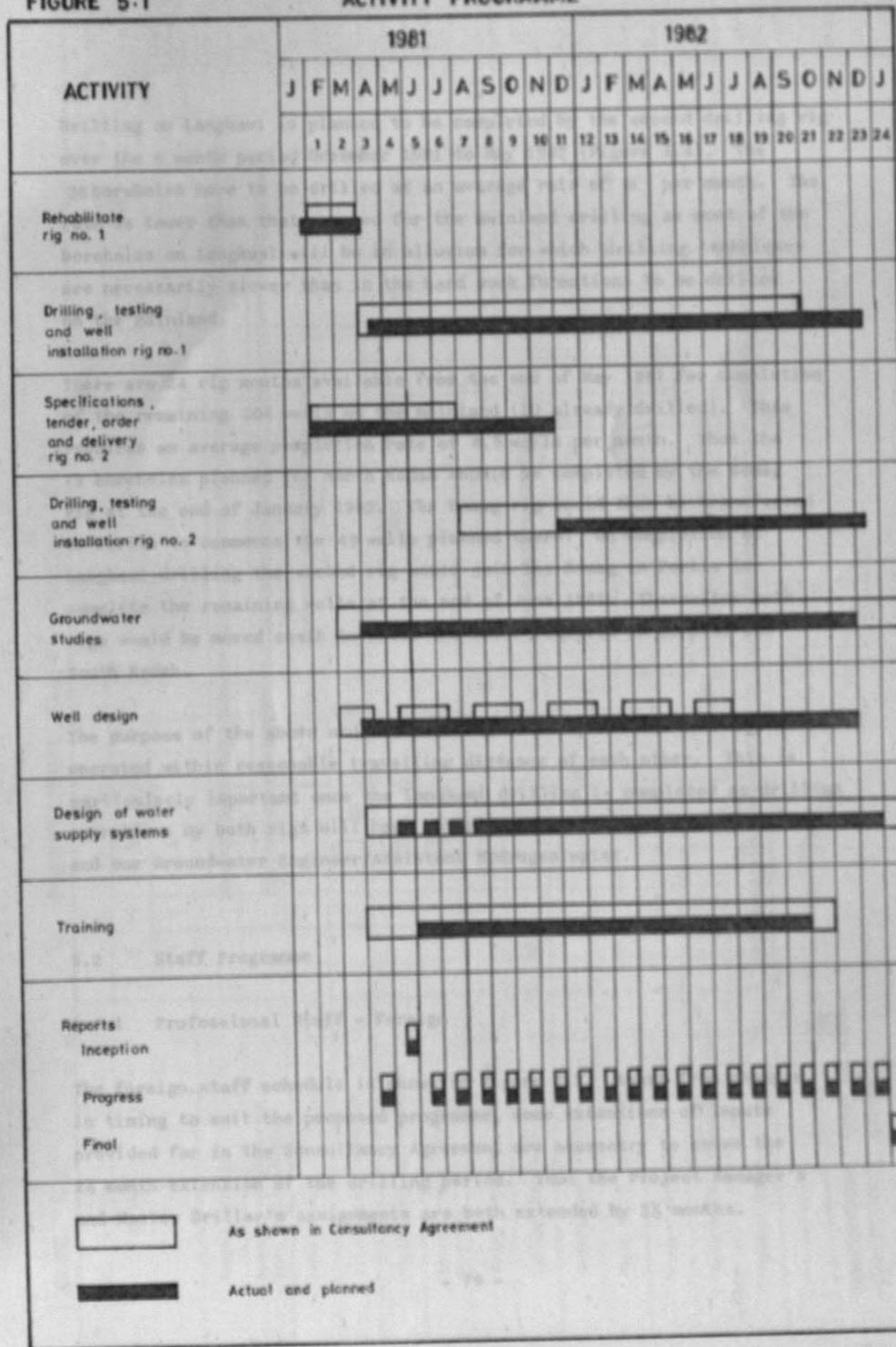
Although the drilling and testing period extends to mid-December instead of finishing in September 1982 as originally envisaged, no change has been made to the 24 month project period. However, should the target completion date not be attainable, the following points would need to be taken into account:

- up to the end of May 1981 drilling progress has been hampered by the lack of a suitable compressor for large diameter and down-the-hole hammer drilling; a suitable compressor is not expected to be available until mid-June.
- well depths may exceed the 30 metre average assumed in the Consultancy Agreement.

Actual and planned

FIGURE 5.1

ACTIVITY PROGRAMME



Drilling on Langkawi is planned to be completed by the second drilling rig over the 6 month period December 1981 to May 1982 (Figure 3.4). The 36 boreholes have to be drilled at an average rate of 6 per month. The rate is lower than that assumed for the mainland drilling as most of the boreholes on Langkawi will be in alluvium for which drilling techniques are necessarily slower than in the hard rock formations to be drilled on the mainland.

There are 24 rig months available from the end of May 1981 for completion of the remaining 204 wells on the mainland (10 already drilled). This requires an average completion rate of 8.5 wells per month. Thus the 79 boreholes planned for North Kedah should be completed by the Bomag rig at the end of January 1982. The Bomag rig would then be transferred to Perlis to commence the 48 wells planned there. On completion of Langkawi drilling the second rig would join the Bomag in Perlis to complete the remaining wells at the end of June 1982. Thereafter both rigs would be moved south to drill the wells required in Central and South Kedah.

The purpose of the above order of working is to enable the two rigs to be operated within reasonable travelling distance of each other. This is particularly important once the Langkawi drilling is completed as drilling operations by both rigs will have to be supervised by the Master Driller and one Groundwater Engineer/Assistant Hydrogeologist.

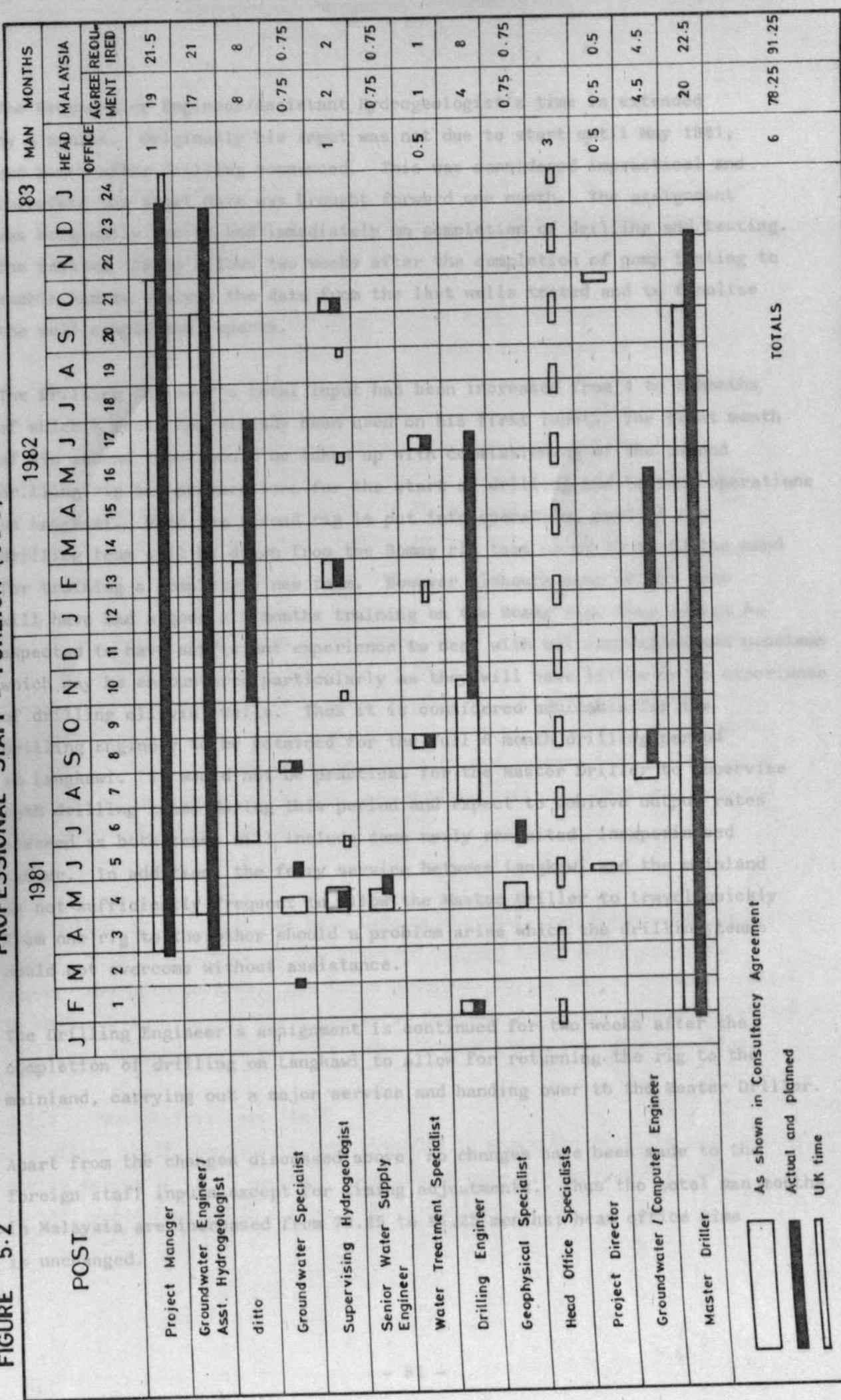
## 5.2 Staff Programme

### 5.2.1 Professional Staff - Foreign

The foreign staff schedule is shown in Figure 5.2. Apart from changes in timing to suit the proposed programme, some extensions of inputs provided for in the Consultancy Agreement are necessary to cover the 2½ month extension of the drilling period. Thus the Project Manager's and Master Driller's assignments are both extended by 2½ months.

FIGURE 5.2

PROFESSIONAL STAFF - FOREIGN (GDC)



As shown in Consultancy Agreement

Actual and planned

UK time



The Groundwater Engineer/Assistant Hydrogeologist's time is extended by 4 months. Originally his input was not due to start until May 1981, one month after drilling commenced. This was considered impractical and therefore the start date was brought forward one month. The assignment was originally due to end immediately on completion of drilling and testing. The revised timing allows two weeks after the completion of pump testing to enable him to analyse the data from the last wells tested and to finalise the well completion reports.

The Drilling Engineer's total input has been increased from 4 to 8 months of which  $\frac{1}{2}$  month has already been used on his first input. The first month of his second input would be taken up with commissioning of the second drilling rig and preparations for the start of drilling and testing operations on Langkawi. When the second rig is put into operation, part of the drilling team will be drawn from the Bomag rig team so as to avoid the need for training a completely new team. However although some of the team will have had a good six months training on the Bomag rig, they cannot be expected to have sufficient experience to deal with all conditions and problems which may be encountered particularly as they will have little or no experience of drilling alluvial wells. Thus it is considered advisable for the Drilling Engineer to be retained for the full 6 month drilling period on Langkawi. It would not be practical for the Master Driller to supervise both drilling teams during this period and expect to achieve output rates planned as both teams will include some newly recruited, inexperienced labour. In addition, the ferry service between Langkawi and the mainland is not sufficiently frequent to allow the Master Driller to travel quickly from one rig to the other should a problem arise which the drilling teams could not overcome without assistance.

The Drilling Engineer's assignment is continued for two weeks after the completion of drilling on Langkawi to allow for returning the rig to the mainland, carrying out a major service and handing over to the Master Driller.

Apart from the changes discussed above, no changes have been made to the foreign staff inputs except for timing adjustments. Thus the total man months in Malaysia are increased from 78.25 to 91.25 months; head office time is unchanged.

### 5.2.2 Professional Staff - Local

The local professional staff schedule is shown in Figure 5.3. Inputs for two posts have been changed and the timing of a third input has been adjusted to suit the amended programme.

The scope of work for the Water Engineer has been increased from that originally envisaged. Deficiencies in the population data, as described in Section 4, mean that additional work is necessary to establish reliable data from which to calculate water demand. This will have to be related to the existing and planned water supply distribution networks and to anticipated well yields in order to evaluate whether the number of wells now allocated to each area is likely to be adequate to meet demand until such time as additional surface water supplies are available. Some reallocation is certain to be desirable.

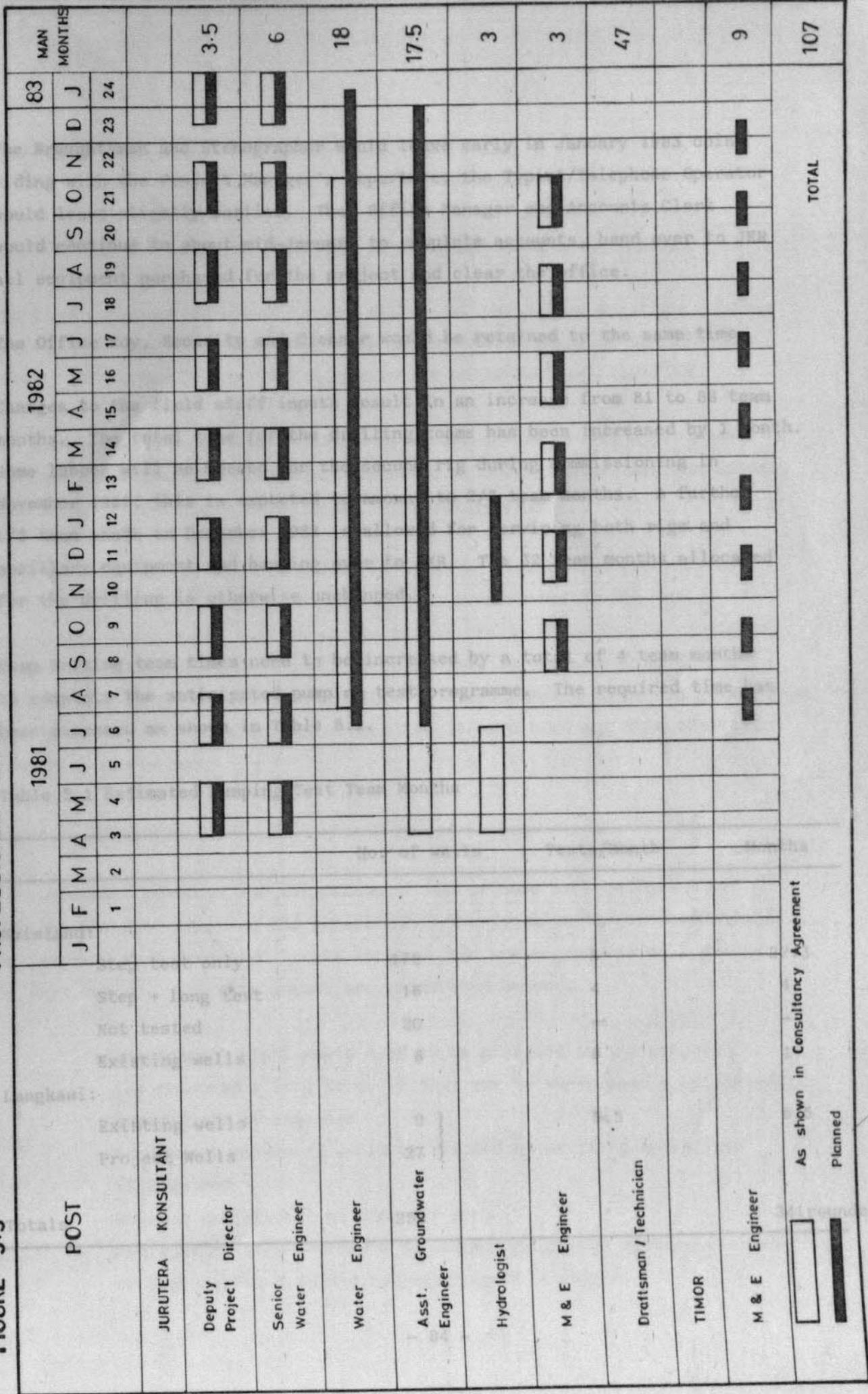
This work, together with the water supply engineering designs, will require continuous liaison with JKR in order to be able to recommend the most suitable schemes for overcoming present water shortages. The Water Engineer's input has therefore been increased from 15 to 18 months. The input is scheduled to start in July 1981 and to be completed in mid January 1983. This allows one month after completion of the last pumping tests for data analysis and preparation of scheme designs.

A reduction of one month has been made to the Assistant Groundwater Engineer's input. This is possible as the start of pumping tests and geophysical survey have been delayed. His input continues to the end of December 1982 to enable him to assist the Groundwater Engineer up to the completion of drilling, testing, data analysis and well completion report preparation.

### 5.2.3 Non-professional Staff

All office staff inputs have been extended to match the drilling and testing period extension of 2½ months. Total man months are increased from 161 to 182, approximately 2½ months average per post.

FIGURE 5.3 PROFESSIONAL STAFF - LOCAL



As shown in Consultancy Agreement  
 Planned

The Draughtsman and Stenographer would leave early in January 1983 coinciding with the Project Manager's departure; the Typist/Telephone Operator would leave slightly earlier. The Office Manager and Accounts Clerk would continue to about mid-January to complete accounts, hand over to JKR all equipment purchased for the project and clear the office.

The Office Boy, Security and Cleaner would be retained to the same time.

Changes to the field staff inputs result in an increase from 81 to 88 team months. The total time for the drilling teams has been increased by 1 month. Some labour will be needed for the second rig during commissioning in November 1981; this is expected to amount to 2/3 team months. A further 1/3 team month in December 1982 is allowed for servicing both rigs and ancillary equipment and handing over to JKR. The 32 team months allocated for the drilling is otherwise unchanged.

Pump testing team times need to be increased by a total of 4 team months to complete the anticipated pumping test programme. The required time has been assessed as shown in Table 5.1.

Table 5.1 Estimated Pumping Test Team Months

	No. of wells	Tests/Month	Months
<b>Mainland:</b>			
Step test only	178	8	22.3
Step + long test	16	4	4
Not tested	20	-	-
Existing wells	8	8	1
<b>Langkawi:</b>			
Existing wells	9	5.5	6.5
Project Wells	27		
<b>Totals</b>	<b>258</b>		<b>34 (rounded)</b>

Step tests are planned to be carried out as follows :

Day 1 - pump installation and pre-test pumping

Day 2 - step test (8-10 hours), start of recovery

Day 3 - complete recovery, remove pump, move to next site.

The long (constant discharge) tests will be of three days duration. It has been assumed that about 20 wells will not be tested owing to insufficient yield. An allowance for testing 8 existing wells has been included.

The pumping test programme on Langkawi is tied to the drilling programme. Both step and constant discharge rate tests will be required and therefore the number of tests per month is an intermediate value.

The non-professional staff schedule is shown in Figure 5.4. It will be noted that the total number of pumping test team months is 36, not 34 as calculated above. The additional two months are to allow for extra labour required in connection with drilling operations in the period up to the end of June 1981. Had it been possible to start pumping tests and geophysical survey earlier, this labour requirement would have been met from the teams for those operations.

#### 5.2.4 Trainees

The Agreement provides for allocation of one or more professional staff for 'on-the-job' training and experience. The Consultants recommendations on training were presented to JKR in April and are reproduced as Appendix B of this report. The main points are summarised below :

- counterpart staff would need to be assigned to the project for reasonably long terms if they are to experience a sufficiently broad field of exposure
- Government personnel could be trained as drilling operatives if required
- minimum qualifications proposed are:  
Hydrogeologist - Geology B Sc degree and proven mathematical ability or Engineering B Sc and hydrogeology M Sc degree.

FIGURE 5.4

NON - PROFESSIONAL STAFF

POST	1981												1982												MONTHS				
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D		83			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24					
OFFICE																													
Office Manager																									21	24			
Draughtsman																									18	21			
Stenographer																									19	23			
Accounts Clerk																									19	21			
Typist / Telephone Operator																									21	22			
Office Boy																									21	24			
Security																									21	23.5			
Cleaner																									21	23.5			
FIELD																									TOTAL	MAN	MONTHS	161	182
Rehabilitation Team																									2	2			
Drilling Team No. 1																									18	20			
Drilling Team No. 2																									14	13			
Pumping Test Team No. 1																									18	19.5			
Pumping Test Team No. 2																									12	16.5			
Geophysics Team																									17	17			
																									TOTAL	TEAM	MONTHS	81	88

Groundwater Engineer - Engineering B Sc degree and some experience of any water field.

Drilling Supervisor - technical secondary education and qualification in some aspect of mechanical engineering to UK, ONC level or equivalent

- brief periods of overseas training could be arranged

### 5.3 Costs

#### 5.3.1 Staff Costs

The revised staff programme results in changes to the foreign and local professional staff and local non-professional staff costs.

Table 5.2 shows the foreign professional staff months and costs as given in the Consultancy Agreement and as now planned. Costs have been calculated at 1980 rates as in the Agreement and show an increase of £29 511.

Table 5.2 Professional Staff Cost - Foreign (GDC), (Schedule E-2)

Post	1980 Rate £	Agreement		Requirement		
		Man Months	Amount £	Man Month	Amount £	
Project Manager	3355	19.0	63 745	21.5	72 133	Mal
	2806	1.0	2 806	1.0	2 806	UK
Groundwater Engineer/ Asst. Hydrogeologist	2129	17.0	36 193	21.0	44 709	Mal
Ditto	2351	8.0	18 808	8.0	18 808	Mal
Groundwater Specialist	3394	0.75	2 546	0.75	2 546	Mal
Computer Engineer	1788	4.5	8 046	4.5	8 046	Mal
→ Supervising Hydrogeologist	3396	2.0	6 792	2.0	6 792	Mal
→	2841	1.0	2 841	1.0	2 841	UK
Senior Water Supply Engineer	2698	0.75	2 024	0.75	2 024	Mal
Water Treatment Specialist	3396	1.0	3 396	1.0	3 396	Mal
	2841	0.5	1 421	0.5	1 421	UK
Drilling Engineer	1763	4.0	7 052	8.0	14 104	Mal
Geophysical Specialist	3396	0.75	2 547	0.75	2 547	Mal
Head Office Specialists	2070	3.0	6 210	3.0	6 210	UK
Project Director	3396	0.5	1 698	0.5	1 698	Mal
	2841	0.5	1 421	0.5	1 421	UK
Master Driller	2222	20.0	44 440	22.5	49 995	Mal
TOTALS		84.25	211 986	97.25	241 497	

Office staff costs are provided in Table 5.3. The local professional staff costs, given in Table 5.3, show an increase of M\$10 120 over those in the Agreement

The local professional staff costs, given in Table 5.3, show an increase of M\$10 120 over those in the Agreement

Table 5.3 Professional Staff Cost - Local, (Schedule E-3)

Post	1980 Rate M\$	Agreement		Agreement	
		Man Months	Amount M\$	Man Months	Amount M\$
<b>JURUTERA KONSULTANT</b>					
Deputy Project Director	9304	3.5	32 564	3.5	32 564
Senior Water Engineer	8510	6	51 060	6	51 060
Water Engineer	4485	15	67 275	18	80 730
Asst. Groundwater Engineer	3335	18.5	61 698	17.5	58 363
Hydrologist	4370	3	13 110	3	13 110
M & E Engineer	8246	3	24 738	3	24 738
Draftsman/Technician	1330	47	62 510	47	62 510
<b>TOTALS</b>					
	<b>TOTALS</b>	<b>96</b>	<b>312 955</b>	<b>98</b>	<b>323 075</b>

Table 5.4 Non-professional Staff Cost - Field (Timor), (Schedule E-4)

Task	Year	Rate M\$	Agreement Man Months	Agreement Amount M\$	Employment Man Months	Amount M\$
Rehabilitation	1981	5370	2	10 740	2	10 740
Drilling 1	1981	14390	3	43 170	4.25	61 638
Drilling 2	1982	14850	3	44 550	10.75	158 663
Drilling 3	1981	14810	2	29 620	1.7	25 177
	1982	13115	2	26 230	11.3	149 365
Pumping Test 1	1981	3700	2	7 400	2	7 400
	1982	3800	2	7 600	11.5	43 700
Pumping Test 2	1981	3500	2	7 000	2	7 000
	1982	3800	2	7 600	11.5	43 700
Geophysics	1981	4800	2	9 600	2.5	12 000
	1982	3777.5	2	7 555	17.3	65 350
<b>TOTALS</b>			<b>22</b>	<b>206 370</b>	<b>62</b>	<b>786 267</b>

Office staff costs are presented in Table 5.4 and show an increase of M\$ 18 465 over those in the Agreement. The field staff costs, shown in Table 5.5, are increased by M\$ 50 027. This is mainly due to extended inputs but a small proportion, about M\$ 1300, is due to transferring inputs between 1981 and 1982.

Table 5.4 Non-professional Staff Cost - Office, (Schedule E-4)

Post	Charge Rate M\$	Agreement		Requirement	
		Man Months	Amount \$	Man Months	Amount £
Office Manager	2100	21	44 100	24	50 400
Draughtsman	1260	18	22 680	21	26 460
Stenographer	840	19	15 960	23	19 320
Accounts Clerk	770	19	14 630	21	16 170
Typist/Telephone Operator	560	21	11 760	22	12 320
Office Boy	350	21	7 350	24	8 400
Security	600	21	12 600	23.5	14 100
Cleaner	150	21	3 150	23.5	3 525
TOTALS		161	132 230	182	150 695

Table 5.5 Non-professional Staff Cost - Field (Timor), (Schedule E-5)

Team	Year	Rate M\$	Agreement		Requirement	
			Month	Amount \$	Month	Amount \$
Rehabilitation	1981	6470	2	12 940	2	12 940
Drilling 1	1981	14360	9	129 240	9.25	132 830
	1982	14650	9	131 850	10.75	157 488
Drilling 2	1981	14810	5	74 050	1.7	25 177
	1982	15115	9	136 035	11.3	170 800
Pumping Test 1	1981	5700	9	51 300	8	45 600
	1982	5800	9	52 200	11.5	66 700
Pumping Test 2	1981	5700	3	17 100	5	28 500
	1982	5800	9	52 200	11.5	66 700
Geophysics	1981	4635	9	41 715	6.5	30 128
	1982	4717.5	8	37 740	10.5	49 534
TOTALS			81	736 370	88	786 397

### 5.3.2 Reimbursable Expenses - Staff and Office

Reimbursable staff and office cost allocations given in Schedule E-6 of the Agreement are expected to be adequate except for transport, per diem allowance (GDC) and subsistence and accommodation (JK) which need to be increased to match the extended staff inputs.

Transport requirements are shown in Figure 5.5 together with vehicle months allocated in the Agreement and those expected to be required. Costs are presented in Table 5.6 and show an increase of M\$ 39 500 over the original allocation.

Table 5.6 Transport Allowance (Schedule E-6, item 2b)

Vehicle type	Rate M\$	Agreement		Requirement	
		Months	Amount M\$	Months	Amount M\$
Cars	2000	82	164 000	97	194 000
Landcruisers	3000	116	348 000	122.5	367 500
Lorries	5000	66	330 000	64	320 000
<b>TOTALS</b>		<b>264</b>	<b>842 000</b>	<b>283.5</b>	<b>881 500</b>

The inputs for foreign professional staff in Malaysia have been increased by 13 man months. Thus the per diem costs are increased by 395 days at M\$ 40 ie M\$ 15 800.

The inputs for local professional staff have been increased by 2 man months. The subsistence and accommodation costs are therefore increased by 60 days at M\$ 30 plus M\$ 60 ie M\$ 5400.

The total increase in Schedule E-6 costs is M\$ 60 700 which can be met from the allocated contingency sum of M\$ 250 000.

### 5.3.3 Reimbursable Expenses - Well Construction

Of the 28 items in Schedule E-7 of the Agreement, 22 are expected to be adequate for completion of the programme but 6 require adjustment. These are items 2, 3, 6, 14, 20 and 27.



Items 2, 3 and 6 - uPVC casing, sockets and slotted pipe

As described in Section 2.4, casing and slotted pipe for the higher yielding wells will need to be 8 inch nominal diameter to permit insertion of suitable pumps. For the mainland wells, 4000 feet of this casing has been suggested as an appropriate allowance. For Langkawi about 1000 feet should suffice. The total of 5000 feet is expected to be needed as 3000 and 2000 feet of casing and slotted pipe respectively.

The additional cost of supplying 8 inch class D instead of 6 inch class E uPVC casing has not been firmly established but is expected to be of the order of M\$ 2 per foot. Application of this increase on a pro rata basis to the rates for sockets and slotted pipe permits rough estimation of the total additional costs shown in Table 5.7. It should be stressed that these costs can be considered as indicative only; if approval in principle is given, firm quotations will be sought.

Table 5.7 Indicative Additional Costs of 8 inch Casing, Sockets and Slotted Pipe

The total estimated increase in costs for Schedule 5-7 is summarized below

Item	Unit	Quantity	Rate M\$	Amount M\$
Casing	lin. ft.	3000	2	6 000
Sockets	No.	250	2.5	625
Slotted pipe	lin. ft.	2000	3.8	7 600
Total additional cost				M\$ 14 225

Item 14 - Revert

The allocation of 50 no 25 lb bags of Revert is estimated to be adequate for about 12 wells. On Langkawi alone, Revert will be needed for drilling 25 alluvial wells in the Sungai Melaka basin. A similar number of wells on the mainland could also require the use of Revert. Thus a further allocation of 150 bags appears justified; the additional cost would be M\$ 25 014.

#### Item 20 - Borehole geophysical equipment

Quotations obtained from several suppliers of well logging equipment show that it will not be possible to buy all the tools needed for the logs proposed in Section 2.4.1 within the allocation of £14000. The cost is more likely to be in the region of £20000. Actual costs will not be determined until tenders have been called and received but a tentative increase of £6000 in the allocation for this equipment is suggested.

#### Item 27 - Sundry items

During the period up to the end of May 1981, about M\$ 18 000 has had to be expended on items such as pipe stands, tools and miscellaneous materials. This rate of expenditure is expected to be much reduced in future months. However, there is no allowance in Schedule E-7 for cement baskets, centralisers and packers which will be needed for proper construction of the wells. Thus it is suggested that the allocation against this item be increased to M\$ 50 000 subject to review as necessary during the course of the work.

The total estimated increase in costs for Schedule E-7 is summarised below

Sub-totals	2 900 730	57 161	1 060 607	100 144
Items 2, 3 and 6		M\$ 14 225		
Item 14		M\$ 25 014		
TOTALS Item 20	14 225 225	509 150	£ 6 000	340 511
Item 27		M\$ 35 000		
Totals		M\$ 74 239	£ 6 000	

#### 5.3.4 Summary of Costs

The summary of costs in Schedule E-1 of the Agreement is reproduced in Table 5.8 together with the adjusted costs described in the preceding sections. The overall cost increases amount to M\$ 152 851 and £35 511, equivalent to about 5½% of the original total cost.

Table 5.8 Summary of Costs

Item	Agreement		Adjusted Costs	
	N\$	£	N\$	£
STAFF COSTS				
E-2 Professional Staff (GDC)		211 986		241 497
E-3 Professional Staff (JK)	312 955		323 075	
(Timor)	45 540		45 540	
Non-professional Staff:				
E-4 Office	132 230		150 695	
E-5 Field	736 370		786 397	
Sub-totals	1 227 095	211 986	1 305 707	241 497
ESTIMATED REIMBURSABLE EXPENSES				
E-6 Staff and Office	1 666 815	35 644	1 666 815	35 644
E-7 Well Construction	1 321 923	61 500	1 396 162	67 500
Sub-totals	2 988 738	97 144	3 062 977	103 144
TOTALS:	4 215 833	309 130	4 368 684	344 641

## TERMS OF REFERENCE

## 1. Background and Objective

1.1 The States of Kedah and Perlis in the northwest of Peninsular Malaysia encounter drought every year for about 5 months (December to April) and during this season traditional sources of water deplete in quantity and quality. In areas not served by piped water supply, dependence on shallow well supplies especially in the rural areas has been the practice. However during the prolonged drought season the majority of these wells dry up and PWD Kedah/Perlis have to mount drought relief measures by transporting drinking water to the drought-stricken areas. The drought-relief measures even extend to areas at the extremities of the existing reticulation system where poor supply in terms of quantity and pressure occur.

1.2 The drought season is an annual affair and by virtue of the fact that more rural roads are being constructed every year, thereby providing easy access to the villages, the request for PWD truck supply will increase in the coming years. This exercise is not only expensive and time consuming but imposes a strain on the PWD's manpower resources and transport facilities.

1.3 The drought pattern is steadily getting worse every year and it is the intention of both State Governments to implement a crash programme of works to supply all these drought-affected villages outside the supply network with a supply of water from wells.

1.4 Under the 'Kedah/Perlis Water Resources Management Study' already completed by a firm of consultants, an exploratory/drilling programme involving 109 wells was completed in 1979. The wells were drilled according to geological and exploratory criteria so as to test the different rock formations. The Government provided the Consultant a drilling rig (BONAG B411) and ancillary equipment with expertise contributed by the Consultant. In addition to the drilling programme carried out with Government drilling rig a separate contract was also let out to a local contractor with supervision provided by the Consultant.

1.5 Based on the findings of the Consultant under the study and the results available in the aforementioned exploratory programme, supplemented with additional drilling where necessary, it is the intention of both the State Governments that additional production wells be developed to meet the water needs of the drought-affected areas. It is envisaged that 200 wells will be required in Kedah and 50 wells in Perlis. This crash programme must be geared to be completed within a period of 20 months.

1.6 The objective of the services to be performed by the Consultants is to allow the 250 communities in Kedah and Perlis to be served with a full reticulated water supply where the ground water resources locally available will reasonably allow. Hand pump supplies will only be designed where it is verified after pumping tests or such other means as may be agreed that conditions do not allow a full reticulated supply.

## 2. Scope of Services

2.1 The following services shall be provided by the Consultant:

- (a) Examine the condition of the existing Bomag drilling rig and its spare parts, rehabilitate the rig and order on the Government's behalf the additional spares and equipment to complete the project.
- (b) Produce specifications and tenders for a second drilling rig, evaluate tenders and place an order for the rig and necessary spares and equipment on the Government's behalf.
- (c) Study and evaluate all relevant existing data and reports which will be made available to the Consultant.
- (d) All consulting services required for the investigation of groundwater resources, the location of wells and the design of wells to the well-head.
- (e) Direct a drilling team or teams to the proposed sites, supervise drilling, obtain samples where required for analysis, determine the type of screen to be used, obtain the necessary materials and casing the tubewell including any necessary gravel packing and keeping adequate records.

- (f) Arrange for the carrying out of discharge tests to confirm the safe yield of each well.
- (g) Analyse and evaluate the pumping test and water sample results and submit the reports to the Government.
- (h) Provide the services for the drilling of 250 boreholes averaging 30 metres deep, lined where necessary with casing and appropriate screening.
- (i) The design of the well head systems, well pumps, and storage tanks, together with the specifications for the pumps and tanks and the sizing of the transmission main between the wells and the storage tanks/treatment works, taking into account the requirements of the distribution system.
- (j) The Consultant will evaluate the water demands and their future projections in relation to the available resources and come to an agreement with the Government on the levels of supply that can be provided.
- (k) The Consultant shall identify the sites of the storage tanks and define their top and bottom water levels, their storage capacity and recommended phasing of construction.
- (l) The Consultant shall identify the need for any additional forwarding or booster pumping stations. The Consultant may be requested to design these on terms and conditions to be mutually agreed upon.
- (m) The Consultant shall identify the need for any water treatment and define the alternative methods, or most suitable method, of treatment.
- (n) The Consultant shall supervise the installation of the wells to the well capping only.
- (o) Prepare monthly progress reports.
- (p) Submit a final report covering all aspects of the Project.

(q) Recommend on future maintenance and operation of all installations.

2.2 The Government may assign one or more professional staff to the Consultant for 'on-the-job' training and experience with this project.

### 3. Facilities to be made available to the Consultant

3.1 The Government shall provide the following equipment:

1 No. lorry mounted Bomag B411 drilling rig

Accessories to the above

1 No. air compressor (Ingersoll Rand)

3 No. 6 inch Grundfos electric submersible pumps

\*1 lorry mounted drilling rig for DTH drilling with accessories

\*1 No. 600 cfm x 200 psi compressor and accessories

2 No. generators

The items already in the Government's possession above are thought to be well maintained apart from certain aspects of the condition of the existing rig and some possible damage to the submersible pumps.

3.2 In addition, the Government will make available a copy of the Kedah-Perlis Water Resources Management Study report, inclusive of the hydrogeological report, the topographic maps and air photographs.

3.3 The Government's water quality testing laboratory staff and facilities at Penang shall be available for testing purposes.

3.4 The Consultant shall recommend the siting of each well for the Government's approval and shall adopt a procedure whereby such approval is requested and obtained without any delay in the progress of the drilling.

3.5 The Government shall provide the following services:

(a) adequate furnished office accommodation at 729 Jalan Mahkota and fencing off of the premises.

(b) assist the Consultant in obtaining any necessary import licences, assist in custom clearance and reimburse any import duties relating to the equipment.

(c) not unreasonably withhold permission for the Consultant to publish papers of scientific interest in learned journals but the Government's approval shall first be obtained. The Consultant shall not divulge any information considered confidential by the Government.

#### 4. Consultant's Personnel

4.1 The Consultant must have suitable and experienced professional Personnel to undertake work of the magnitude enumerated on these Terms of Reference. They shall be members or employees of a firm/firms which specialise in underground water development and water supply engineering with special emphasis on drinking water.

The Personnel may include:-

Hydrogeologist

Geologist/Geophysicist

Water Supply Engineer

Water Treatment Specialist

#### 5. Management of the Project

5.1 The Project will be under the overall charge of the Director JKR Kedah. However, JKR Perlis shall be consulted and its staff may participate in the project when the Consultant carries out his work in that State.

5.2 A co-ordinator shall be assigned to the Project and shall assist the Consultant in any way necessary for the successful completion of the Project.

## 6. Time Completion

6.1 The drilling programme is designed to be completed in 20 months made up as follows:

- (a) 2 months rehabilitation of the existing Bomag Rig.
- (b) 18 months drilling with existing Bomag Rig.
- (c) 6 months for supply of second Government rig.
- (d) 14 months drilling with second Government rig.

The Consultant shall complete the drilling or the equivalent footage thereto in the periods stated above. In the event of delay due to the fault of the Consultant, the Consultant shall retain on site the staff necessary for the proper completion of the work at no additional cost to the Government. However, the Consultant shall be reimbursed by the Government according to the conditions of the Agreement for any extension of time caused by circumstances outside his control.

Drilling is defined as the time actually spent in drilling operations, including normal movement between sites, setting up and dismantling and stoppages due to breakdown not exceeding seven days, but excluding stoppages due to inclement weather conditions.

6.2 The Government shall provide both drilling rigs in such time as to allow 32 rig-months in the 20 months project period specified.

A level of on-the-job training at less than true counterpart level is of course possible. However, the degree of effort on training the actual drilling operatives they directly employ to construct production wells and any specific training of government personnel in this field would have to be delayed until later in the project when the Consultant/Contractor's personnel are themselves adequately trained.

## 6.2 Suitable Personnel

It is proposed that any personnel accorded for full counterpart training have the following minimum qualifications:

## APPENDIX B

### NOTE ON TRAINING OF JKR STAFF

#### B.1 Introduction

On a job like the construction of 250 production wells in Kedah and Perlis there are basically two forms of training that can be given:- on-the-job training and formal training; the way the job is set up, the former is likely to be of far greater importance and value. It is therefore proposed that any training component provided be based essentially on on-the-job training with a small content of formal lectures and instructions. Pure formal training, both in Malaysia and UK would however be essential for such specialist fields as digital groundwater modelling on computer.

The implications of on-the-job training are effectively that staff to be trained would have to be assigned to the project on a counterpart basis for reasonably long terms and that the expatriate counterpart to whom they are assigned would also have to have a long-term input. It is considered that the minimum training period on this basis is about 9 months if trainees are to experience a sufficiently broad field of exposure. Thus on present plans, some three counterpart trainees could be accepted at any one time and a total of six during the currency of the project. They would have to be in the disciplines of (2 each) - drilling supervisor, groundwater engineer and hydrogeologist.

A level of on-the-job training at less than true counterpart level is of course possible and essential for drilling operatives. However, the Consultant/Contractor is already obliged to spend a considerable degree of effort on training the actual drilling operatives they directly employ to construct production wells and any specific training of government personnel in this field would have to be delayed until later in the project when the Consultant/Contractor's personnel are themselves adequately trained.

#### B.2 Suitable Personnel

It is proposed that any personnel seconded for full counterpart training have the following minimum qualifications :-

a) Drilling Supervisor - technical secondary education and qualification in some aspect of mechanical engineering to UK, ONC level or equivalent.

b) Hydrogeologist - Geology B Sc degree and proven mathematical ability or engineering B Sc and hydrogeology M Sc degree.

c) Groundwater Engineer - Engineering B Sc. degree and some experience of any water field.

Anyone proposed for full formal training in groundwater modelling would require to be vetted by the Consultant in advance, since his experience and background would be more important than his formal qualifications. These qualifications would be either a degree in geology, engineering, hydrogeology or even environmental sciences. However, it is only possible to train someone, in the short time available, in computer groundwater modelling if he has existing background or experience in either groundwater or computer modelling in general but almost certainly not if he lacks both. The ideal candidate would be someone with an M Sc degree in hydrogeology and a first degree in either geology or engineering, of proven mathematical ability and 3 to 5 years of field experience.

Personnel for drilling operatives need not necessarily have any formal qualifications, since the required characteristics are simply intelligence common sense and foresight. However some formal technical education in the form of post matriculation technical school or college certificate would be desirable as initial evidence of these factors. A working knowledge of English language would also be desirable, both as evidence of application and a surer means of transmitting training; this latter not only because of the language of the Consultant's personnel but also because international drilling terminology is a jargon based on English, which makes sense only if approached from its initial derivations.

However, the primary consideration at this level is the fact that the

### B.3 Possible Programme

an employee will require a considerable degree of initial training. It is not considered therefore that specifically

Whilst it was stated previously that two of each discipline of the counterpart trainees could be accepted during the programme (and the Consultants are quite willing to accept this approach) it is clear that training given on this basis would be rather superficial.

A drilling supervisor trained in this manner for example might be able to oversee subsequent drilling operations carried out by a competent contractor, but it is unlikely that he would be suited to instigate and control a new drilling programme in variable conditions with equipment for which he was directly responsible. Similarly, hydrogeologists and groundwater engineers need exposure to a range of conditions broader than those locally available and the simplest way to ensure this is to couple a longer period of on-the-job training with a brief period of overseas combined and formal training.

Thus the recommended counterpart training programme would be based on one counterpart for each expatriate long-term specialist for the whole term of the programme, with provisional allocations of overseas training periods for the hydrogeologist and groundwater engineer. Assuming that either the counterpart hydrogeologist or the groundwater engineer was the person selected for training in groundwater modelling, his period of formal overseas training would be extended. The bar-chart in Figure B.1 shows the recommended secondment periods, starting dates and periods overseas.

Regarding drilling operatives, the critical personnel for future operations are considered to be assistant or shift drillers, field mechanic and pump test supervisors. A future 'tool-pusher' or master driller would have to be chosen either from the best of the trained drillers or the counterpart drilling supervisor and there is no way to say at present which of these would in the event prove most suitable. A driller's prime function is to produce good quality hole in the least possible time with minimal damage to the equipment used. This can be an art as much as a science and a formally untrained person with the correct 'feel' for the job can be superior to someone with years of classroom training or theoretical knowledge.

However, the primary consideration at this level is the fact that the Consultants/Contractors own employees will require a considerable degree of initial training. It is not considered therefore that specifically assigned government trainees can be accepted before about month six of the programme. Thereafter, basic training could be given to about three persons every seven to eight months in a variety of the fields considered, provided two drilling rigs were operating.

The recommended procedure then would be to accept three trainee operatives at about month six, train them for the next 7-8 months, at that stage assess the best and assign him for more intensive training as a 'tool pusher' and either continue the training of the remainder or replace them with two new training operatives. These alternatives are also illustrated in Figure B.1.

#### B.4 Facilities and Approvals

Whilst the Consultant has adequate office space and general facilities both in UK and Malaysia to accommodate and service trainees on the scale envisaged, so that no specific reimbursement would be sought for these services, it is clear that there are particular costs involved in a training programme which must be met.

It is assumed that the government would directly pay or reimburse all wages, salaries, allowances and travel costs of trainees both in Malaysia and UK and would reimburse specific course and textbook or training aid expenditures. The most common failures of training programmes of the type envisaged are incentive to trainees to participate in field work and adequate transport to get them there. The Consultant's transport requirements are tailored quite tightly to the pure execution requirements of the project and it is therefore assumed that the extra requirements for trainees would be met by specific transport allocations. It is hoped that trainees pay scales would be structured in such a way as to encourage them to actively participate in field operations.

One aspect of general training programmes requires specific emphasis and understanding. By definition, most trainees do not fully comprehend the implications of the job they are undertaking, simply because of their inexperience. Similarly, simply because training is necessary, the selection process for trainees, initially at least, is almost bound to produce candidates who are either temperamentally or qualification-wise unsuited to the work for which they are being trained. It must be recognised that it is a waste of both money and effort to continue with training of such persons.

It is therefore proposed that all trainees be subject to at least a four-month probationary period during which their suitability for further training can be assessed. If at anytime during this period they are deemed to be unsuitable, the Government should remove them at the Consultant's request, replacing them at the Government's option.

Such removal or replacement must not necessarily be regarded as a blemish on the performance record of the individual concerned since an assessment of 'unsuitable for training' is as likely to derive from inadequate selection as from inadequate performance. Nevertheless, the possibility of being so assessed is a powerful incentive to perform.

Trainees

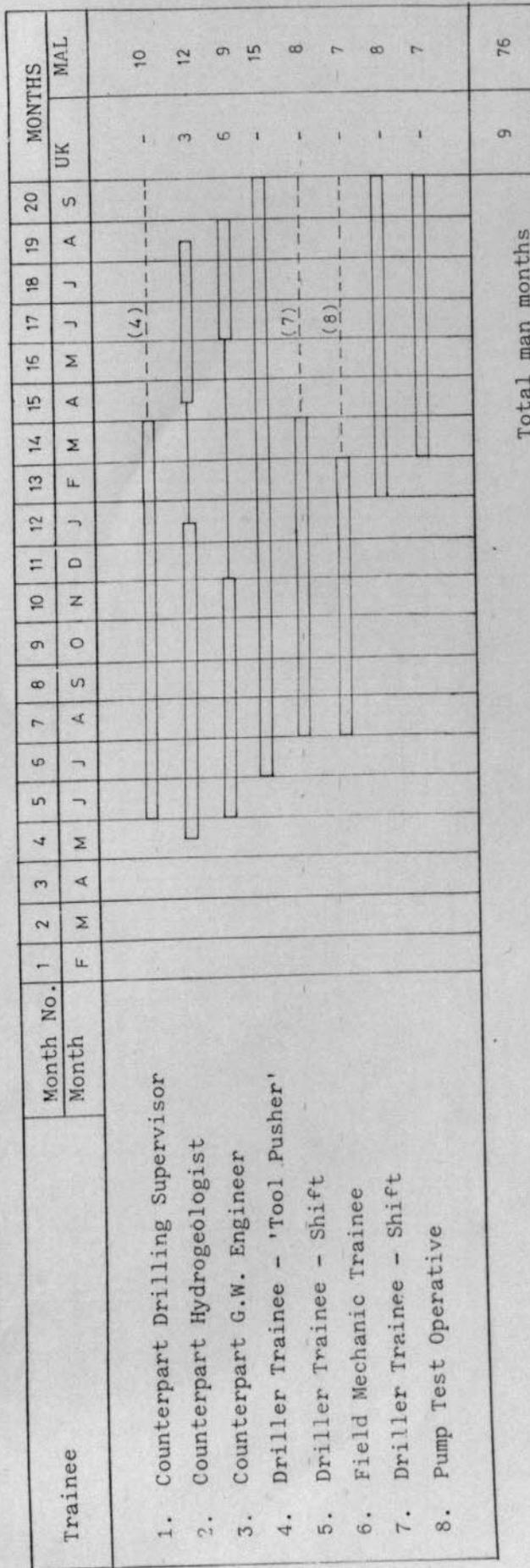
1. Counterpart Drilling Technicians
2. Counterpart Hydrogeologists
3. Counterpart C.W. Engineers
4. Driller Trainee - Tool Pusher
5. Driller Trainee - Shift
6. Field Mechanic Trainee
7. Driller Trainee - Shift
8. Pump Test Operator

in Malaysia

in U.K.

alternative No. 1/1

Figure B.1 Trainee Programme



 in Malaysia  
 in U.K.  
 alternative to (4)