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Groundwater supply studies in Northern Kelantan

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Abstract: Hydrological investigation was undertaken to evaluate the groundwater resources that would meet or contribute to the water supply needs of Northern Kelantan. A total of 24 exploratory wells and two production wells were drilled at localities where the aquifer was most likely to be productive. Based on the results, the shallow aquifer is favoured for development because it has good quality water, gets recharged readily and wells are shallow giving rise to low construction and pumping cost. The 3rd aquifer has water of acceptable salinity (10-65 mg/l) and based on existing literature it is also favoured for development at selected localities.

It is proposed to utilize both these aquifers to provide water supplies of up to 172 Ml/d to the year 2000 for Kota Baru and Bachok districts. For the district of Tumpat, the shallow aquifer at Wakaf Baru will be able to meet the projected total water requirement of 22.8 Ml/d to the year 2000. Well-fields proposed in the vicinity of Kg. Sg. Petai and Gong Kedak may prove adequate to meet demand of 10 Ml/d to the year 2010 for Pasir Puteh district.

INTRODUCTION

Hydrogeological investigation was undertaken to evaluate groundwater resources that would meet or contribute to the water supply needs of Northern Kelantan. The main area selected was in the vicinity of Kota Baru (Fig. 1) where water demand is greatest.

EXISTING SYSTEMS

At present there are 18 water supply systems in Northern Kelantan. They can be categorised into groundwater supply systems and river abstraction supply systems as set out in Table 1. As groundwater constitutes the largest source of supply in the study area, a total of 9 groundwater supply systems are located in and around the town of Kota Baru. Most of the groundwater is abstracted from the lst aquifer whereas at Tanjong Mas the 3rd aquifer is developed. Details of the 9 mentioned well-fields is given in Table 2. Except for Tanjong Mas and Wakaf Baru where iron is removed from groundwater by treatment, the groundwater from the other well-fields is only chlorinated and put into supply.

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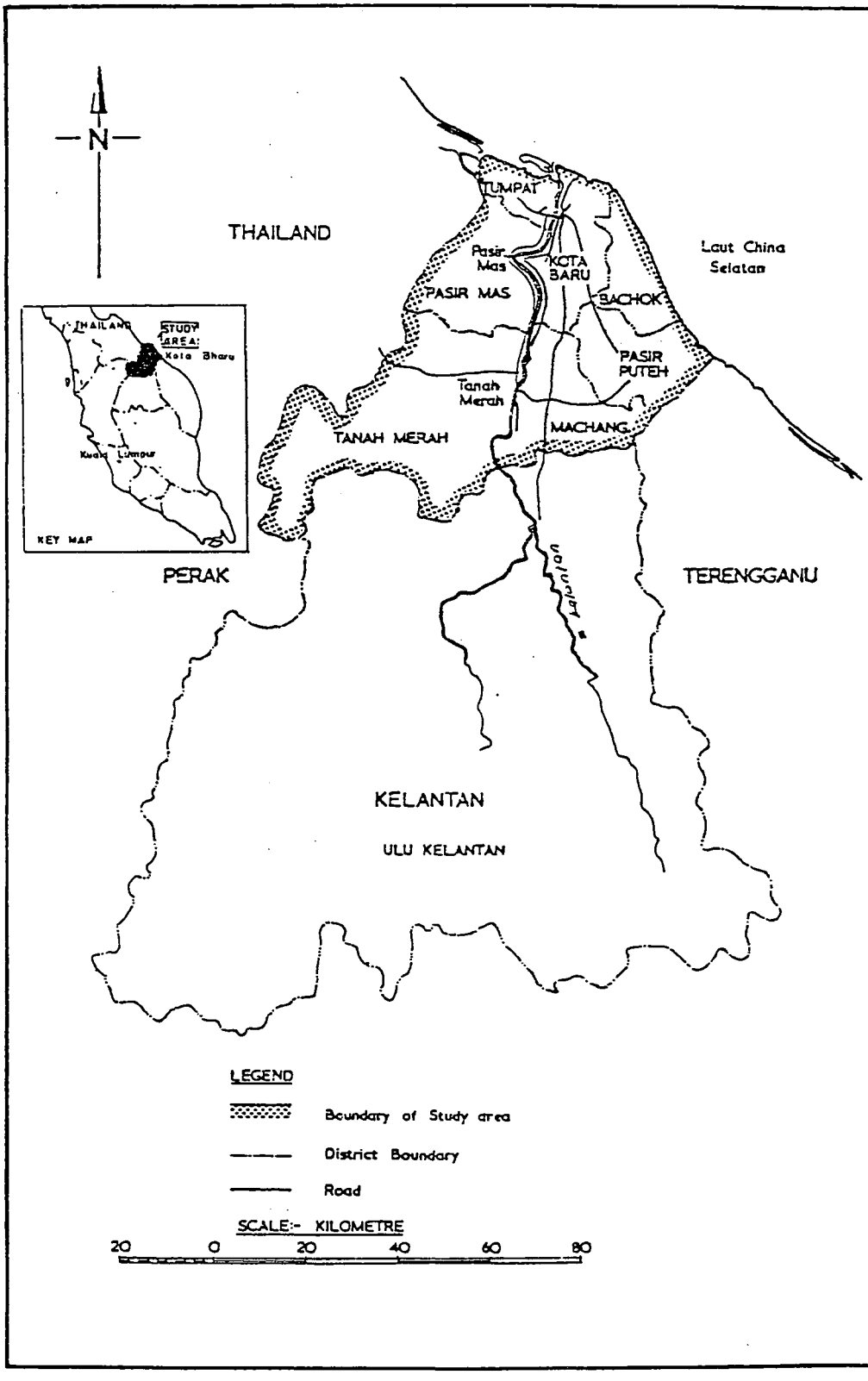

Figure 1 : Location map of Kelantan State

Table 1: Water Supply Systems in Northern Kelantan

District	Water supply systems	Design capacity Ml/d	Source of supply	Additional treatment facilities available
Kota Baru	Kg. Puteh	25.1	Groundwater	No
	Kubang Krian	12.0	Groundwater	No
	Tg. Mas	9.1	Groundwater	Yes
	Pintu Geng	1.0	Groundwater	No
	Pengkalan Chepa	3.3	Groundwater	No
Bachok	Kg. Chap	2.3	Groundwater	Yes
	Kg. Jelawat	0.8	Groundwater	No
Pasir Puteh	Wakaf Bunut	18.2	River Abstraction	Yes
Tumpat	Wakaf Baru	18.2	Groundwater	Yes
	Kg. Sedar	0.9	Groundwater	Yes(closed)
Pasir Mas	Sg. Lemal	2.3	River	Yes(standby)
	Kg. Kelar	11.4	River	Yes
	Rantau Panjang	0.7	Groundwater	No
Machang	Sg. Sat	0.4	River	Yes (closed)
	Temangan Baru	0.4	River	Yes (closed)
Tanah Merah	Tanah Merah - Sg. Kelantan	20.5	River	Yes
	Tanah Merah	0.5	Groundwater	Yes (closed)
	Air Lanas	0.5	River	No

Table 2: Details of Wellfields in and around Kota Baru

District	Existing Wellfields	Total Designed Capacity Ml/d	1985 Supply Ml/d	Number of Wells
Kota Baru	Kg. Puteh	25.06	22.30	18
Kota Baru	Pintu Geng	1.00	0.96	6
Kota Baru	Tanjong Mas	9.08	3.18	9
Kota Baru	Kubang Krian	12.00	7.26	8
Kota Baru	Pengkalan Chepa	3.27	1.80	11
Tumpat	Wakaf Baru	18.16	12.11	4
Pasir Mas	Rantau Panjang	1.18	1.18	3
Bachok	Kg. Chap	2.27	1.63	3
Bachok	Kg. Jelawat	0.82	0.50	1
		72.84	50.92	

SHALLOW GROUNDWATER

The composition of the lst aquifer (shallow groundwater) comprises of sand and gravel that extends from the ground level in some places or the base of the surface clay down to the next major clay bed. Generally, it lies between 5 to 15 metres depth below ground surface. In some places it is unconfined and in other places it is confined by the surface clay. In most places the shallow groundwater is fresh and of suitable quality but locally iron concentration can be in the range of 0.85 mg/l to 10.95 mg/l. The shallow groundwater is the most exploited source in the Kelantan groundwater basin.

DEEP GROUNDWATER

The groundwater contained in the aquifers beneath the shallow groundwater are collectively termed as "Deep Groundwater". Three main aquifer intervals in addition to the shallow aquifer have been recognised east of the Kelantan river and named the 2nd, 3rd and 4th aquifers respectively. The 3rd aquifer which lies between 45 to 130 m depth contains the better quality water and thus has been developed at Tanjong Mas. The water in the 2nd aquifer is brackish whereas it has been found to be saline in the 4th aquifer.

GROUNDWATER DEMAND AND EVALUATION

Based on population projection on a 5 yearly basis, the expected groundwater demand for urban use to the year 2010 is shown in Table 3. It can be seen that the groundwater demand exceeds the 1985 designated capacity of 72.84 Ml/d by amounts increasing from 12 Ml/d in 1985 to 211 Ml/d in 2010. In view of this increasing deficit in groundwater demand, an investigation programme was launched to evaluate availability of groundwater to meet all or part of the projected demand.

Table 3: Expected groundwater demand for urban use

District	1985 Total Designated Capacity	Projected Demand					
		1985	1990	1995	2000	2005	2010
	Ml/d	Ml/d	Ml/d	Ml/d	Ml/d	Ml/d	Ml/d
Kota Baru	50.41	55.50	76.13	115.66	150.76	182.15	220.54
Tumpat	18.16	14.36	16.87	19.60	22.78	25.02	27.57
Bachok	3.09	11.60	13.40	17.82	21.27	23.55	26.08
Pasir Puteh	-	2.16	6.47	9.03	9.42	9.64	9.85
Total	72.84	84.80	112.87	162.11	204.23	240.36	284.04
Increase		11.96	40.03	89.27	131.39	167.52	211.20

The investigation was confined to the shallow aquifer being the most likely system to yield the required quantity and quality. Deeper aquifers were evaluated from existing data. A total of 24 exploratory wells (100 mm ø) were drilled at localities where the aquifer was most likely to be productive (Fig. 2). Strata samples were geologically logged, exploratory wells were gamma-ray logged and short pumping test of 1 hr duration was carried out at all wells to allow water sampling for chemical analysis and drawdown measurements. Each well was disinfected with sodium hypochlorite solution on completion. Water levels in all wells were recorded at the end of the evaluation programme. Based on the findings of the investigation, 2 production wells of 300 mm ø were drilled at the most productive areas. Details of the exploratory and production wells are given in Tables 4 and 5. The test pumping results of the investigation as given in Table

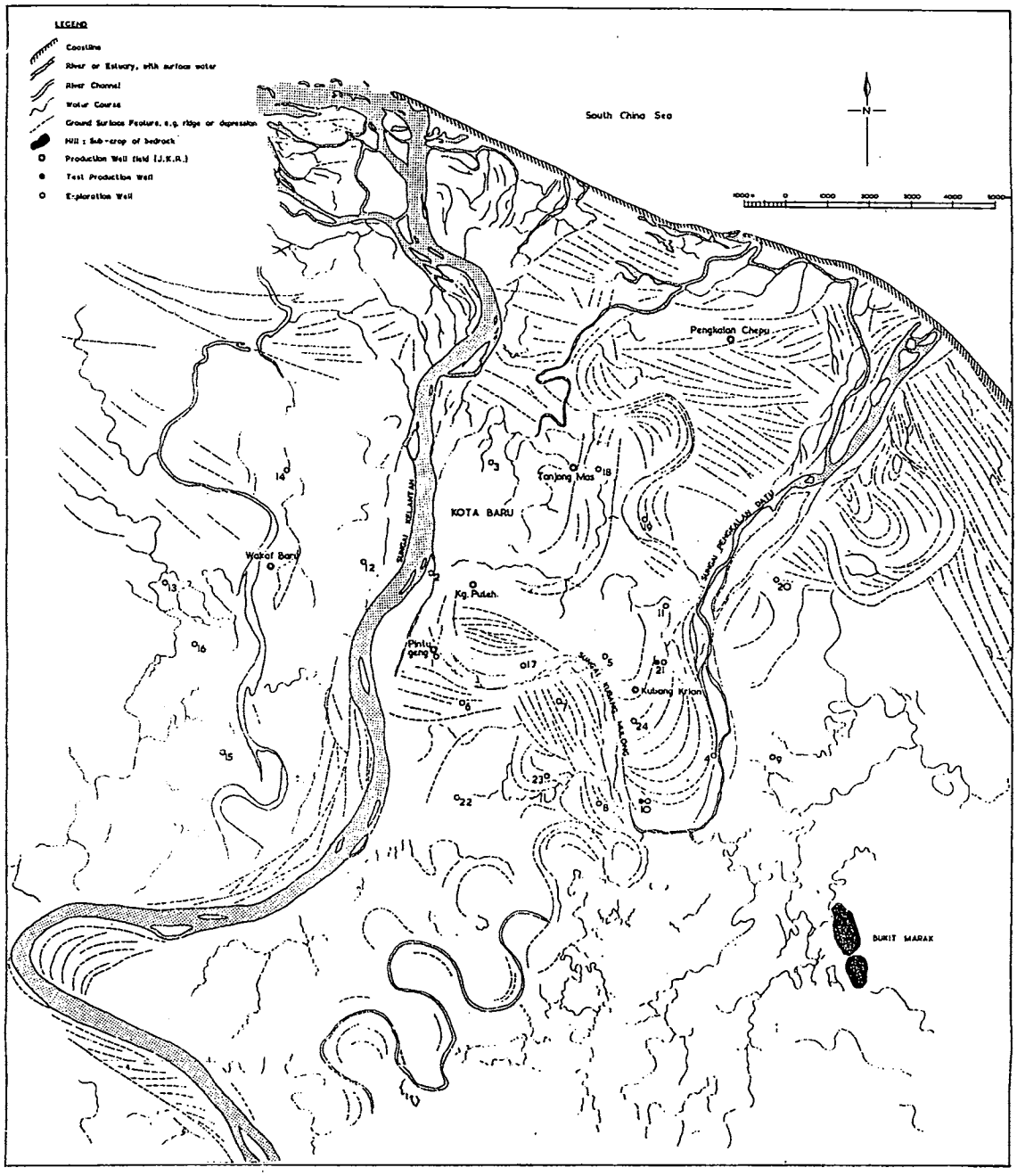

Figure 2: Groundwater Study - Surface feature map for Districts of Kota Baru, Tumpat & Pasir Mas

Table 4: Exploration Well Data

Well No. Location	Unit/Datum	1 Pintu Geng	2 Sultan Yahya Putra Bridge	3 Wakaf Mek Zainab	4 Wakaf Stan	5 Kg. Chabang Pasir	6 Wakaf Che Ye	7 Kg. Pasir Hor	8 Kg. Seribong
Elevation G.S.	m (a. mean sea level)	7.44	2.00	2.52	5.61	5.25	6.52	6.18	6.26
Elevation Collar	m (a. mean sea level)	7.88	2.42	3.05	6.08	5.82	7.07	6.68	6.80
Depth Drilled	m (b. ground surface)	15.00	15.00	14.50	15.00	19.50	15.00	12.00	16.00
Steel Collar	m (b. ground surface)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Casing (100mm PVC)	m (b. ground surface)	15.00	11.50	13.50	15.00	16.00	14.50	11.50	15.50
Slotted Interval	m (b. ground surface)	4.5-14.0	4.0-11.0	3.0-12.5	4.5-13.0	12.0-15.0	3.0-13.5	3.0-10.5	7.5-14.5
Static Water Level	m (b. collar)	6.59	2.04	2.35	5.65	4.49	5.01	5.00	5.67
Static Water Level	m (b. ground surface)	6.16	1.70	1.80	5.22	3.94	4.51	4.53	5.15
Static Water Level	m (a. mean sea level)	1.29	0.38	0.70	0.43	1.33	2.06	1.68	1.13
Date SWL Measured	1985	28/7	28/7	28/7	28/7	28/7	28/7	28/7	28/7
Depth Upper Clay	m (b. ground surface)	6.20	3.20	3.00	4.80	12.80	4.50	4.20	5.00
Aquifer Interval(s)	m (b. ground surface)	6.2-13.4	3.2-7.8	3.0-11.0	4.8-12.5	12.8-14.5	4.5-10.3 12.3-13.9	4.2-10.0	5.0-12.4
Saturated Aq Thickness	m	7.20	4.60	8.00	7.30	1.80	7.40	5.50	7.20
Water Conductivity	micromhos/cm at 25°C	90	160	300	80	220	70	50	40
Water Salinity	mg/l TDS, by analysis	76	76	125	56	87	64	41	45
Water pH	(measured in field)	-	5.60	-	5.30	5.70	5.30	5.00	5.60
Water Fe	(acidified sample)	1.20	0.40	2.10	0.60	4.80	0.50	0.70	1.10

Table 4 : Exploration Well Data (Continued)

Well No. Location	Unit/Datum	9 Kg. Binjai	10 Kg. Chicha 5.5 Batu	11 Kg. Darat Demit	12 Pasir Pekan	13 Kg. Delima	14 Kg. Kebakar	15 Padang Pg Manan (Polytech)	16 Kg. Bunut Susu
Elevation G.S.	m (a. mean sea level)	5.88	5.67	3.30	6.53	4.89	3.12	7.75	6.73
Elevation Collar	m (a. mean sea level)	6.34	6.17	3.84	7.00	5.13	3.71	8.23	7.14
Depth Drilled	m (b. ground surface)	17.00	15.50	21.00	13.50	19.80	10.60	18.30	10.50
Steel Collar	m (b. ground surface)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Casing (100mm PVC)	m (b. ground surface)	17.00	15.50	14.50	12.50	-	11.00	-	10.30
Slotted Interval	m (b. ground surface)	8.0-16.0	4.5-14.3	12.0-13.5	7.5-11.2	-	4.5-10.0	-	1.2-9.0
Static Water Level	m (b. collar)	4.96	5.49	3.18	5.38	-	1.69	-	2.44
Static Water Level	m (b. ground surface)	4.54	5.03	2.66	4.92	-	1.12	-	2.05
Static Water Level	m (a. mean sea level)	1.38	0.68	0.66	1.62	-	2.02	-	4.70
Date SWL Measured	1985	28/7	28/7	28/7	28/7	-	28/7	-	28/7
Depth Upper Clay	m (b. ground surface)	8.90	4.60	7.90	5.90	18.5+	3.50	18.30+	3.30
Aquifer Interval(s)	m (b. ground surface)	8.9-16.0	4.6-13.2	7.9-8.9	5.9-11.1	-	3.5-9.3	-	3.3-5.2 6.8-9.1
Saturated Aq Thickness	m	7.10	8.20	1.00	5.20	-	5.80	-	4.20
Water Conductivity	micromhos/cm at 25°C	90	60	-	40	-	90	-	40
Water Salinity	mg/l TDS, by analysis	45	58	-	55	-	84	-	45
Water pH	(measured in field)	5.00	5.60	-	5.20	-	6.20	-	5.90
Water Fe	(acidified sample)	0.70	1.20	-	5.90	-	4.50	-	2.80

Table 4 : Exploration Well Data (Continued)

Well No. Location	Unit/Datum	17 Kg. Ayer Deras	18 Kg. Rambutan Rendang	19 Kg. Tapang	20 Kg. Kedai Lalat	21 Universiti Kb. Krian	21B Universiti Kb. Krian	22 4.5 Batu Jln. K. Krai	23 Kg. Padang Penyadap	24 Kg. Chicha
Elevation G.S.	m(a. mean sea level)	3.77	4.99	4.91	3.89	4.11	-	4.84	5.65	6.10
Elevation Collar	m(a. mean sea level)	4.22	5.40	5.15	4.33	4.48	4.24	5.21	6.04	6.56
Depth Drilled	m(b. ground surface)	16.00	14.60	23.00	21.30	13.00	25.00	18.00	18.20	15.00
Steel Collar	m(b. ground surface)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Casing (100mm PVC)	m(b. ground surface)	6.50	12.70	21.50	21.80	13.50	24.50	15.50	16.50	12.50
Slotted Interval	m(b. ground surface)	3.0-5.4	3.0-7.0 8.0-11.6	3.0-9.9 12.1-19.8	8.5-18.9	4.0-11.5	21.7-24.5	9.5-14.5	7.5-14.5	3.0-11.0
Static Water Level	m(b. collar)	2.34	4.97	3.99	3.76	3.89	3.66	1.83	4.88	5.77
Static Water Level	m(b. ground surface)	1.93	4.96	3.57	3.33	3.55	-	1.48	4.50	5.34
Static Water Level	m(a. mean sea level)	1.88	0.43	1.16	0.57	0.59	0.58	3.38	1.16	0.78
Date SWL Measured	1985	28/7	28/7	28/7	28/7	28/7	12/8	28/7	28/7	28/7
Depth Upper Clay	m(b. ground level)	1.80	4.30	4.20	8.40	6.50	6.50	8.00	4.80	5.10
Aquifer Interval	m(b. ground surface)	1.8-5.3	4.3-4.9 8.3-11.5	4.2-9.2 11.1-19.4	8.4-18.0	6.5-10.7	6.5-11.0 20.0-25.0	8.0-13.3	4.8-14.2	5.1-9.4
Saturated Aq Thickness	m	3.50	3.20	13.30	9.60	4.20	9.50	5.30	9.40	4.10
Water Conductivity	micromhos/cm at 25°C	120	130	120	100	120	120	120	40	60
Water Salinity	mg/l TDS, by analysis	100	90	93	66	80	150	155	48	53
Water pH	(measured in field)	6.00	5.40	6.50	5.90	5.40	7.30	6.00	6.50	5.50
Water Fe	(acidified sample)	0.65	1.20	5.30	2.50	5.00	8.20	7.50	2.20	1.20

Table 5 : Production Well Data

Well No Location	Unit / Datum	10P Kg. Chicha 4.5 Batu	21P Universiti Sains Malaysia
Elevation G.S.	m (a Mean Sea Level)	5.75	4.10
Elevation of Collar	m (a Mean Sea Level)	6.10	4.47
Depth Drilled	m (b Ground Suface)	18.20	26.20
Steel Collar	m (b Ground Surface)	3.00	3.00
Casing	m (b Ground Surface)	15.20	26.20
Screen Interval (s)	m (b Ground Surface)	6.10 - 12.10	7.90 - 13.40
			21.80 - 25.80
Static Water Level	m (b Collar)	5.37	3.91
Static Water Level	m (b Ground Surface)	5.02	3.54
Static Water Level	m (a Mean Sea Level)	0.73	0.56
Date SWL Measured	(1985)	28/7	12/8
Depth Upper Clay	m (b Ground Surface)	5.30	6.50
Aquifer Interval (s)	m (b Ground Surface)	5.30 - 17.60	6.50 - 13.10
			19.80 - 26.00
Saturated Aq. Thickness	m	12.30	12.80
Water Conductivity	micro mhos / cm at 25°C	6.00	-
Water Salinity	mg / l TDS, by analysis	95.00	-
Water pH	(measured in field)	-	-
Water Fe	(acidified sample)	3.60	-

Table 6: Test Pumping Data

	Transmissivity m^2/d	Aquifer Thickness m	Permeability m/d
Kg. Puteh	7,000	9.0	800
Pintu Geng	5,000	7.2	700
Kubang Krian	7,700	11.0	700
Wakaf Baru	8,000	8.0	1,000
Kg. Chica (10P)	13,000	8.2	1,600
Universiti Sains (21P)	24,000	10.9	2,200

6 confirms with the high values of aquifer transmissivity and permeability. These were also observed in previous studies. The general shape of the water-table (Fig. 3) as measured in 1976 was also confirmed.

FUTURE GROUNDWATER DEVELOPMENT

The effect on water level drawdowns caused by pumping was predicted by analytical methods and mathematical modelling. A number of computer programs were run to predict movement of salinity along the Kelantan river. Based on the above results, the shallow aquifer is favoured for further development because it is recharged readily, wells are shallow (less than 20 m deep) giving rise to low construction and pumping costs.

A typical well-field would comprise two wells located at 50 m apart and a stand-by well at a similar distance. At a total pumping rate of 6.5 Ml/d (megalitres per day), the drawdown will comprise the following elements (at maximum).

Regional drawdown	2.0 m
Interference drawdown	0.8 m
Well drawdown	1.3 m
	4.1 m

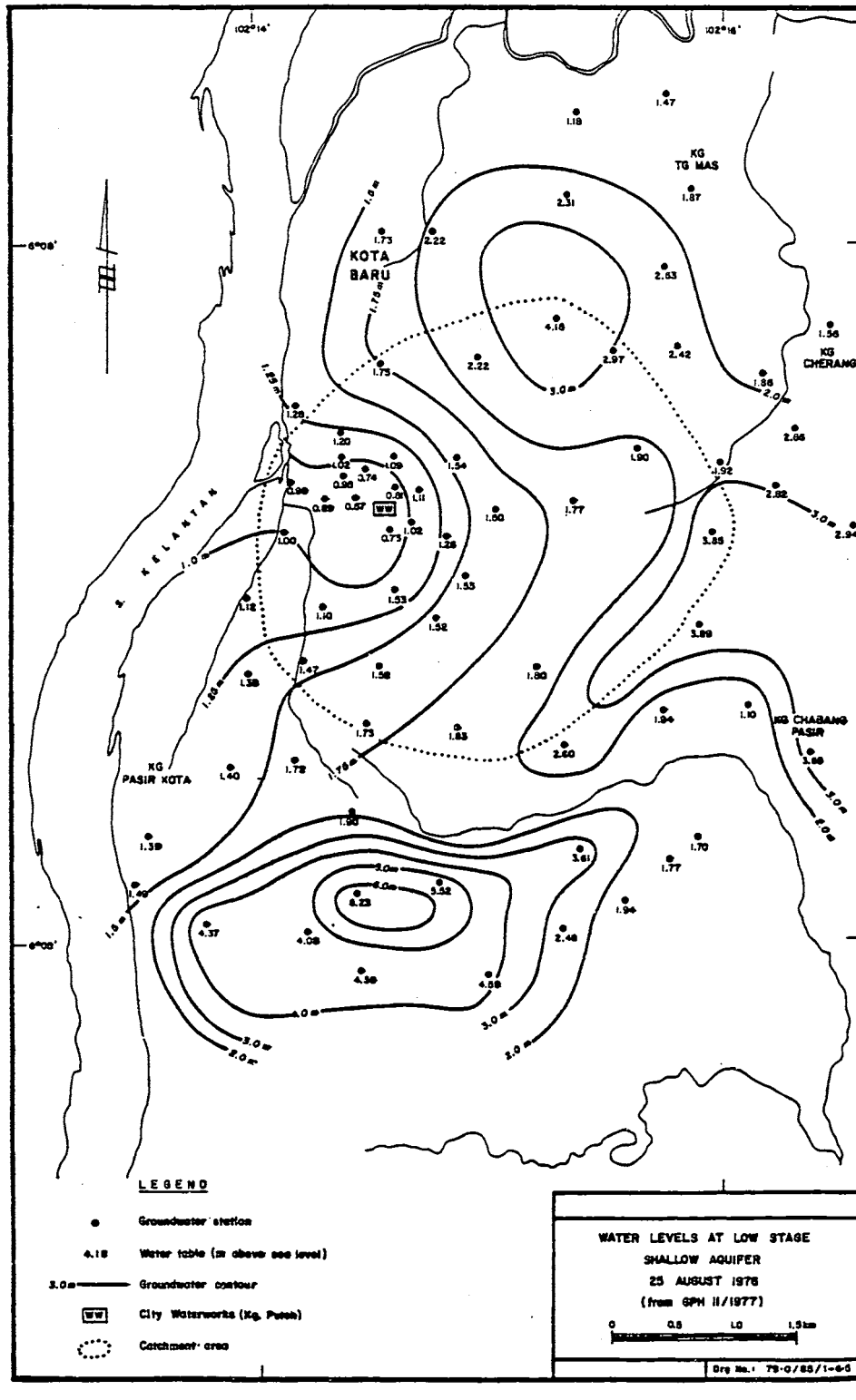

Figure 3 : Water levels at low stage, shallow aquifer, 25 August 1976 (from GPH II/1977)

Table 7: Well-Fields - Production Rates

	Production Rate Ml/d
1. Shallow Groundwater - Kota Baru District	
Kg. Puteh	20.0
Pintu Geng	10.0
Kg. Wakaf Che Ye	10.0
Kg. Padang Enggang	10.0
Kg. Gaung	10.0
1 km West of Kg. Padang	6.5
Kg. Penyadap	6.5
Kg. Pasir Hor	6.5
Kg. Chica batu 5.5	6.5
Kubang Krian	10.0
Kg. Tapang	6.5
Kg. Rambutan Rendang	4.0
Kg. Jambu	6.5
	133.0
2. Deep groundwater - Kota Baru District	
Tanjong Mas	9.0
Kg. Puteh	9.0
Kubang Krian	9.0
	27.0
3. Shallow Goundwater - Tumpat District	
Wakaf Baru	14.0
Near Wakaf Baru	9.0
	23.0
4. Shallow Groundwater - Pasir Puteh District	
Gong Kedak	2.0
Kg. S. Petai	8.0
	10.0

Such drawdown is acceptable provided these sites have the required possible thickness of aquifer with the pumps set deep in the sump below the screen. Most prospective areas are between Kelantan and Pengkalan Datu rivers from latitude of Pintu Geng to 4 km such of Pintu Geng, east of Tanjong Mas and finally south and north of Wakaf Baru on the western side of Kelantan river (See Figure 2).

Based on the information reviewed at Tanjong Mas, Kg. Puteh and Kg. Panji, the 3rd aquifer is favoured for development. Wells constructed in this aquifer have yielded up to 3.5 Ml/d each.

PROPOSED GROUNDWATER UTILIZATION

The shallow and deep groundwater in the Kota Baru district is to be utilised to provide water supplies of up to 140 Ml/d to meet projected demand for Kota Baru and Bachok beyond 1995. To meet the projected demand of 172 Ml/d to the year 2000 an additional 32 Ml/d could be obtained from the two sources if aquifer response allows it, alternatively the shortfall may be compensated by groundwater from the western side of Kelantan river. Stage development and close monitoring of water-levels and production from each well-field will allow progressive assessment of the aquifer response to groundwater extraction. A centralised treatment plant is recommended for treating the groundwater.

For the district of Tumpat, a well-field constructed at least 1 km south of present well-field at Wakaf Baru will be able to meet the projected total water requirement of 22.8 Ml/d to the year 2000.

For the Pasir Puteh district, the initial 2 Ml/d for Gong Kedak can be extracted locally but within 5 years the demand will exceed the limited resource. Well-fields are proposed in the vicinity of Kg. Sg. Petai where the aquifer may prove adequate to meet projected demand of 10 Ml/d to the year 2010. A breakdown of the production rates at the respective wellfields is given in Table 7.

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