CHAPTER 3

WATER RESOURCES STUDIES

3.0 WATER RESOURCES STUDIES

3.1 HYDROLOGICAL STUDY

3.1.1 Introduction

3.1.1.1 The Putrajaya Lake system was created by the impoundment of the Sg. Chuau. Its catchment is predominantly that of the Sg. Chuau's, except for a small section on the South East corner (part of Sg. Limau Manis), which was added to it due to the shaping of the natural terrain by the construction of a canal linking two sections of the Sg. Chuau (see Figure 2.7.1, Chapter 2). Thus, the amount of water in the Lake will depend predominantly on the amount of runoff from the Sg. Chuau catchment. The lack of runoff entering into the Lake or significant losses of water from the Lake will result in the deterioration of the water quality in the Lake, through the increase of pollutant concentration in the Lake. Hence, it is critical that all possible runoff arising from the Lake catchment should enter into the Lake system.

3.1.1.2 In order to quantify the discharge from the catchment entering into the Lake system at different time periods, and for different possible land-use scenarios in the catchment, a hydrological model of the catchment has to be set-up and calibrated for use. The outputs from the model simulations can then be fed into the water quality model of the Lake system to evaluate its water quality for the various land-use scenarios.

3.1.1.3 The hydrological model adopted for use in this study is the NAM conceptual rainfall-runoff model, which is part of a package of hydrological, hydraulic and water quality modelling software developed by the Danish Hydraulic Institute. For the purpose of modelling the water quality in the Lake system a daily simulation time interval is considered adequate and has been used in this study. The modelling exercise involved collection and preparation of the pertinent hydrological input data, model set-up and calibration, and simulation for the discharge outputs for the various proposed land-use scenarios for the catchment.

3.1.2 Hydrological input data

3.1.2.1 The Drainage and Irrigation Department is collecting hydrological data in the area. There are four rainfall stations and one pan evaporation station in the vicinity of the study area. A streamflow station was established at the Phase 1A temporary dam site for several months in 1994. The details on the location and recording period at each of the stations are given in Table 3.1.1.

Table 3.1.1 Details of Hydrological Stations located in the vicinity of the Study Area

Item	Type of Station	Station No.	Name of Stations	Latitude	Longitude	Date Installed Manual/Auto	Date closed
1.	Rainfall	2816 112	Ladang Galloway	02°53’45”	101°39’50”	10/24 (M)	08/94
2.	Rainfall	2916 001	Prang Besar	02°54’17”	101°41’50”	1/81 (A)	10/94*
3.	Rainfall	2916 002	Puncak Niaga	02°55’40”	101°41’18”	1/95 (A)	
4.	Rainfall	2917 106	Ladang West Country	02°58’35”	101°43’40”	1/24 (M)	3/95
5.	Rainfall	2917 001	Stor JPS Kajang	02°59’30”	101°47’50”	4/75(A)	
6.	Streamflow		Temporary Dam			3/94	11/94
7.	Evaporation	2916 301	Prang Besar	02°55’40”	101°41’50”	1/81	10/94

* Station shifted to Puncak Niaga (Treatment Plant)

3.1.2.1 Rainfall data

(1) The availability of the rainfall records were first studied. The records for Ladang West Country and Ladang Galloway were excellent with no missing data gaps in the record at all. The records at Stor JPS Kajang is also good but there were some minor gaps while that at Prang Besar were also good, except for a big gap in 1988.

(2) The consistency of the rainfall records from three stations i.e. Prang Besar, Ladang West Country and Ladang Galloway, were subjected to a double mass curve analysis, with the reference station at Stor JPS Kajang. The exercise involves the

plotting of the cumulative annual rainfalls at each of the 3 stations against the cumulative annual rainfall at Stor JPS Kajang, which is a principal station operated by DID. The curves are given in Figure 3.1.1. It can be seen from the double mass curve plots (all three plots exhibit approximately constant slopes) that the rainfall records at Prang Besar, Ladang West Country and Ladang Galloway were all consistent with that at Stor JPS Kajang.

(3) The range in the annual rainfall is not great, ranging from 2087 mm at Ladang Galloway at the Southern tip of the catchment, 2148 mm at Prang Besar in the middle part of the catchment to 2319 mm at Ladang West Country in the upper reaches of the catchment. According to McCuen (1989), when the annual catch at the rain gauges differ by less than 10%, then the Station-Average Method for estimating missing rainfall, P_m can be used which is given as

$$P_m = 1/n \sum_{i=1}^{n} P_i$$

where P_i is the catch at gauge i

(4) As the difference in annual catch between the rain gauges is ±11 %, the Normal-Ratio Method which uses the annual catch in deriving weights, is therefore employed in this Study in estimating missing rainfall data. The general formula for computing P_m is then

$$P_m = \sum_{i=1}^{n} w_i P_i$$

(5) The weight for station is computed by $w_i = A_x / nA_i$

Where A_i is average annual catch at gauge i
A_x is average annual catch at station x
n is number of stations

(6) Figure 3.1.2 shows the monthly rainfall distributions at the 4 stations. It can be seen that all 4 stations exhibit similar monthly distribution, with periods of heavy rainfall during the inter-monsoon months of March to May, with monthly rainfalls

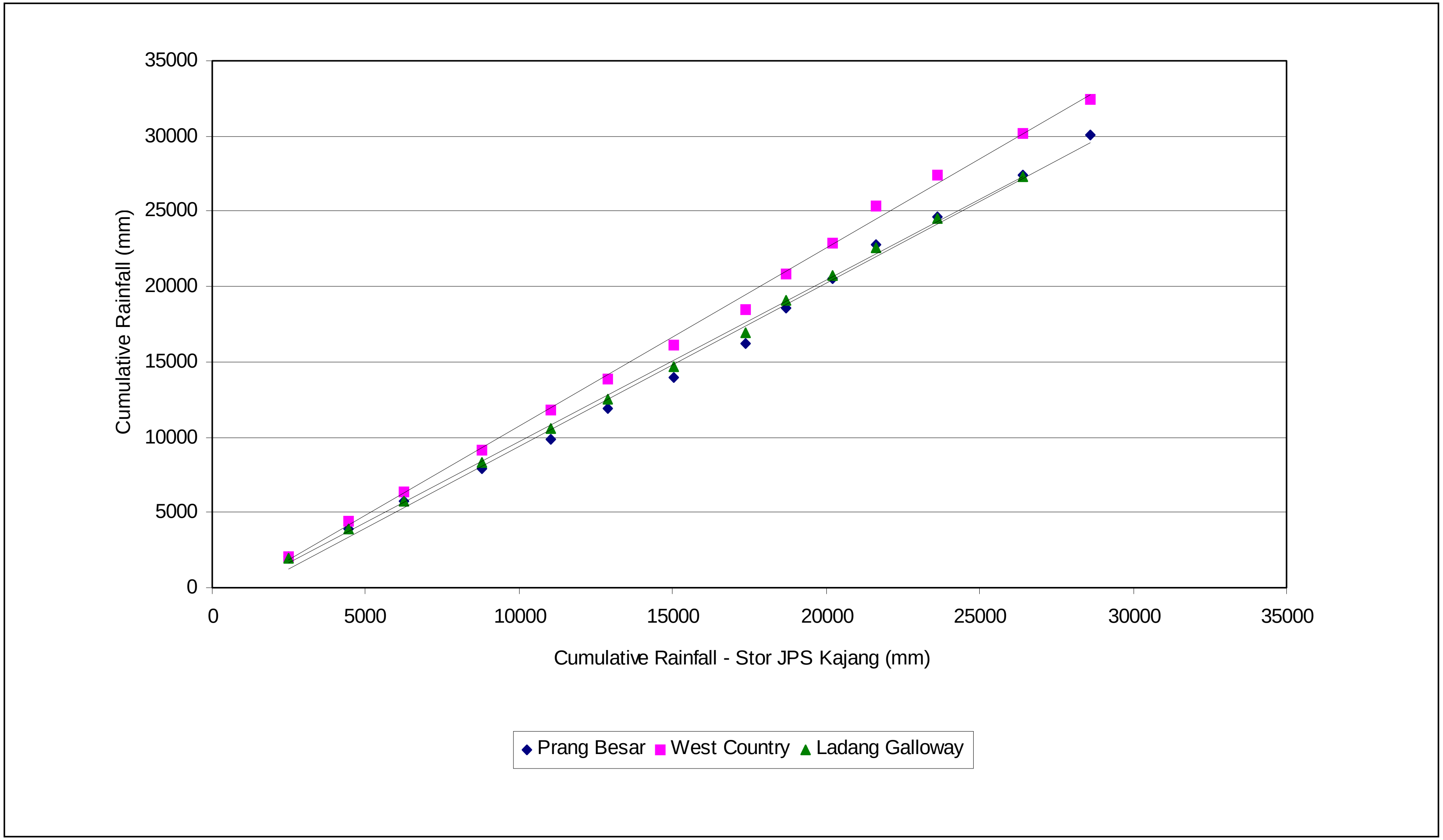


Figure 3.1.1 : Double-mass Curve Analysis of Rainfall Data (1981 - 1994)

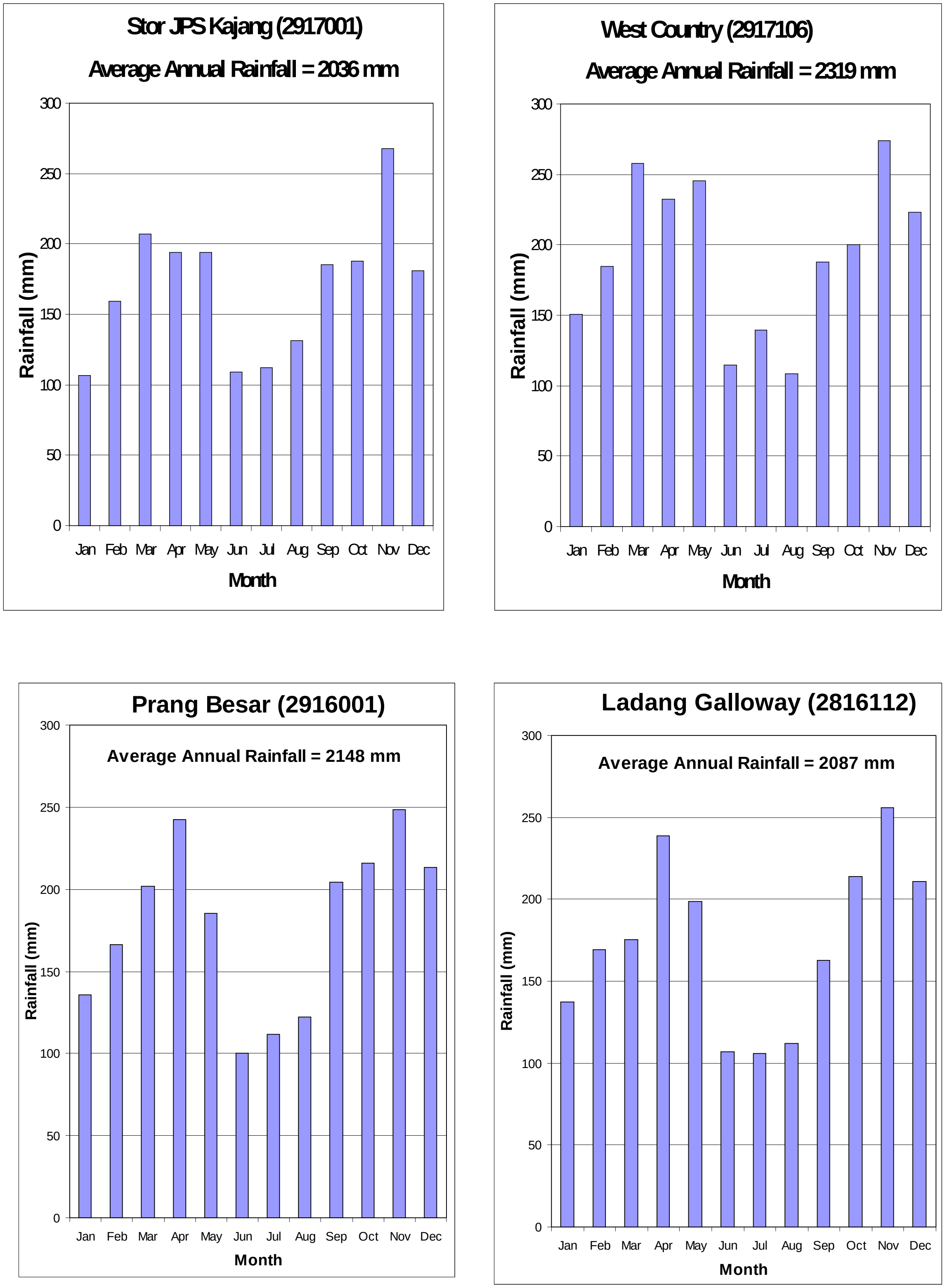


Figure 3.1.2 : Monthly Rainfall Distributions at the 4 Stations (1981 – 1994)

of 150-250mm and also during the North-East monsoon months of October to December, with monthly rainfalls of 200-250mm. The periods from January to February and June to August are relatively drier, with moderate rainfalls of 100-150mm. The monthly rainfall data of the above mentioned rainfall stations for the period 1981-1994 are as tabulated in Tables 3.1.2a and 3.1.2b.

3.1.2.2 Evaporation data

(1) The accuracy of the pan evaporation data is moderate due to operational difficulties associated with the frequent and high intensity rainfall. The method of quality control adopted by DID, as described in the DID Water Resources Publication No. 5 (1976), has been used.

(2) The average annual pan evaporation at Prang Besar is 1720mm. The monthly distribution of the pan evaporation is given in Figure 3.1.3. It can be seen that the range is small, ranging from 130mm in November to December to 155mm in February and July to August. The monthly pan evaporation data at Prang Besar for the period 1981-1992 are as tabulated in Table 3.1.3.

3.1.2.3 Streamflow data

(1) The processed daily streamflow data (Pressure Bulb Recorder) from DID is available for the months of March 1994 to November 1994. The daily mean discharge ranges from a low of 0.21 m^3/s to 2.2 m^3/s. It should be noted here that the data quality from the Pressure Bulb Recorder is however, somewhat lower compared to DID principal streamflow stations which employ more expensive higher accuracy water level recorders. The daily streamflow data at Temporary Dam for the period March to November 1994 are as shown in Table 3.1.4.

3.1.3 Rainfall Runoff Model

3.1.3.1 Method of approach and model selection

(1) In order to produce estimates of monthly streamflows at the gauged site only, any of the following approaches could be adopted:

(i) use of a daily catchment model (rainfall runoff model) which is calibrated using daily data from which monthly data are then extracted

Table 3.1.2a : Monthly Rainfall (1981 – 1994)

Prang Besar (2916001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jumlah
1981	121	150	63	411	390	50	60	50	175	258	201	171	2097
1982	18	118	147	303	237	130	103	89	52	198	315	135	1843
1983	82	66	134	131	248	74	133	202	273	148	173	113	1774
1984	322	345	112	190	106	130	128	77	111	91	306	237	2153
1985	94	217	169	170	234	8	159	47	123	289	165	274	1948
1986	258	85	259	382	156	28	90	61	115	268	231	120	2050
1987	131	23	136	237	173	92	92	156	240	293	118	371	2059
1988	220	209	354	212	69	150	211	193	234	80	268	94	2294
1989	142	280	351	145	171	140	38	210	226	261	270	176	2407
1990	96	151	199	224	138	98	141	97	255	166	189	195	1946
1991	86	60	79	307	195	74	3	86	176	399	300	448	2211
1992	44	255	189	131	191	41	103	200	147	66	223	286	1872
1993	123	191	189	325	234	150	188	69	285	247	449	284	2730
1994	167	179	450	231	59	240	114	176	450	259	274	89	2685
Mean	136	166	202	243	185	100	112	122	204	216	248	213	2148

Ladang Galloway (2816112)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jumlah
1981	76	129	86	414	250	42	49	81	155	207	215	228	1929
1982	55	92	115	291	217	128	117	118	44	181	338	260	1953
1983	54	47	227	177	328	118	172	246	176	130	111	58	1841
1984	321	408	108	323	123	116	147	125	137	126	452	255	2639
1985	74	240	193	135	343	0	192	45	151	425	259	151	2204
1986	227	97	258	226	283	17	71	103	109	190	179	157	1915
1987	90	26	12	294	85	184	87	144	290	345	192	374	2120
1988	266	221	270	340	80	107	158	149	177	127	269	104	2267
1989	200	314	348	128	75	118	43	107	242	237	229	130	2169
1990	67	98	116	148	149	47	116	45	146	187	236	214	1566
1991	116	66	98	231	196	120	3	68	214	178	198	402	1888
1992	59	266	69	225	234	85	61	229	160	66	220	264	1935
1993	167	199	214	236	320	158	164	77	197	339	411	271	2751
1994	153	174	342	175	100	261	106	35	82	259	274	89	2049
Mean	137	170	175	239	199	107	106	112	163	214	256	211	2087

Table 3.1.2b : Monthly Rainfall (1981 – 1994)

Ladang West Country (2917106)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jumlah
1981	119	219	101	201	463	103	56	26	145	189	252	140	2014
1982	25	175	217	308	291	228	111	98	159	150	402	216	2378
1983	139	60	198	105	283	109	156	162	256	185	202	154	2009
1984	327	400	277	337	161	94	182	101	147	100	454	201	2781
1985	64	332	317	250	364	32	167	90	158	267	259	348	2648
1986	260	45	388	321	218	46	122	46	62	183	234	120	2045
1987	141	105	220	211	171	39	153	290	211	274	180	242	2237
1988	299	209	354	212	69	150	211	193	234	80	268	94	2373
1989	140	227	312	127	200	90	44	180	374	258	233	196	2381
1990	96	110	179	216	202	104	227	81	206	214	182	192	2009
1991	140	65	247	346	320	83	24	71	179	307	385	342	2509
1992	104	291	170	162	187	42	132	125	178	68	176	428	2063
1993	155	100	216	222	382	185	265	20	243	266	331	362	2747
1994	101	249	418	237	123	301	106	35	82	259	274	89	2274
Mean	151	185	258	233	245	115	140	108	188	200	274	223	2319

Stor JPS Kajang (2917001)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jumlah
1981	234	361	82	403	513	26	68	43	190	158	139	196	2411
1982	12	101	152	82	214	189	102	81	122	204	450	226	1932
1983	71	83	185	107	175	111	159	320	200	194	129	79	1810
1984	152	437	188	213	159	136	183	82	165	136	459	213	2522
1985	22	174	284	184	154	11	140	106	188	284	334	370	2249
1986	186	56	367	326	180	71	95	62	84	225	144	69	1862
1987	67	111	154	161	167	128	98	426	164	276	177	200	2127
1988	144	193	360	223	76	209	214	164	356	60	349	26	2371
1989	117	83	206	72	104	119	3	37	233	92	78	163	1304
1990	67	72	228	66	54	92	118	86	180	246	182	117	1506
1991	64	24	95	166	129	78	52	105	91	184	300	161	1447
1992	12	216	121	251	211	28	126	159	255	99	323	212	2011
1993	217	155	225	264	310	102	173	71	271	218	406	346	2754
1994	133	168	259	202	269	228	42	104	95	259	282	163	2202
Mean	107	159	207	194	194	109	112	132	185	188	268	181	2036

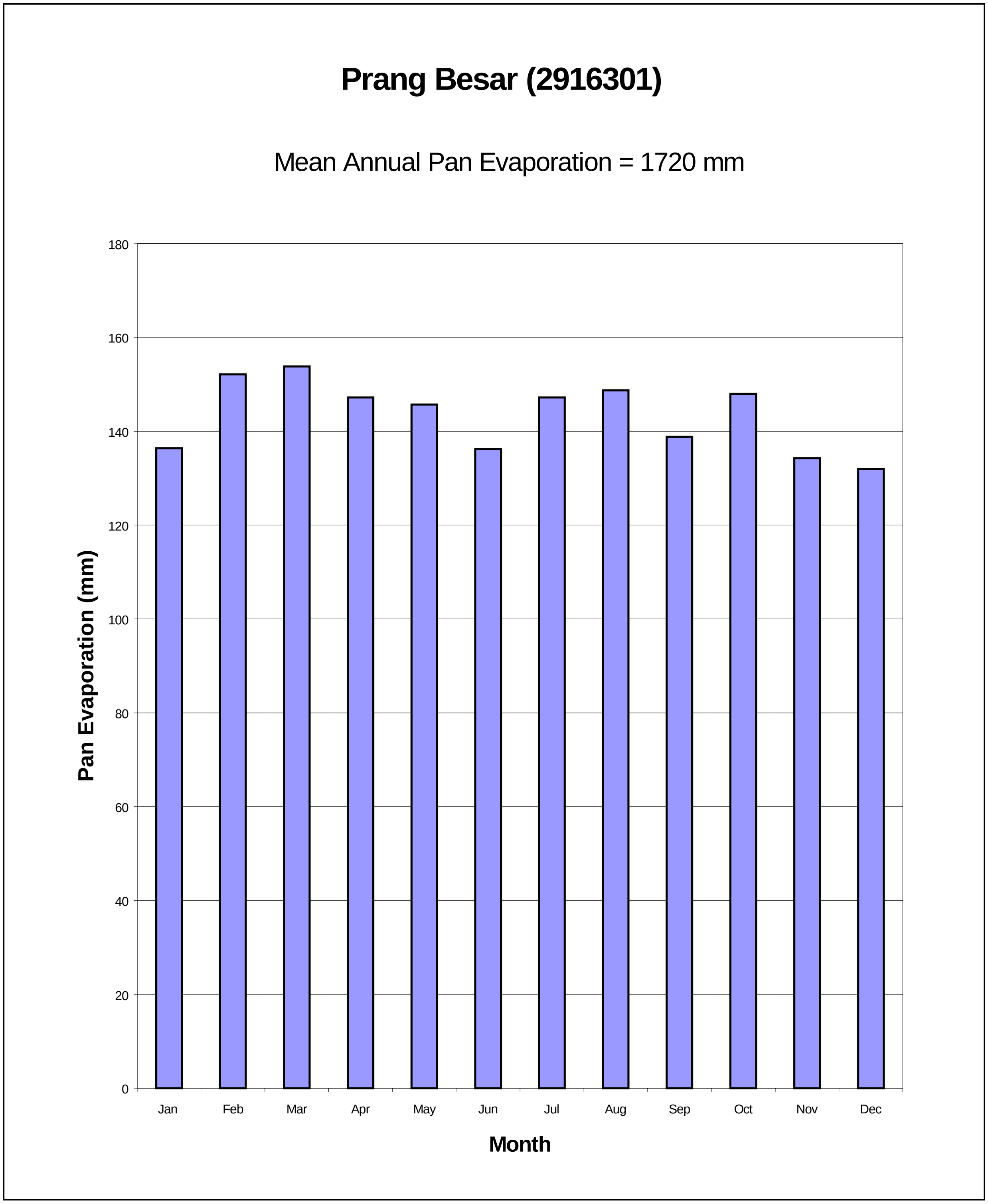


Figure 3.1.3 : Monthly Distribution of Pan Evaporation at Prang Besar Station (1981 1992)

Table 3.1.3 : Monthly Pan Evaporation at Prang Besar (2916301) for 1981 – 1992

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jumlah
1981	114	144	181	158	134	140	189	189	133	149	132	137	1799
1982	131	139	147	150	138	123	149	133	140	159	140	140	1688
1983	140	134	125	122	127	124	137	136	128	152	158	104	1585
1984	113	94	134	146	144	126	121	125	120	119	149	143	1533
1985	142	137	121	107	126	122	153	180	148	133	110	130	1608
1986	120	140	148	146	166	158	164	154	141	151	123	142	1753
1987	124	169	189	151	151	136	147	156	149	180	124	130	1806
1988	153	165	150	161	147	142	145	142	146	158	138	136	1781
1989	154	171	147	154	152	133	144	149	144	147	151	147	1792
1990	145	226	165	165	153	140	139	144	139	153	127	154	1850
1991	157	149	165	155	157	167	151	147	151	123	132	93	1747
1992	146	156	175	153	152	123	128	131	128	152	129	127	1699
Mean	136	152	154	147	146	136	147	149	139	148	134	132	1720

	March	April	May	Jun	July	August	September	October	November
1	0.01	1.50	0.69	1.36	0.66	0.52	0.47	0.38	1.12
2	0.17	3.46	0.69	1.02	2.05	0.51	0.46	0.40	0.74
3	0.17	1.98	0.69	2.01	1.67	0.50	0.45	0.43	0.57
4	0.19	0.93	0.67	1.70	0.84	0.50	0.45	0.40	0.52
5	0.26	0.72	1.81	1.25	0.66	0.49	0.45	0.60	0.50
6	0.51	0.68	1.62	0.78	0.62	0.49	0.44	0.87	0.49
7	0.68	0.66	0.88	0.68	0.61	0.48	0.51	0.62	0.65
8	0.89	0.65	0.72	0.67	0.61	0.48	0.51	0.44	0.76
9	0.49	0.64	0.68	0.66	0.60	0.48	0.47	0.40	0.80
10	3.71	0.64	0.67	0.64	0.60	0.48	0.48	0.39	0.68
11	2.64	1.17	0.66	0.63	0.59	0.48	0.45	2.16	0.55
12	0.87	0.94	0.66	0.63	0.58	0.47	0.43	1.65	0.51
13	0.55	0.89	0.65	0.62	0.58	0.92	0.43	0.70	0.49
14	0.86	0.89	0.64	0.61	0.57	0.85	0.42	0.50	0.48
15	0.79	0.71	0.64	0.60	0.57	0.84	0.42	1.15	2.04
16	1.00	0.66	0.63	0.60	0.60	0.65	0.42	1.70	1.67
17	1.56	0.70	0.90	0.59	0.58	0.62	0.41	1.35	0.86
18	1.30	0.78	0.98	0.59	0.56	0.60	0.51	0.84	1.19
19	0.77	0.68	0.71	0.58	1.18	0.53	0.59	0.60	0.91
20	0.52	1.74	0.64	0.57	1.10	0.49	0.59	0.85	1.14
21	0.46	1.47	0.67	0.57	0.69	0.48	0.46	0.88	2.19
22	0.44	0.83	0.78	0.97	0.59	0.47	0.42	0.63	2.65
23	0.44	1.14	0.66	0.81	0.57	0.46	0.42	0.57	2.01
24	0.66	1.41	0.81	0.62	0.56	0.46	0.46	0.55	1.16
25	2.19	1.49	0.74	0.58	0.56	0.45	0.42	0.53	0.82
26	2.58	1.19	0.64	0.57	0.55	0.45	0.40	0.52	2.35
27	1.38	0.96	0.61	0.81	0.54	0.51	0.40	0.51	1.84
28	0.73	0.75	0.59	0.78	0.53	0.61	0.39	0.50	0.98
29	0.71	0.70	0.59	1.10	0.53	1.11	0.39	0.50	0.79
30	0.73	0.68	0.59	0.96	0.53	0.76	0.39	0.49	0.76
31	0.60		0.58		0.53	0.52		0.88	
Mean	**0.93**	**1.05**	**0.76**	**0.82**	**0.71**	**0.57**	**0.45**	**0.74**	**1.07**

Table 3.1.4 : Daily Streamflow Data at Temporary Dam for March - November 1994 (m3/s)

(ii) use of a monthly water balance model
(iii) use of a statistical model (regression model)

(2) Due to the short record period available for calibration, methods (ii) and (iii) could not be expected to produce good estimates.

(3) Also neither of methods (ii) and (iii) could be used directly to obtain discharge estimates at points other than the calibration sites, whereas this is possible with current daily flow models which is subdivided into a number of subcatchments.

(4) The model selected is the NAM Model which is one of the modules in MIKE 11. As the water quality module of MIKE 11 is also used for this study it is possible for the simulated runoff from NAM Model to be inputted automatically for the water quality modelling.

3.1.3.2 NAM Model

(1) The NAM Rainfall Runoff Model is a set of linked mathematical statements describing the behaviour of the land phase of the hydrological cycle. It is a deterministic, conceptual, lumped type of model requiring only moderate data input requirements.

(2) The model simulates the rainfall-runoff process in a catchment by means of 4 different and mutually interrelated storages. Figure 3.1.4 shows the model structure. The 4 storages were used to represent the hydrologically important physical elements in the catchment, such as the average soil moisture content and surface storages in the catchment. They are used to continuously account for the changes in the moisture content of the modelled physical elements in the catchment.

(3) A brief description of the pertinent model parameters are given below:

(i) θ_{WP} = Soil moisture at wilting point

(ii) θ_{FC} = Soil moisture at field capacity

(iii) θ_{SAT} = Soil moisture at saturation point

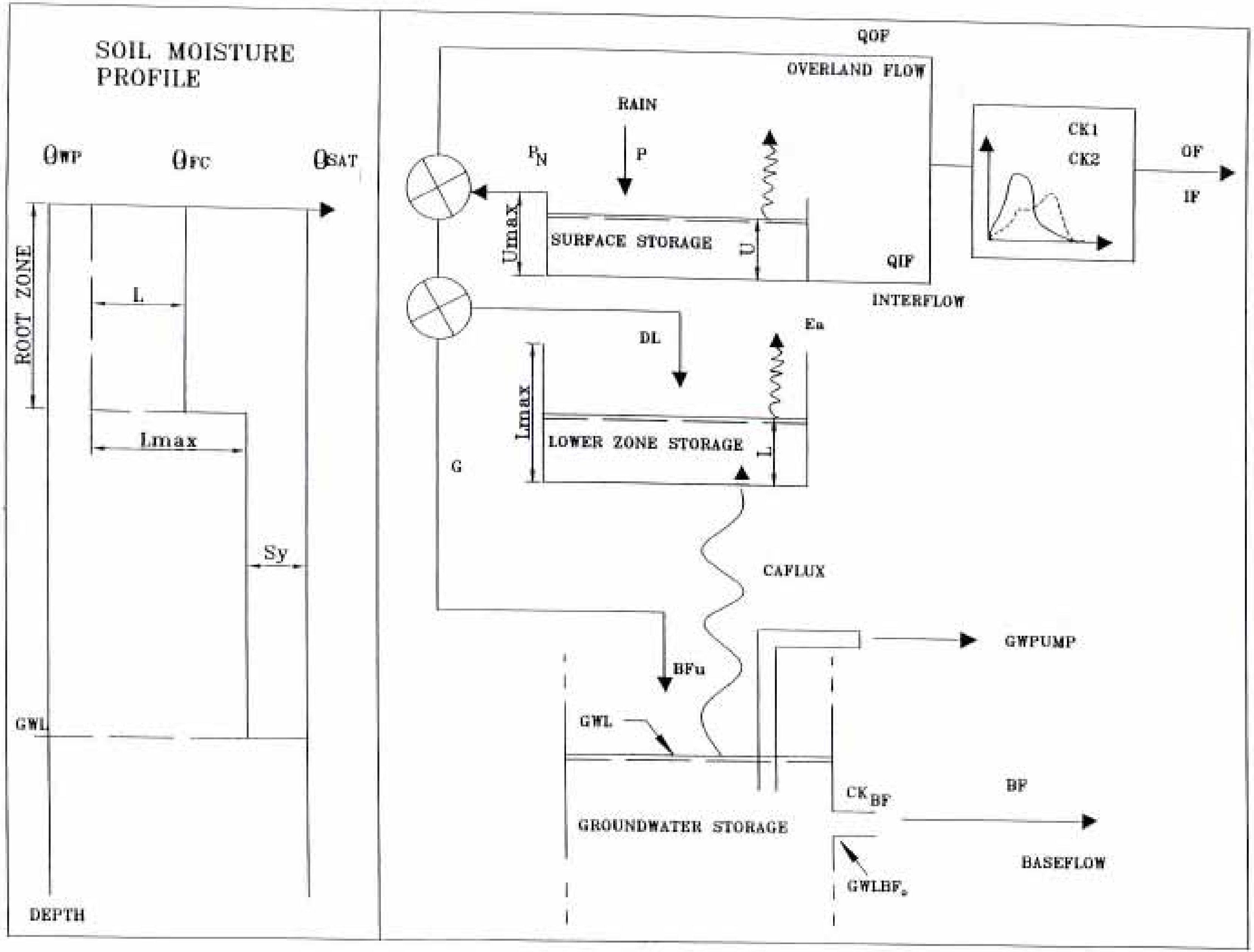


Figure 3.1.4 The Structure of the NAM Model

(iv) L = Moisture content at lower zone storage

(v) L_{max} = Maximum moisture content at lower zone storage

(vi) Sy = Specific yield

(vii) GWL = Ground water level

(viii) P = Precipitation

(ix) P_N = Excess precipitation

(x) U = Amount of water in surface storage

(xi) U_{max} = Maximum amount of water in surface storage

(xii) DL = Amount of infiltration that increase moisture content, L, in lower zone storage

(xiii) G = Excess infiltration moisture that percolate deeper and recharge ground water storage

(xiv) Q_{OF} = Overland flow

(xv) Q_{IF} = Interflow

(xvi) Ea = Evapo transpiration

(xvii) CK1, CK2 = time constants for routing interflow and overland flow.

(xviii) CQ_{OF} = overland flow runoff coefficient

(xix) CK_{BF} = time constant for baseflow.

(xx) CAPFLUX = capillary flux

(xxi) $GWLBF_o$ = maximum groundwater table depth causing baseflow

(xxii) BF = baseflow

(xxiii) GWPUMP = net groundwater abstraction

(4) The input data to the model are rainfall and potential evapotranspiration. The model main outputs are the runoff, groundwater level values, as well as information about other elements of the land phase of the hydrological cycle, such as the temporal variation of the soil moisture content and groundwater recharge.

3.1.3.3 Specification of subcatchments

The Sg. Chuau catchment up to the Temporary Dam Site was divided into a number of subcatchments so that runoff into the five wetlands can be modelled. This resulted in 15 subcatchments and these are shown in Figure 3.1.5.

3.1.4 Model Calibration

3.1.4.1 Data used for Calibration

Daily streamflows at the temporary dam site from March to November 1994 (this period cover the wet intermonsoon months of March to May and September to October and the relatively drier months of June, July and August) were available though with some gaps in parts of April and May. Daily rainfall data from Prang Besar, Ladang West Country and Ladang Galloway (rain gauge representation of subcatchments determined using Thiessen Method) and also monthly pan evaporation (adopting a pan coefficient of 0.8, as in DID Water Resources Publication No. 5 1976) data from Prang Besar were used. The quality of these data will limit the goodness of fit of the model.

3.1.4.2 Rationale for Model Calibration

(1) Initial model parameters for all subcatchments were taken from the calibration run considering the catchment as a whole with the outlet at Temporary Dam Site. Parameter values are selected after a number of program runs with varying parameters using the following criteria:

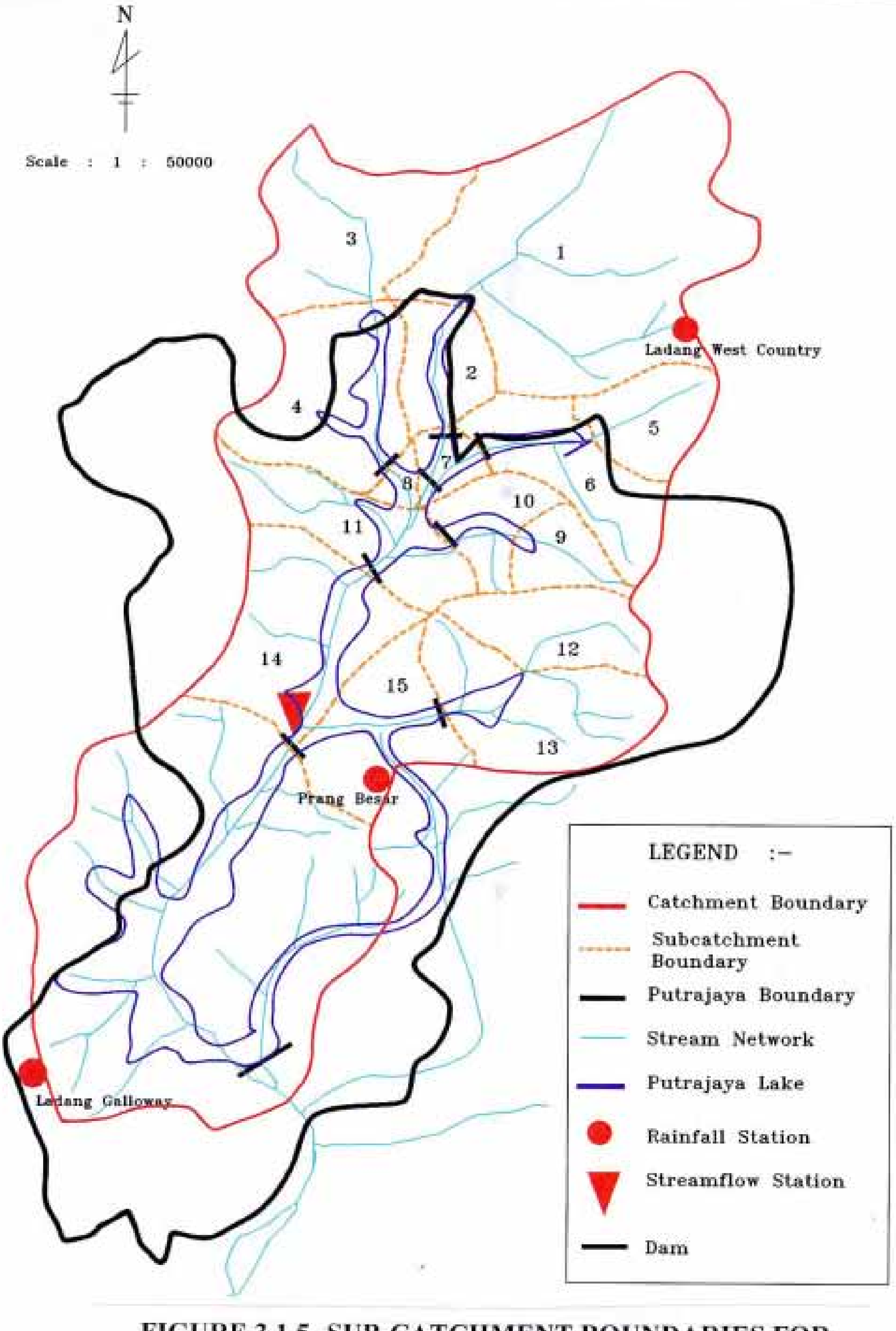


FIGURE 3.1.5 SUB-CATCHMENT BOUNDARIES FOR RAINFALL-RUNOFF MODELLING

(i) best agreement with observed flow sequences by statistics of daily flow
(ii) by reproduction of high flow events and recession shape

(2) It cannot be expected that exact sequences of the observed daily flows can be reproduced when there is significant spatial variability especially during convective thunderstorm activity. The model should however produce sequence of flows adequately representing the catchment response to incident rainfall.

(3) The parameters selected for each subcatchment, as a result of the calibration procedure, and the test statistics used are given in Tables 3.1.5 and 3.1.6. Figure 3.1.6 shows the results of the comparison between the simulated and observed runoff. The simulated daily flows at Temporary Dam for March to November 1994 are given in Table 3.1.7.

(4) The difference between the mean observed and mean simulated discharges is fair at 14 %. The variance as expressed by the coefficient of variation is well preserved at 0.524 for the observed discharge and 0.523 for the simulated discharge. The coefficient of determination (an index of overall model fit) is rather low at 0.418. The low value is attributed to instances of very low catches at the rainfall stations but high flows at the streamflow station and also conversely instances of high catches at the rainfall stations but moderate flows at the streamflow station (as discussed due to highly localised convective storms in the catchment). Considering all these indicators together, it is concluded that these parameters represent a reasonable fit for the daily flows.

Table 3.1.5: Selected Parameter Values for NAM Model

	Description	Units	Sub catchment No.														
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1. U max	Maximum water content in surface storage	mm	25	37.5	25	37.5	37.5	37.5	37.5	37.5	40	37.5	37.5	40	40	40	40
2. L max	Maximum water content in roof zone storage	mm	250	375	250	375	375	375	375	375	400	375	375	400	400	400	400
3. CQ_{of}	Overland flow runoff coefficient (Calibration based on 1994 Landuse)		0.35	0.3	0.3	0.35	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Overland flow runoff coefficient (Current Landuse, 1999)		0.4	0.35	0.3	0.4	0.35	0.3	0.4	0.35	0.3	0.3	0.4	0.3	0.3	0.3	0.4
	Overland flow runoff coefficient (Future Landuse as Proposed in Masterplan)		0.6	0.5	0.3	0.45	0.6	0.75	0.8	0.7	0.75	0.5	0.8	0.7	0.7	0.8	0.7
4. CKIF	Time constant for inter flow	hour	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
5. CK_1, CK_2	Time constant for routing inter and overland flow	hour	26	24	35	20	35	20	10	10	20	20	20	25	25	22	20
6. Sy	Specific yield		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
7. A	Catchment area	Km^2	8.10	1.54	2.78	2.84	1.41	2.31	0.60	0.15	0.70	1.03	2.05	1.33	2.63	3.17	1.73

Table 3.1.6: Error Statistics for NAM Model

Mean	Observed (m^3/s)	0.43
	Simulated (m^3/s)	0.49
	Difference (%)	14
Coefficient of Variation	Observed	0.524
	Simulated	0.523
Coefficient of Determination		0.418

Figure 3.1.6 Simulated Discharge versus Observed Discharge (Mac – Nov 1994) at Temporary Dam Site

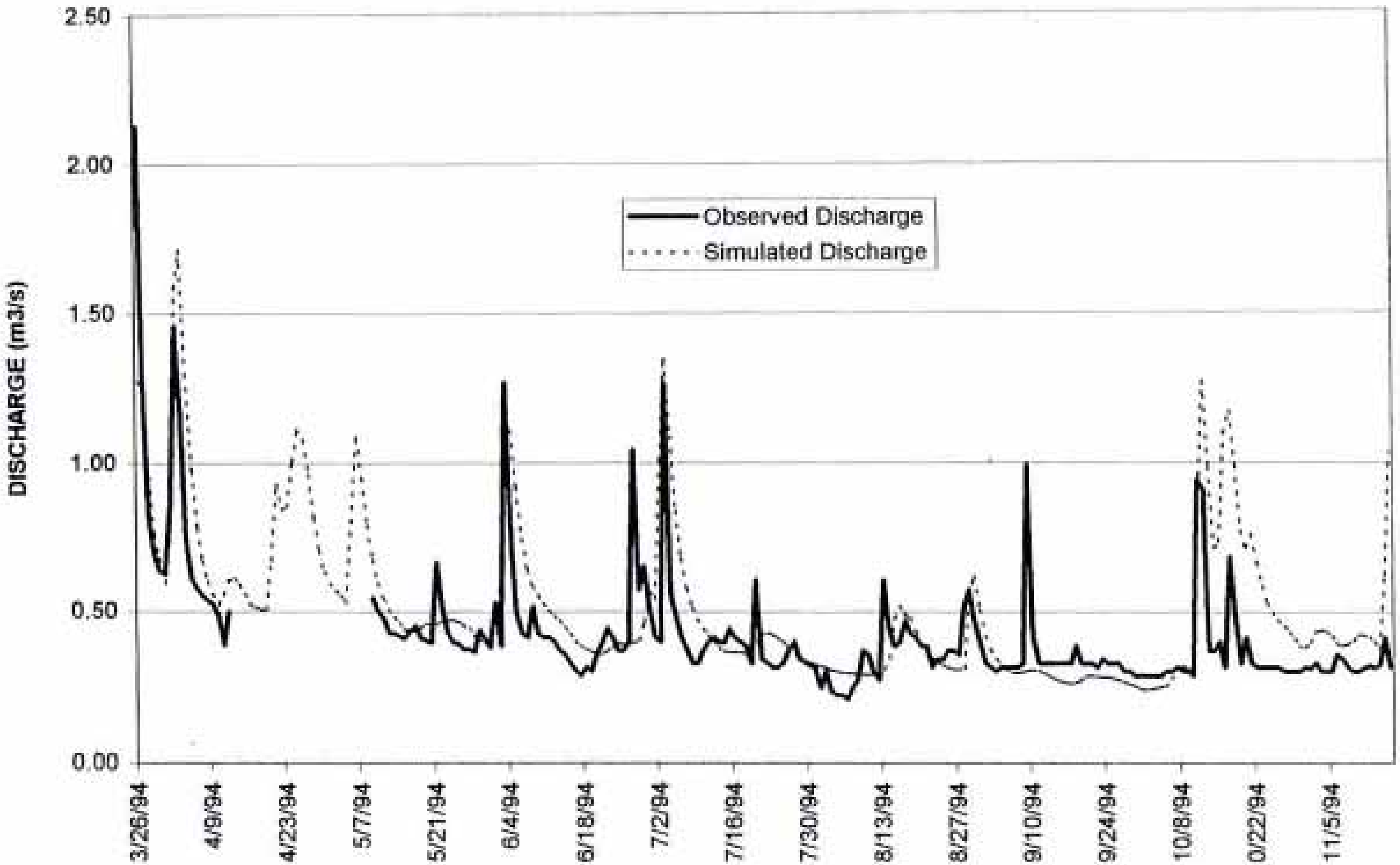


Table 3.1.7 : Simulated Daily Streamflow Data at Temporary Dam for March - November 1994 (m3/s)

	March	April	May	Jun	July	August	September	October	November
1	0.01	0.77	0.59	0.47	0.55	0.32	0.42	0.24	0.40
2	0.14	1.59	0.57	0.58	1.01	0.31	0.37	0.24	0.43
3	0.12	1.71	0.55	1.02	1.35	0.31	0.34	0.24	0.44
4	0.12	1.30	0.53	1.11	1.09	0.30	0.32	0.25	0.43
5	0.12	0.97	0.80	0.92	0.84	0.30	0.31	0.25	0.41
6	0.16	0.78	1.09	0.75	0.68	0.29	0.30	0.28	0.39
7	0.23	0.67	0.95	0.64	0.56	0.29	0.30	0.31	0.39
8	0.36	0.60	0.79	0.58	0.51	0.29	0.30	0.32	0.39
9	0.34	0.56	0.67	0.55	0.47	0.29	0.30	0.31	0.41
10	0.74	0.53	0.60	0.52	0.44	0.29	0.31	0.30	0.42
11	1.45	0.56	0.54	0.50	0.42	0.29	0.30	0.82	0.42
12	1.17	0.61	0.50	0.48	0.39	0.29	0.30	1.27	0.41
13	0.84	0.61	0.48	0.46	0.38	0.31	0.29	0.98	0.39
14	0.73	0.59	0.46	0.44	0.37	0.34	0.28	0.72	0.37
15	0.68	0.56	0.44	0.42	0.36	0.48	0.27	0.74	0.63
16	0.70	0.53	0.43	0.40	0.36	0.52	0.26	1.10	1.03
17	0.89	0.52	0.43	0.39	0.36	0.49	0.26	1.17	0.89
18	0.96	0.51	0.45	0.37	0.36	0.48	0.26	0.99	0.94
19	0.82	0.51	0.46	0.37	0.37	0.43	0.27	0.77	0.89
20	0.65	0.67	0.46	0.36	0.40	0.39	0.28	0.71	0.89
21	0.53	0.93	0.46	0.36	0.42	0.36	0.29	0.76	1.36
22	0.46	0.84	0.47	0.37	0.43	0.35	0.28	0.66	1.86
23	0.41	0.85	0.47	0.38	0.42	0.33	0.28	0.59	1.90
24	0.38	1.01	0.47	0.39	0.41	0.32	0.28	0.53	1.53
25	0.72	1.11	0.47	0.39	0.40	0.31	0.28	0.50	1.15
26	1.27	1.08	0.46	0.39	0.39	0.31	0.27	0.47	1.47
27	1.25	0.96	0.44	0.39	0.37	0.31	0.27	0.45	1.65
28	0.95	0.81	0.42	0.40	0.35	0.31	0.26	0.43	1.31
29	0.76	0.70	0.41	0.47	0.34	0.55	0.25	0.41	1.02
30	0.68	0.63	0.40	0.56	0.33	0.62	0.24	0.38	0.85
31	0.60		0.39		0.32	0.51		0.38	
Mean	0.62	0.80	0.54	0.51	0.50	0.36	0.29	0.57	0.84

3.1.5 Streamflow Extension for Current and Future Landuse

3.1.5.1 After a satisfactory calibration of the NAM Model, the next stage was to input the 14 years rainfall data at Prang Besar, Ladang West Country and Ladang Galloway i.e from 1981 to 1994 into the model to simulate the runoff into the wetlands for Current (1999 Landuse) and Future Landuse (as proposed in Landuse Masterplan). A CQ_{OF} value of 0.8 was adopted for built up areas and for open space covered with trees and grass, CQ_{OF} is taken as 0.3. A weighted CQ_{OF} was then computed for each Subcatchment as given in Table 3.1.5 for both Current and Future Landuse. These simulated runoffs into the wetlands for Current and Future Landuse scenarios are in turn used as inputs for water quality modelling purposes.

3.1.5.2 Figures 3.1.7a to 3.1.7e illustrate the simulated runoffs into the wetlands for Current and Future Landuse respectively. For the Future Landuse scenario, it can be seen that the daily peak runoff increases are significant for Upper East, Lower East and Sg. Bisa Wetlands and with slight increase and insignificant change in daily peak runoff into Upper North and Upper West Wetlands respectively. It can be also seen that there are slight to moderate decreases in the daily baseflows into Upper East, Lower East and Sg. Bisa Wetlands.

3.1.5.3 This phenomena tally well with increase in impervious areas (which causes increase in surface runoff and corresponding decrease in infiltration and baseflow) as a result of housing developments earmarked in the catchments of Upper East, Lower East and Sg. Bisa.

3.1.6 Compensation Flow

3.1.6.1 The design lake water level is at RL 21.0 m which is ensured by setting the main dam spillway crest level at RL 21.0 m. The dam is in effect acting like a weir on a stream such that any inflow, less any losses mainly through open water evaporation, into the lake will spill through the spillway into Sg. Chuau downstream of the dam.

3.1.6.2 To ascertain the quantity of flow spilling via the spillway the discharge at the Main Dam was simulated for the period 1981-1994. The long term discharge at Main Dam was then checked

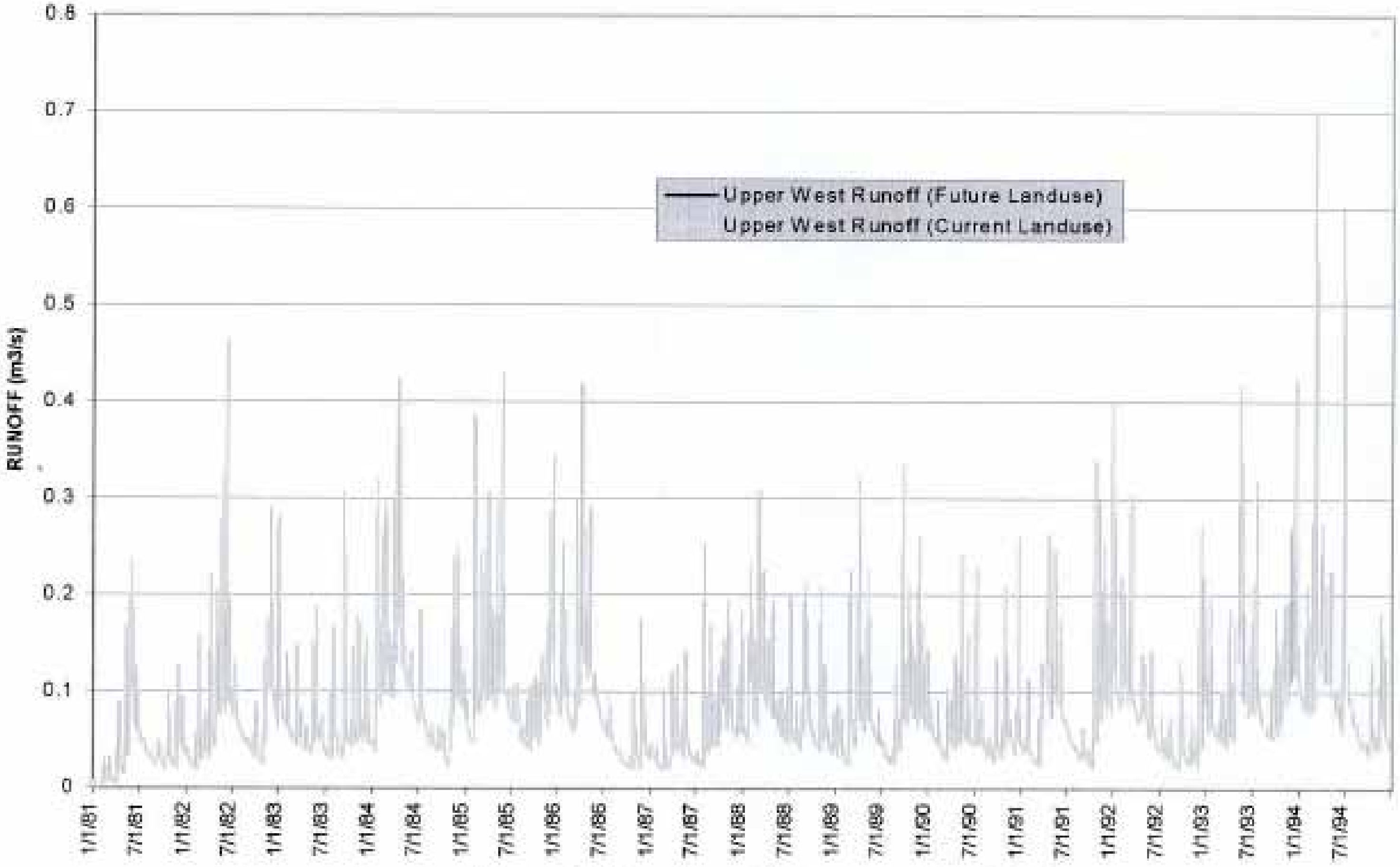


Figure 3.1.7a : Runoff into upper West Wetland

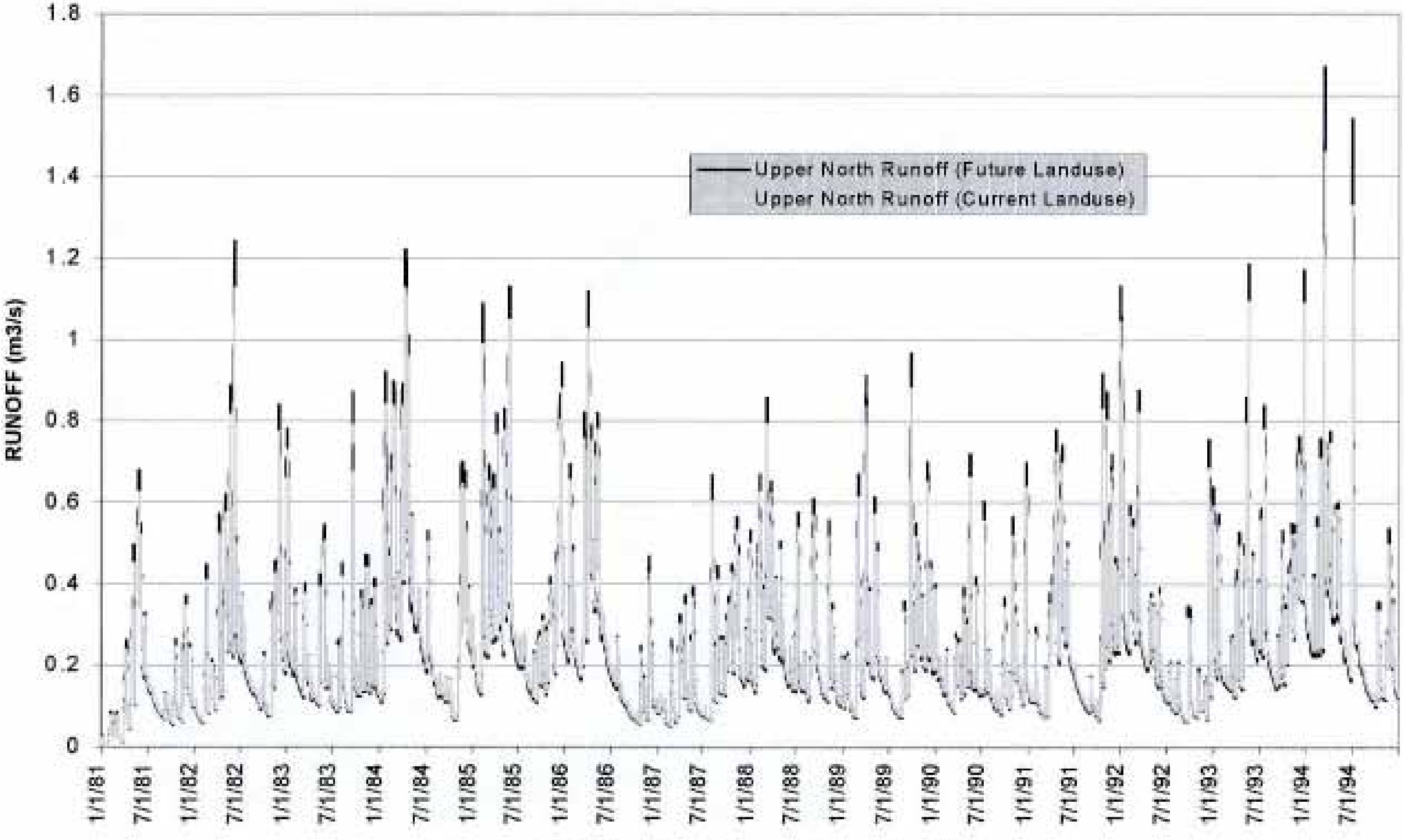


Figure 3.1.7b : Runoff into Upper North Wetland

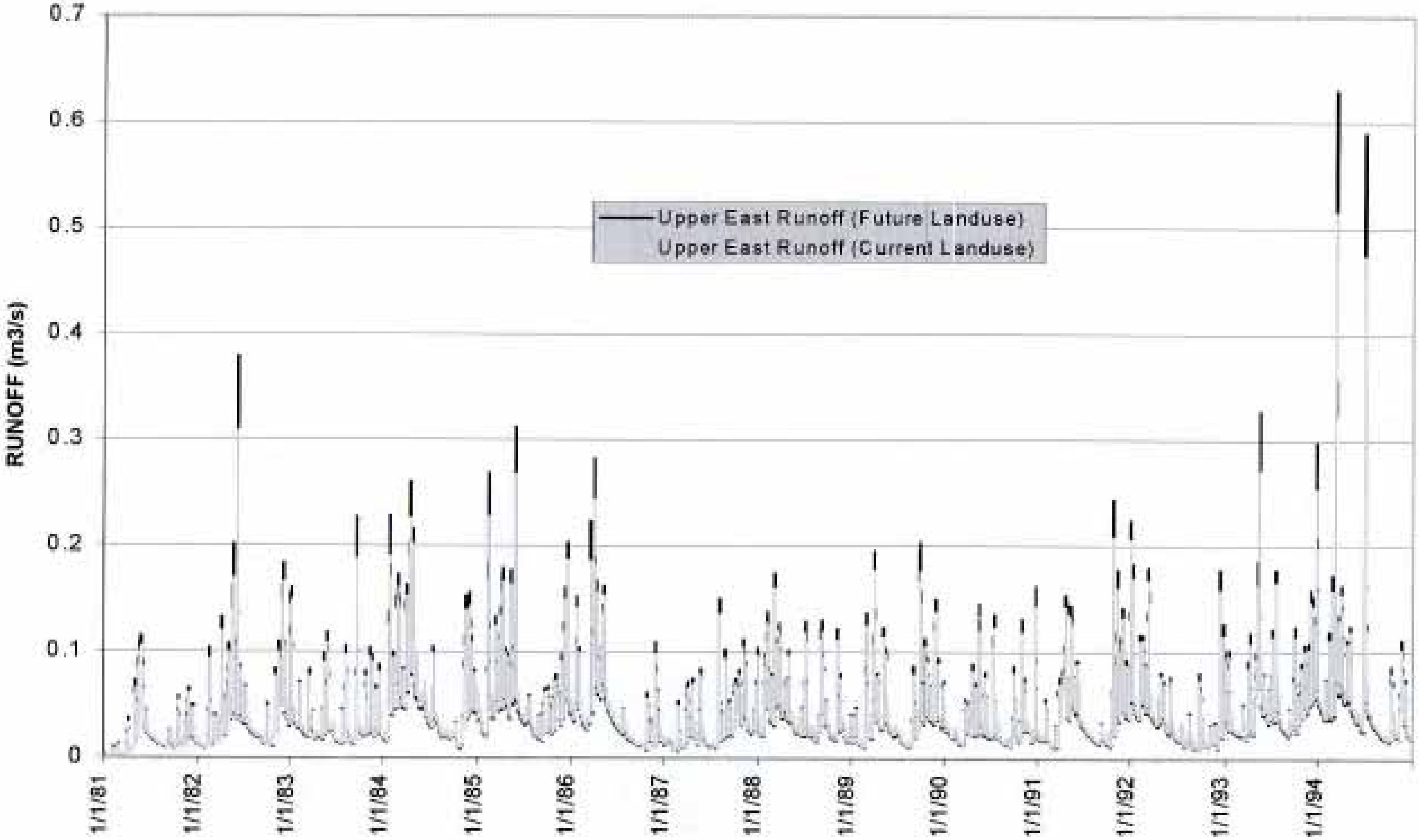


Figure 3.1.7c : Runoff into Upper East Wetland

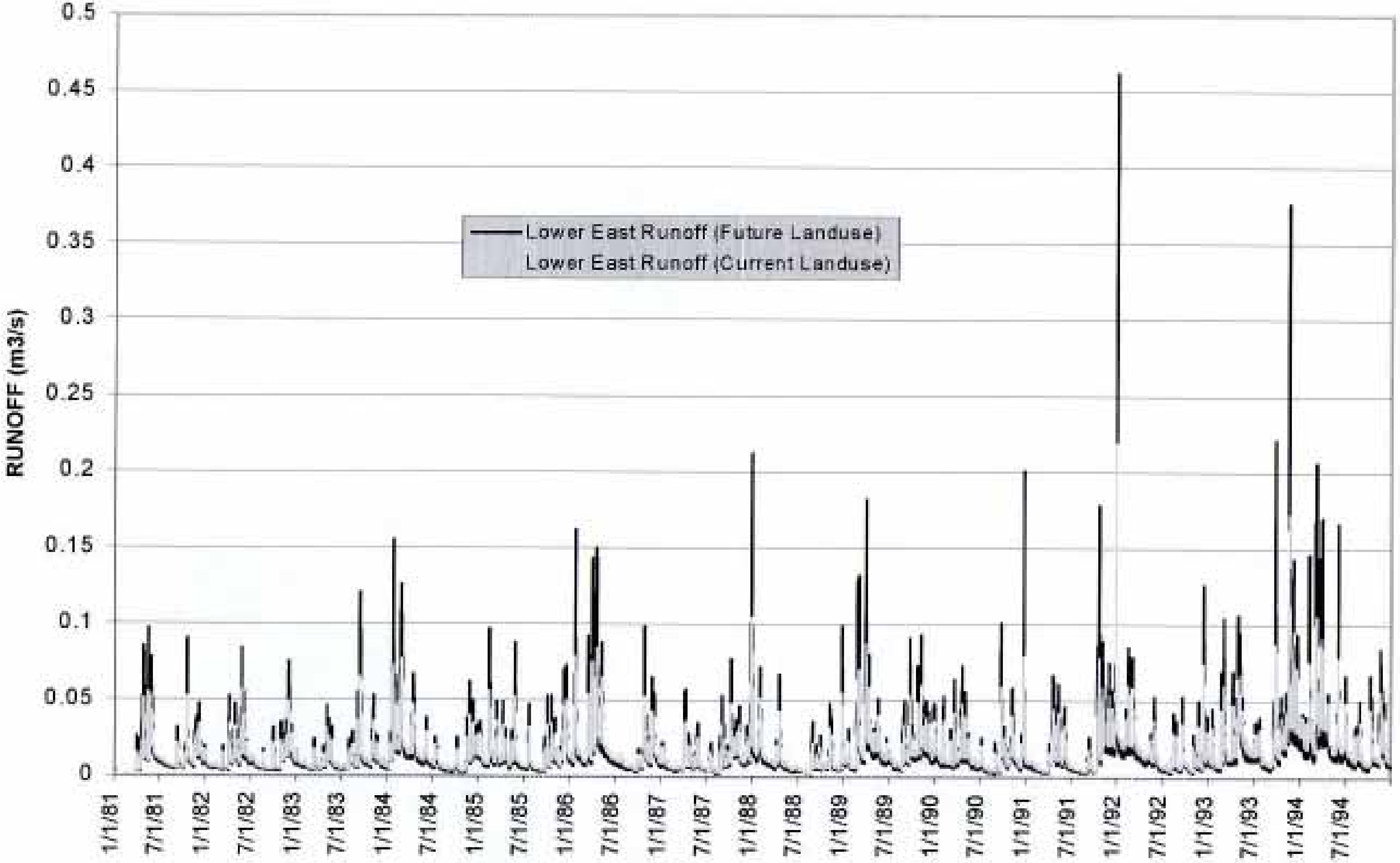


Figure 3.1.7d : Runoff into Lower East Wetland

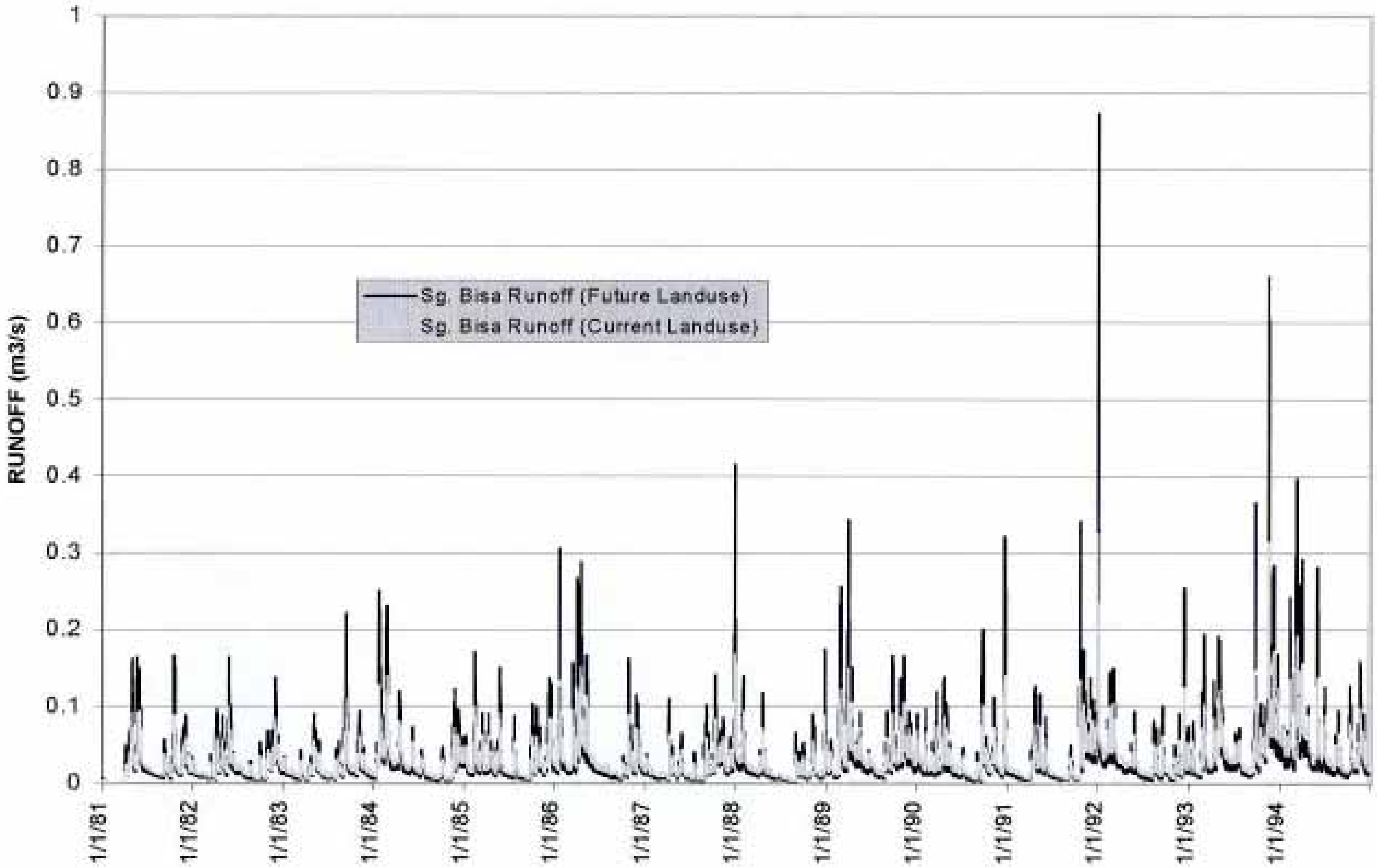


Figure 3.1.7e : Runoff into Sg. Bisa Wetland

using regional low flow relationships developed for the National Water Resources Study (NWRS, 1999).

3.1.6.3 The simulated discharge at the Main Dam for the period 1981-1994 is shown in Figure 3.1.8. Throughout the simulation period, spilling occurs at the Main Dam following closely the rainfall pattern in the Putrajaya Lake Catchment i.e. low flows ranging from 0.2 - 0.3 m^3/s in the drier months of June to August and high flows in the months of March to May and September to December. The mean flow for the simulation period was 1.28 m^3/s.

3.1.6.4 Using regional low flow relationships developed for NWRS, 1999 two conditions were evaluated, i.e

(i) when the inflow is the Average Annual Flow (AAF)
(ii) when the inflow is the Mean Annual Minimum of one day mean discharge (MAM)

3.1.6.5 The AAF was determined according to the following relationship developed for the National Water Resources Study (NWRS, 1999).

$$AAF = e^{-6.3638} \times AREA^{0.9416} \times (MAR - AE)^{0.5033}$$

Where AREA - catchment area at Main Dam
MAR – Mean Annual Rainfall
AE – Actual Evaporation

Putting AREA = 45.3 km^2
MAR = 2150 mm
AE = 1300 mm

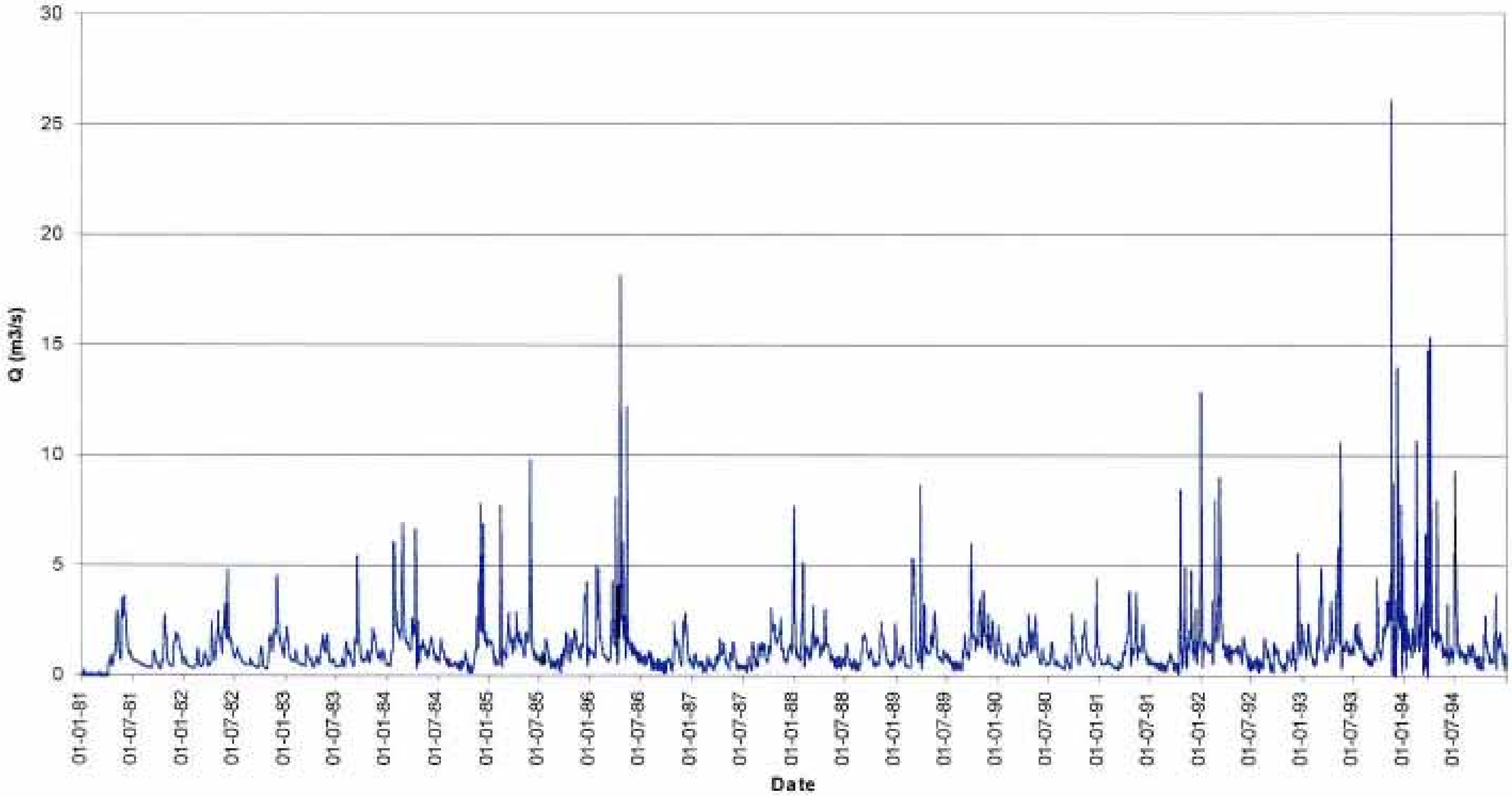
We get AAF = 1.86 m^3/s

3.1.6.6 The mean annual minimum of one day mean discharge (MAM) was computed based on the following relationship developed for the NWRS (1999).

$$MAM = e^{-15.3} \times AREA^{1.009} \times (MAR - AE)^{1.58}$$

Where AREA - catchment area at Main Dam
MAR – Mean Annual Rainfall

Figure 3.1.8 : Simulated Discharge at Putrajaya Main Dam (1981-1994)



AE – Actual Evaporation

Inputting the same AREA, MAR and AE as above,

We get MAM = 0.332 m^3/s

3.1.6.7 Hence, with net evaporation over the lake area of 650 ha amounting to 0.053 m^3/s, about 97% of AAF or 1.81 m^3/s will flow via the spillway into Sg. Chuau downstream of the dam. Similarly, with MAM as inflow and deducting net evaporation over the lake, 84% of MAM or 0.279 m^3/s will flow through the spillway.

A check was made to ascertain whether there will be any spill from the lake during a severe drought of 50-year return period. The 7 day 50 year return period low flow ($Q_{7,\ 50}$) was estimated at 0.183 m3/s ($Q_{7,\ 50}$ computed using the expression given below developed by NWRS).

$$\mathbf{Q_{D,T}/\ MAM = -0.018(-LN(LN(T/(T-1))))^3 + 0.1519(-LN(LN(T/(T-1))))^2 - 0.5058(-LN(LN(T/(T-1)))) + 1.1346)}$$

Deducting net evaporation losses from the lake at 0.7 mm/ day or 0.053 m^3/s, the lake will still spill 0.13 m^3/s of flow downstream of the dam.

3.1.6.8 Unlike a direct supply reservoir where water impounded is taken to supply necessitating releases in the form of compensation flows, the Putrajaya Lake as demonstrated above will spill water downstream ranging from 0.279 - 1.81 m^3/s for mean annual minimum and average annual flow conditions.

3.1.6.9 According to NWRS, the recommended compensation flow downstream of a direct supply reservoir is 10 % of AAF. In the case of Putrajaya Lake as shown in Figure 3.1.8, spilling at the Main Dam occurs throughout the simulation period (1981-1994) and from regional low flow analysis above, the flows through the spillway exceed 0.186 m^3/s (10 % of AAF) which is therefore more than adequate to meet compensation flow requirements. The compensation flow of 0.186 m^3/s, however needs to be checked with observed flows before it is implemented at Putrajaya Main Dam.

3.1.6.10 Based on a previous Report on Preliminary Design of Drainage, Lake Development and Temporary Dam, December 1995, prepared by HKA Hydrology and Water Resources Consultant, it was estimated that the lake will fill up in about 10 months (without any compensation flow) for the case of a 1 in 10 year dry (probability that a given flow is equalled or exceeded is 90%) minimum flow. When compensation flow of 0.186 m^3/s is provided for downstream users it was found that the infilling of the lake took about 11 months (see Figure 3.1.9).

3.1.6.11 Therefore it is still possible to provide compensation flow during infilling of the lake, though complete filling is only delayed by about one month which is acceptable.

3.1.7 Rainwater Harvesting and Utilisation

3.1.7.1 Rainwater harvesting and utilisation for domestic, industrial and other uses is consumptive in nature i.e the bulk of the rainwater harvested and utilised will be lost from the catchment. Consequently, widespread rainwater harvesting in the Putrajaya lake catchment can lead to reduced inflows to the streams feeding the lake.

3.1.7.2 Detail studies on rainwater harvesting and utilisation, taking into consideration aspects such as total roof areas and water demand requirements in the Putrajaya lake catchment, need to be done to determine

(i) impact of rainwater harvesting on the inflows into the Putrajaya lake
(ii) policy prescriptions and regulations to be incorporated into existing By Laws, for controlling rainwater harvesting and utilisation in the Putrajaya lake catchment

3.1.7.3 It is therefore recommended that during infilling of the lake no rainwater harvesting should be allowed except where the quantities involved are small and that too with the permission of Perbadanan Putrajaya.

3.1.7.4 Any rainwater harvesting after lake infilling could only be considered pending the outcome and recommendations of the

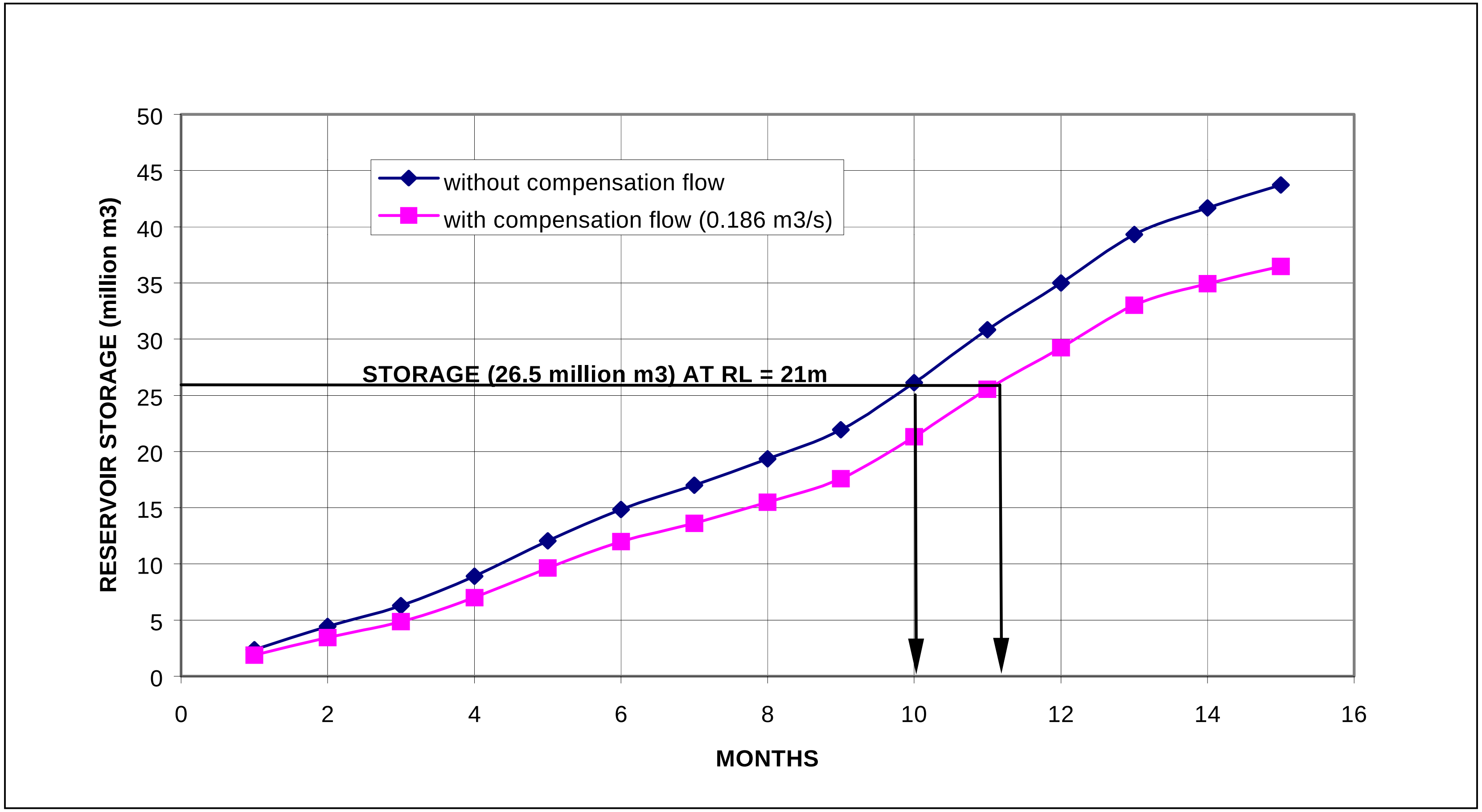


Figure 3.1.9 **Predicted Filling Times for Putrajaya Lake with and without Compensation Flow at 90% Probability (1 in 10 year dry minimum flow)**

detail rainwater harvesting and utilisation study mentioned above.

3.1.8 Proposed Hydrological Stations Network

3.1.8.1 The proposed hydrological stations network is shown in Figure 3.1.10. Two rainfall stations are proposed on two subcatchments in the upstream part of the lake catchment. Another three rainfall stations are proposed at the Central Wetlands, downstream of Upper Bisa Wetlands and at Cyberjaya. The existing rainfall station at Puncak Niaga has to be maintained.

3.1.8.2 Seven streamflow stations are proposed one each at Upper West Wetlands, Upper North Wetlands, Upper East Wetlands, Lower East Wetlands, Upper Bisa Wetlands, Cyber Jaya and Putrajaya Commercial Precinct. Five water level stations are proposed at the downstream weirs of Upper West, Upper North, Upper East and Central Wetlands and one water level station at the Main Dam.

3.1.8.3 Six groundwater stations are proposed one each at Upper West Subcatchment (near MARDI), and Upper North (near UPM Hostels), two at the Central Wetlands, one at downstream of Upper Bisa Wetlands and one at Cyberjaya.

3.1.8.4 The estimated cost of the hydrological stations network are tabulated in Table 3.1.8.

3.1.8.5 Using data from the proposed hydrological stations the rainfall runoff processes in the Putrajaya Lake catchment can be better calibrated and the simulations from the current NAM Rainfall Runoff Model improved. This would also aid in the better and efficient management of the catchment's water resources.

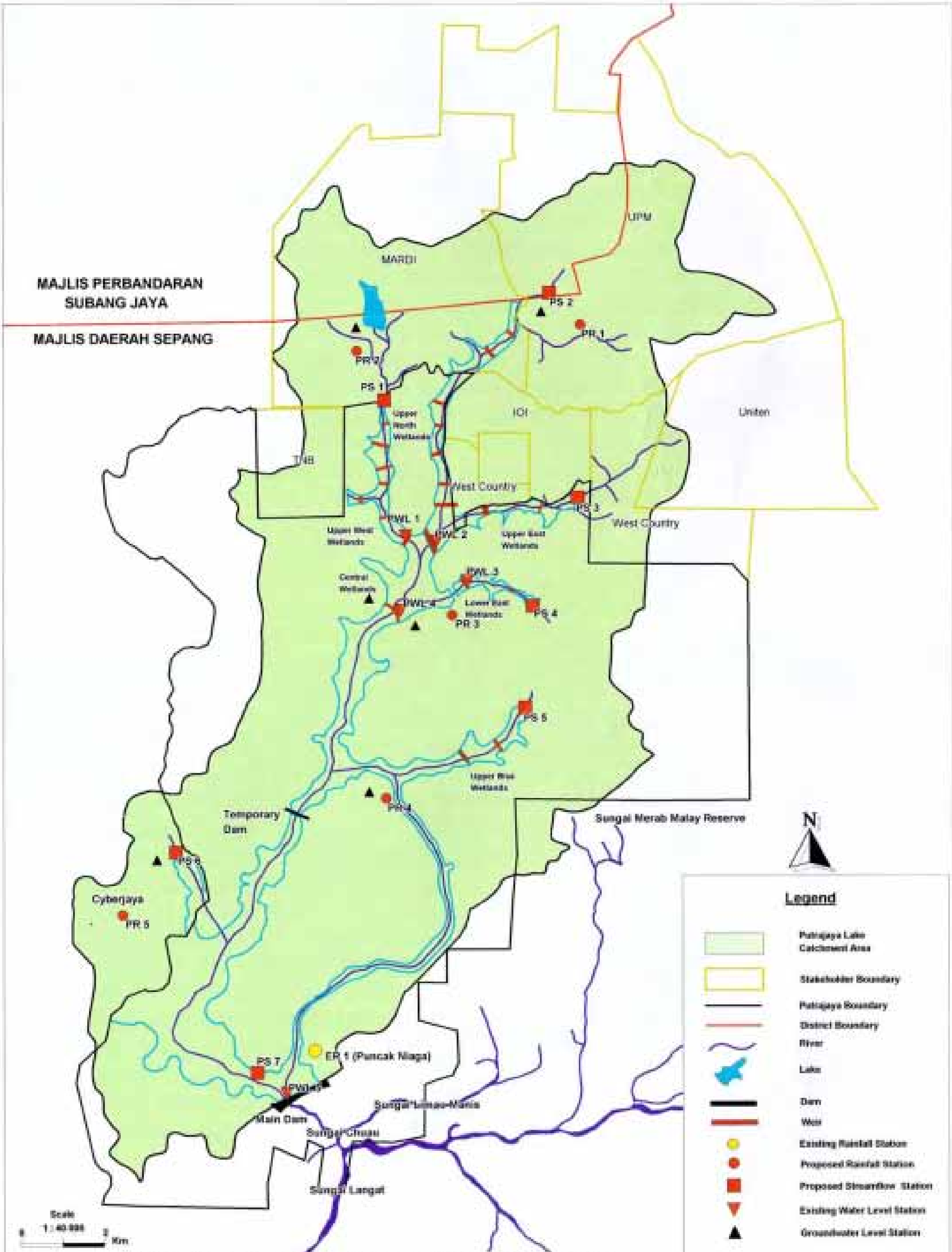


Figure 3.1.10 Existing and Proposed Hydrological Stations

Table 3.1.8 : Cost of Hydrological Stations

Item		No. of Station	Rate (RM)	Total Cost (RM)
1 Setting up of Rainfall Recorder Station				
i. Continuous Rainfall Sensor			10,000.00	
ii. Housing (Civil Works)			5,000.00	
iii. Data Logger			6,000.00	
iv. Commissioning			4,000.00	
v. Maintenance (1 Year)			3,000.00	
	Total (RM)	**5**	**28,000.00**	**140,000.00**
2 Setting up of Automatic Streamflow Station				
i. Area Velocity Flow Meter (Water Level and Velocity Sensor)			20,000.00	
ii. Housing (Civil Works)			20,000.00	
iii. Data Logger			6,000.00	
iv. Commissioning			5,000.00	
v. Maintenance (1 Year)			3,000.00	
	Total (RM)	**7**	**54,000.00**	**378,000.00**
3 Setting up Automatic Water Level Station				
i. Water Level Sensor			13,000.00	
ii. Housing (Civil Works)			15,000.00	
iii. Data Logger			6,000.00	
iv. Commissioning			5,000.00	
v. Maintenance (1 Year)			3,000.00	
	Total (RM)	**5**	**42,000.00**	**210,000.00**
4 Setting up Automatic Groundwater Level Station				
i. Water Level Sensor			13,000.00	
ii. Housing (Civil Works)			10,000.00	
iii. Data Logger			6,000.00	
iv. Commissioning			5,000.00	
v. Maintenance (1 Year)			3,000.00	
	Total (RM)	**6**	**37,000.00**	**222,000.00**
			GRAND TOTAL (RM)	**950,000.00**

3.2 SOIL EROSION AND SEDIMENTATION STUDY

3.2.1 Introduction

3.2.1.1 Soil erosion arising from the land clearing and earthworks activities, associated with development in the catchment, has been identified as a major threat to the water quality of Putrajaya Lake. Thus, there is a need to identify and map the areas in the catchment with high soil erosion potential to facilitate land-use planning in the catchment. There is also a need to define the guidelines for the control of soil erosion and sedimentation in the catchment arising from the development activities in the catchment.

3.2.1.2 Soil erosion is defined as the detachment, entrainment and transport of soil particles from their place of origin by the agents of erosion, such as water, wind and gravity. It is a form of land degradation and can be categorised as either *geological or accelerated* erosion. Geological erosion is part of the natural wearing down of the earth's land surface and occurs at rates ranging from virtually imperceptible soil creep to dramatic sudden landslides. Accelerated erosion results from human activities exposing the soil surface and thus enabling erosive agents such as rain to wash away topsoil and the underlying weathered rock. The rate of erosion and sedimentation in a catchment is a function of changes in the surface drainage patterns, terrain roughness, vegetation and climatic conditions.

3.2.1.3 In order to map the soil erosion potential in the catchment a soil erosion model, CALSITE, is used in this study. The CALSITE (Calibrated Simulation of Transported Erosion) model uses the Universal Soil Loss Equation and the IDRISI GIS to define the soil erosion potential map of a catchment. It requires rainfall, soil, topography and land-use maps of the catchment as inputs. The modelling exercise will involve collection and preparation of the pertinent input maps, model set-up and calibration, and simulation for the soil erosion potential maps associated with the various proposed land-use scenarios for the catchment.

3.2.2 The CALSITE Model

3.2.2.1 The CALSITE Model uses a combination of the Universal Soil Loss Equation (USLE) and a delivery ratio function to determine the soil erosion and sediment yield from a catchment. The equation for the estimated average annual soil erosion loss, in tonnes/ha/year, is given in Equation 3.1.

$$\mathbf{SE = R \times K \times LS \times CP} \tag{3.1}$$

Where,

SE = Estimated average annual soil erosion loss (tonnes/ha/year)
R = Rainfall Erosivity Factor
K = Soil Erodibility Factor
LS = Slope Length and Steepness Factor
CP = Combined Crop Cover and Conservation Practice Factor

3.2.2.2 LS and CP are dimensionless, whereas the dimension for R and K varies but their product will be equal to the dimension of SE.

3.2.2.3 The Sediment Yield (SY) is calculated based on Equation 3.2

$$\mathbf{SY = DR \times SE} \tag{3.2}$$

Where,

SY = Sediment yield (tonnes/ha)
DR = Delivery ratio (a calibrated value from 0 – 1)

3.2.2.4 The latest version of the CALSITE model allow the analysis of spatial variation in the erosion and sediment in a catchment, through the use of a raster GIS, IDRISI.

3.2.2.5 The input digital data and maps have to be pre-processed into digital images of rainfall, land use, land cover and slope, before they can be used by the CALSITE model. An elevation image, produced by the pre-processing task is used to determine the delivery ratio, which is then inputted into the model. Map information on topography, soils, land use and rainfall were digitised using AutoCad software, which are then converted to the raster format.

3.2.3 Preparation of input data

3.2.3.1 The following information and maps pertinent to the study were obtained from various government departments and agencies:

- Topographical maps of the catchment, with a scale of 1:50,000, from the Survey and Mapping Department, 1993.
- Soil Map and Erodibility Factor map for Peninsular Malaysia, with a scale of 1:1,000,000, published by the Kementerian Pertanian Malaysia
- Rainfall data from the Hydrology Division, Drainage and Irrigation Department
- Land-use map of Selangor and the Wilayah Persekutuan, with a scale of 1:125,000, published by the Kementerian Pertanian Malaysia, 1995
- Future Land-use map for Putrajaya.

3.2.3.2 The information collected were pre-processed as follows:

(a) Rainfall map

The pre-processing task is to create an annual isohyet contour map showing the spatial distribution of rainfall in the study area, using the annual rainfall depth data of the year to be modelled. The map can be interpolated and drawn using the annual rainfall data from the rainfall stations, described in Section 3.1.2. Figure 3.2.1 shows the image of the average annual rainfall map after the interpolation process.

(b) Soil map

The information on the soil type in the catchment, was obtained from soil characteristics investigation and analysis carried out by Universiti Putra Malaysia.

(c) Elevation and slope map

The topographic map was used to define the elevation differences in the catchment for subsequent computation of slopes and flow paths in the catchment. The contours obtained from the topographic map, with a scale of 1 : 50,000, are digitised and other points are interpolated using IDRISI's Intercom component. Based on the digitised topographic contours the elevation map (Figure

3.2.2) was generated. The slope map (Figure 3.2.3) is then derived from the elevation map using IDRISI's Surface component.

(d) Land-use map

(1) In the Preliminary Report, for present land-use map, digitising was only for Putrajaya catchment only, resulting in the creation of soil erosion potential for Putrajaya catchment only. Soil erosion potential covering the whole Perbadanan Putrajaya area and Putrajaya catchment is included in the Draft Final Report. As for future Land-use, digitising was done for the Perbadanan Putrajaya area as well the Putrajaya Lake Catchment area.

(2) The above processed maps were then geometrically rectified to a common map base and scale so that they can be subsequently overlain to create the soil erosion potential map.

3.2.4 Model calibration and set-up

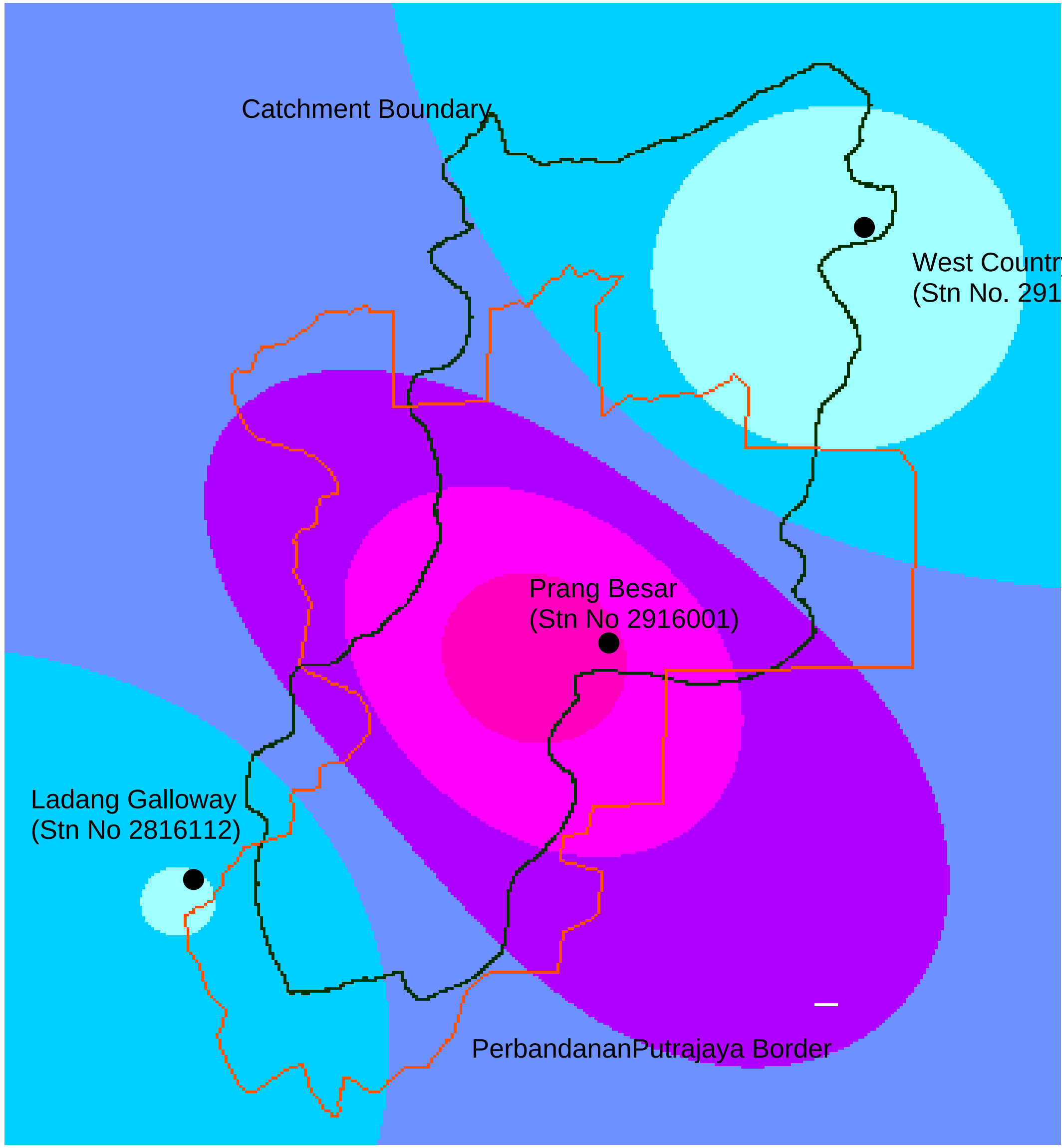
3.2.4.1 For the calibration of the CALSITE model it is important that data on the observed sediment yield from the catchment be obtained. The most reliable and accurate data are those collected from hydrographic surveys in the catchment. Thus, surveys to collect the required data for the calibration will carried out.

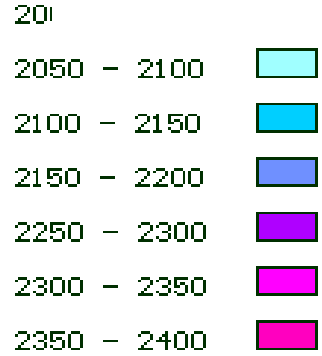
3.2.4.2 From Equation (3.1), it can be seen that the estimated annual soil erosion loss is the product of four parameters. They are the rainfall erosivity factor (R-factor), soil erodibility factor (K-factor), slope length and steepness factor (LS-factor) and conservation practice factor (CP-factor). The image files containing the information on the four factors were pre-processed, as described in Section 3.2.3 above.

3.2.4.3 Among the four factors, the K-factor and the LS-factor are assumed to have insignificant changes throughout the catchment. However, since the R-factor and the CP-factor are related to the rainfall and land-use in the catchment they are expected to vary with time. This implies that the R-factor and CP-factor images are dependent on the year being considered.

Figure 3.2.1 : ANNUAL SPATIAL RAINFALL DISTRIBUTION MAP

Unit in mm





CATCHMENT DEVELOPMENT AND MANAGEMENT PLAN FOR PUTRAJAYA LAKE

Figure 3.2.2 : ELEVATION MAP

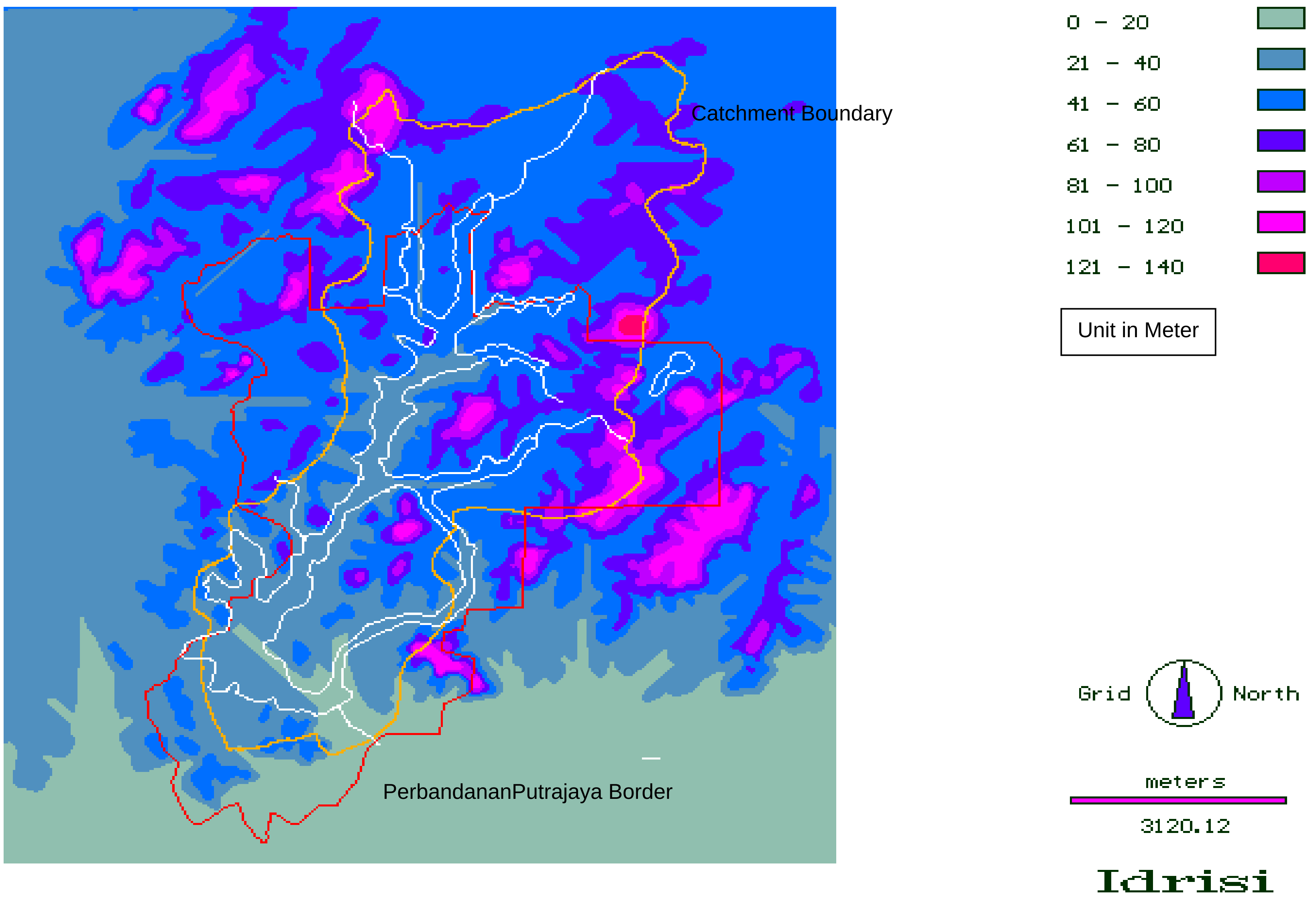
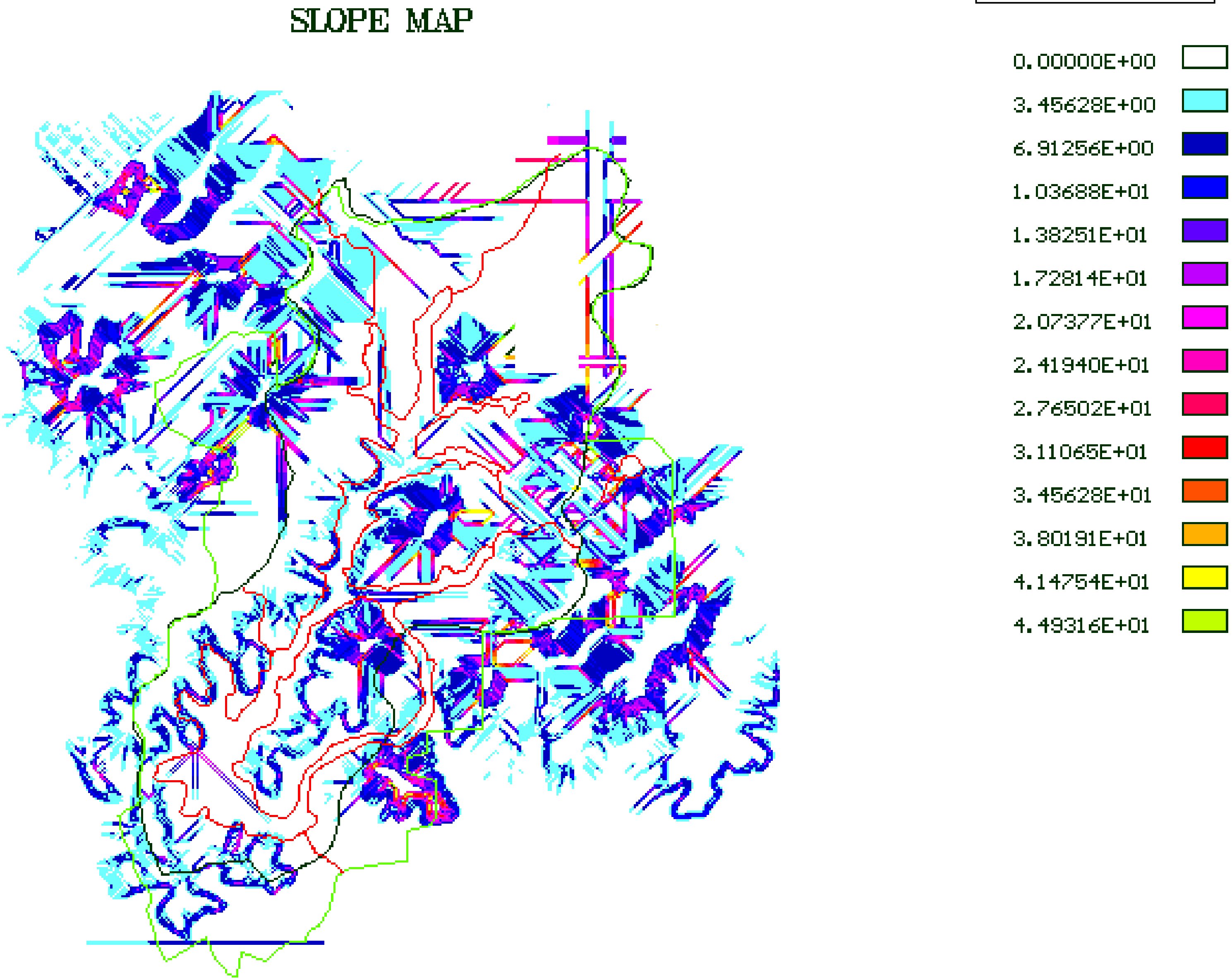


FIGURE 3.2.3: SLOPE MAP



3.2.4.4 The following assumptions have been made in the derivation of the images associated with the four factors used in this study.

(a) Rainfall erosivity factor (R-factor)

(1) The USLE measures rainfall erosivity as the product of the annual kinetic energy of rainfall (E) and the greatest intensity of a 30-min storm (I_{30}). Normally, this method is impractical. It is because the prediction for potential soil erosion is on annual basis (ton/ha/yr). The Model offers two options for deriving R-factor from annual rainfall based on empirical methods. The first is an equation by Bols which has been derived from data collected in Indonesia and has been applied in the Philippines. The other is a regression equation derived by Harper based on the analysis of Hawaii data and has been modified for use in Thailand.

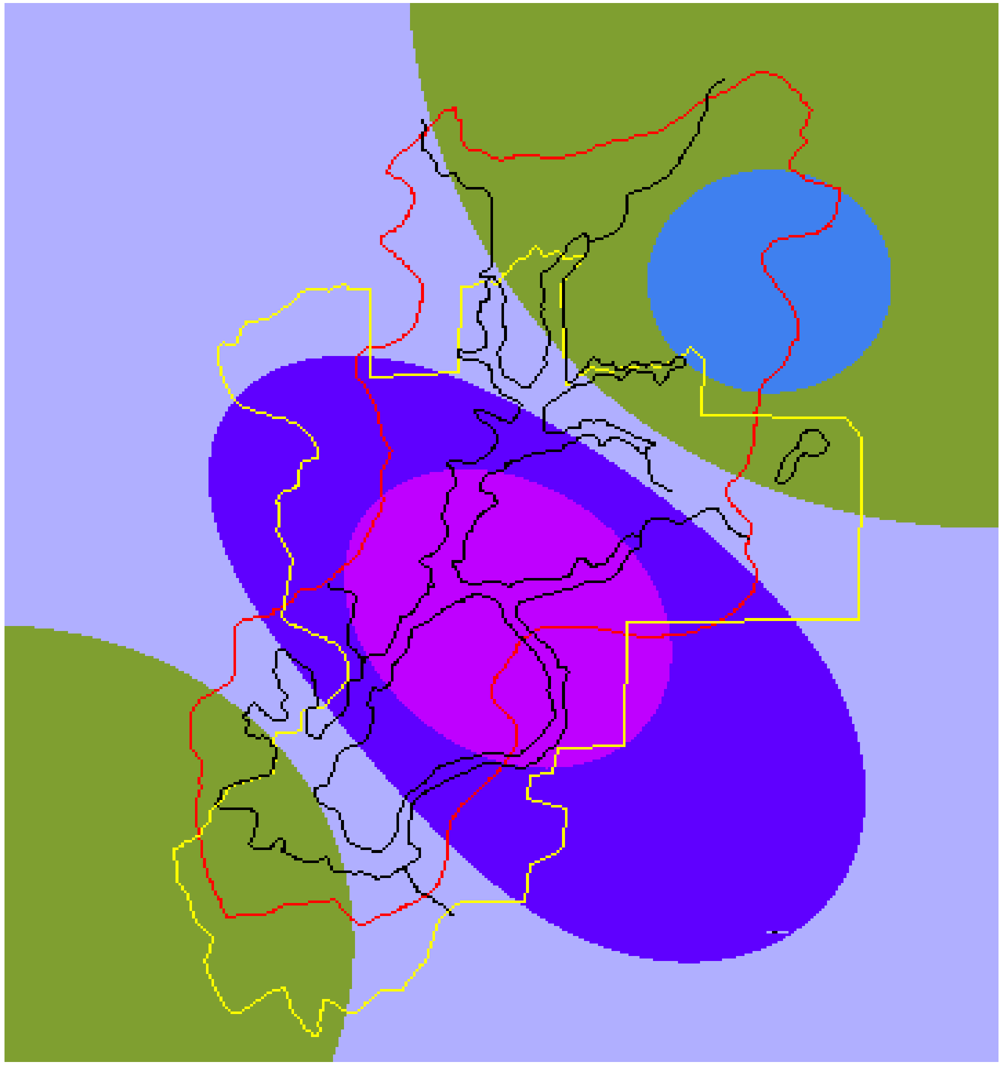
(2) However, for Peninsular Malaysia, Morgan tried to overcome the lack of data to derive the erosivity factor by making use of total daily rainfalls to predict the daily erosivity values. The annual erosivity factors derived from the sum of the daily erosivity values were found to correlate well with the annual rainfall. This relationship was also found in studies carried out at UPM. Figure 3.2.4 shows R-Factor for Perbadanan Putrajaya Lake Catchment Area.

(3) In view of the absence of better information it has been assumed in this study that the annual rainfall depth shall be used in place of the rainfall erosivity factor. This implies that the R-factor has a dimension of mm and thus the dimension of the soil erodibility factor (K-factor) has to be modified to tonnes/ha/mm to ensure dimensional consistency.

(b) Soil Erodibility Factor (K-factor)

The K-factor relates soil erodibility to the texture, organic matter content, structure and permeability of a soil type. Each soil type in the image can be assigned a K-value in the model to generate the soil erodibility image. The Ministry of Agriculture, Malaysia has considered the above method to get the R-factor to be acceptable and has adopted it for use in the Ministry of Agriculture. Thus, it

FIGURE 3.2.4 : R- FACTOR MAP



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has prepared K-factors map for the different types of soils in Malaysia for use with the method. For this study, K-Factor map (Figure 3.2.5) were produced based on soil investigation characteristics carried out by University Putra Malaysia.

(c) Slope length factor (LS-factor)

The derivation of the slope-length image requires two images - the slope image and the length-of-slope image. The slope image is obtained from the elevation image as explained earlier. The length-of-slope image (L-value) is generated by the model through the processes of determining the aspects and flow accumulation at each pixel of the image, based on the information in the elevation image.

(d) Conservation Practice factor (CP-factor)

The surface management factor, CP, is a ratio that compares the soil loss from a field cultivated with a particular crop type or vegetation cover with that from a field with bare soil. It has a value of zero, when the soil is completely protected, to a value of one for bare soil. The CP-factor image is generated based on the land-use images produced from the land-use map, by assigning pertinent CP-factors for the various types of land cover in the catchment as shown in Figure 3.2.6**.**

3.2.5 Model simulation

3.2.5.1 Based on the above R, K, LS and CP factor image inputs the simulated output of the CALSITE model is the soil erosion loss image. The R-factor image was produced using the average annual rainfall image from Prang Besar, Ladang Galloway and Ladang West Country. The simulated soil erosion loss map, based on the 4 images above were generated from the available information and were based on three (3) scenarios:

1. Current Landuse
2. Future Landuse
3. Without Cover (worst case scenario)

FIGURE 3.2.5 : K – FACTOR MAP

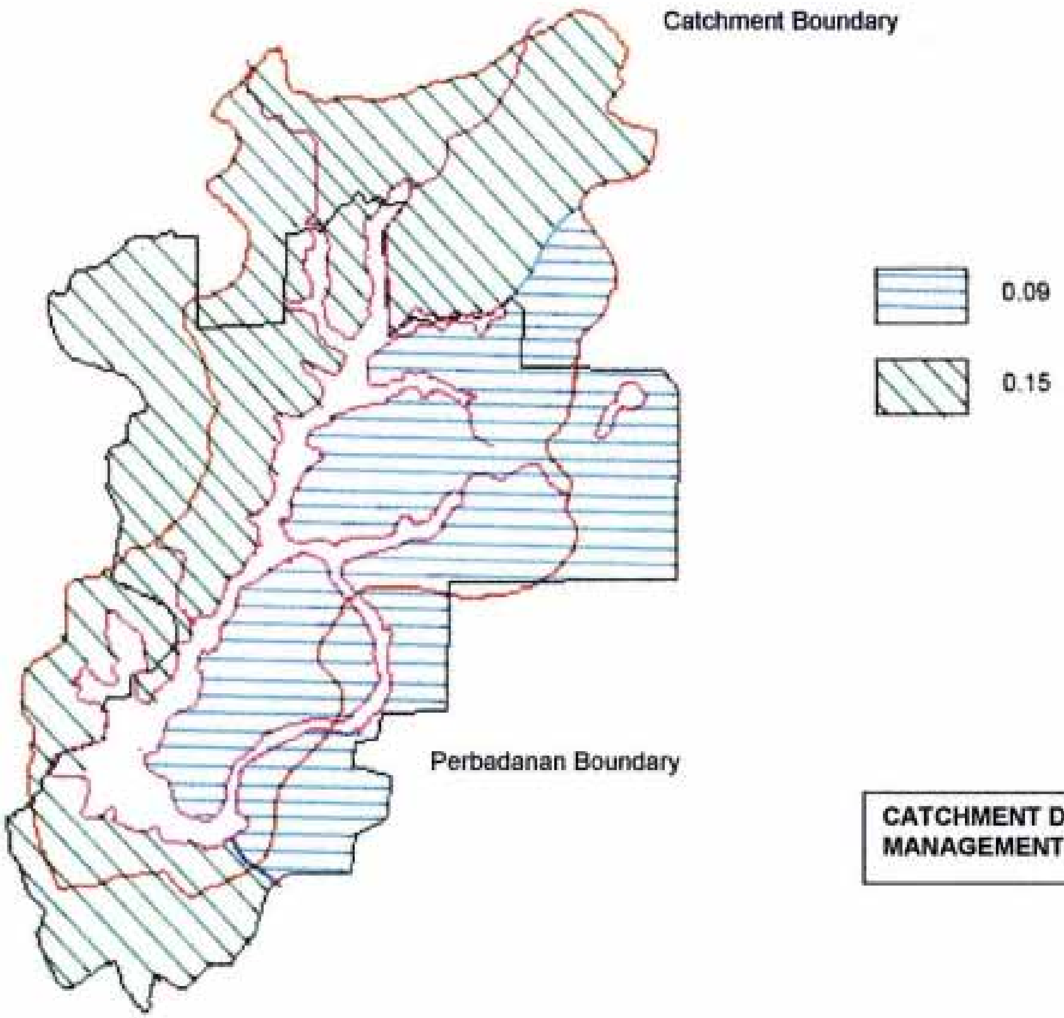

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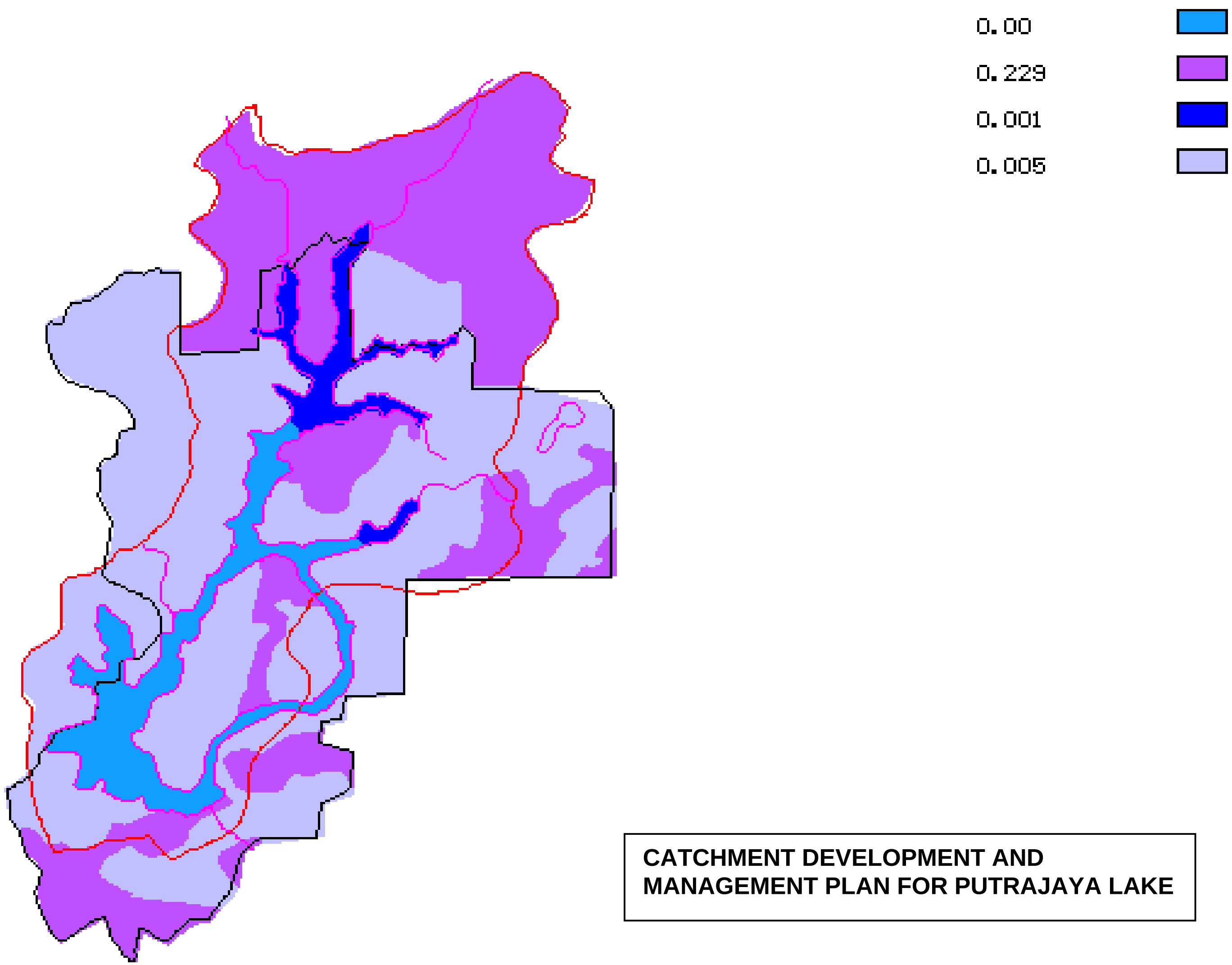
FIGURE 3.2.6: CP – FACTOR MAP



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(2) The worst case scenario with a CP value of 1 was used to generate the soil erosion loss map. The worst case scenario consider that soil surface is totally bare and without any cover. This scenario will only be significant when considering any new developments involving major earthworks. From this map, it can be predicted and determined the location where erosion will occur most. Preliminary preventive measures to minimise soil erosion then can be taken during earlier stage of the projects.

3.2.5.1 Soil Investigation Characteristics by UPM

(1) Soil expert from Universiti Putra Malaysia has been appointed on 23 July, 1999 to carry out soil investigation characteristics to determine the properties of soil within Perbadanan Putrajaya area and the area within Putrajaya Lake Catchment.

(2) The objective of the soil investigation is to determine parameters required for the refinement of data input to the CALSITE model. The result of the investigation also can be used for future study.

(3) Scope of the investigation include the following:-

1. Soil Texture
2. Particle Size Distribution (USDA Particle Size Class)
    - i. Hydrometer Sedimentation
    - ii. Sieve Analysis
    - iii. Percent organic matter
    - iv. Percent rock content
3. Permeability Test
4. Soil Structure
    - Very fine granular
    - Fine granular
    - Moderate or coarse granular
5. Moisture Content
6. Soil Erodibility Factor, K
7. Soil Description
8. Soil Erodibility Map

3.2.6 CALSITE Modelling results

3.2.6.1 Based on the CALSITE model, soil erosion for Perbadanan Putrajaya is low compared to other studies that have been carried out in other areas. Table 3.2.1 shows the comparison of the estimated erosion rate for various studies.

Table 3.2.1 : Erosion Rate from Selected Watershed in Malaysia and Singapore

Location	**Area (km2)**	**Estimated Erosion Rate (ton/ha/yr)**			**References**
		Forest	Agriculture	Construction	
1. Sg. Tekam Forest Reserve	0.57	0.27			Peh (1981)
2. Sg. Telom, Cameron Highland	77.0	0.3	26		Shallow (1956)
3. Sg. Kial, Cameron Highland	21.0	0.3	25		Shallow (1956)
4. Sg. Bertam, Cameron Highland	73	0.3	22		Shallow (1956)
5. Upper Sg. Anak Air Batu	5.9			11,000	Leigh (1982)
6. Denuded Plot, Upper Sg. Anak Air Batu	0.06			6,000	Leigh (1982)
7. Erosion Grid Plot, NUS, Singapore	2.5×10^{-6}			1,300	Chatterjea (1989)
9. Sg. Kurau, Perak			500 (agriculture and urbanising areas)		DID (1997)
10. Putrajaya Lake Catchment	60.7		50 (Current Landuse) 150 (Future Landuse)	300 (Average) 600 (Max)	

3.2.6.2 From Table 3.2.1, the erosion rate for Putrajaya Lake Catchment is very well below the construction rate and slightly above the agriculture rate. Compared to other studies, the erosion rate was very much lower. This is due to the topography of the Putrajaya Lake Catchment area which is gently undulating.

3.2.6.3 From Figure 3.2.7, it can be observed that soil erosion rates (Current Landuse) for the major part of Putrajaya Lake Catchment area is below 50 ton/ha/yr, which is considered low. Only small pockets of hilly terrain in the Putrajaya Lake Catchment have erosion rates of between 51 to 200 ton/ha/yr.

3.2.6.4 From Figure 3.2.8 (current landuse), for major part of Putrajaya Lake Catchment area, sediment yield is well below 10 Ton/ha/yr. On some parts of the catchment boundary (hilly area) covering the eastern part of Upper Bisa Wetland have a value of between 50 to 60 ton/ha/yr.

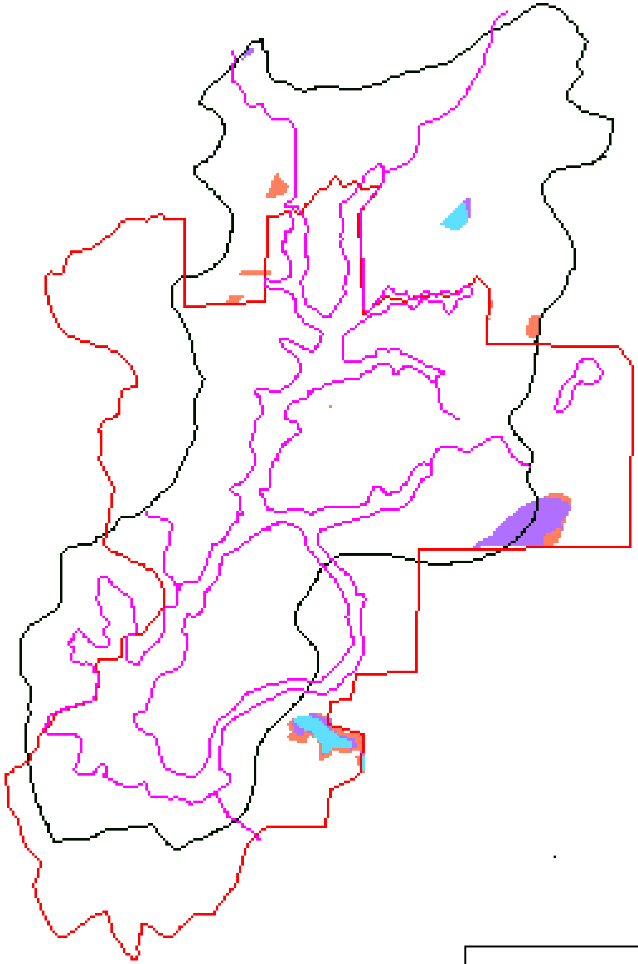
3.2.6.5 For Future Landuse (Figure 3.2.9) the major part of Putrajaya Lake Catchment has a soil erosion rate of below 150 ton/ha/yr. In the north-western fringes near MARDI and eastern fringes near West Country and Upper Bisa wetlands the soil erosion rates goes up to 200-300 ton/ha/yr.

3.2.6.6 From Figure 3.2.10, for major part of Putrajaya Lake Catchment area the sediment yield is up to 50 ton/ha/yr. On some parts on upper north catchment area (MARDI and UPM site) and on the fringes of Upper Bisa Wetland, it register sediment yield of between 60 to 80 ton/ha/yr. On the West Country site, due to hilly terrain the sediment yield is between 80 to 100 ton/ha/yr.

3.2.6.7 For worst case scenario i.e. without cover (Figure 3.2.11) the major part of Putrajaya Lake Catchment has a soil erosion rate of about 300 ton/ha/yr. In the north-western fringes near MARDI and eastern fringes near West Country and Upper Bisa wetlands the soil erosion rate goes up to 400-600 ton/ha/yr.

3.2.6.8 From Figure 3.2.12, sediment yield for major part of Putrajaya Lake Catchment is between 50 to 100 ton/ha/yr. On the Upper North catchment area and on the eastern part of Upper East and Lower East Wetland, sediment yield is between 200 to 250 ton/ha/yr.

FIGURE 3.2.7 : SOIL EROSION (CURRENT LANDUSE)



Unit in Ton/Ha/Year	
0 - 50	
51 - 100	
101 - 150	
151 - 200	

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FIGURE : 3.2.8 : SEDIMENT YIELD (CURRENT LANDUSE)

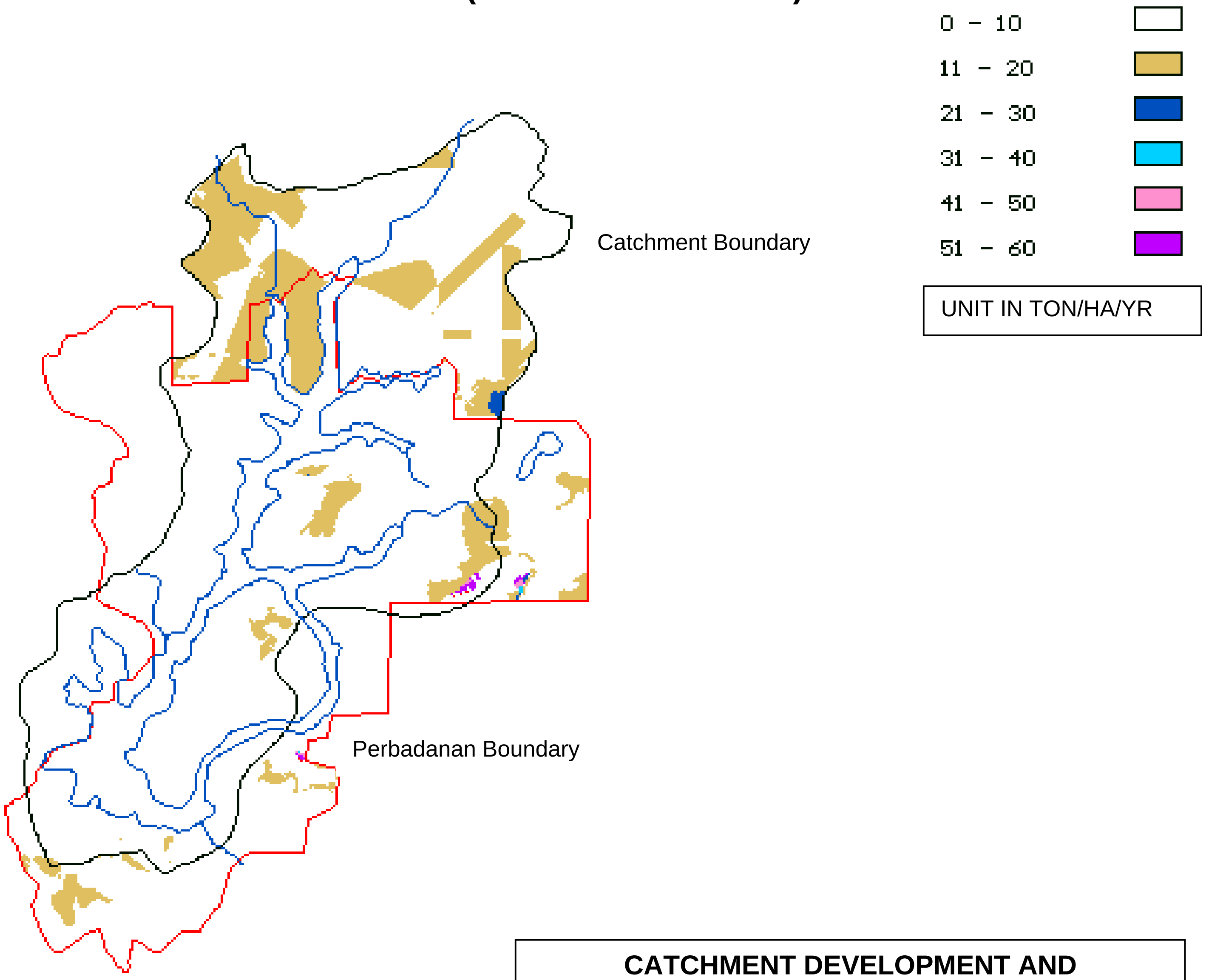

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FIGURE 3.2.9: SOIL EROSION MAP (FUTURE LANDUSE)

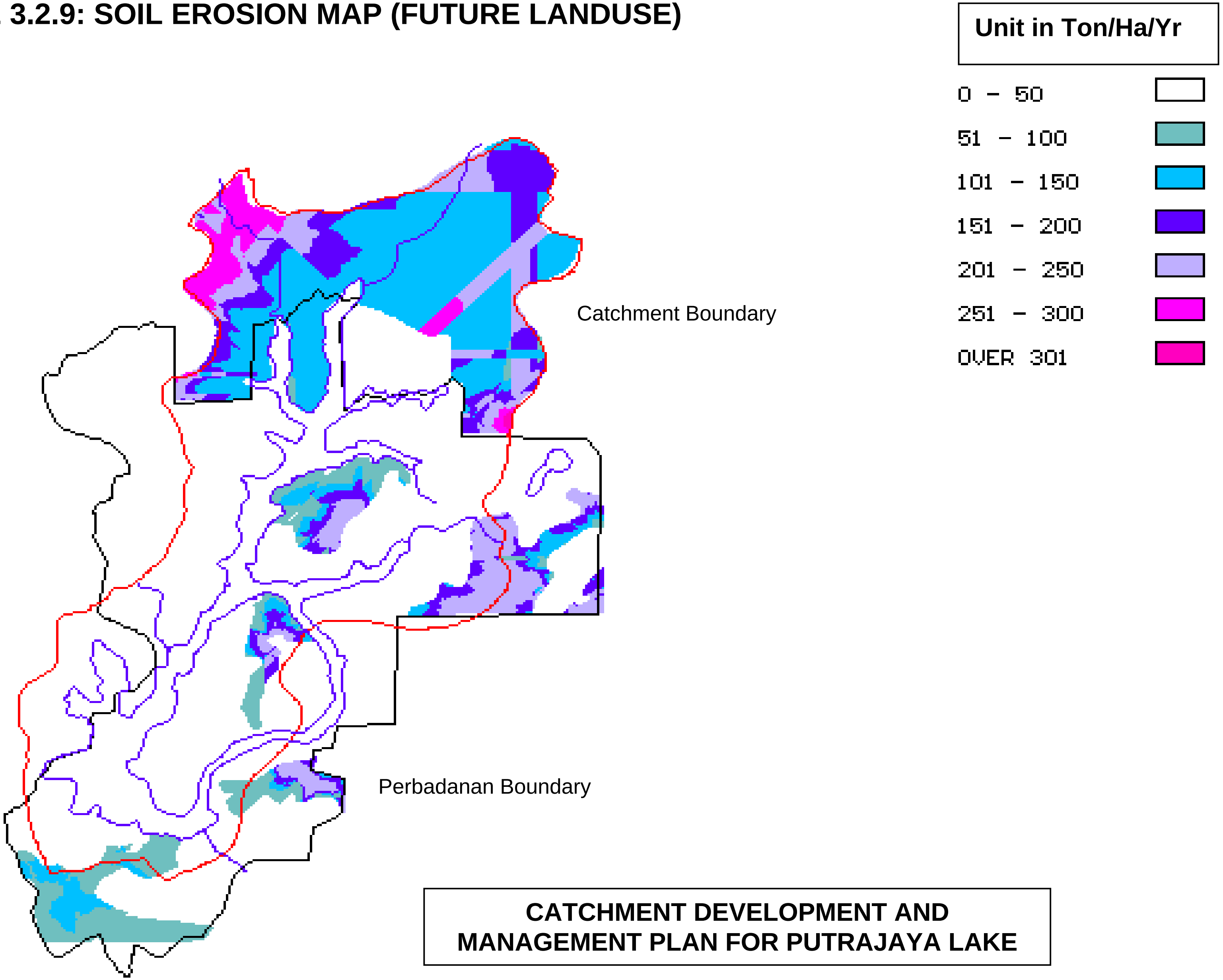

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FIGURE 3.2.10 : SEDIMENT YIELD (FUTURE LANDUSE)

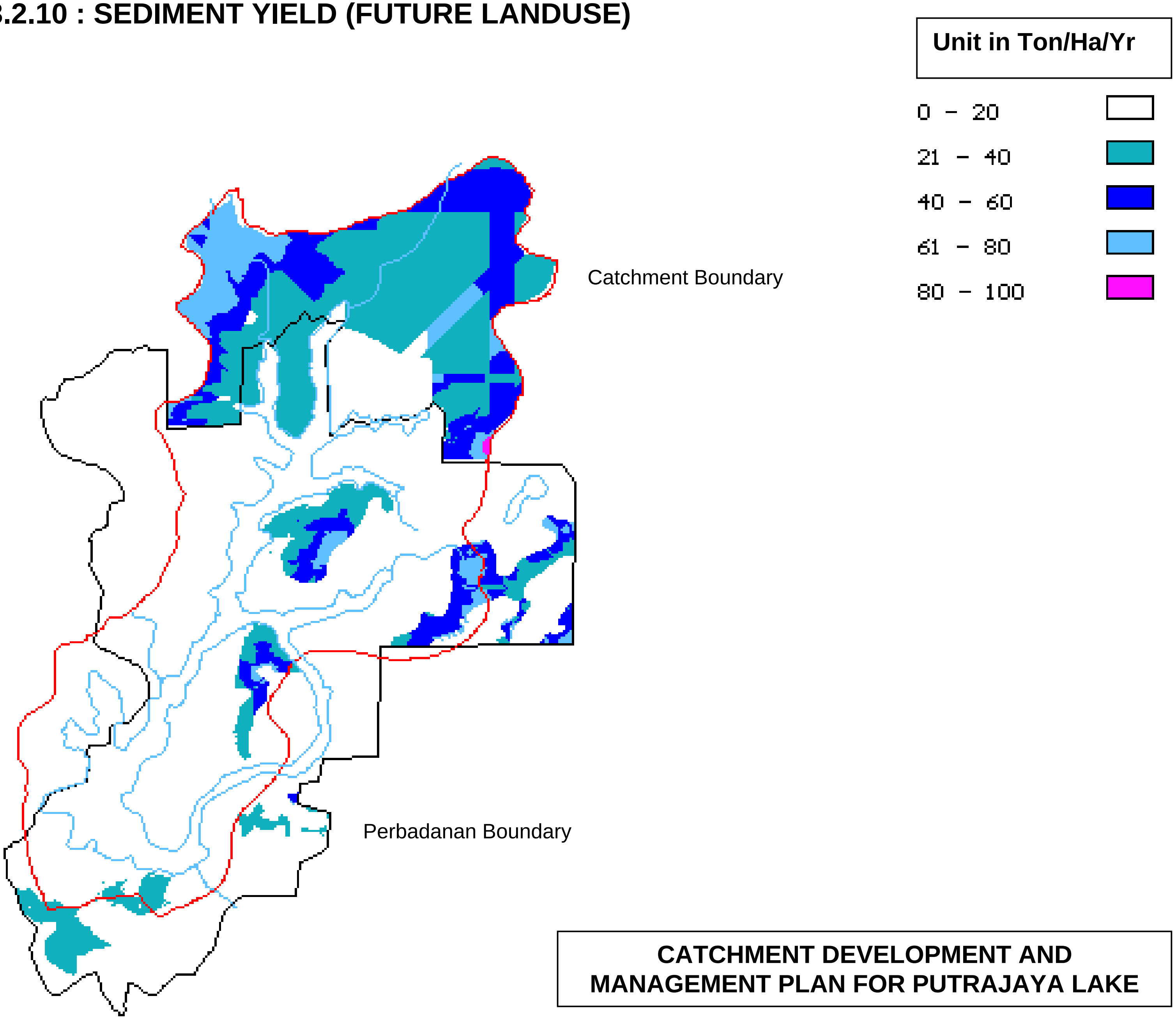

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FIGURE 3.2.11 : SOIL EROSION (WITHOUT COVER)

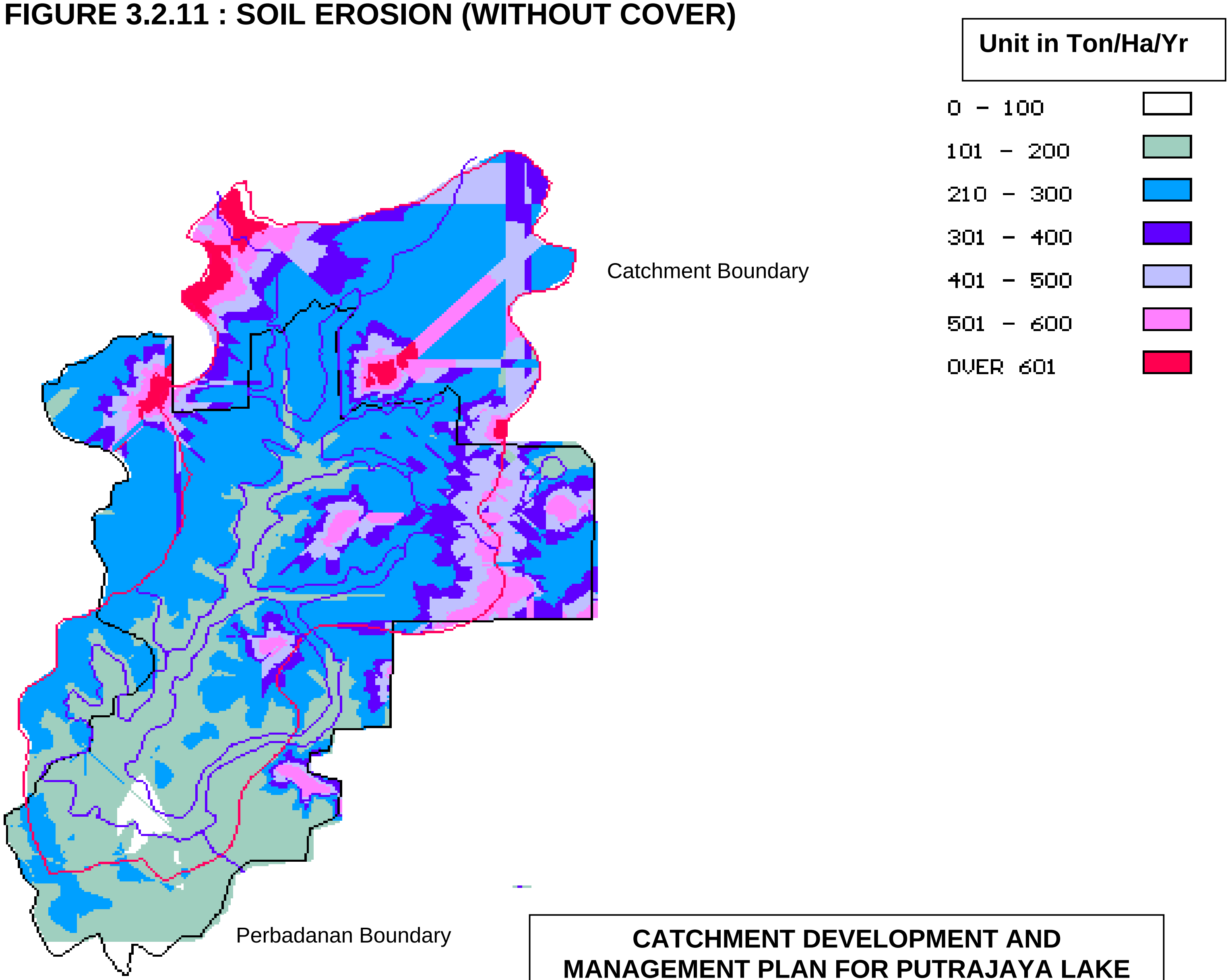

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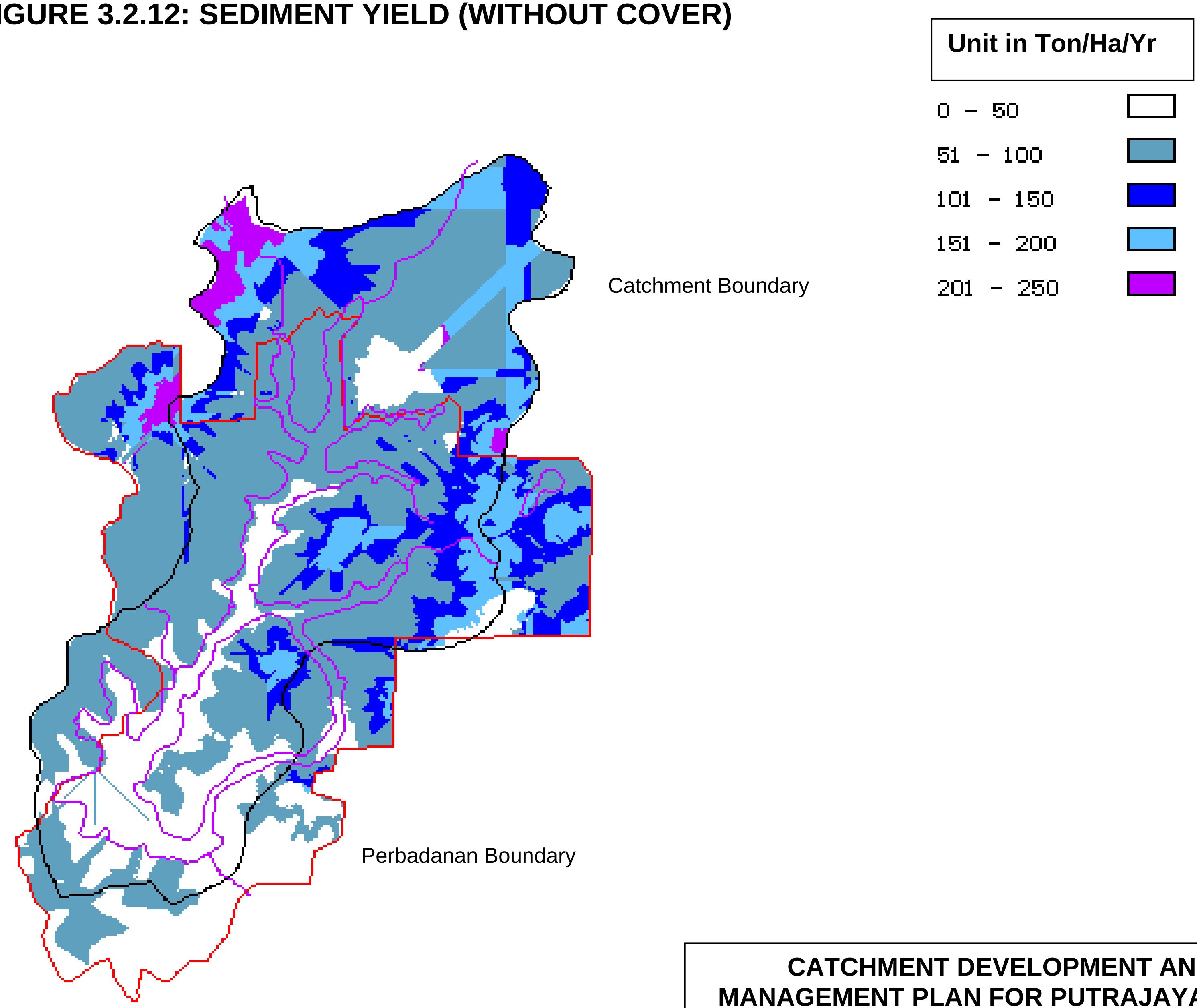
FIGURE 3.2.12: SEDIMENT YIELD (WITHOUT COVER)



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3.2.6.9 Based from this result, for future Land-use scenario soil erosion problems is expected to be rather mild in the Putrajaya Lake Catchment area provided on-site erosion controls, continuous monitoring, and regular maintenance are carried out.

3.2.6.10 However, at the area with higher erosion rate especially near the eastern and northern boundary of Putrajaya Lake Catchment, on-site erosion and sediment controls should be implemented and monitored closely during any development works to prevent sediment entering the wetlands and Putrajaya Lake.

3.2.7 Review of Existing Guidelines and Legislation on Erosion and Sediment Control

3.2.7.1 Environmental Legislation and Guidelines

(i) Putrajaya Environmental Management Guide

Based on the report on "Putrajaya Environmental Management Guide", Matter pertaining Erosion and Sediment was mentioned in Chapter 2.10: Environment Management Plan (EMP) of the report "Putrajaya Environmental Management Guide".

2.10.6.4(ii) - Environmental Management–Construction Stages

2.10.7.3.1 - Environmental Management – Operation Stages

Attachment (Table A7.2 in Appendix 7)

2.10.8(7) - Audit Requirements

Attachment (Table A7.3 in Appendix 7)

(ii) "Guidelines for Prevention and Control of Soil Erosion and Siltation in Malaysia", Department of Environment (DOE), October 1996

The guideline is recommending various measures for the control of soil erosion and river sedimentation to adopted when undertaking site clearing and earthworks. It outlines the principles for sound practices required to minimise soil erosion and sedimentation and should be considered as basis for practicable measures to prevent serious soil degradation.

(iii) Land Conservation Act 1960, Revision 1989

Part III of the act – Control of silt and erosion.

The act empower State Land Administrator to serve notice to the land owners or occupiers of any land regarding the movement of soils or stone that likely to cause damage to other land.

(iv) Street, Drainage and Building Act 1974
Earthworks (Perbadanan Putrajaya) By-Laws 1996

(1) Erosion protection were mentioned and covered in some parts of the above mentioned by-laws:-

Part II 6(d)(vii)	- protection to the earthworks against erosion, including protection during the continuance of the earthworks.
Part IV 18(b)	- that silt traps and sediment control facilities are adequately provided and properly maintained.
Part IV 18(d)	- that slopes are adequately protected against erosion.

(2) As mentioned and commented in the Chapter 8.1.5.4 (1) *Drainage, Building and Earthworks* in Putrajaya Environmental Management Guide, although there were sufficient power within Perbadanan Putrajaya to address the erosion and sedimentation issues, it appeared that the approach were not adequate. In order to address the issues, specific task and more focus should be given regarding control or erosion and sedimentation.

(3) As for area outside of the jurisdiction of Perbadanan Putrajaya, the respective Majlis Daerah should adhere to the existing By-laws, act and guidelines.

3.2.10 Recommendations for Soil Erosion and Sediment Control

3.2.10.1 'Erosion and Sediment Control By Law'

(1) In view of the importance and sensitivity of the study area, and the effect of erosion and sedimentation to the wetland and Putrajaya Lake, it make sense for erosion and sedimentation control to be regulated separately at Perbadanan Putrajaya level. Although erosion and sediment control were mentioned briefly in the Street, Drainage and Building Act 1974 Earthworks (Perbadanan Putrajaya) By Laws 1996, a new By Law entitled 'Erosion and Sediment Control By Law' is recommended for Perbadanan Putrajaya and the Local Authorities within Putrajaya Lake Catchment Area as it is the most effective way in implementing and enforcing erosion and sediment control.

(2) Among key features of an effective erosion and sediment control By Laws are the following:

i. Since erosion and sedimentation control will be directly affecting the wetland and lake, persons or contractor that involved in the earthworks must be informed that maintaining water quality in the lake is the paramount objectives and must be maintained at required level. The By Laws will provides a legal basis for Perbadanan to prosecute the offender if water pollution occurs due to their negligence.

ii. All earthworks that may result in a significant erosion and sedimentation should require permit or approval. Other activities involving very minor earthwork may be exempted.

iii. Temporary and permanent erosion and sediment control plan must be submitted for approval. This provision is the most important and provide strong enforcement tools. The consultant or contractor must specify the erosion and sediment control measures for approval by Putrajaya.

iv. Provision should include timetables for regular reporting, site inspection and schedules when the consultant or contractor will start the earthworks. This will enable

Perbadanan to make necessary arrangement to inspect and monitor the progress of the works.

v. Perbadanan also may require modification of an erosion and sedimentation control plan when they feel that such plan is not adequate or ineffective. This provision will provide legal basis for requiring plan changes after initial plan approval.

vi. Strong enforcement should be made available to Perbadanan. A sequence of progressive provisions, such as suspension or revocation of permit, fine and imprisonment should be included in the by-law. The penalties must be severe enough for the offender to comply to the By Laws.

vii. Contractor is required to provide security in the form of deposit or performance bond to finance the remedial works in case the works is not satisfactory and need repair.

(3) There are many other provision that can be incorporated in the By Laws to make it more effective. However, enforcement also played the key part to ensure that erosion and sediment control measures can be implemented successfully. Even though there are punitive provision in the By Laws, using them meant that implementation of the project plans has been unsuccessful. There were many stages before actual action can be taken against the contractors.

3.2.10.2 Standards for Erosion and Sediment Control

(1) It is recommended that a ‘Standards for Erosion and Sediment Control’ detailing design and specifications for erosion and sediment control works and plan be developed to support the ‘Erosion and Sediment Control By Law’.

(2) Developers and engineers involved in earthworks need to comply with the ‘Standards for Erosion and Sediment Control’ in order for their Erosion and Sediment Control Plan submission (which is mandatory under the new By Law) to be approved by the Perbadanan Putrajaya and other Local Authorities within the Putrajaya Lake Catchment.

3.3 GEOLOGICAL/HYDROGEOLOGICAL STUDY

3.3.1 Introduction

3.3.1.1 The groundwater recharge into and seepage loss from the Putrajaya Lake system is an important management issue, related to the water quantity in the Lake.

3.3.1.2 Also an understanding of the groundwater flow regime is essential for the management of non-point sources pollutant entry into the Lake system through infiltration and groundwater seepage.

3.3.1.3 An adequate understanding of the geological and hydrological setting in the catchment is essential for the identification of any potential problems related to the above issues and for the formulation of appropriate management strategies to address them.

3.3.2 The Geological Setting

3.3.2.1 The catchment area has an undulating topography with low hills rising up to over 100m above sea level.

3.3.2.2 The geology of the catchment is found in the Geological Survey of Malaysia (GSM) report entitled *"Geologi dan Sumber Mineral Kawasan Sepang-Telok Datok, Selangor"* by Abdullah Sani bin Hashim (in manuscript).

3.3.2.3 Figure 3.3.1 shows the geological structures and distribution of the rock formation in the catchment.

3.3.2.4 Rock Formation

(1) The following geological formations are present and outcrop within the catchment area.

- Quaternary - River Alluvium
- Carboniferous-Permian - Kenny Hill Formation
- Silurian - Hawthornden Formation

(2) The alluviums are found in the flat and low-lying areas in the Central and Southern part of the catchment. They overlie the Hawthornden and Kenny Hill Formations. The thickest

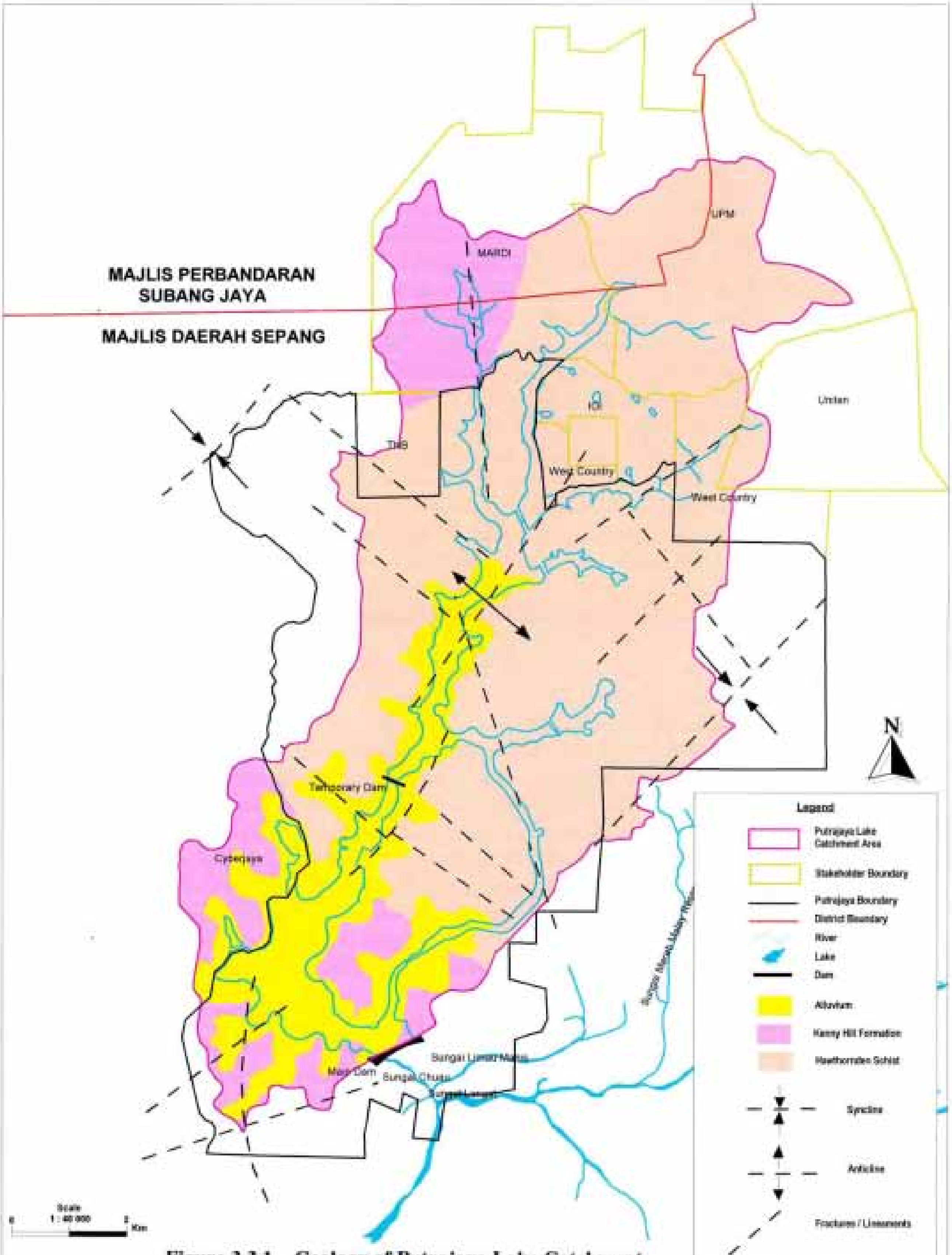


Figure 3.3.1 Geology of Putrajaya Lake Catchment

sequence is developed along the plains and the lower reaches of the Sungai Chuau and Sungai Limau Manis, and their tributaries.

(3) The Kenny Hill Formation is found in the West and Northwest and consists of sandstone and shale which have undergone some degree of regional metamorphism.

(4) The Hawthornden Formation occupies about 70% of the area. This unit is made up of metamorphosed rocks i.e. quartz-mica schist, quartz schist and graphitic schist. This Formation is the oldest rock unit outcropping in the catchment area.

3.3.2.5 Structure

(1) From aerial photographs and satellite imagery analysis studies conducted by the GSM, the geological environment in and around the catchment is regionally folded along the NE-SW axis resulting in the development of broad anticlines and synclines. Within the study area an anticline is demarcated to run along Sungai Chuau.

(2) In addition to the folding, the tectonic movement has also resulted in fracturing and the development of joints in the incompetent metamorphosed rocks. Major fractures and joints seen as lineaments can be pick up in the aerial photographs. In the study the presence of 3 sets of lineaments trending NNE-SSW, NW-SE and NE-SW have been recognised.

3.3.3 The Hydrogeological Setting

3.3.3.1 In any catchment area groundwater is a component of the total water resources available from rainfall. This is illustrated in Figure 3.3.2, which gives a schematic diagram of the hydrological flow components in a catchment. Part of the rain that falls onto the ground moves as surface runoff into the rivers and streams. However, a certain portion enters the subsurface through infiltration. The infiltrated water then moves downwards through the unsaturated zone under the action of gravity and through the saturated zone in a direction determined by the surrounding hydraulic situation. They will subsequently emerge from the ground as discharges into surface bodies such as streams, rivers and lakes.

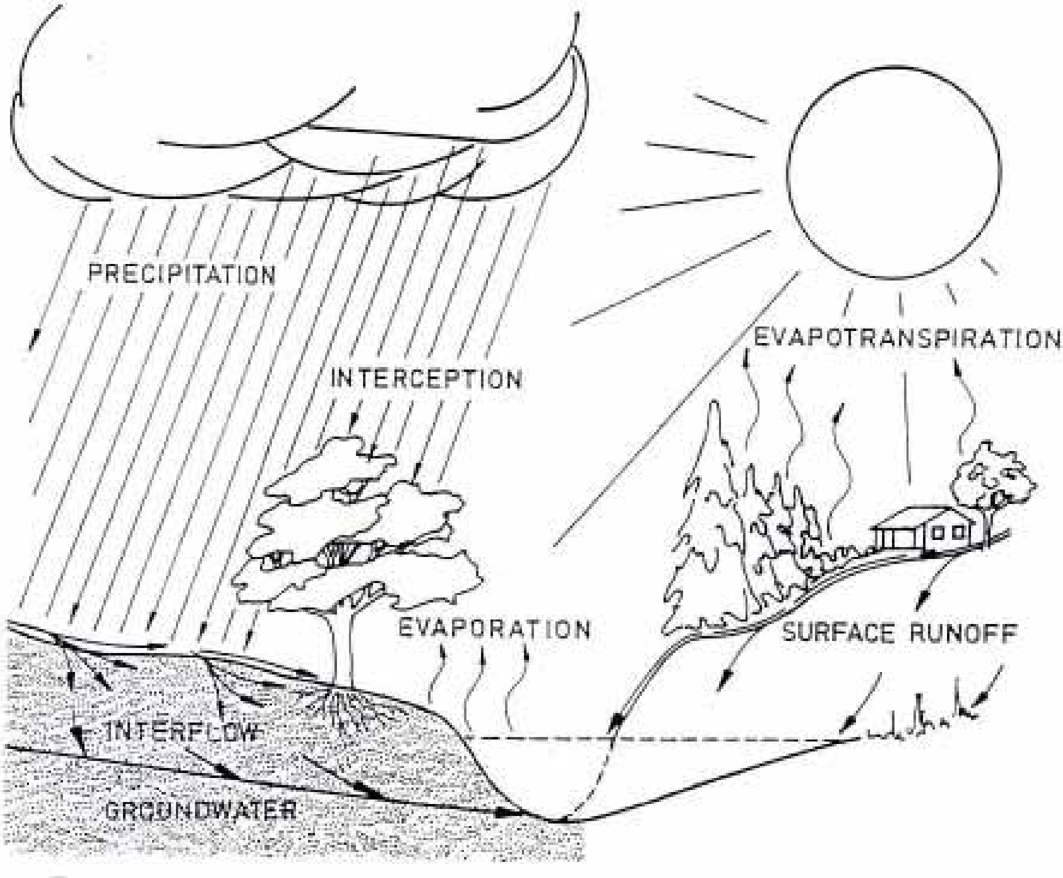


Figure 3.3.2 Hydrological Cycle

3.3.3.2 For the study area the groundwater catchment basin is similar in shape and size to that which has been established for the surface water catchment, and is the area demarcated by the basin's watershed boundary.

3.3.3.3 The regional groundwater flow system within the basin will register flow directions towards the low-lying areas i.e. the valleys, rivers, streams and lakes. This has been confirmed by the GSM through their analysis of the levels in the groundwater piezometric heads recorded in the tube wells carried out during their investigation for groundwater in the Perang Besar area.

3.3.3.4 The GSM report on the groundwater investigation for Perang Besar also discussed the aquifer systems in the Sungai Chuau catchment. Aquifers are found in the Kenny Hill and Hawthornden Formations. They are also found in the alluvium.

3.3.3.1 Aquifer in the Kenny Hill and Hawthornden Formations

(1) The Kenny Hill and the Hawthornden have suffered regional metamorphism and are dense and indurated. The primary porosity of the rocks in these formations is low and not significant. Water bearing zones, commonly described as hard rock aquifer, are related to secondary features such as joints and fractures. Joints and fractures increase the storage capacity and facilitate greater mobility of groundwater. The azimuth and distribution of the major joints and fractures are shown in Figure 3.3.1.

(2) Some characteristics of the hard rock aquifer in the Sungai Chuau catchment are recorded from 2 well localities as indicated in Figure 3.3.3.

(3) In the area previously occupied by Perang Besar Estate, located in the central part of the basin, two wells were constructed by Pacific Industrial & Mining and Drilco Sendirian Berhad. The wells, TWC-1 and TWC-2, built to reach depths of 137 meters and 53 meters, respectively gave an optimum yield of 16 cubic meters/hour/well (3520 gallons/hour/well). It was noted that the initial discharge rate was higher, 22 cubic meters/hour/well (4840 gallons/hour/well), indicating that the fracture system is local in extent and the aquifer is restrictive and irregular in size.

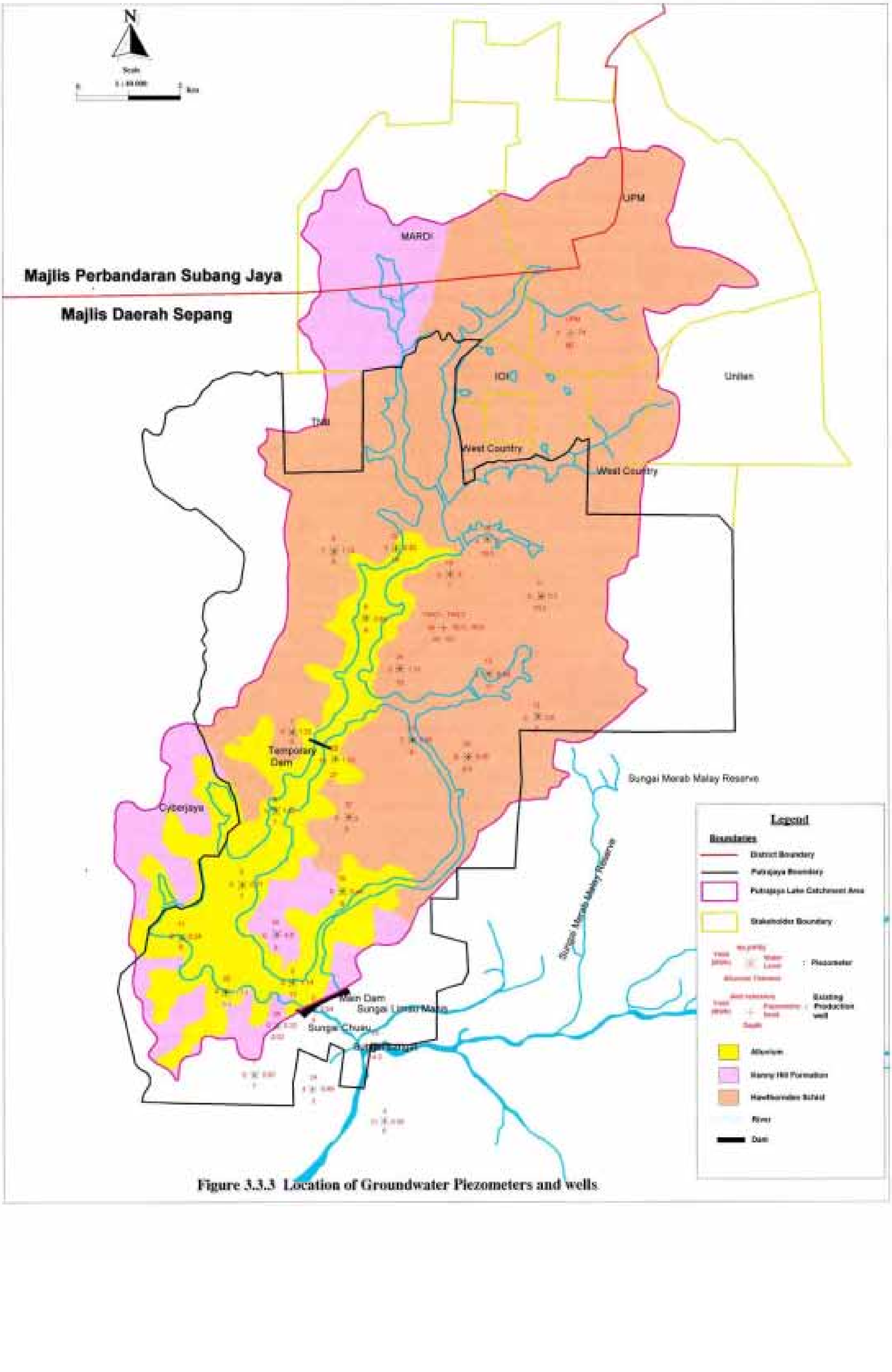


Figure 3.3.3 Location of Groundwater Piezometers and wells

(4) At the UPM, located in the North-Western end of the catchment, one well (UPM) was constructed by Soilmec and Drill Equip Supply Company close to the Sungai Chuau. The well reaches a depth of 60 metres and intercepted a fractured zone between 42 metres to 54 metres below ground surface in the metamorphic rocks. Again the optimum yield computed is lower than the initial discharge, 6 cubic meters/hour (1320 gallons/hour) and 7 cubic meters/hour (1540 gallons/hour), respectively confirming that the aquifer system in the hard rock is local in extent.

3.3.3.2 Aquifer in the Alluvium

(1) The groundwater potential of the Alluvium in the catchment has been investigated by the GSM (Nazan et al., 1994). Table 3.3.1 gives the results of the yield from the 27 piezometers and wells constructed in the Alluvium. The Alluvium was found to comprise of clay, sand, fine gravel, silt and peat and varies from 4 to 14.3 metres in thickness. Bore hole records show that coarse sediments (aquifer zone) of sand and gravel generally form the lower layers while finer components of clay and silt constitute the upper parts. Sand and gravel layers are thicker closer to the river, particularly along the flood plains and near the lower reaches of Sungai Chuau, and peat layers were recorded in several bore holes and vary in thickness from 20 cm to 213 cm. The lithologic logs for HPB 4, 8, and 10 (see Figures 3.3.4, 3.3.5 & 3.3.6) give an insight on the geologic profile of the Alluvium in areas where aquifer is present. Wells sunk in these layers give yields up to 6.8 cubic meters/hour (1500 gallons/hour).

(2) Pumping test analysis conducted by the GSM shows the Transmissivity (T) and storage coefficient (S) of the Alluvium aquifer range from 84 to 163 m^2/day and $4.8x10^{-4}$ to $4.9x10^{-3}$, respectively.

3.3.3.3 Groundwater Quality

(1) Groundwater samples analysed by the GSM show that the pH of the water in the Alluvium ranges from 6.1 – 7.1. The water in the hard rock is slightly more alkaline. TWC-1 gives a pH value of 7.3 while a figure of 7.2 is recorded in the UPM well. The hard rock water is higher in bicarbonate and hence low in iron content, whereas the Alluvium water is lower in bicarbonate and accordingly higher in iron content.

Table 3.3.1 Hydrologeological information from piezometers and wells

Ref.No (HPB)	Depth (m)	Alluvium thickness (m)	Water level (m). (B.G.L)*	Yield (m^3/hour)
1	6	6	0.91	0
2	6	4	2.54	7
3	12	12	1.14	0
4	6	8	0.09	11
5	7	6	0.71	3
6	7	6	1.52	11
7	6	8	1.22	0
8	6	6	0.84	7
9	6	6	1.12	1
10	6	6	0.57	5
11	6	6	0.34	6
12	6	6	0.90	0
13	6	7	6.94	0
14	6	7	3.0	0
15	6	14.3	0.70	6
16	6	9	4.80	4.8
17	6	10.5	5.5	0
18	6	19.2	3.0	4
19	6	8	3.44	0
20	6	6.5	1.14	0
21	8	12	7.17	0
22	6	18.45	0.93	1
23	6	6.5	0.45	0
24	6	12.0	0.89	4
25	6	9	1.52	10
26	3	3.02	0.32	0
27	6	9	3.0	0
TWC 1	137	-	15.3	16
TWC 2	53	-	10.5	16
UPM	60	-	7.4	7

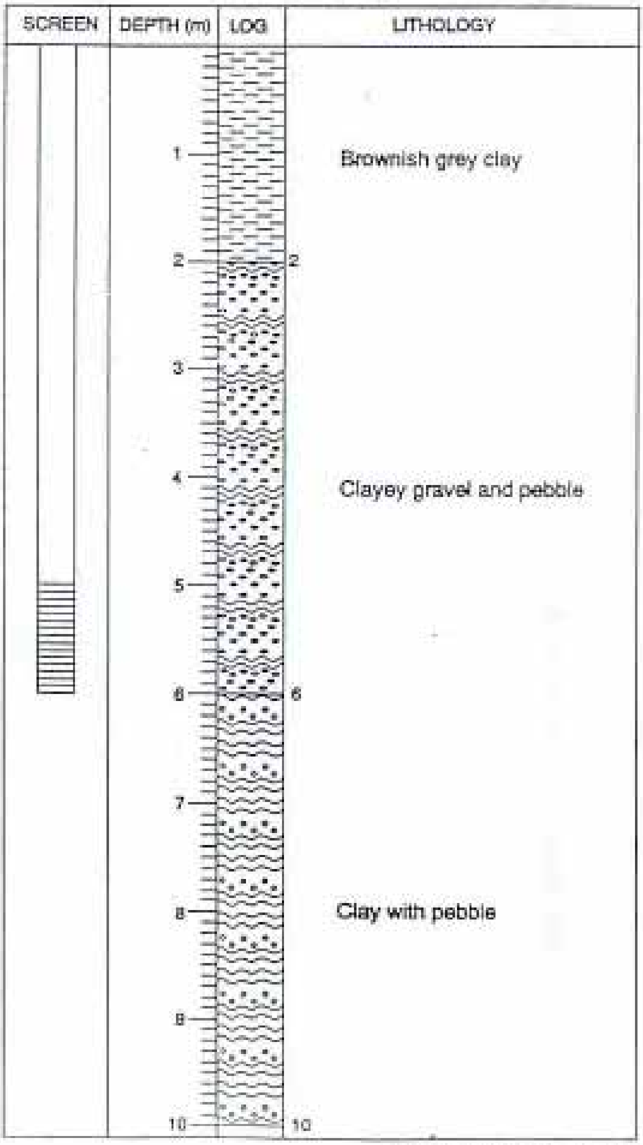
Mohd. Nazan et al 1994

Note: B.G.L: Below Ground Level

Figure 3.3.4 Geological Profile of HPB 4

No. HPB 4	Location : PERANG BESAR
Elevation : 12.21m	X= 4108 Y= 3195
Method of Drilling : Straight Flushing	
Drilling Date : 23. 4. 94	
Total Depth : 10.00m	
Comments : Piezometer diameter 40mm. Good aquifer for shallow well.	

WELL LOG



Date : 23. 4. 94
Capacity : 6.8m³ /hour
Duration : 360 minutes
Transmissivity : 93m²/day
Method : Theis
Storage Coefficient : 0.00049
Static water level : 0.09m
Drawdown : 0.69m

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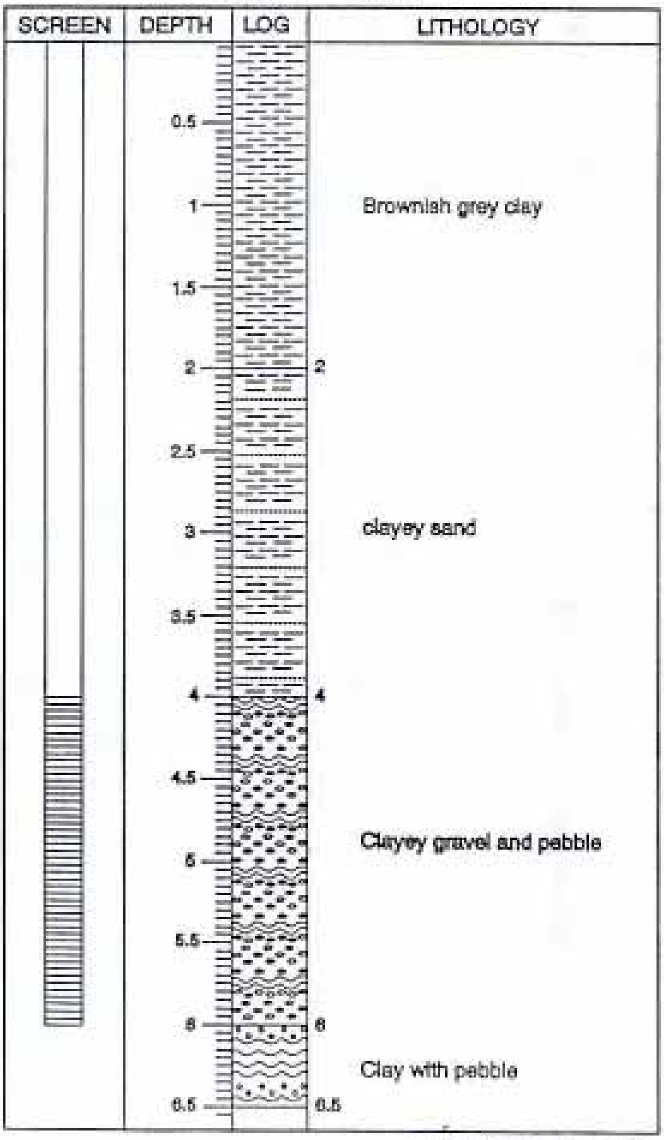
Figure 3.3.5 Geological Profile of HPB 8

No. HPB 8	Location : PERANG BESAR
Elevation : 11.32m	X = 4103 Y= 3258
Method of Drilling : Straight Flushing	
Drilling Date : 23. 4. 94	
Total Depth : 6.50m	
Comments : Piezometer diameter 40mm. Good aquifer for shallow well.	

WELL LOG



Date : 23. 4. 94
Capacity : 6.8m³/hour
Static water level : 0.84m

No pumping test

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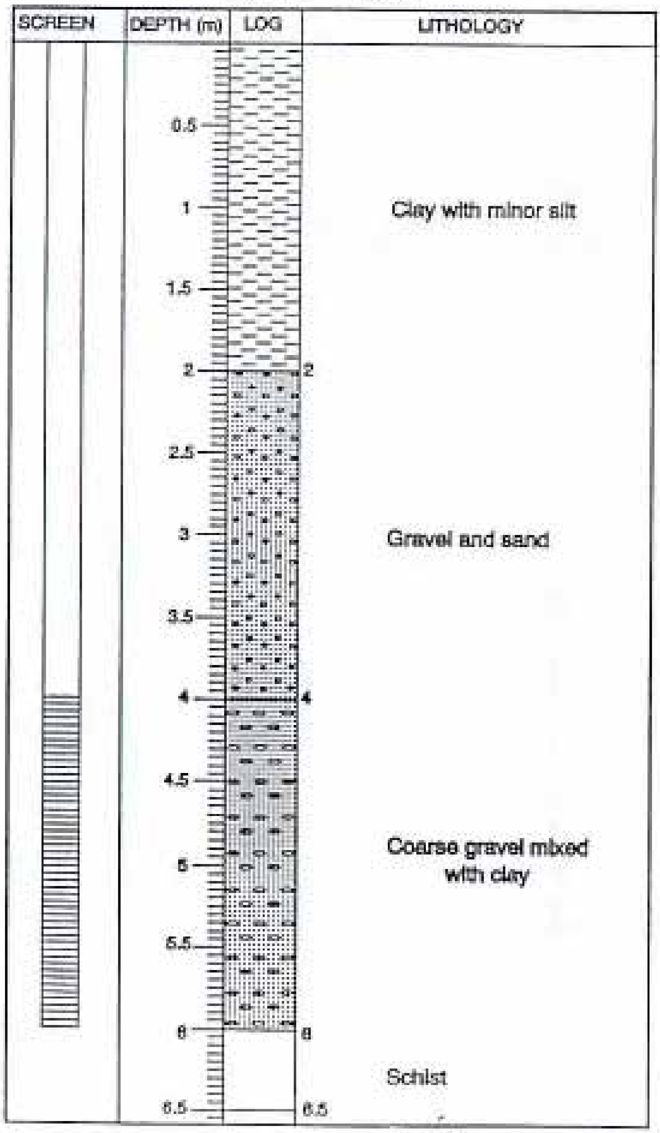
Figure 3.3.6 Geological Profile of HPB 10

No. HPB 10	Location : PERANG BESAR
Elevation : 13.91m	X = 4103 Y = 3258
Method of Drilling : Straight Flushing	
Drilling Date : 23. 4. 94	
Total Depth : 6.50m	
Comments : Piezometer in alluvium overlying the Hawthornden Schist. Diameter 40mm. Yield is not good.	

WELL LOG



Date : 25. 4. 94
Capacity : 5.5m³/hour
Duration : 300 minutes
Transmissivity : 156m²/day
Method : Theis
Storage Coefficient : 0.0005
Static water level : 0.52m
Drawdown : 0.40m

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(2) Nitrate, sulphate and ammonia are low in all the samples. *This suggests that the groundwater was relatively unpolluted at the time of the investigation*. It is also noted that the water samples registered only trace amounts of heavy metals.

(3) Table 3.3.2 gives the chemistry of the groundwater in area. The data in the table constitutes an important base line reference on the quality of the groundwater in the catchment.

3.3.4 Water Quantity Management Issues

Two water quantity management issues, related to the hydrogeology of the catchment, have been identified. They are:

- Groundwater recharge to the Lake
- Groundwater seepage losses from the Lake

3.3.4.1 Groundwater recharge to the Lake

(1) Other than the emergence of infiltration water to streams which subsequently discharged into the Lake, the geological and hydrogeological setting of the Sungai Chuau catchment reveals no other natural contribution of water, such as the presence of artesian water from the subsurface. However, through artificial means, using mechanical pumping, groundwater from the Alluvium aquifer can be abstracted for use as an emergency contingency during periods of prolonged drought, even though the quantity may not be very large.

(2) To avoid disturbing the hydrological regime of the Lake the location of the wells are to be located down stream to the Lake. It is proposed that a well field consisting of 6 wells designed for a total of ½ cusec (10,000g/hour) be built for the above purpose. The proposed well design is shown in Figure 3.3.7. If approved the wells are to be constructed after the dam and lake has been completed.

(3) It is anticipated that since the volume of water abstracted is small, there will be little or no implication on downstream water quantity. In addition, it is pertinent to note that this volume is less than the designed seepage of the dam (see Section 3.3.4.2 (c))

Table 3.3.2 Chemistry of Groundwater in the Sungai Chuau Basin

Sample No.		HPB 4	HPB 5	HPB 6	HPB 8	HPB 10	HPB 11	HPB 12	HPB 20	HPB 25	TWC 1	UPM	WHO (1984)
Parameter													
Ca	ppm	7.5	5.4	5.5	3.0	2.0	1.1	3.2	3.2	8.5	24	51	-
Mg	ppm	0.8	1.4	1.4	1.4	0.6	0.5	1.6	1.5	2.7	4.6	3.8	-
Na	ppm	2.0	26	24	7.6	23	25	6.4	8.2	6.4	27	6.1	200
K	ppm	0.9	2.1	1.6	1.6	1.7	1.7	1.4	1.4	0.9	2.2	2.4	-
CO3	ppm	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
HCO3	ppm	22	79	59	37	60	62	40	37	65	166	170	-
Cl	ppm	6	7	2	2	2	2	2	1	2	2	6	200
SO4	ppm	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	5.00	400
NO3	ppm	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
NO2	ppm	<0.005	0.170	0.205	0.010	0.120	0.109	<0.005	<0.005	<0.005	<0.005	<0.005	-
NH3	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-
NH4	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-
F	ppm	<0.5	4.4	4.0	<0.5	4.1	4.2	<0.5	<0.5	<0.5	3.1	<0.5	-
P	ppm	0.03	0.93	0.15	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1.5
As	ppm	<0.005	<0.005	0.009	0.010	0.009	0.011	<0.005	0.005	0.006	<0.005	<0.005	0.05
Al	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	-
Fe	ppm	<0.1	7.2	7.3	2.4	5.4	<0.1	10	9.9	8.8	0.8	<0.1	0.3
Mn	ppm	<0.1	0.2	0.2	0.2	0.2	<0.1	0.2	0.2	0.2	0.1	<0.1	0.1
Cu	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Pb	ppm	<0.01	<0.01	0.04	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Zn	ppm	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1	<0.1	-
Co	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
No	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Ni	ppm	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Cd	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Sr	ppm	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Ba	ppm	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Se	ppm	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-
B	ppm	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	-
Cr	ppm	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	-
Hg	ppb	0.2	2.7	<0.2	<0.2	<0.2	<0.2	1.0	<0.2	1.1	<0.2	<0.2	-
pH		6.1	7.0	6.9	6.4	7.1	7.0	6.1	6.1	6.7	7.3	7.2	6.8 - 9.2
Colour	H.U.	5	5	15	5	10	5	5	5	5	10	5	5
Turb.	N.T.U.	<1	246	292	3.4	259	244	2.4	1.6	7.4	<1	214	5
Cond.	umhos/cm	63	172	115	69	120	123	69	68	107	270	250	-
SiO2	ppm	11	15	16	8.9	16	15	11	9.3	28	56	24	-
Total Solid	ppm	96	598	736	88	652	766	70	108	150	222	230	-
Diss. Solid	ppm	54	132	108	70	100	106	62	64	100	208	210	-
Hardness	ppm	22	19	20	13	7.5	4.8	15	14	32	79	143	-

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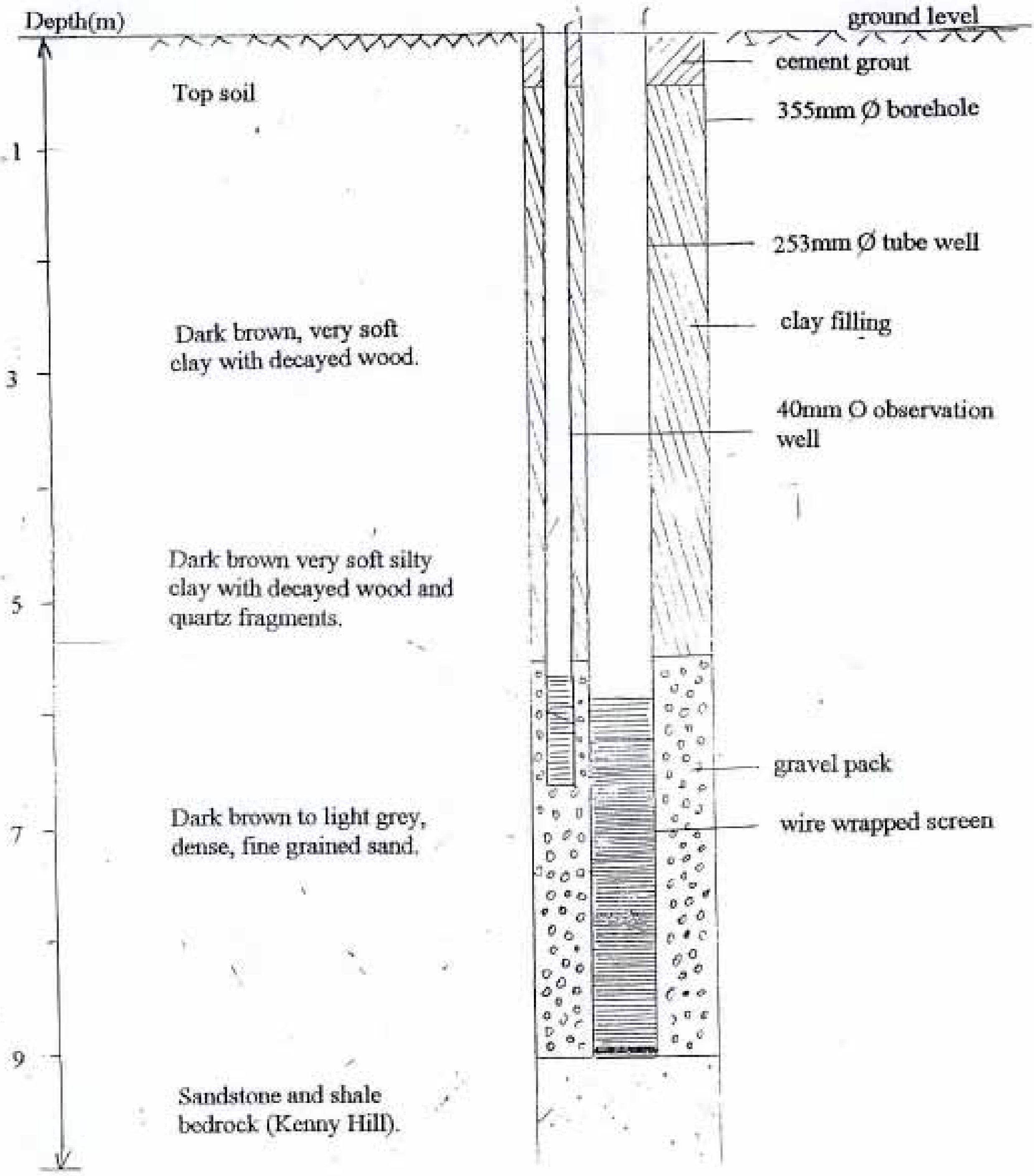
Notes : Values for all parameters are in parts per million (ppm),
except for pH, turbidity in Nephelometric Colour Units (N.T.U.),
colour in Hazen Unit (H.U.), conductivity in umhos/cm and
Hg in parts per billion (ppb)
Turb. = Turbidity.
Cond. = Conductivity.
Diss. = Dissolved.

Figure 3.3.7 Proposed Well Design



3.3.4.2 Groundwater seepage losses from the Lake

The geological and hydrogeological setting of the basin presents three possible situations for water seepage losses. They are:

- Losses through the hard rock
- Losses through the peat layers
- Losses through the Alluvium aquifer

(1) Losses through the hard rock

Although the catchment is resting on top of an anticline and is criss-crossed by 3 sets of fracture lineaments, water loss through the bedrock is not expected to be large. This is because the primary porosity and permeability of the metamorphosed Hawthornden schist and the Kenny Hill are low and water movement is confined along joints and fractured zones. Evaluation of wells constructed in these zones indicated that these joints and fracture systems are localised and lack regional connection.

In addition, the residual soil developed over the Hawthornden Schist and the Kenny Hill are 3 to 8m and 5 to 10m in thickness, respectively.

The soil are described as:

Hawthornden Schist: Yellowish red to red sandy to silty clay with subordinate amount of fine lateritic gravels. Consistency varies from soft to stiff.

Kenny Hill: Yellowish brown to red soft to stiff clayey silt/sand with subordinate amounts of lateritic sand, gravel and iron concretions.

The estimated coefficient of permeability of the residual soil is 10^{-8} m/sec and thus movement of groundwater through the above soils is low.

(2) Losses through the peat layers

Within the catchment, peat is found only in the Alluvium and is located on lower grounds. In the area occupied by Cyberjaya, the peat layers outside the catchment are not connected with the peat inside the catchment. Thus, there is no hydraulic conductivity between them. No groundwater is expected to flow out of the catchment at the South-Eastern edge.

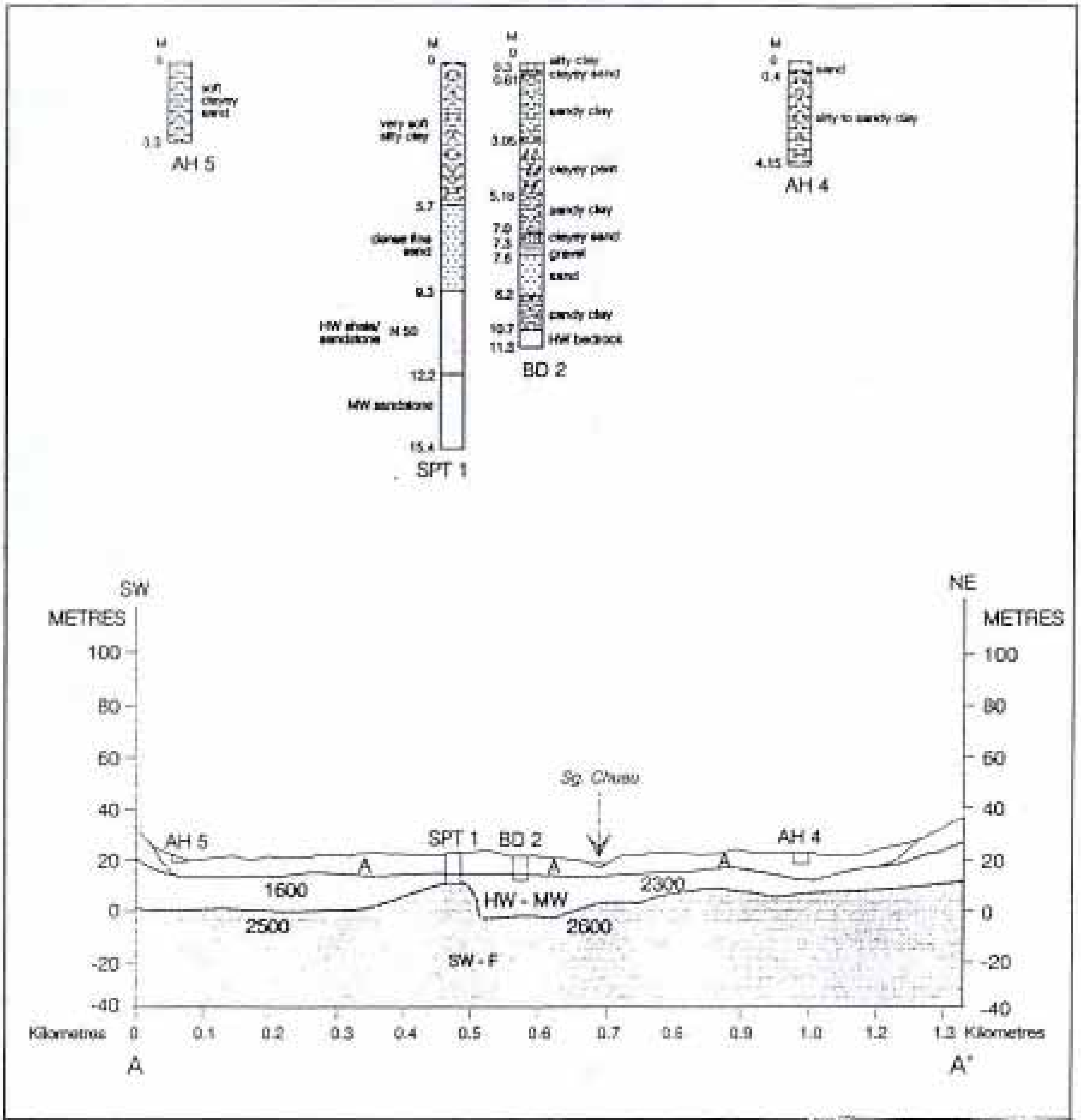
However, peat is found in the Alluvium in the proposed site of the main dam in the South and it is anticipated that water in the Lake can be lost there through the peat layers. Angkasa GHD Engineers Sdn. Bhd., the consultant for the design and construction of the dam has taken cognisance of the situation and it is noted in their report that in the construction of the dam all clay and peat layers are to be removed.

(3) Losses through the Alluvium aquifer

The nature of the alluvium at the lower reaches of Sungai Chuau is illustrated in the geological cross section (Figure 3.3.8) across the proposed dam site. Bore log SPT1 shows an upper most sequence of silty to sandy clay with decayed wood of about 5.7m thick. Beneath the clay is a 3.3m aquifer layer of fine-grained sand. The borehole bottomed on sandstone with interbeds of shale of the Kenny Hill Formation. Water loss through the alluvium aquifer may be an issue here. Angkasa GHD Engineer Sdn. Bhd. has taken note of this and has stated in their report that all sandy and pervious foundation materials are to be removed. The dam is to be embedded 1000mm into the residual soil (grade-4 rock material) with a designed seepage of not more than 100m3 per day through the dam and its foundation.

The Alluvium at the locality where the flow of the upper reaches of Sungai Limau Manis is diverted towards the Putrajaya area comprises 2m of sandy clay. No distinct aquifer is present. As such water loss through the Alluvium here may not be significant.

Figure 3.3.8 Geological Cross-section at Proposed Main Dam site



(After Chow,W.S. 1994)

LEGEND

Clay	AH	-	Auger hole
Silt	BD	-	Banka drillhole
Peat	SPT	-	Standard Penetration test-hole
Sand	A	-	Alluvium
Gravel	RS - CW	-	Residual soil-completely weathered
Bedrock	HW - MW	-	Highly to moderately weathered
	SW - F	-	Slightly weathered to fresh bedrock
	2000	-	Projected seismic velocity in metres per second

3.4 REFERENCES

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