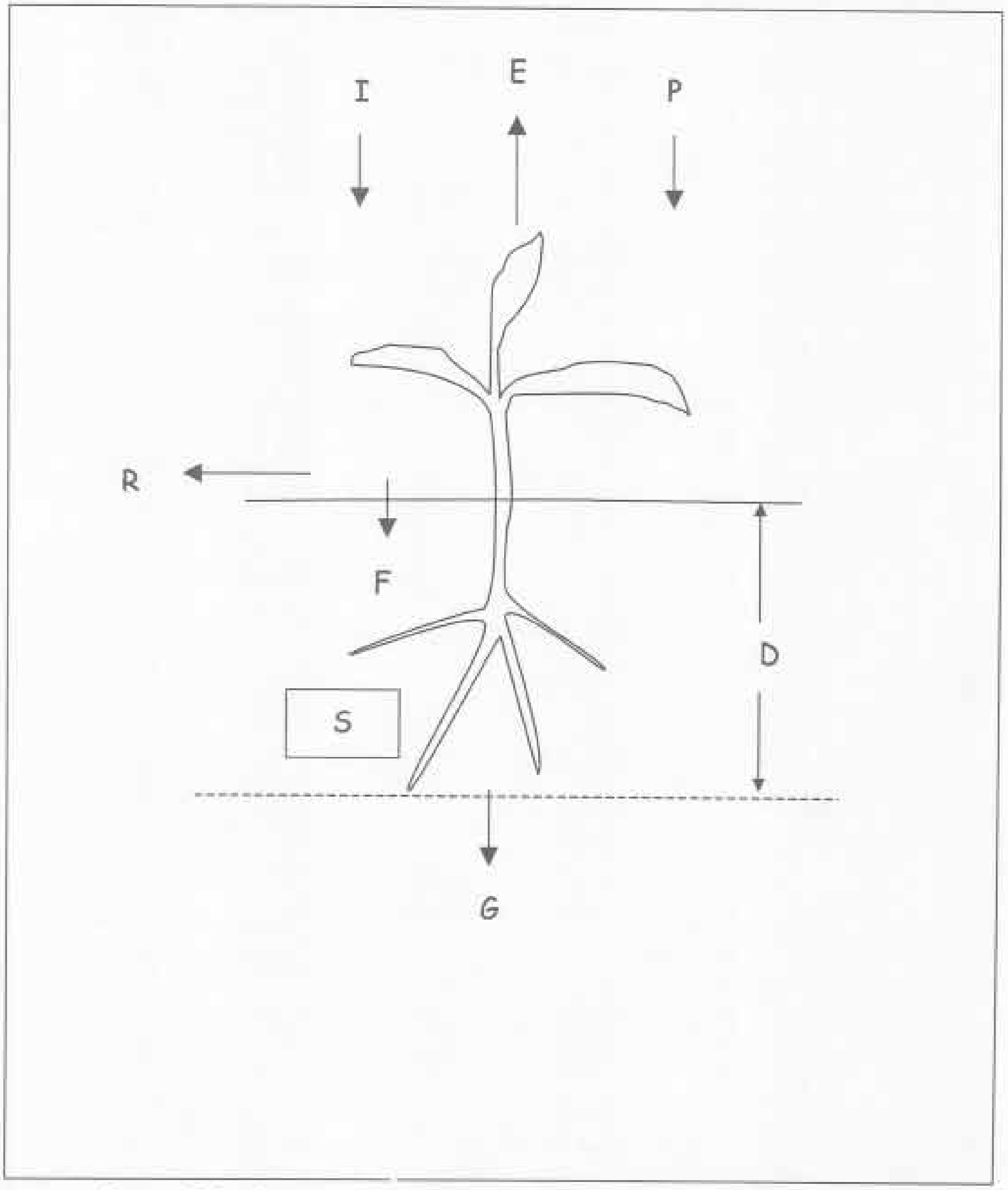
10.6 SOIL MOISTURE WATER BALANCE MODEL

The soil-plant-water relationship for an irrigation unit is as follows:



I	Irrigation	S	Soil moisture
P	Precipitation	G	Percolation to groundwater
E	Evapotranspiration	D	Root depth
R	Surface runoff	F	infiltration

Fig 10.4 Soil-Plant-Water Relationship

The figure above shows the various components of the soil moisture water balance model at time period I and the general water balance equation is as follows:

$$S_i = S_{i-1} + F_i - E_i - G_i \qquad \text{.......................} \ (10.3)$$

The unit time period commonly adopted is one day.

The infiltration Fi is given by:

$$Fi = Pi + Ii$$

$$\text{If } Fi > Fmax \text{ then } Fi = Fmax \qquad \text{....................} \ (10.4)$$

The surface runoff is therefore:

$$Ri = Pi + Ii - Fi \qquad \text{....................} \ (10.5)$$

Gi the percolation into the groundwater is computed by:

$$Gi = Si\text{-}1 + Fi - Ei - FC$$

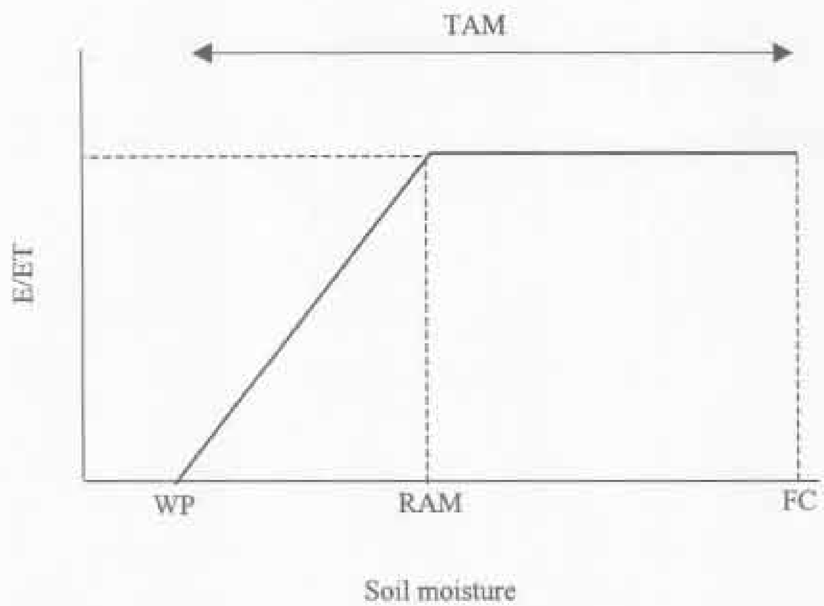
$$\text{If } Gi < 0 \text{ then } Gi = 0 \qquad \text{.......................} \ (10.6)$$

Ei the evapotranspiration depends on several factors namely:

- The type of plant and its stage of growth and correspondingly its crop coefficient Kc
- The reference crop evapotranspiration Eto which has to be computed from climate data or obtained by multiplying the pan evaporation by a factor.
- The soil moisture availability.

  - If Si-1 > RAM (readily available soil moisture) then

    Ei = Kc X Eto



Where E = actual evapotranspiration and

ET = Kc X Eto

Fig 10.5 : Actual Evaporation – Soil Moisture Relation

Actual planting schedule and crop variety

The consumptive use of water depends on the crop coefficient Kc which varies according to the type of plants and the stage of plant growth. The stage of plant growth would vary from place to place. To be able to compute consumptive use of water at each irrigation area, it would be necessary to know the planting schedule and the area planted. Kc of trees, palms and ground covers would stabilized after a few years when the plants matured. Kc will continue to vary for annuals, but if the proportion of such plants are small, it may be more practical to assign a higher fixed KC values for annuals.

10.7 IRRIGATION DECISION SUPPORT SYSTEM

The DSS will comprise soil water balance models configured for various irrigated public realm areas in Putrajaya. Water balance computations will indicate the water requirements of the various areas and accordingly the water supply required. With a properly configured DSS irrigation will be to a large extent demand driven and water allocation can be optimized. It is envisage that optimal management of water supply could only be arrived at after various trial runs of the decision support system as there are many parameters in the system that could not be accurately estimated in the proposed model. The model will eventually be more realistic as feedback from SCADA system is compared to model output and parameters adjusted accordingly.

A soil-plant-water model such as described above will be conceptualized for water balance modelling. Irrigation will be controlled by the activation of pumps. Therefore irrigated areas modeled will be divided according to areas under the command of each pump. There is a need to cater for areal variation of rainfall, areal variation of plant types, soil type, etc.

At the master station in PPJ, the irrigation manager can query each telemetric rainfall stations to obtain rainfall that occurred since the last query. The rainfall over each area will be computed based on the Thiessen polygon method.

Supply of irrigation water to each area will be computed from real-time monitoring of discharge through metered pipelines

The DSS will have a graphical user interface that supports point and click functions making it easy for the user to navigate through the data entry, water balance modelling and model updating processes. The various steps in the DSS can be presented in the form of tables and flow charts.

For water balance computations the scheme will be divided into target irrigated areas. For each target irrigated areas there will be a need to specify the parameters tabulated below:

Target Irrigated Area		**Area**	**Plant**		**Soil**				**Irrigation**		
		(m2)	**Kc**	**RD mm**	**FC mm/m**	**TAM mm/m**	**RAM mm/m**	**FM mm/hr**	**Priority**	**IR mm/hr**	**Ef**
pl-1a	Taman Botani	31,175	1.1	500	230	140	70	5	1	3	0.8
pl-1b	Oval Road	270	1.1	500	230	140	70	5		3	0.8
pl-2	Taman Putra Perdana	34,036	1.1	500	230	140	70	5	1	3	0.8
pl-3a	Dataran Putra	2,362	1.1	500	230	140	70	5	1	3	0.8

pl-3b	Perdana Walk	1,218	1.1	500	230	140	70	5	1	3	0.8
pl-3c	Promenade	8,894	1.1	500	230	140	70	5	1	3	0.8
pl-3d	Putra Bridge	960	1.1	500	230	140	70	5	1	3	0.8
pl-3e	Linear Park 1	4,300	1.1	500	230	140	70	5	1	3	0.8
pl-4a	Linear Park 2	4,500	1.1	500	230	140	70	5	1	3	0.8
pl-4b	Parcel A, B	22,000	1.1	500	230	140	70	5	1	3	0.8
pl-4c	Oval Road	180	1.1	500	230	140	70	5	1	3	0.8
pl-5a	Linear Park 3,4	9,072	1.1	500	230	140	70	5	1	3	0.8
pl-5b	Parcel C,D	20,000	1.1	500	230	140	70	5	1	3	0.8
pl-5c	Oval Road	200	1.1	500	230	140	70	5	1	3	0.8
pl-6a	Linear Park 5	4,536	1.1	500	230	140	70	5	1	3	0.8
pl-6b	Parcel E,F,G	29,000	1.1	500	230	140	70	5	1	3	0.8
pl-6c	Oval Road	160	1.1	500	230	140	70	5	1	3	0.8
pl-7	Plant nursery	669	1.1	500	230	140	70	5	1	3	0.8
pl-8	Istana Hinggap	7,448	1.1	500	230	140	70	5	1	3	0.8
pl-9	Government Reserve 1	2,947	1.1	500	230	140	70	5	2	3	0.8
pl-10	Local Distributor D2	3240	1.1	500	230	140	70	5	2	3	0.8
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.

•	•	•	•	•	•	•	•	•	•	•	•
p7-1	Promenade	1046.4	1.1	500	230	140	70	5	2	3	0.8
t7-1	Primary distributor D3	1701	1.1	500	230	140	70	5	3	3	0.8
t7-2	Secondary distributor D3	2727	1.1	500	230	140	70	5	3	3	0.8
t7-3	Local distributor D3	756	1.1	500	230	140	70	5	3	3	0.8
t7-4	U2 spine road	3240	1.1	500	230	140	70	5	3	3	0.8
•	•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•	•
p19-1	Taman Lindungan	9,974	1.1	500	230	140	70	5	2	3	0.8
p19-2	Buffers	3,120	1.1	500	230	140	70	5	3	3	0.8
p19-3	Neighborhood Park	41	1.1	500	230	140	70	5	3	3	0.8
p19-4	Promenade	7,416	1.1	500	230	140	70	5	2	3	0.8
p19-5a	Educational facility	5,041	1.1	500	230	140	70	5	2	3	0.8
p19-5b	Health	955	1.1	500	230	140	70	5	2	3	0.8
p19-5c	Public amenity facilities	1,447	1.1	500	230	140	70	5	2	3	0.8
p19-5d	Public utility facilities	43,176	1.1	500	230	140	70	5	2	3	0.8

p19-6	Plant nursery (allocation)	669	1.1	500	230	140	70	5	1	3	0.8
p19-7	Primary distributor Jln Lingkaran Bandar	2,592	1.1	500	230	140	70	5	2	3	0.8
p19-8	Secondary distributor D3 road	8,208	1.1	500	230	140	70	5	3	3	0.8

Where

Kc	Crop coefficient	TAM	Total available moisture
WP	Wilting point	RAM	Readily available moisture
RD	Root depth	FM	Infiltration rate
L1	Soil moisture limit, triggering irrigation	L2	Irrigate to this level of soil moisture
Ef	Irrigation efficiency	IR	Irrigation rate

The SCADA system will receive rainfall data regularly at preset intervals from the proposed telemetric rainfall stations. These data will need to be converted to areal rainfall for each of the Precincts..

To convert observed point rainfall to areal rainfall a matrix of Thiessen weights will have to be set up.

Matrix of Thiessen Wts

Rain Stn \ Area	Precinct							
	1	2	.	.	.			20
PR1								
PR2								
PR3								
PR4.								
PR5								

Areal rainfall {AR1, AR2, AR3,…….AR20} is computed by multiplying
the recorded rainfall {PR1, PR2,.... PR5} with the matrix of Thiessen weights as shown below.

$$\begin{pmatrix} AR1 \\ AR2 \\ AR3 \\ . \\ . \\ . \\ AR20 \end{pmatrix} \begin{pmatrix} 0.0 & 0.0 & 0.3 & \ldots & 0.0 \\ 0.0 & & & & \\ 0.0 & & & & \\ 0.2 & \text{Matrix of} & & & \\ . & \text{Thiessen Wts} & & & \\ . & & & & \\ 0.0 & & & & \end{pmatrix} \begin{pmatrix} PR1 \\ PR2 \\ . \\ . \\ . \\ PR5 \end{pmatrix} \quad .... (10.8)$$

Evaporation values will be obtained from Putrajaya's Automatic weather station and will be converted to reference crop evapotranspiration Eto by multiplying with an appropriate factor. For pan evaporation (Epan) the conversion factor is 0.75 i.e.

$$Eto = 0.75 \text{ X } Epan \qquad .... (10.9)$$

Evapotranspiration loss E from each irrigated area will be computed using the following equation:

$$E = Kc * Eto \qquad .... (10.10)$$

If soil moisture is low, actual evapotranspiration will be less than that shown in Eqn 10.10. The method for estimating evapotranspiration under water stressed condition presented in Eqn 10.7 above.

To cater for varying Kc values within a sub area, the average crop coefficient Akc will have to be computed for each sub-block and for each day.

$$AKc = \frac{Kc1*A1 ++Kc2*A2+\ldots\ldots KcN*AN}{\sum Ai} \quad \ldots (10.11)$$

To avoid missing evaporation values from affecting water balance computations, it is proposed that default values of daily evaporation be stored in the system and these default values could be used if necessary. The default evaporation values are long term average evaporation.

Month	daily evaporation (mm/day)
Jan	3.5
Feb	3.9
Mar	4.0
Apr	4.0
May	3.8
Jun	3.6
Jul	3.7
Aug	3.7
Sep	3.6
Oct	3.6
Nov	3.3
Dec	3.7

The water balance computations is expected to estimate the following:

- Effective rainfall
- Surface runoff
- Losses
- Irrigation water requirement
- Water depth in the field

Water supply to the various sub areas will have to account for irrigation efficiency. If irrigation efficiency is low, it has to be compensated by a higher rate of irrigation Ia.

i.e. $$Ia = (I \div Ef) * 100 \quad \ldots\ldots\ldots\ldots\ldots (10.12)$$

To be useful, attempts must be made to translate water balance results to water management decisions. For a start water balance will estimate the soil moisture depletion. The amount of irrigation required and whether to initiate irrigation or not will depend on the degree of soil moisture depletion.

For systematic decision making, irrigation managers will have to set various target or threshold levels to describe soil moisture depletion and consequently, the decisions that would have to be made once the water levels reaches these threshold levels. For simplicity, it is proposed that 4 soil moisture deficit levels be set i.e. SM1, SM2, SM3 and SM4. As a start it is proposed that the soil moisture deficit levels be set as follows:

- SM1 – at this level soil moisture is at or higher than field capacity and therefore no irrigation is required.
- SM2 – at this level soil moisture is at 60% RAM, irrigation is given depending on the priority of the area and abundance of water source
- SM3 – at this level soil moisture is at 30% RAM, irrigation is given depending on the priority of the area and abundance of water source
- SM4 – at this level soil moisture is at 10% RAM, irrigation is critical but if water source is scarce the area may not be irrigated unless it is high priority area.

To simplify operations it is felt that the amount of irrigation to be applied in each irrigation application should be standardized. In the case of sprinklers and dripper line irrigation the amount of water applied for each irrigation application is determined by the sprinkler and dripper line which sets the irrigation rate and the irrigation satellite which governs the duration of irrigation application. For sprinklers and dripper lines, daily irrigation application is the norm and it is recommended that each irrigation application be set to 5mm. This amount of irrigation is just sufficient to satisfy evapotranspiration needs. In the case of trucking, 5mm per irrigation application is also recommended. Attempt should be made to improve efficiency of irrigation application by trucking. Water manually applied by hose on the plants will not be efficiently distributed and a lower irrigation efficiency rate should be assigned.

However, soil moisture is not the only criteria for the determination of irrigation supply to the field. There is a need to examine the depletion level of the various sources of water. The Lake level for instance is an important consideration and when drawdown reaches critical levels, decision will have to be made to cut down irrigation to conserve water. Deficit irrigation will have to be practiced in some less important planted areas while the more important areas such as the promenade will continue to receive optimum irrigation (100% I) while in less critical areas the irrigation can be reduced to (50% I) The deficit irrigation strategy for the Lake could be as follows:

Lake drawdown (mm)	Irrigation criteria (% I)								
	Priority 1			Priority 2			Priority 3		
	SM4	SM3	SM2	SM4	SM3	SM2	SM4	SM3	SM2
50	100	100	75	100	75	50	100	75	50
100	100	100	75	100	75	50	100	75	50
150	100	100	75	100	75	50	100	75	50
200	100	100	75	100	75	50	75	50	25
250	100	100	75	100	75	50	75	50	25
300	100	75	50	75	50	25	75	50	25
350	100	75	50	75	50	25	50	50	25
400	100	75	50	75	50	25	50	25	0
450	100	75	50	75	50	25	50	25	0
500	100	75	50	75	50	25	30	25	0

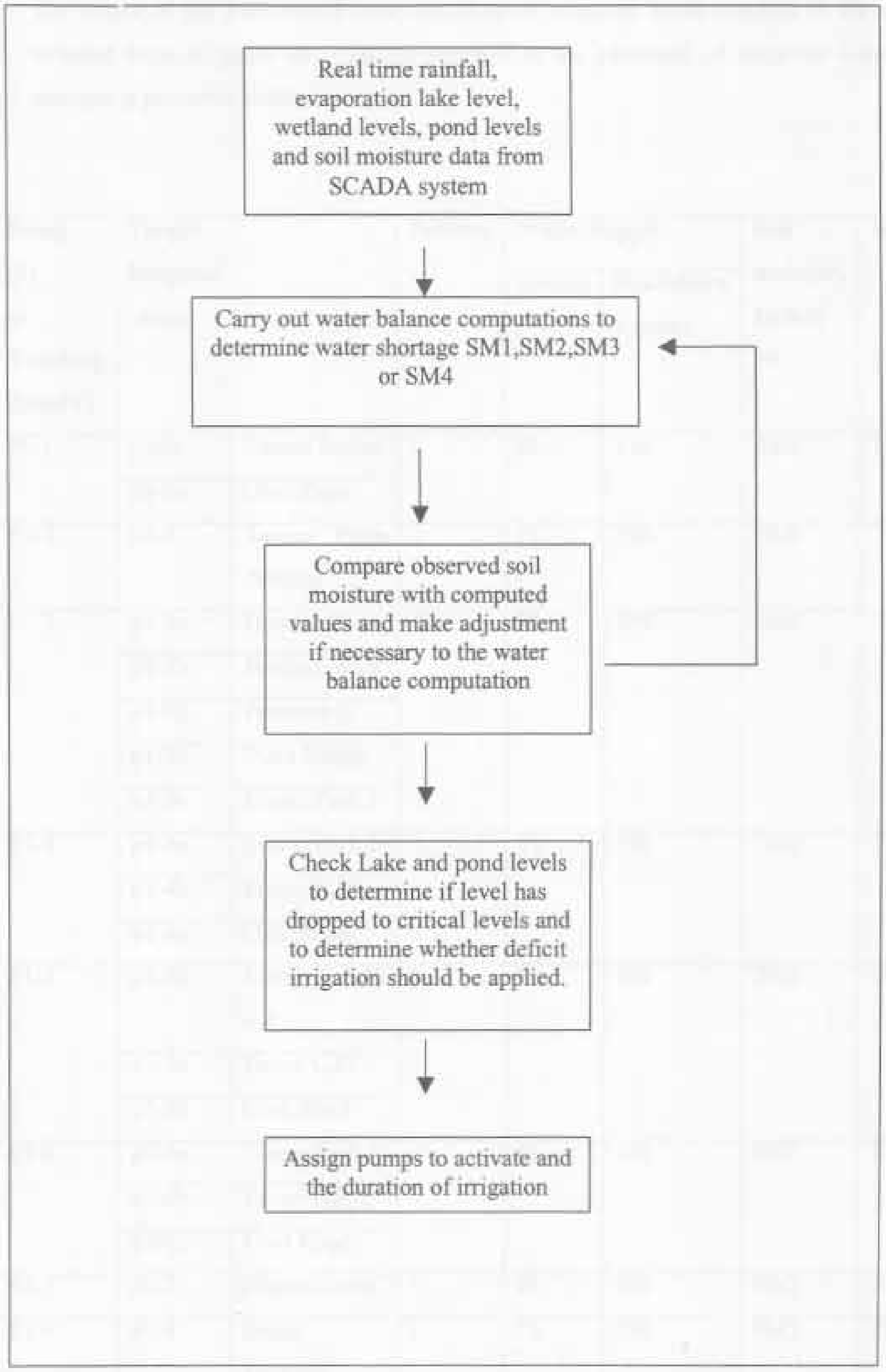


Fig 10.6: Flow Chart of the Irrigation Decision Support System

The output of the DSS would be a tabulation of irrigation to be supplied to the various irrigated areas to guide the irrigation manager in the allocation of irrigation water. An example is presented below.

Pump (P) or Trucking Zone(T)	Target Irrigated Area		Priority	Water Supply		Soil moisture Deficit >=	Irrigate (%I)
				Source	Drawdown > (mm)		
P1-1	p1-1a	Taman Botani	1	PL	150	SM2	75
	p1-1b	Oval Road					
P1-2	p1-2	Taman Putra Perdana	1	PL	150	SM2	75
P1-3	p1-3a	Dataran Putra	1	PL	150	SM2	75
	p1-3b	Perdana Walk					
	p1-3c	Promenade					
	p1-3d	Putra Bridge					
	p1-3e	Linear Park 1					
P1-4	p1-4a	Linear Park 2	1	PL	150	SM2	75
	p1-4b	Parcel A, B					
	p1-4c	Oval Road					
P1-5	p1-5a	Linear Park 3,4	1	PL	150	SM2	75
	p1-5b	Parcel C,D					
	p1-5c	Oval Road					
P1-6	p1-6a	Linear Park 5	1	PL	150	SM2	75
	p1-6b	Parcel E,F,G					
	p1-6c	Oval Road					
P1-7	p1-7	Plant nursery	1	PL	150	SM2	75
P1-8	p1-8	Istana Hinggap	1	PL	150	SM2	75
P1-9	p1-9	Government Reserve 1	2	PL	150	SM2	50
P1-10	p1-10	Loca Distributor	2	PL	150	SM2	50

		D2					
.							
.							
.							
P7-1	p7-1	Promenade	2	PL	150	SM2	50
P7-1	t7-1	Primary distributor D3	3	PL	150	SM2	25
T7-2	t7-2	Secondary distributor D3	3	PL	150	SM2	25
T7-3	t7-3	Local distributor D3	3	PL	150	SM2	25
T7-4	t7-4	U2 spine road	3	PL	150	SM2	25
.							
.							
P19-1	p19-1	Taman Lindungan	2	STP2	50	SM2	50
P19-2	p19-2	Buffers	3	STP2	50	SM2	25
P19-3	p19-3	Neighborhood Park	3	STP2	50	SM2	25
P19-4	p19-4	Promenade	2	STP2	50	SM2	50
P19-5	p19-5a	Educational facility	2	STP2	50	SM2	50
	p19-5b	Health	2	STP2	50	SM2	50
	p19-5c	Public amenity facilities	2	STP2	50	SM2	50
	p19-5d	Public utility facilities	2	STP2	50	SM2	50
P19-6	p19-6	Plant nursery (allocation)	1	STP2	50	SM2	75
P19-7	p19-7	Primary distributor Jln Lingkaran Bandar	2	STP2	50	SM2	50

P19-8	p19-8	Secondary distributor D3 road	3	STP2	50	SM2	25

The decision to activate or not to activate the pump and for how long to activate the pump depends on the computed soil moisture deficit and irrigation priority assigned.

10.8 CONCLUSIONS AND RECOMMENDATIONS

The need to manage the allocation of water for irrigation is important as it could lead to savings in water and in pumping.

For systematic management of irrigation there must be first the ability to monitor the status of irrigation requirements and the status of water availability.

This can be achieved via a real-time monitoring system gathering rainfall, water level, evaporation and soil moisture via a SCADA system.

The irrigation environment is not in a factory like environment and therefore data gathered has errors and inaccuracies and thus the need to simplify decisions based on a range of values.

Automated and remote control of irrigation can be at the level of the irrigation satellites but the sheer number of satellites makes this an expensive approach and increase the system's susceptibility to vandalism.

It is recommended that the day-to-day control of irrigation be made at the level of booster pumps.

A water balance model is described to indicate how rainfall, evaporation and other data can be used to model the soil moisture depletion on a day-to-day basis.

A decision algorithm is recommended based on which the manager can systematically allocate water based on priority of the area, the soil moisture deficit and the status of water availability. The priority settings and the acceptability of drawdown are subjective and can be changed.

To ensure that future irrigation installations are designed for integrated irrigation management operations an important factor to be considered is that irrigation control satellites should only control areas with the same irrigation priority and if possible booster pumps should only control zones with the same irrigation priority.

The overall system is complex and a software needs to be developed to assist the irrigation manager to monitor and manage the system.

Many parameters of the system model such as irrigation efficiencies, field capacity, infiltration rate etc. are unknown and it is expected that with the use of the model, these parameters could be adjusted to fine-tune the model with time.

11. LEGAL REQUIREMENT

11.1 Introduction

One of the main objectives of the Irrigation Master Plan Study is the determination of irrigation water sources and quantities that are available to meet planned irrigation demands. In Selangor, the control of water use, and abstractions is vested with the relevant State Authority. This includes water supplies, irrigation, management of rivers and canals within the State boundaries. The Consultant envisaged that this component of study will involve desk studies on relevant existing Enactment in support of the objectives as stated above.

The desk studies has led to:

a) recommendations of specific legal requirements that would affect irrigation practices in Putrajaya; and

b) specific policies and guidelines necessary for the proposed development of irrigation infrastructures.

In the implementation of the Irrigation Master Plan, it is expected that legal aspects on water related issues will be:

- The availability and extraction of water for irrigation development;
- Obtaining permission for purpose of water extraction;
- Water Enactment pertaining to extraction and pollution of water sources.

Irrigation practices involve land and water issues, and there are a number of existing Enactment that govern land, water-use, protection of water quality, and irrigation in Malaysia at both Federal and State levels, operating within the requirements of the Federal Constitution.

11.2 Relevant Legal Enactment

Under the Federal Constitution, the individual State Governments in Malaysia have full jurisdiction over water resources within their boundaries, and are therefore the authority to decide how resources should be developed (for example, whether rights to river water abstractions should be granted, or whether new dams should be constructed).

The main enactment of relevance to Putrajaya Irrigation Master Plan are:

1. The Irrigation Areas Act (Revised 1989)
2. Waters Act, 1920 (Revised 1989)
3. The Land Conservation Act
4. Selangor Water Management Authority Enactment (1999)

11.2.1 *The Irrigation Areas Act (Revised 1989)* where the State Authority is empowered to declare irrigation areas by notification in the state Gazette. The Act stipulates provisions regarding supply of irrigation water for agricultural purposes, and protection of irrigation facilities through enforcement and penalties. The Irrigation Areas Act (Revised 1989) is designed mainly for agriculture and can be extended for landscape irrigation practices.

11.2.2 *Waters Act, 1920 (Revised 1989)* where provisions cover for control of rivers and streams and prohibition of activities affecting rivers, e.g. obstruction of rivers, construction of structures over or beside rivers wider than 6m (20 feet), prohibition of diversion of water from rivers unless licensed, prohibition of pollution of rivers (including subterranean water resources, estuary or sea adjacent to the coast of the State), restriction on the construction of walls and buildings on banks of rivers or within flood channels. Under the Waters Act, 1920 (Revised 1989), the entire property in and control of all rivers in any State is vested solely with the State. One of the principal provisions under the Waters Act is that no person may in any manner obstruct or interfere with any river except under and in all accordance with the terms of a license under this Act. The Waters Act is the fundamental law for river and water management. It has provisions for the proprietary right of rivers, water abstraction, prohibition of diversion of water from rivers except under licence, restriction on construction of walls and buildings on banks of rivers or within flood channels. Refer Appendix G for more details.

11.2.3 *The Land Conservation Act* has provisions for the conservation of hill land, the protection of soil erosion and control of silt. The main purpose of this Act is for the control of unauthorised clearing of hill lands for agriculture. The Act is under the jurisdiction of the Land Office. There are apparent shortcomings in the control and enforcement of the Act. This has led to serious soil erosion, slope failures and land slips, which have caused heavy siltation of rivers, streams and urban drainage systems, especially in hilly areas which are being cleared for housing development.

11.2.4 *Selangor Water Management Authority Enactment 1999 (LUAS Enactment)*

In June 1998, the National Water Resources Council was established to resolve legal, institutional and financial issues and to improve/co-ordinate river basin development and management on a national basis to ensure the long-term sustainability of water supply. Irrigation practices involve land and water, and a review of the water sector in the State indicated the existence of many Agencies involved in the management of water resources. Selangor is the first State in Peninsular Malaysia to form a Water Management Board called Lembaga Urus Air Selangor (LUAS) to manage the State's water resources. One of the key functions is:

- water quality control, monitoring criteria and standards including strategies for protection of watersheds, control of point and non-point pollution, ***licensed water abstractions, control of wasteful use,*** and a general precautionary approach to the assessment of development externalities.

11.3 Management of Water Sources for Irrigation And Licensed Water Abstraction

It is clear that the LUAS Enactment (1999) shall apply to all rivers wholly within the State of Selangor and to all river basins, catchment areas, wetlands, groundwater, and water bodies within the State of Selangor except those wholly within the Federal Administrative Centre of Putrajaya. However, it is pertinent to note that Putrajaya Lake commands a catchment area of 48 km^2, out of which approximately 40% or 20 km^2 falls outside Putrajaya Development area boundary. As the aesthetic and irrigation function of Putrajaya Lake need to be maintained, the water quality and inflow into the lake must be coordinated and properly managed. It is permission for licensed water abstractions require close interaction between Putrajaya and LUAS to ensure the sustained development of irrigation.

11.4 Irrigation Policy and Management

Whilst this Study is primarily aimed at identifying the irrigation facilities in a form of a Master Plan, and the water resources needed to ensure adequate water supply to meet projected needs, it is clear that policy environment in which these investments are made is of critical relevance. These policies would encompass the following:

- this irrigation Master Plan will form the basis, and future direction pertaining to irrigation development, irrigation water utilisation and management; In the context of Putrajaya, there will be remote pocket areas where development of water resources for irrigation will not be cost effective. The areas are small isolated areas located far away from the water source and to develop an irrigation water distribution system to convey water to the area will be expensive. Isolated private properties and small remote parks will fit into this category.

  In this area, landscaping should be designed to minimise water demand i.e. by planting plant species that require less watering such as trees and drought resistant plants. Water supply could be from JBA supply and if large quantities are required water may have to be transported via trucks to these areas.

- a clear policy on extent of irrigation and priority of irrigation in times of drought.

  In times of drought, irrigation will have to be progressively cut down to conserve water. This is especially critical if the supply is drawn from Putrajaya Lake. Alarm levels are to be set for the Lake, and when the lake drawdown hits an alarm level, the irrigation supply would have to be cut down in certain areas. In this respect, there is a need to priorities the irrigated areas so that in the event of a drought the areas which will be under-irrigated will be known and the irrigation manager can then allocate water accordingly. The IWMS software should have this feature built-in to assist the irrigation manager in drought management.

- a clear irrigation policy on public and private facilities;

  In the public sector a centralised irrigation system will be provided. This system will be controlled by PPJ so that management of water supply in the event of a drought is under control. For the private sector, however, irrigation is left to the individual owners. Developers of the private properties, however, would have to conform to guidelines on irrigation water source development as set out in this master plan. The Master Plan provides guidelines on the size of water harvesting facilities required. In many cases, however, the water harvesting facilities will not provide sufficient water for the planted areas in an extreme drought. But with the presence of these water harvesting facilities, the usage of JBA supply could be reduced.

- type of recommended plants, zoning of landscape areas and private and public domains; emphasis should be placed on growing landscape trees and plants that will not require any irrigation after the first 3 years of growth. The choice of grass ground covers that can withstand drought situations. In this respect, cow grass is a suitable choice as it is able to regenerate itself after a drought and would probably withstand low level irrigation better than many other ground covers.

- a clear policy on source management in the need for conservation of water and on water quality control, monitoring criteria and standards including strategies for protection of watersheds, control of point and non-point pollution; One of the recommendations is to adopt water conservation strategies once the draw down in the Putrajaya lake reaches a predefined critical level. In times of drought, under irrigation of crops is permitted to conserve water. Certain priority areas will continue to receive full irrigation while irrigation supply to less important irrigated areas will be reduced.

- licensed quantities of water abstractions with guidelines consistent with the Irrigation Master Plan. Developers of irrigation infrastructures should seek the State Authority for license to abstract water. The water abstraction may incur payment in respect of every license under the Waters Act in form of an annual fee as may be imposed by the State Authority. As discussed in the Master Plan, the plant groupings are divided into 4 major categories namely trees, palms, shrubs and ground covers and lawn. The irrigation demand of each group is determined by considering factors such as soil and its available water, evapotranspiration rate of plants, the root zone depth and plant quantity.

The quantity of water abstracted from the Lake by the various proposed pumps are as tabulated in Appendix SC (Executive Summary Report).

- policy on irrigation coverage and control of wasteful use; the extent to which irrigation water supply is provided in various precincts is shown in Appendix SB (Executive Summary Report).

- a clear cut policy on demand management such as rainwater harvesting, use of drainage water and minimising water usage by recycling of water; demand management is concerned with finding an appropriate balance between the benefits of using irrigation water and the cost of supply. Demand management concerns issues relating to ways to promote more desirable levels and patterns of use. With increasing costs of new source works and supplies, demand management can be an alternative that can be considered in future, in the context of reducing irrigation water consumption. Demand management techniques include water conservation; reducing water consumption, and using rainwater harvesting. The Consultant is of the opinion that demand management policies and strategies if implemented can contribute to a reduction in the overall irrigation water consumption.

- policy for private sector/households involvement in the provision and use of irrigation water.

- In individual households or in any privately owned properties, which could be office or commercial complexes, it is difficult to impose upon the owners the source of water to be used.

11.5 Guidelines on Irrigation Development

11.5.1 Introduction

The guideline sets out conditions/requirements for irrigation development in the Putrajaya. Putrajaya Corporation is the controlling Agency, and prior approval (with the exception of individual household irrigation) for all large irrigation development is necessary. To ensure speedy processing, irrigation development applications shall be subjected to the following requirements.

11.5.2 Irrigation Development

In preparing proposals for irrigation, reference should be made to the Putrajaya irrigation Master Plan which shall form the basis, and future direction pertaining to irrigation development, water utilisation, management and operation of facilities.

11.5.2.1 Information And Details To Be Submitted

- Background information;
- Type of irrigation development;
- Implementation Schedule;
- Copy of Land Title;
- Name of Consultant and letter of Appointment;
- Profile of Consultant;
- A Key plan with a scale of 1 : 25000 or 1 : 50 000 showing the location;
- Site plan both hard copy and digital format to a scale of 1in 1000 showing the following:
- Information of existing infrastructure at the proposed irrigation site;
- Relevant details such as lot boundaries, structures, ground levels within 300 m of the site;
- Details of relevant revenue sheets, district name, and north point are to be shown in the site plan;
- Type of plants and landscape proposals, irrigation system layout plans and details; Location point of water extraction (To state whether proposals comply with the Putrajaya Irrigation Master Plan)
- Design drawings and layout plans for the water control structures, irrigation pipelines and pumping systems;
- Irrigation and drainage:

- Proposals for water extraction and method of irrigation;
- Mode of operation and maintenance after completion;
- Analysis of irrigation water requirement;
- Permission from State Authority for extracting water from rivers and natural streams;
- Water quality assessment in terms of suitability for specified irrigation development;
- Quantity of water extraction/diversion; duration of extraction
- Location plan of river and point of water extraction

* Spot levels at 20 meters intervals including contour lines at 0.5 meter intervals to be plotted on the site/layout plan; All levels are to be based on Land Survey Datum
* Details of construction methods to ensure that the existing infrastructure works are not affected, and that excavation works shall not endanger any adjacent properties, structures or buildings.

11.5.2.2 Design Calculation and Plan

All design works shall be carried out by Professional Engineers registered with the Board of Engineers Malaysia. Details of calculation and design drawings to suitable metric scales for all irrigation works, sprinklers, pipelines, pumping stations, retention ponds, etc. are required to be submitted.

11.5.2.3 Water Quality Requirements

The guidelines are spelt out in EIA Order of 1987. Industrial estate development for medium and heavy industries covering an area of 50 hectares or more is a prescribe activity under item 9 (b) of the Schedule of the EIA order 1987. Section 34 A of the Environmental Quality Act (EQA) 1974, requires the submission of an EIA report prior to granting approval by the relevant approval Authority. According to the guidelines set by the DOE the target for water quality suitable for irrigation is Class IV. Detailed design drawings including computations, to suitable scales for the water quality control and enhancements measures are required to be submitted.

11.5.2.4 *Reporting and Documentation*

A report on the proposed irrigation development encompassing the above requirements is to be submitted. The formats for report submissions are as follows:

Size of Report	: A4
Plan in report	: A3
Construction drawings	: A1

11.6 Checklist for Irrigation Development

This Study has formulated a Checklist for Irrigation Development. The checklist as set out in Appendix H (Main Report) is prepared to:

(a) ensure that proposed irrigation projects are developed in harmony with total development infrastructures; and

(b) assist the Local Authority in the processing of applications.

The guideline is prepared to serve as an aid to Planners, Developers and Consultants that are involved in irrigation development. In this aspect, the relevant PPJ's Checklist such as Form SA, PB and PBS are expanded and updated to incorporate the above additional data as follows,

(a) Form SA amended to Form SA (Pindaan 1)

Senarai Semakan Permohonan untuk Permohonan Kebenaran Merancang Bagi Kelulusan Susun Atur (Seksyen 21, Akta Perancangan Bandar dan Desa, 1976)

(b) Form SA1 amended to Form SA1 (Pindaan 1)

Senarai Semakan Permohonan untuk Permohonan Kebenaran Merancang Bagi Kelulusan Susun Atur (Seksyen 21, Akta Perancangan Bandar dan Desa, 1976)
- Kandungan Laporan Cadangan Pemajuan

(c) Form PB amended to Form PB (Pindaan 1)

Senarai Semakan Permohonnan untuk Permohonan Kebenaran Merancang Bagi Pendirian Bangunan (Seksyen 21(3) Mengenai Pendirian Bangunan, Akta Perancangan Bandar dan Desa, 1976)

(d) Form PB1 amended to Form PB1 (Pindaan 1)

Senarai Semakan Permohonnan untuk Permohonan Kebenaran Merancang Bagi Pendirian Bangunan (Seksyen 21(3) Mengenai Pendirian Bangunan, Akta Perancangan Bandar dan Desa, 1976)
- Kandungan Laporan Ringkas Cadangan Pemajuan

(e) Form PBS1 amended to Form PBS1 (Pindaan 1)

Senarai Semakan Permohonnan untuk Permohonan Kebenaran Merancang Bagi Pendirian Bangunan Sementara (Seksyen 21(3) Mengenai Pendirian Bangunan, Akta Perancangan Bandar dan Desa, 1976)

(f) Lampiran B(i) amended to Lampiran B(i) (Pindaan 1)

Senarai Semakan Teknikal untuk Permohonan Kebenaran Merancang Bagi Pelan Susun Atur (Seksyen 21, Akta Perancangan Bandar dan Desa, 1976)
- Laporan Sokongan LCP Termasuk Pelan/Gambarajah/Model

(g) Lampiran B(i) amended to Lampiran B(i) (Pindaan 1)

Senarai Semakan Teknikal untuk Permohonan Kebenaran Merancang Bagi Pendirian Bangunan (Seksyen 21(3) Mengenai Pendirian Bangunan, Akta Perancangan Bandar dan Desa, 1976)
- Laporan Ringkasan Cadangan Pemajuan dan Pelan – pelan Sokongan Lain

(h) Form PH remains

Senarai Semakan Permohonan untuk Permohonan Pelan Pra-Hitungan

The amended checklists are given in Appendix H.

TABLE

Table 2.1 Existing Rainfall Station Around Putrajaya

JPS Station number	Location	Average Annual Rainfall
2917001	Stor JPS Kajang	2036 mm
2917106	Ladang West Country	2319 mm
2916001	Prang Besar	2148 mm
2816112	Ladang Galloway	2087 mm

Table 2.2 Zero Rain Analysis At Ladang West Country (Nos: 2917160)

Year	Consecutive Day	Starting Date
1948	13	15,Aug,1948
1949	13	05,Jan,1949
1950	20	03,Sep,1950
1951	11	06,Aug,1951
1952	19	10,Jan,1952
1953	13	07,Aug,1953
1954	15	05,Aug,1954
1955	15	21,May,1955
1956	11	29,May,1956
1957	14	09,Feb,1957
1958	18	30,Jun,1958
1959	15	24,May,1959
1960	11	23,May,1960
1961	9	21,Jan,1961
1962	15	28,Jan,1962
1963	11	08,Sep,1963
1964	17	16,May,1964
1965	13	04,Jan,1965
1966	12	24,Jun,1966
1967	10	05,Jul,1967
1968	11	17,Jun,1968
1969	12	19,Jul,1969
1970	16	11,Aug,1970
1971	10	04,Mar,1971
1972	12	24,Jun,1972
1973	13	21,Apr,1973
1974	13	08,Aug,1974
1975	12	03,May,1975
1976	16	20,Jan,1976
1977	15	08,Sep,1977
1978	14	16,Jul,1978
1979	13	14,May,1979
1980	14	21,Jan,1980
1981	25	26,Jul,1981
1982	16	15,Jan,1982
1983	17	03,Jan,1983
1984	10	12,Aug,1984
1985	20	29,Jul,1985
1986	23	02,Aug,1986
1987	14	27,Jan,1987
1988	12	09,Dec,1988
1989	22	12,Jul,1989
1990	16	20,May,1990
1991	17	04,Jun,1991
1992	22	26,Aug,1992
1993	23	20,Jan,1993
1994	24	14, Aug 1994
1995	10	4, Jul 1995
1996	14	17, Jun 1996
1997	11	2, Jan 1997
1998	15	29, Jan 1998

Zero Rain = 0 mm

Table 2.3 Zero Rain Analysis At Ladang Galloway (Nos: 2816112)

Year	Consecutive Day	Starting Date
1939	29	04,Jul,1939
1941	13	27,May,1941
1947	18	13,Jul,1947
1948	19	11,Jul,1948
1949	24	02,Jan,1949
1950	26	14,Jun,1950
1951	22	06,Jun,1951
1952	14	20,Jul,1952
1953	20	10,Aug,1953
1954	14	07,Aug,1954
1955	18	20,May,1955
1956	16	30,Apr,1956
1957	14	09,Feb,1957
1958	17	27,Nov,1958
1959	16	24,May,1959
1960	27	16,May,1960
1961	29	13,Jan,1961
1962	21	22,Jan,1962
1963	21	23,Jan,1963
1964	17	16,May,1964
1965	26	26,May,1965
1966	13	18,Jul,1966
1967	11	03,Jun,1967
1968	20	18,Feb,1968
1969	17	19,Jul,1969
1970	15	14,Jan,1970
1971	15	24,Feb,1971
1972	15	10,Jan,1972
1973	18	27,Jan,1973
1974	26	21,May,1974
1975	17	08,May,1975
1976	19	14,May,1976
1977	16	27,Feb,1977
1978	14	26,Jan,1978
1979	15	10,Jan,1979
1980	18	06,Feb,1980
1981	25	25,Jul,1981
1982	27	18,Jul,1982
1983	17	01,Feb,1983
1984	14	08,Aug,1984
1985	38	31,May,1985
1986	20	18,Jun,1986
1987	9	13,Feb,1987
1988	10	14,May,1988
1989	14	05,Jun,1989
1990	20	05,Feb,1990
1991	28	07,Jul,1991
1992	16	15,Jan,1992
1993	12	28,Jul,1993
1994	14	14,Jan 1994
1995	14	18, Aug 1995
1996	18	27, Jun 1996
1997	15	2, Feb 1997
1998	16	28, Feb 1998

Zero Rain = 0 mm

Table 2.4 Results of No-Rain Analysis

	Average	10-yr	20-yr	50-yr
Number of consecutive days of no rain				
0 mm/day	15	20	22	24
< 5 mm/day	22	31	33	36
< 10 mm/day	29	40	43	47
< 15 mm/day	36	50	55	67
Total days of no rain				
0 mm/day	204	–	–	–
< 5 mm/day	264	–	–	–
< 10 mm/day	290	–	–	–
< 15 mm/day	310	–	–	–

Table 2.5 Evaporation Data

Eto computed From climate data of MMS
mean from 1968-1995 (Kuala Lumpur International Airport)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.38	26.74	27.04	27.16	27.37	27.28	26.91	26.85	26.68	26.57	26.27	26.26	26.79
	Max	32.04	32.90	33.08	33.02	32.72	32.53	32.15	32.27	31.93	31.95	31.46	31.42	32.29
	Min	22.22	22.49	22.98	23.48	23.70	23.30	22.91	22.89	22.90	23.09	23.08	22.71	22.98
RH (%)	Mean	80.95	80.04	81.07	83.32	82.79	81.30	80.86	80.70	82.48	83.38	85.00	83.70	82.13
	Max	96.68	96.29	96.46	96.73	96.20	95.86	95.71	95.59	96.16	96.46	96.96	96.84	96.33
	Min	54.07	52.11	53.93	58.32	59.63	58.07	57.91	56.88	58.77	59.39	61.82	59.59	57.54
Sunshine hours	Mean	6.18	6.93	6.73	6.59	6.56	6.48	6.54	6.11	5.35	5.49	5.05	5.33	6.11
U2 (m/sec)	Mean	0.22	0.27	0.27	0.27	0.30	0.30	0.35	0.32	0.32	0.30	0.27	0.22	0.29
ETo (mm/day)	mean	3.48	3.93	4.03	3.95	3.77	3.62	3.67	3.71	3.61	3.58	3.29	3.33	3.66

Eto computed From climate data of MMS
mean from 1968-1995 (Petaling Jaya)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C)	Mean	26.80	27.17	27.45	27.49	27.78	27.79	27.34	27.38	27.03	27.00	26.61	26.61	27.20
	Max	32.55	33.25	33.53	33.48	33.18	33.07	32.61	32.75	32.48	32.60	32.00	32.06	32.80
	Min	23.05	23.31	23.79	24.11	24.31	24.03	23.64	23.71	23.62	23.62	23.53	23.24	23.66
RH (%)	Mean	77.80	77.54	78.75	80.86	80.30	77.82	78.18	77.32	80.09	80.88	83.09	80.64	79.44
	Max	94.38	94.23	94.63	95.23	94.43	93.39	93.63	92.95	94.29	94.55	95.52	94.88	94.34
	Min	52.48	51.14	53.04	56.57	57.95	56.27	56.79	55.64	57.80	58.27	60.57	57.34	56.15
Sunshine hours	Mean	5.89	6.65	6.34	6.20	6.15	6.09	6.17	5.91	5.22	5.40	4.66	5.13	5.82
U2 (m/sec)	Mean	0.25	0.25	0.25	0.25	0.27	0.27	0.30	0.30	0.27	0.30	0.25	0.22	0.27
Eto (mm/day)	mean	3.48	3.88	3.97	3.88	3.69	3.55	3.60	3.69	3.61	3.59	3.22	3.21	3.61

JPS's Pan Evaporation Data

STN NO	YEAR	JAN	FEB	MAC	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
2916301	1981-90	4.3	5.2	4.9	5.0	4.7	4.8	4.8	4.9	5.0	4.8	5.0	4.4	4.8

Table 2.6 Parameters For 800mm per annum Runoff Model

Parameter	Value	Parameter	Value
SS	3	FC	1.0
FS	1.2	DCS	300
RC	0.3	DCT	360
RS	0	A	0.2
RR	0	GSU	150
RK	0.2	GSP	2
RX	1.2	GDEL	0
RDEL	0		

Table 2.7 Parameters For 300mm per annum Runoff Model

Parameter	Value	Parameter	Value
SS	5	FC	1.5
FS	1.5	DCS	300
RC	0.1	DCT	360
RS	0	A	0.2
RR	0	GSU	600
RK	0.3	GSP	1.5
RX	1.2	GDEL	0
RDEL	0		

Table 3.1 Summary of Land Use Areas for Irrigation

S/N	Land Uses	Gross Land Area (ha)	%
1	Government institutional use	270.67	9.4
2	Public amenity facilities	400.23	13.6
3	Public utility facilities (excl. detention ponds & existing water treatment plant)	71.05	2.4
Sub-total		741.95	31.0
4	Open space (excl. Putrajaya Lake and wetlands)	1133.15	38.5
5	Residential	910.90	31.0
6	Commercial	151.30	5.0
7	Service Industry	4.65	0.1
Total		2941.95	100.0
8	Roadside landscape buffer and street planting reserve (referring to U5, U4, U3 and U2 roads only)	62555m	

Source:

1. *Gross land areas extracted from approved layout plans for Precincts 1, 8, 9, 10, 13 and 16; UDG reports for Precincts 5, 6, 7, 11, 14, 15, 17, 19, 20; DUD for Precincts 2,3 and 4; Master Plan Review for Putrajaya and Revised Master Plan, November 1999.*

2. *Length of major and secondary roadways scaled from Master Plan November 1999.*

Table 5.1 The Characteristics of Bungor Series

Characteristic	Description
Colour	Brownish yellow to yellowish brown
Texture	Fine sandy loam.
Structure	Weak to moderate medium and fine sub-angular blocky and consistence friable to firm with depth
Drainage	Well drained
Water Retention	Moderate low
Depth	Deep

(Source: *Panduan mengenai siri-siri tanah utama di Semenanjung Malaysia*, 1993, Jabatan Pertanian Semenanjung Malaysia.)

Table 5.2 Wilting Point, Field Capacity and Available Water Based On Soil Texture.

Soil Texture	Wilting Point (mm/m)	Field Capacity (mm/m)	Available Water (mm/m)
Medium Sand	25	100	75
Fine Sand	33	125	92
Sandy Loam	50	166.7	116.7
Fine Sandy Loam *	66.7	216.7	150
Loam	100	266.7	166.7
Silt Loam	116.7	291.7	175
Clay Loam	150	316.7	166.7
Clay	216.7	333.3	116.6

(Source: *Soil, their chemistry and fertility in tropical Asia*, 1966, Prentice Hall)

* denotes texture of Bungor Series

Table 5.3 The Range and Average Of The Root Zone Depth

Plant Category	Range of Root Zone Depth (m)	Average Root Zone Depth (m)
Tree	1.00 – 2.00	1.50
Shrub	0.50 – 1.20	0.85
Palm	0.70 – 1.30	1.00
Ground Cover and Lawn	0 – 0.60	0.30

(Source: *Irrigation practice and water management*, 1984, FAO)

Table 5. 4 Average Evapotranspiration Rate For Plant Groups

Plants	Etcrop	Average Etcrop
Trees		
Hevea brasiliensis (Rubber tree)	6.32	4.33
Coffea spp (Coffee)	2.74	
Cocoa	2.74	
Persia americana (Avocado)	2.26	
Citrus spp (Citrus)	2.88	
Shrubs		
Musa spp (Banana)	4.66	4.53
Ananas cosmosus (Pinapple)	2.33	
Helianthus annus (Sunflower)	6.15	
Lycopersicon esculentum (Tomato)	4.76	
Nicotiana tabacum (Tobacco)	4.76	
Palms		
Cyrtostachis renda (Red Palm)	3.56	3.57
Licuala grandis (Fan Plam)	3.58	
Groundcover and Lawn		
Arachis hypogea (Ground nut)	5.85	4.87
Allium cepa (Onion)	3.75	
Various turf grasses	5.00	

(Source : Irrigation practice and water management. 1984.FAO)

Table 5.5 Average Evapotranspiration Rate and Calculated Water Requirement For Each Category of Plant

Plant Type	Average Evapotranspiration Rate	Calculated Water Requirement, L
Tree	4.33 mm / No / day	24 L / No / day
Palm	3.57 mm / No / day	7.1 L / No / day
Shrub	22.65 mm / sq. m. / day	6.3 L / sq. m. / day
Ground Cover and Lawn	121.75 mm / sq. m. / day	3.1 L / sq. m. / day

(Source: *Crop water requirement*, 1977, FAO)

Table 5.6

OPTION 1 - SUMMARY OF IRRIGATION WATER DEMAND BY PRECINCT FOR ALL PRECINCTS

Water requirement per plant (liter/plant/day for Tree & Palm or litre/m2/day for Shrub & Ground cover & Lawn):
Tree: 24.00 Palm: 7.10 Shrub: 6.30 Ground cover & Lawn (GC & L): 3.1

Precinct type	Gross land area (ha)	Plant Quantity				Full Irrigation Demand		PHASE 1A				PHASE 1B				PHASE 2			
								Full Water Demand		Water Demand + 3 years		Full Water Demand		Water Demand + 3 years		Full Water Demand		Water Demand + 3 years	
		Tree (No)	Palm (No)	Shrub (m2)	GC & L (m2)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)
Precinct 1	171.24	26,981	7,856	121,560	657,729	3,453,018	97,186	2,905,735	0	579,260	0	255,277	0	255,277	0	292,007	97,186	74,591	37,297
Precinct 2	179.70	37,899	9,206	178,121	830,611	4,671,479	99,189	0	0	0	0	4,671,479	99,189	1,308,732	38,066	0	0	0	0
Precinct 3	55.33	5,694	1,808	25,289	87,872	365,650	84,346	0	0	0	0	0	0	0	0	365,650	84,346	189,599	32,370
Precinct 4	218.19	18,604	4,716	69,204	257,939	851,084	280,368	0	0	0	0	0	0	0	0	851,084	280,368	280,367	107,597
Precinct 5&6	287.82	52,098	9,508	187,340	841,962	2,236,998	1,032,134	0	0	0	0	0	0	0	0	2,236,998	1,032,134	670,460	290,435
Precinct 7	67.64	11,938	2,680	51,294	277,925	750,658	234,869	0	0	0	0	595,430	0	107,265	0	155,228	234,869	134,022	68,959
Precinct 8	148.60	25,564	5,695	121,995	546,227	935,375	1,049,394	76,894	936,304	16,223	258,461	858,482	12,958	258,316	4,973	0	100,131	0	38,427
Precinct 9	188.35	29,297	3,815	89,259	407,471	939,436	683,999	74,574	227,263	19,049	62,735	691,254	444,603	209,784	122,730	173,608	12,133	6,154	4,656
Precinct 10	92.29	16,039	3,014	74,497	395,695	938,659	619,339	759,497	580,326	128,687	160,196	179,162	0	137,587	0	0	39,013	0	10,769
Precinct 11	320.85	56,914	10,046	226,312	960,571	1,747,261	1,927,626	0	0	0	0	1,747,261	1,927,626	499,376	535,854	0	0	0	0
Precinct 12	98.56	19,861	2,870	72,061	387,176	819,249	602,132	0	0	0	0	0	0	0	0	819,249	602,132	236,869	167,167
Precinct 13	380.53	50,387	2,461	54,922	171,262	2,599,765	0	1,550,051	0	867,432	0	598,005	0	129,569	0	451,710	0	86,930	0
Precinct 14, 15 & DE	604.20	99,140	13,222	253,359	901,881	3,563,296	1,271,782	0	0	0	0	3,563,296	1,271,782	701,443	359,524	0	0	0	0
Precinct 16	102.63	19,035	2,965	73,652	344,532	795,877	638,693	0	0	0	0	795,877	638,693	252,604	177,323	0	0	0	0
Precinct 17	98.10	17,484	3,026	64,768	348,582	842,708	417,251	0	0	0	0	0	0	0	0	842,708	417,251	255,664	115,514
Precinct 18	161.45	21,755	3,659	81,819	343,606	864,317	583,214	0	0	0	0	0	0	0	0	864,317	583,214	423,713	162,461
Precinct 19	291.94	44,983	7,239	151,026	679,288	1,939,961	906,278	0	0	0	0	0	0	0	0	1,939,961	906,278	657,819	250,768
Precinct 20	380.53	166,756	8,331	161,877	516,213	7,840,897	226,731	0	0	0	0	0	0	0	0	7,840,897	226,731	5,092,278	63,474
TOTAL	**3,827.96**	**720,528**	**101,917**	**2,058,356**	**8,956,539**	**36,155,689**	**10,754,530**	**5,366,751**	**1,743,893**	**1,610,650**	**481,392**	**13,955,523**	**4,394,851**	**3,860,154**	**1,238,469**	**16,833,416**	**4,615,785**	**8,308,487**	**1,349,894**

Table 5.7

OPTION 2 - SUMMARY OF IRRIGATION WATER DEMAND BY PRECINCT FOR PROPOSED AREA USING LAKE WATER (PUBLIC REALMS ONLY)

Water requirement per plant (liter/plant/day for Tree & Palm or litre/m2/day for Shrub & Ground cover & Lawn):
Tree: 24.00 Palm: 7.10 Shrub: 6.30 Ground cover & Lawn (GC & L): 3.10

								PHASE 1A				PHASE 1B				PHASE 2			
Precinct type	Gross land area (ha)	Plant Quantity				Full Irrigation Demand		Full Water Demand		Water Demand + 3 years		Full Water Demand		Water Demand + 3 years		Full Water Demand		Water Demand + 3 years	
		Tree (No)	Palm (No)	Shrub (m2)	GC & L (m2)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)	Public (l / day)	Private (l / day)
Precinct 1	141.07	24,329	6,691	105,226	614,224	3,329,086	0	2,817,429	0	553,702	0	255,277	0	255,277	0	256,380	0	65,490	0
Precinct 2	141.18	34,005	7,470	155,194	755,714	4,354,404	0	0	0	0	0	4,354,404	0	1,227,738	0	0	0	0	0
Precinct 3	41.01	4,706	907	16,726	69,184	365,650	0	0	0	0	0	0	0	0	0	365,650	0	189,599	0
Precinct 4	170.59	15,319	2,384	40,739	195,821	851,084	0	0	0	0	0	0	0	0	0	851,084	0	280,367	0
Precinct 5&6	7.00	966	378	9,156	38,500	121,740	0	0	0	0	0	0	0	0	0	121,740	0	34,610	0
Precinct 7	0.30	2,224	514	9,470	104,462	381,204	0	0	0	0	0	240,839	0	22,290	0	12,727	0	2,769	0
Precinct 8	10.70	7,179	1,821	29,814	217,265	743,212	0	76,894	0	16,223	0	666,318	0	211,732	0	0	0	0	0
Precinct 9	82.58	1,949	239	5,373	91,602	558,014	0	0	0	0	0	430,376	0	48,110	0	0	0	0	0
Precinct 10	19.15	3,300	1,472	26,256	221,198	886,603	0	758,964	0	128,512	0	0	0	0	0	0	0	0	0
Precinct 11	12.50	7,652	1,912	29,818	240,270	644,135	0	0	0	0	0	644,135	0	78,897	0	0	0	0	0
Precinct 12	38.51	11,777	1,450	27,837	219,932	819,249	0	0	0	0	0	0	0	0	0	819,249	0	236,869	0
Precinct 13	360.53	50,387	2,461	54,922	171,282	2,599,765	0	1,550,051	0	887,432	0	598,005	0	129,569	0	451,710	0	86,930	0
Precinct 14, 15 & DE	180.10	39,865	1,601	39,545	20,013	0	0	0	0	0	0	1,279,295	0	0	0	0	0	0	0
Precinct 16	11.93	5,187	784	15,696	134,464	442,568	0	0	0	0	0	570,206	0	202,118	0	0	0	0	0
Precinct 17	56.10	11,800	1,984	34,209	232,754	842,708	0	0	0	0	0	0	0	0	0	842,708	0	255,684	0
Precinct 18	102.67	13,835	2,220	38,840	182,006	864,317	0	0	0	0	0	0	0	0	0	864,317	0	423,713	0
Precinct 19	5.67	782	306	7,416	31,185	98,610	0	0	0	0	0	0	0	0	0	98,610	0	28,034	0
Precinct 20	113.65	15,473	4,601	73,030	423,437	1,306,054	0	0	0	0	0	0	0	0	0	1,306,054	0	276,053	0
TOTAL	**1,455.25**	**250,737**	**39,192**	**719,268**	**3,963,292**	**19,208,403**	**0**	**5,203,338**	**0**	**1,565,868**	**0**	**9,038,855**	**0**	**2,175,732**	**0**	**5,990,228**	**0**	**1,880,119**	**0**