Problem with ponds and tank storages is their potential of being mosquito breeding areas. Ponds in park areas will receive water from the adjacent park areas. As such the water would contain a high concentration of nutrients from fertilizers. This could lead to algae bloom in ponds.

6.2.1 Ponds

Besides rainfall harvesting ponds could also be designed as temporary storages for water pumped from the lakes or wetland and to be used to irrigate plants in the vicinity of the ponds. Having a temporary storage would buffer the pumping requirements during peak irrigation periods. An irrigation watering window of 8 hours a day would require a certain pumping rate to supply the water required during the 8 hours if pumped directly from the lake. But, with the presence of a temporary storage pond, pumping from the lake to the pond can be carried out over 24 hours. This would require only one third (1/3) the original pumping rate.

At the masterplan stage, pond design can only be addressed conceptually. As far as irrigation requirements are concerned, this study would identify the size of ponds required and consequently what size of irrigation area the pond could serve. With rainfall harvesting alone the ponds could only serve a limited area but if the ponds are designed with pumping from the lake to supplement the water if drawdown is excessive, the area served could be much more.

Detailed design of the ponds would have to be carried out by the individual landscape architect have considered the aesthetics and blending of water features with the landscape. The pond will definite have a dead storage (permanent storage) volume as to maintain the aesthetic function of the pond, there must be a minimum water depth for fishes and plant live to thrive. Fishes are necessary to prevent mosquito breeding. The active storage depth is the depth of storage important for irrigation and is assumed to be 1.5 m. This depth is considered reasonable, but actual depth of active storage would depend on the terrain and proposed landscaping works. Reduction in active storage depth must be compensated by larger pond areas. Typical inlet and outlet structure for these ponds can be obtained from various references and some will be selected to be incorporated as examples for landscape designers. The hydraulics of pond outlet structures will have to be checked against a standard design flood to ensure damage due to overspilling during a flood is minimized.

Ponds require large areas and there are already areas identified to be developed as stormwater detention ponds which we hope could also be used for harvesting rainwater for irrigation. Besides storm water detention ponds, other ponds could be developed within the parks to harvest rainwater. Looking at the terrain we have identified some ponds but actual shape and final location of the ponds will have to be decided by the designers of the parks taking into account other factors such as aesthetics, safety and recreation.

Three flood retention ponds were identified as potential water source for irrigation (see Map 2 in Executive Summary). The catchment areas of these ponds were estimated from PPJ's Drainage Masterplan Report. The pond area was estimated and assuming an active storage of 1m, the pond storages were computed. These were then checked against required pond storages for various sizes of irrigated areas. The results are presented in Table 6.1.

Retention Pond 3 (RP 3) in Precinct 14 has sufficient storage to cater for an irrigation demand of 0.2 Mld for a 50-yr design return period. But if we accept a 5 year return period as the design criteria, the pond could cater for a demand of 0.26 Mld.

Basing on the analysis, other than RP 3 the irrigated areas for the other ponds were too small and could not contribute much to irrigation supply.

Table 6.1 Water Availability For Existing Pond During Drought

Pond ID	RP1	RP2	RP3
Precinct	9	11	14
Catchment area (ha)	25	20	60
Pond area (ha)	3.0	0.8	15.0
Active storage depth (m)	1	1	1
Active storage (m3)	30000	8000	150000
Water Availability During Drought:			
5-Year Return period (Mld)	0.100	0.070	0.260
10-Year Return period (Mld)	0.090	0.060	0.240
25-Year Return period (Mld)	0.085	0.055	0.230
50-Year Return period (Mld)	0.080	0.050	0.200

RP – denotes Return Period

It is envisaged that the situation will be even worse if we were to locate new ponds in the parks. The three detention ponds are located at strategic low points where catchment contributing the runoff is sizeable and judging from the terrain, it is unlikely that the new ponds located in the parks would not have very large catchment areas unless major works are carried out to reshape the terrain. It is therefore felt that ponds if developed are to supplement supply, the main reliable source of water should come from other sources.

Detention ponds in parks, will also contribute towards improving the quality of runoff reaching the lake. Parks with high fertilizer and pesticide input will contaminate stormwater. A pond will capture the initial storm runoff or the "first flush" of stormwater, which is often the most polluted.

6.2.2 *Tanks*

The idea of using tanks to store water primarily as a means of reducing storm runoff at source and at the same time harvesting rainwater for washing and watering (non-drinking usage) has been mooted by JPS about 5-years ago. Subsequently, Kementerian Perumahan dan Kerajaan Tempatan (KPKT) had published a guideline for installing rainwater collection and utilization system. The design of the system has been specified in this guideline. The recommended storage capacities of tanks for various types of buildings are as in Table 6.2

Table 6.2 Recommended Tank Storage Capacity For Various Building Types

Building Type	Tank Storage(litres)
Terrace house	1120
Bungalow	1800
Multi Storey Building	Depends on type of building

An issue of concern is mosquito breeding. To prevent breeding of mosquitoes the guideline recommends:

- Use the water regularly to deplete the storage and stagnant water should be drained out.
- If rainwater is to be kept for several days use 'Abate-1-SG' to prevent mosquito breeding
- Cover the tank and even have a net cover over the outlet as mosquitoes can enter the tank through the outlet

Usage of water in tanks, especially if it is in private homes would be difficult to control. We reckon that this method would be a good way to supplement water supply and to reduce the usage of the more expensive drinking water supply for irrigation at times. However, the need to quickly empty water from the tank after the rain to prevent mosquito breeding and to ensure tha the system has storage for the next storm clearly conflicts with the need to conserve water for irrigation. In the private homes, stored rainwater if at all used for watering the plants would be a bonus and would reduce the demand of water from other sources

The recommended storage volume of tanks tabulated above is for the purpose of reducing peak stormwater runoff. If water is required for irrigation larger tanks or separate tanks would have to be provided. Size of storage required for irrigation supply depends on

- the reliability (return period) of irrigation supply imposed
- the size of the catchment area (CA) of the rainfall harvesting tank/pond
- the size of planted area (IA) to be irrigated
- the type of plants

The storage size expressed in terms of cubic metres per square metre of land to be irrigated (using a assumed 5mm/day irrigation requirement) is as tabulated in Table 6.3.

Table 6.3 Storage Requirement For Various Droughts

CA/IA	Storage required (m^3/m^2)			
	5-yr	10-yr	25-yr	50-yr
2.0	0.18	0.25	0.40	0.60
2.5	0.10	0.15	0.25	0.25
3.0	0.07	0.12	0.18	0.22

In the case of terrace houses, the rain from rooftops could be harvested. In this case the roof is the catchment area (CA). Gardens are the irrigated areas (IA). Garden area is small and the CA/IA is around the order of 3. If we consider a garden size of 50 m^2 then the size of the active storage should be 0.07 X 50 m^3 which is about 3.5 m^3 and this storage is required to ensure supply during a 5-year return period drought.

Underground drainage cells

Besides ponds and tanks for rainwater harvesting, there are available new and innovative systems for stormwater retention, which may be worthwhile considering. One such system, involve the installation of underground drainage cell (see Figure 6.1). The drainage cell is a permeable modular tanks designed for storing and transporting groundwater. Essentially, it is a permeable plastic grid. The voids are large to maximize water storage volume. Apparently the plastic grid of a commercially available drainage cell only reduces the tank volume by 4% leaving 96% of the grid volume available for water storage

In rainwater harvesting, these cells could replace the conventional ponds and tanks.

These drainage cells could replace open ponds in the parks. To store water, impermeable linings will have to be installed underground encasing the drainage cells. The advantage is water is stored underground and therefore evaporation loss is negligible. Without open ponds more space becomes available for other uses.

Even if there are ponds these drainage cells could be used together with other systems to purify water entering the ponds so that the problem of algae bloom in the pond will not become an issue.

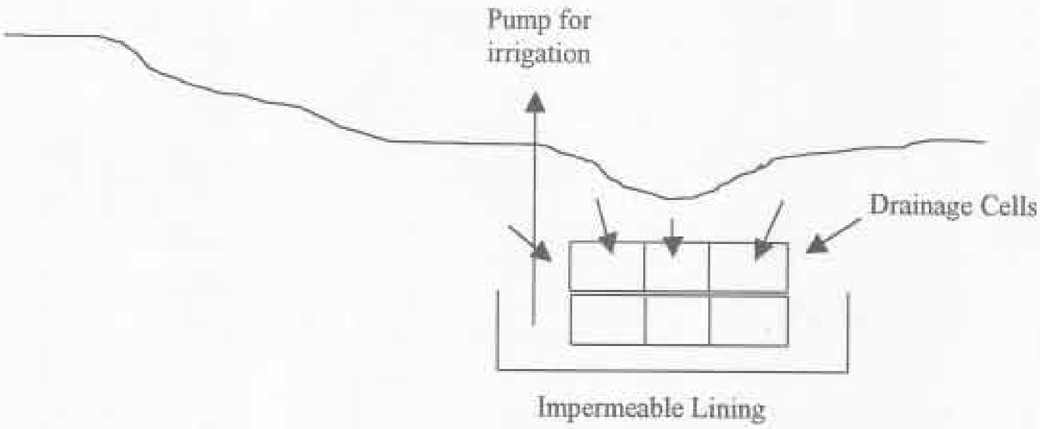


Figure 6.1: Underground Drainage Cell For Rainwater Harvesting

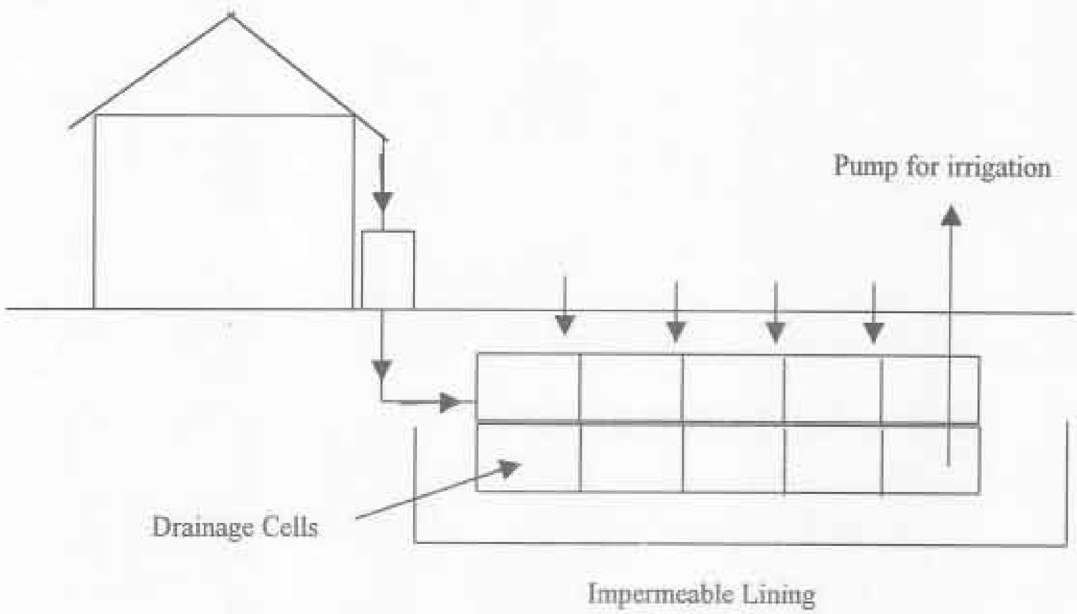


Figure 6.2: Underground Tank Cell For Rainfall Harvesting

For housing estates the provision of such tanks in every house will reduce peak flood discharge and impermeable linings could be installed to store water for irrigation (see Figure 6.2).

This technology is new to the country. JPS is currently testing the use of such drainage cells for stormwater runoff reduction in a project in Tronoh. It is recommended that PPJ implement a pilot project to assess its viability in flood attenuation and also in conserving water for irrigation before extending the concept to other areas. A possible site for this pilot project would be Taman Wawasan which is being developed.

Besides the detention ponds several other potential rainfall harvesting site were identified in the park areas. Rainfall harvesting can be in the form of pond, underground tanks or drainage cells. The development of these rainfall harvesting site will serve several functions i.e. irrigation supply, flood peak attenuation and water quality improvement.

6.2.3 Policy on Rainwater Harvesting for Irrigation

Rainwater harvesting is encouraged by JPS to attenuate stormwater runoff at source. However, the flood mitigation/attenuation function is already taken care of in Putrajaya with the presence of the Putrajaya Lake. Thus the implementation of rainwater harvesting for flood attenuation will not be made mandatory in Putrajaya but it can be selected as an option for purpose of irrigation.

6.2.4 Guidelines on Rainwater Harvesting

It is recommended that the new development especially in the private realm which are beyond the control of PPJ in terms of the day to day operation of irrigation system and government buildings, rainwater harvesting should be encouraged. Guidelines for development of rainwater harvesting are detailed in Appendix A.

6.3 Ground water

Based on the "Catchment Development and Management Plan for Putrajaya Lake Report (Draft Final), abstraction of groundwater for irrigation purposes can be done by building a well field consisting of 6 wells from the alluvium downstream of the lake so as to avoid disturbing the hydrological regime of the lake. The designed yield amounts to 0.5 cusec (10,000 gallons/hour) only, this amount is too small to be useful. Appendix B gives a detailed assessment of the ground water.

6.4 Treated Sewage Water

Under Phase 1 development, the PE (population equivalent) for Putrajaya is 100,000. Based on 100 L/day/PE, the net available water after treatment from STP1 is 10 Mld.

It is not practical to pipe sewage water to remote areas. It is envisaged that the most practical approach would be to use treated sewage water for precincts near to the treatment plant. Treated water from the sewage water treatment plant (STP 1) in Precinct 14 (available water of 10Mld) could probably be used for irrigating the surrounding areas in Precincts 14 and 15 and DE (total irrigation demand of 0.70 Mld). The water from the sewage plant (STP 2) in Precinct 20 (available water of 60 Mld) could be used for nearby areas in Precincts 5, 6 19 and 20 (total irrigation demand of 6.27 Mld). Applying water to the land for irrigation is in fact further treating the quality of the sewage water which would otherwise be released directly to the drainage system. Treated sewage water will be evaporated away and if leached into the ground will be filtered when it emerges into the drainage system.

Usage of sewage water may be sensitive in places of worship and religious significance. Therefore watering using sewage water in these areas is not recommended for instance the cemetery area in Precinct 20.

The phasing of Sewage Treatment Plant STP2 in Precinct 20 is as follows:

Stage 1	-Complete by year 2003	for 300,000 population
Stage 2	-Complete by year 2006	for 300,000 population

6.5 Augmentation from Sungai Langat

Sungai Langat is a large river nearby where external water supply could be sourced. The catchment of Sungai Langat near to Putrajaya is about 1200 km^2. This is 250 times larger than the catchment of Putajaya Lake and as such the flow in Sungai Langat is relatively large. However, Sungai Langat water is currently being tapped for water supply at the Langat mile 10 intake, the Cheras mile 11 intake and the Semenyih Intake. The Langat and Semenyih dams constructed upstream regulate the flow into Sungai Langat during dry weather and the impose

d compensation release past the Semenyih Intake is 90 Mld. Three major water users downstream of the Semenyih Intake are as below.

Table 6.4 **Committed Abstraction Along Sungai Langat Downstream Of Putrajaya**

Main water users along Sungai Langat downstream of Sungai Chuau	**Abstraction (Mld)**
Bukit Tampoi water supply intake	34
Genting Sanyen	14
Mega Steel	15
Total	63

All together the major downstream water users require 63 MLD of water which gives a balance of 90-63 = 27 Mld. Taking into account the riparian needs downstream there is very little water left for Putrajaya Irrigation needs.

Pumping from Sungai Langat would entail the construction of intake, and installation of pipelines to bring water from Sungai Langat to Putrajaya. Owing to this, other Potential sources of water for the southern area such as the sewage treatment plant STP2, the Lake or development of rainfall harvesting ponds should be considered.

6.6 Putrajaya Lake And Impact Due To Irrigation Abstraction

6.6.1 Water Balance Analysis

The Putrajaya Lake and the wetlands are the biggest and most conspicuous water bodies in the area and would be an obvious source of water. Already several areas are pumping water from the lake for irrigation and for practical reasons some areas near to the lake would need to source water from the lake and probably from the wetlands if necessary. As mentioned above, there are constraints to sourcing water from the lake as the lake performs an important aesthetic and recreational function and any adverse impact on this function due to water abstraction for irrigation would not be acceptable.

To complicate matters, the lake is developed in two stages. Stage one of the lake development is already completed and impoundment started. Under Phase 1A, the total area of the lake is estimated to be 110 ha.

The Lake will be developed to its final designed size of 400 ha under Phase 1B.

The longitudinal section of the lake and the wetlands were taken from PPJ's Drainage Master Plan (see Figure 6.3). The lake level is to be maintained at +21 M LSD. The terrain in

Putrajaya is steep. Wetlands levels are stepped up through a series of weirs to raise the water level as high as +31.65 m LSD (at wetland UN8) – an average gradient of about 1:500.

At this stage of the study we have not considered using the wetland, which covers a total area of 120ha., as a source of supply but have not ruled it out completely. Bringing water from the main lake to land of higher elevations would require some form of temporary storage at the location to be irrigated. Having some form of temporary water storage would reduce peak pumping rates. This temporary storage could be in the form of additional ponds in parks as discussed in section 6.2 above or the wetland could be used as the temporary storage. Issues with using the wetland as temporary storage would have to be identified and resolved.

Daily water balance studies were carried out to determine the draw down of the lake. A schematic of the water balance analysis is illustrated in the Figure 6.4.

6.6.2 *Sensitivity of Lake Drawdown*

The estimated total irrigation requirement from both the public and private realm is 16.8 MLD. The source of water for irrigation could be 100% from the lake or partly from the lake and part from other sources such as ponds and sewage water. Analysis was carried to determine the impact of water abstraction from the lake for various irrigation scenarios. The resulted maximum lake drawdown based on 800mm and 300mm annual runoff model respectively are tabulated in Table 6.5.

Table 6.5 Maximum Lake Drawdown For Various Irrigation Options

Option	Areas irrigated with Lake water		Irrigation Demand (MLD)	Maximum Lake Drawdown (mm)	
	Precincts	**Realm**	***Shrub Only***	**800 arm[1]**	**300 arm[1]**
1a	All Precincts	Public and private	16.8	125	420
1b	All Precincts	Public realm only	13.7	75	370
2	Selected areas as in APPENDIX SC	Public realm only	5.62	25	75

[1] *arm denotes mm annual runoff model*

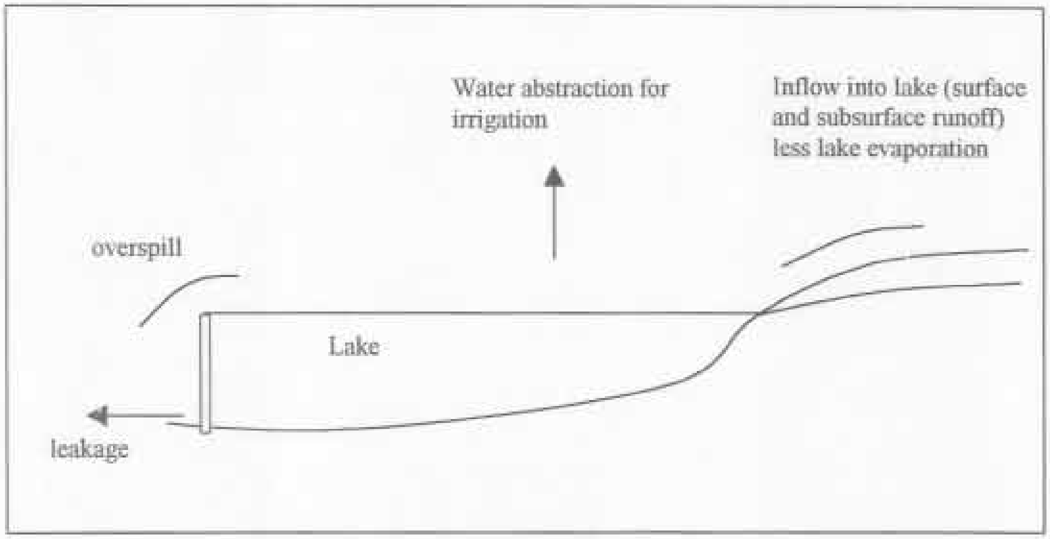
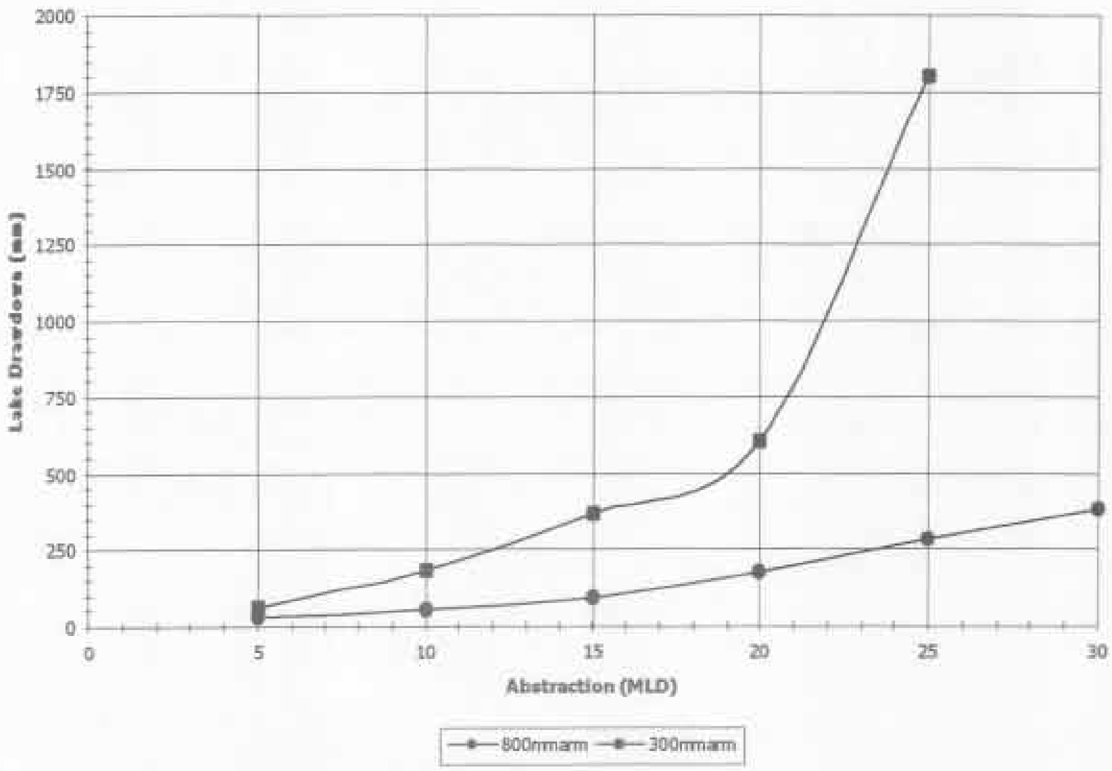


Figure 6.4 : Components of Lake Water Balance Computations

The lake drawdown due to water abstraction for 800mm and 300mm annual runoff model is presented in Figure 6.5.



arm denotes annual runoff model

Figure 6.5 Putrajaya Lake Drawdown Chart

i) ***Results of 800mm Annual Runoff Model***

Option 1a water balance study

Under Option 1a all irrigation requirements from the public and private realm will come from the lake. The total irrigation demand during a dry day is 17 Mld. Theoretically when it rains, irrigation will be reduced or cut off completely. But to allow for inefficiencies we have assumed that irrigation will be completely cut off only when rain exceeds 10mm. If rain is less than 10mm we have assumed that the full amount of irrigation will be supplied. Water balance computation was carried out using the 51 years (1947 to 1998) of generated inflow data. The maximum drawdown is 125 mm.

Option 1b water balance study

Under Option 1b the total amount to be abstracted for irrigation in a dry day is 14 Mld. With less abstraction the drawdown is lesser than that of Option 1a. The maximum drawdown is 75 mm.

Option 2 water balance study

Under Option 2 the total amount to be abstracted for irrigation in a dry day is 5.6 Mld. The maximum drawdown is 25 mm.

Sensitivity Analysis

The reliability of the computations above depends to a great extent the accuracy of estimation of inflows into the lake. It was pointed out that the observed inflow at Prang Besar seems rather low compared to the flows in rivers nearby. Therefore we have adopted a model that gave a higher annual runoff of 800mm rather than the model that gave an annual runoff of 300mm. Suppose, for reasons unknown, the annual runoff in this river is actually that low then our estimation of lake drawdown would be underestimated. The lower runoff model was therefore reevaluated and its results incorporated in our water balance study. Comparison of the two runoff models is tabulated in Table 6.5.

ii) ***Result of 300mm Annual Runoff Model***

Option 1a, 1bAnd 2

Results show that the drawdown is 420 mm and 370mm for Option 1a and 1b respectively. For Option 2, the drawdown is about 75mm but with conservation measures this drawdown can be reduced.

Conclusions

The lake drawdown scenario can be quite sensitive to the model adopted (see Table 6.5). To plan for the conservative case we would recommend that Option 2 irrigation water allocation using the lower flow model be adopted.

Finally there will be pocket areas where development of water resources especially for irrigation may not be cost effective. These areas are small isolated areas located far away from the water source and therefore to develop a irrigation water distribution system to convey water to this area will be expensive. Isolated private properties and small remote parks will fit into this category.

6.6.3 *Impact Due To Lake Drawdown*

The obvious source of irrigation water for Putrajaya would be from Putrajaya Lake. This lake has an inundated area of about 4 km^2 and is replenished by stormwater runoff from a catchment of about 60 km^2. However, the lake performs an important aesthetic function and excessive draw down would expose the sides of the lake. Informal discussions with Putrajaya indicate that the allowable draw down is about 1 metre. The depth of draw down depends on:

- The amount of water required for irrigation and this is directly proportional with the area to be irrigated. The gross area to be irrigated in Putrajaya is 38 km^2 of which 26 km^2 is in the Public Realm and 12 km^2 is in the Private Realm.
- The severity of a drought event occurring in Putrajaya and its Lake catchment.

Water balance studies indicate that the draw down is approximately 420mm (adopting the observed model at Prang Besar) if all the irrigation water needs (shrubs only) are obtained from the Lake. This is within the acceptable lake draw down limit of PPJ. However, it is not possible to source all the irrigation supply from the Lake as the economics and practicality of the delivery system as well as the 'no dig policy ' are factors that need to be considered in the selection of water sources. Lake water in conjunction with other sources and water conservation measures are recommended in order to achieve the most cost effective irrigation option.

6.7 Augmentation From Sungai Gajah

Sungai Gajah which flows through the fringe of Precinct 11 has an approximate catchment area of 2 km^2 and based on its estimated low flow of 0.16 MLD, it can only irrigate about 3 ha of planted area by direct pumping and piping. However, it is observed that during normal time, the flow in Sungai Gajah is quite substantial. During periods of normal flow arrangements can be made to truck water from Sungai Gajah rather than from the Lake which is much further away. Ideally the educational use class parcel located beside Sungai Gajah should tap water from this river using pump, this option is however no longer applicable as Sg Gajah will become a covered concrete channel.

6.8 Mining Pond in Precinct 20

The mining pond area of about 8 ha is located in precinct 20 is a potential source of irrigation water for the precinct. So far no survey has been conducted for the pond. Nevertheless, the catchment area from which this pond gets its source of water is estimated to be about 25 ha.

From analysis, this pond could in the long term sustain irrigation requirement of approximately 0.3 Mld only. This is sufficient for the cemetery (demand of 0.2 Mld) but insufficient for the nursery (demand of 4.8 Mld) in precinct 20.

7. WATER QUALITY

7.1 Putrajaya Lake

The averaged water quality index (WQI) for seven subcatchments in the Putrajaya Lake (Phase 1A) has indicated the lake water to be within Class II, whose quality is higher than the Class IV standard specified for irrigation under the Proposed Interim National Water Quality Standards (INWQS) (see Table C1 and C2 in Appendix C). Hence, water from the Putrajaya Lake is suitable to be used for irrigation.

The monitoring results have shown that the present water quality in the lake generally complies with the limits stipulated in the Putrajaya Lake Ambient Water Quality Standard except for ammoniacal nitrogen and *E. coli*. The water should be treated using standard disinfection techniques prior to being used for irrigation. In view of this, it is recommended PPJ shall continuously monitor the *E. coli* content in the Lake to reconfirm the necessity of disinfection.

7.2 Other Water Resources

7.2.1 Ground Water

Based on previous studies conducted by the Geological Survey Department (1994), the ground water within Putrajaya was observed to range from being slightly acidic to neutral. The concentrations of nitrate, sulphate and ammonia have been found to be below their respective detection limits in all boreholes. The groundwater samples also registered trace amounts of heavy metals. It is recommended that sampling of the groundwater be carried out to determine the present groundwater quality prior to being used for irrigation.

7.2.2 Treated Sewage Effluent

Effluent that is being discharged from the sewage treatment plant near to the Gate 1 of the Federal Administrative Center of Putrajaya complies with Standard A of the Environmental Quality (Sewage and Industrial Effluent) Regulations, 1979 (see Table C3 and C4 in Appendix C). It is proposed that the effluent be disinfected to minimise the risk of disease transmission during spraying.

7.2.3 *Sungai Langat*

The water quality at station no. 2917608 which is located at the upper reaches of Sg. Chuau was found to be within Class II in 1995. As the river goes into the lake and flows downstream, water quality of Class II category was observed at station no. 2916603. However, at the confluence of Sg. Chuau with Sg. Langat, the water quality deteriorated to Class III standard.

A grab sample was taken at the main river of Sg. Langat near Kg. Simpang Empat, approximately 3.4 km upstream of the confluence between Sg. Langat and Sg. Chuau. Results of the water quality analysis should that the concentration of iron, total coliform and *E. coli* have surpassed their respective Class IV limits (see Table C5). Hence, it is recommended that the river water be disinfected to minimise the risk of disease transmission during irrigation.

7.2.4 *Mining Pond*

Grab samples were taken from an ex-mining pond in Precinct 20, near to the Taman Selatan in Dengkil for water quality analysis. The water was found to be highly acidic with pH of 2.5. The concentrations of iron and manganese were found to be higher than Class IV limits (see Table C6). Hence, water from the ex-mining pond is considered to be unsuitable for irrigation.

8. IRRIGATION STRATEGIES

8.1 Introduction

As control and management of irrigation water in the public and in the private realm is very different, the irrigation strategies adopted in these two realms would necessarily be different.

It is proposed that PPJ will directly control and manage the irrigation of planted areas in the public realm. Consequently the approach in water resources development, the delivery of irrigation water and the operation of the system can be planned in greater detail.

On the other hand, the day to day operation of irrigation systems in the private realm i.e. gardens in private homes are beyond the control of PPJ. Therefore it would not be realistic to combine both systems. Guidelines will be provided for irrigation water source development within private properties to irrigate their planted areas.

8.2 Public Realm Irrigation Strategies (Source Development)

In the public realm the various potential sources of irrigation water have been examined which include:

- Rainwater harvesting tanks/ponds
- Groundwater
- Treated sewage water
- Augmentation from Sungai Langat
- Putrajaya Lake
- JBA water supply
- Sungai Gajah
- Disused mining pond in Precinct 20

It is proposed that the public realm will obtain water mainly from:

- Putrajaya Lake and
- Sewage treatment plants (STP1 and STP2)

The lake is the obvious source for water and many areas close to the lake will take water from the lake. For areas far away from the lake, delivery of water will be a problem that has to be resolved. It is convenient and neat to deliver water from the lake to the plants via pipes. But several factors have rendered this approach unacceptable. One factor of constraint is Putrajaya's 'no dig policy'. In developed areas such as in Precincts 9 and 11 irrigation pipelines could not be installed because possible pipe routes are already paved and laying of pipes will require digging. The other factor is the cost effectiveness of delivering water to isolated small irrigation areas. For these areas, although water may still come from the lake, the mode of delivery of water could be by tankers. For isolated pockets of irrigated areas located far from the lake, it will be more practical to use JBA water for irrigation.

Sewage Treatment Plants, STP1 and STP2 could theoretically supply about 70 Mld of irrigation water. This is a large source of water and it is proposed that some of this water be used to irrigate area in their vicinity so that the reliance on lake water could be reduced since Lake drawdown is a major concern. Again the delivery of water is via pipelines, which would be a practical and more effective arrangement, and by tankers if the situation and the 'no dig policy' do not allow the construction of pipelines. The proposed irrigation water demand from the sewage plants are as below.

- STP1 to supply water (0.7 Mld) to Precincts 14, 15 and Diplomatic Enclave (DE).
- STP2 to supply water (6.3 Mld) to Precincts 5, 6, 19 and 20 (excluding promenade and cemetery).

Disinfection is required for sewage water effluent to reduce the risk of disease for recreational users of surface waters and to minimise contamination downstream. Due to the presence of impurities in water, continuous chlorinating treatment is proposed as subsequent phase of treatment for sewage water effluent. Chlorination will also retard the possible growth of algae to prevent clogging of irrigation application system. Disinfection facility shall be designed to be able to supply dosages of disinfectant at least 100% higher than normal doses in order to provide disinfection in case of emergencies such as construction for expansion. The treatment system shall provide a chlorine residual concentration of 1.5-2 mg/L in the water before discharging to the storage pond.

The other Precincts will generally source irrigation water from the Lake and JBA water for certain area. Simulation studies were carried out using approximately 51 years of daily rainfall data and it was found that the drawdown is around 60 mm (see Figure 6.5) based on 300mm annual runoff model. In the simulation studies the effect of urbanization, and the need to provide for compensation flow (taken as 10% of annual average flow) and the return flow due to irrigation were considered.

To supplement irrigation water it is recommended that ponds be developed for harvesting rainwater. However, for the pond or any rainwater harvesting proposal to be effective, the catchment area contributing to the pond, the size of the pond and the weather pattern would have to be assess. If the catchment is small, a larger pond size will not help very much as not much water could be harvested. If the weather pattern is such that the there is a prolonged dry season, then a larger storage would be required to sustain the drawdown during a prolonged dry season.

There are a number of hilltop parks in Putrajaya and within these parks. However, there is not much catchment area for rainfall harvesting to be effective. Moreover siting a pond in a hilltop area creates a potential risk to slope stability and other hazards associated with overtopping of ponds and increasing of pore water pressure in hill slopes. It is difficult and costly to irrigate parks on hill, it has been proposed that (Chapter 4) parks shall be maintained natural and to adopt the reforestation concept thus obviating the need of a permanent irrigation system.

8.3 Public Realm Irrigation Strategies (Delivery)

Delivery of water to the planted area is complicated by the fact that irrigation pipelines were not considered when utility trenches were constructed for some of the existing areas. This coupled with the no-dig policy of Putrajaya makes it necessary to consider other ways to deliver irrigation water.

For areas where installation of pipelines is not possible or practical, water could be delivered by trucks to irrigate the roadside plants.

Even though delivery of water could be carried out by using trucks, these trucks could only access the roads in the area and irrigate only the road side plants. To water the interior of parks a system of pipelines within the park is still necessary. Without pipes and sprinkler systems, the interior of parks not accessible by water trucks will not be irrigated. However these areas could strategically be cultivated with for instance cow grass, which is reputed to be hardy and be able to regenerate itself when rain finally falls after a prolonged drought.

For areas yet to be developed, the new utility trenches laid will have to allow space for the irrigation pipelines so that water can be delivered directly to the irrigated areas.

8.4 Private Realm Irrigation Strategies

In the private realm, attempts have been made to develop guidelines for developing rainfall harvesting tanks or ponds. However, owing to practicality in long term maintenance and problem in bearing the cost, this shall be adopted with care.

Size of storage required depends on

- the reliability (return period) of irrigation supply imposed
- the size of the catchment area (CA) of the rainfall harvesting tank/pond
- the size of planted area (IA) to be irrigated
- the type of plants

The storage size expressed in terms of cubic metres per square metre of land to be irrigated (using a assumed 5mm/day irrigation requirement) is as tabulated below:

Table 8.1 Storage Requirement for Rainfall Harvesting Tank/ Pond

CA/IA	Storage required (m3/m2)			
	5-yr	10-yr	25-yr	50-yr
2.0	0.18	0.25	0.40	0.60
2.5	0.10	0.15	0.25	0.25
3.0	0.07	0.12	0.18	0.22

In the case of commercial buildings, the rain from rooftops could be harvested. In this case the roof is the catchment area (CA). Gardens are the irrigated areas (IA). Garden area is small and the CA/IA is in the order of 3. If a garden size of 50 m^2 is considered then the size of the active storage should be 0.07 x 50 m^3 which is about 3.5 m^3 which would be able to see through the irrigation needs during a 5-year drought event. To cater for a drought event of 50-years then the size of ponds or tanks will have to be much bigger.

Tanks are also recommended for reducing storm runoff at source. However the storm reduction function conflicts with the water harvesting function of the tank. Water stored for irrigation purposes will occupy space meant for storm water attenuation. If space permits, ponds could be constructed for water harvesting.

Conditions vary from project to project and it is not possible in this masterplan to standardise the size of tanks or ponds for the developers of private areas except to provide a chart as shown above on how various sizes of storage provide could supplement water for irrigation depending on the size of the catchment of the rainwater harvesting facility and the size of the area to be irrigated.

8.5 Proposed Irrigation Strategies in Each Precinct

Precinct 1

Within this precinct, irrigation main supply has been designed for several areas and in some areas the system have been installed. The areas are:

- Taman Botani including a plant nursery (from existing intake, E4),
- Taman Putra Perdana (from existing intake, E5),
- Dataran Putra & Perdana Walk (from existing intake, E7),
- Linear Parks 1 to 5 (from existing intake, E3),
- Promenade (from existing intake, E3),
- Governments offices in Parcels A to G (from existing intake, E3),
- Putra Bridge (from existing intake, E7),
- Bridge 10 (from existing intake, E6), and
- Masjid Putra (from JBA water)

All these areas take water from the Lake. The capacity of the systems is adequate for the type of planting intended for these areas.

Some areas requiring irrigation are located in the high grounds far away from the Lake.

- VIP Hotel
- Istana Hinggap
- Government Reserve 1

However, the irrigation pumps for Taman Putra Perdana have already accounted for the needs of Istana Hinggap and the government reserve 1.

For the VIP Hotel, rainwater harvesting facilities should be provided to store storm water runoff from rooftops and the garden for irrigation. The catchment area is limited and it would not be advisable to construct large ponds in the highland as it may undermine the soil stability of slopes. Rainwater harvested will be rather limited and irrigation would have to be supplemented using JBA supply. As water is scarce it is also recommended that this area be planted with drought resistant species.

The Public Utilities areas in this precinct are:

- DCC
- Telekom HQ
- Substation
- Bus Depot

These areas have been constructed and irrigation has not been designed for. These are small areas and it is recommended that water for irrigation in these areas be from the JBA supply.

There are about 6.1 km of road reserves and the plants require irrigation which has not been designed for. Although the roads have been constructed, it has been decided that irrigation water would have to be delivered by pipeline taking the water from the Lake.

Precinct 2

In this precinct, irrigation for Taman Wawasan, Persisiran Wawasan, Waterfront, Dataran Wawasan and the Boulevard North have been designed by various consultants to take water from the Lake (via E10 and E11). For the isolated government parcels, tapping from JBA is more practical as the development is currently ongoing (phase 1B). For the road system, pipe reticulation from pump house (PH1 at precinct 18) is proposed.

Precincts 3 and 4

In these 2 Precincts, water for the public realm areas will be obtained from Putrajaya Lake via pipe from pump house PH1 and PH2 (located at Precinct 18 and 4 respectively) and the proposed main irrigation line.

Precincts 5 and 6

Water for the parks, government reserves and road reserves in these areas will be mainly obtained from STP2 (located at Precinct 1?). However for the promenade, which is next to the lake and religious areas, water will be from the lake pumped via Pump House PH5 at Precinct 6.

Precinct 7

This Precinct is partly developed and with the constraint of the 'no dig Policy' delivery of water from the nearest source i.e. the Lake would have to be by pipeline where possible from proposed pump house PH4 (located at Precinct 8). Putrajaya Lake water supply delivered using pipeline is proposed for the road reserves and JBA water for ERL station reserve. The government reserve, city parks and the neighbourhood parks (which would be about 10% of the residential land area) will have to be irrigated using JBA supply.

It should be observed that in order to avoid digging up the paved roads for irrigation pipe laying, pipe-jacking is warranted in certain locations which will be determined during construction stage.

Precinct 8

The Lake Valley Park, and the promenade which is located next to the lake will obtain water from the Lake via pipelines or trucking (if more practical) from pump house PH4.

The surroundings of the community and neighbourhood park area are currently under construction and JBA water has been recommended as the source of water for irrigation.

Likewise the source of water for irrigating the plants in the already constructed Government institutional areas will be from rainwater harvesting or JBA supply.

Water for irrigating the plants along the road reserve will be from the lake delivered using pipeline. The irrigation requirement of the road reserves is not large. As the precinct is under construction, pipe-jacking may be required at certain paved locations that will be determined during construction stage.

Precinct 9

Taman Rimba Desa is the main park area. It is located at the hilltop and water supply is a problem. Delivery of water to this area is also a problem due to Putrajaya's 'no dig policy'. As such water, if required, have to be pumped from the lake into trucks and conveyed to this park using trucks. Due to difficulties in conveying water to the hill park, it is proposed that it should be reforested and relies on rainfall.

There is a flood retention pond RP1 which could be used for irrigating the community and neighbourhood park. However due to the scattered nature of the parks, JBA water is recommended.

Government institutional reserve, ERL and LRT will have to be irrigated by JBA water and road reserves by pipeline from the Lake.

Development of precinct is currently in progress as such laying of irrigation pipe will be difficult, pipe-jacking may be warranted in certain locations. These locations will be determined during construction stage.

Precinct 10

An irrigation system has been installed in PMR tapping water from the Lake from existing intake, E9. Water for irrigating the promenade could be taken from the lake from the pump house PH4 (located at Precinct 8). JBA water will be used to irrigate small areas in the kindergarten, surau and TNB substation and Telekom area. Water for irrigating the road reserve will have to be supplied by pipeline from the Lake.

As the precinct is already fully developed, in order to avoid digging up the paved roads for irrigation pipe laying, pipe-jacking is required at certain locations as required by PPJ.

Precinct 11

A large metropolitan park Taman Saujana Hijau with a land area of 42 ha sits on a ridge. The area is located far from the Lake and water cannot be piped to the area under the 'no dig policy'. It is proposed that this park adopt the reforestation concept so that permanent irrigation is not required.

Although there is a retention pond RP2, however due to the community and neighbourhood parks being scattered and the no dig policy, it will be necessary to obtain irrigation water through JBA water supply. Sg Gajah is no longer a suitable source as it has been planned to be converted into a covered channel.

The rest of the irrigated areas including, government reserves and the road reserves will have to rely on water from JBA water or the Lake water delivered via trucks.

Precinct 12

Parks located next to the wetland will tap water from the wetland via pump house PH6. Currently there are two water circulation pipes from the Wetland Main Pumping Station (to Upper East Wetland and Lower East Wetland) pumping water from the Lake to the wetland using the wetland to further improve the water quality. The proposed pump house PH6 is located at the downstream of the Lower East Wetland. The parks and other public areas in this Precinct will use water from PH6 for irrigation.

Precinct 13

Precinct 13 is essentially Taman Wetland. The plant species selected for both the wetland zone and the zone of intermittent inundation is able to self-sustain and perpetuate themselves after a period of drought. Hence, no irrigation system is proposed. However, for the shrubs in Taman Wetland (namely, Wetland Park) PPJ has been irrigating the shrub using truck. A more permanent system can be implemented by extending a pipe from the proposed pump PH7.

The existing plant nursery is currently tapping from the Wetland's cell through a temporary pump set. It is proposed that the pump house PH7 be located nearby the nursery and pump from the nearby Upper West Wetland.

Although the area is already developed, it is recommended that irrigation pipeline be laid to water the primary distributor road reserve areas as watering by truck in high speed roads is not practical.

Precincts 14, 15 & DE

In this area, the largest park area is Taman Rimba Alam which is to be developed as a natural park. The two large retention ponds (named as RP3) in the area with an approximate surface area of 15 ha and a combined catchment area of 60 ha. Water in these ponds can provide only 0.2 Mld of irrigation water while the combined demand for these three precincts is 0.7 Mld.

STP1 is proposed as an irrigation source for three precincts for the parks, government reserves and road reserve areas since RP3 could not meet the demand of these three precincts.

Precinct 16

The largest park area in this precinct, Taman Warisan Pertanian already has an irrigation system designed from gravity line from elevated storage tank, ST1 that is pumped by pump

E8 from intake pond IP (see Map2 of Executive Summary). Since the storage tank has a capacity of 3-month water demand, it will be self - sufficient.

The promenade will take water from the lake via E3 (for northern area of DPM) or PH3 (located at Precinct 19 for southern area of DPM).

The DPM residence's irrigation requirements have already been designed to tap water from the lake i.e. via existing intake E3.

Due to the 'no dig policy', the other government institutional reserve and the road reserve areas will be irrigated by JBA water or from the lake delivered using trucks.

Precinct 17

A pump house PH3 (located at Precinct 19) is proposed to pump water from the lake and to distribute water to the various parks, government institutional reserves and road reserves via pipelines.

Precinct 18

It is proposed that water for irrigation be pumped from pumping station PH1 located at Precinct 18 and to distribute water to the various parks, government institutional reserves and road reserves via pipelines.

The park, Taman Puncak Banjaran is located on hilly area. It is therefore preferred that the park be reforested such that permanent irrigation facilities are not required. However recently PPJ has decided to landscape the park. Owing to this strategy, irrigation facilities will therefore be required.

Precinct 19

The promenade in this precinct is next to the lake and will therefore obtain its irrigation water from the lake. The other areas i.e. the parks, government institutional reserve and road reserve will obtain their irrigation water from STP2 with proper pipe reticulation system, except religious areas which will obtain water from rainfall harvesting supplemented by JBA.

The park, Taman Lindungan is on hilly area. It is preferred that this park be reforested so that no permanent irrigation system is required. However, recently PPJ has decided to landscape the park with palms and bamboo. Owing to this, irrigation facilities will therefore be required.

Precinct 20

The park, Taman Selatan is on hilly area of the precinct. For economical reasons, it is proposed that this park be maintained natural so that no permanent irrigation system is required.

Water from STP2 (located at Precinct 19) will be used to supply water for irrigating Nursery Putrajaya and the road reserve areas. The water requirement for Nursery Putrajaya has been proposed to tap from an 'Irrigation Pond/mining pond' by the designer for the nursery. This can be used during normal period but as the contributing catchment to this pond is not big enough to withstand a prolong severe drought of 1 in 50 years return unless it is very wide which is not an economical size.

Religious areas and the cemetery will be irrigated with water from the lake (via PH 5 located at Precinct 6) as religious sensitivities may not permit the use of STP2 water for irrigation. There were suggestions to look into the possibility of using water spilled from the lake for irrigation. This source of water would not be very reliable and effective as spilling only occurs during the rainy season when water requirements are low. During the drought season when water requirement is high, over spilled water is not available.

9. IRRIGATION SYSTEM AND COST ESTIMATES

9.1 Irrigation Options Considerations

Various alternative systems have been evaluated and details are presented in Appendix J.

The recommended systems are described below.

9.2 Proposed Irrigation System

The proposed systems comprise of one or combination of the following sources/system:

a) Source from Putrajaya Lake (by pipe reticulation)

b) Source from Sewage Treatment Plant (by pipe reticulation)

c) Source from JBA (by tapping off from nearby JBA main)

d) Trucking (from Putrajaya Lake)

9.2.1 Irrigation Zone

A total of nine (9) irrigation zones have been proposed (Map 3 in Executive Summary Report). Each zone will be served by intake either from Lake or sewage treatment plant, or combination of both sources. Isolated pockets of irrigation areas which are far from water source or where 'no dig Policy' is in place, JBA water and trucking are proposed.

The summary of irrigation zones served by Putrajaya Lake, JBA water and trucking respectively are shown in table below.

Table 9.1 Irrigation Zoning And The Water Demand (Public Realm Only)

a) From Lake

Zone	Intake	Source	Precinct	Water Demand (m^3/day)
I	PH1	Lake	2, 3 & 18	457
II	PH2	Lake	3 & 4	457
III	PH3	Lake	16, 17 & 19	443
IV	PH4	Lake	7, 8, 9 & 10	355
V	PH5	Lake	5, 6 & 20	611
VI	PH6	Lake	12	237
VII	PH7	Lake	13	1029

Table 9.1 **Irrigation Zoning And The Water Demand (Public Realm Only)** (con't...)

b) From Sewage Treatment Plant

Zone	Intake	Source	Precinct	Water Demand (m^3/day)
IX	SP1	STP1	14, 15 & DE	695
X	SP2	STP2	5, 19 & 20	6269

c) From JBA Water Main

Zone	Intake	Source	Precinct	Water Demand (m^3/day)
		JBA Main	All precincts Except 3, 4, 12, 13, 17, 18 & 20	924

d) Trucking (From Lake)

Zone	Intake	Source	Precinct	Water Demand (m3/day)
		Lake	11 & 16	95

Detailed water source / demand for each landuse area is given in Appendix SC of the Executive Summary.

9.2.2 *Mechanical And Electrical Consideration*

The number and capacity of pumps has been selected to provide a minimum standby capacity of 50 %. Pump house can be of either concealed type (underground) or exposed type (above ground). The exposed type is proposed based on the following reasons:

a) Above ground pump house provides better access for installation, operation and maintenance works.

b) There is no chance of the electrical switchboards and pump motors being flooded.

c) Artificial rocks and vegetation can be used to camouflage the pump houses.

The intake design criteria are given in Appendix D and the pump capacity required for each intake is tabulated in Table 9.3.

9.2.3 Pipe Reticulation Consideration

The pipe reticulation is proposed based on the following design criteria and assumptions:

a) The pipe sizing is based on a 8-hours watering window (areas that required less watering window will have to be irrigated in a staggered order);

b) The velocity in pipe is limited to 1.5 m/s; and

c) The pipe is proposed to be of high density polyethelene (HDPE for pipe less than 300mm diameter) or mild steel concrete lined (MSCL for bigger size); and

d) Pipe - jacking is warranted at certain locations to avoid digging up paved roads for irrigation pipe laying.

The proposed pipe route and the pipe sizes are indicated in Map 2 and Map 2a – 2h (Executive Summary). The pipe sizes vary from 110mm to 350mm diameter.

Typical pipe location along road, common utility trench (CUT) and promenade are shown in Figure 9.1a – 9.1c, Figure 9.2a – 9.2c and Figure 9.3 respectively.

9.2.4 Storage Pond for Treated Sewage Water Consideration

After the effluent from the sewage treatment plant has been treated, it will have to be stored before applying to the irrigation system as timing of inflow into the plant may not coincide with the irrigation window. Hence additional storage pond has to be provided and the design consideration is based on the following criteria:

a) Storage capacity of 1 day demand;

b) Storage pond depth of 3m with a free board of 0.6m; and

c) Storage pond side slope of 1(V) : 2 (H).

9.2.5 Trucking Consideration

For areas that have already been developed, being developed or substantially completed (in Precincts 11 & 16) or surrounded by developed areas (e.g. Precinct 11) where 'no dig policy' is a constraint, irrigation by means of trucking have been proposed. The design consideration is based on the following assumption;

a) Average truck capacity of 3 m^2 per truck; (the truck can be either $1m^3$ or $10m^3$ truck pending on road traffic constraint)

b) Truck trip of 6 times per day;

c) Normal working hour of 12 hour per day;

d) Truck kiosk of 8 truck capacity for water refilling;

Based on the precinct boundary and the total number of trucks required, two (2) trucking zones have been proposed as below. The layout plan of the truck depot and kiosk is shown in Figure 9.4 and 9.5 respectively.

Table 9.2 Proposed Grouping of Trucking Zone

Group	Precinct	Requirement of Truck			
		Number	Depot & Kiosk Location	Depot	Water Refilling Kiosk
1	16	1	Prec. 12*, 13* & 15	2 No. (25m x 25m)	2 No. (20m x 40m)
2	11	4	Prec. 7 & 8	1 No. (35m x 35m)	1 No. (20m x 40m)

*Note: * The kiosk & depot as proposed in Precinct 12 & 13 respectively is provisional only and will be utilised in the event that the kiosk or depot location in precinct 15 cannot be made available.*

9.2.6 Locational And Design Criteria For Irrigation Facilities

Site identification and selection for pump houses/intakes, truck depots (for overnight parking and repairs), water filling stations (for trucks) and ponds for storage and disinfection (of treated water from the sewage treatment plants) are to be undertaken by the respective planners or designers for the precinct. The locational and design criteria as given in Appendix E are to be used as guidelines in site selection and planning and design of these facilities

9.2.7 Cost Estimates and Area Required For Irrigation Facilities

The cost estimate for capital cost as well as operation and maintenance (O&M) cost per annum are generated and tabulated in Table 9.3. The summarised estimates represented in Table 9.4 below.

For O&M cost, the irrigation frequency is based on 260 day per year assuming irrigation is required for day that rainfall is less than 5mm (from Chapter 2).

Table 9.4 **Grand Summary Of Cost Estimate For Proposed Irrigation System**

	Capital Cost RM	Annual O & M RM
Pipe System		
Intake & Pump (at Lake & STP)	7,560,000	607,593
Pipe Reticulation	13,650,900	273,018
Watering System	4,589,052	229,454
Intake Pond Excavation at STP	683,664	13,673
Disinfection for STP	150,000	86,792
Sub-total	**26,633,616**	**1,210,530**
Committed Costs	6,536,561	
Truck	650,000	353,600
JBA Water	1,000,000*	1,453,563
Operation , Maintenance & Management		
Tools & Equipment	200,000	10,000
Integrated Irrigation Management (IIMS)-soft & hardware	1,000,000	50,000
Subtotal	**1,200,000**	**60,000**
GRAND TOTAL	**36,020,177**	**3,077,693**

*** Allow Cost for tapping from existing JBA pipe*

9.3 Irrigation Application System, Scheduling Concept And Centralised Control System

The commonly used watering system which are Spray System and Drip System as well the basic concepts of irrigation scheduling concept comprising of Block System, Valve-In-Head System and Quick Coupling System and the proposed irrigation centralised control system for PPJ are described in details in Appendix F.

10 INTEGRATED IRRIGATION MANAGEMENT SYSTEM

10.1 Objectives

The main objective of the Irrigation Irrigation Management System (IIMS) is to enable systematic irrigation management, improve efficiency of water allocation and optimised management of water resources. Irrigation is mainly targeted at maintaining the soil moisture in the planted areas to an optimum level that satisfy the water requirements for plant survival and growth and at the same time do not promote water wastage. Knowledge of the status of soil moisture is thus the key to systematic irrigation management and soil moisture can be monitored by direct measurement of soil moisture using tensiometers or indirectly by monitoring rainfall and evaporation. Besides, the overall irrigation system in Putrajaya is complex. Eventually, there may be more than 100-pumps (mainly booster pumps to supply pressurized water to the sprinklers and driplines). In certain areas water is supplied by truck. Source of water comes mainly from the Putrajaya Lake, supplemented by water from sewerage treatment plants. There is a need to monitor and manage this system.

With modern electronics and communications technology, it is now possible have remotely located sensors recording rainfall, water level, evaporation and soil moisture and automatically sending the data to the irrigation control center which could be in PPJ headquarters. Similarly, the pumps in the irrigation system and their status can be monitored. Real-time data provides the irrigation manager with knowledge of the current status of the irrigation areas with which he can use to better manage the irrigation system.

The most direct indicator of irrigation requirement is soil moisture and if the soil moisture of various areas can be monitored then the irrigation manager or an automated system can be programmed to supply the irrigation water.

Indirectly, soil moisture can also be estimated by monitoring other contributing factors to soil moisture, such as rainfall. For instance, if it is already raining heavily in certain Precincts, then irrigation in that Precinct can be cut down thus saving water.

Besides the day to day allocation of irrigation water the irrigation manager also needs to monitor his water supply status and to implement water conservation if it is found that the supply has drop below critical limits. If the drawdown of Putrajaya Lake, which is the main source of irrigation water supply drops below a predefined critical level then its time to implement water conservation measures.

A decision support system (DSS) is proposed to assist Putrajaya's irrigation manager in the operation of the irrigation system The conceptual design of the DSS will be developed in this study outlining the various methods whereby water requirements of various irrigated areas could be estimated and how this could lead to a decision on how much and when to supply irrigation. Eventually the DSS will be in the form of a computer software residing in the irrigation central control center with real-time hydrological and climatic data will be available at this control center via a SCADA system. The development of the software for the DSS and the SCADA system is beyond the scope of this study and will not be attempted.

10.2 Remote Data Acquisition For Irrigation Management

To be able to manage the system remotely, real-time data on the status of water and catchment conditions must be available. This would require the setting up of a network of hydrological stations with telemetric links to the Irrigation Control Centre (ICC).

NAHRIM (1999) had proposed a hydrological network comprising, 5 rainfall stations, 7 streamflow stations and 5 water level stations. These stations could be used for the purpose of real-time hydrological monitoring and remote automation of irrigation. The locations of these stations are as shown in Figure 10.1.

NAHRIM's proposed water level station at PWL5 would be adequate for monitoring the Putrajaya Lake level but additional water level stations will be required for ponds and wetlands which are meant for irrigation water supply and where drawdown of water from these water sources would be of concern to Putrajaya's irrigation manager. The exact locations of these water level stations could be specified as and when pond locations are confirmed.

Evaporation does not vary very drastically with location. The average pan evaporation in Putrajaya is about 4.5 mm/day and this value can be used if evaporation data from the proposed Automatic Weather Station in Putrajaya are not available.

The most important parameter as far as irrigation is concerned is soil moisture. It is therefore proposed that a network of soil moisture monitoring stations be set up. However, soil moisture is a relatively variable characteristic compared to evaporation and even rainfall, as soil moisture is affected by changes in rainfall, soil type, terrain, plant species and also the depth at with it is being measured.

10.3 Irrigation Control

There are two major types of irrigation system:

- Pipe irrigation
- Trucking

10.3.1 Pipeline Irrigation Control

Fig. 10.2(a) shows a schematic of a typical pipe irrigation network. Water is pumped by the main pump from the water source e.g. Putrajaya Lake or STP2 pond and is conveyed via pipelines to various target irrigation zones. At the various zones there are booster pumps to supply pressurized water to the various areas where there are satellite controls which further allocates water to individual distributor lines that service the various irrigated sub-areas. The satellite controls allocate water to individual distributor lines according to preprogrammed time schedules. Each line finally delivers water to the plant either through drip lines or sprinklers.

Drip lines and sprinklers have a predesigned rate of water delivery. They are therefore preset at the time of installation and during the operational phase, the rate of delivery cannot be changed. The satellite controls can be programmed to open the valves of individual lines at user selected time schedules and time intervals. Therefore the lowest level of irrigation control would be at the satellite level. If more water is required the satellite control can be programmed to irrigate more frequently or for a longer period of time. If satellites are linked to a soil-moisture meter (such as tensiometers, gypsum blocks) local control would be possible as soil moisture would be the most accurate indicator of need to irrigate. Each satellite normally control between 16 to 32 sprinklers and driplines. However, based on experience in some of the already developed irrigation areas in Precinct 1, it is estimated that the number of satellites would be in the order of 2500. Remote and automated control at the level of satellites would be expensive at the rate of RM 5000 per control. Moreover, the measurement of soil-moisture has reliability problems. Manual control would require substantial manpower and is not recommended for day-to-day operations. Occasional adjustment to control e.g. during a drought may be possible.

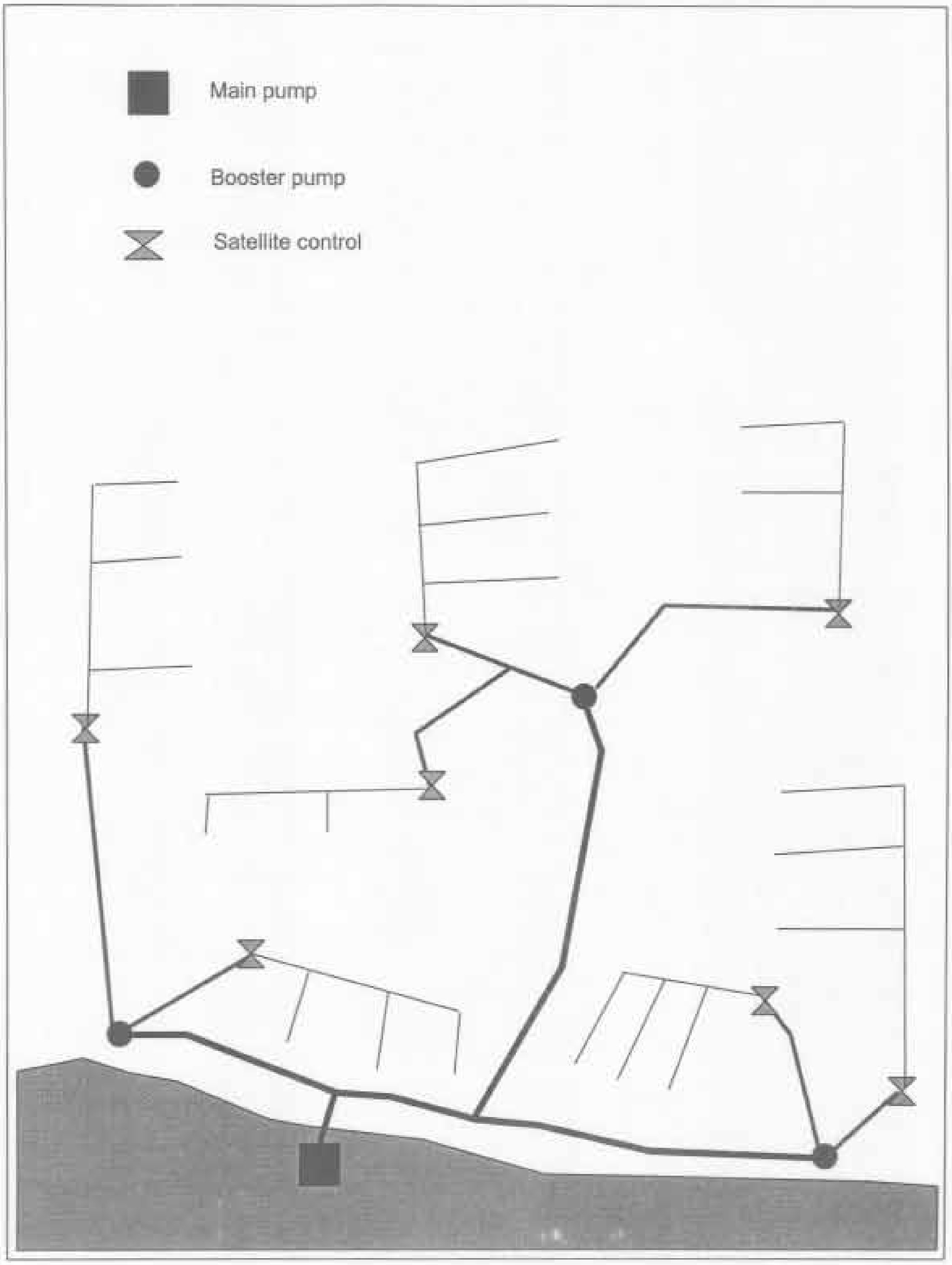


Fig. 10.2(a): Schematic of a Typical Pipeline Irrigation System

The next level of control would be at the level of booster pumps. If booster pumps are not activated then irrigation would not occur even if the satellites trigger valves to open for irrigation. The number of booster pumps is much lesser, of the order of 70 to 100. The level of control is at zone level. It is envisaged that there will be a need to under irrigate certain less important areas when water resources availability is critical. By under irrigation, the system should be able to supply, say, half, one-third or quarter the normal supply. To accomplish this, the satellites must be programmed to irrigate in short time intervals several times per day instead of a single application per day. The level of control at booster pump level is recommended.

10.3.2 Trucking irrigation control

In areas irrigated by trucking, water allocation is also dependent of soil moisture and water availability. Irrigation involves transporting water to the area and spraying water on the plants via a hose. Process is very much man-power dependent and efficiency and evenness of water application is lower.

The overall irrigation of Putrajaya within the Public Realm involves two major types of system. A system for determining the need for irrigation that caters for both systems is required. Since direct measurement of soil-moisture is not an easy task for a big area like Putrajaya, it is proposed that indirect methods to monitor soil moisture be adopted. The water balance approach to compute soil-moisture coupled with some measurement so of soil moisture for the purpose of validation is proposed and described below.

10.4 DATA FOR WATER BALANCE ANALYSIS

A decision support system (DSS) based on an irrigation water balance model is proposed. The aim of water balance computations is to indirectly estimate the soil moisture and provide a basis for activating pumps in areas where irrigation is delivered via pipelines and activate trucking of irrigation water where irrigation is to be supplied via trucks. The concept behind the water balance model will be developed under this study. It is envisaged that the water balance model will be updated regularly using real time information from the proposed monitoring network. The data requirements of the DSS are as described below.

Rainfall

Rainfall would be the single most important parameter in the water balance equation. The amount of water contributed by rainfall is substantial. Another characteristic of rainfall is that it varies significantly from area to area and fluctuates significantly with time. This is especially so in west peninsular Malaysia as the rainfall here is localised compared to monsoon rains, which are often widespread. Duration of rainstorm is often short (often lasting 1-3 hours) and the rainfall intensity can be high.

Rainfall in the west coast of Peninsular Malaysia is dominated by localized intense thunderstorms. The rainfall can be very intense (intensities of 20-30 mm/hr) are common. Such rainfall would have more than replenish the water requirement in the planted areas and irrigation would not be required. As such it may be necessary to check rainfall as frequently as every hour so that timely action could be taken to adjust the supply.

Evaporation

Pan evaporation is about 4.8mm/day and does not vary very much with area. Pan evaporation data could be recorded and sent daily to the ICC as an input to the water balance analysis. The water balance equations would require potential evapotranspiration (Eto) values. Epan values will be converted to its equivalent Eto by multiplying Epan with an appropriate pan coefficient Kp before being used for water balance analysis. Pan evaporation data as it is collected currently by JPS and Jabatan Perkhidmatan Kajicuaca (JPK) is a manual process and which could not be automated for remote monitoring.

Soil Moisture Characteristics

The most important parameter for irrigation is soil moisture. There are instruments for monitoring soil moisture such as tensiometers, gypsum blocks, moisture meters. The reliability and representativeness of readings varies.

Indirect methods of estimating soil moisture and hence when to irrigate

Several properties of soils are important for estimation of irrigation requirements. The properties include:

Field capacity (FC) determines how much water the soil can retain against gravity. Obviously clayey soil will have a higher FC then sandy soil.

Wilting point (WP) is the moisture level below which the plant will wilt and die.

The total available soil moisture (TAM) is therefore equal to:

TAM = FC-WP .... (10.1)

The readily available soil moisture (RAM) is a fraction of TAM i.e.:

RAM = p.TAM .... (10.2)

Where p is a fraction depending on type of plant

Typical p values ranges from 0.3 to 0.7

Indicative values of FC, WP for various soil types are given below:

Soil Type	FC (%)	WP (%)
Sand	4.79	3.17
Fine sand	3.29	1.33
Sandy loam	9.69	4.17
Fine sandy loam	16.80	8.93
Silt loam	23.36	6.12
Silt clay loam	21.70	5.02
Clay loam	24.15	11.55
Clay	31.12	25.70
Loam	37.90	19.03

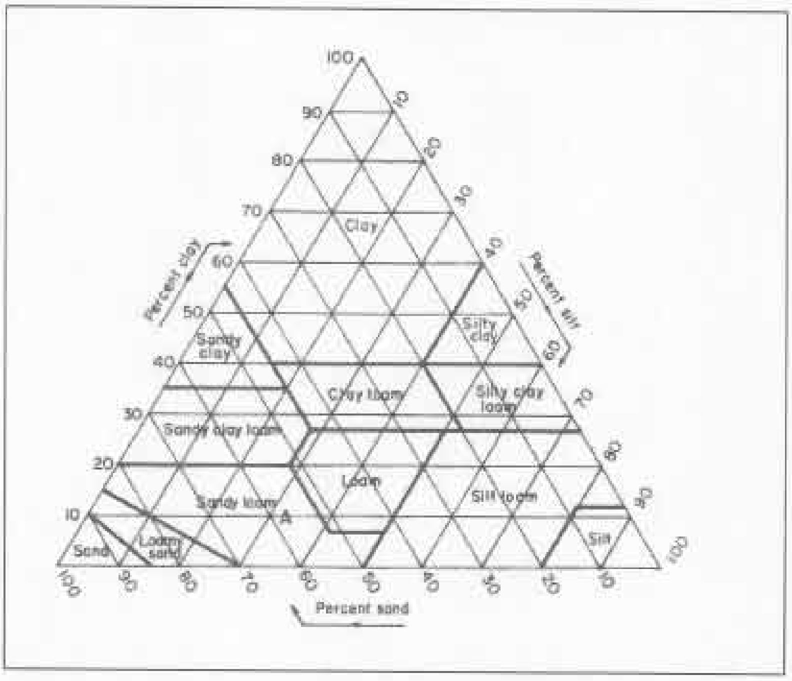


Figure 10.3 (a): Classificaton of Soil Types

10.5 PROPOSED TELEMETRIC SYSTEM

Under the City Control Center (CCC), there will be a network of telemetric rainfall, water level and an automatic weather station in Putrajaya (See Figures 10.1 and 10.2)

These data are monitored on a real-time basis, by the Parks and Environmental Management System (PEMS) Module of the CCC. Tensiometers could be installed at some sites and data transmitted to PEMS.

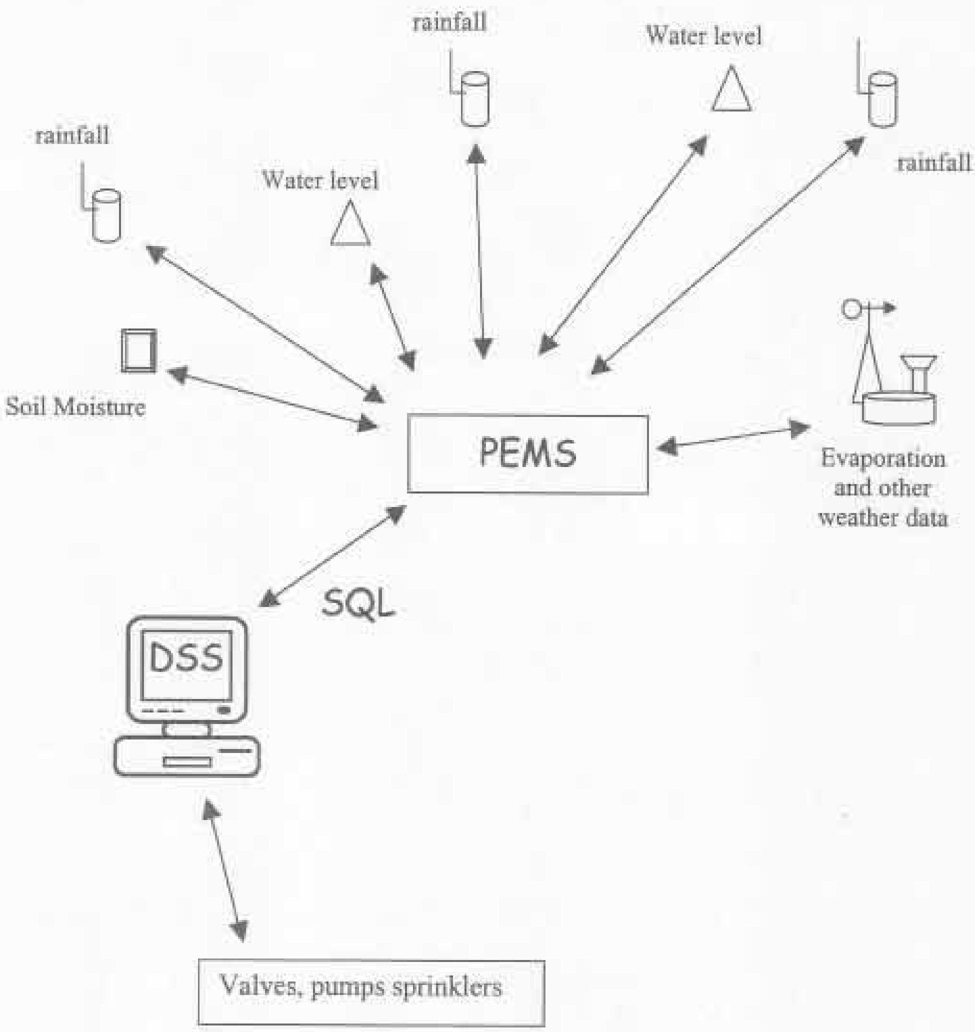


Figure 10.3 : Remote Hydrological Stations