USING GEOGRAPHICAL INFORMATION SYSTEM (GIS) TO DETERMINE THE WATER CATCHMENT AREA: MALAYSIA APPLICATION STUDY

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Introduction

Malaysia has a vision to be a full developed and industrialised country by the year 2020. With respects, the infrastructures provision is now become a major consideration to develop widely in the country. In order to achieve the vision, the government is still confronting with one main enigma and obviously referred to the water supply system, especially in the generation and the distribution process. This situation become critical in 1998 where 80% of *Klang Valley* area mostly are residential and industrial consumer experienced a very painful insufficient water supply until the government imposed a water-rationing program to the consumer. Why do we need water rationing while we have our own natural resources? The situation just open up the eyes of responsible departments and the role of planners become significant as such as to look after the comprehensive land use planning approach as a tool-kit to solve that problem. Thus, according to *Department of Forestry of Selangor State*, the water problem mostly caused by illegal logging, uncontrolled agricultural land opening and illegal or unsuitable industrial site location including harvesting activities which, eventually at the end altering and declining the existing and potential water catchment areas. To

address it, this paper describes on the application of GIS as a new technique of approach to determine the potential of water catchment areas in *Selangor State* and to provide an opportunity to computer processing of geographically references data, which add a new dimension on environmental management and planning development.

Why GIS? GIS provides the facility to extract different sets of information from the data and visualised as required, thus allowing the system to produce exactly the needs of the user *(Hamer, N., 1995)*. Thus, it also can equip an analysis and presentation of large volumes of information required in decision-making process. In form of digital data, analysis and modelling can be performed and for example; selecting the area or building, extracting or sieving the map layer, capturing data, data storage and etc. This natural environment which is in *Islam*, the so called signs of *Allah (sentence of Allah)* or the proof of existence of *God (Al-Quran, 3:83)* however should be converted into a digital format before it can be used in the analysis stage (Lukman et al, 1999). All these data or parameter, which were used in determining the water catchment area, with the method of analysis and study findings will be discussed in detail further.

The Study Background

This study was fully conducted by utilising GIS related software that are *MapInfo Ver. 5.0* and *Vertical Mapper Ver. 2.0*. Both are chosen due to their ability to produce map, to manage data and to operate elevation analysis. Hence, the choicest arguments emerged that both tools are capable to edit and create analysis within a shorter time in map development (which is crucial in planning environment).

For the purpose of the study, three (3) areas (district) have been focussed namely *Daerah Gombak, Daerah Hulu Selangor* and *Daerah Hulu Langat*. Most of these three districts area are covered with a catchment area which function as the main raw water resource supply of the state *(refer to Figure 1.0).* At the same time, they are consists of several important geographic criterions, which

are potentially identified to be reserved for water catchment area. Most of the areas to be studied are located at the foothill of *Banjaran Titiwangsa* that is recognised as the backbone of *Semenanjung Malaysia*. Generally some rivers run into the *Negeri Selangor* are started from here. Hence, for the research purposes, the broad planning process by using GIS, according to *Marzuki (1996)* will be embarked to facilitate more manpower and cost.

Water Catchment Area Characteristic

The public, even within related government's department always argues what is a water catchment area. As a simple and upon working definition, water catchment area is an area from the water intake point at any water treatment plan and upstream which including all the rivers run into the main river *(refer to Figure 2.0)*. Generally its consists of rich forestland in a very natural profile. Consequently, the water catchment area working definitions that extracted from the GIS database, are based on the guidelines prepared by *Department of Town and Country Planning, Peninsular Malaysia.* The definitions are as follows:

- the area situated upper than water intake point
- the area situated upper than 100 m from sea level
- the area situated at more than 10° slope
- existing dams and their catchment
- the area situated at the surface on underground water

The natural profile defined and used here that advocates the area suitable for water catchment area are based on information gathered from a literature review and extracting from a various responsible government department. Upon the literature review, most of the areas are covered with forests and rivers *(Mays, L. W., 1996)*. It should be protected and managed properly owing to their essentiality as follows:

- to control the water resources quality apparently for water supply purposes
- to ensure enough water resources
- to optimise the land uses, and
- to achieve a balance between development and environment.

In this research, the identified resources must be viewed holistically in concern with the need of society and water boundary itself as a complex living ecosystem. Another factors involved in defining the catchment area are the distribution of rainfall and its quantity. Identically, the land topography, stream network, type of vegetation, river catchment, geology, soil and etc, are the most important characteristics that should be associated with engineering aspects. Recently, in order to protect the existing catchment area, few regulations had been set-up, such as a guideline to avoid any development at the high land up to 150 meter.

The total area of water catchment area and the area of upstream, which are facing the reservoir/ dam, are the area with high level of sensitivity. This physical form guides the river run into the dam. In order to ensure it always be protected, the locations of the highest peak of topography are first to be carefully aligned. Otherwise, the amount of the resources water will effect the reservoir water level. Because of this reason, it was hard to determine a suitable stream-channel runoff to locate a new water treatment plant. A several related factors should be included such as the density of water runoff, the length of channel area, sedimentation factors and the index of biochemical. It becomes the crucial part in the water supply system. This implies obviously that the location of water catchment area sites should be restricted. The best approach is by putting water catchment area outside the developed area and creating a buffer zone in between.

Identification of Water Catchment Area: Conventional Approach

Previously, a conventional approach map overlaid has been used in identifying of water catchment area. After listing the parameters or factors to zone the water catchment area, either in a manual way or automated (computerised), the parameters were overlaid and the finding come-up with a measurements which based on the characteristics priority listed before. The disadvantages of this manual method are too slow, inaccurate and betray to mistake or error. The GIS cost-effectiveness method is become genuinely acknowledged to undertake the process. Besides from processing the spatial data, it can be stored and retrieved perfectly the attributes or information gathered with the spatial data.

The Database Development: Terrain and Man-Made Types of Data

The topographic map data in a digital form presents and enormously a very useful database for the development of GIS. The *Department of Surveying and Mapping, Malaysia* is responsible department for the cadastral surveys (topographic map) of Peninsular Malaysia and mapping process for the entire country. The establishments of Computer Assisted Mapping System (CAMS) in 1988 introduces significant impact on activities such as data acquisition, storage and retrieval, manipulation and generation of output (maps) which could be managed efficiency and accurately. The system also enabled to create Digital Elevation Model (DEM), Digital Terrain Model (DTM) and Global Positioning System (GPS–to put the area in the world locational space).

Since, the GIS operation requires a digital form of database, and for this research, in identifying a possible digital data, some literature search and discussion with various departments and agencies had been conducted to define the data that can rely on. The Table 2 shows the available data have been collected and available to use. Due to a complexity of data management and in line to produce a simple order for retrieving process, one set of criteria has been simplified. The final listed criteria set-up is namely:

- existing reservoir
- existing acquifer (ground water) area
- existing water catchment area (relate with river alignment and forest)
- topography-slope
- topography contour, and
- existing land use

Then, after the map based data have been collected, the data are divided into two categories either in form of digital or hard copy. The digital form data is readily use liken to hard copy which must be converted into a digital form first. The process of conversion started with scanning the map in their true scale, followed by digitizing with putting raster image together with geocoding and creating attribute table. Accordingly, the creations of coverage by the digitizing stage results of data, is referred to the unit of scale in the computer. These coordinate automatically defined according to the position of the map. The *MapInfo Ver. 5.0* can transform the digitized coverage (computer) coordinates into a common coordinate system (in real world) which allows identical features in different coverage to be represented by the same coordinates. In some cases, compensation for image or map distortion may be necessary *(Devereux et al, 1990 in Suntheralingam, R., 1994)*. The process is called coordinate transformation and for this research the transformation from *Cassini-Sodner* into *Rectified Skewerd Orthomorphic (RSO)* for *Selangor States* uses. Each element or geometry in the map has parameters that tell the characteristics such as line types, symbols, colours, etc.

Study Analysis

This section will describe the analysis of the criteria. The findings of the analysis are as follows.

Existing reservoir/ dam

All the existing reservoirs/ dams are totally preserve and protect from any development. They are properly and accurately aligned and will be put as the main criteria to be conserved.

Existing ground water resources (acquifer)

Same as existing dams, the areas which have been traced are classified have a very high sensitive level that should be recovered too. So far, from 4 areas have been discovered in whole the Selangor States, two zones are located in the study area.

Existing water catchment area

Recently, water catchment area was identified as a catchment area for each reservoir and water intake point. Referred to existing reservoir catchment area, water intake point catchment areas are still not determined yet. So, in this research by using a similar concept of zoning the reservoir water catchment area, several new locations of water catchment area for water intake point also have been discovered. Surprisingly, there were few new areas being developed with industrial, agriculture and harvest activities (after cross reference with land use map). For that areas, its were defined have a moderate sensitivity level compared with untouched reservoir water catchment area.

Topography – slope analysis

The Department of Town and Country Planning of Selangor State, has divided the slope class into 3 categories that was tabulated in Table 5 By sieving the map of slope and existing water catchment area, most of the areas above 25° are located within the catchment area. It shows that the importance to gazette

that area which classified has a very steep slope and suitable for any type of development.

Topography – elevation analysis

For the elevation analysis, the research team has classified the findings into three categories. The over 300 m high areas are categorised has a high sensitivity level which are found mostly at mountainous area. A hilly area (300m~100m) is defined that have a moderate level of sensitivity which potentially bared into landslide, erosion and fast flood. The rest are categorised as a lowland area (100m and less).

Land use analysis

In general, more water catchment areas have found, a more quantity of raw water can be produced. In the other hand, more areas developed within the catchment, the water quantity not only decreased, but it is also will be polluted the water resources. For that reason, it was very grateful when the *Selangor State* still has a huge number of coverage of forest compared with built-up areas (refer to Table 8.0).

Findings of The Study

Finally, the overlaid coverage map of identified criteria will be looked identically. Before that, the priority indicator of each criterion is determined with a suitable weight. The priority of criteria is carefully defined according to their importance in zoning water catchment areas. All the maps were overlaid by using *'Overlay Map'* operation in the software. As a result, the scores appeared then divided into four ranks with four categorise and then called as the comprehensive Management Plan.

Management Zone	Activity(s) Allowed	Selected Guideline(s)	Immediate Action
(1) Conservation	None of development allowed except very passive activities such as research, education and nature tourism.	Guideline of Uphill Development, 1995 by *Dept. of Town and Country Planning, Federal.*	Need to be conserve and control strictly especially to the approved development inclusive the under development project nearby the reservoir and aquifer.
(2) Preservation	None of development allowed except very passive activities such as research, education and nature tourism, agro-base tourism, recreations and controlled logging activities.	Guideline of Uphill Development, 1995 by *Dept. of Town and Country Planning, Federal.*	Same as above and camping activities are not allowed within the existing water catchment area boundary.
(3) Control (1st category)	Low scale development (environmental friendly)	Guideline of Uphill Development, 1995 by *Dept. of Town and Country Planning,Federal.* Environmental Quality Order(Listed Activity) (Environmental Impact Assessment), 1987	Monitoring, assessing and reducing proposal at hill slope. Development at 25° slope is not allowed immediately.
(4) Control (2nd category)	Very controlled logging, certain types of crop, certain types of harvesting, certain developments allowed, no mining activity allowed and no nuclear and radioactive based activities allowed.	Environmental Impact Assessment, 1974 (Act 127) and Amendment (1985) (Environmental Impact Assessment Guidelines For – Groundwater and/or Surface Water Supply Projects), Environmental Quality Order (Listed Activity) (Environmental Impact Assessment), 1987, Riverfront Development Guideline, 1993 by *Dept. of Irrigation and Drainage, Selangor..*	Re-zone industrial area. Demolish setinggan area at the bank of the river. Add-up buffer zone at both side of river. Identifying the land use not the activity of the development proposed.

Source: Water Catchment Area Study Team, 1998.

Conclusion

The findings of the analysis have been used to develop a comprehensive Management Plan pertaining to the development of catchment areas for the selected districts with the highest degrees of sensitivities. The Management Plan has identified and divided the studies area into four (4) specific zone viz. the Conservation Zone, Preservation Zone, Controlled Zone 1 and Controlled Zone 2. The linking of GIS with simulation of environmental considering heralds a new era in environmental management. Indeed, the multifaceted nature of the environment calls for a multi-disciplinary approach to better understand, monitor and manage it. But, the greater challenge is the very nature of the environment. The more we learn to model its complex structures and process, the more it yields of its complexities that demands even more integrated systems to model it (Amstrong, H. D., 1989).

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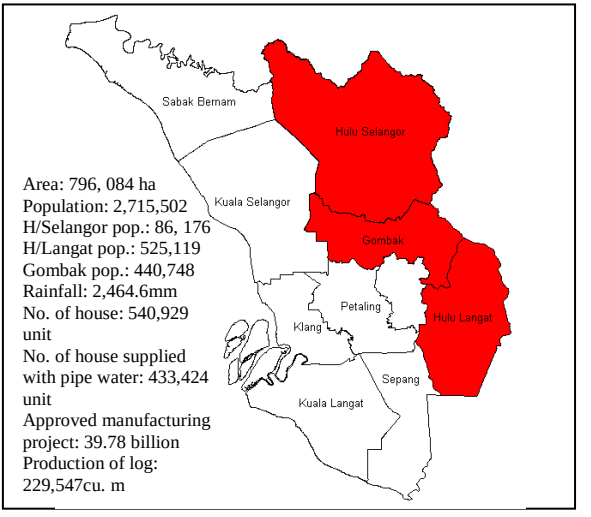
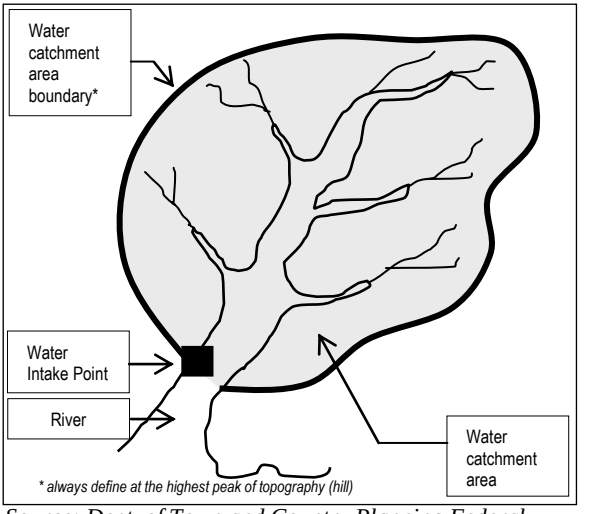
APPENDIX 1 – List of figures

Figure 1.0: Selangor State: The Study Area



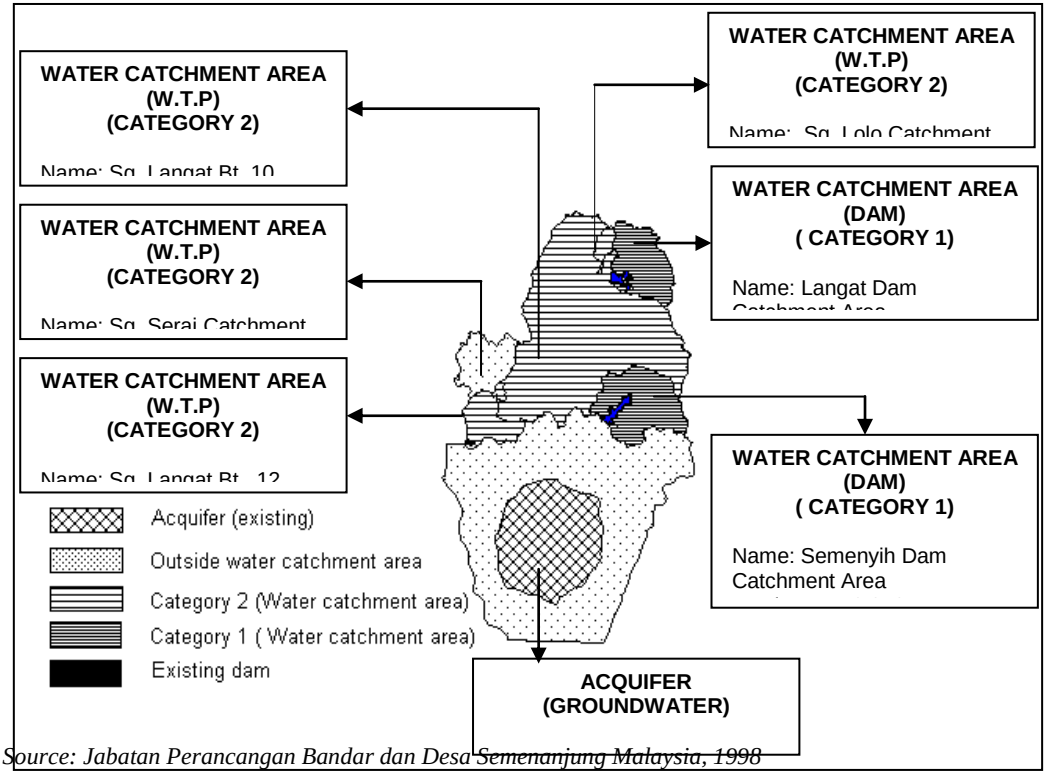
Source: State Secretary, 1995

Figure 2.0: Water Catchment Area



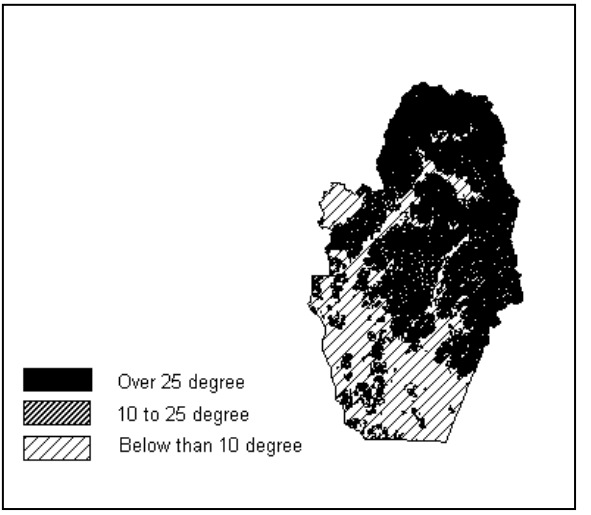
Source: Dept. of Town and Country Planning,Federal, 1998

Figure 3.0: Location of Existing Reservoirs, Aquifers and Water Catchment Area (Hulu Langat)



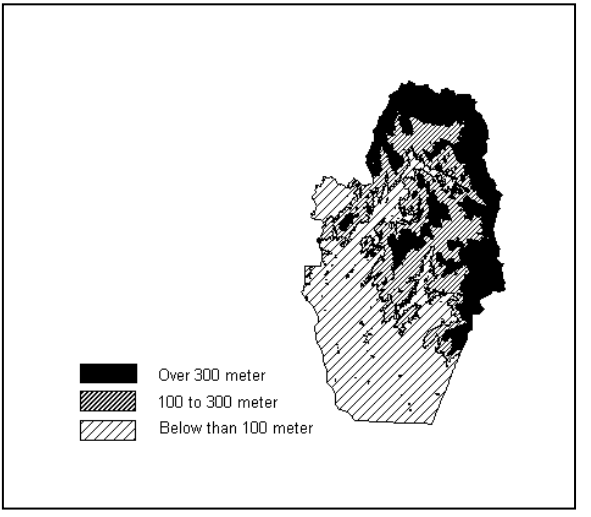
Source: Jabatan Perancangan Bandar dan Desa Semenanjung Malaysia, 1998

Figure 4.0: Slope Analysis (Hulu Langat)



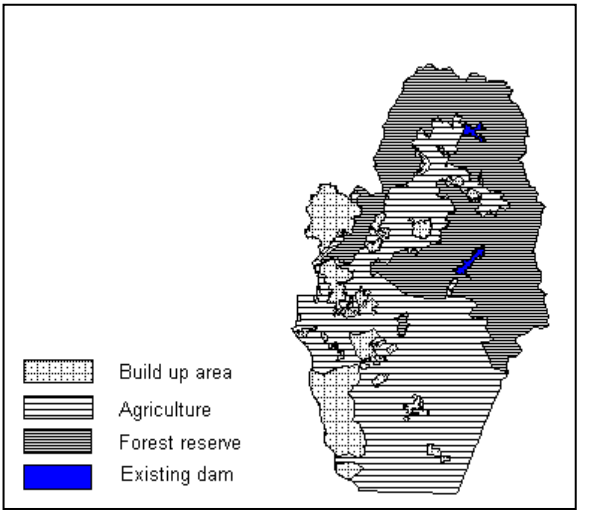
Source: Water Catchment Area Study Team, 1998

Figure 5.0: Elevation Analysis (Hulu Langat)



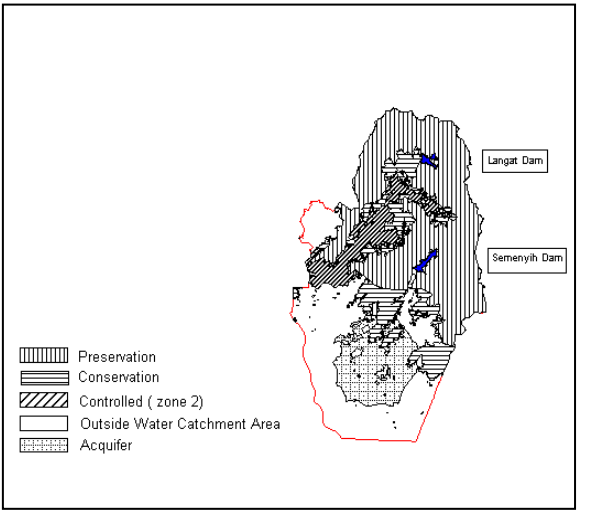
Source: Water Catchment Area Study Team, 1998

Figure 6.0: Land use Plan (Hulu Langat)



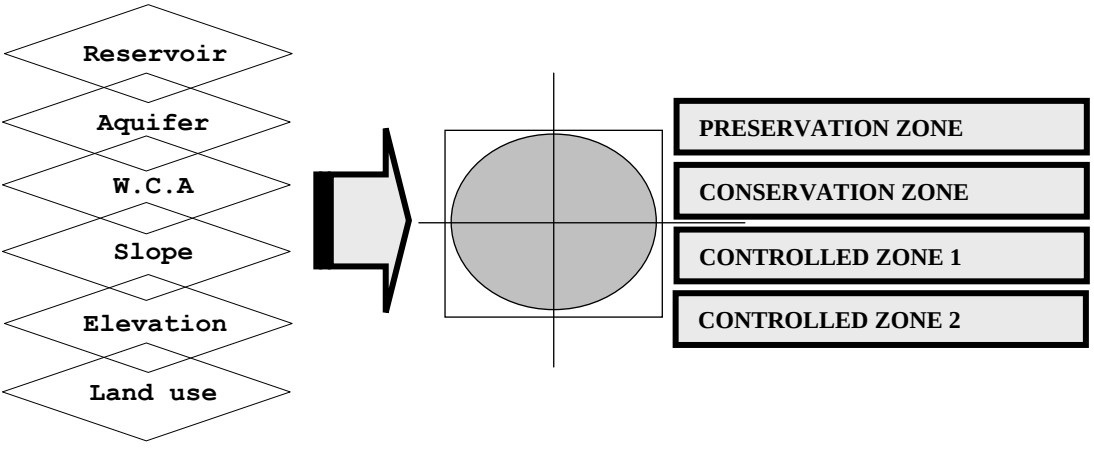
Source: Water Catchment Area Study Team, 1998

Figure 7.0: Management Plan (Hulu Langat)



Source: Water Catchment Area Study Team, 1998

Figure 8.0: Data base Overlay Concept



Source: Water Catchment Area Study Team, 1998

APPENDIX 2 – List of tables

Table 1.0: Breakdown of Total Area Studied

No	District	Acre	%
1	Hulu Selangor	433, 500	54.4
2	Gombak	155, 400	19.6
3	Hulu Langat	207, 300	26.0
	Total	**796, 200**	**100.0**

Source: Water Catchment Area Study Team, 1998

Table 2.0: A List of DataBase and Their Sources

Type of Data	Source	Form	Original Format
State and district boundary-*display only*	DEGIS* data	Digital	Cassini** and the attribute
Land lot	*Jabatan Ukur dan Pemetaan Malaysia*	Digital	Cassini and the attribute
Topography	DEGIS data	Digital	Cassini and the attribute
	Jabatan Ukur dan Pemetaan Malaysia	Digital and Hard copy (Topo Map)	-
	Jabatan Perancangan Bandar dan Desa Negeri Selangor	Hard copy (Highly Area Plan)	-
Geological aspect	Readjustment of DEGIS data	Digitising	Cassini and the attribute
	Jabatan Kaji Bumi Negeri Selangor	Hard copy (Location of Aquifer Plan)	-
Forest and landscape area	DEGIS data	Digital	Cassini and the attribute
	Jabatan Perhutanan Negeri Selangor	Hard copy (Forest Distribution Plan)	-
Hydrology and irrigation-display only	DEGIS data	Digital	Cassini and the attribute
	Jabatan Ukur dan Pemetaan Malaysia	Digital	Cassini and the attribute
	Jabatan Pengairan dan Saliran Negeri Selangor	Hard copy (River Alignment Plan)	-
Reservoir and water intake point	DEGIS data	Digital	Cassini and the attribute
	Jabatan Pengairan dan Saliran Negeri Selangor	Water Intake Point (co-ordinate)	-
Physical development	DEGIS data	Digital	Cassini and the attribute

	Jabatan Perancangan Bandar dan Desa Negeri Selangor	Hard copy (Land use Plan)	-
	Jabatan Ukur dan Pemetaan Malaysia	Digital	Cassini and the attribute

** DEGIS – Darul Ehsan Geographical Information System is one strategic planning database constructed by Seksyen Perancangan Ekonomi, Unit Perancangan dan Pembangunan Negeri Selangor. It consists of socio-economic and spatial based data.*

***Cassini – One of projection to display GIS map or plan (another projection is Rectified Skewerd Orthomorphic)*

No:	Criteria	Description
1.	**EXISTING RESERVOIR**	▪ Function – to collect the river water for reserving, to control flood and to control the quantity and the water level for intake point in each reservoir scheme. ▪ The quality and quantity are depends on the capacity of the resource water from the catchment area of the reservoir. ▪ It should not be disturb/distract to avoid unusual treatment process. ▪ Recently, there are five locations of reservoir in the study area *(refer to Figure 3.0).* ▪ Any development proposed or approved should be controlled strictly due to their function as a flood control naturally.
2.	**EXISTING AQUIFER (Groundwater Resource)**	▪ Definition – The water remained or laid on the surface of hard stone/soil that has less permeability surface or layer under the ground level. ▪ Few locations of aquifer are discovered distribute at Hulu Langat and Hulu Selangor districts*(refer to Table 3.0 and Figure 3.0)*

Table 3.0: Total Area of Aquifer by District

No.	District	Acre
1	Hulu Selangor	7,457
2	Hulu Langat	27,980
	Total	**35,437**

Source: Water Catchment Area Study Team, 1998 & Jabatan Geologi Negeri Selangor, 1998

3.	**EXISTING WATER**	▪ Most areas covered by the forests and rivers. ▪ Mostly located at hill slope and the boundary align at the peak of the

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hill/mountain surrounding the dam.

- 2 category of water catchment area forest, namely:
  i. in the reservoir catchment itself
  ii. at the water intake point catchment
- The reservoir water catchment area determined as a very high degree of sensitivity.
- It also allowed only a very passive activity like educational purposes, research based activities and nature based tourism activities.
- Figure 5.0 show the location of existed reservoir (dam) water catchment area and 20 locations of water intake point identified through the study *(refer to Figure 3.0)*.
- Meanwhile, the water intake point catchment forest categorised has a moderate sensitivity level.
- The development here will be controlled by a very strict guideline monitored by Jabatan Befallen Air Negeri Selangor and Jabatan Alam Sekitar Negeri Selangor *(source: Jabatan Bekalan Air Negeri Selangor, 1998).*
- There are 2 categories of water intake point catchment forest,
  i. at upstream of the river
  ii. at downstream of the river

4. TOPOGRAPHY – SLOPE ANALYSIS

- The 20 m interval contour is used in the study
- For study purposes, the slope analysis are divided into 3 categories, they are as follows:

Table 4.0: Category of Slope and Sensitivity

Development Allowed*	**Slope Class**	**Classification**	**Sensitivity Level**
Housing, commercial, institution and hotel	0° - 9°	Moderate	Low
Housing and commercial	10° - 25°	Steep	Moderate
Not allowed	25°	Very steep	High

** Source: Jabatan Perancangan Bandar dan Desa Negeri Selangor, 1998*

Table 5.0: Slope Level and Total Area Defined

Degree Level	**> 10°**		**10° - 25°**		**> 25°**	
District	Acre	%	Acre	%	Acre	%
Hulu Selangor	201, 600	46.3	140, 200	32.2	94, 150	21.5
Gombak	75, 190	48.2	52, 750	33.8	27, 960	18
Hulu Langat	98, 900	47.6	65, 120	31.4	43,320	21
Total	**375, 690**	**47%**	**258, 070**	**32.3%**	**165, 430**	**20.7%**

Source: Water Catchment Area Study Team, 1998(also refer to Figure 4.0 to see the distribution)

5. TOPOGRAPHY – ELEVATION ANALYSIS

- Normally, the hill defined as the area located between 100m – 300m, and for mountain is area located over 1000m from sea level.
- Through this study, below is the importance and description of the elevation criteria.

Table 6.0: The Importance of Elevation and Their Sensitivity

Classification	Elevation(m)	Sensitivity	Description
1. Lowland area	< 100	Low	Less important in contributing into water catchment development.
2. Hilly area	100 – 300	Moderate	Mostly the hill slope area bared into landslide, erosion and fast flood.
3. Mountainous area	Over 300	High	Protected forest (area), very sensitive bio-diversity of flora and fauna and mostly have over 25% slope.

Source: Water Catchment Area Study Team, 1998

Table 7.0: Elevation Level and Total Area Defined

Degree Level	**0 - 100 m**		**100 – 300 m**		**> 300 m**	
District	Acre	%	Acre	%	Acre	%
Hulu Selangor	239, 200	29.4	68, 390	15.7	128, 000	54.9
Gombak	70, 890	45.8	47, 160	30.5	36, 700	13.7
Hulu Langat	96, 200	46.5	61, 720	29.8	48, 730	23.7
Total	**406, 290**	**51%**	**177,270**	**22.2%**	**213, 430**	**26.8%**

Source: Water Catchment Area Study Team, 1998(also refer to Figure 5.0 to see the distribution)

6. LAND USE CRITERIA

- In general, the quantity of water at any particular are surface of area covered by trees, forests or shrubs.
- For study purpose, the study team has classified the type of land use and their capability to preserve the water by them The land use

and capability are as follows:

Table 8.0: Land Use Classification and Water Preserving

Land use	**Capability to Preserve Water(%)**
Forest	80 – 100
Crops	40 – 50
Housing	50 – 60
Town/built-up area	0 – 10

Source: Water Catchment Area Study Team, 1998

Table 9.0: Distribution of Land Use of Focussed District

District	**Forest(ac)**	**Agriculture(ac)**	**Built-up (ac)**
Hulu Selangor	199, 700	44, 680	186, 600
Gombak	83, 340	9, 209	61, 570
Hulu Langat	80, 520	98, 160	26, 600
Total	**363, 560**	**152, 049**	**274, 770**

Source: Water Catchment Area Study Team, 1998 (also refer to Figure 6.0 to see the distribution)

- From the finding of the research, the preserve forest should not be developed and must be preserve to ensure the everlasting raw water reserves.

Table 10.0: Criterion Indicator and Total Score

Criteria	**Priority**	**Sub-Sector**	**Sensitivity**	**Weight**	**Score**
Reservoir	Totally preserve	-	-	-	-
Aquifer	Totally preserve	-	-	-	-
Existing Water Catchment Area	2	Reservoir forest	High	3	6
		WIP (1st category)	High moderate	2	4
		WIP (2nd category)	Moderate	1	2
Slope	1.5	> 25°	High	3	4.5
		10° - 25°	Moderate	2	3
		< 10°	Low	1	1.5
Elevation	1	> 300 m	High	3	3
		100 – 300 m	Moderate	2	2

		< 100 m	Low	1	1
Land Use	1	Preserve forest	High	3	3
		Agriculture	Moderate	2	2
		Built-up area	Low	1	1

Source: Water Catchment Area Study Team, 1998