Water Resources Publication No. 21

STUDY ON THE RIVER WATER QUALITY TRENDS AND INDEXES IN PENINSULAR MALAYSIA

2009

WATER RESOURCES MANAGEMENT AND HYDROLOGY DIVISION
DEPARTMENT OF IRRIGATION AND DRAINAGE
MINISTRY OF NATURAL RESOURCES AND ENVIRONMENT
MALAYSIA

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Although every effort and care has been taken in selecting the methods and proposing the recommendations that are appropriate to Malaysian conditions, the user is wholly responsible to make use of this water resources publication. The use of this Manual requires professional interpretation and judgment to suit the particular circumstances under consideration.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Jabatan Pengairan dan Saliran (JPS) is monitoring about 25 parameters at 28 river gauging stations located in the Peninsular Malaysia to study the water quality trends in the rivers. Data has been collected from 1996 but no study was conducted to evaluate the data. Therefore, it was long due to carry out a study to evaluate the data and determine the water quality trends in the rivers.

1.2 OBJECTIVES

The main objective of this water resources publication (WRP) is to document the findings of a study funded by JPS. The specific objectives were to:

- Review the available water quality data in terms of practicality and requirement to suit the need of local environment;
- Develop a tool to examine the trend or pattern of each pollutant; and
- Develop a tool to establish the river index relating the quantity and quality of the river flow.

1.3 SCOPE OF WORK

Within the above framework, the major scopes of work included but not limited to the followings:

- To examine the nature and quality of the existing water quality data and parameters for the development of a river index for JPS to suit local environment.
- To develop the relationship of each (groups) parameters and river index based on appropriate mathematical formulation.
- To assign the river index scores of selected important parameters to various percentiles for rating curve development.
- To review the method of monitoring and quantification of non point source pollution loading.
- To comment on the existing parameters monitored by JPS.

CHAPTER 2

STUDY AREA AND DATA AVAILABILITY

2.1 STUDY AREA

Locations of the 28 stations are shown in Figure 1. It was observed that most of the stations are located in the States of Johor (5), Selangor (7), Kelantan (8) and Kuala Lumpur (5). Few are located in Melaka (2) and Kedah (1), as listed in Table 1.

2.2 DATA AVAILABILITY

Although 28 water quality parameters and 12 other information (Figure 2) were supposed to be recorded, according to the usual monitoring scheme/plan of JPS, a few parameters were not recorded in the filed data sheet. Among those, DO, pH, river flow, stage, etc. are the most important ones. Few other data were also sometimes missing for certain stations. The status of water quality data availability against each parameter is reported in Table 2.

All of the stations are manual, from where grab samples are collected periodically (usually monthly or when gauging exercise is conducted). Then the samples are sent to the nearest laboratory of the Department of Chemistry, Malaysia for tests. Standard procedures (MIHP, 2007 and DID, 1981) are followed during the sampling and testing of the water samples.

2.3 REVIEW OF JPS WATER QUALITY DATA

The following observations were noted during review of the water quality data recorded by JPS and Department of Chemistry, Malaysia:

- Many stations did not have data for certain years (without any certain pattern).
- Although the information on the rainfall (during sampling) should be recorded in the data sheet (item 14 in Figure 2) but it was not available. As such, the flow data was estimated based on the hourly water flow data recorded by the JPS.
- pH should be measured at site and at laboratory. However, only one pH value was available in the report furnished by the Department of Chemistry.
- Few water quality data are not reliable, either exceptionally low or high. It was also not realistic to consider those values as outliers.
- Detection limits for certain parameters (e.g. Ammonia, F^-, Cl^-, NO_3^-, Mn, PO_4^-, Turbidity, etc.) were not consistent.

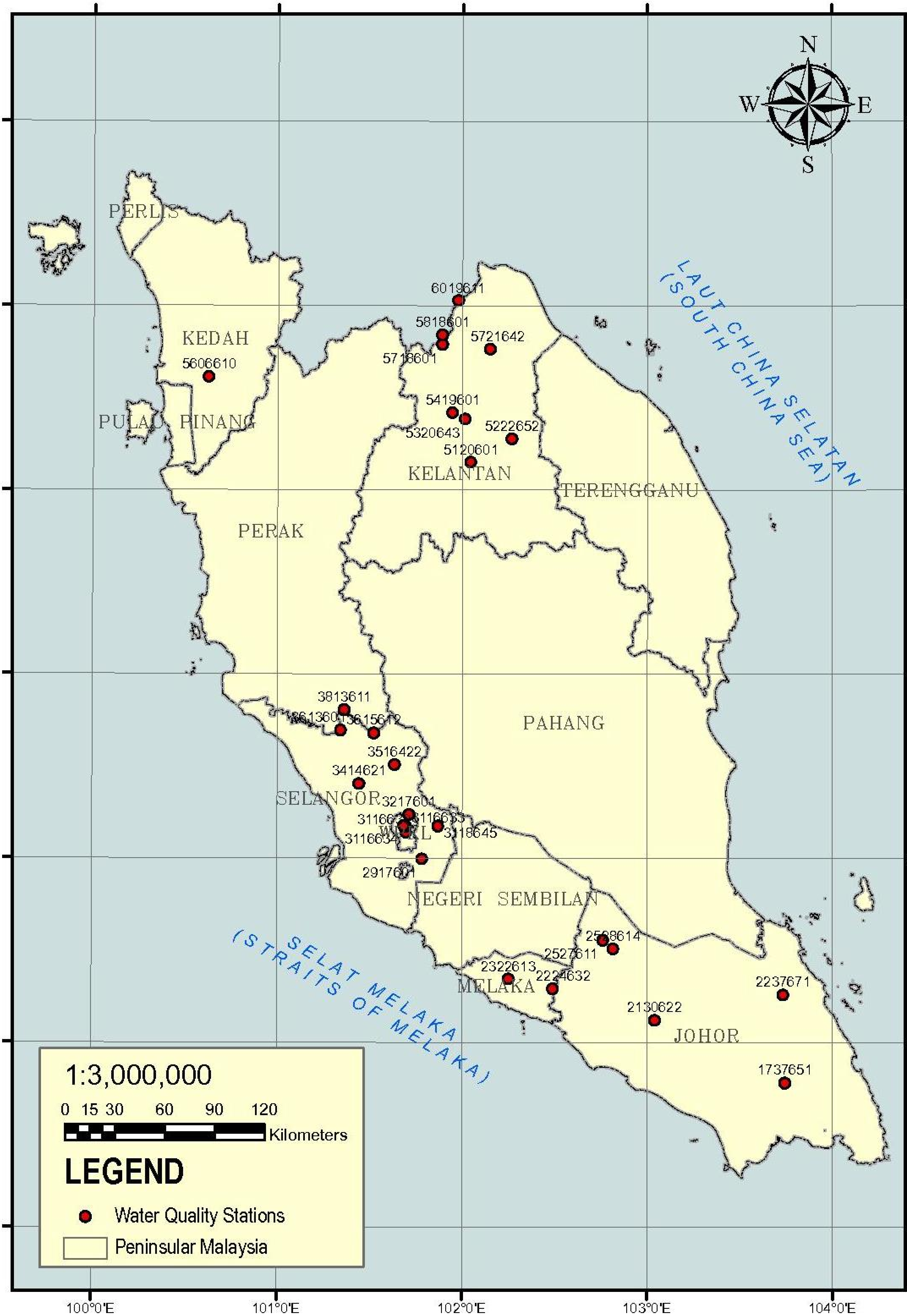


Figure 1 : The study Area and Locations of the Water Quality Stations

Table 1: List and Particulars of the Stations

No	Station Number	Station Name	State	District	Year Start	Year & No. of Records	Hourly Flow Data	Active	Latitude (xx°xx‘xx“)	Longitude (xx°xx‘xx“)	Catch. Area (km^2)
1	1737651	Sg. Johor at Rantau Panjang	Johor	Kota Tinggi	09/05	3 & 16	Yes	Yes	01 46 50	103 44 45	1130
2	2130622	Sg. Bekok di Batu 77, Jalan Yong Peng/Labis	Johor	Segamat	05/06	2 & 16	Yes	Yes	02 07 15	103 02 30	350
3	2237671	Sg. Lenggor di Bt 22, Kluang/Mersing	Johor	Mersing	07/05	3 & 6	Yes	Yes	02 15 30	103 44 10	207
4	2527611	Sg. Muar di Buloh Kasap	Johor	Segamat	01/05	3 & 46	Yes	Yes	02 33 20	102 45 50	3130
5	2528614	Sg. Segamat di Segamat	Johor	Kota Tinggi	01/05	3 & 46	Yes	Yes	02 30 25	102 49 05	658
6	5606610	Sg. Muda di Jam Syed Omar	Kedah	Kuala Muda	01/97	6 & 96	Yes	Yes	05 36 35	100 37 35	3330
7	5120601	Sg. Nenggiri di Jambatan Bertam	Kelantan	Gua Musang	11/98	8 & 50	Yes	Yes	05 08 55	102 02 45	2130
8	5222652	Sg. Lebir di kampong Tualang	Kelantan	Kuala Krai	02/98	8 & 46	Yes	Yes	05 16 30	102 16 00	2430
9	5320643	Sg. Galas di dabong	Kelantan	Kuala Krai	05/97	4 & 27	Yes	Yes	05 22 55	102 00 55	7770
10	5419601	Sg. Pergau di Batu Lembu	Kelantan	Kuala Krai	11/98	8 & 80	Yes	Yes	05 25 05	101 53 30	1290
11	5718601	Sg. Lanas di Air Lanas	Kelantan	Jeli	04/97	9 & 74	Yes	Yes	05 47 10	102 09 00	80
12	5721642	Sg. Kelantan di Guillmard	Kelantan	Tanah Merah	06/97	4 & 38	Yes	Yes	05 45 45	101 53 30	11900
13	5818601	Sg. Golok di Kg. Jenob	Kelantan	Tanah Merah	04/97	9 & 79	No	Yes	05 50 25	101 58 40	216
14	6019611	Sg. Golok di Rantau Panjang	Kelantan	Pasir Mas	08/00	4 & 24	Yes	Yes	06 01 30	102 29 35	761
15	2224632	Sg. Kesang di Chin Chin	Melaka	Selatan	07/97	11 & 226	Yes	Yes	02 17 25	102 15 10	161

Table 1: List and Particulars of the Stations (Continued)

No	Station Number	Station Name	State	District	Year Start	Year & No. of Records	Hourly Flow Data	Active	Latitude (xx°xx'xx")	Longitude (xx°xx'xx")	Catch. Area (km²)
16	2322613	Sg. Melaka di Pantai Belimbing	Melaka	Utara	07/97	7 & 132	Yes	Yes	02 20 35	101 47 10	350
17	2917601	Sg. Langat Di Kajang	Selangor	Ulu Langat	01/93	10 & 180	Yes	Yes	02 59 40	101 52 20	380
18	3118645	Sg. Lui di Kg. Lui	Selangor	Ulu Langat	01/93	10 & 169	Yes	Yes	03 10 25	101 26 35	68
19	3414621	Sg. Selangor di Rantau Panjang	Selangor	Kuala Selangor	01/93	10 & 116	Yes	Yes	03 24 10	101 35 05	1450
20	3516622	Sg. Selangor di Rasa	Selangor	Hulu Selangor	01/93	9 & 140	Yes	No	03 30 25	101 20 40	321
21	3613601	Sg. Selangor di Ulu Ibu Empangan	Selangor	Hulu Selangor	01/93	10 & 154	No	Yes	03 41 35	101 31 20	1290
22	3615612	Sg. Bernam di Tanjung Malim	Selangor	Hulu Selangor	01/93	10 & 179	No	Yes	03 40 45	101 21 50	186
23	3813611	Sg. Bernam di Jambatan SKC	Selangor	Sabak Bernam	01/93	10 & 201	No	Yes	03 48 15	101 41 50	1090
24	3116630	Sg. Klang di Jambatan Sulaiman	WP, KL	Kuala Lumpur	07/05	0.4 & 7	No	Yes	03 08 20	101 41 50	468
25	3116633	Sg. Gombak di Jalan Tun Razak	WP, KL	Kuala Lumpur	07/05	0.4 & 7	Yes	Yes	03 10 25	101 41 50	122
26	3116634	Sg. Batu di Sentul	WP, KL	Sentul	07/05	0.4 & 7	No	Yes	03 10 35	101 41 50	145
27	3117602	Sg. Klang Di Lorong Yap Kuan Seng	WP, KL	Kg. Baru	07/05	0.4 & 7	No	No	03 09 55	101 43 10	160
28	3217601	Sg. Gombak Ibu Bekalan KM 11 Gombak	WP, KL	Gombak	07/05	0.4 & 7	No	No	03 14 10	101 42 50	85

JABATAN KIMIA
MALAYSIA

Peringatan-Lapuran ini tidak
boleh digunakan untuk iklan
No. Talipon: . . . .
No: Makmal: . . . .
Rujukan tuan:

.....................19...........

LAPURAN

Berkenaan . . . .
contoh-contoh yang diterima daripada JPT, Ibu Pejabat,
Kuala Lumpur dibawa oleh . . . . pada 21.2.79.

I. Bacaan Luar		Cols	
1. Station No.		1 – 8	9. Sample No:
2. Sampling Data (Day/M/Yr)		9 – 16	10. Station Name:
3. Time of Sampling:		17 24	11. Gauge Height (Metres):
4. Discharge (CMS):		25– 32	12 Type of Sampler:
5. Sample Depth (Metres):		33 –40	13. Sample Treatment:
6. Water Temperature °C:		41 –48	14. Raining/Not Raining (Cross out one)
7. pH (Field):		49 56	15. Name of Observer:
8. Dissolved Oxygen		57 –64	16. General Observations of Water: (viz by sight, smell, touch, etc.)

(a) Sample of Field Data Sheet

II. Laporan Makmal		Cols			
1. Colour:	< 5*	65 – 72	16. BOD:	0.2	25 – 32
2. Turbidity: (NTU)	36	73 – 80	17. COD:	10.6	33 – 40
3. Conductivity:	35	1 – 8	18. Nitrate:	0.27	41 – 48
4. Hardness:	21	9 – 16	19. Ammonia:	0.06	49 – 56
5. Total Solids at 105°C	86	17 – 24	20. Phosphate:	0.36	57 – 64
6. Suspended Solids:	19	25 – 32	21. Silica:	16	65 – 72
7. Dissolved Solids	67	33 – 40	22. Iron:	1.9	73 – 80
8. pH (Lab.)	6.8	41 – 48	23. Manganese:	0.06	1 – 8
9. Alkalinity:	27	49 – 56	24. Fluoride:	0.20	9 – 16
10. Calcium:	5.2	57 – 64			17 – 24
11. Chloride:	2.5	65 – 72			25 – 32
12. Potassium:	0.8	73 – 80			33 – 40
13. Magnesium:	1.9	1 – 8			41 – 48
14. Sodium:	3.0	9 – 16			49 – 56
15. Sulphate:	0.0	17 – 24			57 – 64

(a) Sample of Lab Data Sheet

Figure 2: Water Quality Data Sheets used by JPS

Table 2: Status of Water Quality Data Availability for Various Stations

No	Station Number	Station Name	State	River	pH (unit)	DO (mg/L)	Colour (Hazen)	Cond. (µS/cm)	Turbidity (NTU)	Alkalinity (mg/L)	Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	AN (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
1	1737651	Sg. Johor at Rantau Panjang	Johor	Sg. Johor	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	Y	I	Y	Y	Y	Y	Y
2	2130622	Sg. Bekok di Batuu 77, Jalan Yong Peng/Labis	Johor	Sg. Labis	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	Y	Y	Y	I	Y
3	2224632	Sg. Kesang di Chin Chin	Melaka	Sg. Kesang	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	Y	I	Y	Y	I	Y	Y	Y	Y
4	2237671	Sg. Lenggor di Bt 22, Kluang/Mersing	Johor	Sg. Jemaluang	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	Y	Y	Y	Y	Y	I	I	I	Y	Y	Y	Y
5	2322613	Sg. Melaka di Pantai Belimbing	Melaka	Sg. Melaka	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	Y	Y	Y	Y	Y	Y	Y	Y	Y
6	2527611	Sg. Muar di Buloh Kasap	Johor	Sg. Muar	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	Y	I	Y	I	Y	Y	I	I	Y
7	2528614	Sg. Segamat di Segamat	Johor	Sg. Sebol	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	Y	Y	Y	I	Y	Y	Y	I	I
8	2917601	Sg. Langat Di Kajang	Selangor	Sg. Langat	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	I	I	Y	I	I	I	I	I
9	3116630	Sg. Klang di Jambatan Sulaiman	WP, KL	Sg. Klang	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
10	3116633	Sg. Gombak di Jalan Tun Razak	WP, KL	Sg. Gombak	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
11	3116634	Sg. Batu di Sentul	WP, KL	Sg. Batu	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
12	3117602	Sg. Klang Di Lorong Yap Kuan Seng	WP, KL	Sg. Klang	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13	3118645	Sg. Lui di Kg. Lui	Selangor	Sg. Lui	Y	N	Y	Y	Y	I	I	I	I	I	I	I	I	I	I	I	I	I	Y	Y	I	I	I	I	I
14	3217601	Ibu Bekalan KM 11 Gombak	WP, KL	Sg. Gombak	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
15	3414621	Sg. Selangor di Rantau Panjang	Selangor	Sg. Selangor	Y	N	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	I	I	I	I	I	Y	Y	I	I	I	I	I

Table 2: Status of Water Quality Data Availability for Various Stations (Continued)

No	Station Number	Station Name	State	River	pH (unit)	DO (mg/L)	Colour (Hazen)	Cond. (µS/cm)	Turbidity (NTU)	Alkalinity (mg/L)	Hardness (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	AN (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
16	3516622	Sg. Selangor di Rasa	Selangor	Sg. Selangor	I	N	I	I	I	I	I	I	I	I	I	Y	Y	Y	Y	Y	I	I	Y	Y	Y	Y	Y	Y	Y
17	3613601	Sg. Selangor di Ulu Ibu Empangan	Selangor	Sg. Bernam	I	N	I	I	I	I	I	I	I	I	I	Y	Y	I	I	I	I	I	Y	Y	Y	Y	Y	I	I
18	3615612	Sg. Bernam di Tanjung Malim	Selangor	Sg. Bernam	I	N	I	I	I	I	I	I	I	I	I	Y	Y	I	I	I	I	I	Y	I	Y	Y	I	I	I
19	3813611	Sg. Bernam di Jambatan SKC	Selangor	Sg. Bernam	I	N	I	I	I	Y	I	I	I	I	I	I	Y	I	I	I	I	I	I	Y	Y	I	I	I	I
20	5120601	Sg. Nenggiri di Jambatan Bertam	Kelantan	Sg. Nenggiri	Y	N	Y	Y	I	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	N	N	Y	N	Y	I	I	I	N
21	5222652	Sg. Lebir di kampong Tualang	Kelantan	Sg. Lebir	Y	N	Y	Y	I	Y	Y	Y	Y	Y	Y	Y	I	Y	I	I	N	N	Y	N	Y	I	Y	I	N
22	5320643	Sg. Galas di dabong	Kelantan	Sg. Galas	Y	N	Y	I	I	Y	Y	Y	Y	Y	Y	I	I	I	I	I	N	N	Y	N	Y	I	I	I	N
23	5419601	Sg. Pergau di Batu Lembu	Kelantan	Sg. Pergau	Y	N	Y	Y	I	Y	Y	Y	Y	Y	Y	Y	I	Y	I	I	N	N	Y	N	Y	I	I	I	N
24	5606610	Sg. Muda di Jam Syed Omar	Kedah	Sg. Muda	Y	N	N	I	N	I	N	Y	Y	N	N	I	I	I	I	N	I	I	Y	I	I	Y	Y	I	I
25	5718601	Sg. Lanas di Air Lanas	Kelantan	Sg. Lanas	Y	N	Y	I	I	Y	Y	Y	Y	Y	Y	I	I	I	I	I	N	N	Y	N	Y	I	I	I	N
26	5721642	Sg. Kelantan di Guillmard	Kelantan	Sg. Kelantan	I	N	I	I	I	Y	Y	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
27	5818601	Sg. Golok di Kg. Jenob	Kelantan	Sg. Golok	Y	N	Y	Y	I	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	N	N	Y	N	Y	I	I	I	N
28	6019611	Sg. Golok di Rantau Panjang	Kelantan	Sg. Golok	Y	N	Y	Y	I	Y	Y	Y	Y	Y	Y	Y	I	I	I	I	N	N	Y	N	Y	I	I	I	N

Legend,

Y - Data complete

I - Data incomplete

N - No data available

CHAPTER 3

LITERATURE REVIEW

The literature review was necessary to evaluate the existing river or water quality indexes (local and international) and to determine their suitability to asses the water quality data collected from JPS stations. The literature review also helped propose a new unique index with the main intention to assess the river status based on the quantity (flow) and quality data collected by JPS.

3.1 WATER QUALITY PARAMETERS

Having good water quality is important for a healthy river and ecosystem. Several basic conditions must be met for aquatic life to thrive in the water. When these conditions are not optimal, species populations become stressed. When conditions are poor, organisms may die. Thus, various water quality parameters need to be measured in order to determine the health of the river water so that it is safe to use for any purpose. In order to develop a water quality or river index, there are several parameters that need to be considered. These parameters can be divided into four groups, which are physical, chemical, biological and radioactive.

3.1.1 Physical Parameters

There are many types of physical parameters such as temperature, turbidity, total dissolved solids, total suspended solids, etc. used for the evaluation of water quality. Each of the parameters has significant impact on the water quality.

The water temperature is a measure of the heat content of the water mass and influences the growth rate and survivability of aquatic life. Different species of fish have different needs for an optimum temperature and tolerances of extreme temperatures (Davis and McCuen, 2005). Many of the physical, biological, and chemical characteristics of a river are directly affected by temperature. Most waterborne animal and plant life survives within a certain range of water temperatures, and few of them can tolerate extreme changes in temperature (WSDE, 2002).

Turbidity indicates the amount of fine particles suspended in water. High concentrations of particles can damage the habitats for fish and other aquatic organisms (Said *et al*., 2004). Turbidity is more concern with aesthetic point of view. High turbid water shortens the filter runs. Many pathogenic organisms may be encased in the particles and protected from the disinfectant (Avvannavar and Shrihari, 2007).

Total suspended solids (TSS) is usually referred to the particles in water which is usually larger than 0.45 µm. Many pollutants (e.g. toxic heavy metals) can be attached to TSS, which is not good for the aquatic habitat and lives. High suspended solids also prevent sunlight to penetrate into water. Total dissolved solid (TDS) consists of dissolved minerals and indicates the presence of dissolved materials that cannot be removed by conventional filtration. The presence of synthetic organic chemicals (fuels, detergents, paints, solvents etc) imparts objectionable and offensive tastes, odors and colors to fish and aquatic plants even when they are present in low concentrations (Avvannavar and Shrihari, 2007).

3.1.2 Chemical Parameters

pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, total phosphate, metals, oil and grease are the examples of chemical parameters used to determine the water quality. The pH value of water is a measure of the acid strength in the water.

The pH directly measures the activity (approximately the concentration) of the hydrogen ion, H^+. The lower the pH, the higher the H^+ activity and the more acidic is the water (Davis and McCuen, 2005). The neutral pH is considered as 7.0. DO is a measure of the amount of oxygen freely available in water. It is commonly expressed as a concentration in terms of milligrams per liter, or as a percent saturation, which is temperature dependent. The colder the water, the more oxygen it can hold (Said *et al*., 2004).

Biochemical Oxygen Demand (BOD) determines the strength of pollutants in terms of oxygen required to stabilize domestic and industrial wastes. For the degradation of oxidizable organic matter to take place minimum of 2 to 7 mg/L of DO level is to be maintained at laboratory experimentation or should be available in the natural waters (Avvannavar and Shrihari, 2007) BOD also measures the amount of food (mainly organic) for bacteria found in water. The BOD test provides a rough idea of how much biodegradable waste is present in the water (WSDE, 2002). COD test is commonly used to measure the amount of organic and inorganic oxydizable compounds in water. Most applications of COD determine the amount of total oxidizable pollutants found in surface water, making COD a useful measure of water quality. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution.

Nitrates are a measure of the oxidized form of nitrogen and are an essential macronutrient in aquatic environments. Nitrates can be harmful to humans, because our intestines can break nitrates down into nitrites, which affect the ability of red blood cells to carry oxygen. Nitrites can also cause serious illnesses in fish (Davis and McCuen, 2005). Phosphorus is important to all living organisms. However, excessive phosphorus causes algae blooms, which are harmful to most aquatic organisms. They may cause a decrease in the DO levels of the water, and in some cases temperature rise. This can result in a fish kill and the death of many organisms (Said *et al*., 2004).

Metals occur naturally and become integrated into aquatic organisms through food and water. Trace metals such as copper, selenium, and zinc are essential metabolic components at low concentrations. However, metals tend to bioaccumulate in tissues and prolonged exposure or exposure at higher concentrations can lead to illness. Elevated concentrations of trace metals can have negative consequences for both wildlife and humans. Human activities such as mining and heavy industry can result in higher concentrations than those that would be found naturally (Carr and Neary, 2006).

Oil in water can be present in four basic forms which are free oil, mechanically emulsified oil, chemically emulsified oil, and dissolved oil. Free oil will rise to the surface of the water in which it is contained. Mechanically emulsified oil is caused by agitating a free oil and water mixture to the point where it breaks the oil up into very small droplets (10-20 microns). High water temperatures and use of liquid vegetable oils promote mechanically emulsified oil. Oil and grease may also become chemically emulsified, primarily through the use of detergents and other alkalis. Chemically emulsified oil particles are very small (<1 micron) and do not rise to the surface of the water regardless of how much time is allowed. Oil may also be present as dissolved oil in which case it is no longer present as discrete particles. Oil generally becomes dissolved in water through the use of degreasing compounds which are soluble in both oil and water.

3.1.3 Biological Parameters

In order to assess the quality of water, biological parameters should also be considered. Fecal coliform and groups of microorganism are the examples of biological parameters.

Fecal coliform is a form of bacteria found in human and animal waste. Fecal coliform are bacteria whose presence indicates that the water may have been contaminated with human or animal fecal material. If fecal coliform counts are high in a site, it is very likely that pathogenic organisms are also present, and this site is not recommended for swimming and other contact recreation (Said *et al*., 2004).

A few micro–organisms are an important cause of the corrosion of steel pipes. Water for the purpose of drinking that contained micro–organisms can cause sensory defects in odor, color and taste. Various health related problems due to contaminated waters are diarrhea, abdominal cramps and vomiting due to salmonella, cholera is due to vibro cholera, infection of lungs due to mycobacterium (Avvannavar and Shrihari, 2007).

3.2 WATER QUALITY INDEXES

Extensive literature review was conducted to evaluate, compare and find a method suitable to develop an index for JPS, Malaysia. Most of the countries practices Water Quality Index (WQI) method which is similar to the existing DOE index (DOE, 1994) that expresses quality of water via a single number by combining measurements of selected physical, chemical, biological and radioactive parameters (Cude *et al.*, 1997). Generally, WQI is a unitless number varies between 0 and 100. A higher index value represents good water quality. Therefore, a numerical index is used as a management tool in water quality assessment (Avvannavar and Shrihari, 2007).

WQI basically acts as a mathematical tool to convert the bulk of water quality data into a single digit, cumulatively derived, numerical expression indicating the level of water quality. This, consecutively, is essential for evaluating the water quality of different sources and in observing the changes in the water quality of a given source as a function of time and other influencing factors (Sarkar and Abbasi, 2006). WQI has been developed to assess the suitability of water for a variety of uses. The index reflects the status of water quality in lakes, streams, rivers, and reservoirs. The concept of WQI is based on the comparison of the water quality parameter with respective regulatory standards (Khan *et al.*, 2003).

Water quality index combines several important water quality parameters that give an overall index of the water quality for a specific use. Different pollutants and factors are required for the development of an index. The simplest WQI reflect on several simple water quality parameters such as dissolved oxygen, total suspended solid, pH, and possibly some nutrients. Measurements of each of these parameters are taken and compared to a classification table, where the water is identified as excellent, good, fair, poor or very poor (Davis and McCuen, 2005).

There are numerous water quality indexes that have been developed to help water quality divisions in some U.S. states, Canada, and Malaysia. However, most of these indexes are based on the WQI developed by the U.S. National Sanitation Foundation (NSF) (Said *et al.,* 2004). The present method used in Malaysia to calculate the WQI is based on opinion poll (Khuan *et al.,* 2002).

Although WQI has the potential to summarize complex scientific information on water quality into a simpler form for assessment, communication and reporting purposes; there are merits and demerits of using WQI approach (UNEP GEMS, 2005).

Some of the advantages of indexes are:

- WQIs can be used to show water quality variation both spatially and temporally;
- Provide a simple, concise and valid method for expressing the significance of regularly generated laboratory data;
- Aid in the assessment of water quality for general uses;
- Allow users to easily interpret data with respect to certain parameters;

- Can identify water quality trends and problem areas based on selected variables;
- Provide a screening tool for further evaluation;
- Improve communication with the public and increases public awareness of water quality conditions;
- Assist in establishing priorities for management purposes.

Some of the limitations are:

- Provide only a summary of the selected parameters;
- Cannot provide complete information on water quality;
- Cannot evaluate all water quality risks;
- Can be subjective and biased in their formulation;
- Because of differing climates and conditions they are not universally applicable;
- Are based on conceptual generalisations that are not universally applicable;
- Have the prerequisite of requiring groups/sets of indicators in their formulation;
- Perfectionist scientists and statisticians tend to disapprove of, and criticise, methodology, thereby eroding credibility as a screening management tool.

The most widely used water quality index developed by National Sanitation Foundation (NSF) of the USA and the Malaysian WQI are briefly discussed in the following section. Literature on the other WQI can be obtained from Said *et al*., 2004; Rocchini and Swain, 2001; Cude, 2001; Sarkar and Abbasi, 2005; CCME, 2001 and Boyacioglu, 2007.

3.2.1 National Sanitation Foundation Water Quality Index

One of the earliest efforts to develop a WQI was done in association with the National Sanitation Foundation (NSF). A panel of 142 persons was assembled throughout the U.S.A with known expertise in water quality management. Three questionnaires were mailed to each panelist to solicit expert opinion regarding the WQI and the procedure incorporated many aspects of the Delphi method, an opinion research technique first developed by Rand Corporation. In the first questionnaire, the panelists were asked to consider 35 analytes for possible inclusion in a WQI and to add any other analytes they felt should be included. The panelists also were asked to rate the analytes that they would include on a scale from 1 (highest significance) to 5 (lowest significance).

The results from the first survey were included with the second questionnaire and the panelists were asked to review their original response. The purpose of the second questionnaire was to obtain a closer consensus on the significance of each analyte. Also included was a list of nine new analytes that had been added by some respondents in the first questionnaire. For the second questionnaire, the panelists were asked to list no more than 15 most important analytes for inclusion from the new total of 44.

From these first two responses, nine analytes had been derived for inclusion in the WQI. In the third questionnaire, the panelists were asked to draw a rating curve for each of the nine analytes on blank graphs provided. Levels of water quality (WQ) from 0 to 100 were indicated on the y-axis of each graph while increasing levels of the particular analyte were indicated on the x-axis. Each panelist drew a curve which they felt best represented the variation in WQ produced by the various levels of each parameter. Then, all the curves had been averaged to produce a single line for each analyte. Statistical analysis of the ratings was used to assign weights to each analyte, where the sum of the weights is equal to 1. The nine parameters and their corresponding weights are listed in Table 3. The water quality value for each analyte then was calculated as the product of the rating curve value (also known as the Q-value) and the WQI weight (WSDE, 2002).

Table 3: NSF WQI Analytes and Weights

Parameter/Analyte	**WQI Weights**
Dissolved oxygen	0.17
Fecal coliform (or *E. coli*)	0.15
pH	0.12
BOD_5	0.10
Nitrates	0.10
Phosphates	0.10
$\Delta t\ ^oC$ from equilibrium	0.10
Turbidity	0.08
Total solids	0.08

Once the overall WQI score is known, it can be compared against a scale given in Table 4 to determine how good the water is on a given day.

Table 4: NSF WQI Quality Scale (WSDE, 2002)

WQI	**Quality of water**
91-100	Excellent
71-90	Good
51-70	Medium or average
26-50	Fair
0-25	Poor

3.2.2 Review of Malaysian Water Quality Index

The water quality index introduced by the Department of Environment (DOE) is being practiced in Malaysia for about 25 years. The index considers six parameters. The Malaysian WQI is an opinion-poll formula. A panel of experts was consulted on the choice of the parameters and the weightage was assigned to each parameter. The parameters which have been chosen are dissolved dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), suspended solid (SS), pH value (pH), and ammonical nitrogen (AN) (Khuan *et. al,* 2002).

The WQI approved by the DOE (Equation 1) is calculated based on the above six parameters. Among them DO carries maximum weightage of 0.22 and pH carries the minimum of 0.12 in the WQI equation. The WQI equation eventually consists of the sub-indexes, which are calculated according to the best-fit relations given in Equations 2 - 7. These equations are graphically presented in Appendix A. The formulas used in the calculation of WQI are:

$$WQI = 0.22\ SI_{DO} + 0.19\ SI_{BOD} + 0.16\ SI_{COD} + 0.16\ SI_{SS} + 0.15\ SI_{AN} + 0.12\ SI_{pH} \qquad (1)$$

Where,

WQI = Water quality index; SI_{DO} = Sub-index of DO; SI_{BOD} = Sub-index of BOD; SI_{COD} = Sub-index of COD; SI_{AN} = Sub-index of AN; SI_{SS} = Sub-index of TSS; SI_{pH} = Sub-index of pH.

Sub-index for DO (in % saturation):

$SI_{DO} = 0$ for DO < 8 (2a)

$= 100$ for DO > 92 (2b)

$= -0.395 + 0.030DO^2 – 0.00020DO^3$ for 8 < DO < 92 (2c)

Sub-index for BOD:

$SI_{BOD} = 100.4 – 4.23BOD$ for BOD < 5 (3a)

$= 108e^{-0.055BOD} – 0.1BOD$ for BOD > 5 (3b)

Sub-index for COD:

$SI_{COD} = -1.33COD + 99.1$ for COD < 20 (4a)

$= 103e^{-0.0157COD} – 0.04COD$ for COD > 20 (4b)

Sub-index for AN:

$SI_{AN} = 100.5 – 105AN$ for AN < 0.3 (5a)

$= 94e^{-0.573AN} – 5\ |AN – 2|$ for 0.3 < AN < 4 (5b)

$= 0$ for AN > 4 (5c)

Sub-index for SS:

$SI_{SS} = 97.5e^{-0.00676SS} + 0.05SS$ for SS < 100 (6a)

$= 71e^{-0.0016SS} – 0.015SS$ for 100 < SS < 1000 (6b)

$= 0$ for SS > 1000 (6c)

Sub-index for pH:

SI_{pH} = 17.2 – 17.2pH + 5.02pH^2 for pH < 5.5 (7a)

= -242 + 95.5pH – 6.67pH^2 for 5.5 < pH < 7 (7b)

= -181 +82.4pH – 6.05pH^2 for 7 < pH < 8.75 (7c)

= 536 – 77.0pH + 2.76pH^2 for pH > 8.75 (7d)

Based on the Malaysian WQI, water quality is classified according to one of the following categories shown in the Table 5.

Table 5: Classes in Malaysian Water Quality Index (DOE, 2005)

Parameter	**Class**				
	I	**II**	**III**	**IV**	**V**
AN	< 0.1	0.1-0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
BOD	< 1	1 – 3	3 – 6	6 – 12	> 12
COD	< 10	10 – 25	25 – 50	50 – 100	> 100
DO	> 7	5 – 7	3 – 5	1 - 3	< 1
pH	> 7	6 – 7	5 – 6	< 5	< 5
TSS	< 2.5	25 – 50	50 - 150	50 - 30	> 300
WQI	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

However, a few limitations were identified while reviewing Malaysian water quality index procedure and the long term data recorded in various river basins in Malaysia. These are given below (Mamun *et al*., 2007):

a. pH is not a problem for most of the Malaysian rivers and thus can be eliminated from the existing WQI equations. However, pH should be monitored to assess the suitability of water for other usages as required by the National Water Quality Standards – NWQS;
b. No nutrient (phosphorus, nitrogen, etc.) is considered in the existing WQI equation;
c. Aesthetically the river water should be attractive to the citizen. There are suspended solids (SS) in the existing WQI procedure but SS do not always represent the clarity of the water. Thus, one parameter (Turbidity) could be included to indicate the transparency of water;
d. The distribution of WQI values are not uniform for five Classes set for the assessment of water quality in Malaysia.

The existing WQI was assessed for its suitability for the JPS data and discussed in the following section. Other international WQI procedures was studied too and were evaluated to fit in this study. This activity was conducted based on the published literature accessible through printed and electronic sources. The JPS water quality data could not be fitted to the existing DOE WQI equations due to lack of dissolved oxygen (DO) data. Similarly, WQI equations practiced in overseas countries were not suitable due to lack of certain data required for the specific WQI procedures.

3.3 NONPOINT SOURCE POLLUTION

The easiest way to define nonpoint source pollution is to term as “storm generated pollution”. The rainwater washes away the pollutants accumulated on the land surfaces, rooftops and vegetation, and ultimately drains into the water bodies. Most of the pollutants are generated due to human activities, while the rests are due to natural degradation of soil and other components of the urban environment. The broad category of NPS pollutant is sediment, nutrient, organic, inorganic and toxic substance originating from landuse activities and/or from the atmosphere, which are carried to surface water bodies by storm runoff. NPS pollution is said to occur when the rate at which these materials enter water bodies exceed natural levels.

3.3.1 Nonpoint Source Pollutants

The most common nonpoint source pollutants from urban areas are stated according to their groups.

Chemo-physical Pollutants: The chemo-physical pollutants that may be significant in the case of NPS pollution are pH, Total Dissolved Solids (TDS), Conductivity, Turbidity and Total Suspended Solids (TSS). pH may be a problem in the highly industrial regions due to the potential of generating acid rain and runoff. The most common problems are encountered due to high turbidity and high TSS.

Organic Pollutants: These pollutants are composed of organic matters, which are degraded fast and have the potential to cause oxygen depletion in the receiving water bodies. These pollutants are expressed in terms of biochemical oxygen demand (BOD), chemical oxygen demand (COD), Total Organic Carbon (TOC), Oil and Grease (O&G), etc. However, BOD and COD are the most common parameters studied for the NPS pollution monitoring and control (US EPA, 1983; Pitt *et al*., 1993).

Inorganic Pollutants: Inorganic pollutants are mainly the metals and others in organic compounds. A few of the metals are toxic at high concentration and have the tendency to accumulate into the tissue of aquatic flora and fauna. The most common heavy metals observed (US EPA, 1983) in the urban storm runoff due to urban activities are Zinc (Zn), Lead (Pb), Copper (Cu), Chromium (Cr), Cadmium (Cd), Nickel (Ni), etc.

Toxic Pollutants: Besides heavy metals, toxic pollutants in urban runoff are mainly referred as herbicides, pesticides, PAHs, PCBs and other carcinogenic elements including the most common heavy metals (Pitt *et al*. 1993; Lee and Lee, 1993).

Microbial Pollutants: The most common microbial pollutant in the urban runoff is coliform bacteria. Total and faecal coliforms are of special interest due to their easy access into the storm runoff either through anthropogenic sources or sewer overflows. Spread of waterborne diseases in the developing countries due to NPS pollution is identified as one of the main issues, which is more detrimental than the sedimentation problem (Field *et al*., 1993; Wanielista and Yousef, 1993).

3.3.2 Sources of NPS Pollutants

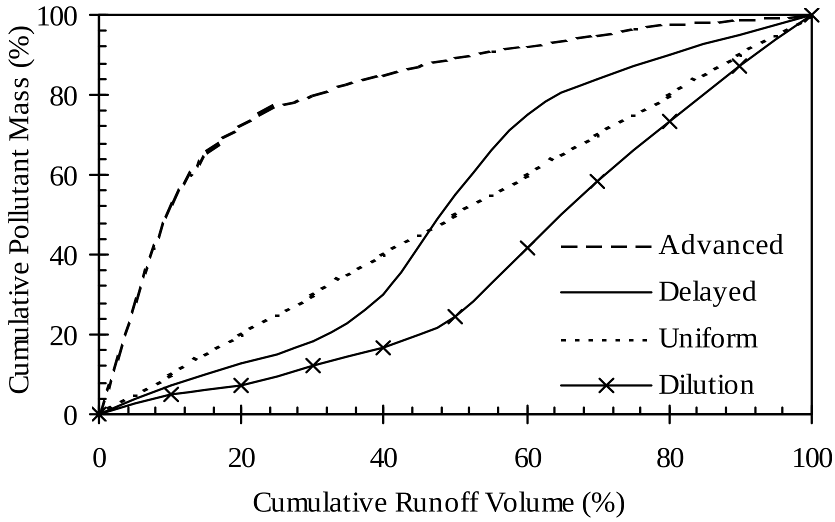
In general, the most predominant source of nonpoint pollution are the agricultural, urban and urbanising areas. These activities include plantation, construction or renovation activities, transportation, gardening, solid waste handling, accidental spills, etc.

According to DID (2000) the typical sources of urban NPS pollutants include:

- air emissions (chemicals, nutrients and metals);
- household gardens, public open spaces, sporting facilities (TSS, pesticides, fertilisers, etc.);
- street litter and garbage (leaves, cans, bottles, papers, plastics, etc.);
- domestic and wild animals (faeces, BOD, bacteria, etc.);
- automobiles (COD, motor oil, heavy metals, tyre, brake materials, etc.);
- wastewater discharges and sewer overflows (nutrients, BOD, bacteria, zinc, copper, etc.);
- industry and industrial processes (chemicals, COD, metals, etc.);
- commercial activities e.g. stock yards, vehicle repair workshops in open spaces, etc. (TSS, COD, oil & grease, etc.);
- construction sites (litter, soils, building products, rubble, etc.);
- accidents and spills (petrol, oil, chemicals, etc.) and
- landfills (nutrients, BOD, COD, metals, etc.)

3.3.3 First Flush Phenomenon

The term “First Flush” is frequently used in NPS or diffuse pollution control. A first flush is defined as the initial high pollutant loadings that may occur in the initial period of a storm event. Depending on rainfall pattern and catchment properties the initial part of the storm is sometimes referred to as either the first hour of rainfall or a specific amount of runoff in the first hour (Harrison and Wilson 1985; Kuo and Zhu, 1989). Vorreiter and Hickey (1994) considered the occurrence of first flush if the concentration of pollutants increased from dry levels on the incline of the hydrograph. Loading characteristics of urban runoff can be advanced,



lagging, mixed or uniform, as shown in Figure 3 (Griffin *et al*., 1980). The accepted and easiest way to determine the existence of first flush is to plot the cumulative flow versus cumulative load. If the pollutant loadings result in a curve that lies above a diagonal line extended from the origin (the first flush divider), then a flushing action occurred because the amount of pollutant mass at certain time is higher than the amount of runoff.

First flush has been regarded as one of the important issues in the management of water quality due to the shock loadings of pollutants into water ways, either in terms of the pollutant mass or the pollutant concentration. However, the extent of shock load is relative to the size of the receiving water bodies. The result of these shock loadings of pollutants may be an acute toxicity towards the aquatic environment. Studies on the impact of shock pollutant loadings with a high pollutant concentration have shown that these shock loads are acutely toxic to aquatic invertebrate (Hall and Anderson 1988).

Figure 3: Types of First Flush Phenomenon of Storm Runoff (Griffin *et al*., 1980)

A few studies have shown that the pollutant concentrations are highest in the early stages of the runoff process (Ellis and Sutherland, 1979; Griffin *et al.*, 1980; Lee *et al.*, 2002 and Gupta and Saul, 1996; Harrison and Wilson 1985; Vorreiter and Hickey, 1994). In some studies pollutant loading, instead of pollutant concentration, was considered as the main criteria to define first flush. However, in the NURP data, the first flush was not clearly evident (US EPA, 1983). There are several factors that affect the first flush; these include:

- storm intensity and depth;
- catchment characteristic (slope, imperviousness, shape and size);
- landuses;
- drainage network; and
- nature of the pollutant.

3.3.4 NPS Pollution Load Calculation

For the design of any structural facility to abate NPS pollution, it is important to know how much pollution load is expected to be generated from the area concerned. According to the present global practices, pollution from the NPS sources are calculated four ways:

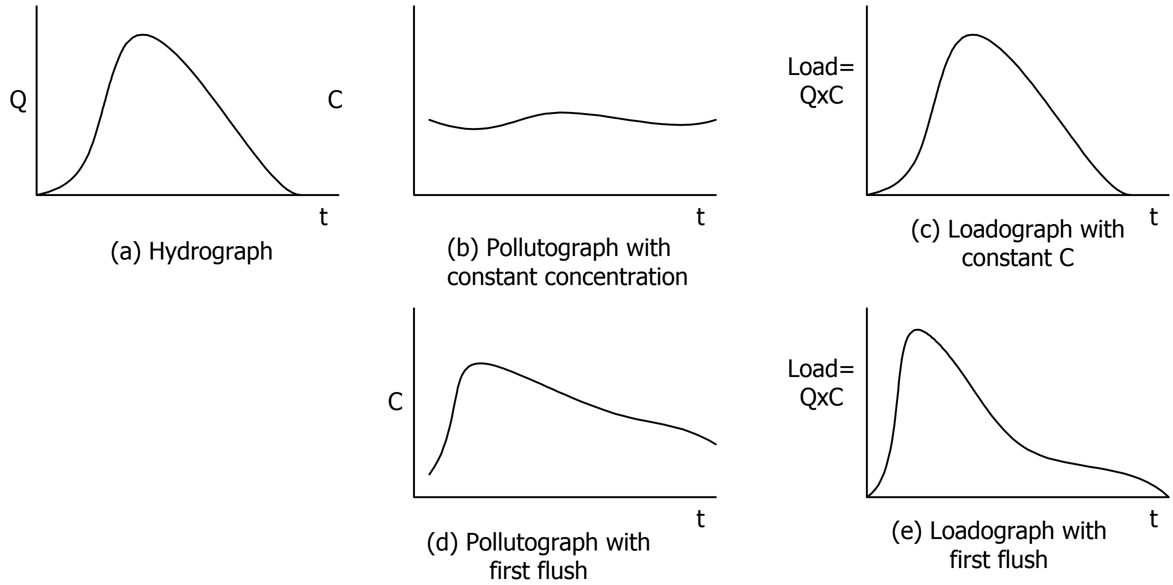
1. Event mean concentration (EMC) method;
2. Pollution loading rate method;
3. Export equation method; and
4. Modelling through build-up and wash-off data.

Event Mean Concentration (EMC) Method: This is the most common method to estimate pollution loading due to storm runoff. In this method, stormwater samples are taken at various intervals to study the quality of storm runoff during the whole rain event. The collected samples are analysed for the quality and Equation 8 is used to calculate the event mean concentration. It is considered that EMC of any particular parameter represents the average concentration over the storm event. In order to calculate annual or any other pollution load due to diffuse pollution, the EMC value is multiplied with the corresponding runoff amount.

$$EMC_{stormwater} = \frac{\Sigma Q_{wwf}C_{wwf} - \Sigma Q_{dwf}C_{dwf}}{\Sigma Q_{wwf} - \Sigma Q_{dwf}} \qquad (8)$$

where, the subscripts "*wwf*" and "*dwf*" denote the wet weather flow (combined wastewater & stormwater) and dry weather flow (wastewater only) from the study area. If there is no discharge of wastewater from the point sources of the area then the components of flow (*Q*) and concentration (*C)* for the "*dwf*" in Equation 8 should be ignored in calculating EMC of storm runoff.

It is important to note that the EMC results from a flow-weighted average, not simply a time average of the concentration (DID, 2000). When the EMC is multiplied by the runoff volume, an estimate of the event loading to the receiving water is obtained. As is evident from Figure 4, the instantaneous concentration during a storm can be higher or lower than the EMC, but the use of the EMC as an event characterisation replaces the actual time variation of concentration. This ensures that mass loadings from storms will be better represented.



FFigure 4: Effect of First Flush on Shapes of Pollutograph and Loadograph (DID, 2000)

Just as instantaneous concentrations vary within a storm, EMCs vary from storm to storm (Figure 5) and from site to site as well (DID, 2000). The median or 50th percentile EMC at a site, estimated from a time series of the type illustrated in Figure 5, is called the site median EMC. When site median EMCs from different locations are aggregated, their variability can be quantified by their median and coefficient of variation to achieve an overall description of the runoff characteristics of a constituent across various sites.

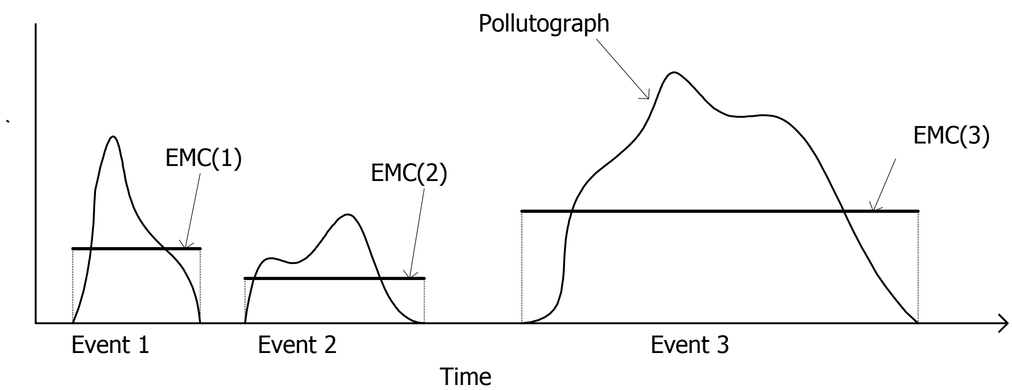


Figure 5: Possible Inter-storm Variation of Pollutographs and EMCs (DID, 2000)

Pollution Loading Rate Method: In this method, EMC values are determined for various ranges of storm event and then multiplied with the runoff generated during the corresponding storm event to calculate the loading in terms of kg. pollutant/mm runoff. Sometimes the calculated load is again divided by the catchment areas studied to express the loading rate in terms of kg./ha/mm runoff. However, long-term data is required to apply this method with reasonable accuracy and higher confidence level. A typical equation for the estimation of pollution load for a certain amount of rainfall is given in Equation 9.

$$L = L_r \,.\, R_O \,.\, C \,.\, A \qquad (9)$$

where,

L = Pollution load of any parameter (kg.);

L_r = Loading rate of particular pollutant (kg./mm/ha);

R_O = Runoff (mm); and

A = Watershed area (ha).

Export Equation Method: The pollutant export equations are determined based on the statistical analysis of long-term runoff quality data. The most common parameters considered in the equations are rainfall, runoff, catchment size, landuse type, etc. If the equations are developed based on the pollution load generated by each unit of the catchment area then the effect of the catchment area is ignored in the equation (DID, 2000). Format of NPS pollutant export relations used in MSMA is given in Equation 10.

$$L_r = a.R_O^{\,b} \qquad (10)$$

where,

L_r = Loading rate of particular pollutant (kg./km^2);

a = Coefficient;

b = Exponent; and

R_O = Runoff (mm per storm event).

Besides statistical regression equation, empirical equations are also used to estimate pollution loading from the NPS sources (Chin, 2000). The most widely used pollutant equations are the USGS model and EPA model. Based on 2,813 storms at 173 urban stations in 13 metropolitan cities in the USA, Driver and Tasker (1990) developed empirical NPS export formula for ten pollutants (Equation 11). Dependent and independent variables of the equation for various pollutants are given in Table 6.

$$Y = 0.454(N)(BCF)10^{[a+b\sqrt{(DA)}+c(IA)+d(MAR)+e(MJT)+f(X2)]} \qquad (11)$$

where, *Y* is the pollutant load (kg.) for the pollutants listed in Table 6, *N* is the average number of storms in a year, *BCF* is the biased correction factor, *DA* is the total contributing drainage area (ha), *IA* is the impervious area as a percentage of the total catchment area (%), *MAR* is the mean annual rainfall (cm), *MJT* is the mean minimum temperature in January (^oC) and *X2* is an indicator variable that is equal to 1.0 if commercial plus industrial landuse exceeds 75% of the total catchment area and is zero otherwise.

Table 6: Coefficients of the USGS Empirical Equation for Pollution Load

Pollutants (*Y*)	Coefficients of the Empirical Equation						
	a	*b*	*c*	*d*	*e*	*f*	*BCF*
COD	1.1174	0.1427	0.0051	-	-	-	1.298
TSS	0.5926	0.0988	-	0.0104	-0.0535	-	1.521
TDS	1.1025	0.1583	-	-	-0.0418	-	1.251
TN	-0.2433	0.1018	0.0061	-	-	-0.4442	1.345
AN	-1.4022	0.1002	0.0064	0.0089	-0.0378	-0.4345	1.277
TP	-2.0700	0.1294	-	0.00921	-0.0383	-	1.314
DP	-1.3661	0.0867	-	-	-	-	1.469
Cu	-1.9336	0.1136	-	-	-0.0254	-	1.403
Pb	-1.9679	0.1183	0.0070	0.00504	-	-	1.365
Zn	-1.6302	0.1267	0.0072	-	-	-	1.322

The USEPA (Heany *et al*., 1977) also developed a set of empirical formulae that is used to estimate the mean annual pollutant loads in the urban storm runoff. The Equation 12 - 14 are valid for the urban areas in the USA having separate sewer systems. The average pollutant concentration can be calculated from the annual pollutant load by dividing the load by annual runoff amount following the formula given in Equation 15 and 16.

$$M_s = 0.0442\alpha Pfs \tag{12}$$

$$f = 0.142 + 0.134D^{0.54} \tag{13}$$

$$s = N_s/20 \tag{14}$$

$$R = [0.15 + 0.75(I/100)]P - 3.004d^{0.5957} \tag{15}$$

$$d = 0.64 - 0.476(I/100) \tag{16}$$

where, M_s is the amount of pollutant (kg./ha/yr), α is a pollutant loading factor (e.g. for TSS of residential area α = 16.3), *P* is annual rainfall (cm/yr), *f* is a population density function (Equation 13) depends on the population density in person per hectare (*D*), *s* is the street sweeping factor which depends on sweeping interval, if N_s > 20 days then *s* = 1.0 and if $N_s \leq$ 20 days then *s* should be determined from Equation 14. *R* is the annual runoff (cm), *I* is the average imperviousness of the catchment area (%) and *d* is the depression storage that can be determined from Equation 16.

3.3.5 *Site Selection Criteria*

Site or catchment selection for NPS or diffuse pollution study is very important. It is also important to make sure that runoff or discharges from other areas do not enter into the drainage system of the selected study area. Once the study catchment is selected, its important parameters such as total area, slope, imperviousness, directly connected impervious area (DCIA), road coverage and drainage length should be determined.

3.3.6 *Runoff Sampling Procedure*

In the case of runoff sampling, the automatic sampler should be used, which can be programmed with condition (based on the rainfall amount, water level in the river or drain, runoff volume, etc.) to activate pump to take grab samples at various intervals. For each storm event, a maximum of 24 samples can collected from the drainage outlet to cover the whole runoff hydrograph. Non-uniform sampling intervals can be chosen to cover the whole runoff hydrographs and also to suit the requirements of studying the first flush phenomenon. For example, the first 10 samples can be collected at 1-minute interval, the next 9 samples at 3-minute and the rest 5 samples at 5-minute intervals. However, the intervals will depend on the size of the catchment or study area. Unless first flush determination is one of the objectives of the NPS pollution study, composite sample should be prepared to determine the EMC from one testing only. The procedure to determine amount of "aliquots" (sample volumes) required from individual bottle can be followed by the method mentioned in Section 30.2.4 of Chapter 30 in MSMA (DID, 2000).

CHAPTER 4

METHODOLOGY OF RIVER INDEX DEVELOPMENT

Based on the extensive literature review, it is understood that none of the indexes are developed based on historical data and the existing methods are also not suitable for the development of WQI based on the JPS data only. It is also realised that an index can be developed for overall protection of the water environment considering physical, biochemical, microbial, biodiversity, toxicology, etc. or it can be developed to serve the activity or purpose of a single organization. As such, due to absence of certain important parameters (such as, DO, total nitrogen, certain heavy metals, bacteria, etc.) it is recommended that the proposed river index for JPS should be named as JRI and include specific flow ($m^3/s/km^2$), TSS (mg/L), TDS (mg/L) and Turbidity (NTU). The naming of the index as "JRI" and selection of parameters eliminates any chance of conflict with the existing WQI developed by the DOE, Malaysia. The uniqueness of the JRI is that this is the only index that considers flow as one of the variables. Based on the literature review none of the indexes practiced through out the world considers flow data as a variable.

4.1 SELECTION OF THE PARAMETERS

Depending on the data availability and to suit JPS' main activity, the following parameters are selected for the JPS River Index (JRI):

1. Specific Flow, which is instantaneous flow divided by the catchment area at the station ($m^3/s/km^2$). This parameter would indicate the decrease in dry day baseflow and increase in rainy day runoff rate. The baseflow rate in a natural catchment would be about 0.05 $m^3/s/km^2$ as recommended by JICA and practiced by JPS. Any reduction from this value during dry days would indicate lowering in baseflow due to development activity, which is not good for a healthy river environment. On the other hand the frequent (e.g. annual) specific runoff or flood flow for the natural catchments in the Peninsular Malaysia is close to 1. Therefore, any specific flow value greater than 1 would indicate increased specific flow due to land developments (agricultural, urban, etc.). As such, inclusion of specific flow in the JRI would be very useful and represent the river status in a better and holistic way (considering water quantity and quality).
2. Total Suspended Solids, which represents the sediments that adsorbs many pollutants on the surfaces (mg/L);
3. Total Dissolve Solids, which represents salts and minerals that indicates the dissolved minerals in the water (mg/L); and
4. Turbidity, which represents the clarity and aesthetic property of water that is very important to make the river and water appealing to the people (NTU).

As, the existing WQI (DOE, 1994) already considers other pollution parameters (pH, DO, BOD_5, COD and AN), scope of the JRI is set to four parameters only, which are more relevant to JPS's nature of responsibility. JRI developed based on these parameters will also help achieve the objective of evaluating the past data collected by JPS. This is due to the fact that most of the stations, generally, got those data required for the proposed JRI.

4.2 DEVELOPMENT OF THE RATING CURVES

The rating curves for the JRI sub-indexes were developed based on the following considerations.

1. It is understood from the literature review that most of the rating curves for the indexes are developed based on expert peoples' perception, understanding and understanding on the effect of the selected parameter on the environment and target usage.
2. Sub-indexes of four JRI parameters are also developed based on that concept.
3. The rating curves for JRI are proposed based on local and international practices.
4. National water quality standards (NWQS), MASMA (DID, 2000) and other materials were also referred in selecting the parameters and rating curves for JRI.
5. Wherever possible, the proposed JRI rating curves are compared with the similar curves practiced worldwide.
6. Two rating curves for specific flow are proposed to represent the flow condition for rainy and non-rainy day flow. Rating curve for the flow was not compared as the rating curve of flow is not considered in any of the indexes practiced worldwide.

4.3 SELECTION OF THE WEIGHING FACTORS

1. The existing WQI weighing factor for each parameter was used as a guide to develop the new weighing factor in this study (for JRI). The existing WQI used for the selection of weighing factor would be Malaysian WQI, Universal WQI and NSF WQI (Table 7).
2. Weighing factor for each parameter was determined based on the importance of the parameter with respect to the over all index and its importance on the river status and morphology. The weighing factor was calculated based on the weightage (based on a scale of 1 to 5) assigned to each parameter selected for the JRI.

Table 7: Summary of Weighing Factor from Three Existing Indexes

Parameters	Weighing Factor		
	Malaysia WQI	**Universal WQI**	**NSF WQI**
DO	0.22	-	0.17

BOD	0.19	-	0.10
COD	0.16	-	-
AN	0.15	-	-
SS	0.16	-	-
pH	0.12	-	0.12
Total coliform	-	0.114	0.15
Cadmium	-	0.086	-
Cyanide	-	0.086	-
Mercury	-	0.086	-
Selenium	-	0.086	-
Arsenic	-	0.113	-
Nitrate-nitrogen	-	0.086	-
DO	-	0.114	-
pH	-	0.029	-
BOD	-	0.057	-
Total phosphorus	-	0.057	-
Nitrates	-	-	0.1
Phosphates	-	-	0.1
ΔT ^{o}C from equilibrium	-	-	0.10
Turbidity	-	-	0.08
Total solids	-	-	0.08
References	(DOE, 2005)	(Boyacioglu, 2007)	(Irvine *et al.*, 2003)

4.4 SELECTION OF LIMITS FOR CLASSES AND PARAMETERS

The National water quality standard was used (wherever possible) as the guide to select the limits and classes for each parameter.

4.5 CLASSIFICATION OF RIVER STATUS

1. The river status can be classified into five main classes from I to V.
2. Class II, III, and IV was further sub-divided into three classes (A, B and C), where each class will have the range of 10 values. This is proposed to control and monitor the river water quality in a more protective manner. A wide range of the class will result in loose monitoring and control of the river water quality. Most of the time the

polluters may like to satisfy the minimum quality or standard to belong to any target class.

4.6 FLOWCHART OF THE JRI METHODOLOGY

Procedure of the formulation of new JRI is shown, as a flowchart, in Figure 6.

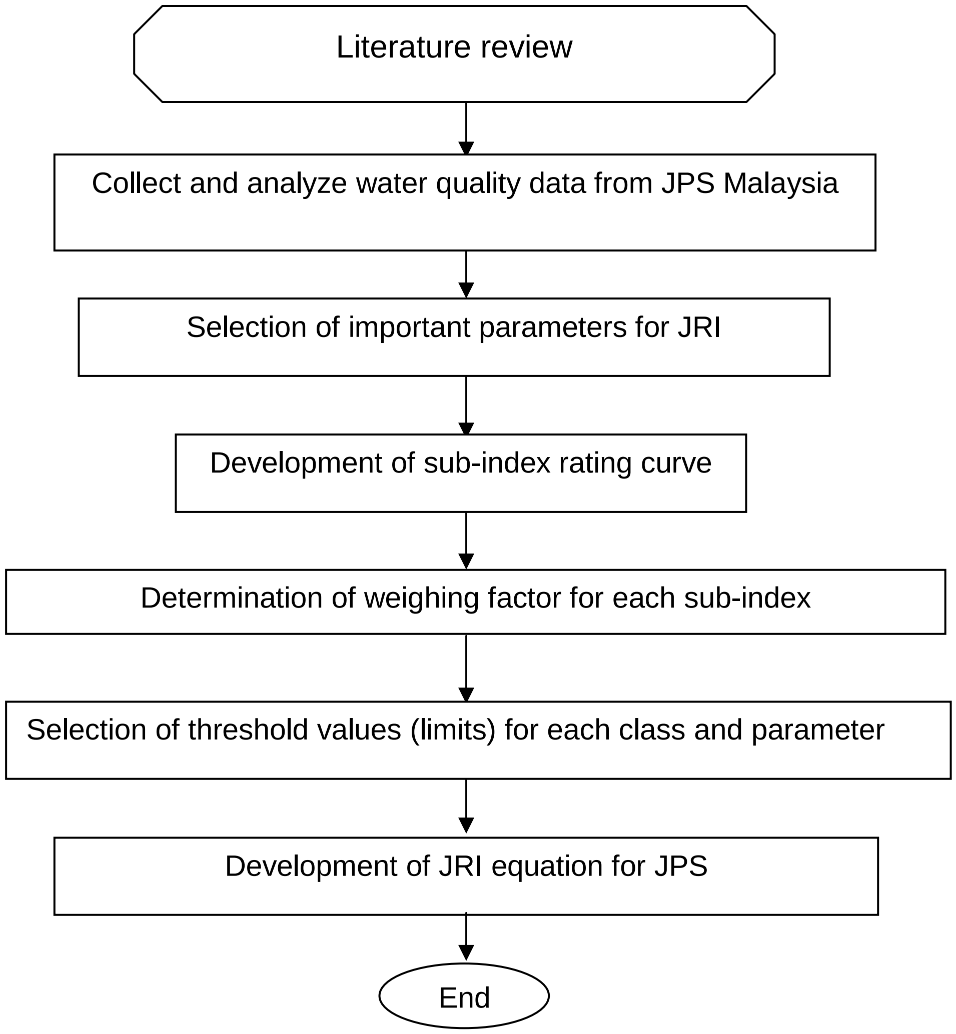


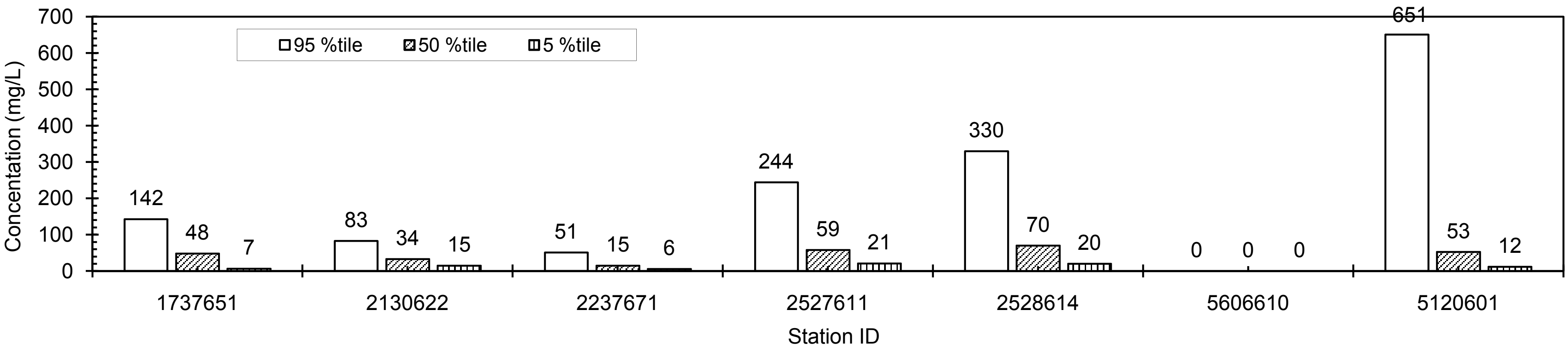
Figure 6: Flowchart for the Development of JRI

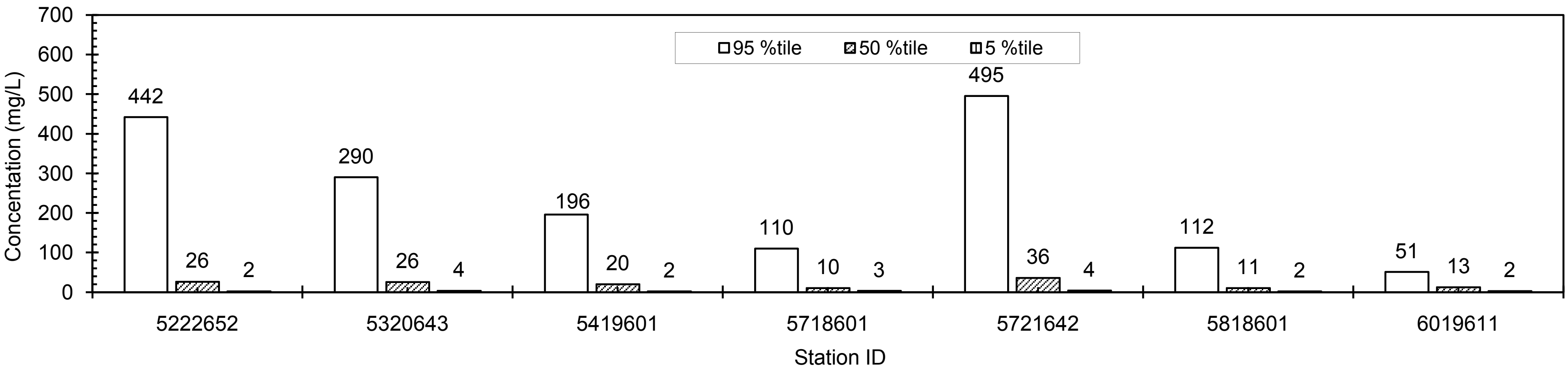
CHAPTER 5

RESULTS AND DISCUSSION

5.1 EVALUATION OF WATER QUALITY DATA

Various annual percentiles of the water quality parameters were calculated to assess the violation of water quality with respect to the existing National Water Quality Standards – NWQS developed by the Department of Environment Malaysia (DOE). In general, it was observed that median value of iron (Fe), chemical oxygen demand (COD) and in few cases suspended solids (SS) exceeded the Class III limit, which is the minimum class of water expected in the river that can be treated with conventional treatment facilities. Statistical summary of the water quality data is presented in Appendix B. The water quality of the important parameters for each station (for all available data) were analysed and plotted for comparison purpose (Figure 7 to 14).

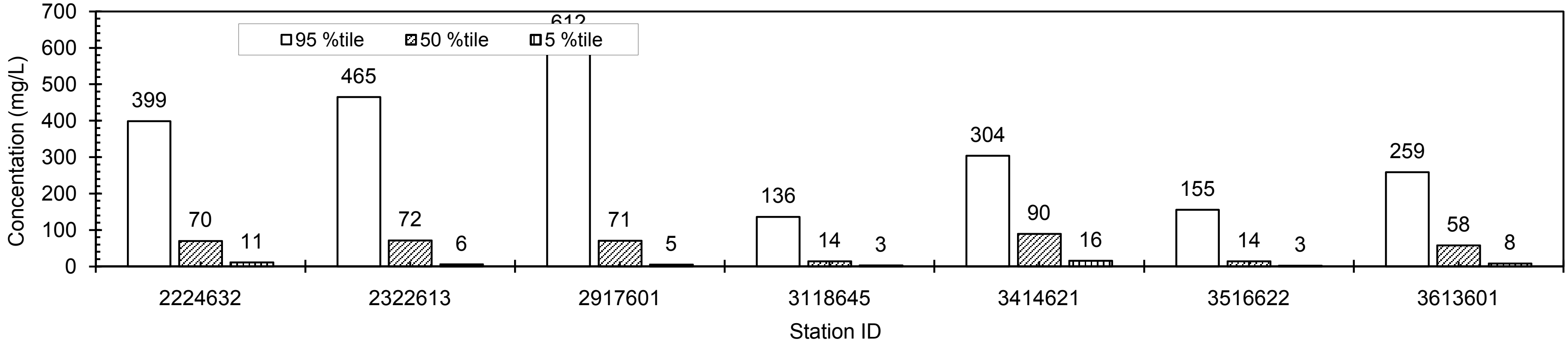


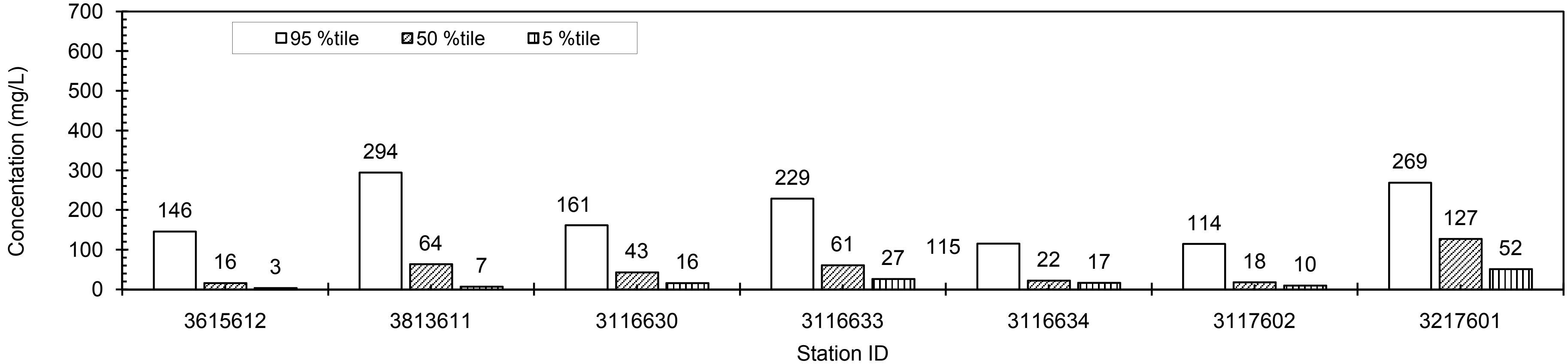


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
Turbidity	NTU	5	50	50	-	-	-	1000

Figure 7: Percentile Values of Turbidity at Various Stations

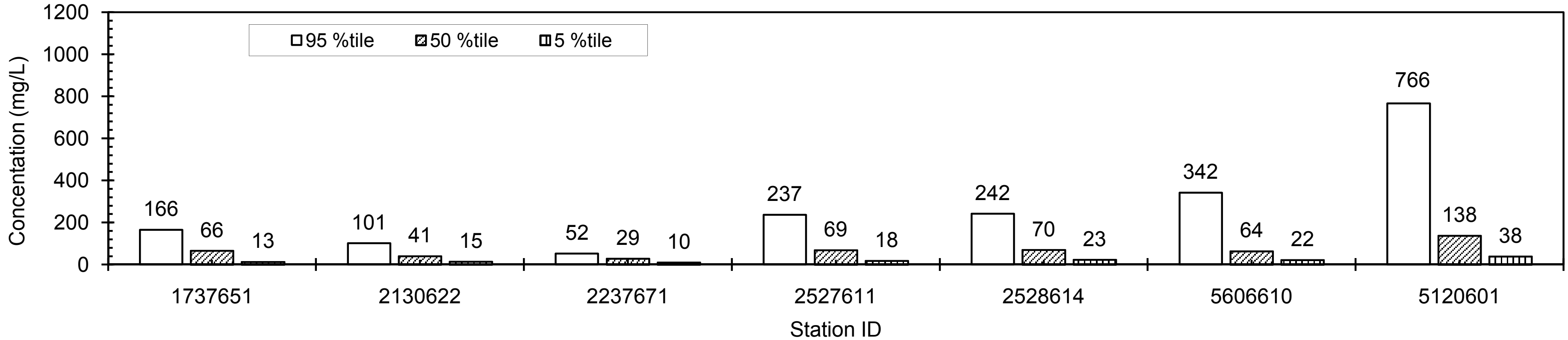


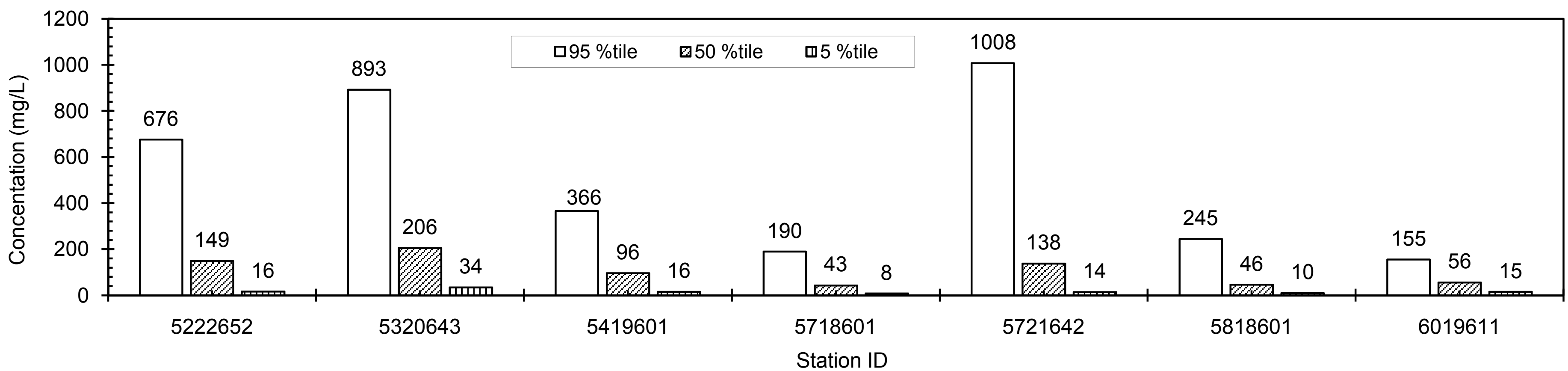


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
Turbidity	NTU	5	50	50	-	-	-	1000

Figure 7: Percentile Values of Turbidity at Various Stations (Continued)

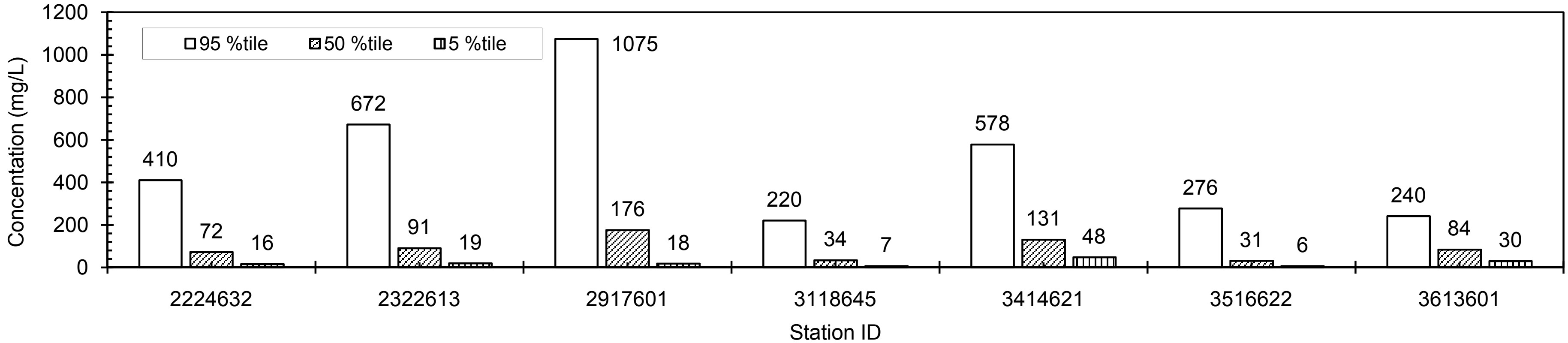


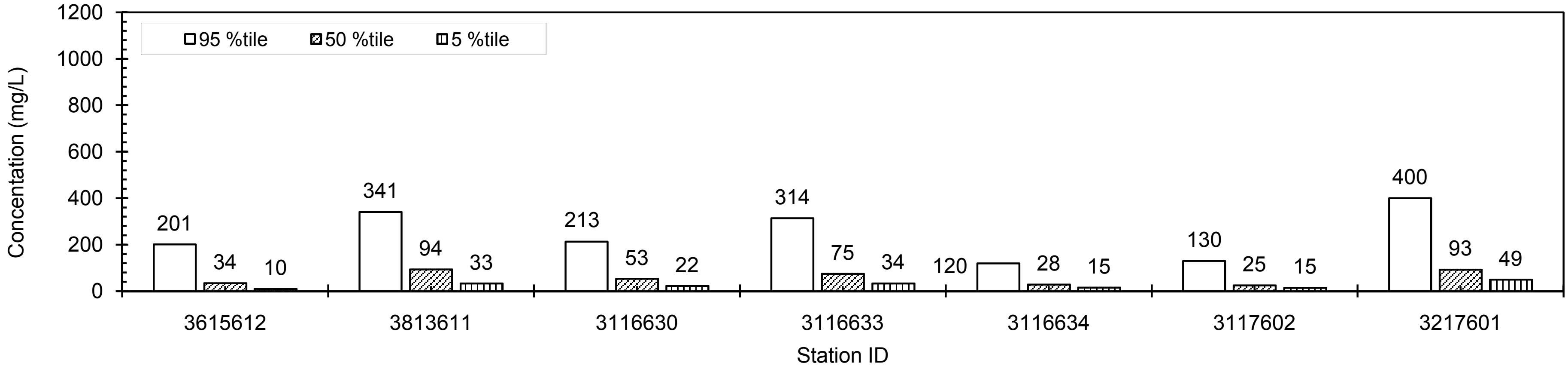


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
TSS	mg/L	25	50	50	150	300	>300	

Figure 8: Percentile Values of TSS at Various Stations

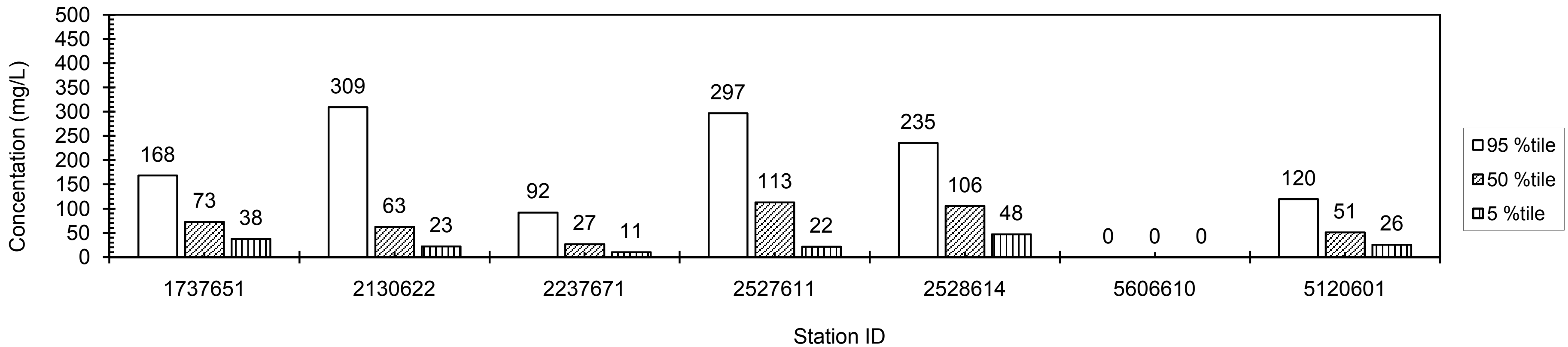


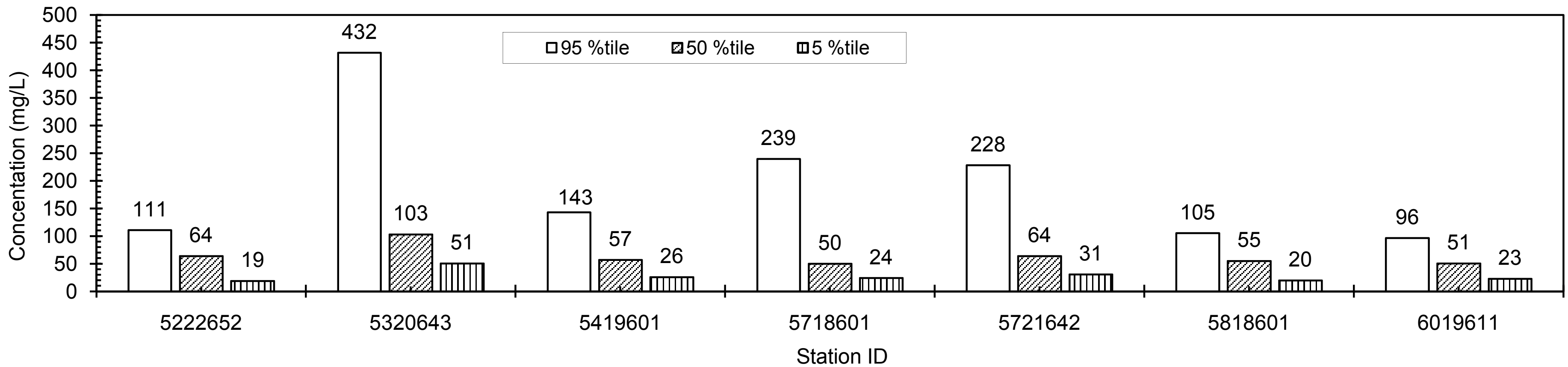


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
TSS	mg/L	25	50	50	150	300	>300	

Figure 8: Percentile Values of TSS at Various Stations (Continued)

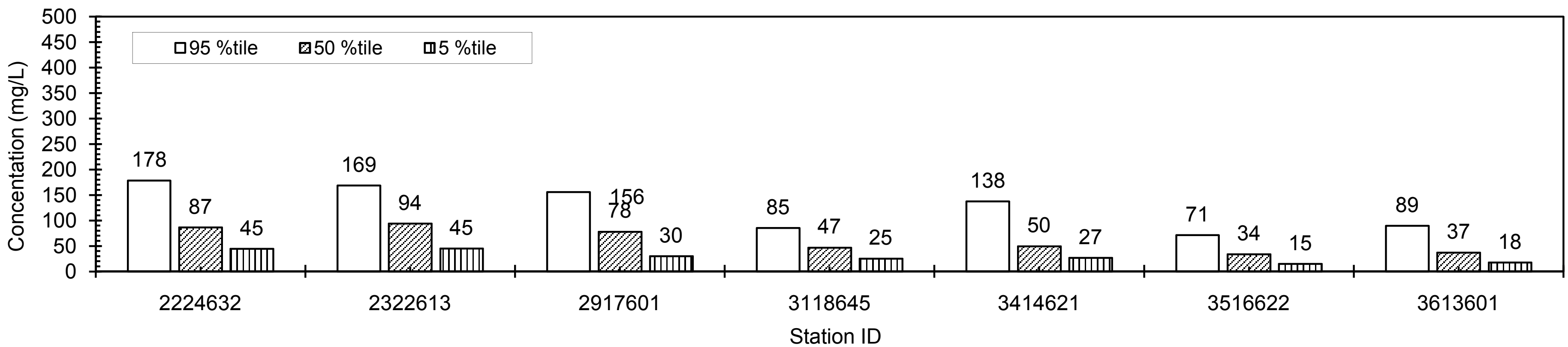


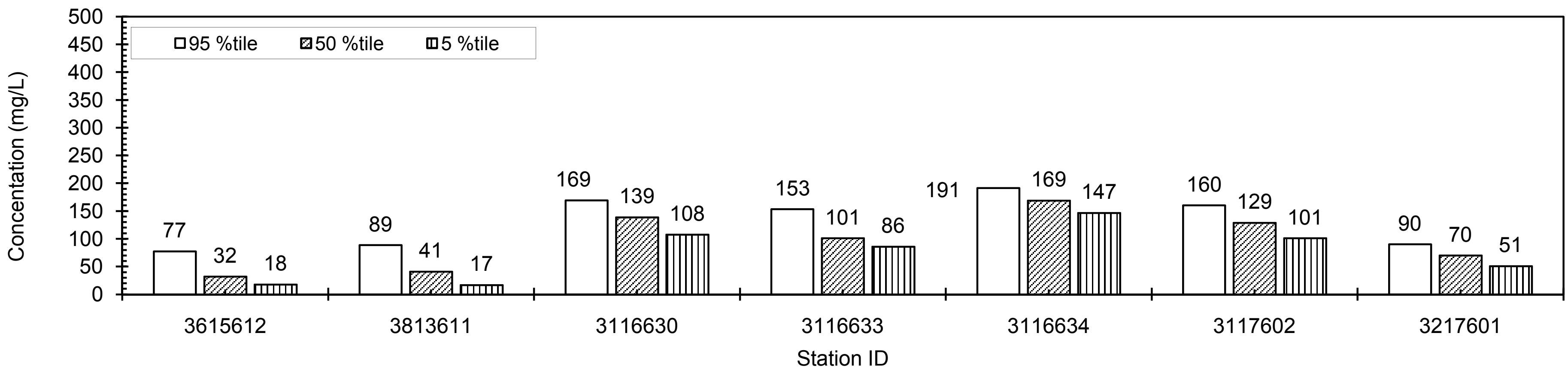


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
TDS	mg/L	500	1000	-	-	4000	-	1500

Figure 9: Percentile Values of TDS at Various Stations

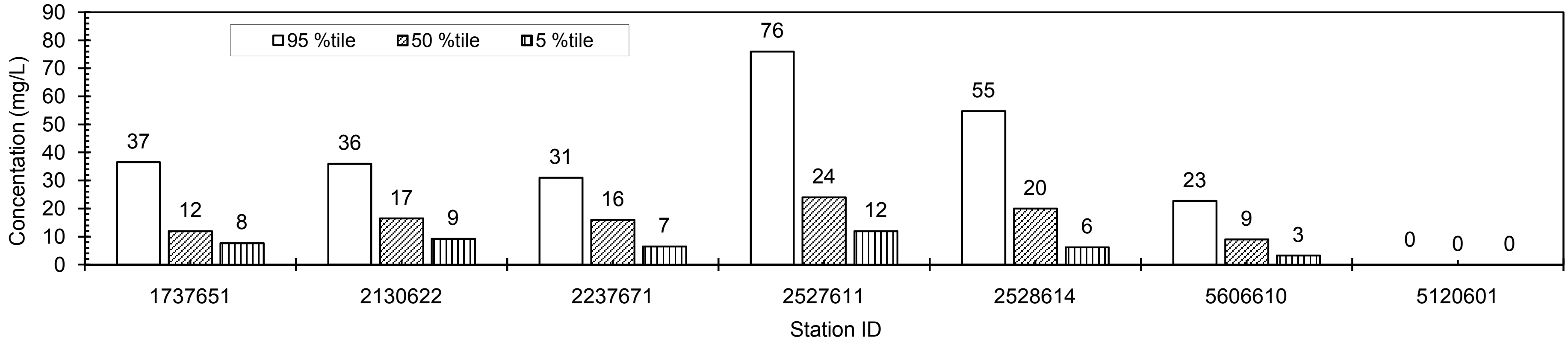


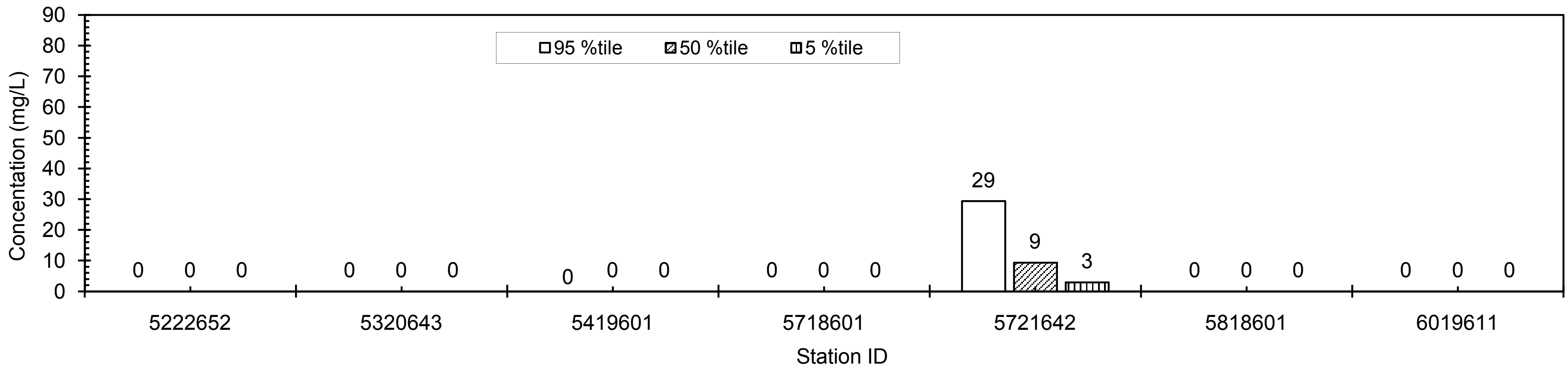


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
TDS	mg/L	500	1000	-	-	4000	-	1500

Figure 9: Percentile Values of TDS at Various Stations (Continued)

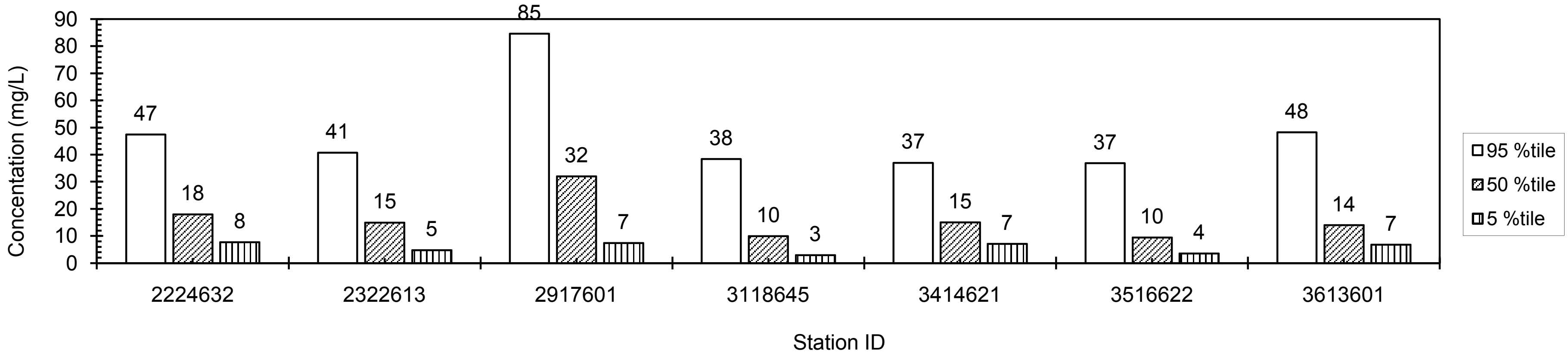


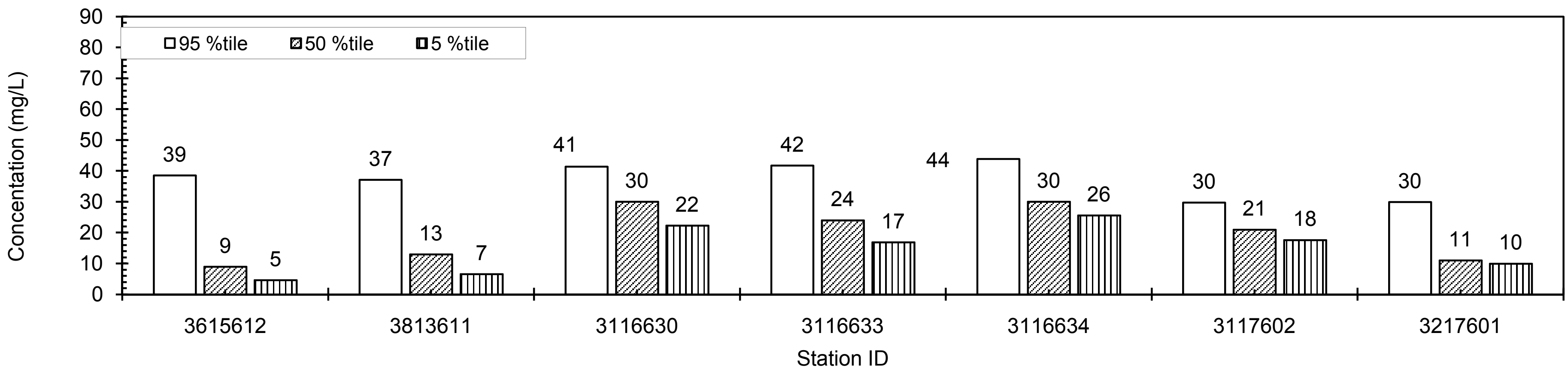


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
COD	mg/L	10	25	25	50	100	>100	10

Figure 10: Percentile Values of COD at Various Stations

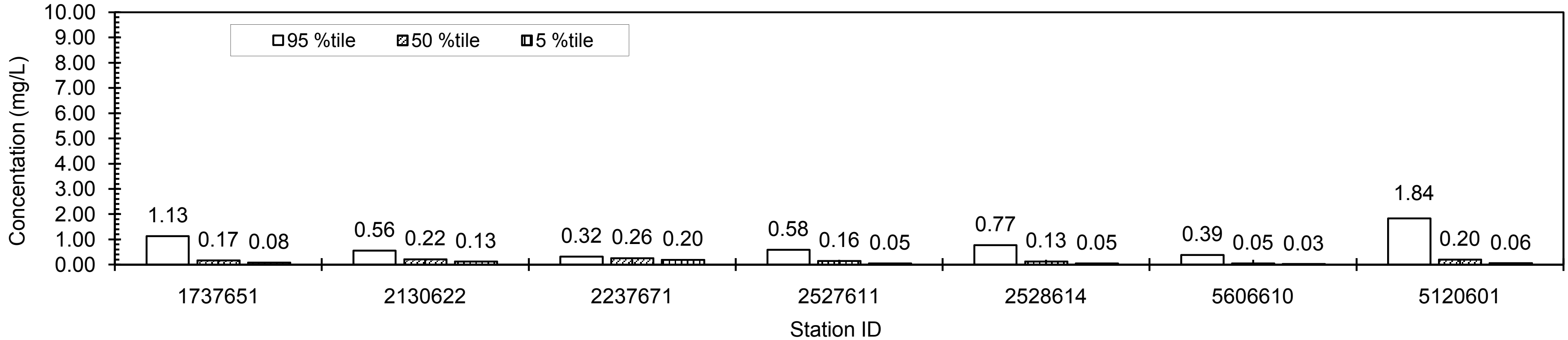


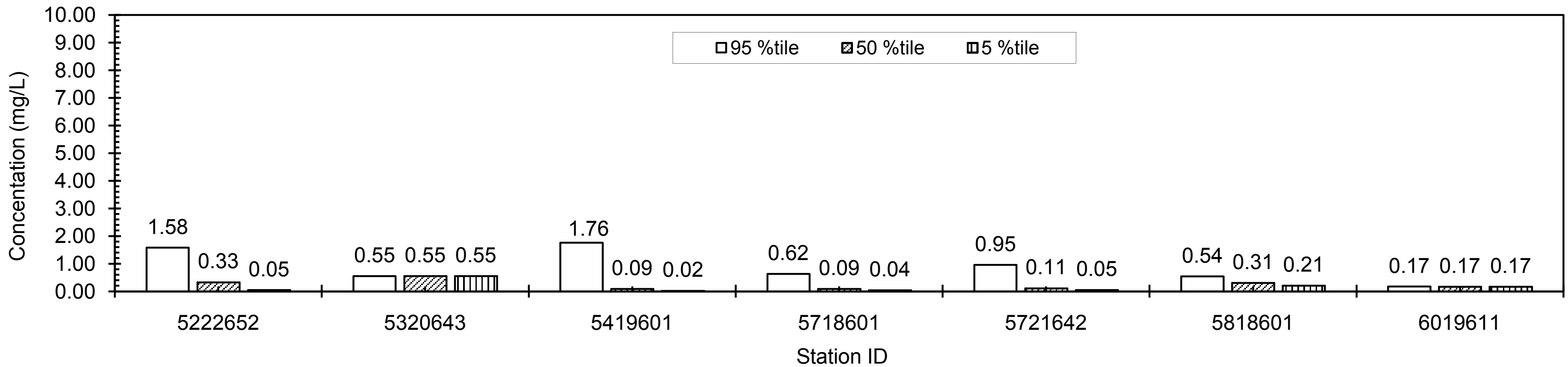


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
COD	mg/L	10	25	25	50	100	>100	10

Figure 10: Percentile Values of COD at Various Stations (Continued)

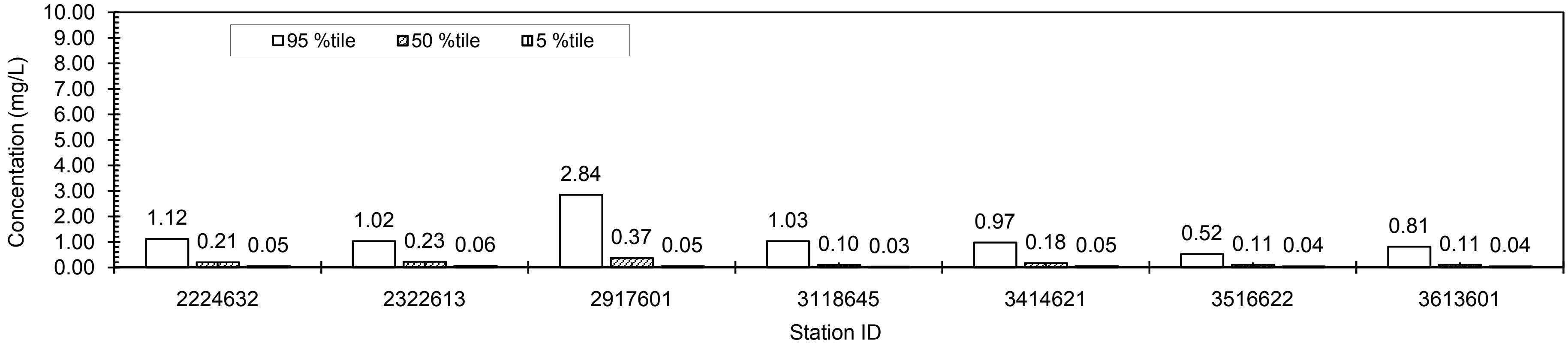


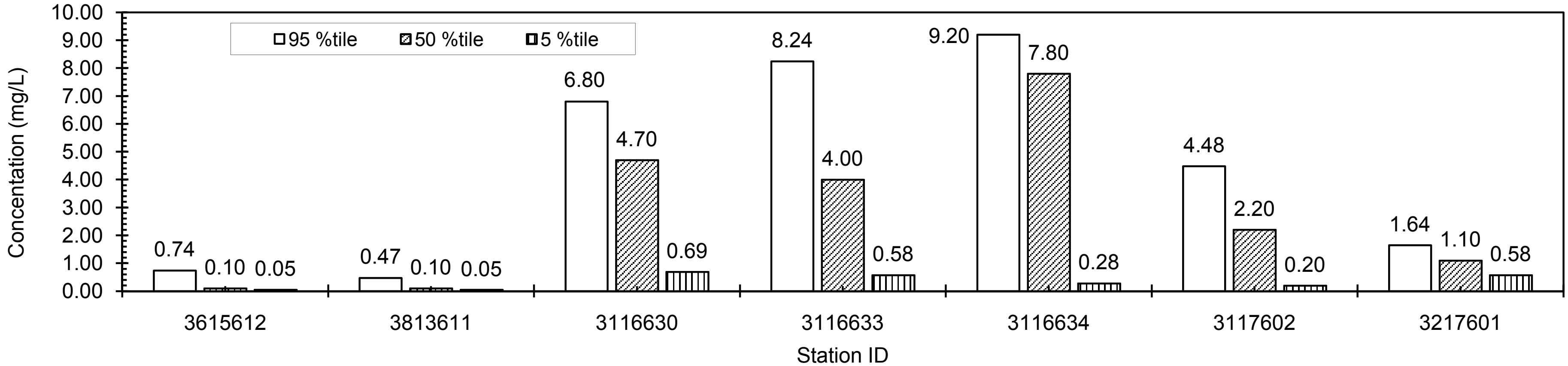


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
AN	mg/L	10	25	25	50	100	>100	10

Figure 11: Percentile Values of Ammoniacal Nitrogen at Various Stations

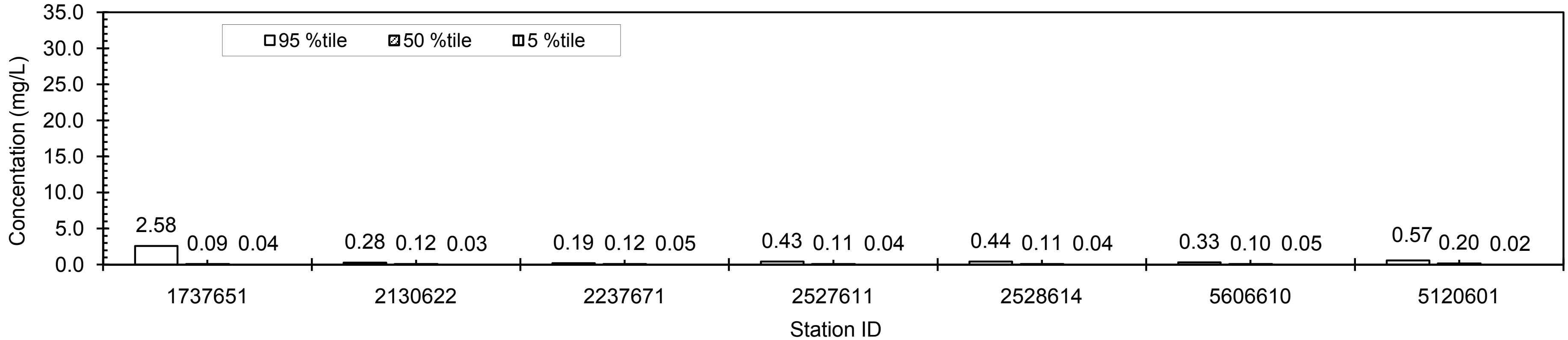


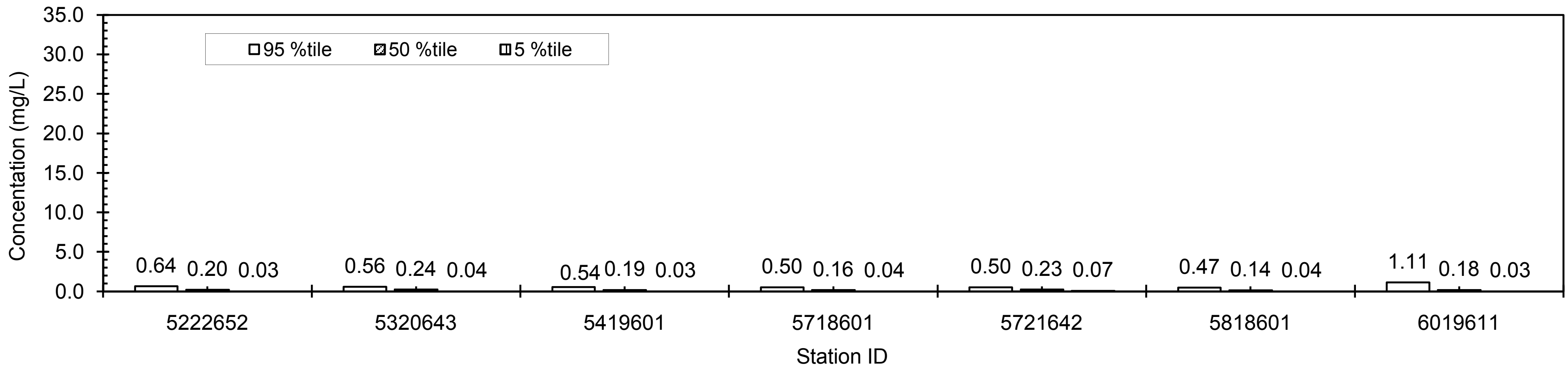


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
AN	mg/L	10	25	25	50	100	>100	10

Figure 11: Percentile Values of Ammoniacal Nitrogen at Various Stations (Continued)

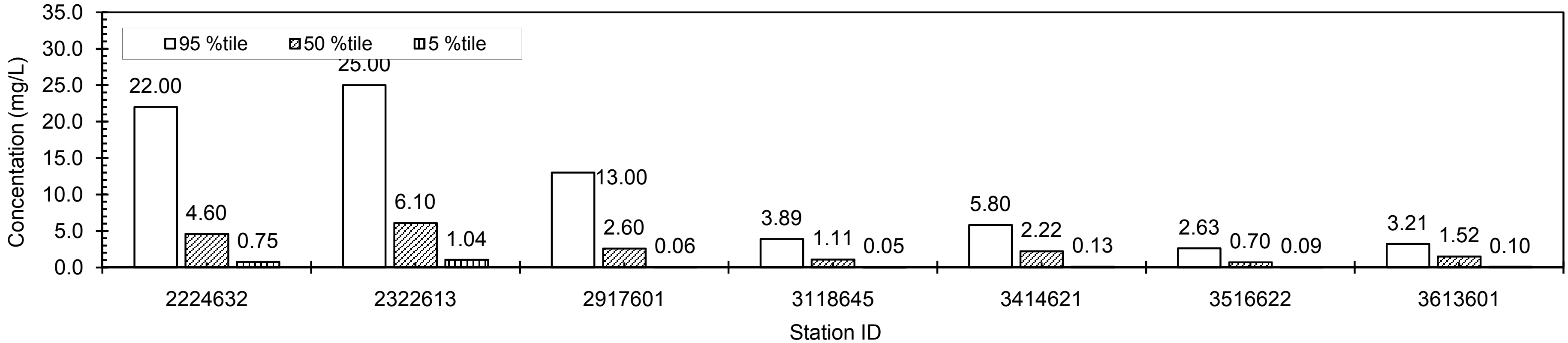


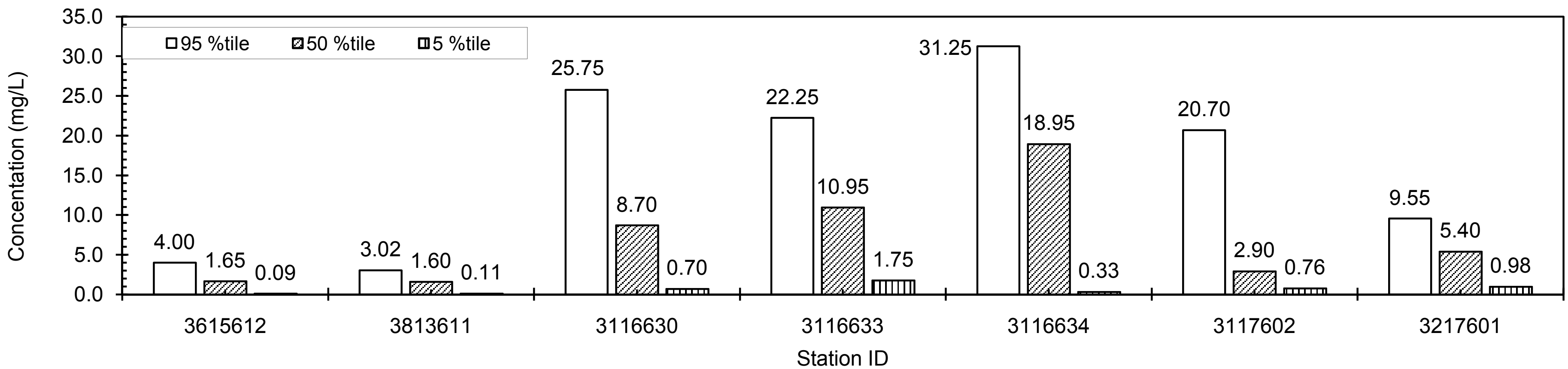


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
NO_3	mg/L	-	-	-	-	-	-	-

Figure 12: Percentile Values of Nitrate at Various Stations

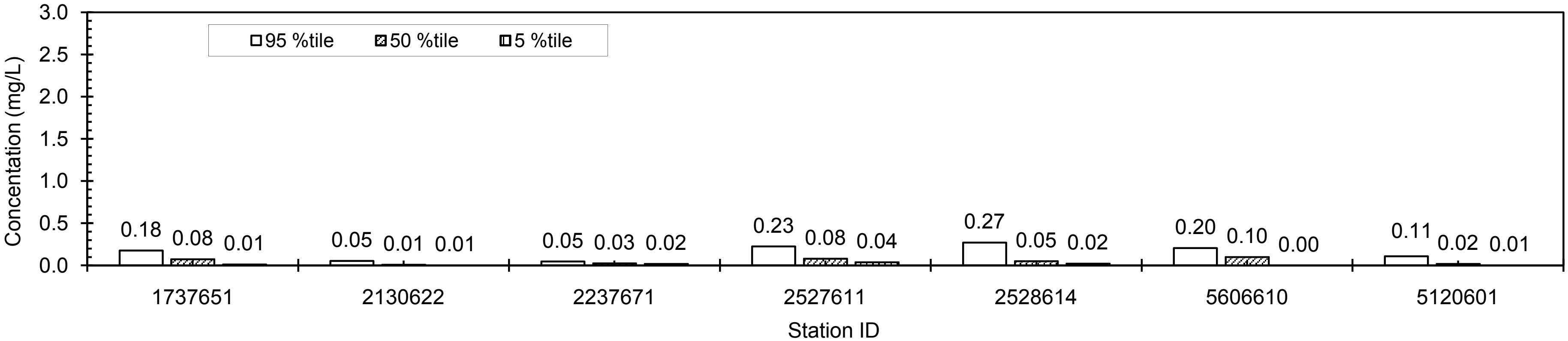


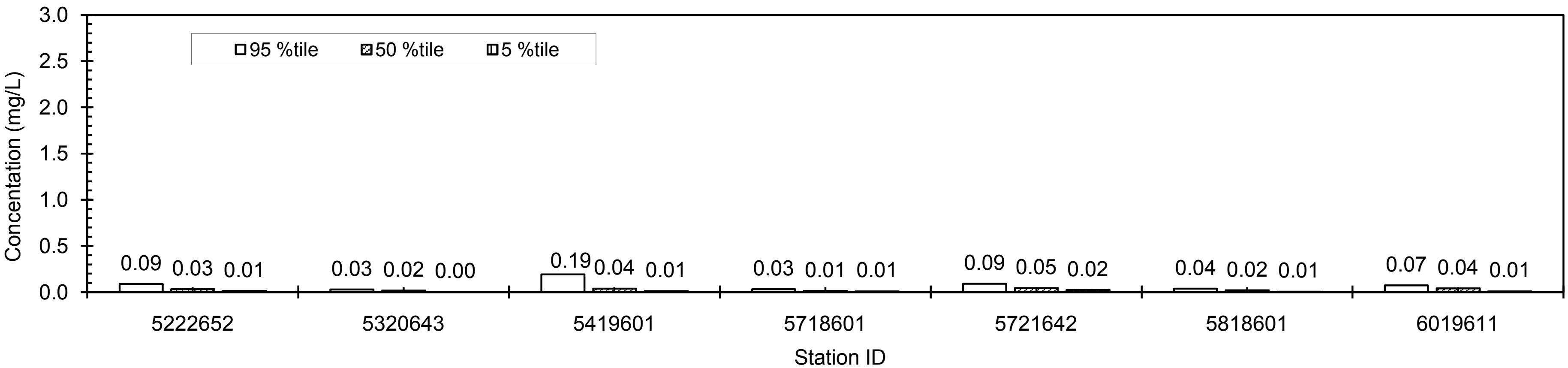


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
NO_3	mg/L	-	-	-	-	-	-	-

Figure 12: Percentile Values of Nitrate at Various Stations (Continued)

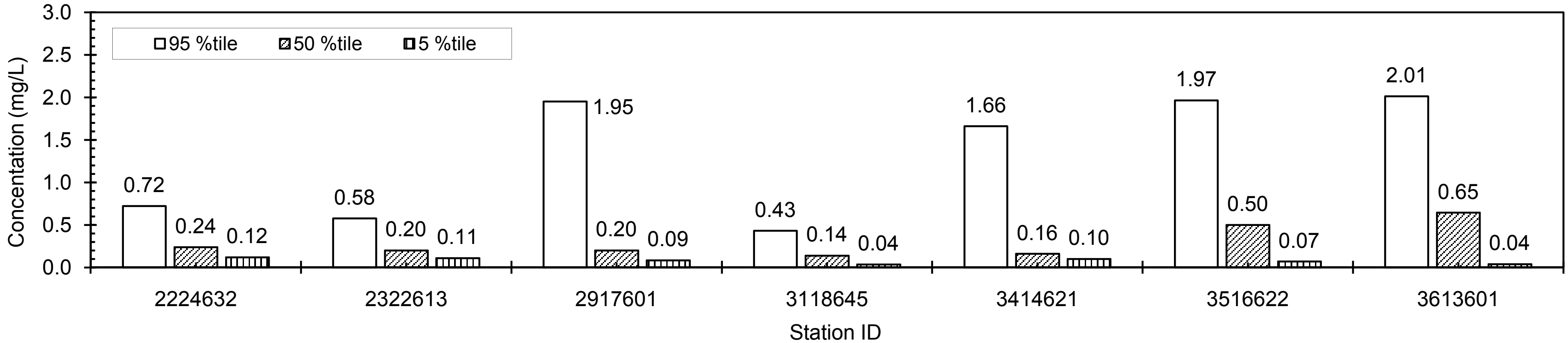


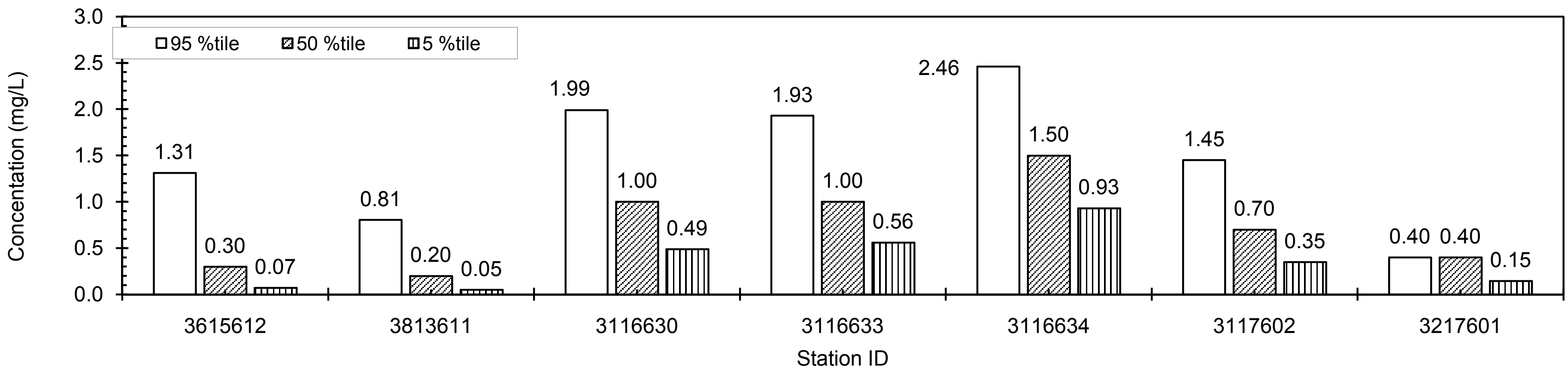


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
PO_4	mg/L	-	0.10	-	0.10	-	-	-

Figure 13: Percentile Values of PO_4 at Various Stations

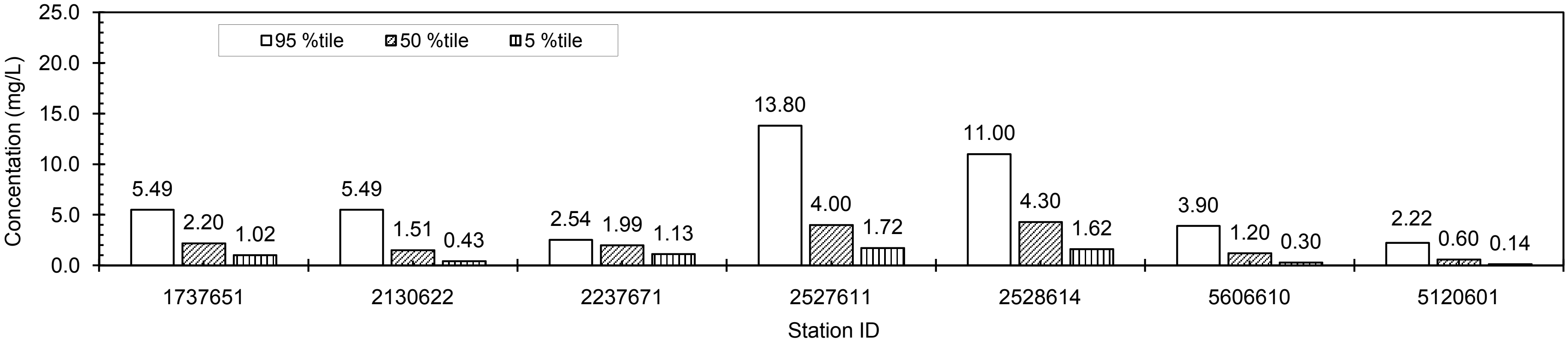


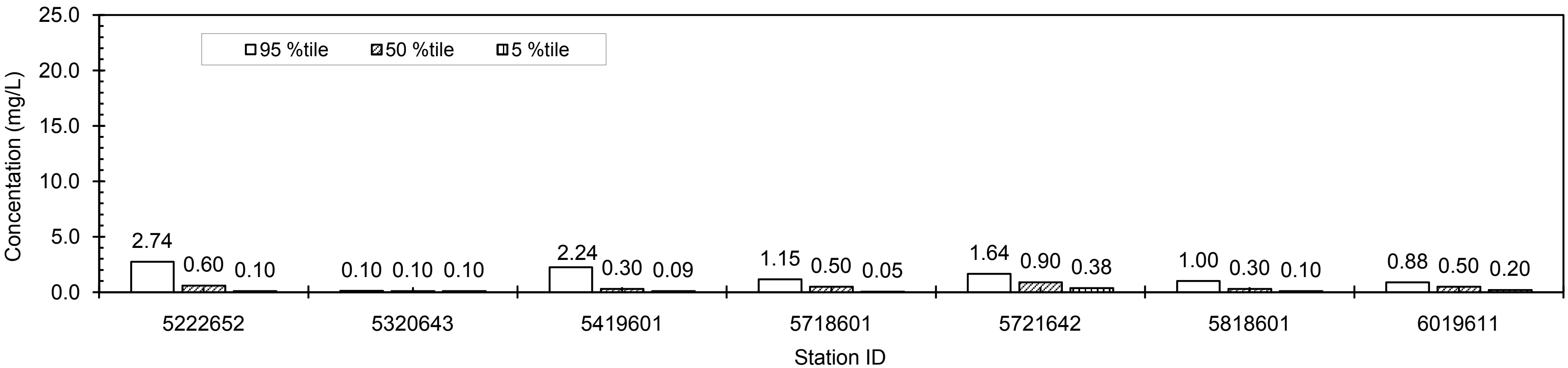


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
PO_4	mg/L	-	0.10	-	0.10	-	-	-

Figure 13: Percentile Values of PO_4 at Various Stations (Continued)

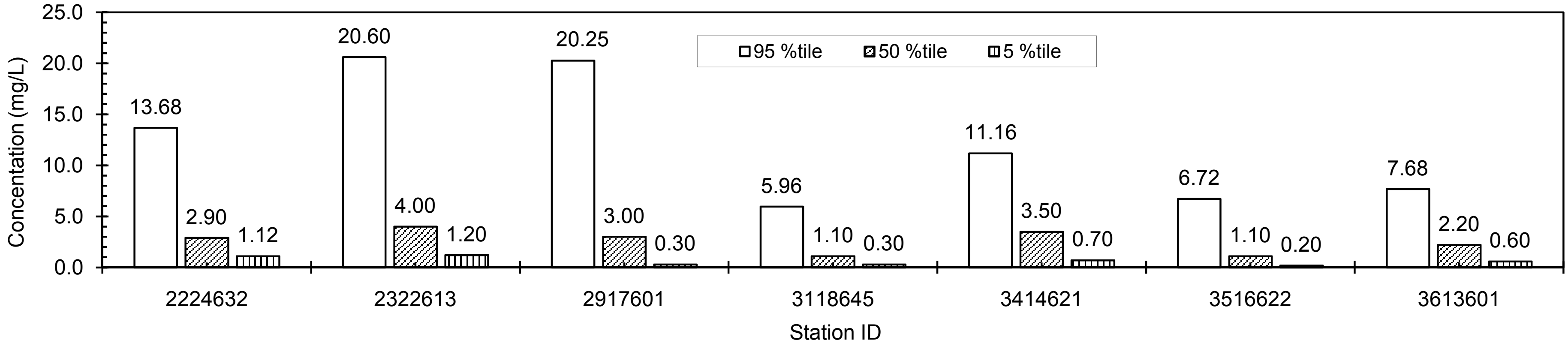


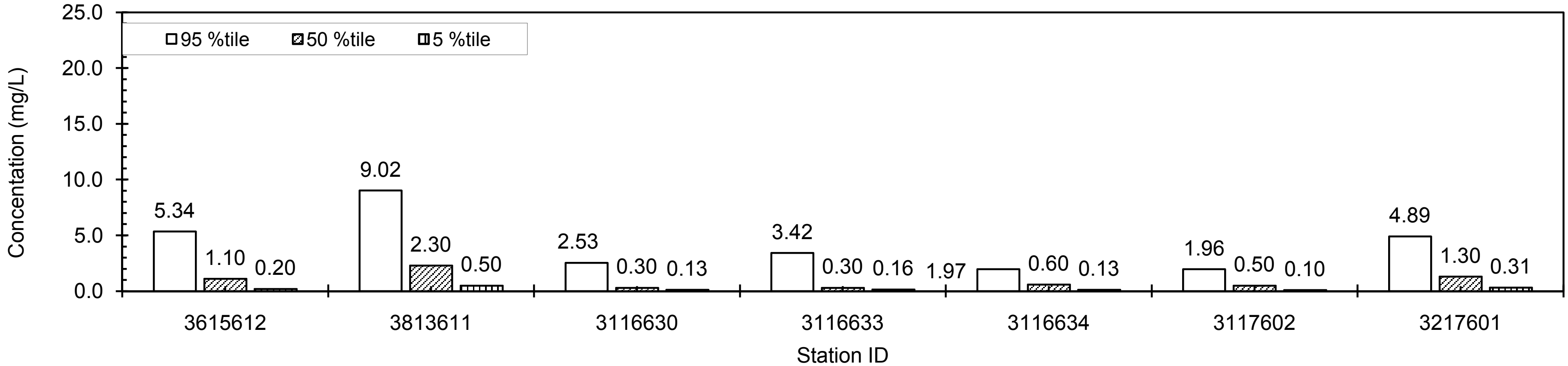


National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
Iron	mg/L	-	0.3	-	1	1	-	1

Figure 14: Percentile Values of Fe (Iron) at Various Stations





National Water Quality Standards (NWQS) and Ministry of Health (MOH) Malaysia Guidelines

Parameter	Unit	Class I	Class IIA	Class IIB	Class III	Class IV	Class V	MOH
Iron	mg/L	-	0.3	-	1	1	-	1

Figure 14: Percentile Values of Fe (Iron) at Various Stations (Continued)

5.2 EVALUATION OF WATER QUALITY TRENDS

The presence or absence of trends over time is a good indication of the degree to which water quality is responding to changes in the catchment and season. Trend analyses of the water quality data was done graphically and with the help of statistical tools. Annual median, 95 percentile and 5 percentile values for each station was calculated and plotted to see the annual trends. However, the plots could not reveal any specific trend due to missing data. Sample plots of water quality trend at a station are shown in Figure 15 and 18.

5.3 EVALUATION OF RIVER FLOW DATA

One of the good things of JPS water quality monitoring scheme is that flow values can be estimated (except a few missing cases) at the sampling locations which are eventually happen to be the JPS river gauging stations. Flow data is very important to evaluate the status of river condition. Therefore, quartile analysis was also conducted to study the variation of historical daily average flow data (minimum, mean and maximum) at the station and during sampling (Appendix B). The specific flow was used to compensate the effect of catchment size on the flow data and to make the data comparable with that of other stations.

5.4 EVALUATION FOR NONPOINT SOURCE POLLUTION LOADING

Monitoring of non-point source pollution loading is a necessary but costly element in water quality monitoring study, as it requires capture of event rainfall and runoff data which includes collection of runoff sample at various intervals for the whole event. The existing monitoring system is not suitable for the reliable calculation of pollution loading due to NPS sources. Confirmed information is not available if the sampling was done during rainfall events. It is most likely that most of the water quality data collected by JPS was during the non-rainy periods, if not all. If that is the case the data mainly represents the dry-weather flow water quality. Therefore, it is very unlikely to use the existing data to estimate pollution loading from the non-point pollution sources.

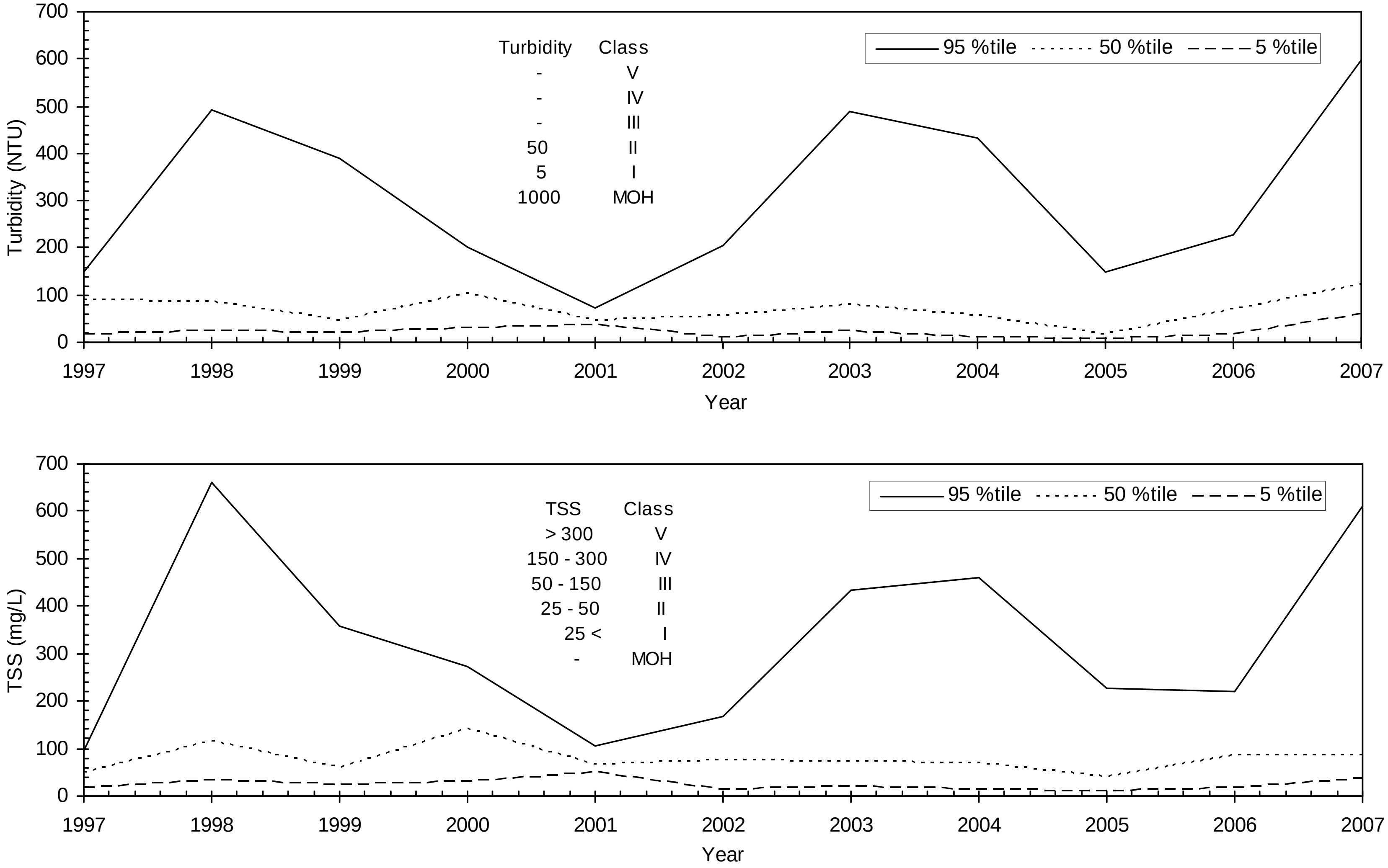


Figure 15: Annual Percentile Values of Turbidity and TSS of Sg. Kesang at Chin Chin (Station 2224632)

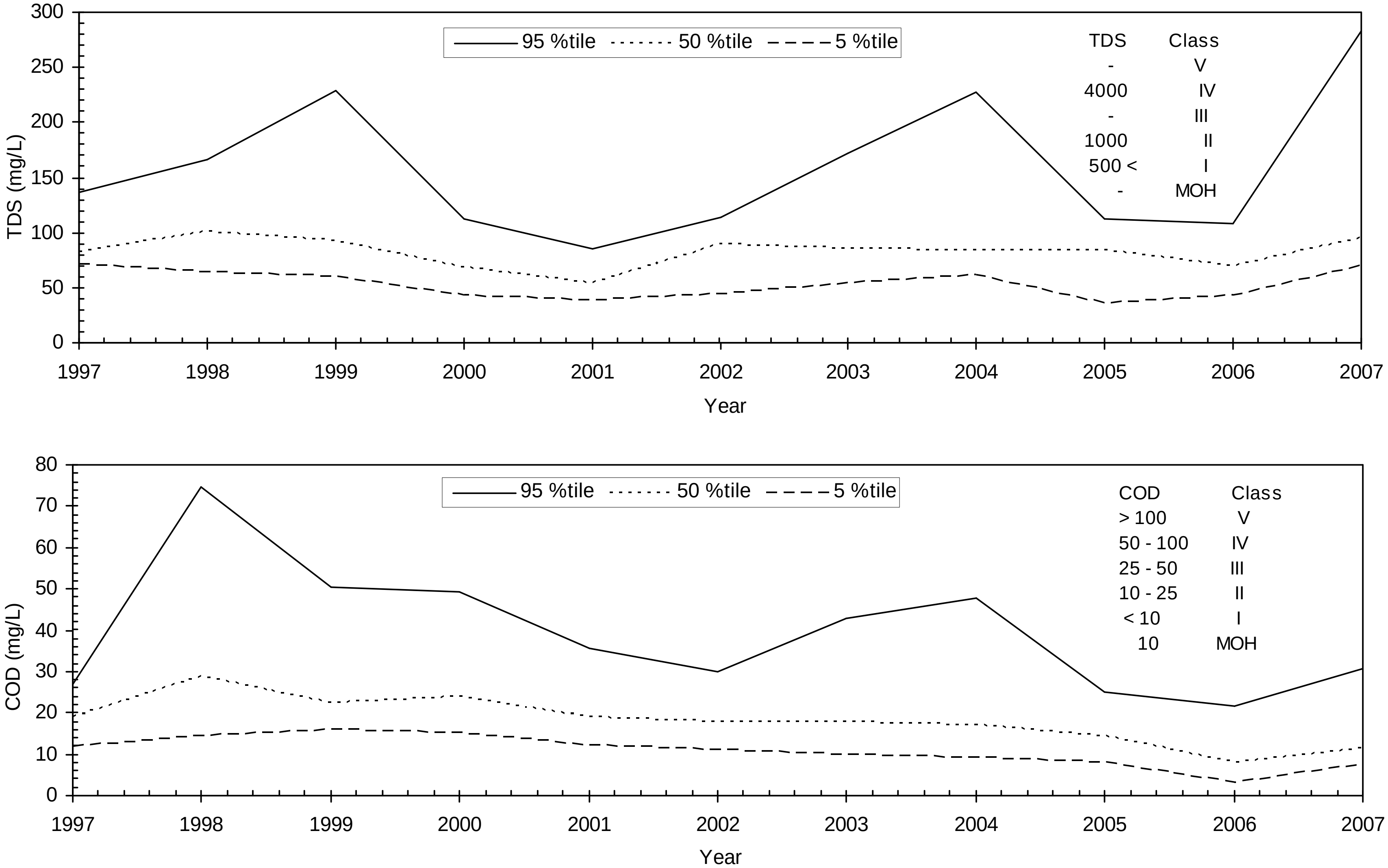


Figure 16: Annual Percentile Values of TDS and COD of Sg. Kesang at Chin Chin (Station 2224632)

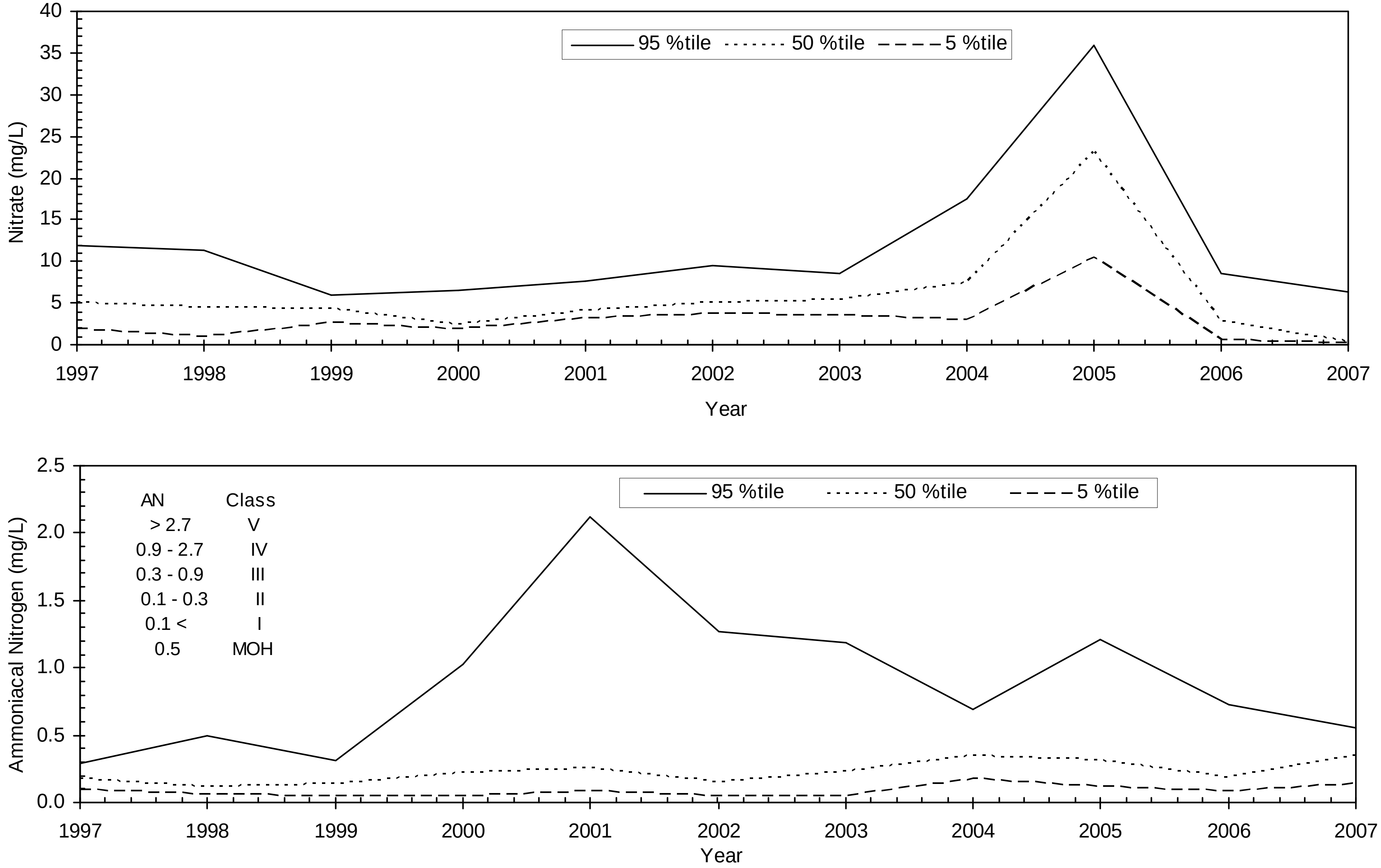
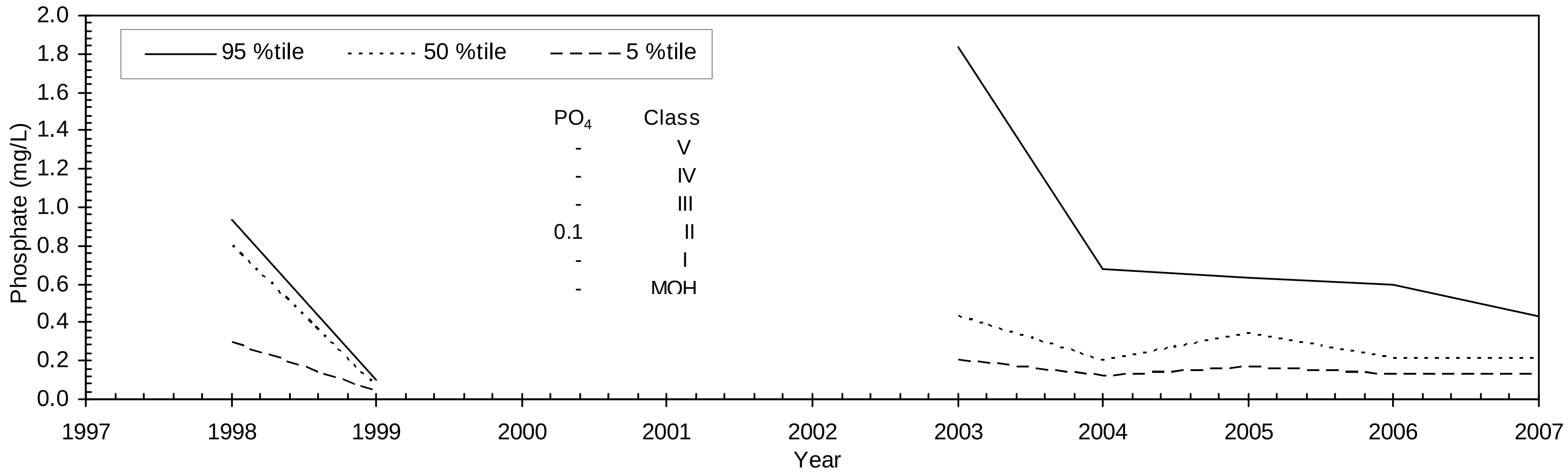


Figure 17: Annual Percentile Values of Nitrate and Ammoniacal Nitrogen of Sg. Kesang at Chin Chin (Station 2224632)



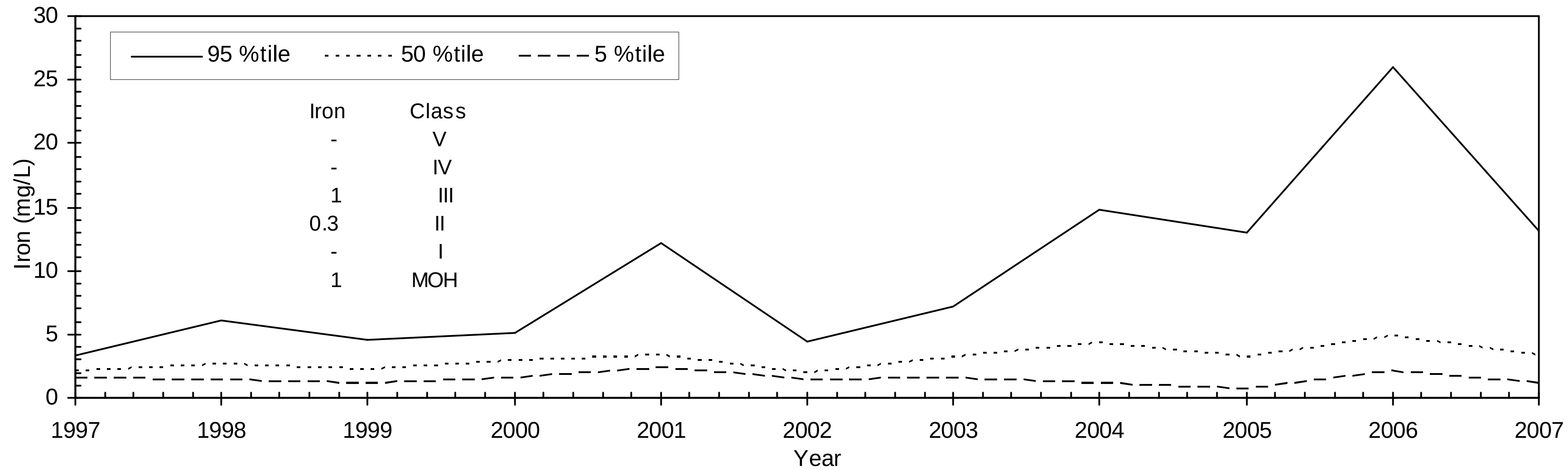


Figure 18: Annual Percentile Values of Phosphate and Iron of Sg. Kesang at Chin Chin (Station 2224632)

Landuse, landcover and topographical information for the catchment up to the gauging/sampling stations provided in Table 8 would be useful for the calculation and verification of pollution loading from point and non-point sources. However, information in provided in the table might not be up to dates. Therefore, a proper reconnaissance survey would be required to evaluate the present landuse pattern of the catchments.

Table 8: Topography and Landcover of the Catchments at Water Quality Monitoring Stations

No	Statn No	Station Name	Area (km^2)	Topography	Vegetation
1	1737651	Sg. Johor at Rantau Panjang	1130	About 60% of the catchment is undulating highland rising to heights of 366 m while the remainder is lowland and swampy.	The highland in the north is mainly under jungle while in the south a major portion had been cleared and planted with oil palm and rubber.
2	2130622	Sg. Bekok di Batuu 77, Jalan Yong Peng/Labis	350	About 30% of the area is fairly mountainous country covered by forest rising to a maximum height of cover 610m. The remainder is hilly lands with a small area and swampy low lying land along Sg.. Bekok towards the lower part of the catchment. The central part is rubber estates.	Towards the north-east of the station is a small stretch of both virgin and logged over forest and towards the east, inland swamps and virgin forest.
3	2237671	Sg. Lenggor di Bt 22, Kluang/Mersing	207	About 30% of the catchment is mountainous country rising to heights of 549m, while the remainder is undulating to flat lands.	Totally forested, but many areas have been logged over. Generally low-lying with some hilly areas.
4	2527611	Sg. Muar di Buloh Kasap	3130	About 30% of the catchment area mainly on the eastern side is mountainous rising to a maximum height of over 610 m. The rest consists of hilly undulating land and at the western border is a small patch of swampy land around the river station, 60% of the area is covered by primary forest.	In the upper hill area, patches of forest are found most of which has been logged over. Part of the area has been developed and fresh water swamps are found in the north-east direction of the station.
5	2528614	Sg. Segamat di Segamat	658	About 70% of the catchment is hilly to mountainous country rising to heights of 915 m and the remainder is hilly undulating land with swamps.	The mountainous areas are under jungle, while undulating land is mainly under rubber with some padi cultivation in the lowlands.
6	5606610	Sg. Muda di Jam Syed Omar	3330	The catchment area is generally of fairy undulating land from the central towards the southwestern region, but very mountainous and steep on the northeastern side. The mountainous region has heights reaching to 2700 meters above mean sea level, and it makes 70% of the catchment.	About 60% of the catchment is under forest cover which is managed mainly under forest reserves namely. Ulu Muda F.R, Rimba Teloi F.R, Bukit Perak F.R. and Gunung Inas F.R. The lower part is covered mainly with under rubber and paddy.

No	Statn No	Station Name	Area (km^2)	Topography	Vegetation
7	5120601	Sg. Nenggiri di Jambatan Bertam	2130	Data Not Available	Data Not Available
8	5222652	Sg. Lebir di kampong Tualang	2430	Almost the whole area is mountainous and steep with heights of over 914 m. above mean sea level especially in the eastern border. There is a small area of low lying land for cultivation along Sg.. Lebir and Sg.. Aring and a very small area of swampy land and limestone hills on the western side of the catchment area. The highest peak is Gunong Badong of 1326 m. The whole catchment is under the Lebir Relai Forest Reserve.	Whole area is under forest, most of which is jungle and a few patches had been harvested.
9	5320643	Sg. Galas di Dabong	7770	Situated on the eastern side of the Main Range, the majority of the catchment area is steep mountainous and hilly country rising to a maximum height of over 1830 m, above mean sea level. On the southern side of the catchment there is a small area of limestone hills and also a small area of low lying land for cultivation along the river valley.	Almost 80% of the area is under forest which is virgin except for patches cleared for development.
10	5419601	Sg. Pergau di Batu Lembu	1290	Data Not Available	Data Not Available
11	5718601	Sg. Lanas di Air Lanas	80	Data Not Available	Data Not Available
12	5721642	Sg. Kelantan di Guillmard	11900	About 95% of the catchment is steep mountainous country rising to heights of 2135 m while the remainder is undulating lands.	The mountainous areas are under virgin jungle while rubber and some rice are planted in the lowlands.
13	5818601	Sg. Golok di Kg. Jenob	216	Data Not Available	Data Not Available
14	6019611	Sg. Golok di Rantau Panjang	761	The main river, Sg.. Golok, with its two major tributaries, Sg.. Jedok and Sg.. Golok, with its two major tributaries. Sg.. Jedok and Sg.. Lanas, drains this basin of lowlying to undulating country. The sourse of these rivers is in the southern part of the catchment where the terrain lies within the 76 m to 763 m contour lines. These flow in a northerly direction.	The majority of this catchment is undeveloped and covered with virgin jungle, lalang and swamp. A very small portion is cultivated for rubber. Padi is cultivated along the rivers on a small scale.
15	2224632	Sg. Kesang di Chin Chin	161	About 10% of the catchment is hilly country rising to heights of 305 m, and the bulk of the southern catchment is low-lying undulating land.	More than half of the catchment is developed for rubber with padi cultivation along the banks of the river. The rest of the catchment is under belukar and jungle.

No	Statn No	Station Name	Area (km^2)	Topography	Vegetation
16	2322613	Sg. Melaka At Pantai Belimbing	350	This catchment consists of low-lying and undulating hills in the south and mountainous country in the north border. A small area, extending from Kg.. Dalong down stream is below the 15m contour line. The main river, Sg.. Malacca, and its major tributary, the Sg.. Batang Melaka, rise in hilly to mountainous terrain in the north. These two rivers meander through low-lying and undulating land on their way to the sea.	This catchment is developed for rubber to a limited extent. Padi is cultivated on a small scale along the rivers. Hilly and mountainous areas are covered with lalang and virgin jungle.
17	2917601	Sg. Langat Di Kajang	380	The major part of the catchment area is fairly mountainous country rising to maximum height over 305m, in the north. The remainder is hilly undulating land with about 10% of the lowland above 15m, along the Sg. Langat	The low lying areas are under rubber with a small portion of forest towards the north of the station
18	3118645	Sg. Lui di Kg. Lui	68	The area is fairly undulating with hills rising to about 275m at the edge of the catchment. The low lying area are found along the flood plains of Sg. Mantau and its tributaries	The mountainous are under virgin jungle while rubber is cultivated in the lesser hilly area and foothills along Sg. Lui and its tributaries. A little wet rice is cultivated in certain areas of the flood plains of Sg. Lui
19	3414621	Sg. Selangor di Rantau Panjang	1450	About 30% of the catchment is steep mountainous country above 610m and rising to heights of 1678m, 38% is hilly country and the remainder undulating low terrain	About two-third of the catchment is under jungle and the remainder mostly under rubber. There is some tin mining within the catchment
20	3516622	Sg. Selangor di Rasa	321	The majority of the catchment is mountainous; only a very small area long the Sg. Selangor, at Rasa, is below the 76m contour line. The source of the Sg. Selangor is in rugged mountainous country, above the 915m contour line	At the southern end of the catchment rubber is cultivated in the hilly areas. The remainder areas are covered with virgin jungle.
21	3613601	Sg. Selangor di Ulu Ibu Empangan	1290	Data Not Available	Data Not Available
22	3615612	Sg. Bernam di Tanjung Malim	186	About 78% of this catchment is steep mountainous country rising to height of 1830m. while the remainder is hilly country	The mountainous areas are under jungle, while the hilly undulating areas are mainly under rubber
23	3813611	Sg. Bernam di Jambatan SKC	1090	About 89% of the catchment is steep mountainous country rising to height of 1830m. The remainder is hilly land with swamps.	The mountainous areas are under virgin jungle, while the hilly areas are mostly under rubber. Tin mining is being carried out within this catchment

No	Statn No	Station Name	Area (km^2)	Topography	Vegetation
24	3116630	Sg. Klang di Jambatan Sulaiman	468	Situated on the western side of the Main Range, about half of the entire catchment is steep mountainous country rising to heights of 1433 m, the remainder is hilly land.	Hilly areas are mostly under rubber and small low-lying areas are under tin mining.
25	3116633	Sg. Gombak di Jalan Tun Razak	122	About 60% of the catchment is steep mountainous country rising to heights of 1220 m. the remainder is hilly undulating land.	The mountainous areas are under virgin jungle, while the hilly areas are mostly under rubber. Small low-lying areas are under padi cultivation and tin mining.
26	3116634	Sg. Batu di Sentul	145	About 40% of the catchment is steep mountainous country rising to heights of 1220 m. remainder is hilly undulating with some swamps along its lower reaches.	The mountainous areas are under jungle, while the hilly areas are mostly under rubber. Some tin mining is being carried out within this catchment.
27	3117602	Sg. Klang Di Lorong Yap Kuan Seng	160	An urbanized catchment area very little cultivation being done. Tin mining is still being carried out on the eastern part of the catchment, and muddy soils along the main river (Sungai Kelang) is obvious. The eastern region, which is part of the main range, is a mountainous and steep area with heights rising up to 1700 metres above mean sea level.	Areas other than residential and rubber plantations are covered by forests located within the Gombak F.R. and Ampang F.R. About 45% of the forest cover is still undisturbed comprising lowland and Hill Dipterocarp Forests with patches of good Seraya Forests.
28	3217601	Ibu Bekalan KM 11 Gombak	85	Data Not Available	Data Not Available

Note: Adopted from Hydrological Data – stream flow and river suspended sediment records 1986-1990, produced by Department of Irrigation and Drainage, Ministry of Agriculture, Malaysia, 1995.

For a reliable NPS pollution loading estimation, baseline dry weather water quality hourly data at each location should be collected for at least three days (one working, one Saturday and one Sunday). Then, runoff events of various return periods should be sampled for runoff quality and development of event mean concentration (EMC) values which can be used to estimate the pollution loading due to NPS.

It is also recommended that rainfall data (using data logging rain gauge) should be collected for the whole event duration during the water sampling. Sampling program for EMC and NPS pollution loading calculation needs to be planned properly to cover the whole hydrograph. Depending on the size of the catchment sampling intervals should be estimated to cover the whole hydrograph. One grab sample, same as what is done for dry-weather water quality monitoring program, is not suitable to calculate the NPS pollution load at any river station. A brief description on the NPS pollution together with standard procedure is recommended in the following section.

5.5 DEVELOPMENT OF JPS RIVER INDEX (JRI)

The parameters for the JRI were selected based on extensive literature review (Table 9), comparison with the NWQS and statistical analysis of the available data. The JRI was developed to evaluate the river status based on Quality (pollution) and Quantity (specific flow) data.

5.5.1 Selection of Parameters

The parameters considered for JRI are Specific Flow, which is instantaneous flow divided by the catchment area at the station ($m^3/s/km^2$) and indicates the changes of flow through the river; Total Suspended Solids (TSS), which represents the sediments that adsorbs many pollutants on the surfaces (mg/L); Total Dissolve Solids (TDS), which represents salts and minerals that indicates the dissolved minerals in the water (mg/L); and Turbidity (TURB) in NTU, which represents the clarity and aesthetic property of water that is very important to make the river and water appealing to the people.

5.5.2 Rating Curves

Rating curves for the specific (normalized) flow indexes were developed to match the local climate and weather conditions (Figure 19). The cut off point of specific flow for dry and rainy day was considered as 0.05 $m^3/s/km^2$, which is recommended by JICA and commonly used by the professionals as a typical value of baseflow in Malaysian rivers. The rating curves for the JRI parameters were developed based on the Malaysian WQI, NWQS and comparing with the overseas water quality indexes. Comparative rating graphs are shown in Figure 20. Two rating curves are given for turbidity as the values will be very different during rainy and non-rainy days. Naturally high turbidity is observed during the storm events due to high flow velocity. The regression equations of the rating curves are given in Table 10.

Table 9: List of Parameters Considered in Various Water Quality Indexes in the World

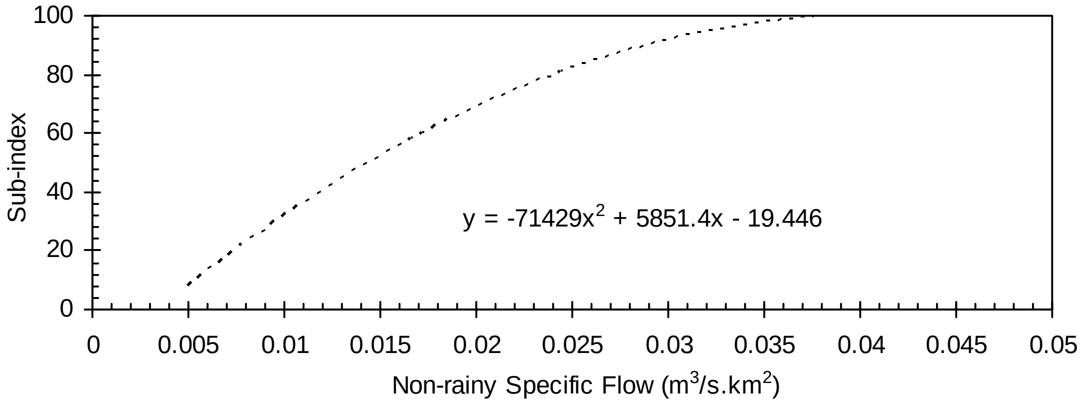
No	Parameter	NSF WQI	Oregon WQI	Washi ngton	UWQI Europe	Argent ina	Chile	Turkey	Spain	Zimba bwe	Nigeria	Korea	China	Thai land	Indon esia	Mala ysia	This Study
Physical																	
1	Turbidity	√	-	√	-	√	-	√	-	-	√	-	-	√	√	-	√
2	TSS	-	-	√	-	-	-	√	√	√	-	-	-	√	√	√	√
3	TDS	√	-	-	-	√	-	-	-	√	-	-	-	-	-	-	√
4	Conductivity	-	-	-	-	√	√	√	-	√	-	√	-	-	√	-	-
5	TS	-	√	-	-	√	-	-	-	-	√	-	-	-	-	-	-
6	Temperature	√	√	√	-	√	√	√	√	√	√	-	-	√	√	-	√ *
Biochemical																	
7	pH	√	√	√	√	√	√	√	√	√	√	-		√		√	√ *
8	DO	√	√	√	√	√	√	√	√		√	-	√	√	√	√	√ *
9	BOD	√	√	-	√	√	√	√	√	√	√	√	√	√	√	√	-
10	COD	-	-	-	-	√	√	√	√	-	-	-	√	√	√	√	√
11	Ammonia-N	-	-	-	-	√	√	√	√	-	-	-	√	√	√	√	√
12	Chloride	-	-	-	-	√	-	√	-	-	-	-	-	-	√	-	-
13	Fluoride	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-	-
14	Cyanide	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-	-
15	Oil & Grease	-	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-
16	Hardness	-	-	-	-	√	-	√	-	-	-	-	-	-	√	-	-
17	Surfactants (MBAS)	-	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-
Nutrient																	
18	TN	-	√	√	√	-	-	-	-	-	-	√	√	-	-	-	√
19	TP	√	√	√	-	√	-	-	√	√	-	√	√	-	√	-	√
20	SO_4	-	-	-	-	√	-	√	-	-	-	-	-	-	√	-	-
21	NO_3	√	-	-	-	√	√	√	√	√	√	-	-	-	√	-	-
22	NO_2	-	-	-	-	√	√	√	√	-	-	-	-	-	-	-	-
23	PO_4	-	-	-	√	-	√	√	-	-	√	-	-	-	-	-	-

Table 9: List of Parameters Considered in Various Water Quality Indexes in the World (Continued)

No	Parameter	NSF WQI	Oregon WQI	Washington	UWQI Europe	Argentina	Chile	Turkey	Spain	Zimbabwe	Nigeria	Korea	China	Thailand	Indonesia	Malaysia	This Study
Metals																	
22	Iron	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	√
23	Mercury	-	-	-	√	-	-	-	-	-	-	-	√	-	-	-	-
24	Selenium	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-	-
25	Arsenic	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-	√
26	Cadmium	-	-	-	√	-	-	-	-	-	-	-	-	-	-	-	-
27	Nickel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	Chromium (IV)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	Lead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	Copper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	Calcium	-	-	-	-	√	-	√	-	-	-	-	-	-	-	-	-
32	Magnesium	-	-	-	-	√	-	√	-	-	-	-	-	-	-	-	-
Microbial																	
33	Faecal Coliform	√	√	√	-	-	-	-	-	-	√	-	-	√	√	-	√
34	Total Coliform	-	-	-	√	√	-	-	-	-	-	-	-	-	-	-	-

Table 10: The Rating Equations for each Parameter Considered for JRI

Parameter	Equations	Conditions
Specific Flow (SF)	$y = -71429x^2 + 5851.4x - 19.446$	Non-rainy Day Sampling for Point Source (< 0.05 $m^3/s/km^2$)
	$y = 3.2167x^2 - 32.989x + 101.29$	Rainy Day Sampling for Non-point Source (> 0.05 $m^3/s/km^2$)
Turbidity (Turb)	$y = 0.0003x^2 - 1.1978x + 112.04$	Non-rainy Day Sampling for Point Source (< 150 NTU)
Turbidity (Turb)	$y = 0.0005x^2 - 0.4634x + 113.97$	Rainy Day Sampling for Non-point Source (< 500 NTU
TSS	$y = 0.003x^2 - 0.7969x + 105.52$	TSS ≤ 100
	$y = 0.0001x^2 - 0.1785x + 71.431$	TSS > 100
TDS	$y = 7E\text{-}05x^2 - 0.1666x + 100.04$	-



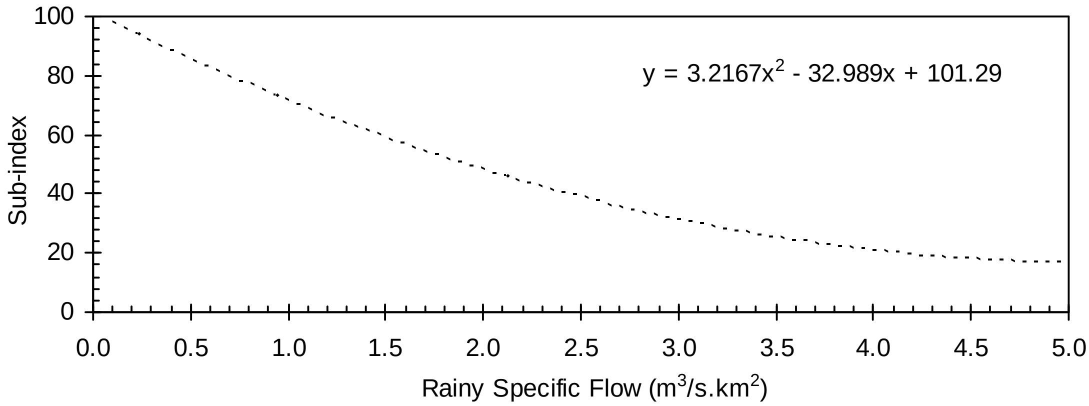


Figure 19: Ratings Curves of Specific Flow for JRI

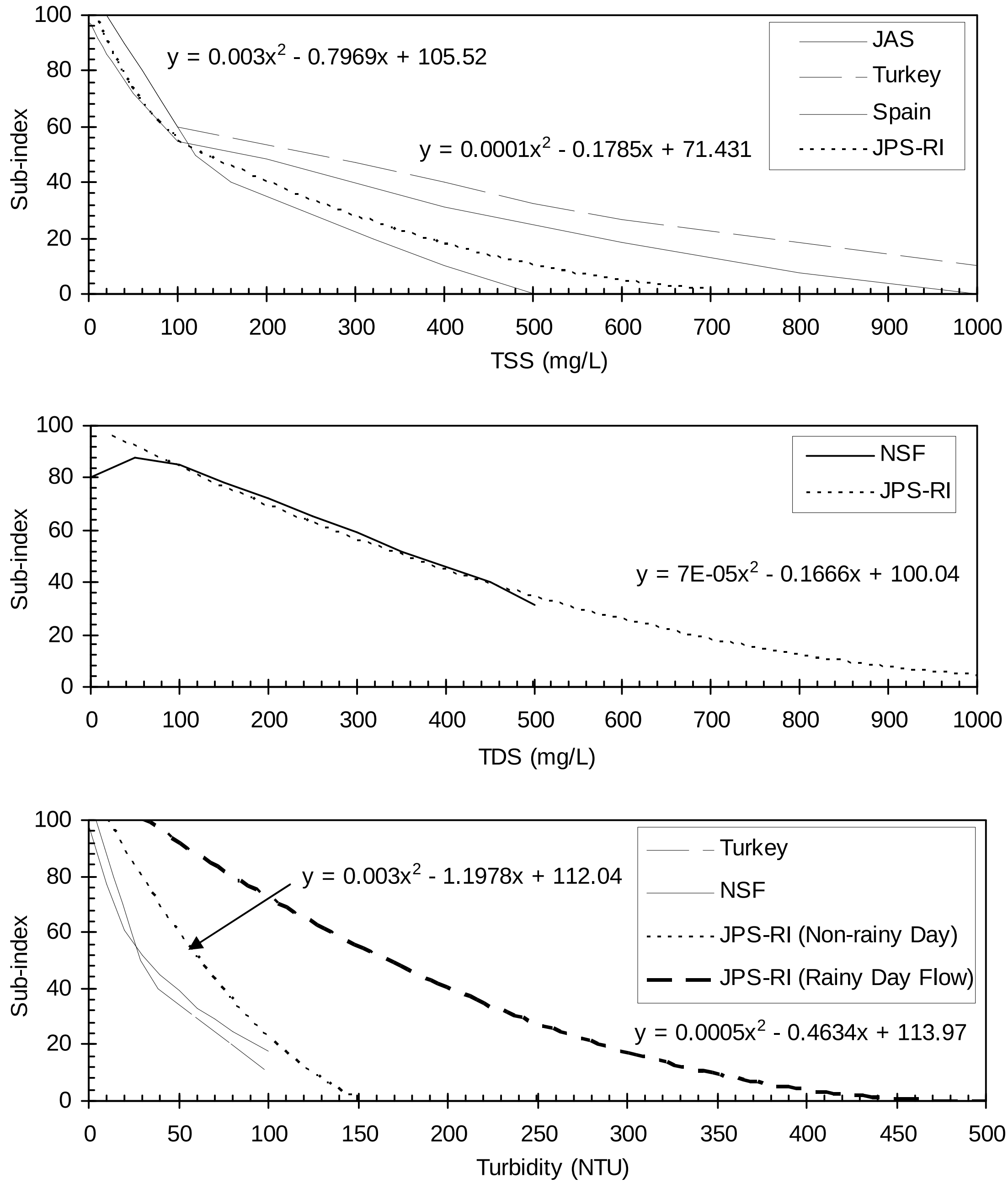


Figure 20: Ratings Curves of Water Quality Parameters for JRI

5.5.3 Weighing Factors

Effect of each parameter on the river/aquatic environment was rated or taken care of by means of the rating curve. Therefore, relative importance of the selected parameters on the river status was evaluated by assigning weighing factor for each parameter. In this exercise, a highest value of 5 could be given to the critical parameter, while the least important parameter could be assigned the value of 1 or less. Then, the calculated fraction for each group of parameters was considered as the weighing factor of each parameter selected for the JRI (Table 11). Various weighing factors practiced worldwide are listed in Table 12, for the purpose of comparison only.

Table 11: Determination of Parameter Weighing Factor for JRI

Parameter	Priority Index (out of 5)	Weighing Factor
Sp. Flow	3.5	0.30
Turb	1.5	0.13
TSS	4.0	0.35
TDS	2.5	0.22
Total	11.5	1.00

5.5.4 Proposed JRI

The tool/equation obtained to determine the quality of the rivers in Malaysia based on JPS River Index (JRI) is;

$$JRI = 0.30*(SI_{SF}) + 0.13*(SI_{Turb}) + 0.35*(SI_{TSS}) + 0.22*(SI_{TDS}) \quad (17)$$

where,

SI_{SF} = Sub-index for specific flow
SI_{Turb} = Sub-index for Turbidity
SI_{TSS} = Sub-index for TSS
SI_{TDS} = Sub-index for TDS

5.5.5 Limits Selected for each Class and Parameter

A thorough review of the available literature was conducted to compare the ranges of quality indexes used in various countries (as given in Table 13). In this study, the class of JRI was divided into five main categories that are from Class I to V. Class II, Class III, and Class IV were then further divided into three sub-sections to make the classifications become more target oriented. Each section was assigned certain range of JRI values, varied from 0 to 100. The threshold values for parameters were determined using the equation of rating curve obtained. The summary of selected limits for each class and parameter is given in the Table 14.

Table 12: Determination of Weighing Factor for JRI

Parameter	NSF	UWQI	Korea	Argentina		Chile	Turkey		Spain		Malaysia
	Factor	Factor	Factor	Factor	Relative	Factor	Factor	Relative	Factor	Relative	Factor
DO (% saturation)	0.17	-	-	-	-	-	-	-	-	-	0.22
Faecal coliform (or *E. coli*)	0.15	-	-	-	-	-	-	-	-	-	-
pH	0.12	0.029	-	0.0233	1	0.1	0.0323	1	0.0385	1	-
BOD_5	0.1	0.057	0.34	0.0698	3	0.17	0.0968	3	0.1154	3	-
Nitrates	0.1	-	-	0.0465	2	0.07	0.0645	2	0.0769	2	-
Phosphates	0.1	-	-	-	-	0.12	0.0323	1	-	-	-
$\Delta t\ ^{o}C$ from equilibrium	0.1	-	-	0.0233	1	0.1	0.0323	1	0.0385	1	-
Turbidity	0.08	-	-	0.0465	2	-	0.0645	2	-	-	-
Total solids	0.08	-	-	0.0930	4	-	-	-	-	-	-
Total Phosphorus	-	0.057	0.33	0.0233	1	-	-	-	0.0385	1	-
Total Nitrogen	-	-	0.33	-	-	-	-	-	-	-	-
Total coliform	-	0.114	-	0.0698	3	-	-	-	-	-	-
Cadmium	-	0.086	-	-	-	-	-	-	-	-	-
Cyanide	-	0.086	-	-	-	-	-	-	-	-	-
Mercury	-	0.086	-	-	-	-	-	-	-	-	-
Selenium	-	0.086	-	-	-	-	-	-	-	-	-
Arsenic	-	0.113	-	-	-	-	-	-	-	-	-
Fluoride	-	0.086	-	-	-	-	-	-	-	-	-
Nitrate-nitrogen	-	0.086	-	-	-	-	-	-	-	-	-
DO (conc.)	-	0.114	-	0.0930	4	0.18	0.1290	4	0.1538	4	-
Ammonia nitrogen	-	-	-	0.0698	3	0.13	0.0968	3	0.1154	3	0.15
Calcium	-	-	-	0.0233	1	-	0.0323	1	-	-	-
Chloride	-	-	-	0.0233	1	-	0.0323	1	-	-	-
Conductivity	-	-	-	-	-	0.06	0.0645	2	0.0769	2	-
COD	-	-	-	0.0698	3	0.17	0.0968	3	0.1154	3	0.16
Hardness	-	-	-	0.0233	1	-	0.0323	1	-	-	-
Magnesium	-	-	-	0.0233	1	-	0.0323	1	-	-	-
Nitrites	-	-	-	0.0465	2	0.07	0.0645	2	0.0769	2	-
Oil and grease	-	-	-	0.0465	2	-	-	-	-	-	-
Dissolved solids	-	-	-	0.0465	2	-	-	-	-	-	-
Sulfates	-	-	-	0.0465	2	-	0.0645	2	-	-	-
Surfactants as MBAS	-	-	-	0.0930	4	-	-	-	-	-	-
Total suspended solids	-	-	-	-	-	-	0.0323	1	0.1538	4	0.16

5.6 USEFULNESS AND APPLICATION OF JRI

The proposed JRI can be considered useful and unique in the sense that it considered river water quantity and quality together. No index can be found in the literature which considered both quantity and quality aspects of river water together with considerations of dry and rainy day conditions. There should be no doubt that flow is a very important component of a river index. The JRI is kept simple by considering 4 important parameters that should be considered to identify a healthy river. Therefore, it is expected that the tool would assist DID in evaluating the status of the rivers and set target to improve the river status.

5.7 HOW TO APPLY JRI

Public, practitioners, and authority personals can easily assess the river water status by using the JRI equations and by following the steps given below:

1. Collect data on river flow (m^3/s), catchment area (km^2), TSS (mg/L), TDS (mg/L) and Turbidity (NTU).
2. Calculate specific flow by dividing the river flow by the catchment area at the sampling point.
3. The calculate sub-index of each parameter using the rating curve equations given in Table 10.
4. Multiply the sub-index value with the weighing factor (Table 11) to get the weighted value of sub-index.
5. Compare the value of the JRI with the classification of given in Table 14 and determine the class or status of the river in terms of the selected parameters.

5.8 SAMPLE CALCULATION OF JRI

Sample calculations of JRI for Station 3414621 (Sg.. Selangor at Rantau Panjang) are given below. The examples show how to apply JRI for dry day flow and rainy day flow conditions. The following data (for JRI) are available for the sampling station at which the catchment area is 1450 km^2. The procedure is given step by step in the following section:

Step 1: Collect Relevant Data (In this case actual data of Station 3414621, Sg.. Selangor at Rantau Panjang is used).

Sample ID	Sampling Date	Sampling Time	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)
(a)	14/03/2006	4:06 p.m	31.0	0.021	88	59	72
(b)	22/03/2006	4:00 p.m	132.7	0.092	279	261	64

(a) Flow during sampling is 31.0 m^3/s.

Step 2: Calculate Specific Flow,

SF = Flow/Catchment Area

= 31.0/1450 = 0.021 $m^3/s.km^2$

As the specific flow is less than 0.05 $m^3/s.km^2$ it is considered "**Non-rainy Day Flow Sample**"

Step 3: Calculate Subindexes for four parameters using the equations from Table 10,

SI_{SF} = -71429x^2 + 5851.4x - 19.446

= -71429*0.021^2 + 5851.4*0.021 - 19.446

= 73.0

SI_{Turb} = 0.0003x^2 - 1.1978x + 112.04

= 0.0003*88^2 - 1.1978*88 + 112.04

= 29.9

SI_{TSS} = 0.003x^2 - 0.7969x + 105.52

= 0.003*59^2 - 0.7969*59 + 105.52

= 68.9

SI_{TDS} = 7E-05x^2 - 0.1666x + 100.04

= 7E-05*72^2 - 0.1666*72 + 100.04

= 88.4

Step 4: Calculate JRI for non-rainy day flow by using Equation 17,

JRI = 0.30*(SI_{SF}) + 0.13*(SI_{Turb}) + 0.35*(SI_{TSS}) + 0.22*(SI_{TDS})
= 0.30*73.0 + 0.13*29.9 + 0.35*68.9 + 0.22*88.4

= 69.3

≈ 69 (to be rounded up to nearest full number)

Step 5: Compare the value of JRI with the values given in Table 14 and determine Class and status of the river.

For this instance, the river belonged to "**Class III-A**" with a Status of "**Fair**".

(b) Flow during sampling is 137.0 m^3/s.

Step 2: Calculate Specific Flow,

SF = Flow/Catchment Area

= 137.0/1450 = 0.092 $m^3/s.km^2$

As the specific flow is higher than 0.05 $m^3/s.km^2$ it is considered "**Rainy Day Flow Sample**"

Step 3: Calculate Subindexes for four parameters using the equations from Table 10,

$SI_{SF} = -71429x^2 + 5851.4x - 19.446$

$= -71429*0.092^2 + 5851.4*0.092 - 19.446$

$= 98.3$

$SI_{Turb} = 0.0005x^2 - 0.4634x + 113.97$

$= 0.0005*279^2 - 0.4634*279 + 113.97$

$= 23.6$

$SI_{TSS} = 0.0001x^2 - 0.1785x + 71.431$

$= 0.0001*261^2 - 0.1785*261 + 71.431$

$= 31.7$

$SI_{TDS} = 7E\text{-}05x^2 - 0.1666x + 100.04$

$= 7E\text{-}05*64^2 - 0.1666*64 + 100.04$

$= 89.7$

Step 4: Calculate JRI for rainy day flow by using Equation 17,

$JRI = 0.30*(SI_{SF}) + 0.13*(SI_{Turb}) + 0.35*(SI_{TSS}) + 0.22*(SI_{TDS})$

$= 0.30*98.3 + 0.13*23.6 + 0.35*31.7 + 0.22*89.7$

$= 60.8$

≈ 61 (to be rounded up to nearest full number)

Step 5: Compare the value of JRI with the values given in Table 14 and determine Class and status of the river.

For this data, the river belonged to "**Class III-B**" with a Status of "**Fair**".

Table 13: Classes Various Water Quality Indexes Worldwide

Range of WQI Value														
Class	**USA**	**Diff.**	**Class**	**Oregon**	**Diff.**	**Class**	**British Columbia**	**Diff.**	**Class**	**UWQI**	**Diff.**	**Class**	**Korea**	**Diff.**
Excellent	91-100	9	Excellent	90-100	10	Excellent	0 - 3	3	Excellent	95-100	5	Very low	91-100	9
Good	71-90	9	Good	85-89	4	Good	4 - 17	13	Good	75-94	19	Low	71-90	9
Medium or Average	51-70	19	Fair	80-84	4	Fair	18 - 43	25	Fair	50-74	24	Medium	51-70	19
Fair	26-50	24	Poor	60-79	19	Borderline	44 - 59	15	Marginal	25-49	24	High	26-50	24
Poor	0-25	25	Very poor	10 - 59	49	Poor	60 - 100	40	Poor	0-24	24	Very high	0-25	25

Table 14: Classes for JPS River Index

Parameter	Unit	Class and Status of the River										
		Clean	**Good**			**Fair**			**Poor**			**Very Poor**
		I	**II-A**	**II-B**	**II-C**	**III-A**	**III-B**	**III-C**	**IV-A**	**IV-B**	**IV-C**	**V**
JRI	**-**	**> 90**	**90-85**	**84-78**	**77-71**	**70-65**	**64-58**	**57-51**	**50-45**	**44-38**	**37-31**	**<30**
Specific Flow, Non-rainy Day (SF)	$(m^3/s.km^2)$	> 0.029	0.0261 – 0.0290	0.0231 – 0.0260	0.0201 – 0.0230	0.0181 – 0.020	0.0161 – 0.0180	0.0146 – 0.0160	0.0131 – 0.0145	0.0111 – 0.0130	0.009 – 0.0110	< 0.009
Specific Flow, Rainy Day (SF)	$(m^3/s.km^2)$	< 0.37	0.370 – 0.534	0.535 – 0.784	0.785 – 1.034	1.035 – 1.274	1.275 – 1.564	1.565 – 1.874	1.875 – 2.184	2.185 – 2.584	2.585 – 3.050	> 3.050
Turbidity, Non-rainy Day	NTU	< 20	20 – 26	27 – 33	33 – 38	39 – 46	47 – 53	54 – 60	61 – 69	70 – 78	79 – 87	> 87
Turbidity, Rainy Day	NTU	< 55	55 – 71	72 – 188	189 – 107	108 – 128	129 – 149	150 – 169	170 – 194	195 – 218	219 – 243	> 228
TSS	mg/L	< 21	21 – 29	30 – 41	42 – 54	55 – 69	70 – 92	93 – 126	127 – 166	167 – 216	217 – 270	> 270
TDS	mg/L	< 66	66 – 95	96 – 144	145 – 192	193 – 230	231 – 290	291 – 346	346 – 396	397 – 466	467 – 539	> 539

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 1737651 (Sg. Johor di Rantau Panjang)																	
95 Percentile Value	158.06	0.140	142	166	168	Rainy Day	99	90	96	94	30	12	33	20	88	II -A	Good
75 Percentile Value	74.65	0.066	87	91	115	Rainy Day	97	80	74	92	30	10	26	20	81	II -B	Good
50 Percentile Value	30.89	0.027	48	66	73	Dry Day	87	76	66	88	26	10	23	19	75	II -C	Good
25 Percentile Value	18.07	0.016	24	49	49	Dry Day	56	52	58	82	17	7	20	18	68	III -A	Fair
5 Percentile Value	10.48	0.009	7	13	38	Dry Day	27	21	45	74	8	3	16	16	45	IV -A	Poor
Number of Data	12	12	16	16	15	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	54.33	0.048	59	76	87	Dry Day	75	65	67	86	23	8	23	19	72	II -C	Good
Standard Deviation	54.03	0.048	45	46	47	Dry Day	29	27	16	7	9	3	5	2	15	- -	-
Minimum Value	5.05	0.004	3	9	30	Dry Day	5	3	44	71	2	0	15	15	43	IV -B	Poor
Maximum Value	168.98	0.150	149	171	190	Rainy Day	99	92	99	95	30	12	34	21	90	II -A	Good
Statistical Values for the Station 2130622 (Sg. Bekok di Batu 77 Jalan Yong Peng Labis)																	
95 Percentile Value	35.30	0.101	83	101	309	Rainy Day	99	95	95	96	30	12	33	21	90	II -A	Good
75 Percentile Value	12.43	0.036	45	81	95	Dry Day	97	94	89	94	29	12	31	20	87	II -A	Good
50 Percentile Value	9.94	0.028	34	41	63	Dry Day	89	87	78	90	27	11	27	20	81	II -B	Good
25 Percentile Value	8.42	0.024	17	23	37	Dry Day	80	65	61	85	24	9	21	18	77	II -C	Good
5 Percentile Value	6.71	0.019	15	15	23	Dry Day	66	54	55	56	20	7	19	12	69	III -A	Fair
Number of Data	14	14	16	16	16	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	13.93	0.040	40	52	96	Dry Day	86	79	75	85	26	10	26	19	81	II -B	Good
Standard Deviation	11.32	0.032	36	34	106	Dry Day	12	17	15	15	4	2	5	3	8	- -	-
Minimum Value	6.45	0.018	15	13	15	Dry Day	64	51	52	42	20	7	18	9	60	III -B	Fair
Maximum Value	47.97	0.137	165	114	421	Rainy Day	99	95	96	98	30	12	33	21	92	I	Clean
Statistical Values for the Station 2237671 (Sg. Lenggor di Batu 42 Kluang Mersing)																	
95 Percentile Value	108.39	0.524	51	52	92	Rainy Day	99	99	96	98	30	13	33	21	91	I	Clean
75 Percentile Value	9.92	0.048	19	33	51	Dry Day	97	97	88	98	30	13	31	21	84	II -B	Good
50 Percentile Value	8.32	0.040	15	29	27	Dry Day	81	96	84	97	25	13	29	21	81	II -B	Good
25 Percentile Value	3.29	0.016	13	11	16	Dry Day	55	94	79	91	17	12	28	20	79	II -B	Good
5 Percentile Value	2.44	0.012	6	10	11	Dry Day	39	89	72	85	12	12	25	18	74	II -C	Good
Number of Data	51	51	51	52	92	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	108.39	0.524	51	52	92	Rainy Day	99	99	96	98	30	13	33	21	91	I	Clean
Standard Deviation	56.92	0.275	20	19	36	Rainy Day	28	5	11	6	8	1	4	1	8	- -	-
Minimum Value	2.23	0.011	3	10	9	Dry Day	35	88	70	83	11	11	24	18	73	II -C	Good
Maximum Value	133.01	0.643	61	57	104	Rainy Day	100	100	98	99	30	13	34	21	92	I	Clean

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 2527611 (Sg. Muar di Buloh Kasap)																	
95 Percentile Value	102.28	0.033	244	236	297	Dry Day	95	84	94	96	29	11	33	21	81	II -B	Good
75 Percentile Value	33.59	0.011	118	119	154	Dry Day	35	69	85	87	11	9	30	19	57	III -C	Fair
50 Percentile Value	17.53	0.006	59	69	113	Dry Day	11	47	65	82	3	6	23	18	52	III -C	Fair
25 Percentile Value	4.87	0.002	40	28	84	Dry Day	0	13	52	76	0	2	18	17	46	IV -A	Poor
5 Percentile Value	2.02	0.001	21	16	22	Dry Day	0	0	35	57	0	0	12	12	40	IV -B	Poor
Number of Data	40	40	46	46	46	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	28.60	0.009	91	93	129	Dry Day	24	42	66	80	7	6	23	17	53	III -C	Fair
Standard Deviation	35.83	0.011	73	108	77	Dry Day	31	31	21	11	9	4	7	2	12	- -	-
Minimum Value	1.74	0.001	19	5	11	Dry Day	0	0	0	47	0	0	0	10	18	V	Very Poor
Maximum Value	171.65	0.055	280	663	377	Rainy Day	100	98	100	98	30	13	35	21	84	II -B	Good
Statistical Values for the Station 2528614 (Sg. Segamat di Segamat)																	
95 Percentile Value	27.19	0.043	330	242	235	Dry Day	99	90	89	92	30	12	31	20	83	II -B	Good
75 Percentile Value	15.29	0.024	100	140	148	Dry Day	80	79	73	88	24	10	25	19	76	II -C	Good
50 Percentile Value	11.48	0.018	70	70	106	Dry Day	61	60	65	83	19	8	22	18	62	III -B	Fair
25 Percentile Value	8.53	0.013	30	50	75	Dry Day	45	35	48	77	14	5	17	17	56	III -C	Fair
5 Percentile Value	3.92	0.006	20	23	48	Dry Day	13	0	34	65	4	1	12	14	48	IV -A	Poor
Number of Data	40	40	46	46	46	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	12.96	0.026	96	100	123	Dry Day	59	55	62	81	18	7	21	18	65	III -A	Fair
Standard Deviation	8.79	0.044	113	76	64	Dry Day	26	30	18	9	8	4	6	2	12	- -	-
Minimum Value	2.92	0.004	10	11	42	Dry Day	5	0	20	55	2	0	7	12	38	IV -B	Poor
Maximum Value	53.72	0.291	570	363	311	Rainy Day	100	100	97	93	30	13	34	20	90	II -A	Good
Statistical Values for the Station 5606610 (Sg. Muda di Jam Syed Omar)																	
95 Percentile Value	213.14	0.064	-	342	-	-	100	-	89	-	30	-	31	-	-	- -	-
75 Percentile Value	104.75	0.031	-	110	-	-	94	-	76	-	29	-	26	-	-	- -	-
50 Percentile Value	45.08	0.014	-	64	-	-	47	-	67	-	14	-	23	-	-	- -	-
25 Percentile Value	22.56	0.007	-	45	-	-	17	-	53	-	5	-	18	-	-	- -	-
5 Percentile Value	13.91	0.004	-	22	-	-	4	-	22	-	1	-	8	-	-	- -	-
Number of Data	84	84	-	94	-	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	78.36	0.024	-	108	-	-	52	-	62	-	16	-	22	-	-	- -	-
Standard Deviation	78.54	0.024	-	118	-	-	37	-	21	-	11	-	7	-	-	- -	-
Minimum Value	11.73	0.004	-	7	-	-	0	-	0	-	0	-	0	-	-	- -	-
Maximum Value	434.24	0.130	-	697	-	-	100	-	100	-	30	-	35	-	-	- -	-

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 5120601 (Sg. Nenggiri di Jam Bertam)																	
95 Percentile Value	313.00	0.147	651	766	120	Rainy Day	100	100	83	96	30	13	29	21	89	II -A	Good
75 Percentile Value	179.72	0.084	126	549	79	Rainy Day	99	98	64	94	30	13	22	20	84	II -B	Good
50 Percentile Value	123.14	0.058	53	138	51	Rainy Day	99	86	49	92	30	11	17	20	76	II -C	Good
25 Percentile Value	96.56	0.045	24	73	35	Dry Day	97	53	9	87	29	7	3	19	62	III -B	Fair
5 Percentile Value	52.75	0.025	12	38	26	Dry Day	79	12	0	81	24	2	0	18	53	III -C	Fair
Number of Data	46	46	46	50	49	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	165.18	0.078	160	358	60	Rainy Day	96	71	40	90	29	9	15	20	73	II -C	Good
Standard Deviation	160.47	0.075	238	502	32	Rainy Day	6	32	30	5	2	4	10	1	12	- -	-
Minimum Value	44.27	0.021	5	23	20	Dry Day	71	3	0	75	22	0	0	16	51	III -C	Fair
Maximum Value	1110.19	0.521	910	3130	161	Rainy Day	100	100	100	97	30	13	35	21	93	I	Clean
Statistical Values for the Station 5222652 (Sg. Lebir di Kg Tualang)																	
95 Percentile Value	3007.72	1.238	440	676	111	Rainy Day	100	100	96	97	30	13	33	21	94	I	Clean
75 Percentile Value	197.35	0.081	146	260	77	Rainy Day	99	100	79	92	30	13	27	20	82	II -B	Good
50 Percentile Value	114.28	0.047	24	149	64	Dry Day	94	89	52	90	29	12	18	19	74	II -C	Good
25 Percentile Value	67.77	0.028	11	50	48	Dry Day	71	37	38	88	22	5	13	19	61	III -B	Fair
5 Percentile Value	30.39	0.013	2	16	19	Dry Day	43	0	9	82	13	0	3	18	49	IV -A	Poor
Number of Data	41.00	41.000	44	46	46	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	513.95	0.212	109	232	63	Rainy Day	84	68	54	90	26	9	19	20	73	II -C	Good
Standard Deviation	931.04	0.383	184	383	27	Rainy Day	21	38	28	4	6	5	10	1	14	- -	-
Minimum Value	15.60	0.006	1	9	10	Dry Day	15	0	0	79	5	0	0	17	47	IV -A	Poor
Maximum Value	3254.12	1.339	837	2480	134	Rainy Day	100	100	100	98	30	13	35	21	95	I	Clean
Statistical Values for the Station 5320643 (Sg. Galas di Dabong)																	
95 Percentile Value	848.68	0.109	290	893	432	Rainy Day	100	100	82	92	30	13	29	20	85	II -A	Good
75 Percentile Value	437.57	0.056	89	381	148	Rainy Day	100	100	61	88	30	13	21	19	77	II -C	Good
50 Percentile Value	377.00	0.049	26	206	103	Dry Day	98	96	39	84	30	13	14	18	68	III -A	Fair
25 Percentile Value	276.55	0.036	11	81	72	Dry Day	96	37	18	77	29	6	6	17	60	III -B	Fair
5 Percentile Value	232.59	0.030	4	34	51	Dry Day	91	9	0	41	28	3	0	9	51	III -C	Fair
Number of Data	25	25	25	26	25	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	411.61	0.053	75	307	152	Rainy Day	97	73	39	78	30	10	14	17	69	III -A	Fair
Standard Deviation	212.84	0.027	99	301	144	Dry Day	3	36	29	18	1	4	10	4	11	- -	-
Minimum Value	209.75	0.027	2	21	47	Dry Day	86	0	0	22	26	1	0	5	51	III -C	Fair
Maximum Value	1132.45	0.146	300	1013	645	Rainy Day	100	100	90	92	30	13	31	20	85	II -A	Good

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 5419601 (Sg. Pergau di Batu Lembu)																	
95 Percentile Value	240.15	0.186	196	366	143	Rainy Day	100	100	94	96	30	13	33	21	94	I	Clean
75 Percentile Value	115.99	0.090	39	211	78	Rainy Day	99	100	77	94	30	13	27	20	88	II -A	Good
50 Percentile Value	69.88	0.054	20	96	57	Rainy Day	97	100	57	91	30	13	20	20	83	II -B	Good
25 Percentile Value	42.06	0.033	9	42	38	Dry Day	93	87	38	87	28	11	13	19	73	II -C	Good
5 Percentile Value	28.43	0.022	2	16	26	Dry Day	75	49	20	78	23	6	7	17	62	III -B	Fair
Number of Data	60	60	73	80	79	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	97.83	0.076	47	140	68	Rainy Day	94	89	58	89	28	12	20	19	81	II -B	Good
Standard Deviation	94.55	0.073	83	145	47	Rainy Day	9	20	24	7	3	3	8	2	10	V	Very Poor
Minimum Value	24.10	0.019	1	4	21	Dry Day	65	12	0	55	20	2	0	12	56	III -C	Fair
Maximum Value	499.30	0.387	478	949	311	Rainy Day	100	100	100	97	30	13	35	21	97	I	Clean
Statistical Values for the Station 5718601 (Sg. Lanas di Air Lanas)																	
95 Percentile Value	27.56	0.344	110	190	239	Rainy Day	100	100	99	96	30	13	35	21	95	I	Clean
75 Percentile Value	5.63	0.070	21	88	76	Rainy Day	98	100	94	94	30	13	33	21	89	II -A	Good
50 Percentile Value	2.81	0.035	10	43	50	Dry Day	93	100	77	92	28	13	27	20	85	II -A	Good
25 Percentile Value	1.71	0.021	6	16	34	Dry Day	76	95	59	88	23	12	20	19	77	II -C	Good
5 Percentile Value	0.54	0.007	3	8	24	Dry Day	21	49	41	64	6	7	14	14	68	III -A	Fair
Number of Data	68	68	70	71	73	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	6.21	0.078	23	60	74	Rainy Day	82	91	75	89	25	12	26	19	83	II -B	Good
Standard Deviation	0.17	0.002	2	7	15	Dry Day	0	0	35	34	0	1	12	7	49	IV -A	Poor
Minimum Value	0.17	0.002	2	7	15	Dry Day	0	0	35	34	0	1	12	7	49	IV -A	Poor
Maximum Value	58.74	0.734	153	232	506	Rainy Day	100	100	100	98	30	13	35	21	98	I	Clean
Statistical Values for the Station 5721642 (Sg. Kelantan di Jam Guillemard)																	
95 Percentile Value	806.51	0.068	495	1008	228	Rainy Day	100	100	95	95	30	13	33	21	82	II -B	Good
75 Percentile Value	407.15	0.034	138	283	88	Dry Day	96	100	71	94	29	13	25	20	76	II -C	Good
50 Percentile Value	266.58	0.022	36	138	64	Dry Day	76	81	49	90	23	11	17	19	67	III -A	Fair
25 Percentile Value	186.76	0.016	12	54	38	Dry Day	55	53	30	86	17	7	10	19	62	III -B	Fair
5 Percentile Value	93.86	0.008	4	14	31	Dry Day	22	4	0	66	7	1	0	14	56	III -C	Fair
Number of Data	36	36	25	37	27	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	336.85	0.028	113	249	84	Dry Day	71	71	50	87	22	9	17	19	69	III -A	Fair
Standard Deviation	84.35	0.007	3	7	26	Dry Day	18	0	0	61	6	0	0	13	56	III -C	Fair
Minimum Value	84.35	0.007	3	7	26	Dry Day	18	0	0	61	6	0	0	13	56	III -C	Fair
Maximum Value	1185.64	0.100	576	1534	264	Rainy Day	100	100	100	96	30	13	35	21	89	II -A	Good

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 5818601 (Sg. Golok di Kg Jenob)																	
95 Percentile Value	-	-	112	245	105	-	-	-	98	97	-	-	34	21	-	- -	-
75 Percentile Value	-	-	25	91	68	-	-	-	89	94	-	-	31	20	-	- -	-
50 Percentile Value	-	-	11	46	55	-	-	-	75	91	-	-	26	20	-	- -	-
25 Percentile Value	-	-	6	23	39	-	-	-	58	89	-	-	20	19	-	- -	-
5 Percentile Value	-	-	2	10	20	-	-	-	34	83	-	-	12	18	-	- -	-
Number of Data	-	-	73	79	79	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	25	75	58	-	-	-	72	91	-	-	25	20	-	- -	-
Standard Deviation	-	-	1	5	17	-	-	-	21	62	-	-	7	13	-	- -	-
Minimum Value	-	-	1	5	17	-	-	-	21	62	-	-	7	13	-	- -	-
Maximum Value	-	-	247	350	256	-	-	-	100	97	-	-	35	21	-	- -	-
Statistical Values for the Station 6019611(Sg. Golok di Rantau Panjang)																	
95 Percentile Value	208.81	0.274	51	155	96	Rainy Day	99	100	94	96	30	13	33	21	91	I	Clean
75 Percentile Value	56.01	0.074	27	80	65	Rainy Day	98	100	90	95	30	13	31	21	85	II -A	Good
50 Percentile Value	19.50	0.026	13	56	51	Dry Day	84	100	70	92	25	13	24	20	82	II -B	Good
25 Percentile Value	12.07	0.016	7	21	29	Dry Day	55	96	61	90	17	13	21	19	78	II -B	Good
5 Percentile Value	7.02	0.009	2	15	23	Dry Day	28	86	46	85	9	11	16	18	72	II -C	Good
Number of Data	23	23	22	24	24	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	52.98	0.070	20	61	50	Rainy Day	75	97	73	92	23	13	25	20	81	II -B	Good
Standard Deviation	5.70	0.007	2	4	17	Dry Day	20	76	39	83	6	10	14	18	60	III -B	Fair
Minimum Value	5.70	0.007	2	4	17	Dry Day	20	76	39	83	6	10	14	18	60	III -B	Fair
Maximum Value	330.27	0.434	90	206	106	Rainy Day	100	100	100	97	30	13	35	21	95	I	Clean
Statistical Values for the Station 2224632 (Sg. Kesang di Chin Chin)																	
95 Percentile Value	136.32	0.847	399	410	178	Rainy Day	99	100	94	93	30	13	33	20	93	I	Clean
75 Percentile Value	40.98	0.255	122	130	104	Rainy Day	96	96	76	89	29	13	27	19	84	II -B	Good
50 Percentile Value	13.56	0.084	70	72	87	Rainy Day	87	80	64	86	27	11	22	19	73	II -C	Good
25 Percentile Value	1.96	0.012	33	44	69	Dry Day	41	48	50	83	13	6	18	18	57	III -C	Fair
5 Percentile Value	0.50	0.003	11	16	45	Dry Day	0	9	15	72	0	1	6	16	43	IV -B	Poor
Number of Data	166	166	226	225	226	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	32.83	0.204	118	118	95	Rainy Day	69	69	62	85	21	9	22	18	70	III -A	Fair
Standard Deviation	0.15	0.001	2	5	29	Dry Day	0	0	0	0	0	0	0	0	27	V	Very Poor
Minimum Value	0.15	0.001	2	5	29	Dry Day	0	0	0	0	0	0	0	0	27	V	Very Poor
Maximum Value	317.17	1.970	2100	1025	554	Rainy Day	100	100	100	95	30	13	35	21	97	I	Clean

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 2322613 (Sg. Melaka di Pantai Belimbing)																	
95 Percentile Value	11.75	0.034	465	672	169	Dry Day	95	96	92	93	29	12	32	20	59	III -B	Fair
75 Percentile Value	4.85	0.014	146	223	116	Dry Day	48	74	76	88	15	10	27	19	56	III -C	Fair
50 Percentile Value	1.82	0.005	72	91	94	Dry Day	9	33	58	85	3	4	20	18	50	IV -A	Poor
25 Percentile Value	1.24	0.004	31	44	74	Dry Day	1	17	41	82	0	2	14	18	48	IV -A	Poor
5 Percentile Value	0.71	0.002	6	19	45	Dry Day	0	0	10	74	0	0	5	16	42	IV -B	Poor
Number of Data	23	23	132	132	131	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	3.26	0.009	145	185	102	Dry Day	24	43	57	84	7	6	20	18	51	III -C	Fair
Standard Deviation	3.39	0.010	260	270	58	Dry Day	32	32	25	8	10	4	8	2	6	V	Very Poor
Minimum Value	0.64	0.002	1	7	15	Dry Day	0	0	0	42	0	0	0	9	40	IV -B	Poor
Maximum Value	12.71	0.036	2150	1701	424	Dry Day	99	99	100	98	30	13	35	21	63	III -B	Fair
Statistical Values for the Station 2917601 (Sg. Langat di Kajang)																	
95 Percentile Value	29.03	0.076	612	1075	156	Rainy Day	99	100	92	95	30	13	32	21	79	II -B	Good
75 Percentile Value	9.76	0.026	182	371	100	Dry Day	83	87	59	92	25	12	20	20	64	III -B	Fair
50 Percentile Value	5.34	0.014	71	176	78	Dry Day	48	55	45	87	15	8	16	19	58	III -B	Fair
25 Percentile Value	4.11	0.011	34	95	51	Dry Day	34	17	23	84	11	3	8	18	51	III -C	Fair
5 Percentile Value	2.17	0.006	5	18	30	Dry Day	8	0	0	76	4	0	0	16	39	IV -B	Poor
Number of Data	145	145	180	179	180	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	8.40	0.022	152	291	83	Dry Day	55	53	43	87	17	7	15	19	58	III -B	Fair
Standard Deviation	8.38	0.022	215	329	42	Dry Day	30	36	27	6	9	5	9	1	13	V	Very Poor
Minimum Value	0.26	0.001	0	4	10	Dry Day	0	0	0	61	0	0	0	13	27	V	Very Poor
Maximum Value	54.58	0.144	1400	1834	261	Rainy Day	100	100	100	98	30	13	35	21	96	I	Clean
Statistical Values for the Station 3118645 (Sg. Lui di Kg. Lui)																	
95 Percentile Value	7.24	0.106	136	220	85	Rainy Day	100	100	100	96	30	13	35	21	94	I	Clean
75 Percentile Value	2.45	0.036	30	68	61	Dry Day	97	100	92	94	29	13	32	20	88	II -A	Good
50 Percentile Value	1.61	0.024	14	34	47	Dry Day	79	96	83	92	24	13	29	20	82	II -B	Good
25 Percentile Value	1.16	0.017	9	18	35	Dry Day	60	79	66	90	18	10	23	20	72	II -C	Good
5 Percentile Value	0.48	0.007	3	7	25	Dry Day	19	22	39	86	6	3	13	19	60	III -B	Fair
Number of Data	153	153	166	167	168	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	2.33	0.034	38	72	51	Dry Day	72	83	77	92	22	11	27	20	80	II -B	Good
Standard Deviation	2.43	0.036	101	163	27	Dry Day	27	25	20	4	8	3	7	1	11	V	Very Poor
Minimum Value	0.34	0.005	0	4	6	Dry Day	8	0	0	64	2	0	0	14	45	IV -A	Poor
Maximum Value	19.56	0.288	1170	1850	243	Rainy Day	100	100	100	99	30	13	35	22	97	I	Clean

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 3414621 (Sg. Selangor di Rantau Panjang)																	
95 Percentile Value	159.50	0.110	304	578	138	Rainy Day	100	100	74	96	30	13	26	21	81	II -B	Good
75 Percentile Value	77.96	0.054	130	205	69	Rainy Day	99	70	59	94	30	9	20	20	74	II -C	Good
50 Percentile Value	52.45	0.036	90	131	50	Dry Day	97	46	50	92	30	6	17	20	69	III -A	Fair
25 Percentile Value	32.47	0.022	55	87	36	Dry Day	76	22	39	89	23	3	14	19	63	III -B	Fair
5 Percentile Value	13.17	0.009	16	48	27	Dry Day	28	0	2	78	8	0	1	17	50	IV -A	Poor
Number of Data	92	92	116	115	114	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	62.70	0.043	115	190	61	Dry Day	84	47	48	90	26	6	17	20	67	III -A	Fair
Standard Deviation	44.60	0.031	109	199	47	Dry Day	23	31	20	7	7	4	7	1	10	V	Very Poor
Minimum Value	6.79	0.005	6	14	8	Dry Day	6	0	0	43	2	0	0	9	28	V	Very Poor
Maximum Value	247.53	0.171	693	1103	414	Rainy Day	100	100	95	99	30	13	33	21	85	II -A	Good
Statistical Values for the Station 3516622 (Sg. Selangor di Rasa)																	
95 Percentile Value	35.08	0.109	155	276	71	Rainy Day	100	100	100	98	30	13	35	21	95	I	Clean
75 Percentile Value	15.65	0.049	32	80	42	Dry Day	99	100	94	96	30	13	33	21	90	II -A	Good
50 Percentile Value	11.03	0.034	14	31	34	Dry Day	96	96	84	94	29	13	29	21	85	II -A	Good
25 Percentile Value	8.78	0.027	8	16	25	Dry Day	87	77	61	93	27	10	21	20	79	II -B	Good
5 Percentile Value	5.40	0.017	3	6	15	Dry Day	59	9	30	89	18	2	10	19	60	III -B	Fair
Number of Data	83	83	137	135	139	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	14.10	0.044	35	72	37	Dry Day	89	82	76	94	27	11	26	20	83	II -B	Good
Standard Deviation	9.72	0.030	56	114	19	Dry Day	14	27	23	3	4	3	8	1	11	V	Very Poor
Minimum Value	2.99	0.009	0	5	5	Dry Day	29	0	0	75	9	0	0	16	48	IV -A	Poor
Maximum Value	56.05	0.175	380	830	160	Rainy Day	100	100	100	99	30	13	35	22	96	I	Clean
Statistical Values for the Station 3613601 (Sg. Bernam di Ulu Ibu Ampangan)																	
95 Percentile Value	-	-	259	240	89	-	-	-	84	97	-	-	29	21	-	- -	-
75 Percentile Value	-	-	110	150	49	-	-	-	73	96	-	-	25	21	-	- -	-
50 Percentile Value	-	-	58	84	37	-	-	-	60	94	-	-	21	20	-	- -	-
25 Percentile Value	-	-	30	51	26	-	-	-	47	92	-	-	16	20	-	- -	-
5 Percentile Value	-	-	8	30	18	-	-	-	34	86	-	-	12	19	-	- -	-
Number of Data	-	-	150	153	152	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	86	114	41	-	-	-	59	93	-	-	21	20	-	- -	-
Standard Deviation	-	-	87	94	23	-	-	-	18	4	-	-	6	1	-	- -	-
Minimum Value	-	-	3	5	8	-	-	-	1	77	-	-	3	17	-	- -	-
Maximum Value	-	-	530	595	145	-	-	-	100	99	-	-	35	21	-	- -	-

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 3615612 (Sg. Bernam di Tanjung Malim)																	
95 Percentile Value	-	-	146	201	77	-	-	-	98	97	-	-	34	21	-	- -	-
75 Percentile Value	-	-	31	57	42	-	-	-	93	96	-	-	32	21	-	- -	-
50 Percentile Value	-	-	16	34	32	-	-	-	82	95	-	-	28	21	-	- -	-
25 Percentile Value	-	-	9	17	26	-	-	-	70	93	-	-	24	20	-	- -	-
5 Percentile Value	-	-	3	10	18	-	-	-	40	88	-	-	14	19	-	- -	-
Number of Data	-	-	173	179	178	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	33	56	39	-	-	-	78	94	-	-	27	20	-	- -	-
Standard Deviation	-	-	50	82	31	-	-	-	19	5	-	-	7	1	-	- -	-
Minimum Value	-	-	0	4	6	-	-	-	0	50	-	-	0	11	-	- -	-
Maximum Value	-	-	370	673	353	-	-	-	100	99	-	-	35	22	-	- -	-
Statistical Values for the Station 3813611 (Sg. Bernam di Jam S.K.C)																	
95 Percentile Value	-	-	294	341	89	-	-	-	82	97	-	-	29	21	-	- -	-
75 Percentile Value	-	-	124	170	52	-	-	-	70	95	-	-	24	21	-	- -	-
50 Percentile Value	-	-	64	94	41	-	-	-	57	93	-	-	20	20	-	- -	-
25 Percentile Value	-	-	29	57	29	-	-	-	44	92	-	-	15	20	-	- -	-
5 Percentile Value	-	-	7	33	17	-	-	-	22	86	-	-	8	19	-	- -	-
Number of Data	-	-	200	199	197	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	100	133	44	-	-	-	56	93	-	-	20	20	-	- -	-
Standered Deviation	-	-	4	11	4	-	-	-	0	77	-	-	0	17	-	- -	-
Minimum Value	-	-	4	11	4	-	-	-	0	77	-	-	0	17	-	- -	-
Maximum Value	-	-	839	1375	149	-	-	-	100	99	-	-	35	22	-	- -	-
Statistical Values for the Station 3116630 (Sg. Klang di Jam Sulaiman)																	
95 Percentile Value	-	-	161	213	169	-	-	-	89	83	-	-	31	18	-	- -	-
75 Percentile Value	-	-	54	73	164	-	-	-	81	79	-	-	28	17	-	- -	-
50 Percentile Value	-	-	43	53	139	-	-	-	72	78	-	-	25	17	-	- -	-
25 Percentile Value	-	-	21	36	132	-	-	-	64	75	-	-	22	16	-	- -	-
5 Percentile Value	-	-	16	22	108	-	-	-	40	74	-	-	14	16	-	- -	-
Number of Data	-	-	7	7	7	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	59	80	143	-	-	-	69	78	-	-	24	17	-	- -	-
Standard Deviation	-	-	66	86	25	-	-	-	20	4	-	-	7	1	-	- -	-
Minimum Value	-	-	15	19	100	-	-	-	31	74	-	-	11	16	-	- -	-
Maximum Value	-	-	204	270	170	-	-	-	91	84	-	-	32	18	-	- -	-

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 3116633 (Sg. Gombak di Jalan Tun Razak)																	
95 Percentile Value	5.54	0.045	229	314	153	Dry Day	100	83	83	86	30	11	29	19	88	II -A	Good
75 Percentile Value	4.66	0.038	116	248	133	Dry Day	99	81	70	85	30	11	24	18	83	II -B	Good
50 Percentile Value	4.53	0.037	61	75	101	Dry Day	98	16	63	84	30	2	22	18	64	III -B	Fair
25 Percentile Value	3.73	0.031	39	58	96	Dry Day	93	12	34	79	28	2	12	17	58	III -B	Fair
5 Percentile Value	3.67	0.030	27	34	86	Dry Day	92	10	25	76	28	1	9	17	57	III -C	Fair
Number of Data	5	5	7	7	7	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	4.47	0.037	96	147	114	Dry Day	96	40	54	82	29	5	19	18	70	III -A	Fair
Standard Deviation	0.85	0.007	87	124	28	Dry Day	4	38	24	4	1	5	8	1	15	V	Very Poor
Minimum Value	3.65	0.030	26	26	84	Dry Day	92	10	25	75	28	1	9	16	57	III -C	Fair
Maximum Value	5.76	0.047	275	320	159	Dry Day	100	83	87	87	30	11	30	19	89	II -A	Good
Statistical Values for the Station 3116634 (Sg. Batu di Sentul)																	
95 Percentile Value	-	-	115	120	191	-	-	-	94	77	-	-	33	17	-	- -	-
75 Percentile Value	-	-	72	56	183	-	-	-	91	75	-	-	31	16	-	- -	-
50 Percentile Value	-	-	22	28	169	-	-	-	86	74	-	-	30	16	-	- -	-
25 Percentile Value	-	-	19	21	162	-	-	-	71	72	-	-	25	16	-	- -	-
5 Percentile Value	-	-	17	15	147	-	-	-	53	71	-	-	18	15	-	- -	-
Number of Data	-	-	7	7	7	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	48	48	170	-	-	-	79	74	-	-	27	16	-	- -	-
Standered Diavation	-	-	16	15	141	-	-	-	48	71	-	-	17	15	-	- -	-
Minimum Value	-	-	16	15	141	-	-	-	48	71	-	-	17	15	-	- -	-
Maximum Value	-	-	117	141	192	-	-	-	94	78	-	-	33	17	-	- -	-
Statistical Values for the Station 3117602 (Sg. Klang At Lorong Yap Kwan Seng)																	
95 Percentile Value	-	-	114	124	160	-	-	-	98	84	-	-	34	18	-	- -	-
75 Percentile Value	-	-	27	36	136	-	-	-	94	81	-	-	33	18	-	- -	-
50 Percentile Value	-	-	18	20	129	-	-	-	91	80	-	-	32	17	-	- -	-
25 Percentile Value	-	-	14	15	122	-	-	-	81	79	-	-	28	17	-	- -	-
5 Percentile Value	-	-	10	8	101	-	-	-	55	75	-	-	19	16	-	- -	-
Number of Data	-	-	7	7	7	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	37	41	130	-	-	-	84	80	-	-	29	17	-	- -	-
Standered Diavation	-	-	9	5	93	-	-	-	46	74	-	-	16	16	-	- -	-
Minimum Value	-	-	9	5	93	-	-	-	46	74	-	-	16	16	-	- -	-
Maximum Value	-	-	151	159	169	-	-	-	100	85	-	-	35	19	-	- -	-

Table 15: Calculated Percentile JRI Values of the Stations

Statistical Parameter	Flow at Sampling (m^3/s)	Sp. Flow ($m^3/s.km^2$)	Turb. (NTU)	TSS (mg/L)	TDS (mg/L)	Sample Represents	Individual Sub-index				Group Sub-index				JRI	Class	River Status
							Sp. Flow	Turb.	TSS	TDS	Sp. Flow	Turb	TSS	TDS			
Statistical Values for the Station 3217601 (Sg. Gombak Ibu Bekalan Km 11 Gombak. This station shifted from Sg. Gombak at Damsite)																	
95 Percentile Value	-	-	269	400	90	-	-	-	16	86	-	-	6	19	-	- -	-
75 Percentile Value	-	-	171	177	78	-	-	-	43	87	-	-	15	19	-	- -	-
50 Percentile Value	-	-	127	93	70	-	-	-	57	89	-	-	20	19	-	- -	-
25 Percentile Value	-	-	57	77	64	-	-	-	62	90	-	-	22	20	-	- -	-
5 Percentile Value	-	-	52	49	51	-	-	-	74	92	-	-	26	20	-	- -	-
Number of Data	-	-	8	8	8	-	-	-	-	-	-	-	-	-	-	- -	-
Mean Value	-	-	134	162	70	-	-	-	45	89	-	-	16	19	-	- -	-
Standard Deviation	-	-	93	155	15	-	-	-	46	98	-	-	16	21	-	- -	-
Minimum Value	-	-	50	40	47	-	-	-	78	92	-	-	27	20	-	- -	-
Maximum Value	-	-	307	492	93	-	-	-	8	85	-	-	3	19	-	- -	-

5.9 EVALUATION OF JPS DATA BY JRI

Many of the JPS stations have the four parameters required to calculate JRI and classify the rivers according to the JRI. As such, the JRI of the stations (with complete sets of data) was calculated for the quantile values and given in Table 4.12. It was observed that, based on the median value (50 percentile), most of the rivers belongs to the category of fair (Class III, 7 stations) to good (Class II, 11 stations). The median value of no station was found to be clean and one station (2322613 at Pantai Belimbing, Sg.. Melaka) was found to be in poor status mainly due to low flow and high turbidity. The JRI value of this station was less due to low specific flow and high turbidity. Nine other stations did not have complete sets of data to calculate the JRI values.

5.10 JPS WATER QUALITY MONITORING PROGRAM

The existing water quality parameters analysed statistically and compared to the national water quality standards (NWQS) of Malaysia. The parameters monitored by the JPS were also compared to those of the DOE Malaysia. Duplication of water quality parameters were observed in JPS monitoring program. It is strongly recommended that JPS and DOE should come into agreement on the locations of the stations to minimise redundancy. If any JPS and DOE station is nearby, only one station can be maintained for the agreed parameters.

5.10.1 Monitoring Parameters

Twenty four water quality parameters are monitored by JPS' water quality monitoring program (Figure 2). The JPS has justified the selection of parameters in the HP No 22, which is given in Table 16. A few parameters, such as total nitrogen, total kjeldhal nitrogen and ammoniacal nitrogen can be added in the list, as these parameters indicates nitrogenous compounds which are often required for most of the water quality simulation softwares.

5.10.2 Quality Control and Quality Assurance Procedure

The consultants have looked into the existing water quality sampling, preservation, transport and laboratory testing procedure for quality control (QC) and the quality assurance (QA). The following points are identified based on the standard practices approved by SIRIM, JPS and DOE Malaysia. It is of utmost importance that whatever procedure is mentioned in the Guide to Water Quality Monitoring Practices in Malaysia - Practices and Techniques of Sampling and Application of Water Quality Data by Various Government Agencies in Malaysia, should be followed in full. Negligence in any of the elements of the whole water quality monitoring exercise would jeopardize the objectives of this expensive activity which require significant amount of human labour, monitory input, chemical and costly equipments.

Table 16: Selection of JPS Water Quality Parameters for Various Applications

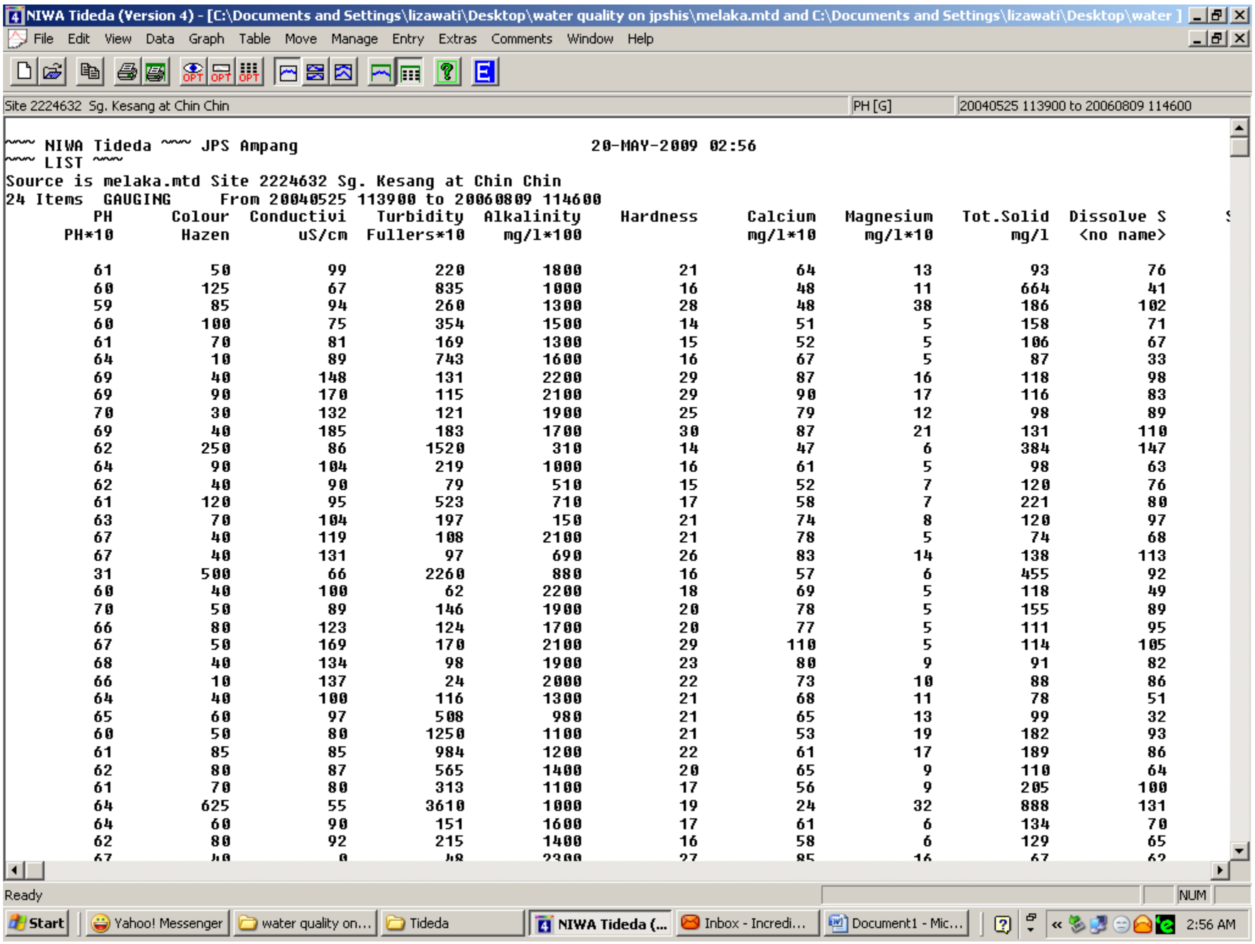
No	Water supply	Fisheries	Experimental Basin Study	Pollution	Representative Basin Study	Irrigation
1	Colour	Colour	Colour	Colour	Colour	Colour
2	Turbidity	Turbidity	Turbidity	Turbidity	Turbidity	Turbidity
3	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity	Conductivity
4	Hardness	Hardness	Hardness	Hardness	Hardness	Hardness
5	Total solids	Total solids	Total solids	Total solids	Total solids	Total solids
6	Suspended solids	Suspended solids	Suspended solids	Suspended solids	Suspended solids	Suspended solids
7	Dissolved solids	Dissolved solids	Dissolved solids	Dissolved solids	Dissolved solids	Dissolved solids
8	pH	pH	pH	pH	pH	pH
9	Calcium	Calcium	Calcium	Calcium	Calcium	Calcium
10	Chloride	Chloride	Chloride	Chloride	Chloride	Chloride
11	Potassium	Potassium	Potassium	Potassium	Potassium	Potassium
12	Magnesium	Magnesium	Magnesium	Magnesium	Magnesium	Magnesium
13	Sodium	Sodium	Sodium	Sodium	Sodium	Sodium
14	Silica	Silica	Silica	Silica	Silica	Silica
15	-	Nitrate	Nitrate	Nitrate	-	Nitrate
16	Ammonia	Ammonia	-	-	-	Ammonia
17	-	Dissolved oxygen	-	Dissolved Oxygen	-	-
18	-	-	-	Phosphate	-	-
19	-	-	-	BOD	-	-
20	-	-	-	COD	-	-
21	Iron	-	-	-	-	-
22	Sulphate	-	-	-	-	-
23	Fluoride	-	-	-	-	-

5.10.3 TIDEDA Program

The TIDEDA software is used by JPS to store and analyse the water quality data. The software has many good features to archive and make use of the data. However, this program is not accessible to the public. Therefore, the clients of the JPS downlads the data in CSV or TEXT format and use their own programs to analyse the data.

Besides storing data, the common features that the TIDEDA program can offer are:

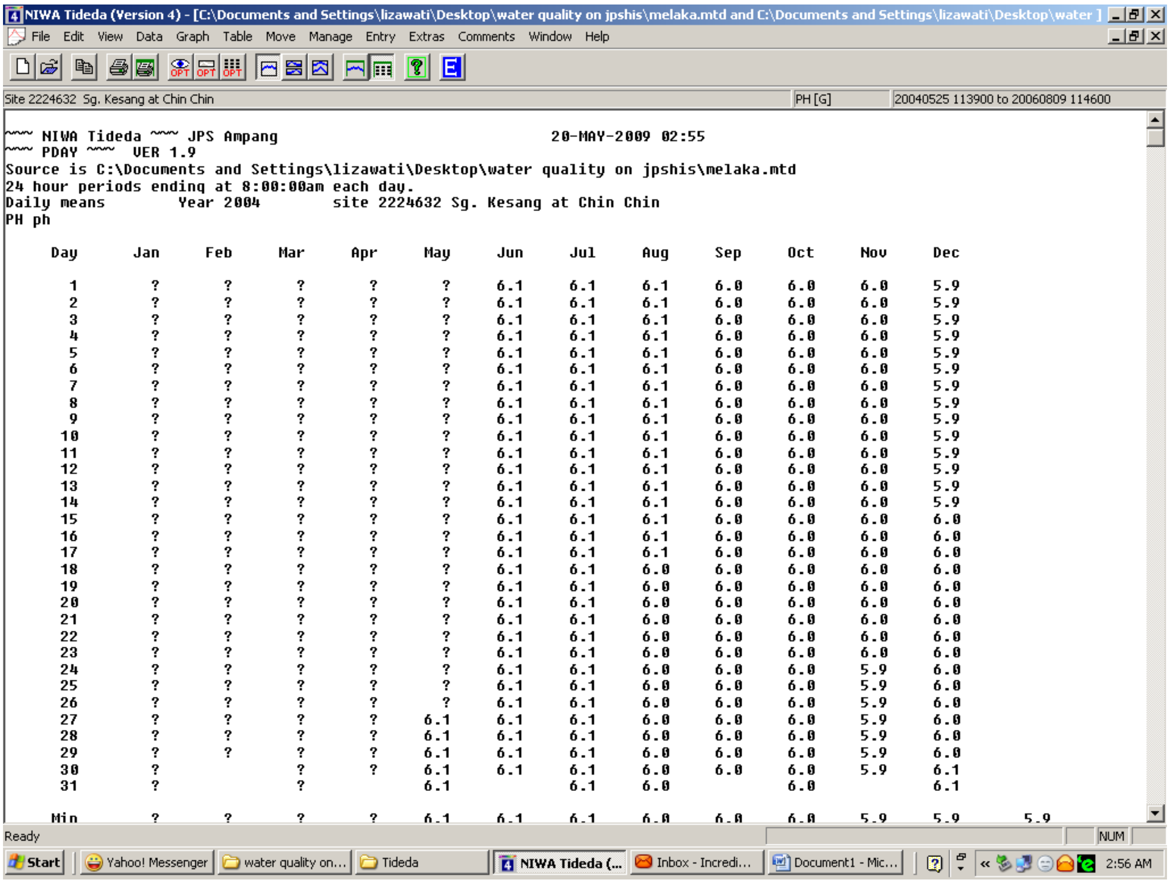
- Tabulate and display data of all water quality parameters according to the stations (Figure 21)
- Generation of daily data according the required parameter (Figure 22).
- The actual values of a few water quality parameters (pH, Turbiidity, Alkalinity, Calcium, etc.) are multiplied by factors varying from 10 to 100. It is strongly recommended that the TIDEDA should be customized to accept and reproduce the water quality values exactly same as reported from the site and laboratory test results.
- The turbidity is measured as NTU but in the TIDEDA program it appears to be as Fullers. The unit of turbidity should be changed in the TIDEDA program as NTU.
- The program is also able to conduct statistical analyses and produce various graphs (Figure 23).
- The program can produce annual time series data.
- It is also recommended that the order and arrangement of the parameters in TIDEDA. program should match the data sheet used for the site and laboratory data.



~~~ NIWA Tideda ~~~ JPS Ampang 20-MAY-2009 02:56
~~~ LIST ~~~
Source is melaka.mtd Site 2224632 Sg. Kesang at Chin Chin
24 Items GAUGING From 20040525 113900 to 20060809 114600

PH PH*10	Colour Hazen	Conductivi uS/cm	Turbidity Fullers*10	Alkalinity mg/l*100	Hardness	Calcium mg/l*10	Magnesium mg/l*10	Tot.Solid mg/l	Dissolve S <no name>
61	50	99	220	1800	21	64	13	93	76
60	125	67	835	1000	16	48	11	664	41
59	85	94	260	1300	28	48	38	186	102
60	100	75	354	1500	14	51	5	158	71
61	70	81	169	1300	15	52	5	106	67
64	10	89	743	1600	16	67	5	87	33
69	40	148	131	2200	29	87	16	118	98
69	90	170	115	2100	29	90	17	116	83
70	30	132	121	1900	25	79	12	98	89
69	40	185	183	1700	30	87	21	131	110
62	250	86	1520	310	14	47	6	384	147
64	90	104	219	1000	16	61	5	98	63
62	40	90	79	510	15	52	7	120	76
61	120	95	523	710	17	58	7	221	80
63	70	104	197	150	21	74	8	120	97
67	40	119	108	2100	21	78	5	74	68
67	40	131	97	690	26	83	14	138	113
31	500	66	2260	880	16	57	6	455	92
60	40	100	62	2200	18	69	5	118	49
70	50	89	146	1900	20	78	5	155	89
66	80	123	124	1700	20	77	5	111	95
67	50	169	170	2100	29	110	5	114	105
68	40	134	98	1900	23	80	9	91	82
66	10	137	24	2000	22	73	10	88	86
64	40	100	116	1300	21	68	11	78	51
65	60	97	508	980	21	65	13	99	32
60	50	80	1250	1100	21	53	19	182	93
61	85	85	984	1200	22	61	17	189	86
62	80	87	565	1400	20	65	9	110	64
61	70	80	313	1100	17	56	9	205	100
64	625	55	3610	1000	19	24	32	888	131
64	60	90	151	1600	17	61	6	134	70
62	80	92	215	1400	16	58	6	129	65

Figure 21: Display Screen of TIDEDA Output for all Water Quality Data at any Station



NIWA Tideda (Version 4) - [C:\Documents and Settings\lizawati\Desktop\water quality on jpshis\melaka.mtd and C:\Documents and Settings\lizawati\Desktop\water]

File Edit View Data Graph Table Move Manage Entry Extras Comments Window Help

Site 2224632 Sg. Kesang at Chin Chin PH [G] 20040525 113900 to 20060809 114600

~~~ NIWA Tideda ~~~ JPS Ampang 20-MAY-2009 02:55
~~~ PDAY ~~~ VER 1.9
Source is C:\Documents and Settings\lizawati\Desktop\water quality on jpshis\melaka.mtd
24 hour periods ending at 8:00:00am each day.
Daily means Year 2004 site 2224632 Sg. Kesang at Chin Chin
PH ph

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
2	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
3	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
4	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
5	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
6	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
7	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
8	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
9	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
10	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
11	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
12	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
13	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
14	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	
15	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	6.0	
16	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	6.0	
17	?	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	6.0	
18	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
19	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
20	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
21	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
22	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
23	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	6.0	6.0	
24	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
25	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
26	?	?	?	?	?	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
27	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
28	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
29	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	6.0	
30	?		?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	6.1	
31	?		?		6.1		6.1	6.0		6.0		6.1	
Min	?	?	?	?	6.1	6.1	6.1	6.0	6.0	6.0	5.9	5.9	5.9

Ready NUM

Start | Yahoo! Messenger | water quality on... | Tideda | NIWA Tideda (... | Inbox - Incredi... | Document1 - Mic... | 2:56 AM

Figure 22: Display Screen of TIDEDA Output for Daily Water Quality Data for any Parameter

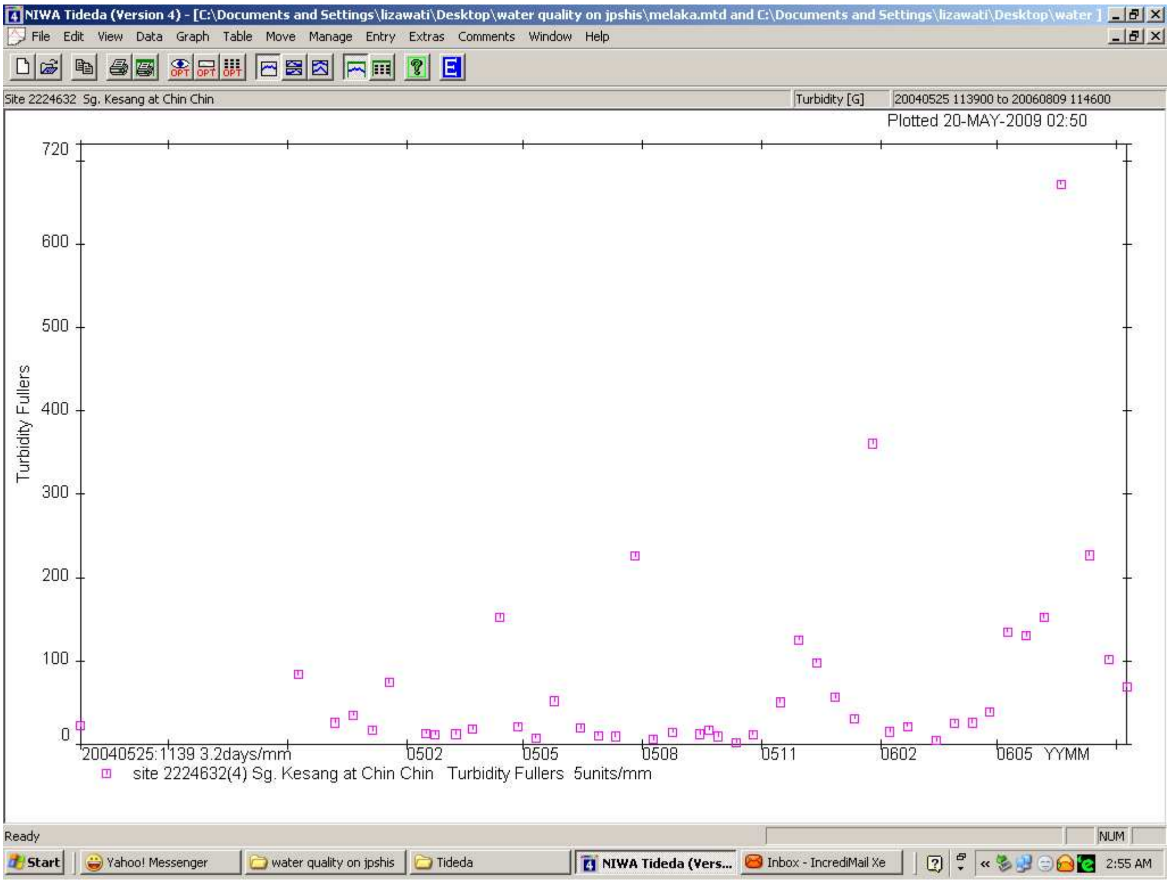


Figure 23: Display Screen of TIDEDA Output for any Water Quality Data at any Station

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The advantages of JPS' water quality monitroing program is that it includes the river flow data wihich is very important for the calculation of pollution loading and necessary for water quality modelling exercise. However, the study output could have been of better quality if all the data were available in regular interval, for all parameters and at all 28 stations monitored by JPS. Missing data and irregularity of the sampling posed a great challenge in achieving the objectives of the study.

Although 24 water quality parameters are being monitored under the existing scheme, a few important parameters (e.g. DO, Nutrients, Toxic Heavy Metals, *E.coli* Bacteria, etc.) were not monitored. As a result the exsiting data was not suitable for the development of comprehensive river index to covering all aspects of the water quality. Adequacy of the parameters were evaluated and appropriate recommendataions are made to improve and optimise the monitoring exercise done by the JPS and Chemistry Departmetn of Malaysia.

Pollution loadings for the parameters are calculated for each stations having the water flow data. In order to compare the contribution of pollution from each catchment, the loads are expressed in terms of kg./km^2/hr. It was observed that most of the stations are relatively located in less developed areas. As a result the stations, generally, indicate the nature of pollution from less developes areas. However, due to irregualarity of data collection, pollution loading for various ARI was not calculated.

Suitability of the exsiting sampling and monitoring scheme was evaluated to quantify the contribution of pollution load from the non-point sources (NPS). Sampling procedure for NPS pollution monitoirng is described in the report. It is also realised that a nationwide NPS pollution study for various landuses would be the first step to develop the EMC database, which is a fundamental requirement for the calculation of NPS pollution loading at any location.

JPS archives all data with the aid of a computer software called TIDEDA, which is found to be very usefull in properly handling huge amount of data. The capability of the customised TIDEDA module for water quality data is reviewd and improvements are recommended to avoid confusion on the format of the values and to ease the data transfer from laboratory data sheet to the TIDEDA program.

A comprehensive literature review was conducted to study the the existing water quaity indexes used in various parts of the worls. Based on the extensive literature review the best possible index is propsed to make use of the JPS Data.

Due to unavailability of a few important parameters (as the original JPS' water quality monitoring program was not intended for any index), a simplified river index (JRI) is proposed consisting of data on Specific Flow, which is instantaneous flow divided by the catchment area at the station ($m^3/s/km^2$); Total Suspended Solids (TSS), which represents the sediments that adsorbs many pollutants on the surfaces (mg/L); Total Dissolve Solids (TDS), which represents salts and minerals that indicates the dissolved minerals in the water (mg/L); and Turbidity (TURB) in NTU, which represents the clarity and aesthetic property of water that is very important to make the river and water appealing to the people.

Rating curves are proposed for the JRI parameters (Specific Flow, Turbidity, TSS, and TDS). Weighing factors for each of the 4 parameters are calculated based on the relative index and the overall JRI is developed to evaluate the river status based on the past data collected by JPS. Due to unavailability of other important data required to develop a comprehensive river index, the proposed JRI is kept simple but very relevent to JPS' main activites and line of actions.

6.2 RECOMMENDATIONS

JPS is recommended to go for ISO for the water quality monitoring system and services. For the time being, the existing guidelines (HP No. 22 and others) should be followed in full. The data sheets used in the sites and laboratory should be completed properly. Proper care should be taken in transporting the data from the site to the laboratory. It is highly recommended to send the sample to the laboratory within 24 hours of sampling.

Two data forms should be used for the data collection one for field information (Bacaan Luar) and other for laboratory data (Laporan Makmal) in Appendix D of HP NO. 22. However, no data was available for Items 4, 5, 6, 8, 9, 13, 14, 15 and 16 of the Bacaan Luar data sheet. It is recommended that these data is important and should be recorded and made available to the customers.

In-situ quality monitoring instruments (e.g. DO, pH, TDS, conductivity, turbidity meter, etc. should be calibrated and operated according to the guideline (operation manual) provided by the supplier (Pengukuran In-situ Water Quality Menggunakan Portable Multiparameter by Lizawati Duri and Azmi Jafri).

Chemicals required for the calibration of the equipments should be stored properly as required and checked for the expiry dates.

Monitoring of in-situ parameters and collection of samples should be done from the running water not from the stagnant water near the banks. All personnel involved in the whole exercise (from sampling, storing, in situ monitoring, transporting, laboratory testing, etc.) must realise that every components are very important to produce reliable data.

Collected samples should be preserved according to the standard procedure (2.7.7.4 Sample Preservation, page 5 of the Guide To Water Quality Monitoring Practices In Malaysia - Practices And Techniques Of Sampling And Application Of Water Quality Data By Various Government Agencies In Malaysia) to preserve the quality of water from any unwanted decay. For certain parameter (COD and Ammonia) pH of the samples should be reduced less than 2.0 to discourage decay of the pollutants.

Due to advancement of the monitoring devices and precision of the laboratory equipments, metals and other parameters should be detected and reported to more decimal points.

Although the information on the rainfall (during sampling) should be recorded in the data sheet (item 14 in Figure 2) but it was not available. As such, the consultant team had to depend on the available flow data to anticipate if the samples represented the flow due to storm events.

pH should be measured at site and at laboratory. However, only one pH value was available in the report furnished by the Department of Chemistry. Detection limits for certain parameters (e.g. Ammonia, F^-, Cl^-, NO_3^-, Mn, PO_4^-, Turbidity, etc.) were not consistent.

If JPS is interested to develop a comprehensive JRI for the classification of rivers in Malaysia, the revised monitoring program should include groups of several parameters namely, River Flow, Physical (TSS, Turbidity, TDS, etc.), Chemical (COD, Ammonia, Heavy Metals, Toxic Elements, etc.), Biological (Coliform Bacteria), etc. In order to make the data useful the frequency of sampling should be properly planned and regular without any missing schedule.

One of the main objectives of the study was to develop a tool to calculate the JPS River Index (JRI). After reviewing many references it was realized that certain important parameters (e.g. dissolved oxygen, toxic metals, faecal coliform – *E. coli*, etc.) are important for any water quality index but not monitored by the JPS. If JPS wish to revise the monitoring program to enhance data acquisition for better assessment and to aid water quality modeling exercises additional parameters would be necessary to be included. Therefore, a revised list of JPS' water quality parameters is proposed in Table 17, which indicates few important parameters should be monitored monthly and others could be monitored quarterly. Different monitoring frequencies are proposed to reduce the operation cost of the Jabatan Kimia and JPS. The parameters included in the TIDEDA database should be same as that shown in Table 17 and the software should be customized to receive the data from the Jabatan Kimia Malaysia without any error.

The bold items in Table 17 should be monitored monthly and the other parameters are recommended to be monitored quarterly. The proposed list of parameters includes all the parameters important for point and non-point pollution sources covering, physical, chemical, nutrients and microbial pollutants. However, the toxic chemicals are not included as those elements are more suited for the DOE's monitoring activity.

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Table 17: Proposed Parameters for JPS Water Quality Monitoring Program

Sampling Date	**Sampling Time**	**Sample ID**	**Weather Condition**	**Event Rainfall (mm)**	**Description of Sample Colour**	**Sampling Depth from Water Surface)**	**Flow Rate (m^3/s)**	**pH (unit)**	**Temp (^oC)**
PS, NPS	PS, NPS	PS, NPS	PS, NPS	NPS	PS, NPS	PS	PS, NPS	PS	PS
PS, NPS	PS, NPS	PS, NPS	PS, NPS	Hydro	Physical	Hydro	Hydro	Chemi	Physical
At Site	At Site	At Site	At Site	At Site	At Site	At Site	At Site	At Site & At Lab	At Site
Turb. (NTU)	**DO (mg/L)**	**DO (% Sat.)**	**TDS (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**TSS (mg/L)**	**Na (mg/L)**	**COD (mg/L)**	*BOD (mg/L)*
NPS	PS	PS	PS	PS, NPS	PS, NPS	NPS	PS, NPS	PS, NPS	*PS*
Physical	Chemi	Chemi	Physical	Chemi	Chemi	Phys	Chemi	Chemi	*Biochem*
At Site	At Site	At Site	At Site	At Lab	At Lab	At Lab	At Lab	At Lab	*At Lab*
TKN (mg/L)	*AN (mg/L)*	*Nitrate (mg/L)*	**TN (mg/L)**	**TP (mg/L)**	*SO_4 (mg/L)*	**Fe (mg/L)**	*As (mg/L)*	*Fecal Coliform (CFU/100 mL)*	*Fecal Streptococci (CFU/100 mL)*
PS, NPS	*PS*	*PS, NPS*	PS, NPS	PS, NPS	*PS*	PS, NPS	*PS, NPS*	*PS, NPS*	*PS, NPS*
Chemi	*Chemi*	*Chemi*	Chemi	Chemi	*Chemi*	Chemi	*Chemi*	*Bacteria*	*Bacteria*
At Lab	*At Lab*	*At Lab*	At Lab	At Lab	*At Lab*	At Lab	*At Lab*	*At Lab*	*At Lab*

Note: PS - Point Source; NPS – Non-point Source; Hydro – Hydrological; Chemi - Chemical.

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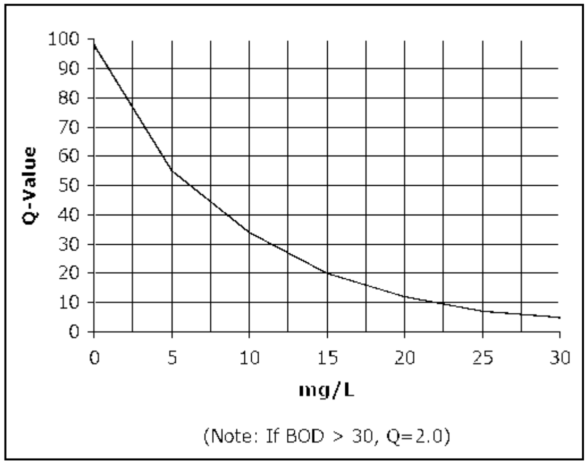
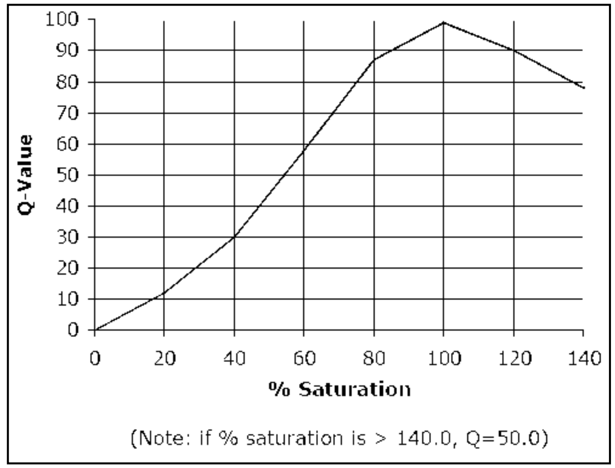
APPENDIX - A

WQI RATING CURVES

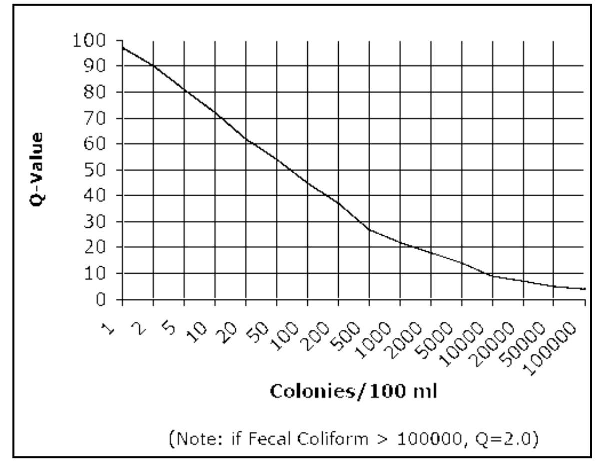
Figure A1: Graphs for each Analyte of NSF WQI



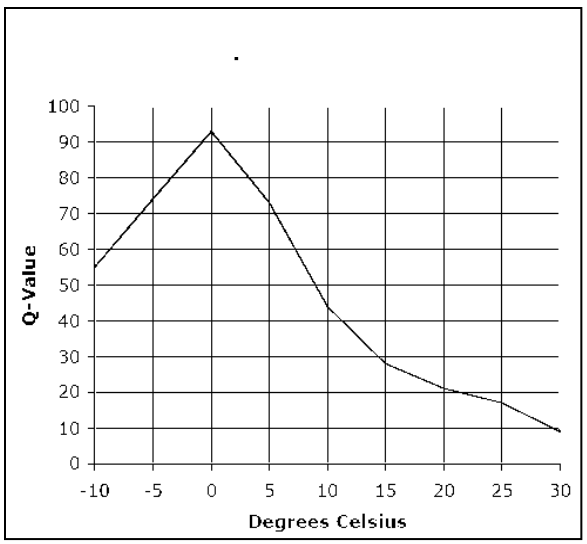
(a) BOD Test Results



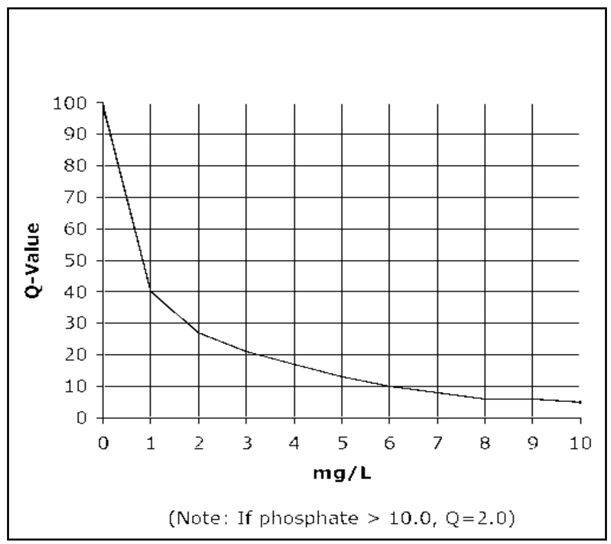
(b) Dissolved Oxygen Results



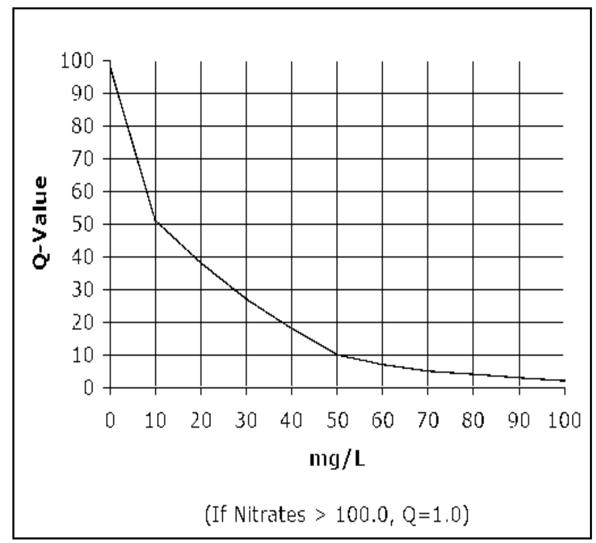
(c) Fecal Coliform Results



(d) Temperature Results

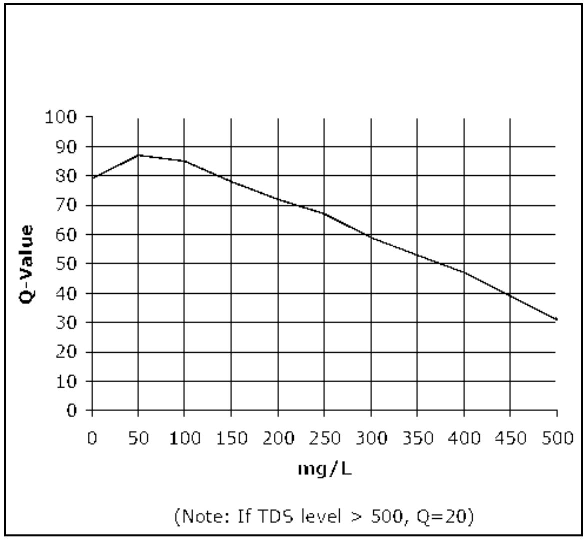


(e) Phosphate Results

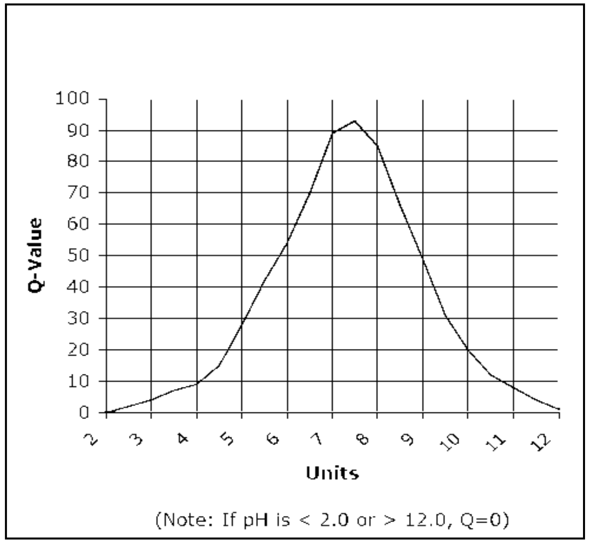


(f) Nitrate Results

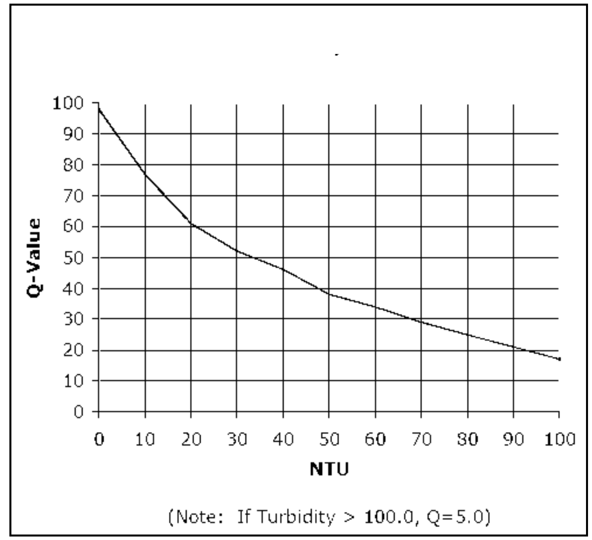
Figure A1: Graphs for each Analyte of NSF WQI (Continued)



(g) Total Dissolved Solids Results

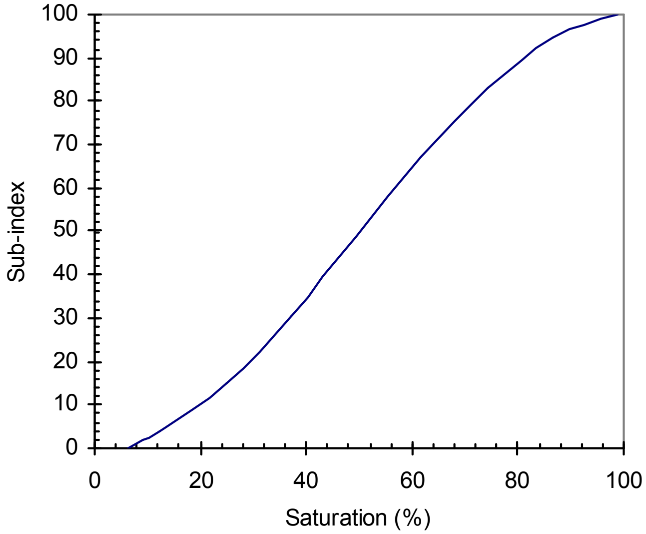


(h) pH Results

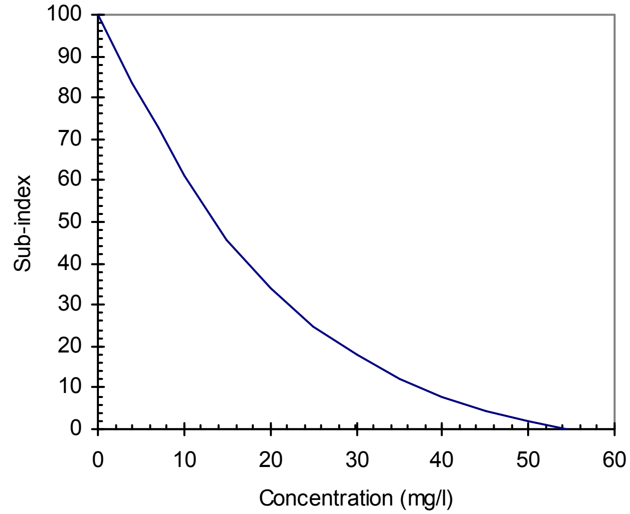


(i)Turbidity Results

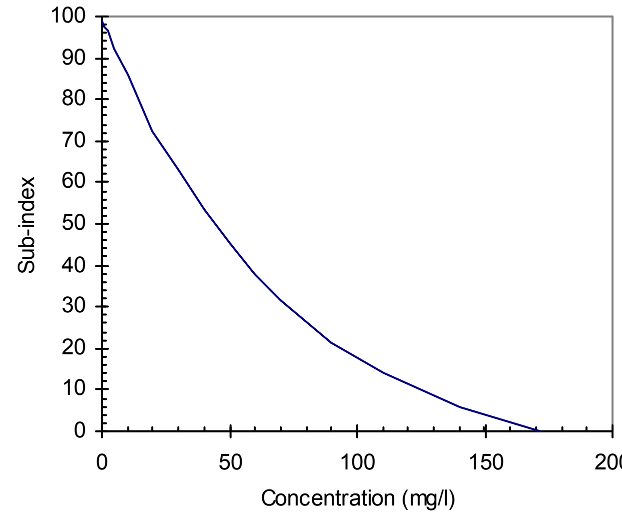
Figure A2: Sub-indices to Determine WQI in Malaysia



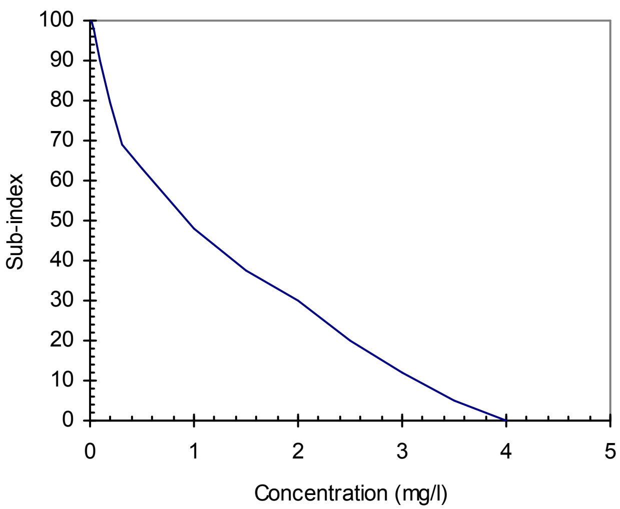
(a) Dissolved Oxygen (DO)



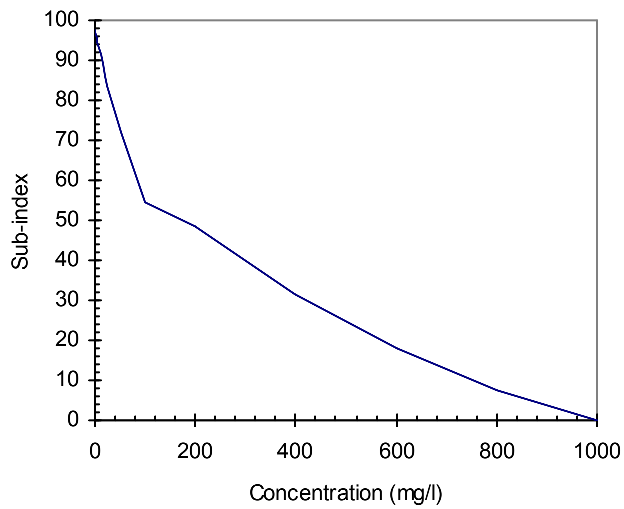
(b) Biochemical Oxygen Demand (BOD)



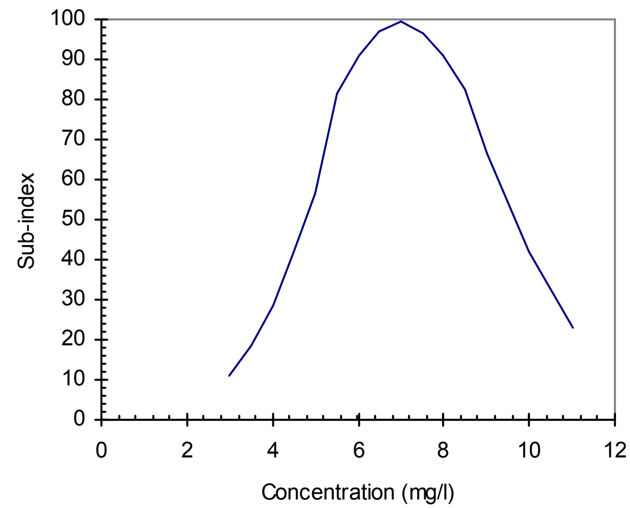
(c) Chemical Oxygen Demand (COD)



(d) Ammoniacal Nitrogen (AN)



(e) Suspended Solids (SS)



(f) pH

APPENDIX - B

STATISTICAL SUMMARY OF THE JRI

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 1737651 (Sg. Johor di Rantau Panjang)																										
95 Percentile	158.1	0.140	6.70	463	79	142.3	16.3	32.5	7.7	4.4	260	168	166	1.13	25.8	6.5	5.16	37	2	10.50	0.10	2.58	0.18	9.78	5.49	0.08
75 Percentile	74.6	0.066	6.40	263	64	86.8	10.3	20.0	4.7	2.9	190	115	91	0.31	19.5	5.1	3.95	23	2	9.78	0.09	0.25	0.10	7.00	3.90	0.03
50 Percentile	30.9	0.027	6.20	150	57	48.0	9.4	15.0	3.4	1.9	159	73	66	0.17	11.5	4.3	3.30	12	2	8.00	0.07	0.09	0.08	4.01	2.20	0.03
25 Percentile	18.1	0.016	5.73	80	46	23.8	5.6	10.8	2.8	1.1	124	49	49	0.11	8.2	2.3	2.30	9	2	5.75	0.05	0.06	0.04	1.92	1.80	0.03
5 Percentile	10.5	0.009	4.88	58	35	7.0	2.8	7.5	2.3	0.7	51	38	13	0.08	3.4	1.6	1.26	8	2	2.52	0.02	0.04	0.01	1.23	1.02	0.02
No. of Data	12.0	12	16	16	16	16	16	16	16	12	16	15	16	12	16	15	15	15	1	16	4	11	8	16	15	10
Mean	54.3	0.048	5.98	203	56	58.9	9.0	16.9	4.3	2.2	157	87	76	0.35	13.9	4.0	3.17	17	2	7.61	0.06	0.56	0.08	4.53	2.84	0.04
Std. Deviation	54.0	0.048	0.64	165	17	45.3	5.3	8.7	3.0	1.3	74	47	46	0.56	8.3	1.8	1.38	11	-	2.76	0.04	1.29	0.06	3.05	1.60	0.03
Minimum	5.1	0.004	4.80	20	24	2.9	1.2	5.5	1.8	0.7	39	30	9	0.07	2.0	1.2	0.22	7	2	1.99	0.01	0.03	0.00	1.00	0.60	0.02
Maximum	169.0	0.150	7.00	650	98	149.0	23.0	37.0	15.0	4.7	330	190	171	2.11	34.0	7.7	5.30	47	2	12.00	0.10	4.40	0.21	10.60	6.40	0.11
Statistical Values for the Station 2130622 (Sg. Bekok di Batu 77 Jalan Yong Peng Labis)																										
95 Percentile	35.3	0.101	7.28	263	97	82.5	20.3	34.3	6.8	4.3	350	309	101	0.56	15.3	10.0	6.75	36	4	9.18	0.25	0.28	0.05	13.25	5.49	0.19
75 Percentile	12.4	0.036	6.70	143	72	45.0	14.5	27.5	5.3	3.8	161	95	81	0.25	12.0	6.8	3.15	19	2	8.25	0.19	0.18	0.02	7.33	2.15	0.06
50 Percentile	9.9	0.028	6.40	120	62	33.5	13.0	17.0	4.9	1.4	122	63	41	0.22	11.0	6.2	2.35	17	2	6.00	0.11	0.12	0.01	4.00	1.51	0.06
25 Percentile	8.4	0.024	6.03	80	57	16.8	10.0	15.0	4.3	1.1	80	37	23	0.18	10.0	5.0	2.18	15	2	5.40	0.06	0.07	0.01	2.68	0.90	0.04
5 Percentile	6.7	0.019	5.60	60	50	15.0	6.1	12.0	3.8	0.9	53	23	15	0.13	9.4	3.6	1.55	9	2	4.75	0.06	0.03	0.01	0.94	0.43	0.03
No. of Data	14.0	14	16	16	15	16	15	16	16	16	16	16	16	14	16	16	16	16	5	16	4	11	12	16	15	11
Mean	13.9	0.040	6.42	133	67	39.6	12.3	21.4	5.0	2.2	148	96	52	0.26	11.4	6.4	3.08	19	2	6.59	0.14	0.13	0.02	5.26	2.05	0.07
Std. Deviation	11.3	0.032	0.62	93	17	36.3	4.5	8.4	1.1	1.5	114	106	34	0.19	2.5	3.0	1.82	15	1	1.69	0.10	0.09	0.02	4.03	1.84	0.07
Minimum	6.5	0.018	5.30	60	49	15.0	5.5	12.0	3.1	0.6	44	15	13	0.12	8.6	1.2	1.40	7	2	4.00	0.06	0.02	0.01	0.22	0.30	0.02
Maximum	48.0	0.137	7.80	450	113	165.0	21.0	38.0	6.9	5.2	502	421	114	0.88	19.0	16.0	8.40	72	4	9.70	0.27	0.29	0.06	14.00	7.10	0.27
Statistical Values for the Station 2237671 (Sg. Lenggor di Batu 42 Kluang Mersing.)																										
95 Percentile	108.4	0.524	6.95	210	134	50.8	5.2	10.3	2.5	1.9	107	92	52	0.32	18.3	3.4	2.70	31	-	2.36	-	0.19	0.05	1.95	2.54	0.05
75 Percentile	9.9	0.048	6.25	88	100	19.0	3.8	8.0	1.2	1.3	83	51	33	0.30	9.8	1.1	2.18	23	-	1.98	-	0.16	0.04	1.75	2.09	0.03
50 Percentile	8.3	0.040	5.40	80	20	15.0	2.2	7.0	1.0	1.2	61	27	29	0.26	8.6	0.8	1.45	16	-	1.73	-	0.12	0.03	1.50	1.99	0.02
25 Percentile	3.3	0.016	4.85	80	17	13.3	2.2	5.3	1.0	1.1	43	16	11	0.23	7.9	0.7	1.21	10	-	1.12	-	0.08	0.02	1.30	1.38	0.02
5 Percentile	2.4	0.012	4.63	32	9	5.7	2.1	2.0	0.8	0.7	15	11	10	0.20	5.3	0.5	0.96	7	-	0.62	-	0.05	0.02	1.13	1.13	0.02
No. of Data	5.0	5	6	6	6	6	5	6	5	6	6	6	5	2	6	5	6	6	-	6	-	2	4	3	6	4
Mean	31.4	0.151	5.62	99	54	21.2	3.2	6.5	1.3	1.2	62	40	28	0.26	10.1	1.4	1.69	17	-	1.57	-	0.12	0.03	1.53	1.84	0.03
Std. Deviation	56.9	0.275	1.00	79	60	20.3	1.5	3.4	0.8	0.5	38	36	19	0.10	5.7	1.4	0.75	10	-	0.73	-	0.11	0.01	0.46	0.60	0.02
Minimum	2.2	0.011	4.60	16	6	3.3	2.1	1.0	0.7	0.6	6	9	10	0.19	4.4	0.5	0.90	6	-	0.49	-	0.04	0.02	1.09	1.10	0.02
Maximum	133.0	0.643	7.10	250	136	61.0	5.5	11.0	2.8	2.1	114	104	57	0.33	21.0	3.9	2.80	33	-	2.48	-	0.20	0.05	2.00	2.68	0.05

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 2527611 (Sg. Muar di Buloh Kasap)																										
95 Percentile	102.3	0.033	7.18	688	151	243.8	33.0	57.8	11.8	6.9	414	297	237	0.58	26.8	20.0	13.85	76	2	16.75	0.16	0.43	0.23	14.25	13.80	0.56
75 Percentile	33.6	0.011	6.79	400	117	117.5	24.0	36.8	9.7	3.9	269	154	124	0.34	21.0	9.9	7.05	32	2	11.75	0.11	0.30	0.13	11.00	6.80	0.18
50 Percentile	17.5	0.006	6.56	200	108	58.5	19.0	31.0	8.0	2.8	194	113	69	0.16	18.0	6.8	5.19	24	2	9.90	0.08	0.11	0.08	5.84	4.00	0.09
25 Percentile	4.9	0.002	6.30	171	91	40.0	16.0	28.0	6.5	2.4	149	84	29	0.08	14.0	5.0	3.80	15	2	8.08	0.05	0.06	0.06	4.12	2.90	0.06
5 Percentile	2.0	0.001	5.65	120	61	21.3	9.3	19.3	3.7	1.6	104	22	18	0.05	8.6	2.1	2.60	12	2	5.50	0.03	0.04	0.04	1.40	1.72	0.03
No. of Data	40.0	40	46	46	46	46	46	46	46	45	46	46	45	38	46	42	44	46	7	46	4	30	31	36	45	43
Mean	28.6	0.009	6.46	296	108	91.1	20.5	33.6	8.0	3.4	226	129	95	0.22	17.4	8.7	6.63	29	2	10.12	0.09	0.22	0.10	7.32	5.71	0.17
Std. Deviation	35.8	0.011	0.66	177	34	72.6	7.6	10.5	2.5	1.7	127	77	109	0.18	6.2	6.9	5.34	23	0	3.36	0.06	0.33	0.07	4.83	4.23	0.21
Minimum	1.7	0.001	3.20	80	49	19.0	8.1	14.0	1.6	1.6	92	11	9	0.04	0.9	1.1	2.20	7	2	4.43	0.03	0.02	0.02	0.39	0.40	0.02
Maximum	171.7	0.055	7.70	700	271	280.0	45.0	65.0	14.0	10.0	807	377	663	0.63	29.0	35.0	33.00	130	2	19.00	0.17	1.83	0.32	22.00	19.00	0.92
Statistical Values for the Station 2528614 (Sg. Segamat di Segamat)																										
95 Percentile	27.2	0.043	6.92	600	127	330.0	32.0	43.0	9.5	4.5	449	235	242	0.77	27.0	10.0	14.00	55	3	11.43	0.10	0.44	0.27	9.12	11.00	0.19
75 Percentile	13.3	0.020	6.53	148	57	37.4	14.5	15.8	3.8	1.8	230	104	126	0.23	18.8	4.3	6.20	18	-	4.28	-	-	0.04	2.76	9.20	0.18
50 Percentile	10.6	0.016	6.40	140	51	27.3	10.6	14.5	2.9	1.6	144	81	78	0.13	16.0	3.8	4.70	15	-	3.90	-	-	0.04	2.38	7.70	0.17
25 Percentile	8.5	0.013	6.20	150	57	30.0	12.3	16.0	3.7	1.5	147	75	50	0.07	13.3	3.8	3.65	15	2	4.92	0.07	0.05	0.03	2.46	2.68	0.04
5 Percentile	3.9	0.006	5.83	80	46	20.0	8.0	13.0	2.8	0.6	92	48	23	0.05	3.4	2.1	2.46	6	2	3.90	0.05	0.04	0.02	0.65	1.62	0.02
No. of Data	40.0	41	46	46	46	46	46	46	46	43	46	46	46	37	46	41	39	46	5	46	3	34	27	34	44	42
Mean	13.0	0.026	6.43	262	75	96.2	16.8	22.0	5.2	2.4	223	123	100	0.22	17.2	5.9	6.60	25	2	6.90	0.08	0.16	0.09	4.34	5.21	0.09
Std. Deviation	8.8	0.044	0.38	166	28	113.4	7.4	9.0	2.1	1.5	112	64	76	0.24	8.2	3.3	5.54	17	1	2.67	0.03	0.14	0.09	2.72	3.44	0.06
Minimum	2.9	0.004	5.50	65	42	10.0	5.8	12.0	2.4	0.5	87	42	11	0.04	0.6	0.5	0.28	6	2	2.40	0.05	0.02	0.02	0.35	0.30	0.02
Maximum	53.7	0.291	7.50	750	179	570.0	39.0	53.0	12.0	9.1	564	311	363	1.15	51.0	18.0	34.00	89	3	15.00	0.10	0.53	0.37	12.00	16.00	0.29
Statistical Values for the Station 5606610 (Sg. Muda di Jam Syed Omar.)																										
95 Percentile	213.1	0.064	7.83	-	66	-	26.0	-	7.7	2.4	-	-	342	0.39	20.0	2.1	-	23	1	9.65	0.20	0.33	0.20	16.00	3.90	-
75 Percentile	104.7	0.031	7.35	-	58	-	21.0	-	6.0	2.0	-	-	110	0.05	16.0	2.1	-	13	1	5.00	0.10	0.14	0.10	6.93	1.80	-
50 Percentile	45.1	0.014	7.00	-	45	-	14.0	-	5.0	1.2	-	-	64	0.05	10.0	2.1	-	9	1	3.00	0.07	0.10	0.10	3.00	1.20	-
25 Percentile	22.6	0.007	6.80	-	36	-	9.0	-	4.0	1.0	-	-	45	0.04	8.0	2.1	-	7	0	1.00	0.00	0.05	0.00	2.00	0.80	-
5 Percentile	13.9	0.004	6.40	-	28	-	5.0	-	2.3	0.0	-	-	22	0.03	6.0	2.1	-	3	0	0.00	0.00	0.05	0.00	0.00	0.30	-
No. of Data	84.0	84	95	-	94	-	90	-	96	96	-	-	94	35	94	1	-	86	60	96	93	34	80	96	93	-
Mean	78.4	0.024	7.08	-	47	-	15.6	-	4.9	1.4	-	-	108	0.30	12.9	2.1	-	12	1	3.56	0.07	0.12	0.08	4.94	1.62	-
Std. Deviation	78.5	0.024	0.46	-	14	-	8.5	-	1.8	0.8	-	-	118	1.34	6.4	-	-	13	1	3.32	0.07	0.09	0.09	5.47	1.50	-
Minimum	11.7	0.004	6.20	-	15	-	3.8	-	0.4	0.0	-	-	7	0.02	4.0	2.1	-	1	0	0.00	0.00	0.03	0.00	0.00	0.00	-
Maximum	434.2	0.130	8.50	-	117	-	62.0	-	10.0	4.0	-	-	697	8.00	50.0	2.1	-	120	3	18.50	0.30	0.46	0.41	36.00	8.60	-

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 5120601 (Sg. Nenggiri di Jam Bertam)																										
95 Percentile	313.0	0.147	7.60	390	62	650.8	29.1	28.1	5.6	3.5	814	120	766	1.84	16.0	2.6	7.19	-	-	3.50	-	0.57	0.11	16.68	2.22	-
75 Percentile	179.7	0.084	7.40	175	50	126.0	24.0	20.0	4.4	2.8	602	79	549	0.53	12.0	1.9	5.21	-	-	2.00	-	0.26	0.05	10.00	1.51	-
50 Percentile	123.1	0.058	7.00	85	46	52.7	20.0	18.0	3.6	2.2	226	51	138	0.20	10.0	1.7	3.45	-	-	1.00	-	0.20	0.02	8.80	0.60	-
25 Percentile	96.6	0.045	6.63	40	39	23.7	16.9	15.0	2.5	1.5	126	35	73	0.15	8.0	1.6	2.48	-	-	1.00	-	0.10	0.01	5.80	0.23	-
5 Percentile	52.7	0.025	6.34	15	29	12.1	13.7	11.0	2.0	0.6	72	26	38	0.06	2.0	0.8	1.91	-	-	1.00	-	0.02	0.01	1.25	0.14	-
No. of Data	46.0	46	50	45	50	46	50	50	50	50	49	49	50	8	49	8	8	-	-	44	-	42	7	46	10	-
Mean	165.2	0.078	6.99	127	46	159.6	20.7	18.4	3.7	2.2	420	60	358	0.54	10.1	1.7	4.04	-	-	2.14	-	0.23	0.04	8.07	0.91	-
Std. Deviation	160.5	0.075	0.43	120	16	238.1	5.3	6.0	1.4	1.2	509	32	502	0.82	4.1	0.7	2.14	-	-	3.72	-	0.23	0.04	4.30	0.84	-
Minimum	44.3	0.021	5.90	10	21	4.6	8.3	9.5	1.6	0.5	21	20	23	0.03	2.0	0.6	1.80	-	-	1.00	-	0.01	0.00	1.00	0.09	-
Maximum	1110.2	0.521	7.62	500	131	909.9	35.0	38.0	10.0	6.3	3164	161	3130	2.50	20.0	2.9	7.40	-	-	23.00	-	1.33	0.13	19.00	2.40	-
Statistical Values for the Station 5222652 (Sg. Lebir di Kg Tualang)																										
95 Percentile	3007.7	1.238	7.80	294	83	442.2	35.8	31.0	9.4	3.9	706	111	676	1.58	14.0	3.7	7.78	-	-	4.00	-	0.64	0.09	16.41	2.74	-
75 Percentile	197.4	0.081	7.60	181	68	158.5	29.0	25.8	7.4	2.8	332	77	260	0.45	12.0	2.1	4.10	-	-	2.00	-	0.27	0.04	10.70	1.55	-
50 Percentile	114.3	0.047	7.35	85	52	26.3	21.9	20.5	4.4	1.8	190	64	149	0.33	10.0	1.7	3.10	-	-	1.00	-	0.20	0.03	9.20	0.60	-
25 Percentile	67.8	0.028	6.80	30	40	9.6	17.3	17.0	3.6	1.5	120	48	50	0.20	8.0	1.3	1.90	-	-	1.00	-	0.14	0.03	3.63	0.25	-
5 Percentile	30.4	0.013	6.40	10	23	2.0	9.2	8.9	2.0	0.7	83	19	16	0.05	4.0	0.9	1.12	-	-	1.00	-	0.03	0.01	1.00	0.10	-
No. of Data	41.0	41	46	44	46	42	46	46	46	44	46	46	46	8	46	43	44	-	-	42	-	44	6	42	39	-
Mean	514.0	0.212	7.24	118	54	113.8	22.8	21.6	5.2	2.2	294	63	232	0.51	9.8	1.8	3.40	-	-	1.77	-	0.25	0.04	8.45	1.32	-
Std. Deviation	931.0	0.383	0.48	125	20	187.2	8.5	9.1	2.5	1.6	386	27	383	0.69	3.9	0.8	1.96	-	-	1.13	-	0.19	0.03	5.29	2.26	-
Minimum	15.6	0.006	6.38	5	13	1.0	3.8	5.0	1.2	0.5	55	10	9	0.02	2.0	0.7	0.70	-	-	0.50	-	0.02	0.01	0.30	0.05	-
Maximum	3254.1	1.339	8.10	700	96	837.0	37.0	62.0	10.8	10.2	2589	134	2480	2.17	20.0	4.3	9.00	-	-	5.00	-	0.96	0.10	22.20	14.00	-
Statistical Values for the Station 5320643 (Sg. Galas di Dabong)																										
95 Percentile	848.7	0.109	7.90	200	69	290.4	27.7	34.2	7.6	4.6	928	432	893	0.55	20.0	2.1	7.82	-	-	3.00	-	0.56	0.03	14.25	0.10	-
75 Percentile	437.6	0.056	7.75	156	61	88.5	25.0	24.5	6.6	1.8	515	148	381	0.55	14.5	1.9	6.70	-	-	2.00	-	0.34	0.02	13.13	0.10	-
50 Percentile	377.0	0.049	7.60	113	52	25.6	22.0	21.0	6.0	1.3	362	103	206	0.55	12.0	1.6	5.30	-	-	1.00	-	0.24	0.02	4.50	0.10	-
25 Percentile	276.6	0.036	7.10	30	45	10.8	20.0	17.0	5.1	1.0	182	72	81	0.55	10.0	1.4	3.90	-	-	1.00	-	0.19	0.01	2.70	0.10	-
5 Percentile	232.6	0.030	6.56	11	40	3.7	16.3	13.3	3.7	0.7	138	51	34	0.55	4.6	1.2	2.78	-	-	1.00	-	0.04	0.00	1.00	0.10	-
No. of Data	25.0	25	27	24	26	25	27	27	27	27	25	25	26	1	24	2	2	-	-	23	-	24	2	16	2	-
Mean	411.6	0.053	7.41	107	53	75.1	22.2	21.4	5.8	1.7	411	152	307	0.55	12.2	1.6	5.30	-	-	1.52	-	0.26	0.02	6.93	0.10	-
Std. Deviation	212.8	0.027	0.44	79	11	99.4	3.4	6.3	1.3	1.3	281	144	301	-	4.6	0.7	3.96	-	-	0.85	-	0.15	0.02	5.39	0.00	-
Minimum	209.8	0.027	6.40	10	32	2.0	15.0	13.0	2.4	0.5	99	47	21	0.55	2.0	1.1	2.50	-	-	1.00	-	0.03	0.00	1.00	0.10	-
Maximum	1132.4	0.146	7.90	300	80	300.0	29.0	38.0	8.0	5.6	1085	645	1013	0.55	20.0	2.1	8.10	-	-	4.00	-	0.65	0.03	15.00	0.10	-

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 5419601 (Sg. Pergau di Batu Lembu.)																										
95 Percentile	240.1	0.186	7.80	183	65	195.6	26.1	24.1	6.0	4.1	443	143	366	1.76	16.0	2.2	7.20	-	-	4.00	-	0.54	0.19	13.64	2.24	-
75 Percentile	116.0	0.090	7.50	70	43	38.6	19.0	18.3	4.0	2.4	294	78	211	0.30	13.0	1.9	3.93	-	-	2.00	-	0.25	0.10	10.00	0.98	-
50 Percentile	69.9	0.054	7.30	40	37	20.2	16.0	15.0	3.2	1.7	153	57	96	0.09	11.0	1.3	3.25	-	-	1.00	-	0.19	0.04	8.75	0.30	-
25 Percentile	42.1	0.033	6.90	20	33	9.2	14.0	11.8	2.0	1.0	91	38	42	0.04	8.0	1.2	2.33	-	-	1.00	-	0.10	0.02	6.50	0.13	-
5 Percentile	28.4	0.022	6.34	9	25	2.0	10.0	7.0	1.2	0.5	57	26	16	0.02	3.8	1.1	2.19	-	-	1.00	-	0.03	0.01	1.00	0.09	-
No. of Data	60.0	60	80	75	79	73	80	80	80	78	79	79	80	8	79	10	10	-	-	78	-	64	5	69	10	-
Mean	97.8	0.076	7.18	60	39	46.8	16.8	15.4	3.3	1.8	205	68	140	0.43	10.5	1.5	3.76	-	-	1.63	-	0.21	0.08	8.16	0.72	-
Std. Deviation	94.5	0.073	0.46	57	13	83.2	4.6	6.1	1.5	1.1	162	47	145	0.80	3.9	0.5	1.91	-	-	1.02	-	0.16	0.08	3.62	0.86	-
	24.1	0.019	5.95	5	23	1.2	8.0	5.0	1.2	0.2	49	21	4	0.02	2.0	1.1	2.10	-	-	1.00	-	0.02	0.01	0.80	0.09	-
Maximum	499.3	0.387	8.00	250	100	477.9	32.0	40.0	10.0	6.1	1027	311	949	2.32	20.0	2.2	7.60	-	-	6.00	-	0.74	0.21	16.20	2.60	-
Statistical Values for the Station 5718601 (Sg. Lanas di Air Lanas)																										
95 Percentile	27.6	0.344	7.70	139	55	110.2	21.9	24.1	4.9	3.5	297	239	190	0.62	18.0	2.2	7.00	-	-	3.60	-	0.50	0.03	13.00	1.15	-
75 Percentile	5.6	0.070	7.50	70	44	20.8	18.0	19.0	4.0	2.2	163	76	88	0.28	14.0	1.7	2.85	-	-	2.00	-	0.24	0.02	10.08	0.75	-
50 Percentile	2.8	0.035	7.20	30	40	10.3	17.0	15.0	3.6	1.7	102	50	43	0.09	11.0	1.5	2.60	-	-	2.00	-	0.16	0.01	7.50	0.50	-
25 Percentile	1.7	0.021	6.80	25	35	5.9	14.0	13.0	3.2	1.2	67	34	16	0.04	8.0	1.2	2.20	-	-	1.00	-	0.10	0.01	4.00	0.11	-
5 Percentile	0.5	0.007	6.20	7	22	3.2	10.0	10.0	1.6	0.7	49	24	8	0.04	2.0	1.1	1.00	-	-	1.00	-	0.04	0.01	1.00	0.05	-
No. of Data	68.0	68	74	70	72	70	74	74	74	73	73	73	71	4	73	10	12	-	-	69	-	61	4	64	11	-
Mean	6.2	0.078	7.13	51	40	22.9	16.2	16.2	3.5	1.8	133	74	60	0.23	10.9	1.5	3.05	-	-	1.91	-	0.19	0.02	7.15	0.49	-
Std. Deviation	9.8	0.122	0.47	42	9	32.9	3.9	5.0	1.0	0.9	94	78	56	0.32	4.2	0.4	2.14	-	-	1.11	-	0.13	0.01	3.94	0.43	-
Minimum	0.2	0.002	6.00	5	20	2.2	5.0	8.0	0.8	0.2	41	15	7	0.04	2.0	1.1	1.00	-	-	1.00	-	0.04	0.01	1.00	0.04	-
Maximum	58.7	0.734	7.90	175	63	153.0	26.0	35.0	6.0	5.3	523	506	232	0.71	20.0	2.4	8.80	-	-	7.50	-	0.67	0.03	17.00	1.30	-
Statistical Values for the Station 5721642 (Sg. Kelantan di Jam Guillemard)																										
95 Percentile	806.5	0.068	8.02	196	71	495.0	30.5	30.2	8.0	3.3	1107	228	1008	0.95	18.5	2.7	7.54	29	3	4.00	0.51	0.50	0.09	15.55	1.64	-
75 Percentile	407.1	0.034	7.70	131	62	137.7	25.0	23.8	6.4	2.4	332	88	283	0.33	14.0	2.3	3.20	20	2	3.00	0.30	0.34	0.08	11.10	1.20	-
50 Percentile	266.6	0.022	7.50	60	56	36.4	23.0	20.0	5.6	1.6	238	64	138	0.11	12.0	1.9	2.60	9	1	2.00	0.30	0.23	0.05	7.70	0.90	-
25 Percentile	186.8	0.016	7.00	38	46	11.8	20.0	18.0	4.8	1.0	111	38	54	0.08	8.0	1.6	2.00	5	1	1.00	0.20	0.14	0.03	3.00	0.60	-
5 Percentile	93.9	0.008	6.20	11	35	4.2	17.0	15.3	3.6	0.7	73	31	14	0.05	4.0	1.3	1.40	3	1	1.00	0.13	0.07	0.02	1.45	0.38	-
No. of Data	36.0	36	37	24	36	25	38	38	37	36	27	27	37	15	36	17	17	12	11	31	7	37	6	30	17	0
Mean	336.9	0.028	7.33	84	54	113.0	23.4	21.2	5.6	1.8	329	84	249	0.31	10.8	1.9	3.15	13	1	1.97	0.29	0.24	0.05	7.60	0.93	-
Std. Deviation	241.8	0.020	0.55	66	12	164.7	4.8	4.9	1.3	1.0	358	65	332	0.49	4.6	0.5	1.92	10	1	1.05	0.16	0.14	0.03	4.73	0.48	-
Minimum	84.4	0.007	6.00	5	33	3.0	15.0	10.0	3.6	0.5	53	26	7	0.05	2.0	1.1	1.00	2	1	1.00	0.10	0.04	0.02	1.00	0.30	-
Maximum	1185.6	0.100	8.10	225	83	576.0	39.8	36.0	8.0	4.6	1575	264	1534	1.98	20.0	2.9	8.10	37	4	4.00	0.60	0.69	0.09	17.00	2.20	-

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 5818601 (Sg. Golok di Kg Jenob)																										
95 Percentile	-	-	7.80	150	60	111.7	20.1	25.2	4.8	4.2	305	105	245	0.54	18.0	2.8	5.04	-	-	5.00	-	0.47	0.04	13.00	1.00	-
75 Percentile	-	-	7.50	70	43	25.0	17.0	18.5	3.6	2.7	163	68	91	0.44	14.0	2.1	3.90	-	-	3.00	-	0.20	0.02	10.30	0.50	-
50 Percentile	-	-	7.10	30	38	10.7	15.0	14.0	3.2	1.5	101	55	46	0.31	12.0	1.7	3.30	-	-	2.00	-	0.14	0.02	8.50	0.30	-
25 Percentile	-	-	6.80	15	33	5.5	12.0	11.0	2.4	1.2	76	39	23	0.26	10.0	1.2	2.70	-	-	1.00	-	0.09	0.01	5.50	0.20	-
5 Percentile	-	-	6.23	5	24	1.9	8.5	9.0	2.0	0.7	57	20	10	0.21	4.0	0.7	1.60	-	-	1.00	-	0.04	0.01	1.00	0.10	-
No. of Data	-	-	79	78	79	73	79	79	79	77	79	79	79	3	77	69	69	-	-	77	0	68	5	65	59	0
Mean	-	-	7.11	49	40	25.3	14.8	15.4	3.1	1.9	133	58	75	0.36	11.4	1.7	3.32	-	-	2.25	-	0.18	0.02	7.85	0.47	-
Std. Deviation	-	-	0.49	45	17	43.5	3.8	5.3	1.0	1.1	83	33	77	0.18	4.2	0.7	1.16	-	-	1.00	-	0.16	0.01	3.61	0.63	-
Minimum	-	-	5.90	5	15	1.4	6.0	7.0	1.2	0.5	39	17	5	0.20	2.0	0.5	1.20	-	-	1.00	-	0.02	0.01	1.00	0.05	-
Maximum	-	-	8.00	200	150	247.0	26.0	36.0	6.4	6.6	460	256	350	0.56	20.0	3.5	8.80	-	-	6.00	-	0.97	0.04	17.00	4.70	-
Statistical Values for the Station 6019611 (Sg. Golok di Rantau Panjang)																										
95 Percentile	208.8	0.274	7.59	150	44	50.6	23.4	29.4	4.8	3.6	214	96	155	0.17	15.7	2.9	3.79	-	-	4.85	-	1.11	0.07	11.50	0.88	-
75 Percentile	56.0	0.074	7.03	100	39	27.1	16.0	20.5	3.6	3.0	142	65	80	0.17	12.0	1.9	3.08	-	-	3.00	-	0.35	0.06	10.53	0.55	-
50 Percentile	19.5	0.026	6.90	60	36	12.6	13.0	16.0	2.8	2.2	107	51	56	0.17	10.0	1.8	2.70	-	-	2.00	-	0.18	0.04	7.85	0.50	-
25 Percentile	12.1	0.016	6.55	30	31	7.2	9.2	14.8	2.4	1.7	66	29	21	0.17	10.0	1.5	2.03	-	-	2.00	-	0.09	0.02	6.50	0.30	-
5 Percentile	7.0	0.009	6.17	20	23	2.5	7.1	12.2	2.0	1.2	49	23	15	0.17	8.0	1.1	1.61	-	-	1.15	-	0.03	0.01	4.64	0.20	-
No. of Data	23.0	23	24	24	24	22	24	24	24	24	24	24	24	1	24	22	22	-	-	24	-	23	2	22	23	-
Mean	53.0	0.070	6.85	69	35	20.0	13.5	18.5	3.4	2.4	112	50	61	0.17	12.2	1.9	2.62	-	-	2.67	-	0.37	0.04	8.40	0.47	-
Std. Deviation	76.9	0.101	0.45	49	7	20.6	5.6	6.63	2.2	1.1	56	25	48	-	7.29	0.8	0.75	-	-	1.17	-	0.59	0.05	3.04	0.22	-
Minimum	5.7	0.007	6.10	5	23	1.7	6.0	10.0	2.0	1.1	44	17	4	0.17	8.0	0.6	1.50	-	-	1.00	-	0.03	0.01	3.50	0.20	-
Maximum	330.3	0.434	7.70	200	48	90.2	29.0	41.0	13.0	6.1	268	106	206	0.17	45.0	4.8	4.40	-	-	6.00	-	2.80	0.08	16.90	1.00	-
Statistical Values for the Station 2224632 (Sg. Kesang di Chin Chin)																										
95 Percentile	136.3	0.847	7.00	348	137	398.5	26.0	29.0	8.3	2.9	578	178	410	1.12	25.4	6.3	10.36	47	6	12.52	0.26	22.00	0.72	15.15	13.68	0.26
75 Percentile	41.0	0.255	6.60	150	95	121.8	21.0	22.0	6.4	1.9	234	104	130	0.35	16.1	4.8	6.80	26	4	9.00	0.15	7.70	0.42	8.50	4.60	0.11
50 Percentile	13.6	0.084	6.30	83	80	70.0	17.0	19.0	5.5	1.4	161	87	72	0.21	12.0	4.0	5.70	18	3	7.70	0.07	4.60	0.24	5.55	2.90	0.05
25 Percentile	2.0	0.012	6.00	60	71	33.0	13.0	16.0	4.6	1.0	122	69	44	0.11	9.5	3.5	4.60	12	2	6.80	0.06	3.60	0.18	3.93	2.00	0.04
5 Percentile	0.5	0.003	5.40	26	56	11.0	8.2	13.0	3.5	0.6	90	45	16	0.05	4.0	2.8	2.66	8	2	5.51	0.02	0.75	0.12	2.73	1.12	0.03
No. of Data	166.0	166	225	226	224	226	225	226	226	212	226	226	225	163	224	207	209	213	35	223	118	171	121	206	224	109
Mean	32.8	0.204	6.28	124	87	118.0	17.1	20.0	5.7	1.6	213	95	118	0.32	14.7	4.2	6.11	22	3	8.05	0.11	6.76	0.34	6.85	4.33	0.10
Std. Deviation	47.8	0.297	0.47	114	28	191.3	6.2	6.0	1.8	1.0	59	51	141	0.37	10.1	1.1	2.61	15	1	2.47	0.11	6.70	0.28	4.50	5.07	0.11
Minimum	0.2	0.001	4.80	10	49	2.4	1.5	5.0	2.0	0.5	59	29	5	0.02	1.4	2.1	0.90	2	2	0.10	0.01	0.10	0.03	0.12	0.10	0.01
Maximum	317.2	1.970	7.70	700	311	2100.0	46.0	59.0	20.0	8.5	1143	554	1025	2.50	80.0	8.5	19.00	99	8	21.70	0.64	40.00	2.04	37.40	45.00	0.82

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 2322613 (Sg. Melaka di Pantai Belimbing)																										
95 Percentile	11.7	0.034	6.80	350	170	464.9	26.3	29.8	8.8	3.0	887	169	672	1.02	35.7	7.1	13.65	41	3	13.65	0.28	25.00	0.58	18.60	20.60	0.35
75 Percentile	4.9	0.014	6.60	140	119	145.5	19.0	24.0	7.3	1.7	318	116	223	0.41	16.3	5.8	8.85	22	3	10.95	0.21	14.00	0.29	11.60	7.80	0.15
50 Percentile	1.8	0.005	6.38	80	100	71.9	16.0	21.0	6.6	1.3	186	94	91	0.23	12.8	5.3	6.95	15	2	9.10	0.16	6.10	0.20	8.90	4.00	0.10
25 Percentile	1.2	0.004	5.90	50	87	31.5	12.8	18.0	5.6	1.0	135	74	44	0.11	10.5	4.6	5.60	9	2	7.70	0.07	4.30	0.14	6.60	2.25	0.07
5 Percentile	0.7	0.002	5.36	30	71	6.0	9.2	16.0	4.3	0.5	98	45	19	0.06	7.8	3.8	3.94	5	2	5.55	0.02	1.04	0.11	3.48	1.20	0.02
No. of Data	23.0	23	132	131	131	132	132	132	132	116	131	131	132	89	131	127	128	126	34	131	71	89	106	129	131	57
Mean	3.3	0.009	6.21	114	106	145.1	16.7	21.6	6.5	1.5	288	102	185	0.35	15.6	5.3	7.67	18	3	9.47	0.16	9.74	0.27	9.66	6.74	0.14
Std. Deviation	3.4	0.010	0.49	102	32	259.8	6.3	5.2	1.5	1.0	286	58	270	0.37	9.4	1.1	3.70	12	4	3.04	0.10	7.98	0.24	4.64	7.56	0.13
Minimum	0.6	0.002	4.40	7	53	0.6	3.5	11.0	2.7	0.5	79	15	7	0.05	4.0	1.0	2.20	1	2	3.80	0.01	0.15	0.04	1.50	0.40	0.01
Maximum	12.7	0.036	7.00	700	233	2150.0	47.3	52.0	12.3	8.5	1774	424	1701	2.40	63.1	8.4	26.00	68	27	25.00	0.55	39.00	1.90	25.50	44.00	0.70
Statistical Values for the Station 2917601 (Sg. Langat di Kajang)																										
95 Percentile	29.0	0.076	7.30	265	218	612.0	57.2	55.0	19.0	2.7	1123	156	1075	2.84	24.0	7.9	17.25	85	19	14.39	0.40	13.00	1.95	19.00	20.25	0.34
75 Percentile	9.8	0.026	6.70	50	131	182.0	34.6	35.6	12.4	1.3	437	100	371	0.89	16.0	5.6	9.43	52	7	8.30	0.25	6.73	0.25	11.07	5.68	0.17
50 Percentile	5.3	0.014	6.40	21	99	71.1	26.2	25.0	8.8	1.0	251	78	176	0.37	16.0	4.4	6.95	32	3	6.00	0.20	2.60	0.20	7.20	3.00	0.10
25 Percentile	4.1	0.011	6.20	10	69	33.8	17.1	18.0	6.0	0.7	183	51	95	0.18	12.0	3.4	4.50	16	2	4.00	0.12	0.24	0.10	3.70	1.30	0.05
5 Percentile	2.2	0.006	6.00	5	39	5.3	10.0	10.0	2.8	0.5	60	30	18	0.05	8.0	2.1	2.30	7	1	1.49	0.07	0.06	0.09	1.17	0.30	0.02
No. of Data	16.0	16	179	16	16	16	15	16	16	14	16	16	16	16	16	16	16	16	14	16	16	16	2	16	15	13
Mean	8.4	0.022	6.53	59	107	151.6	29.2	28.4	9.6	1.1	373	83	291	0.80	15.3	4.8	7.71	38	6	6.68	0.21	4.37	0.40	8.19	4.99	0.13
Std. Deviation	54.0	0.048	0.64	165	17	45.3	5.3	8.7	3.0	1.3	74	47	46	0.56	8.3	1.8	1.38	11	-	2.76	0.04	1.29	0.06	3.05	1.60	0.03
Minimum	0.3	0.001	5.63	5	15	0.0	3.0	8.0	1.0	0.0	43	10	4	0.02	2.0	1.4	0.90	2	1	0.52	0.03	0.03	0.00	0.10	0.10	0.01
Maximum	54.6	0.144	8.83	600	295	1400.0	86.0	85.0	25.0	6.1	1844	261	1834	8.40	51.0	22.0	25.00	192	41	34.00	1.04	36.00	1.95	26.00	40.70	0.68
Statistical Values for the Station 3118645 (Sg. Lui di Kg. Lui)																										
95 Percentile		0.106	7.40	113	94	136.3	24.7	22.4	7.7	1.7	291	85	220	1.03	32.0	4.6	5.81	38	6	7.00	0.30	3.89	0.43	5.79	5.96	0.17
75 Percentile		0.036	6.95	40	51	30.0	17.4	13.9	3.8	1.1	124	61	68	0.18	20.0	3.2	4.00	14	1	3.00	0.14	1.80	0.18	2.11	1.90	0.05
50 Percentile		0.024	6.76	20	40	14.0	15.5	11.0	3.2	0.9	78	47	34	0.10	18.0	2.8	3.50	10	1	1.40	0.10	1.11	0.14	1.60	1.10	0.03
25 Percentile		0.017	6.58	15	36	9.2	13.9	10.0	2.8	0.7	64	35	18	0.06	16.0	2.3	3.10	6	1	0.90	0.08	0.30	0.13	1.30	0.60	0.02
5 Percentile		0.007	6.28	5	33	2.9	12.0	8.6	2.4	0.5	43	25	7	0.03	8.0	1.9	2.50	3	1	0.60	0.03	0.05	0.04	0.44	0.30	0.01
No. of Data		153	168	168	169	166	167	166	166	150	168	168	167	99	168	166	167	142	45	166	148	150	7	162	164	107
Mean		0.034	6.80	35	50	38.4	16.6	12.7	3.7	0.9	126	51	72	0.29	18.9	3.0	3.94	14	2	2.39	0.13	1.36	0.18	2.18	1.94	0.05
Std. Deviation	54.0	0.048	0.64	165	17	45.3	5.3	8.7	3.0	1.3	74	47	46	0.56	8.3	1.8	1.38	11	-	2.76	0.04	1.29	0.06	3.05	1.60	0.03
Minimum		0.005	5.74	0	30	0.0	3.4	4.0	1.6	0.0	28	6	4	0.02	0.1	1.5	1.80	1	1	0.08	0.01	0.03	0.00	0.20	0.10	0.01
Maximum		0.288	8.50	400	383	1170.0	63.0	48.5	15.0	2.7	1960	243	1850	7.20	64.0	14.0	22.00	184	31	17.90	1.04	8.84	0.53	16.30	30.90	0.32

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 3414621 (Sg. Selangor di Rantau Panjang)																										
95 Percentile	159.5	0.110	7.23	210	71	304.0	21.0	23.3	7.2	1.5	712	138	578	0.97	20.0	4.1	5.61	37	3	5.37	0.30	5.80	1.66	7.10	11.16	0.17
75 Percentile	78.0	0.054	6.80	120	55	130.0	16.0	16.0	5.2	1.0	272	69	205	0.42	16.0	3.2	3.88	20	2	4.00	0.12	3.90	0.40	5.30	5.70	0.11
50 Percentile	52.5	0.036	6.51	70	49	90.0	13.0	14.0	4.5	0.7	185	50	131	0.18	12.0	2.9	2.75	15	2	2.80	0.10	2.22	0.16	4.10	3.50	0.08
25 Percentile	32.5	0.022	6.30	30	42	54.6	10.0	12.0	3.6	0.6	139	36	87	0.09	10.0	2.5	2.20	12	1	2.19	0.09	0.52	0.12	3.00	2.00	0.06
5 Percentile	13.2	0.009	6.06	14	33	15.5	7.1	8.8	2.2	0.5	99	27	48	0.05	4.0	2.0	1.59	7	1	1.44	0.06	0.13	0.10	0.58	0.70	0.03
No. of Data	92.0	92	116	116	116	116	116	115	115	100	115	114	115	90	110	110	110	107	48	115	104	112	11	109	109	83
Mean	62.7	0.043	6.60	86	50	114.5	13.4	15.7	4.5	0.9	245	61	190	0.33	12.4	2.9	3.29	18	3	3.14	0.14	2.42	0.46	4.10	4.35	0.09
Std. Deviation	54.0	0.048	0.64	165	17	45.3	5.3	8.7	3.0	1.3	74	47	46	0.56	8.3	1.8	1.38	11	-	2.76	0.04	1.29	0.06	3.05	1.60	0.03
Minimum	6.8	0.005	5.85	5	27	6.4	3.0	4.7	1.3	0.3	1	8	14	0.02	2.0	0.1	1.00	3	1	0.37	0.01	0.06	0.10	0.20	0.10	0.01
Maximum	247.5	0.171	8.60	420	92	693.0	25.0	115.0	11.0	3.7	1172	414	1103	2.69	41.0	6.6	20.00	76	38	10.00	1.10	7.20	2.40	12.00	17.30	0.30
Statistical Values for the Station 3516622 (Sg. Selangor di Rasa)																										
95 Percentile	35.1	0.109	7.61	120	47	155.2	16.2	13.0	4.1	1.4	322	71	276	0.52	24.0	3.3	4.01	37	4	5.05	0.34	2.63	1.97	4.55	6.72	0.16
75 Percentile	15.7	0.049	7.00	60	37	32.0	12.4	10.0	2.8	0.9	112	42	80	0.18	16.0	2.8	3.40	16	1	2.29	0.20	1.40	0.88	1.70	2.15	0.05
50 Percentile	11.0	0.034	6.73	20	30	14.0	10.4	7.5	2.0	0.6	65	34	31	0.11	16.0	2.4	3.00	10	1	1.10	0.19	0.70	0.50	1.20	1.10	0.03
25 Percentile	8.8	0.027	6.51	10	26	7.7	9.1	6.0	1.6	0.5	47	25	16	0.07	12.0	2.2	2.50	6	1	0.70	0.11	0.25	0.20	0.90	0.60	0.01
5 Percentile	5.4	0.017	6.14	5	24	2.5	5.8	4.4	1.0	0.2	29	15	6	0.04	8.0	1.8	2.00	4	1	0.40	0.07	0.09	0.07	0.30	0.20	0.01
No. of Data	83.0	83	135	136	137	137	138	137	136	111	139	139	135	86	140	140	140	116	36	140	132	126	11	131	139	82
Mean	14.1	0.044	6.75	46	33	34.5	10.7	8.0	2.3	0.7	106	37	72	0.24	15.8	2.5	3.04	14	1	1.91	0.19	1.03	0.71	1.63	1.84	0.04
Std. Deviation	9.7	0.030	0.48	72	11	56.1	3.1	2.8	1.4	0.7	122	19	114	0.52	5.6	0.6	0.82	12	1	2.44	0.14	1.14	0.73	1.47	2.30	0.05
Minimum	3.0	0.009	4.80	5	17	0.3	1.6	0.0	0.0	0.0	18	5	5	0.02	8.0	1.3	1.40	2	1	0.10	0.02	0.03	0.00	0.10	0.10	0.01
Maximum	56.1	0.175	8.00	700	103	380.0	20.0	16.0	14.1	7.1	860	160	830	4.07	48.0	7.9	7.50	77	8	21.66	1.30	8.61	2.50	10.30	16.10	0.23
Statistical Values for the Station 3613601 (Sg. Bernam di Ulu Ibu Ampangan)																										
95 Percentile	-	-	7.18	300	46	258.9	17.2	13.0	3.4	1.6	356	89	240	0.81	24.0	3.5	3.48	48	13	5.00	0.29	3.21	2.01	3.49	7.68	0.11
75 Percentile	-	-	6.80	90	36	110.0	12.5	10.0	2.8	1.0	193	49	150	0.17	16.0	2.7	2.50	19	4	2.40	0.12	2.00	0.85	2.00	4.18	0.06
50 Percentile	-	-	6.50	70	29	58.0	9.2	8.1	2.3	0.7	123	37	84	0.11	14.0	2.4	2.10	14	1	1.87	0.10	1.52	0.65	1.55	2.20	0.05
25 Percentile	-	-	6.27	30	27	30.3	7.7	6.2	1.8	0.5	90	26	51	0.07	12.0	2.1	1.70	10	1	1.30	0.07	0.88	0.22	1.10	1.40	0.03
5 Percentile	-	-	5.78	10	24	8.2	5.8	5.0	1.3	0.3	57	18	30	0.04	5.0	1.8	1.10	7	1	0.80	0.04	0.10	0.04	0.66	0.60	0.01
No. of Data	-	-	151	151	151	150	151	148	146	106	152	152	153	110	147	146	145	136	25	152	114	146	8	142	146	100
Mean	-	-	6.52	80	33	86.3	10.3	8.5	2.4	0.8	156	41	114	0.22	14.5	2.5	2.21	17	3	2.24	0.12	1.59	0.75	1.75	3.30	0.05
Std. Deviation	54.0	0.048	0.64	165	17	45.3	5.3	8.7	3.0	1.3	74	47	46	0.56	8.3	1.8	1.38	11	-	2.76	0.04	1.29	0.06	3.05	1.60	0.03
Minimum	-	-	5.29	5	18	2.9	3.1	3.1	0.6	0.0	35	8	5	0.02	1.6	1.2	0.50	1	1	0.26	0.01	0.05	0.00	0.20	0.04	0.01
Maximum	-	-	8.80	400	258	530.0	28.0	28.0	9.7	2.3	708	145	595	3.35	51.0	7.0	6.10	74	15	13.50	0.48	9.50	2.56	8.70	25.90	0.27

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 3615612 (Sg. Bernam di Tanjung Malim)																										
95 Percentile	-	-	7.27	80	46	145.8	16.8	13.0	4.0	1.5	268	77	201	0.74	22.5	3.3	3.20	39	3	5.00	0.28	4.00	1.31	4.26	5.34	0.11
75 Percentile	-	-	6.81	40	36	31.0	12.0	11.0	3.2	0.9	98	42	57	0.18	16.0	2.4	2.50	14	1	2.10	0.12	2.30	0.51	2.70	1.60	0.05
50 Percentile	-	-	6.59	20	32	16.0	10.0	9.1	2.6	0.6	67	32	34	0.10	12.0	2.2	2.10	9	1	1.30	0.10	1.65	0.30	2.10	1.10	0.04
25 Percentile	-	-	6.40	10	28	9.0	8.5	7.1	2.1	0.5	50	26	17	0.07	11.0	2.0	1.80	6	1	1.00	0.09	0.98	0.15	1.60	0.60	0.02
5 Percentile	-	-	5.98	5	24	3.4	6.2	5.2	1.5	0.3	38	18	10	0.05	7.9	1.7	1.50	5	1	0.60	0.05	0.09	0.07	0.30	0.20	0.01
No. of Data	-	-	113	112	114	110	114	114	114	66	115	115	116	96	113	113	112	93	2	114	101	115	12	113	113	53
Mean	-	-	6.60	32	33	32.8	10.5	9.1	2.7	0.7	97	39	56	0.25	13.9	2.3	2.23	13	1	1.93	0.12	1.72	0.46	2.38	1.62	0.05
Std. Deviation	-	-	0.52	36	7	50.4	3.0	2.6	0.8	0.4	100	31	82	0.81	7.6	0.9	0.69	12	2	1.85	0.08	1.30	0.61	2.31	2.10	0.04
Minimum	-	-	3.40	3	19	0.4	2.3	3.6	1.0	0.1	28	6	4	0.03	2.0	1.1	1.20	1	1	0.00	0.01	0.02	0.00	0.10	0.01	0.01
Maximum	-	-	8.68	300	69	370.0	20.0	17.0	5.6	2.3	785	353	673	8.92	84.0	12.0	8.10	88	11	17.00	0.74	6.60	2.50	26.00	16.00	0.28
Statistical Values for the Station 3813611 (Sg. Bernam di Jam S.K.C)																										
95 Percentile	-	-	7.20	213	44	294.1	16.0	12.0	3.5	1.3	424	89	341	0.47	20.0	3.5	3.30	37	2	6.00	0.27	3.02	0.81	3.42	9.02	0.11
75 Percentile	-	-	6.80	83	34	123.5	12.0	9.6	2.8	0.9	217	52	170	0.15	16.0	2.7	2.60	19	1	2.11	0.10	2.00	0.30	2.00	4.90	0.07
50 Percentile	-	-	6.50	60	29	63.5	9.4	8.0	2.2	0.6	137	41	94	0.10	13.0	2.3	2.20	13	1	1.50	0.10	1.60	0.20	1.50	2.30	0.05
25 Percentile	-	-	6.30	30	26	29.0	7.9	6.4	1.8	0.5	97	29	57	0.06	12.0	2.1	1.80	9	1	1.10	0.08	0.82	0.13	1.10	1.30	0.03
5 Percentile	-	-	5.90	5	23	7.1	5.4	5.1	1.3	0.4	65	17	33	0.05	8.0	1.8	1.20	7	1	0.77	0.03	0.11	0.05	0.40	0.50	0.02
No. of Data	-	-	200	200	200	200	201	196	194	149	197	197	199	132	194	194	194	180	30	198	152	189	11	190	193	125
Mean	-	-	6.52	82	31	100.1	10.2	8.1	2.3	0.7	179	44	133	0.16	14.2	2.6	2.31	17	1	2.09	0.11	1.53	0.28	1.94	3.46	0.05
Std. Deviation	-	-	0.41	90	9	110.9	4.7	2.6	1.1	0.3	149	23	137	0.27	5.9	2.1	1.22	20	1	2.11	0.07	1.00	0.29	2.56	3.15	0.03
Minimum	-	-	5.23	5	18	3.8	2.3	1.6	0.8	0.1	8	4	11	0.01	2.0	1.2	0.60	4	1	0.27	0.01	0.04	0.00	0.10	0.10	0.01
Maximum	-	-	7.86	700	103	839.0	56.0	28.0	12.0	2.1	1487	149	1375	2.73	54.0	24.0	16.00	255	4	22.50	0.49	6.20	1.01	26.00	20.70	0.18
Statistical Values for the Station 3116630 (Sg. Klang di Jam Sulaiman)																										
95 Percentile	-	-	6.97	88	364	161.1	104.3	74.1	25.7	2.7	331	169	213	6.80	15.7	7.0	19.70	41	11	17.90	0.40	25.75	1.99	19.00	2.53	0.24
75 Percentile	-	-	6.90	55	293	53.5	90.5	72.0	24.5	2.4	230	164	73	6.80	13.5	6.4	19.00	36	10	12.50	0.35	22.25	1.40	18.50	0.50	0.24
50 Percentile	-	-	6.80	40	270	43.0	81.0	65.0	22.0	1.7	197	139	53	4.70	11.0	5.8	18.00	30	8	12.00	0.30	8.70	1.00	18.00	0.30	0.24
25 Percentile	-	-	6.75	35	262	20.5	68.0	63.5	22.0	1.7	186	132	36	3.20	11.0	5.5	16.00	23	8	11.50	0.30	1.60	0.70	14.00	0.25	0.24
5 Percentile	-	-	6.70	30	196	15.9	61.5	58.8	20.6	1.6	165	108	22	0.69	9.7	4.7	10.01	22	7	8.69	0.23	0.70	0.49	12.00	0.13	0.24
No. of Data	-	-	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Mean	-	-	6.83	50	276	58.6	81.1	66.9	23.0	2.0	222	143	80	4.31	12.2	5.8	16.61	30	9	12.53	0.31	11.67	1.11	16.29	0.76	0.24
Std. Deviation	-	-	0.11	24	65	15.0	17.41	57.0	20.0	1.6	70	25	86	2.82	9.2	4.3	4.14	8	2	3.71	0.07	11.78	0.61	3.09	1.17	-
Minimum	-	-	6.70	30	168	15.0	60.0	57.0	20.0	1.6	158	100	19	0.06	9.2	4.3	8.30	22	6	7.70	0.20	0.60	0.40	12.00	0.10	0.24
Maximum	-	-	7.00	100	387	204.0	110.0	75.0	26.0	2.8	370	170	270	6.80	16.0	7.0	20.00	42	11	20.00	0.40	26.00	2.20	19.00	3.40	0.24

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 3116633 (Sg. Gombak di Jalan Tun Razak)																										
95 Percentile	5.5	0.045	6.97	176	310	228.5	87.4	62.0	21.5	2.2	403	153	314	8.24	15.7	6.0	16.20	42	13	9.97	0.27	22.25	1.93	14.40	3.42	0.21
75 Percentile	4.7	0.038	6.85	100	174	116.0	63.5	52.5	17.5	2.0	344	133	248	4.80	14.5	5.1	12.00	34	10	9.25	0.20	19.00	1.15	12.50	0.75	0.21
50 Percentile	4.5	0.037	6.80	60	155	61.0	58.0	46.0	16.0	1.7	234	101	75	4.00	13.0	4.4	10.00	24	9	8.30	0.20	10.95	1.00	9.70	0.30	0.21
25 Percentile	3.7	0.031	6.75	50	144	39.0	43.5	44.5	14.5	1.5	190	96	58	2.60	12.0	4.2	9.70	20	7	5.45	0.20	3.13	0.80	9.15	0.30	0.21
5 Percentile	3.7	0.030	6.70	33	129	26.6	33.3	39.8	13.3	1.2	146	86	34	0.58	11.3	3.5	7.40	17	6	3.35	0.20	1.75	0.56	8.48	0.16	0.21
No. of Data	5.0	5	7	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	6	7	7	6	7	7	7	1
Mean	4.5	0.037	6.81	84	183	96.0	57.0	49.0	16.6	1.7	262	114	147	4.11	13.3	4.6	11.13	27	9	7.19	0.21	11.45	1.09	10.90	1.00	0.21
Std. Deviation	0.9	0.007	0.11	59	82	87.3	21.6	8.8	3.3	0.4	108	28	26	3	1.8	1.0	3.55	10	3	2.76	0.04	9.39	0.55	2.48	1.57	-
Minimum	3.7	0.030	6.70	30	125	26.0	30.0	38.0	13.0	1.2	127	84	26	0.07	11.0	3.2	6.50	16	5	2.60	0.20	1.60	0.50	8.30	0.10	0.21
Maximum	5.8	0.047	7.00	200	365	275.0	97.0	65.0	23.0	2.2	404	159	320	9.10	16.0	6.3	18.00	45	14	10.00	0.30	23.00	2.20	15.00	4.50	0.21
Statistical Values for the Station 3116634 (Sg. Batu di Sentul)																										
95 Percentile	-	-	7.20	91	416	114.9	134.0	81.7	29.7	2.7	266	191	120	9.20	14.1	8.0	22.70	44	9	17.00	0.50	31.25	2.46	22.50	1.97	0.29
75 Percentile	-	-	7.15	65	359	71.5	118.0	81.0	29.0	2.5	230	183	56	8.88	12.0	7.7	21.50	36	9	17.00	0.45	29.00	1.80	18.00	1.30	0.21
50 Percentile	-	-	7.00	60	341	22.0	100.0	80.0	28.0	2.2	220	169	28	7.80	10.0	7.1	20.00	30	8	15.00	0.40	18.95	1.50	15.00	0.60	0.10
25 Percentile	-	-	6.75	35	320	19.0	94.5	77.0	27.0	2.0	189	162	21	2.02	9.6	6.6	16.50	28	6	14.00	0.40	2.98	1.10	13.50	0.25	0.10
5 Percentile	-	-	6.56	30	289	16.6	91.6	72.9	24.6	1.9	186	147	15	0.28	8.9	6.1	14.00	26	4	9.99	0.33	0.33	0.93	7.33	0.13	0.09
No. of Data	-	-	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	6	7	7	7	3
Mean	-	-	6.93	56	344	48.0	108.0	78.6	27.7	2.2	218	170	48	5.74	11.0	7.1	19.00	33	7	14.67	0.41	16.67	1.56	15.27	0.83	0.17
Std. Deviation	-	-	0.27	25	49	45.1	18.0	3.7	2.1	0.3	35	18	45	4.28	2.2	0.8	3.65	8	2	3.03	0.07	14.96	0.62	5.88	0.80	0.12
Minimum	-	-	6.50	30	280	16.0	91.0	72.0	24.0	1.8	185	141	15	0.23	8.8	6.0	14.00	25	4	8.70	0.30	0.10	0.90	4.90	0.10	0.09
Maximum	-	-	7.20	100	433	117.0	140.0	82.0	30.0	2.7	282	192	141	9.30	15.0	8.0	23.00	46	9	17.00	0.50	32.00	2.70	24.00	2.00	0.31
Statistical Values for the Station 3117602 (Sg. Klang At Lorong Yap Kwan Seng)																										
95 Percentile	-	-	6.97	102	312	114.1	87.2	65.7	23.0	2.2	228	160	130	4.48	16.7	5.4	19.00	30	7	13.80	0.40	20.70	1.45	22.80	1.96	0.15
75 Percentile	-	-	6.85	55	262	26.5	76.0	64.0	22.5	2.1	170	136	39	3.20	15.0	4.9	18.00	26	7	9.95	0.40	14.35	0.95	20.00	0.60	0.15
50 Percentile	-	-	6.80	40	190	18.0	71.0	59.0	20.0	1.8	161	129	25	2.20	13.0	4.7	17.00	21	5	8.50	0.30	2.90	0.70	18.00	0.50	0.15
25 Percentile	-	-	6.70	30	185	14.0	68.0	58.0	20.0	1.7	148	122	17	0.78	12.0	4.2	13.50	20	5	7.75	0.30	1.75	0.53	14.00	0.10	0.15
5 Percentile	-	-	6.63	23	163	9.7	60.0	55.6	19.3	1.5	142	101	15	0.20	10.0	3.6	8.41	18	4	6.05	0.30	0.76	0.35	13.30	0.10	0.15
No. of Data	-	-	7	7	7	7	7	7	7	7	7	7	6	5	7	7	7	7	7	7	7	7	6	7	7	1
Mean	-	-	6.79	50	224	37.0	72.6	60.6	21.0	1.8	170	130	47	2.21	13.3	4.5	15.19	23	6	9.21	0.34	8.07	0.80	17.57	0.64	0.15
Std. Deviation	-	-	0.13	34	62	50.7	10.7	4.2	1.6	0.3	140	23	56	2	2.6	0.7	4.40	5	1.13	3.04	0.05	8.90	0.46	4.08	0.85	-
Minimum	-	-	6.60	20	155	8.7	57.0	55.0	19.0	1.5	140	93	14	0.05	9.2	3.4	7.30	17	4	5.60	0.30	0.40	0.30	13.00	0.10	0.15
Maximum	-	-	7.00	120	331	151.0	92.0	66.0	23.0	2.2	252	169	159	4.80	17.0	5.5	19.00	30	7	15.00	0.40	21.00	1.60	24.00	2.50	0.15

Table B1: Statistical Summary of Pollutant Concentration Data at JPS Stations (from 1995 to 2007)

Parameter	Flow (m^3/s)	Sp. Flow ($m^3/s.km^2$)	pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Statistical Values for the Station 3217601 (Sg. Gombak Ibu Bekalan Km 11 Gombak. This station is shifted from Sg. Gombak at Damsite)																										
95 Percentile	-	-	7.07	246	129	268.9	50.4	33.7	10.3	2.1	458	90	400	1.64	18.0	4.0	8.86	30	6	6.74	0.28	9.55	0.40	7.57	4.89	0.16
75 Percentile	-	-	6.95	120	83	170.5	27.0	26.0	8.4	2.1	253	78	177	1.40	18.0	3.6	6.65	17	4	2.95	0.20	8.40	0.40	5.60	2.25	0.16
50 Percentile	-	-	6.90	80	75	127.0	24.0	25.0	7.4	1.4	175	70	93	1.10	15.0	3.2	5.60	11	2	2.50	0.20	5.40	0.40	4.20	1.30	0.16
25 Percentile	-	-	6.80	80	71	56.5	22.5	23.0	7.0	1.3	147	64	77	0.89	15.0	2.8	5.15	10	2	2.35	0.13	3.15	0.33	3.90	0.80	0.15
5 Percentile	-	-	6.80	45	66	51.5	19.9	21.3	6.1	1.1	121	51	49	0.58	14.3	2.5	4.13	10	2	0.76	0.10	0.98	0.15	1.66	0.31	0.15
No. of Data	-	-	7	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7	6	6	4	7	7	2
Mean	-	-	6.90	116	85	134.0	28.9	25.9	7.8	1.6	232	70	162	1.12	16.1	3.2	6.10	16	3	3.07	0.18	5.45	0.33	4.59	1.89	0.16
Std. Deviation	-	-	0.12	87	29	93.0	14.0	5.3	1.7	0.4	146	15	155	0.46	1.8	0.6	1.88	9	2	2.50	0.08	3.72	0.15	2.30	1.91	0.01
Minimum	-	-	6.80	30	65	50.0	19.0	21.0	5.7	1.1	113	47	40	0.50	14.0	2.4	3.80	10	2	0.10	0.10	0.30	0.10	0.70	0.10	0.15
Maximum	-	-	7.10	300	149	307.0	60.0	37.0	11.0	2.1	539	93	492	1.70	18.0	4.1	9.70	35	6	8.30	0.30	9.80	0.40	8.20	5.70	0.16
National Water Quality Standard (DOE Malaysia)																										
NWQS Classes			pH (unit)	Colour (Hazen)	Cond. (uS/cm)	Turb. (NTU)	Alka. (mg/L)	Hard. (mg/L)	Ca (mg/L)	Mg (mg/L)	TS (mg/L)	DS (mg/L)	SS (mg/L)	NH_3-N (mg/L)	Si (mg/L)	K (mg/L)	Na (mg/L)	COD (mg/L)	BOD (mg/L)	Cl^- (mg/L)	F^- (mg/L)	NO_3-N (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	Fe (mg/L)	Mn (mg/L)
Class I			.8 - 8.	-	1000	5.0	-	-	-	-	525	500	25	0.10	-	-	-	10	1	-	-	-	-	-	-	-
Class IIA			.5 - 9.	-	1000	50.0	-	-	-	0.1	1050	1000	50	0.30	-	-	-	25	3	200	-	-	0.10	-	0.30	-
Class IIB			.5 - 9.	-	-	50.0	-	-	-	-	50	-	50	0.30	-	-	-	25	3	-	-	-		-	-	-
Class III			.0 - 9	-	-	-	-	-	-	-	150	-	150	0.90	-	-	-	50	6	-	-	-	0.10	-	1.00	-
Class IV			.0 - 9	-	6000	-	-	-	-	-	4300	4000	300	2.70	-	-	3 SAR	100	12	79	-	-	-	-	1(leaf)	-
Class V			-	-	-	-	-	-	-	-	-	-	>300	>2.7	-	-	-	>100	>12	-	-	-	-	-		-
MOH Limit			.5 - 9.	-	-	1000.0	-	-	-	150.0	1500	1500	-	0.50	-	-	200.00	10	6	250	-	-	-	-	1.00	-

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