REPORT ON THE ASSESSMENT OF WATER QUALITY IN NORTHERN GUNUNG RARA (NGR) FOREST RESERVE (July 2015)

by

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INTRODUCTION

An environmental baseline sampling was carried out by Hydrology Unit of Forest Research Centre to characterize the water quality of 4 rivers, which drained thru the Northern Gunung Rara (NGR) Sustainable Forest Management project area from the 6th–10th July 2015. These rivers are Sg.Lanap, Sg. Kasuyan, Sg. Kuamut and Sg. Imbok. This assessment is part of the study component required for the Forest Management Plan for NGR project area.

LOCATION OF STUDY AREA

A total of 4 sampling points represent the project watershed and its sub-catchment areas which predominantly drain through the project site (Figure 1). These sampling points are labelled W1 to W4.

The partly undulating and dissected hilly terrain dominates the project area of which 8 rivers flow through or originated from the area (Figure 1). The largest portion (approximately 245.88 km^2) is **Sg. Kuamut** and its tributaries which flow southeastern before it flows to the northern parts of the project area (Table 1). The headwater of this river originated from the Maliau Basin catchment area and flows through the project area. **Sg. Imbok** is the second largest portion with approximately 196.03 km^2. The **Sg. Kuli** river (approximately 98.10 km^2) drains to the north-eastern parts. **Sg. Moritok** with approximately 44.16 km2 drains to the south part of NGR. The **Sg. Kasuyan** and its tributaries with approximately 41.56 km^2 drains most to the eastern part of the project area. **Sg. Lanap** which flows eastern and located at the base camp for the NGR FR with approximately 39.16 km^2. There are few small rivers namely **Sg. Napagon** (17.10 km2) and **Sg. Malibo** (12.34 km^2). All these rivers are tributaries for the Sg. Kuamut river catchment in NGR FR of which flows into the Kinabatangan river catchment in the south. Eventually, all the waters from these rivers drain to the Sulu Sea.

The chemical analyses and water quality classes for all parameters tested for the sampling points in the project area are listed in Table 2.

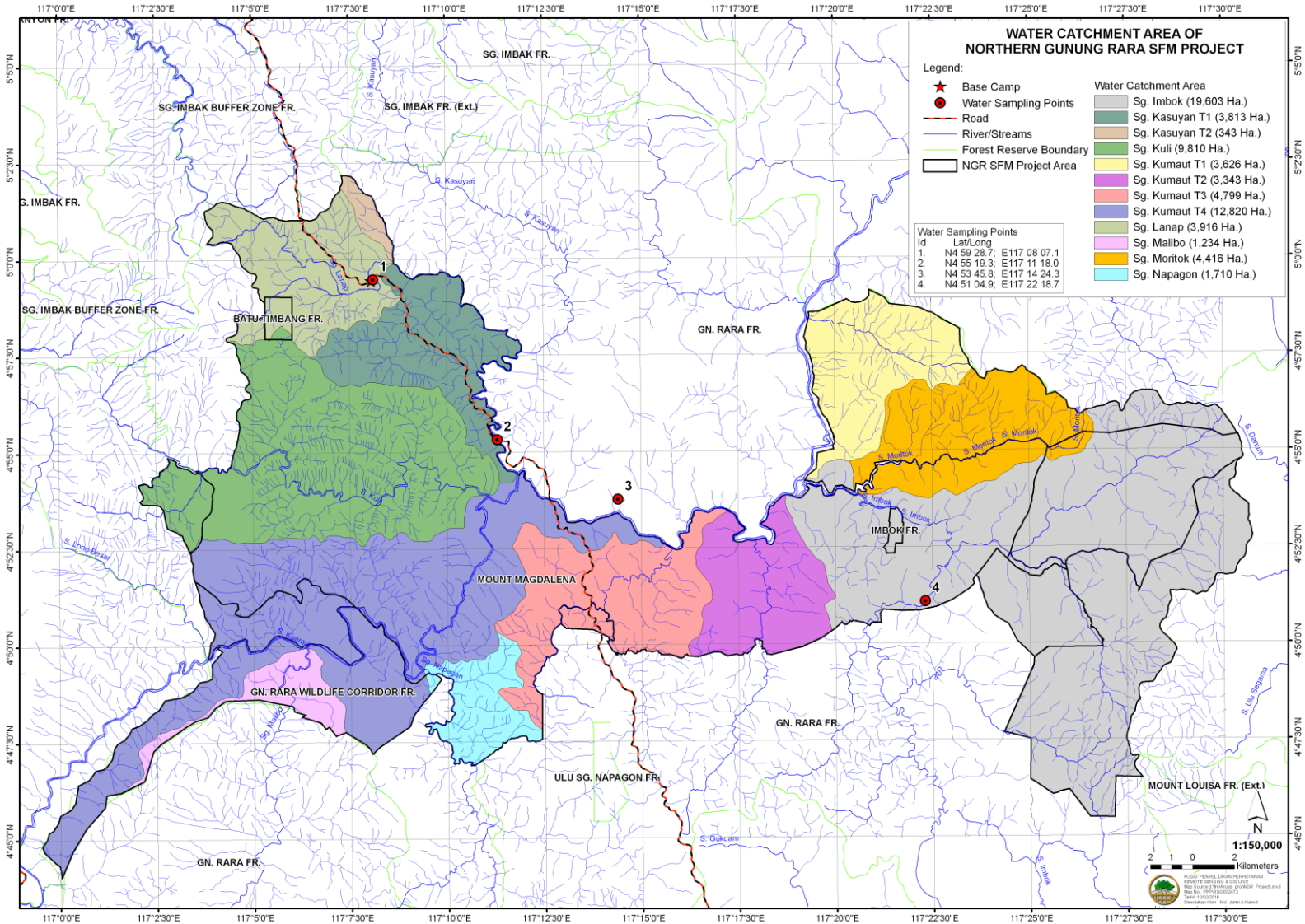

Figure 1. The location of water sampling points to assess river water quality in Northern Gunung Rara Forest Reserve

Table 1. Catchment area in relation to management zone in NGR FR.

No.	Water Catchment Area	NGR FR
1	Sg. Kuamut (T1 – T4)	24,588
2	Sg. Imbok	19,603
3	Sg. Kuli	9810
4	Sg. Moritok	4416
5	Sg. Kasuyan (T1 – T2)	4156
6	Sg. Lanap	3916
7	Sg. Napagon	1710
8	Sg. Malibo	1234
Total Area (Ha)		69,433

Table 2. The location of water quality sampling points in NGR FR (see Map).

Sampling Point	Location	GPS location		Date of Sampling	Surrounding Condition
		Latitude	Longitude		
1	Sg. Lanap	04°59’28. 7”	117°08’07.1”	08/07/2015	Secondary forest
2	Sg. Kasuyan	04°55’19.3”	117°11’18.0”	08/07/2015	Secondary forest
3	Sg. Kuamut	04°53’45.8”	117°14’24.3”	08/07/2015	Secondary forest
4	Sg. Imbok	04°51’04.9”	117°22’18.7”	09/07/2015	Secondary forest

RESULTS

Water Quality

The chemical analyses and water quality classes for all parameters tested for four sampling points in the project area are listed in Table 2.

Table 3. The results of chemical analyses and water quality classes for all parameter tested for sampling location W1-W4 in NGR project area . (BOD in mg/l), Chemical Oxygen Demand (COD in mg/l), Ammoniacal Nitrogen (AN in mg/l), Suspended Solid (SS in mg/l), Dissolved Oxygen (DO in mg/l), fecal coliform (MPN/100mL), total coliform (MPN/100mL), and oil & grease (mg/l).

Parameters Tested	Sampling Location				NWQSM *
	1	2	3	4	
Biological Oxygen Demand (BOD in mg/l)	<1.00	<1.00	<1.00	<1.00	Class I
Suspended Solid (SS in mg/l)	<5.00	9.00	11.00	9.00	Class I
Chemical Oxygen Demand (COD in mg/l)	<10.00	12.5	12.5	18.8	Class I
Ammoniacal-Nitrogen (as N_{3-} N in mg/l)	0.99	<0.20	<0.20	<0.20	Class III (W1) & Class I
Dissolved Oxygen (DO in mg/l)	8.13	7.94	7.82	8.36	Class I
Oil & Grease (mg/l)	<1.50	<1.50	<1.50	<1.50	NA
Total Coliform Count (MPN/100mL)	330	330	330	330	Class I
Fecal Coliform Count (MPN/100mL)	130	79	13	33	Class II (W1) & Class I
pH value	6.99	6.95	6.52	7.30	Class I

∗ National Water Quality Standards for Malaysia

pH Value

The narrow concentration of hydrogen ions between pH 6 to 9 indicates the typical suitability range for the existence of most biological life. Based on the NWQSM, the pH level for all sampling point is classified within the Class I waters quality range (Table 2).

Total Suspended Solid

TSS is an indicator of the amount of land disturbance within the catchment area and relates to the erosion that took place nearby sampling area or upstream. All sampling points registered TSS levels under Class I waters under the National Water Quality Standards for Malaysia (Table 2).

Biological Oxygen Demand (BOD)

This parameter is a measure to indicate the presence of organic waste in the river. All sampling points registered BOD levels within Class I under the Interim National Water Quality Standards for Malaysia (Table 2).

Chemical Oxygen Demand (COD)

This parameter is an indicator of organics in the water and usually used in association with BOD. All sampling points are classified under Class I (Table 2).

Dissolved Oxygen (DO)

DO is an essential indicator in supporting aquatic life. It measures the amount of oxygen (O_2) that is dissolved in the water (Table 2). All sampling points registered DO levels as Class I under the NWQSM.

Ammoniacal- Nitrogen (as N_3-N)

This parameter is an indicator of pollution from excessive usage of ammonia rich fertilizers and often used as a measure of the health of water in natural bodies such as rivers or lakes, or in manmade water reservoirs. One Sampling point sampling point W1 registered level under Class III and other sampling point registered AN levels as Class I under the NWQSM.

Oil and Grease

This parameter is aim to test whether there has been indiscriminate dumping of oil or oily waste into the water systems. All sampled showed levels of oil and grease below measurable ranges (<1.5 mg/l) and reflect near natural reference level (Table 2).

Total Coliform Count (TCC)

The term total coliform count (TCC) refers to a numerical count that generally includes both fecal and non-fecal coliforms, and the observation is used to highlight bacterial contamination of the waters. All sampling points registered TCC levels within Class I NWQSM (Table 2).

Fecal Coliform Count (FCC)

The term refers to a subset numerical count of total coliform, primarily comprising fecal coliforms bacteria that originates from the guts of warm-blooded animals and humans. The observation is used as an indicator of fecal matters. One sampling point's registered FCC levels within Class II, sampling point W1, while other sampling point within Class I NWQSM (Table 2).

Water Quality Index (WQI)

The results of water quality index for W1 to W4 sampling points are listed in Table 4.

Table 4. The water quality index (WQI) for W1 to W4 sampling points in NGR FR. (Note: DO % saturation values were calculated based on dissolved oxygen saturation factor of 8.26 mgL^{-1} at temperature 25° C).

Attributes	Sampling Point			
	W1	W2	W3	W4
DO%	96.09	98.38	94.63	101.17
BOD	1	1	1	1
COD	10	12.5	12.5	18.8
SS	5	9	11	9
pH	6.99	6.95	6.52	7.30
NH3-NL	0.99	0.2	0.2	0.2
SIDO	100	100	100	100
SIBOD	96	96	96	96
SICOD	86	82	82	74
SIAN	48	80	80	80
SISS	95	92	91	92
SIpH	100	100	97	98
WQI	88	92	92	91
CLASS	**II**	**I**	**II**	**II**
WQ STATUS	**Clean**	**Clean**	**Clean**	**Clean**

Synthesis of assessment

In general, the tests for water quality sampled from the various local rivers are characterised as clean water and indicated as Class I and Class II (Table 3). The pH for all rivers generally complied with the standards set for water under Class I of the NWQSM. The acceptable limit for river water pH is 6 to 9, thus the pH for all sampling points are in an acceptable limit. All rivers indicated no trace of oil and grease. There is no indication of excessive usage and harmful level of ammonium nitrate (indicator of extreme used of fertilizer), shown by Ammoniacal-Nitrogen (as N_{3}-N) result, in W2 – W4 sampling point which complied with the standards under Class I. Only W1 sampling point show results Under Class III. When present in levels above 0.1 mg/l N, sewage or industrial contamination may be indicated (Anonymous 2001).

For total suspended solid all sampling points generally complied with the standards set for water under Class I of the National Water Quality Standards for Malaysia, indicating impact of soil erosion is at the minimal level.

No indications of organic pollution in all sampling point as the BOD for all sampling point are under Class I of NQWSM. The amounts of COD in all sampling points are under Class I of NWQSM. For DO amounts all sampling points are under Class I of NQWSM. DO are essential for the aquatic life within the river water. A low DO level would threaten the aquatic community whereas only DO level below 2 mg/l is considered harmful for aquatic life.

Based on the total coliform counts (TCC) and fecal coliform count (FCC), the bacterial contamination levels in all sampling points are under Class I of NQWMS. Only W1 sampling point shows FCC under Class II.

All the river water was sampled on a clear weather and no event of rain. Based on the river water quality index, all sampling points are within Class I and II and categorized as clean river. Nevertheless, water that categorized as Class II required conventional treatment such as boiling before it can be used domestic consumption.

Recommendations

It is recommended that the management team carry out periodic inspection and monitoring at all the sampling points to prevent deterioration of the water quality, especially W1 sampling point at Sg Lanap. The finding of high level of ammonium nitrate loading into the river system required further investigation as the contamination may impact aquatic life. The management team also needs to install signage at all the sampling point to prevent visitors or passerby traversing the road from dumping waste into the watercourse.

REFERENCES

Anonymous (2001). Environmental Protection Agency, Parameters of Water Quality Interpretation and Standards, Johnstown Castle, Co. Wexford, Ireland.

Department Of Environment Malaysia (DOE), 2011. Malaysia Environmental Quality Report 2011. http://www.doe.gov.my/webportal/en/penerbitan-jas/

http://www.wepa-db.net/policies/law/malaysia/eq_surface.htm

APPENDIX I

METHODOLOGY

A. Sampling Method and Parameters Tested for Chemical Analyses

Grab sampling technique were used to collect water samples at proposed location as indicated in Map 1. All samples were preserved accordingly and sent to Chemsain Konsultant Sdn. Bhd (an accredited laboratory) for analysis within 24 hours. Parameters measured were according to the DOE Water Quality Index (WQI) with additional physical and microbiological analysis of the samples. The parameters tested were concentration of hydrogen ion (pH), Biological Oxygen Demand (BOD in mg/l), Chemical Oxygen Demand (COD in mg/l), Ammoniacal Nitrogen (AN in mg/l), Suspended Solid (SS in mg/l), Dissolved Oxygen (DO in mg/l), fecal coliform (FCC MPN/100mL), total coliform (TCC MPN/100mL), and oil & grease (mg/l).

B. Data Analysis

Water Quality Index (WQI) was proposed by the Department of Environment Malaysia and can be used to determine the water quality status and classify the rivers based on the National Water Quality Standards for Malaysia (NWQSM). This water monitoring programme was practised in Malaysia since 1978. The NWQSM provides a convenient means of summarizing water quality data for sampled river water by classifying them into various categories, such as Class I, II, III, IV or V based on Water Quality Index (WQI) and National Water Quality Standards for Malaysia (NWQSM). Subsequently, the water quality status can be grouped into broad classes such as clean, slightly polluted or polluted.

The formulas used in the calculation of WQI is as follows:

$$\mathbf{WQI = 0.22SIDO+0.19SIBOD+0.16SICOD+0.16SISS+0.15SIAN+0.12SI\ pH} \quad (1)$$

where, WQI = Water quality index; SIDO = Sub-index of DO; SIBOD = Sub-index of BOD; SICOD = Sub-index of COD; SIAN = Sub-index of AN; SISS = Sub-index of TSS; SIpH = Sub-index of pH.

Sub-index for DO (in % saturation):

$SIDO = 0$ 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:

$SIBOD = 100.4 - 4.23BOD$ for $BOD < 5$ (3a)

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

Sub-index for COD:

$SICOD = -1.33COD + 99.1$ for $COD < 20$ (4a)

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

Sub-index for AN:

SIAN $= 100.5 - 105AN$ 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:

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

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

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

Sub-index for pH:

SIpH $= 17.2 - 17.2pH + 5.02pH^2$ 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)

APPENDIX II

PHOTO.1. Sampling points W1, Sg. Lanap, sampling was done on a clear weather.

PHOTO.2. Sampling points W1, Sg. Lanap river.

PHOTO.3. Sampling point W2, Sg. Kasuyan, sampling was done on a clear weather.

PHOTO.4. Sampling point W3, Sg. Kuamut river view from the bridge.

PHOTO.5. Sampling points W4, Sg. Imbok, sampling was done on a clear weather.

PHOTO.6. NGR FR basecamp.

APPENDIX III
WATER QUALITY RESULTS

CHEMSAIN KONSULTANT SDN BHD *(130904-U)*
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Tel: +60-88-389671 / 381278 **Fax:** +60-88-381280
Email: laboratory.kk@chemsain.com

TEST REPORT

* NOT FOR ADVERTISEMENT PURPOSES *

Customer	:	Jabatan Perhutanan Sabah PPP Sepilok, PS 1407, 90715 Sandakan, Sabah.	Lab No. Type (No.) of Sample Date Received Date of Report	: : : :	CK/CL405/2294/15 River Water (4) 09th July 2015 27th July 2015
Attn	:	Ms. Noor Azmizah Bt. Andaman	Service Order	:	-

Lab No	2294-1	*Test Method*
Parameter(s)	Sg. Imbok Date: 08/07/15 Time: 1215 Hrs	
pH Value @ 25°C	7.30	*APHA 4500H+ B, 2012*
Biochemical Oxygen Demand in 5 days @ 20°C, mg/L	<1.00	*APHA 5210 B & 4500-O G, 2012*
Suspended Solids, mg/L	9.00	*APHA 2540 D, 2012*
Dissolved Oxygen, mg/L	8.36	*APHA 4500-O G, 2012*
Oil & Grease, mg/L	<1.50	*APHA 5520 B, 2012*
Chemical Oxygen Demand, mg/L	18.8	*APHA 5220 C, 2012*
Ammoniacal-Nitrogen (as NH_3-N), mg/L	<0.20	*APHA 4500-NH_3 C, 2012*

Lab No	2294-2	*Test Method*
Parameter(s)	Sg. Kuamut Date: 08/07/15 Time: 1345 Hrs	
pH Value @ 25°C	6.52	*APHA 4500H+ B, 2012*
Biochemical Oxygen Demand in 5 days @ 20°C, mg/L	<1.00	*APHA 5210 B & 4500-O G, 2012*
Suspended Solids, mg/L	11.0	*APHA 2540 D, 2012*
Dissolved Oxygen, mg/L	7.82	*APHA 4500-O G, 2012*
Oil & Grease, mg/L	<1.50	*APHA 5520 B, 2012*
Chemical Oxygen Demand, mg/L	12.5	*APHA 5220 C, 2012*
Ammoniacal-Nitrogen (as NH_3-N), mg/L	<0.20	*APHA 4500-NH_3 C, 2012*

CHEMSAIN KONSULTANT SDN BHD *(130904-U)*

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Email: laboratory.kk@chemsain.com

MS ISO/IEC 17025
TESTING
SAMM No. 238

TEST REPORT

* NOT FOR ADVERTISEMENT PURPOSES *

Lab No.: CK/CL405/2294/15

Lab No	2294-3	2294-4	*Test Method*
Parameter(s)	Sg. Kasuian Date: 08/07/15 Time: 1420 Hrs	Sg. Lanap Date: 08/07/15 Time: 1500 Hrs	
pH Value @ 25°C	6.95	6.99	*APHA 4500H + B, 2012*
Biochemical Oxygen Demand in 5 days @ 20°C, mg/L	<1.00	<1.00	*APHA 5210 B & 4500-O G, 2012*
Suspended Solids, mg/L	9.00	<5.00	*APHA 2540 D, 2012*
Dissolved Oxygen, mg/L	7.94	8.13	*APHA 4500-O G, 2012*
Oil & Grease, mg/L	<1.50	<1.50	*APHA 5520 B, 2012*
Chemical Oxygen Demand, mg/L	12.5	<10.0	*APHA 5220 C, 2012*
Ammoniacal-Nitrogen (as NH_3-N), mg/L	<0.20	0.99	*APHA 4500-NH_3 C, 2012*

Date of commencement of BOD_5 analysis: 09th July 2015

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ZAYDIE LEONG @ DINO OSMAN
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MS ISO/IEC 17025
TESTING
SAMM No. 238

TEST REPORT

* NOT FOR ADVERTISEMENT PURPOSES *

Customer	:	Jabatan Perhutanan Sabah PPP Sepilok, PS1407 90715 Sandakan, Sabah.	Lab No. Type (No.) of Sample Date Received Date of Report	: : : :	CK/ML405/2295/15 River Water (4) 09th July 2015 14th July 2015
Attn	:	Ms. Noor Azmizah Bt Andaman	Service Order	:	-

Lab No	2295-1	2295-2	*Test Method*
Parameter	Sg. Imbak Date: 08/07/15 Time: 1215 Hrs	Sg. Kuamut Date: 08/07/15 Time: 1345 Hrs	
Total Coliform Count MPN/100ml, 35±0.5°C/48 h	3.3×10^2	3.3×10^2	*APHA 9221B, 2012*
Fecal Coliform Count MPN/100ml, 44.5±0.2°C/24 h	33	13	*APHA 9221E, 2005*

Lab No	2295-3	2295-4	*Test Method*
Parameter	Sg. Kasuian Date: 08/07/15 Time: 1420 Hrs	Sg. Lanap Date: 08/07/15 Time: 1500 Hrs	
Total Coliform Count MPN/100ml, 35±0.5°C/48 h	3.3×10^2	3.3×10^2	*APHA 9221B, 2012*
Fecal Coliform Count MPN/100ml, 44.5±0.2°C/24 h	79	1.3×10^2	*APHA 9221E, 2005*

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APPENDIX III

i. National Water Quality Standards For Malaysia
ii. Water Classes And Uses
iii. DOE Water Quality Classification Based On Water Quality Index
iv. DOE Water Quality Index Classification
v. WQI Formula And Calculation

Source from: Department Of Environment Malaysia (DOE), 2011. Malaysia Environmental Quality Report 2011. http://www.doe.gov.my/webportal/en/penerbitan-jas/

APPENDIX III (i)

ANNEX

NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

PARAMETER	UNIT	CLASS				
		I	IIA/IIB	III#	IV	V
Al	mg/l	▲	-	(0.06)	0.5	▲
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr (IV)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	L
Pb	mg/l		0.05	0.02* (0.01)	5	E
Mn	mg/l		0.1	0.1	0.2	V
Hg	mg/l	N	0.001	0.004 (0.0001)	0.002	E
Ni	mg/l	A	0.05	0.9*	0.2	L
Se	mg/l	T	0.01	0.25 (0.04)	0.02	S
Ag	mg/l	U	0.05	0.0002	-	
Sn	mg/l	R	-	0.004	-	A
U	mg/l	A	-	-	-	B
Zn	mg/l	L	5	0.4*	2	O
B	mg/l		1	(3.4)	0.8	V
Cl	mg/l	L	200	-	80	E
Cl_2	mg/l	E	-	(0.02)	-	
CN	mg/l	V	0.02	0.06 (0.02)	-	
F	mg/l	E	1.5	10	1	
NO_2	mg/l	L	0.4	0.4 (0.03)	-	
NO_3	mg/l	S	7	-	5	IV
P	mg/l		0.2	0.1	-	
Silica	mg/l	O	50	-	-	
SO_4	mg/l	R	250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l	A	-	-	-	
Gross-α	Bq/l	B	0.1	-	-	
Gross-β	Bq/l	S	1	-	-	
Ra-226	Bq/l	E	< 0.1	-	-	
Sr-90	Bq/l	N	< 1	-	-	▼
CCE	µg/l	T	500	-	-	-
MBAS/BAS	µg/l		500	5000 (200)	-	-
O & G (Mineral)	µg/l		40; N	N	-	-
O & G (Emulsified Edible)	µg/l		7000; N	N	-	-
PCB	µg/l		0.1	6 (0.05)	-	-
Phenol	µg/l		10	-	-	-
Aldrin/Dieldrin	µg/l		0.02	0.2 (0.01)	-	-
BHC	µg/l		2	9 (0.1)	-	-
Chlordane	µg/l		0.08	2 (0.02)	-	-
t-DDT	µg/l		0.1	(1)	-	-
Endosulfan	µg/l		10	-	-	-
Heptachlor/Epoxide	µg/l		0.05	0.9 (0.06)	-	-
Lindane	µg/l		2	3 (0.4)	-	-
2,4-D	µg/l		70	450	-	-
2,4,5-T	µg/l		10	160	-	-
2,4,5-TP	µg/l	▼	4	850	-	-
Paraquat	µg/l		10	1800	-	-

Notes :

* = At hardness 50 mg/l $CaCO_3$
\# = Maximum (unbracketed) and 24-hour average (bracketed) concentrations
N = Free from visible film sheen, discolouration and deposits

APPENDIX III (i & ii)

NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes :

N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

WATER CLASSES AND USES

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

APPENDIX III (iii & iv)

DOE WATER QUALITY CLASSIFICATION BASED ON WATER QUALITY INDEX

SUB INDEX & WATER QUALITY INDEX	INDEX RANGE		
	CLEAN	SLIGHTLY POLLUTED	POLLUTED
Biochemical Oxygen Demand (BOD)	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen (NH_3-N)	92 - 100	71 - 91	0 - 70
Suspended Solids (SS)	76 - 100	70 - 75	0 - 69
Water Quality Index (WQI)	81 - 100	60 - 80	0 - 59

DOE WATER QUALITY INDEX CLASSIFICATION

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	> 5.0
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

APPENDIX III (v)

WQI FORMULA AND CALCULATION

FORMULA

WQI = (0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH)
where;

SIDO = Subindex DO (% saturation)
SIBOD = Subindex BOD
SICOD = Subindex COD
SIAN = Subindex NH_3-N
SISS = Subindex SS
SIpH = Subindex pH
$0 \leq WQI \leq 100$

BEST FIT EQUATIONS FOR THE ESTIMATION OF VARIOUS SUBINDEX VALUES

Subindex for DO (in % saturation)

SIDO = 0	for $x \leq 8$
SIDO = 100	for $x \geq 92$
$SIDO = -0.395 + 0.030x^2 - 0.00020x^3$	for $8 < x < 92$

Subindex for BOD

SIBOD = 100.4 - 4.23x	for $x \leq 5$
SIBOD = 108 * exp(-0.055x) - 0.1x	for $x > 5$

Subindex for COD

SICOD = -1.33x + 99.1	for $x \leq 20$
SICOD = 103 * exp(-0.0157x) - 0.04x	for $x > 20$

Subindex for NH_3-N

SIAN = 100.5 - 105x	for $x \leq 0.3$
SIAN = 94 * exp(-0.573x) - 5 * | x – 2 |	for $0.3 < x < 4$
SIAN = 0	for $x \geq 4$

Subindex for SS

SISS = 97.5 * exp(-0.00676x) + 0.05x	for $x \leq 100$
SISS = 71 * exp(-0.0061x) - 0.015x	for $100 < x < 1000$
SISS = 0	for $x \geq 1000$

Subindex for pH

$SIpH = 17.2 - 17.2x + 5.02x^2$	for $x < 5.5$
$SIpH = -242 + 95.5x - 6.67x^2$	for $5.5 \leq x < 7$
$SIpH = -181 + 82.4x - 6.05x^2$	for $7 \leq x < 8.75$
$SIpH = 536 - 77.0x + 2.76x^2$	for $x \geq 8.75$

Note:
* means multiply with