FINAL REPORT

PENYEDIAAN PELAN PENGURUSAN LEMBANGAN SUNGAI BERSEPADU SUNGAI MUDA,KEDAH/PULAU PINANG (SEKSYEN PEMODELAN & KUALITI AIR)

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ABSTRACT (120 words)

Not significant to the report

1. INTRODUCTION

Lembangan Sungai Muda terletak di Negeri Kedah Darul Aman. Keluasan kawasan tadahan bagi lembangan Sungai Muda ialah seluas 4,219 km persegi. Sungai Muda adalah sungai terpanjang didalam negeri Kedah iaitu lebih kurang 178 km. Jajaran Sungai Muda rnelalui beberapa daerah seperti Baling, Sik dan Kulim, sebeluin ianya mengalir keluar melalui daerah Kuala Sungai Muda ke Selat Melaka. Sebahagian daripada jajaran Sungai Muda menjadi sempadan di antara Negeri Kedah dan Pulau Pinang. Antara sungai-sungai utama di dalam Lembangan Sungai Muda adalah: Sungai Ketil, Sungai Lahar Endin, Sungai Tembus, Sungai Sedim dan Sungai Chepir, Sungai Sok, Sungai Teliang dan Sungai Baho. Bilangan penduduk yang mendiami lembangan Sungai Muda adalah seramai lebih kurang 201,234 orang yang kebanyakannya tertumpu di kawasan rendah dan dataran banjir. Komposisi gunatanah semasa lembangan Sungai Muda adalah terdiri daripada perbandaran dan infrastruktur (5%), perlanian (40%), hutan (50 %) dan lain-lain (5 %).

Di negeri Kedah sungai ini amat penting terutamanya setelah sebuah empangan dibina di punca sungai ini sekitar Hulu Muda di bawah Rancangan pengairan Muda yang dilancarkan sernasa Rancangan Malaysia Kedua. Rancangan pengairan ini bertanggungjawab membekalkan air secukupnya kepada petani-petani di sekitar kawasan ini yang dikenali sebagai jelapang padi negara. Kawasan penanaman padi sekitar Sungai Muda membekalkan kira-kira sejuta tan metrik beras pada setiap tahun atau 40% daripada keperluan beras Malaysia. Rancangan pengairan ini mernbolehkan penanaman padi di musim diamalkan dengan mernbekalkan air secukupnya ketika musim kemarau. Sungai Muda juga bertemu dengan Sungai Beris di lernbah Sungai Beris yang sernpit. Pengurusan Lembangan Sungai Bersepadu 'Integrated River Basin Managenrent (IRBM), adalah satu proses penyelarasan pemuliharaan, pengurusan dan pembangunan sumber air, tanah dan sumber alam yang berkaitan di antara sektor di dalam sesebuah lernbangan sungai bertujuan untuk meningkatkah faedah ekonorni dan sosial daripada surnber air tersebut di sarnping memelihara ekosistem alam sekitar secara saksama. Pelan IRBM adalah penting supaya segala aktiviti di dalam lembangan dapat diuruskan secara komprehensif. Faedah dan pendekatan ini perlu rnelibatkan semua pihak dengan peranan dan fungsi yang jelas, bersesuaian dengan perundangan dan akta-akta sedia ada untuk menguurus dan mengawal sesebuah lembangan sungai. Kaedah IRBM ini perlu diterapkan dan diamalkan oleh agensi-agensi dan pihak berkaitan yang berkepentingan di dalam lembangan tersebut. Di antara komponen-komponen utama IR.BM adalah perancangan, pencegahan, penguatkuasaan, pembaikan, peningkatan kesedaran, perundangan, pembentukan intitusi, dan kewangan.

2. RESEARCH METHODOLOGY

2.1 Methodology of Water Quality Primary Data

Collection and analysis of water samples for the determination of loading is in accordance with internationally-accepted protocols. Hence water samples collection, preservation and analytical methodologies is conducted following the World Health Organisation, 1987 and Standard Methods for the Examination of Water and Wastewater, American Public Health Association (APHA). The testing laboratory is an ISO 17025 accredited laboratory for all the parameters to be analysed. In-situ measurements of pH, temperature, conductivity, turbidity, dissolved oxygen and ammoniacal-nitrogen is conducted with a proper calibrated multi-parameter water quality probe.

2.2 Water Quality Assessment and Identification of Water Pollution Issues

The water quality status of Sg Muda is going to be assessed based on the current DOE network of water quality stations as part of the National River Water Quality Monitoring Programme from which long term temporal trends can be discerned. To assure temporal representativeness, the monitoring works encompassed both a low flow regime as well as high flow.

2.2.1 Computation of Water Quality Index

The ambient water quality standards are categorised into five classes based on their beneficiary uses as shown in Table 1.0. Six parameters namely dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids, (SS), ammoniacal nitrogen (AN) and pH are used to compute the WQI.

Among these parameters, DO carries maximum weightage of 22% and pH carries the minimum of 12% in the WQI equation. The WQI equation eventually consists of the sub-indices, which are calculated according to the best-fit relations given in Equations 1 to 7.
The formula used in the calculation of WQI is:

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

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 + 0.030DO2 – 0.00020DO3 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 + 5.02pH2	for pH < 5.5	(7a)
	= -242 + 95.5pH – 6.67pH2	for 5.5 < pH < 7	(7b)
	= -181 +82.4pH – 6.05pH2	for 7 < pH < 8.75	(7c)
	= 536 – 77.0pH + 2.76pH2	for pH > 8.75	(7d)

Note: Pollutant concentration is in mg/L for all parameters except pH.

Table 1.0: 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

Source: Environmental Quality Report 2015

The water quality of any river is considered to be suitable for a specific use as long as it is within the range specified for the designated classes. The classification is based on ranking where Class 1 is the best and Class V is the worst water quality.

The beneficial uses specified in NWQS put emphasis on the suitability of water for domestic water supply, fisheries and aquaculture, livestock drinking, recreation and agricultural use (Table 2.0).

Table 2.0: Classification and uses

No	**CLASS**	**USES**
1	Class I	Conservation of natural environment Water supply I - practically no treatment necessary Fishery I - very sensitive aquatic species
2	Class IIA	Water supply II - Conventional treatment required Fishery II - Sensitive aquatic species
3	Class IIB	Recreational use with body contact

4	Class III	Water supply III – extensive treatment required Fishery III - Common, of economic value and tolerant species, livestock drinking
5	Class IV	Irrigation
6	Class V	None of the above

2.3 Inventory of Pollution Sources

A comprehensive collection of point and non-point pollution sources within the basin forms the basis for the Sg Muda Basin Management. All the point pollution sources within the Sg Muda Basin can be categorised into several as shown in **Table 3.0**.

Table 3.0: Inventory Categories

No	Category	Sub-category
1.	Industry	• Food factory • Chemical factory • Wood factory • Cement factory • Metal factory • Machinery • Palm oil factory • Workshop • Electronic factory
2.	Sewage Treatment Plant (STP)	• Public • Private • Individual septic tank
3.	Commercial	• Hotel • Restaurant
4.	Institutional	• Education • Health • Religious • Military Camp
5.	Animal Farming	• Cattle • Chicken • Sheep • Goat
6.	Aquaculture	• Fish • Prawn
7.	Markets	• Wet market • Dry market

8.	Mining	• Quarry • Sand
9.	Others	• Water Treatment Plant (WTP)

2.4 Pollution Loading – Point Sources (PS)

The main wastewater generating premises of the different point sources identified were used for loading calculations of the sub basins. In order to calculate the loading contribution from many different point sources within the sub basins, representative samples were taken and loading calculations was used as a basis of extrapolation.

Pollution load estimation from point source will be determined based on a comprehensive inventory of point source compilation. The inventory of point sources also includes the discharge points of the sources as well as the entry point into the river system.

2.5 Non-Point Source Loading Estimation

Non-point pollution sources will be assessed on the basis of major landuse categories. Actual estimates of loading will be extrapolated to the corresponding acreage of the respective landuse to reflect loading contribution from NPS. NPS loading from selected landuse types will be determined during rainfall events. The base flow characteristics before rainfall event will determined at each of the location. Water samples at selected storm water drains will be collected before and incrementally during rainfall events and sent to the laboratory for analysis. The corresponding hydrological measurements will be also determined during the sampling procedures. The NPS loading determined will be then extrapolated to the corresponding total areas of the various landuse categories.

For each landuse categories, at least 2 set of samples will be taken during each rainfall event. Discharge measurements as well as in-situ measurements will be also taken. The Event Mean Concentration (EMC) method will be used in determining the loading. EMC represents the concentration of a specific pollutant contained in storm water runoff coming from a particular landuse within a basin area.

2.6 Point Sources (PS) and Non-Point Sources (NPS) Sampling Location

For the purpose of pollution loading estimation, 28 nos of sampling point have been selected for PS and NPS sampling. The location dedicated for NPS sampling will be on the basis of major landuse categories. The study areas of the landuse chosen as well as the corresponding areas will be estimated using the latest satellite imageries. The site chosen for each category of landuse such as developed area, agriculture, undeveloped area such as bare land and forest will be determined through site survey using the following criteria;

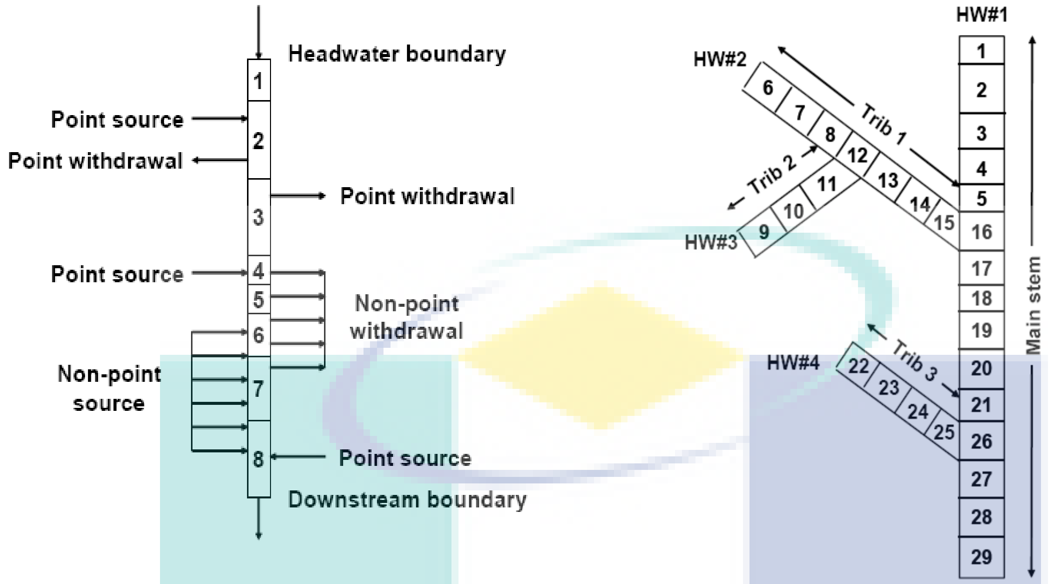
(i) Clearly represent the landuse category
(ii) Accessible and safe
(iii) Manageable size
(iv) All drain converged into one outlet

2.7 Water Quality Modelling

QUAL2K (or Q2K) is a river and stream water quality model. A river is represented in the QUAL2K model as a linked group of streams and tributary reaches **(Figure 4.1 a & b)** that consist of headwaters (the beginning of a stream reach) and sequential strings of completely mixed reactors, which are referred to as computational elements. The QUAL2K model calculates a flow and mass balance for each computational element. The non-point sources and withdrawals are modeled as line sources. As in **Figure 4.1 (c)**, the non-point source or withdrawal is demarcated by its starting and ending kilometre points. Its flow is then distributed to or from each element in a length-weighted fashion.

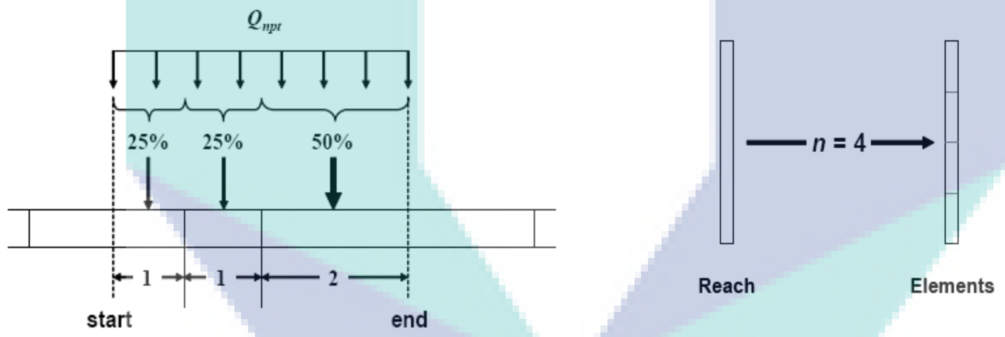
The forcing function used for estimating transport is the stream discharge, which is assumed to be constant. Stream velocity, cross-sectional area, and depth are computed from stream flow. The QUAL2K model performs dissolved oxygen balance by including major source and sink terms in the mass balance equation. QUAL2K is similar to QUAL2E in the following aspects:

a) **One-dimensional.** The channel is well-mixed vertically and laterally;
b) **Steady state hydraulics.** Non-uniform, steady flow is simulated;
c) **Diurnal heat budget.** The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale;
d) **Diurnal water-quality kinetics.** All water quality variables are simulated on a diurnal time scale;
e) **Heat and mass inputs.** Point and non-point loads and abstractions are simulated



(a) **QUAL2K Segmentation Scheme for a River with no**

(b) **QUAL2K Reach Representation**



(c) **Non-Point Source Flow Distribution**

(d) **Division of Reach Elements**

Figure 4.1: QUAL2K Stream Reach System (Chapra et al., 2006)

The QUAL2K framework includes the following new elements:

a) **Software Environment and Interface**. QUAL2K is implemented within the Microsoft Windows environment. It is programmed in the Windows macro language: Visual Basic for Applications (VBA). Excel is used as the graphical user interface;

b) **Model segmentation.** QUAL2E segments the system into river reaches comprised of equally spaced elements. In contrast, QUAL2K uses unequally-spaced reaches. In addition, multiple loadings and abstractions can be input to any reach;

c) **Carbonaceous BOD speciation.** QUAL2K uses two forms of carbonaceous BOD to represent organic carbon. These forms are a slowly oxidizing form (slow CBOD) and a rapidly oxidizing form (fast CBOD). In addition, non-living particulate organic matter (detritus) is simulated. These detritus materials are composed of particulate carbon, nitrogen and phosphorus in a fixed stoichiometry;

d) **Anoxia.** QUAL2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations;

e) **Sediment-water interactions.** Sediment-water fluxes of dissolved oxygen and nutrients are simulated internally rather than being prescribed. That is, oxygen (SOD) and nutrient fluxes are simulated as a function of settling particulate organic matter, reactions within the sediments, and the concentrations of soluble forms in the overlying waters;

f) **Bottom algae.** The model explicitly simulates attached bottom algae;

g) **Light extinction.** Light extinction is calculated as a function of algae, detritus and inorganic solids;

h) **pH.** Both alkalinity and total inorganic carbon are simulated. The river's pH is then simulated based on these two quantities;

i) **Pathogens.** A generic pathogen is simulated. Pathogen removal is determined as a function of temperature, light, and settling.

Although the above improvements generate more accurate river bio-kinetics and overall representation, the applicability of the model, in terms of data requirement becomes rather extensive. The speciation between *fast*-BOD and *slow*-BOD is a good example, where majority of current practices only measure BOD_5 or Ultimate BOD. For instances such as this, several technical assumptions have to be made in order for the model to correctly converge.

2.7.1 Modelling Approach and Scope

Several key factors need to be considered prior to the commencement of the modeling exercise, such as; the modelling assumptions, limitations, scenarios, delineation and data requirements. These factors are even more relevant to such a large basin as Sg Muda. The general QUAL2K model assumptions and limitations shall apply to this study which include;

i. Streams are well mixed and generally homogenous with an evenly distributed concentration pattern, vertically and laterally. This is coherent to 1-dimensional water quality modeling.

ii. Flow characteristics in QUAL2K will be simulated on a steady flow basis, with data collected from field surveys as well as authenticated/recognized literature values, from government agencies including but not limited to; the Department of Irrigation and Drainage (DID) and Meteorological Services Department.

iii. Water quality parameters to be simulated include Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5, uBOD represented as *fast*-BOD in QUAL2K), Ammoniacal Nitrogen (NH_3-N), Nitrate (NO_3^-), Inorganic Solids (Total Suspended Solids) and Phosphorous. The model is based on ultimate cBOD, so the 5-day measurement will be extrapolated to incur this value. By default, a decay rate k, of 0.23 shall be assumed for the ambient stream conditions (similar to QUAL2E). For water samples that have distinct variance in the k value (e.g., sewerage, leachate, etc.) adjustments will be made based on literary values. It should be noted that, besides practical considerations of time and expense, there may be other benefits from using the 5-day measurement with extrapolation, rather that performing a longer-term cBOD. Although extrapolation does introduce some error, the 5-day value has the advantage that it would tend to minimize possible nitrification effects which, even when inhibited, can begin to be exerted on longer time frames (Chapra et al., 2006).

3. LITERATURE REVIEW

Not significant to the report.

4. FINDINGS

4.1 Water Quality Results for River

The water quality status of Sg Muda and its sub –basins during both period of samplings, in this case; Low Flow and High Flow which was conducted on 25 Mei-1 June 2018 and 29 October to 5 November 2018 respectively. The results are shown in the following Table 4.0 and Table 5.0 while Figure 1.0 depicted the WQI during both flows. From the results obtained, the upper stream of Sg Muda is considered ‘Clean’ and registered NWQS Class II during both flows. However, Sg Muda is facing water quality degradation during low flow condition at the middle stream towards the downstream of the river. Sg Jerong as one of its tributaries located at the middle stream breached the NWQS Class II and was within Class III. At the downstream, severe degradation registering NWQS Class IV was observed during both flows condition.

Table 4.0: Water Quality Results During Low Flow Sampling

CODE	STATION ID	DO%	BOD	COD	SS	pH	NH3-N	WQI	CLASS	WQ STATUS
SMU1	Sg Muda Upstream	65.00	3.00	5.00	4.00	6.73	0.10	88	II	C
SMU2	Sg Muda Upstream 1	62.33	2.00	4.00	2.00	6.61	0.10	88	II	C
SSO3	Sg Sok Downstream	67.33	2.00	5.00	10.00	6.65	0.10	89	II	C
SSO2	Sg Sok Midstream	73.33	2.00	5.00	8.00	7.40	0.10	90	II	C
SSO1	Sg Sok Upstream	72.33	2.00	3.00	32.00	7.43	0.10	88	II	C
SMU3	Sg Muda Upstream 2	68.67	5.00	8.00	6.00	6.68	0.10	86	II	C
SMU4	Sg Muda Upstream 3	66.67	4.00	7.00	8.00	6.52	0.30	84	II	C
SBE2	Sg Beris Downstream	63.67	6.00	13.00	8.00	6.65	0.30	80	II	SP
SBE1	Sg Beris Upstream	74.00	3.00	5.00	4.00	6.57	0.20	89	II	C
SMU5	Sg Muda Upstream 4	66.00	5.00	16.00	6.00	6.49	0.10	84	II	C
SJE3	Sg Jenen Downstream	69.00	4.00	7.00	4.00	6.09	0.40	83	II	C
SJE2	Sg Jenen Midstream	65.00	6.00	14.00	212.00	6.14	0.90	66	III	SP
SJE1	Sg Jenen Upstream	63.33	4.00	13.00	248.00	5.99	1.60	58	III	P
SMU6	Sg Muda Midstream 1	66.33	3.00	6.00	18.00	6.35	0.20	85	II	C
SMU7	Sg Muda Midstream 2	67.00	3.00	5.00	130.00	5.27	0.20	73	III	SP
SCH3	Sg Chepir Downstream	67.67	4.00	7.00	22.00	5.26	0.30	79	II	SP
SCH2	Sg Chepir Midstream	65.33	3.00	7.00	24.00	5.94	0.30	82	II	C
SCH1	Sg Chepir Upstream	69.33	2.00	5.00	4.00	6.40	1.20	82	II	C
SSU2	Sg Sungkup Downstream	64.67	2.00	5.00	10.00	6.01	0.20	85	II	C
SSU1	Sg Sungkup Upstream	66.33	2.00	5.00	6.00	5.96	0.10	88	II	C
SMU8	Sg Muda Midstream 3	61.00	4.00	6.00	84.00	6.40	0.40	76	II	SP
SKT3	Sg Ketil Downstream	65.67	6.00	18.00	46.00	6.29	0.10	79	II	SP
SKT2	Sg Ketil Midstream	57.00	6.00	13.00	28.00	7.03	0.10	79	II	SP
SKT1	Sg Ketil Upstream	68.33	4.00	11.00	12.00	7.00	0.10	86	II	C
SLA2	Sg Selambau Downstream	55.67	3.00	5.00	26.00	6.07	0.20	80	II	SP
SLA1	Sg Selambau Upstream	39.33	4.00	6.00	4.00	6.27	0.10	78	II	SP

SSE3	Sg Sedim Downstream	63.33	4.00	8.00	67.00	6.38	0.50	77	II	SP
SSE2	Sg Sedim Midstream	62.67	5.00	14.00	86.00	6.22	0.70	72	III	SP
SSE1	Sg Sedim Upstream	74.67	5.00	12.00	4.00	6.48	0.10	87	II	C
SKA2	Sg Karangan Downstream	68.33	7.00	12.00	44.00	6.24	0.30	78	II	SP
SKA1	Sg Karangan Upstream	71.67	4.00	6.00	4.00	6.34	0.20	87	II	C
SMU9	Sg Muda Downstream 1	62.33	5.00	8.00	30.00	6.45	0.30	79	II	SP
SJE2	Sg Jerong Downstream	47.00	4.00	10.00	12.00	6.22	0.30	76	II	SP
SJE1	Sg Jerong Upstream	50.67	10.00	34.00	32.00	6.52	0.30	48	IV	P
SKO2	Sg Korok Downstream	59.67	7.00	13.00	24.00	6.38	0.10	79	II	SP
SKO1	Sg Korok Upstream	9.33	21.00	73.00	10.00	6.12	8.30	37	IV	P
SMU10	Sg Muda Downstream 2	58.00	4.00	6.00	46.00	6.43	0.30	78	II	SP
SMU11	Sg Muda Downstream 3	57.67	5.00	15.00	30.00	6.88	0.40	76	II	SP
SMU12	Sg Muda Downstream	49.00	421.00	1207.00	17.00	6.34	2.00	25	V	P

Table 5.0: Water Quality Results During High Flow Sampling

CODE	STATION ID	DO%	BOD	COD	SS	pH	NH3-N	WQI	CLASS	WQ STATUS
SMU1	Sg Muda Upstream	80.00	7.00	12.00	23.00	6.92	0.20	84	II	C
SMU2	Sg Muda Upstream 1	73.00	7.00	15.00	24.00	6.48	0.20	81	II	C
SSO3	Sg Sok Downstream	78.00	4.00	6.00	54.00	6.81	0.20	85	II	C
SSO2	Sg Sok Midstream	76.00	4.00	6.00	35.00	6.70	0.20	85	II	C
SSO1	Sg Sok Upstream	84.00	3.00	5.00	1.00	6.75	0.20	91	II	C
SMU3	Sg Muda Upstream 2	78.00	7.00	14.00	3.00	6.52	0.30	83	II	C
SMU4	Sg Muda Upstream 3	85.00	4.00	7.00	11.00	6.03	0.10	90	II	C
SBE2	Sg Beris Downstream	84.00	6.00	9.00	1.00	5.96	0.60	84	II	C
SBE1	Sg Beris Upstream	83.00	5.00	11.00	1.00	5.89	0.70	83	II	C
SMU5	Sg Muda Upstream 4	83.00	4.00	6.00	18.00	5.95	0.20	87	II	C
SJE3	Sg Jenen Downstream	84.00	2.00	5.00	27.00	6.11	0.40	86	II	C
SJE2	Sg Jenen Midstream	86.00	3.00	5.00	38.00	6.00	0.50	85	II	C
SJE1	Sg Jenen Upstream	82.00	3.00	5.00	44.00	5.92	0.50	84	II	C
SMU6	Sg Muda Midstream 1	84.00	4.00	7.00	1.00	6.17	0.20	89	II	C
SMU7	Sg Muda Midstream 2	81.00	6.00	13.00	20.00	6.22	0.20	85	II	C
SCH3	Sg Chepir Downstream	82.00	5.00	7.00	19.00	5.86	0.30	84	II	C
SCH2	Sg Chepir Midstream	85.00	4.00	7.00	16.00	6.00	0.30	86	II	C
SCH1	Sg Chepir Upstream	87.00	4.00	8.00	5.00	6.09	0.10	91	II	C
SSU2	Sg Sungkup Downstream	72.00	2.00	4.00	6.00	5.93	0.20	88	II	C
SSU1	Sg Sungkup Upstream	88.00	3.00	5.00	1.00	5.61	0.10	92	II	C
SMU8	Sg Muda Midstream 3	80.00	5.00	10.00	39.00	5.85	0.30	82	II	C
SKT3	Sg Ketil Downstream	74.00	6.00	9.00	55.00	6.36	0.30	80	II	SP
SKT2	Sg Ketil Midstream	84.00	4.00	6.00	33.00	6.56	0.20	88	II	C
SKT1	Sg Ketil Upstream	76.00	3.00	5.00	63.00	6.71	0.20	85	II	C
SLA2	Sg Selambau Downstream	69.00	2.00	4.00	13.00	6.11	0.20	87	II	C

SLA1	Sg Selambau Upstream	65.00	4.00	9.00	14.00	6.14	0.20	83	II	C
SSE3	Sg Sedim Downstream	61.00	5.00	10.00	38.00	5.77	0.60	75	III	SP
SSE2	Sg Sedim Midstream	70.00	3.00	5.00	49.00	6.09	0.60	80	II	SP
SSE1	Sg Sedim Upstream	86.00	3.00	5.00	1.00	6.64	0.20	91	II	C
SKA2	Sg Karangan Downstream	65.00	8.00	17.00	1.00	5.96	0.70	76	II	SP
SKA1	Sg Karangan Upstream	67.00	4.00	6.00	23.00	5.85	0.40	80	II	SP
SMU9	Sg Muda Downstream 1	80.00	7.00	14.00	42.00	6.22	0.20	81	II	SP
SJE2	Sg Jerong Downstream	45.00	4.00	6.00	31.00	6.14	0.20	75	III	SP
SJE1	Sg Jerong Upstream	52.00	7.00	10.00	22.00	6.14	0.30	47	IV	P
SKO2	Sg Korok Downstream	16.00	17.00	46.00	59.00	6.42	5.50	39	IV	P
SKO1	Sg Korok Upstream	39.00	7.00	15.00	33.00	5.87	0.70	65	III	SP
SMU10	Sg Muda Downstream 2	77.00	5.00	9.00	3.00	6.29	0.20	87	II	C
SMU11	Sg Muda Downstream 3	75.00	3.00	6.00	36.00	6.49	0.10	87	II	C
SMU12	Sg Muda Downstream	76.00	6.00	12.00	22.00	6.37	0.20	84	II	C

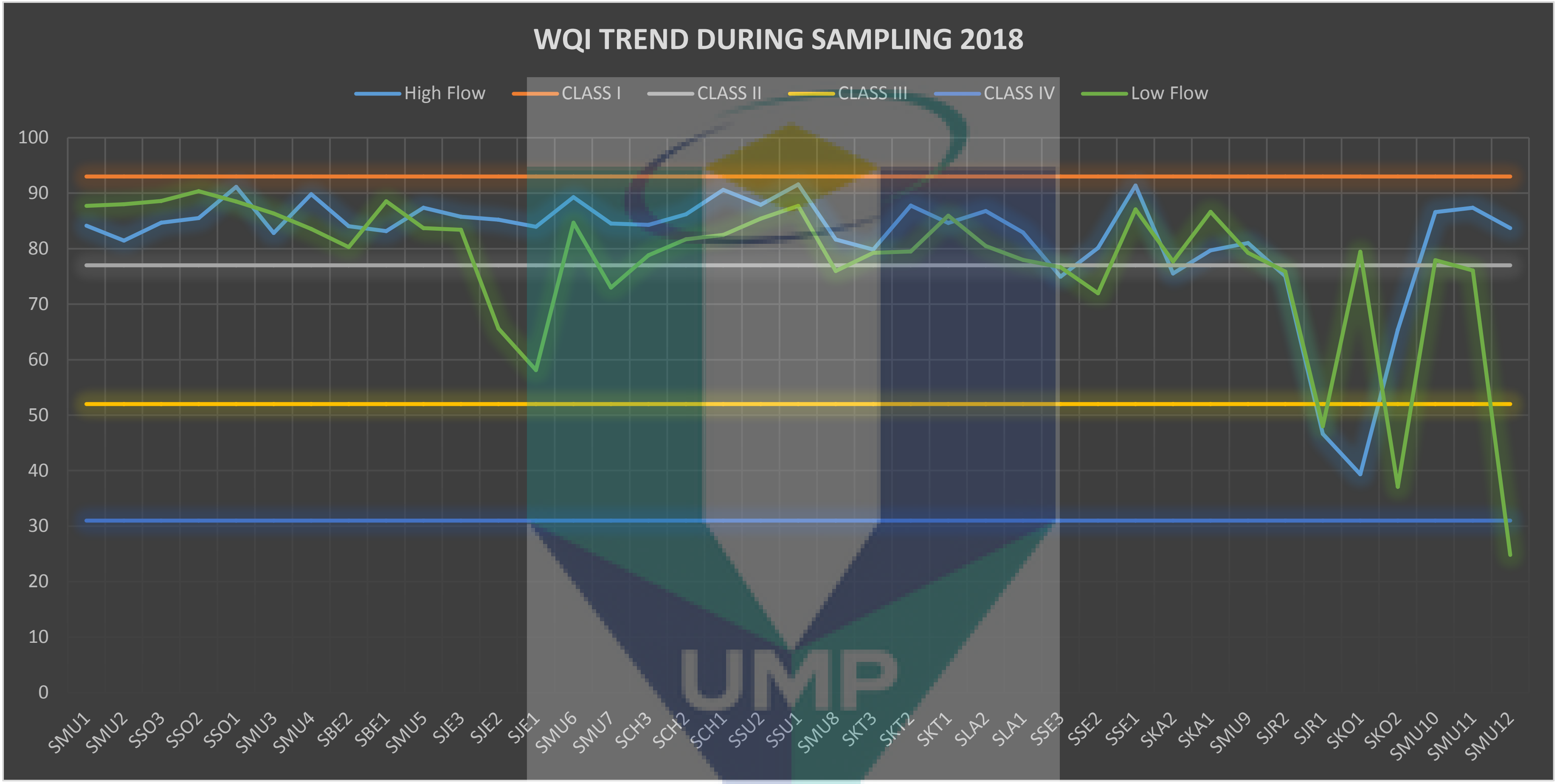


Figure 1.0: WQI During Low Flow and High Flow of the Current Study

4.2 Pollution Loading From Point Sources

Loading from point sources were then calculated for the whole of Sg Muda Basin. Table 6.0 to 9.0 show the loading results based on four parameters; BOD, COD, TSS and NH_3N.

Table 6.0: BOD Loading

Main Category	Sub-Category	Mainstream Loading (kg/day)	Sok Loading (kg/day)	Beris Loading (kg/day)	Sedim Loading (kg/day)	Chepir Loading (kg/day)	Ketil Loading (kg/day)	Karangan Loading (kg/day)	Selambau Loading (kg/day)	Jeneri Loading (kg/day)	Sungkup Loading (kg/day)	Jerong Loading (kg/day)	Korok Loading (kg/day)
INDUSTRY	Industry 1	779.6736			64.9728			64.9728					
	Industry 2	266.1984			532.3968			798.5952					
	Industry 3												
	Industry 4	655.776					43.7184						
	Industry 5	1.65888				0.10368		0.10368					
	Industry 6	77.76				38.88							
	Industry 7	52766.21			6595.776	3297.888	13191.55	8244.72					
SEWAGE	S1												
	S2												
	S3												
COMMERCIAL	C1	31674.24			87713.28		360599						
	C2												
	C3												
	C4												
ANIMAL HUSBANDRY	AH1	428.1984			142.7328			142.7328					
	AH2									290.6496			
	AH3	6493.133							927.5904	1855.181			
	AH4	941.76							941.76	941.76			
	AH5								941.76				
MINE & QUARRY	MQ1	226.368				169.776	113.184		0	113.184			
	MQ2												
MARKET	M1	14686.27					4895.424						

Table 7.0: COD Loading

Main Category	Sub-Category	Mainstream Loading (kg/day)	Sok Loading (kg/day)	Beris Loading (kg/day)	Sedim Loading (kg/day)	Chepir Loading (kg/day)	Ketil Loading (kg/day)	Karangan Loading (kg/day)	Selambau Loading (kg/day)	Jeneri Loading (kg/day)	Sungkup Loading (kg/day)	Jerong Loading (kg/day)	Korok Loading (kg/day)
INDUSTRY	Industry 1	2670.797			222.5664			222.5664					
	Industry 2	667.1808			1334.362			2001.542					
	Industry 3												
	Industry 4												
	Industry 5	4.97664				0.31104		0.31104					
	Industry 6	388.8				194.4							
	Industry 7	149935.1			18741.89	9370.944	37483.78	23427.36					
SEWAGE	S1												
	S2												
	S3												
COMMERCIAL	C1	77455.87			214493.2		881805.3						
	C2												
	C3												
	C4												
ANIMAL HUSBANDRY	AH1	1218.24			406.08			406.08					
	AH2									835.6176			
	AH3	18446.4							2635.2	5270.4			
	AH4	2933.28							2933.28	2933.28			
	AH5								2933.28				
MINE & QUARRY	MQ1	565.92				424.44	282.96			282.96			
	MQ2												
MARKET	M1	29393.28					9797.76						

Table 8.0: TSS Loading

Main Category	Sub-Category	Mainstream Loading (kg/day)	Sok Loading (kg/day)	Beris Loading (kg/day)	Sedim Loading (kg/day)	Chepir Loading (kg/day)	Ketil Loading (kg/day)	Karangan Loading (kg/day)	Selambau Loading (kg/day)	Jeneri Loading (kg/day)	Sungkup Loading (kg/day)	Jerong Loading (kg/day)	Korok Loading (kg/day)
INDUSTRY	Industry 1	1575.936			131.328			131.328					
	Industry 2	202.176			404.352			606.528					
	Industry 3												
	Industry 4	1126.224					75.0816						
	Industry 5	1.10592				0.06912		0.06912					
	Industry 6	3110.4				1555.2		0					
	Industry 7	19464.19			2433.024	1216.512	4866.048	3041.28					
SEWAGE	S1												
	S2												
	S3												
COMMERCIAL	C1	16870.46			46718.21		192063.7						
	C2												
	C3												
	C4												
ANIMAL HUSBANDRY	AH1	101.088			33.696			33.696					
	AH2									1326.089			
	AH3	11805.7							1686.528	3373.056			
	AH4	1468.8							1468.8	1468.8			
	AH5								1468.8				
MINE & QUARRY	MQ1	8036.064				6027.048	4018.032			4018.032			
	MQ2												
MARKET	M1	4572.288					1524.096						

Table 9.0: NH_3-N Loading

Main Category	Sub-Category	Mainstream Loading (kg/day)	Sok Loading (kg/day)	Beris Loading (kg/day)	Sedim Loading (kg/day)	Chepir Loading (kg/day)	Ketil Loading (kg/day)	Karangan Loading (kg/day)	Selambau Loading (kg/day)	Jeneri Loading (kg/day)	Sungkup Loading (kg/day)	Jerong Loading (kg/day)	Korok Loading (kg/day)
INDUSTRY	Industry 1	23			1.93536			1.93536					
	Industry 2	125			250.9004			376.3506					
	Industry 3	0											
	Industry 4	150					9.9792						
	Industry 5	0.080179				0.005011		0.005011					
	Industry 6	6.9984				3.4992							
	Industry 7	45.6192			5.7024	2.8512	11.4048	7.128					
SEWAGE	S1												
	S2												
	S3												
COMMERCIAL	C1	797.472			2208.384		9078.912						
	C2												
	C3												
	C4												
ANIMAL HUSBANDRY	AH1	65.8368			21.9456			21.9456					
	AH2									386.9273			
	AH3	3379.38							482.7686	965.5373			
	AH4	237.6							237.6	237.6			
	AH5								237.6				
MINE & QUARRY	MQ1	33.9552				25.4664	16.9776			16.9776			
	MQ2												
MARKET	M1	1596.672					532.224						

4.3 Water Quality Modelling Results

The following sub chapters depicted the modelling results of Sg Muda discussion. Several scenarios were simulated in this study;

1) Baseline Low Flow Scenario (Scenario 1)
2) Baseline High Flow Scenario (Scenario 2)
3) Low Flow Scenario LF7Q5, LF7Q10 LF7Q20 (Scenario 3)

4.3.1 Scenario Simulation of Low Flow and High Flow of Sg Muda (Scenario 1 and Scenario 2)

The simulation of scenarios 1 and 2 concentration was pertinent in the determination of the Waste Assimilative Capacity (WAC) relative to NWQS Class II for the Sg Muda and flow condition.

4.3.1.1Sg Muda Mainstream - Concentration and Loading Simulation

The Dissolved Oxygen (DO) levels of Sg Muda mainstream during both scenarios were well within Class II throughout the river (Figure 2.0). As shown in Figure 3.0, the BOD concentration during Scenario 1 was well within Class II until the mid-stream however exceeded the NWQS Class II threshold towards the river mouth. Meanwhile the BOD concentration for Scenario 2 was within NWQS Class III throughout the river with subsiding pattern towards the river mouth. In terms of BOD loading, the loading during Scenario 1 was well within the Sg Muda carrying capacity of Class II from upstream to mid-stream and started to breach the Class II threshold towards the river mouth. For Scenario 2, the BOD loading breached the Class II carrying capacity of Sg Muda throughout the river (Figure 3.0). Basically, Sg Muda mainstream is facing contamination of NH_3-N throughout the river during Scenario 1; the NH_3-N concentration exceeded the NWQS Class II and was well within Class III however the levels at the most upstream was still within Class II. However during Scenario 2, the NH_3-N concentration was well within NWQS Class II however breached the Class II threshold at about KM 40 towards the river mouth (Figure 4.0). In terms of NH_3N loading, both scenarios demonstrated a violation of Class II Sg Muda river carrying capacity throughout the river.

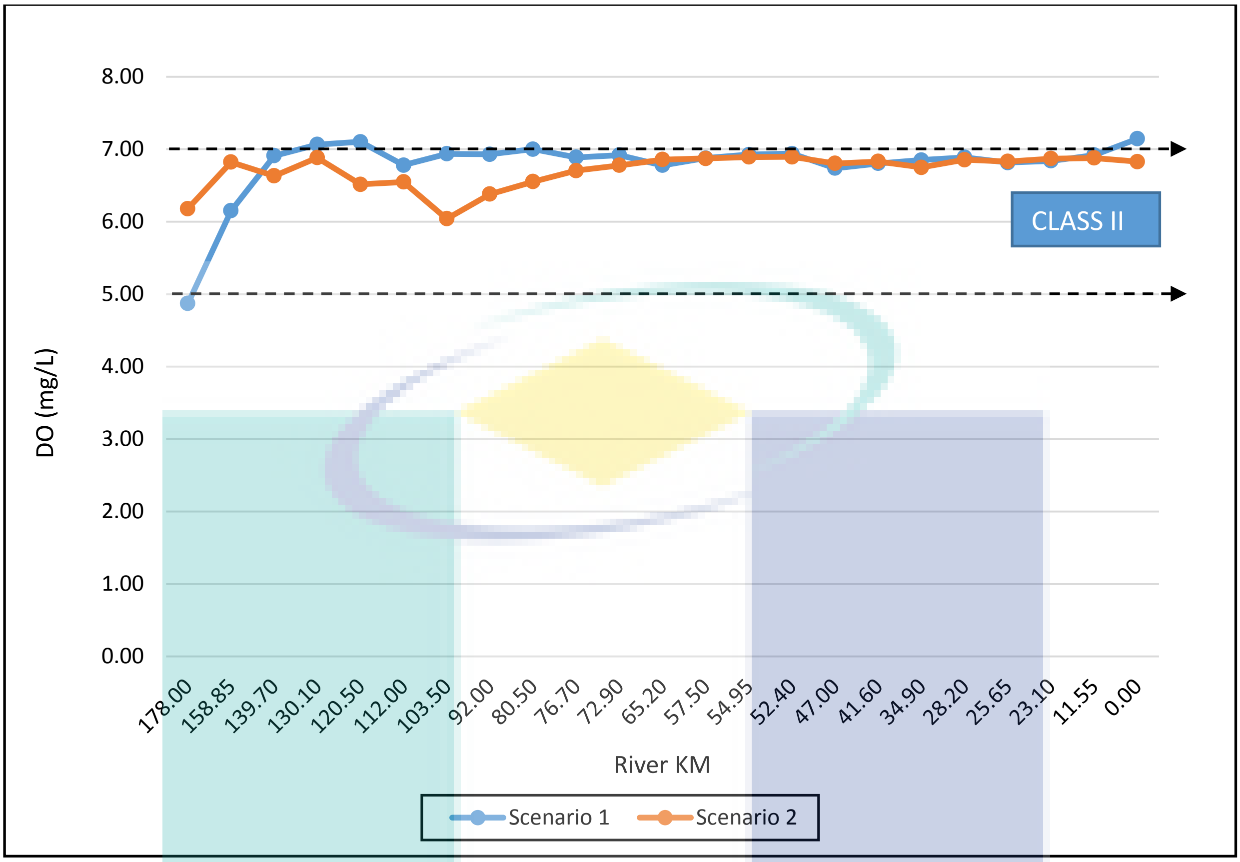


Figure 2.0: Sungai Muda Dissolved Oxygen (DO) Spatial Trend Concentration

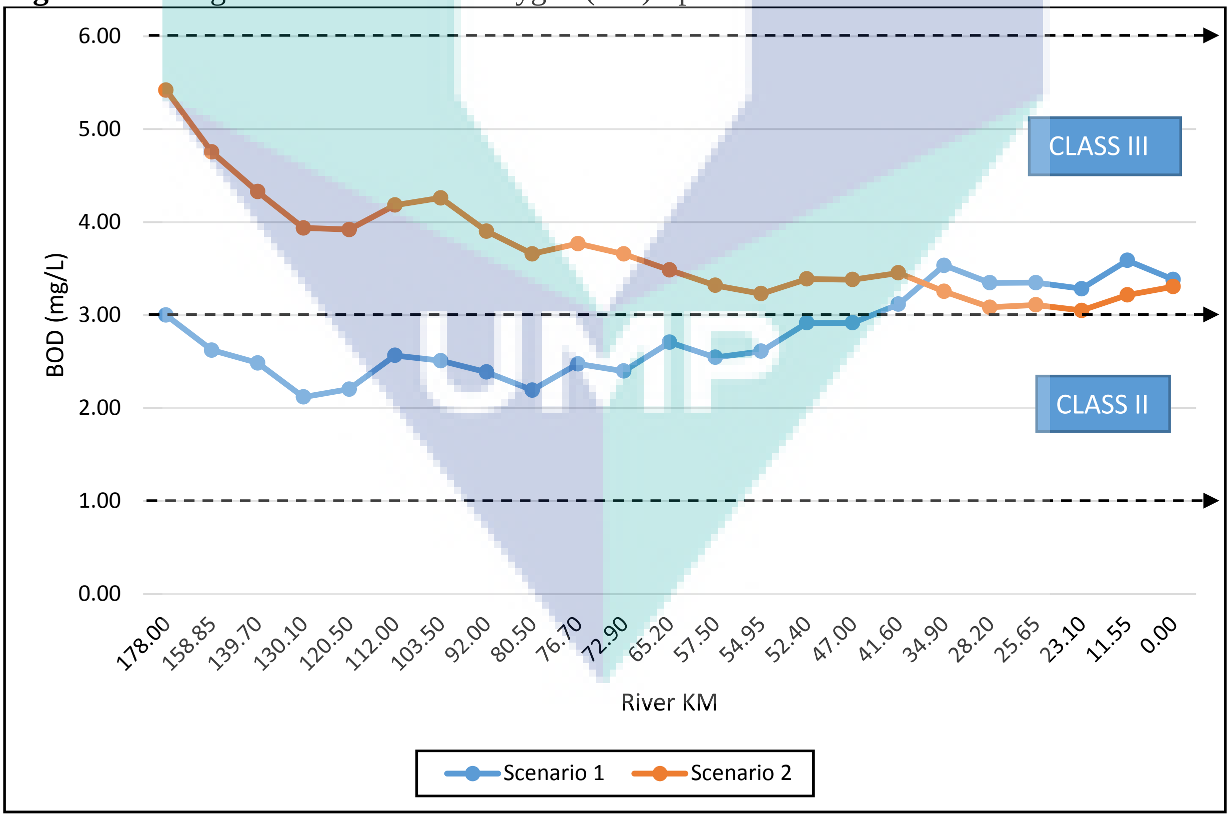


Figure 3.0: Sungai Muda Biochemical Oxygen Demand (BOD) Spatial Trend (Concentration)

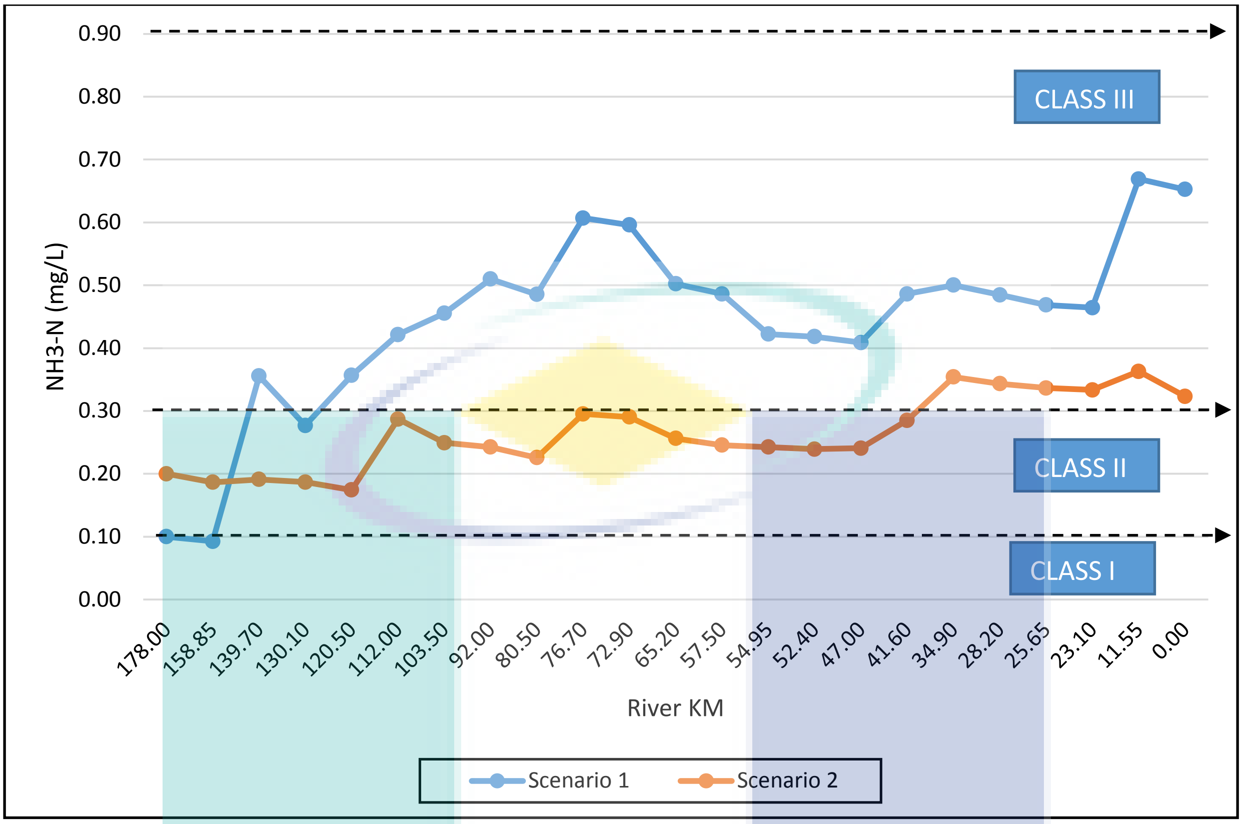


Figure 4.0: Sungai Muda Ammoniacal Nitrogen (NH_3-N) Spatial Trend (Concentration)

For TSS, the concentration was well within NWQS Class II for both scenarios as illustrated in Figure 5.0. However in terms of its loading, during Scenario 1 the loading was well within the Class II of Sg Muda river carrying capacity throughout the river meanwhile during Scenario 2, the loading breached the Class II threshold at the most upstream and at about KM 35 towards the river mouth.

The results obtained from the modeling exercise show that the Sg Muda is not facing the nutrient contamination of Nitrate (NO_3-N) throughout the river as the concentration were well within NWQS Class II threshold (Figure 6.0) during both flow scenarios. Its loading was then well within Class II of Sg Muda river carrying capacity. In terms of Phosphorus (P) contamination, the concentration during both scenarios exceeded the NWQS Class II threshold at the mid-stream of the river while the most upstream of Sg Muda as well as at KM 35 towards the river mouth, the was well within Class II. Meanwhile for its loading, Scenario 2 depicted the violation of the NWQS Class II river carrying capacity throughout the river however for Scenario 1, the violation was only observed at the most downstream.

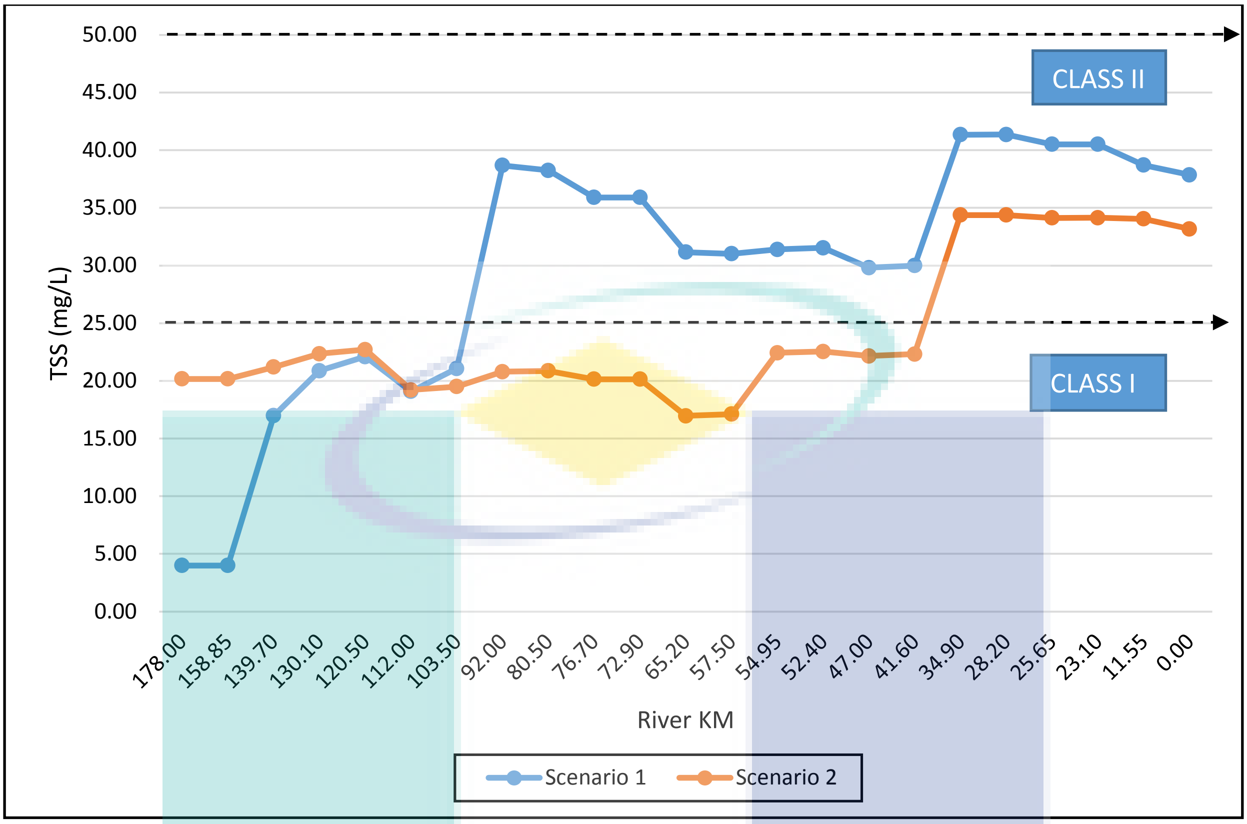


Figure 5.0: Sungai Muda Total Suspended Solid (TSS) Spatial Trend (Concentration)

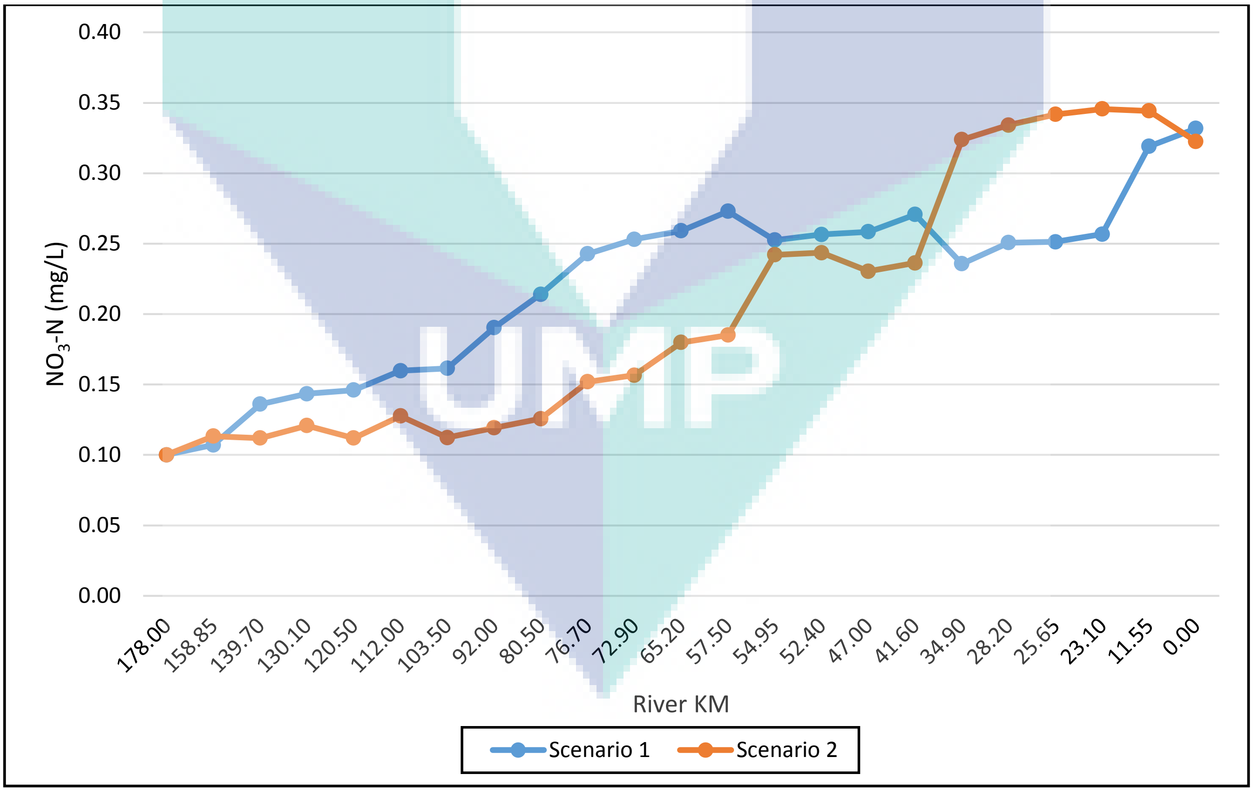


Figure 6.0: Sungai Muda Nitrate (NO_3-N) Spatial Trend (Concentration)

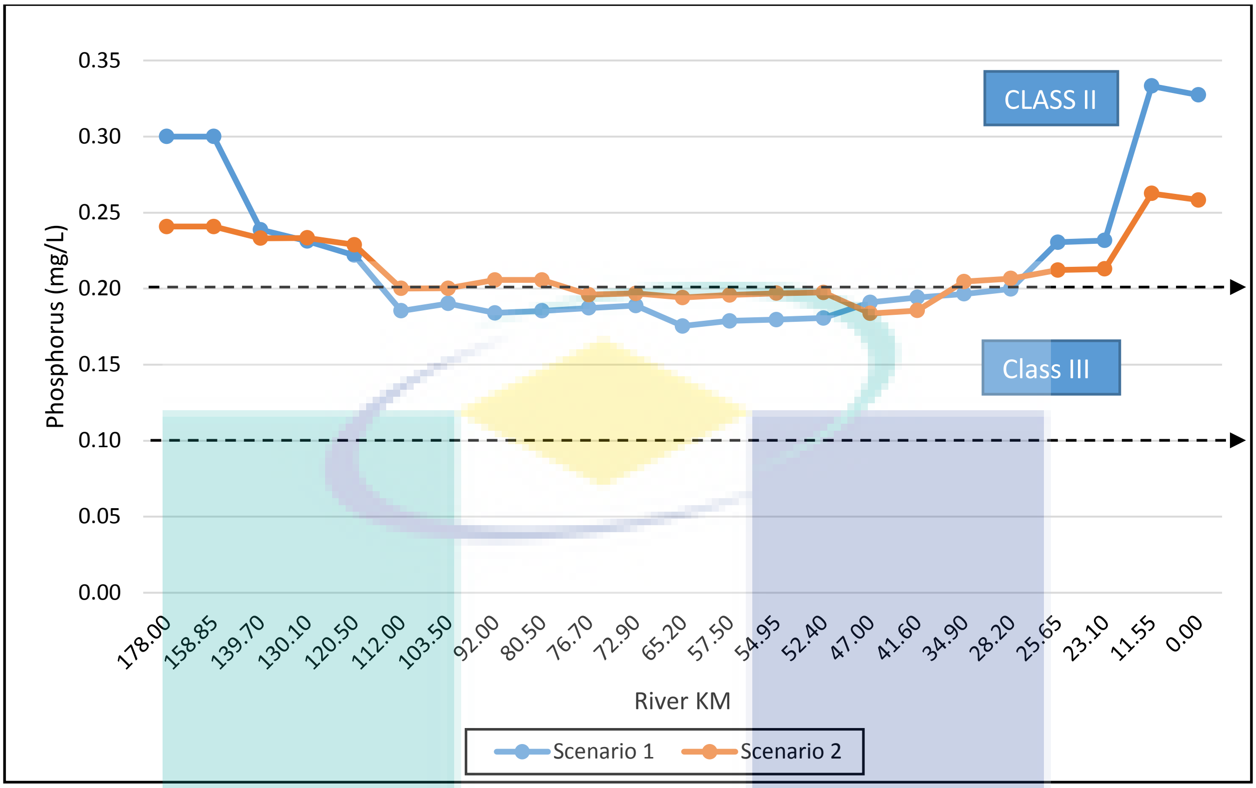


Figure 7.0: Sungai Muda Phosphorus (P) Spatial Trend (Concentration)

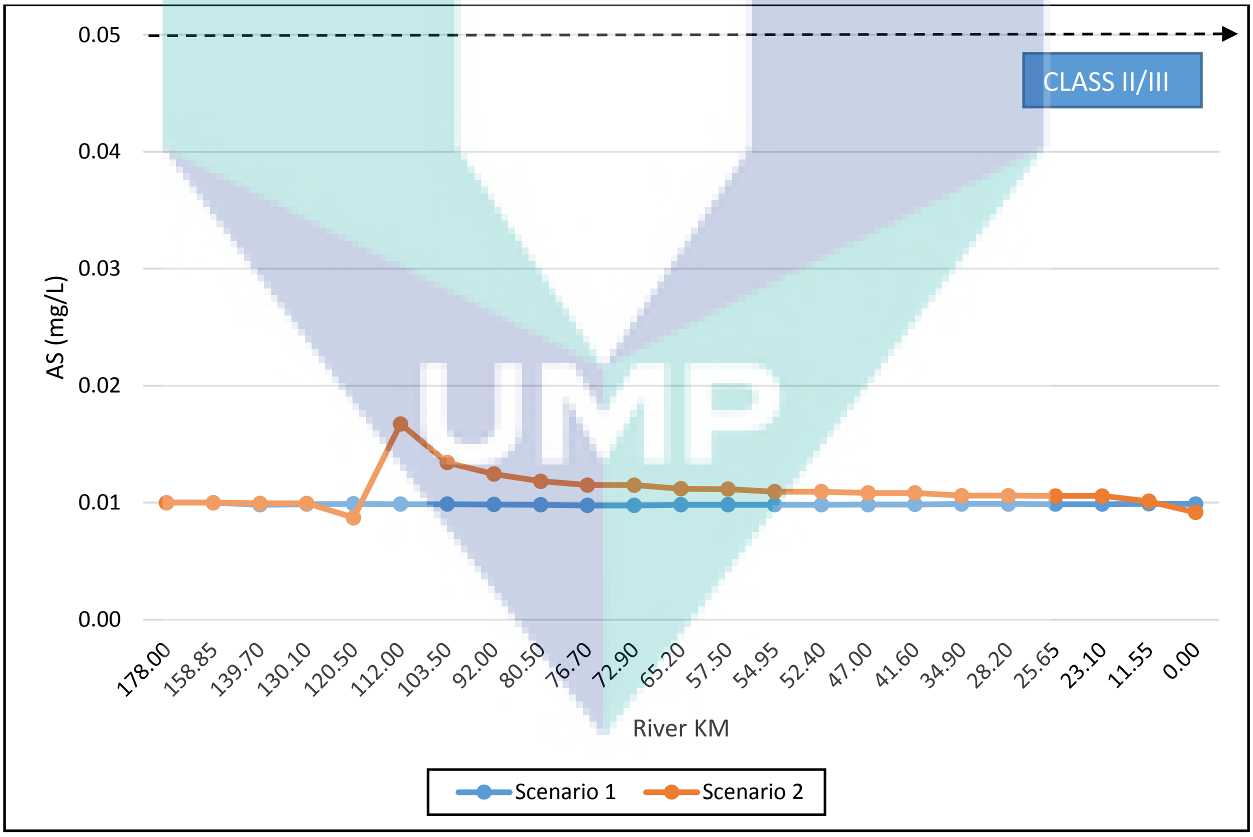


Figure 8.0: Sungai Muda Arsenic (As) Spatial Trend (Concentration)

From the modeling exercise conducted in this study, Sg Muda mainstream is not facing heavy metals contamination of arsenic (As) (Figure 8.0), iron (Fe) (Figure 9.0) and plumbum (Pb)

(Figure 10.0) throughout the river as the concentrations were well within NWQS Class II and Ministry of Health Raw Drinking Water Standard. Moreover, the loading of heavy metals were well within the Class II of Sg Muda river carrying capacity.

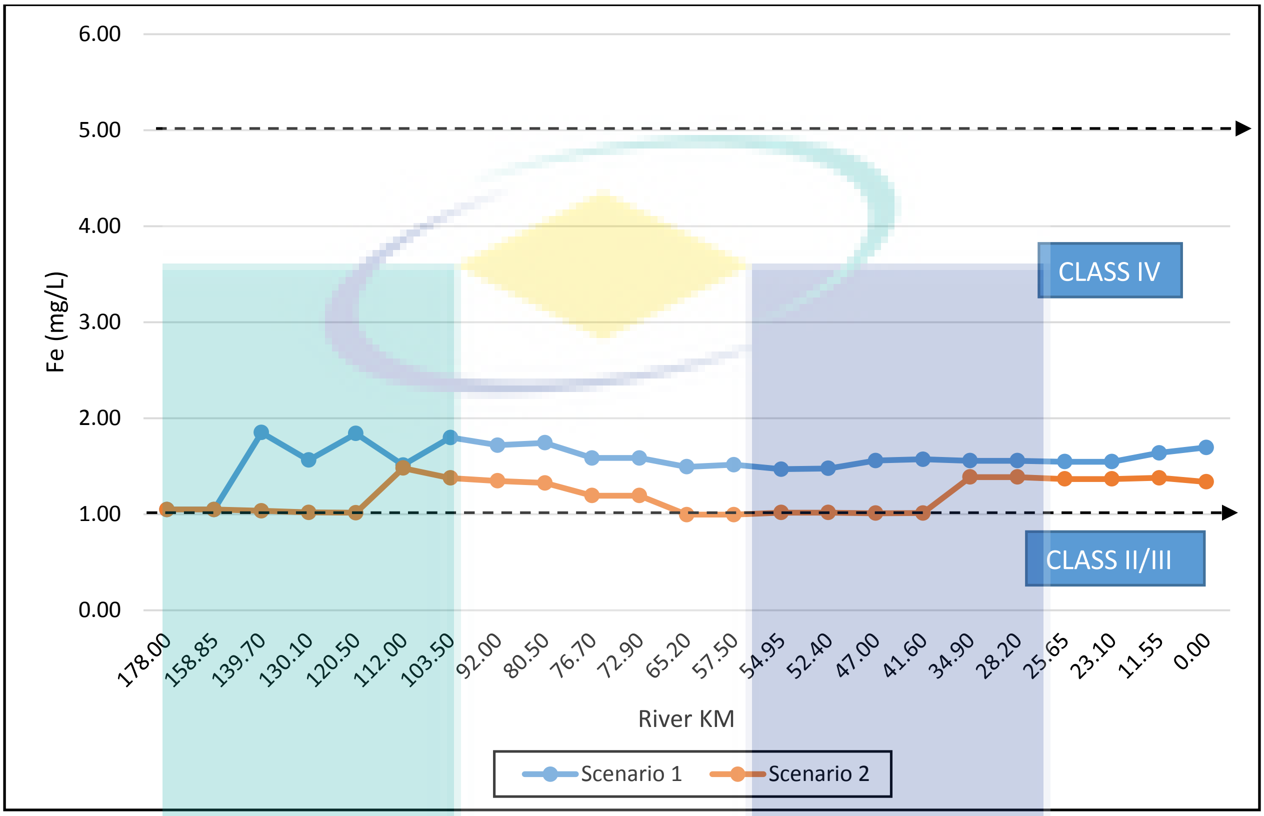


Figure 9.0: Sungai Muda Iron (Fe) Spatial Trend (Concentration)

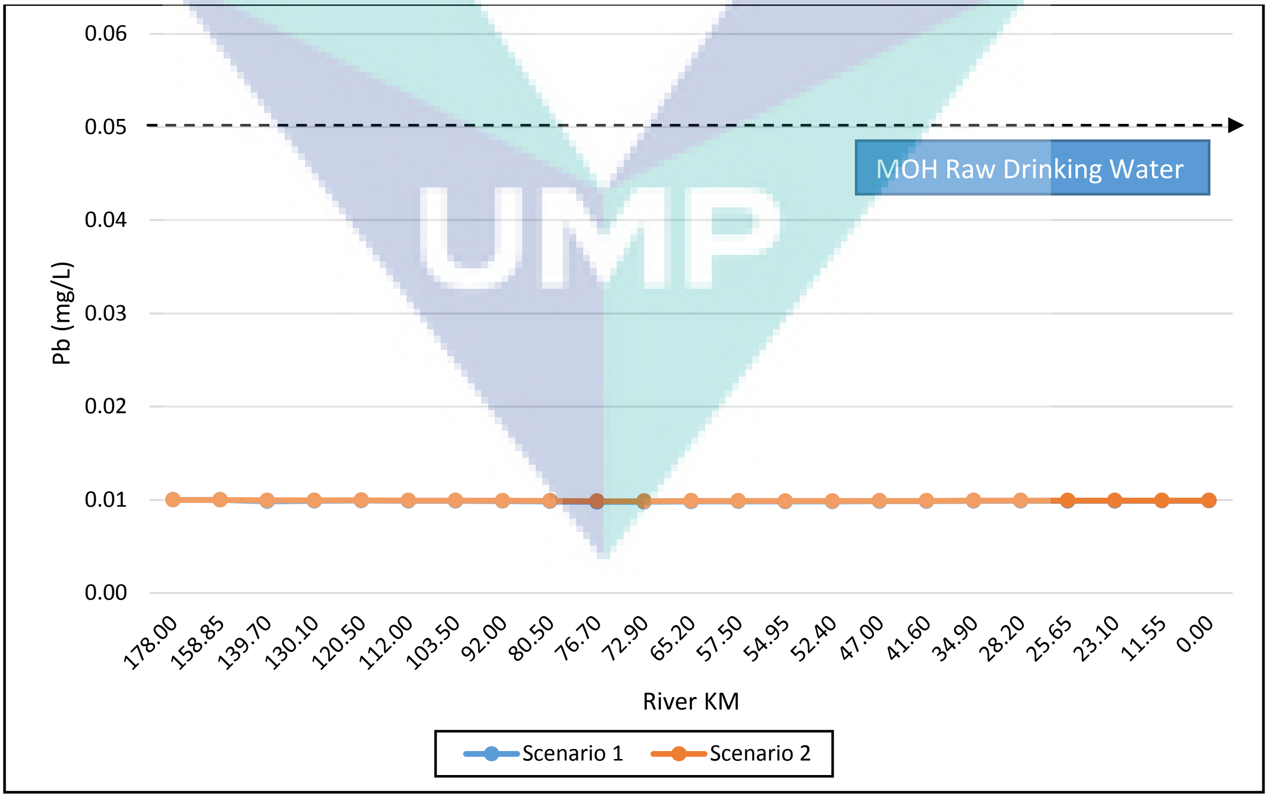


Figure 10.0: Sungai Muda Lead (Pb) Spatial Trend (Concentration)

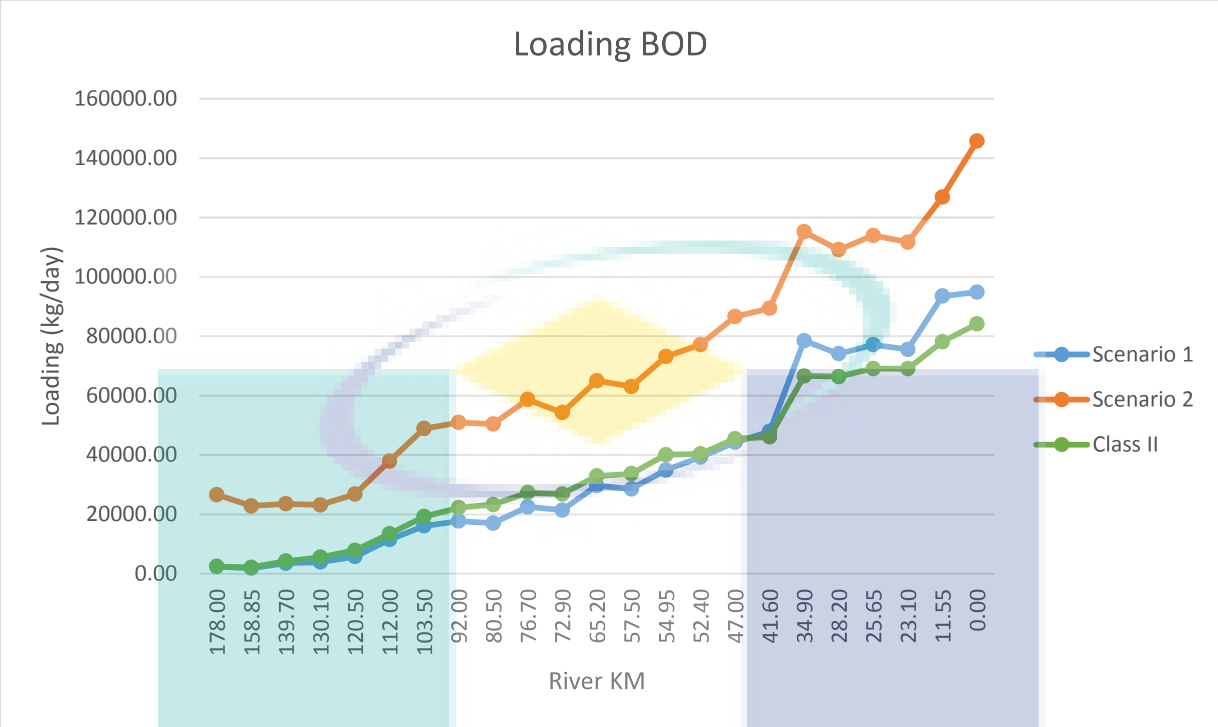


Figure 11.0: Sg Muda Biochemical Oxygen Demand (BOD) Spatial Trend (Loading)

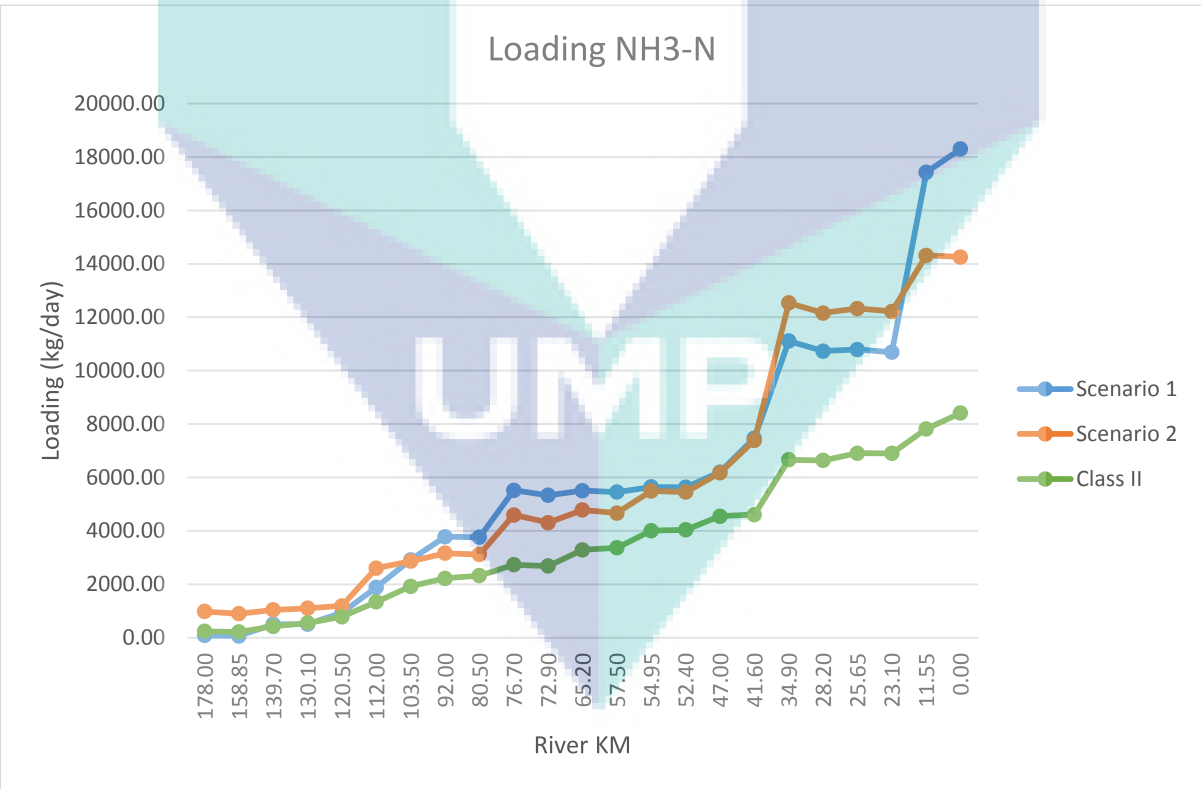


Figure 12.0: Sg Muda Ammoniacal Nitrogen (NH3-N) Spatial Trend (Loading)

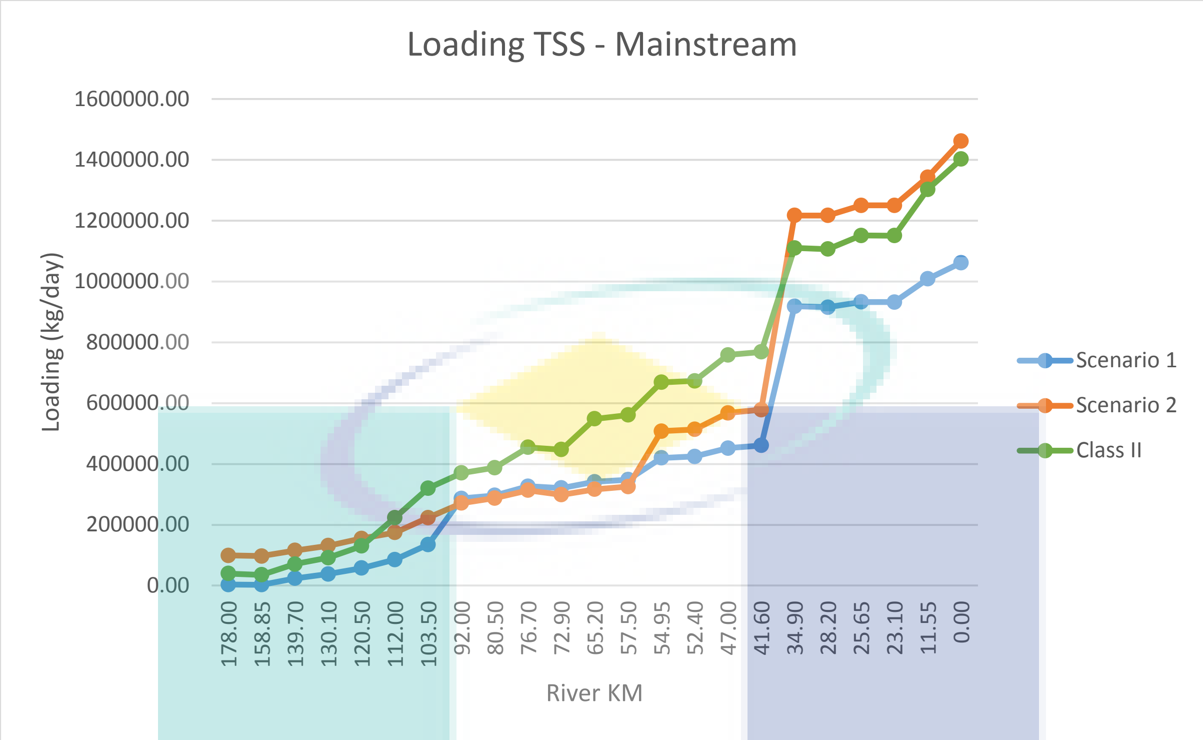


Figure 12.0: Sg Muda Total Suspended Solid (TSS) Spatial Trend (Loading)

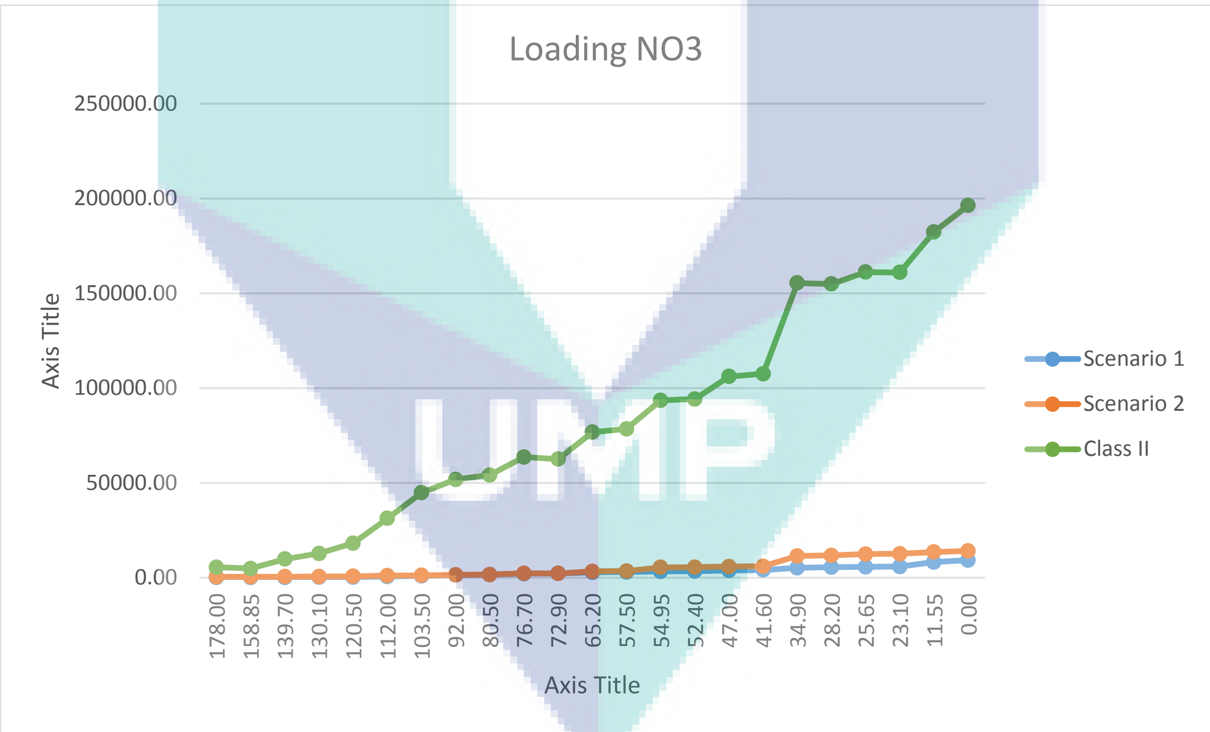


Figure 13.0: Sg Muda Nitrate (NO_3-N) Spatial Trend (Loading)

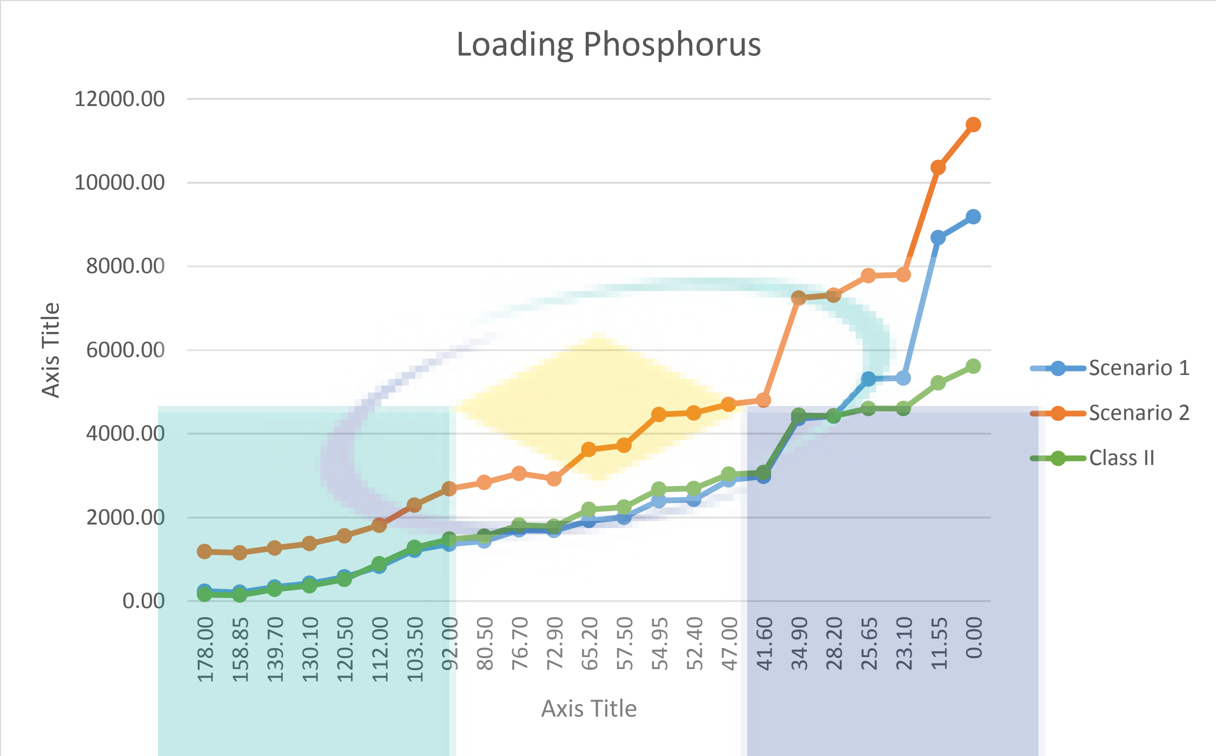


Figure 14.0: Sg Muda Phosphorus (P) Spatial Trend (Loading)

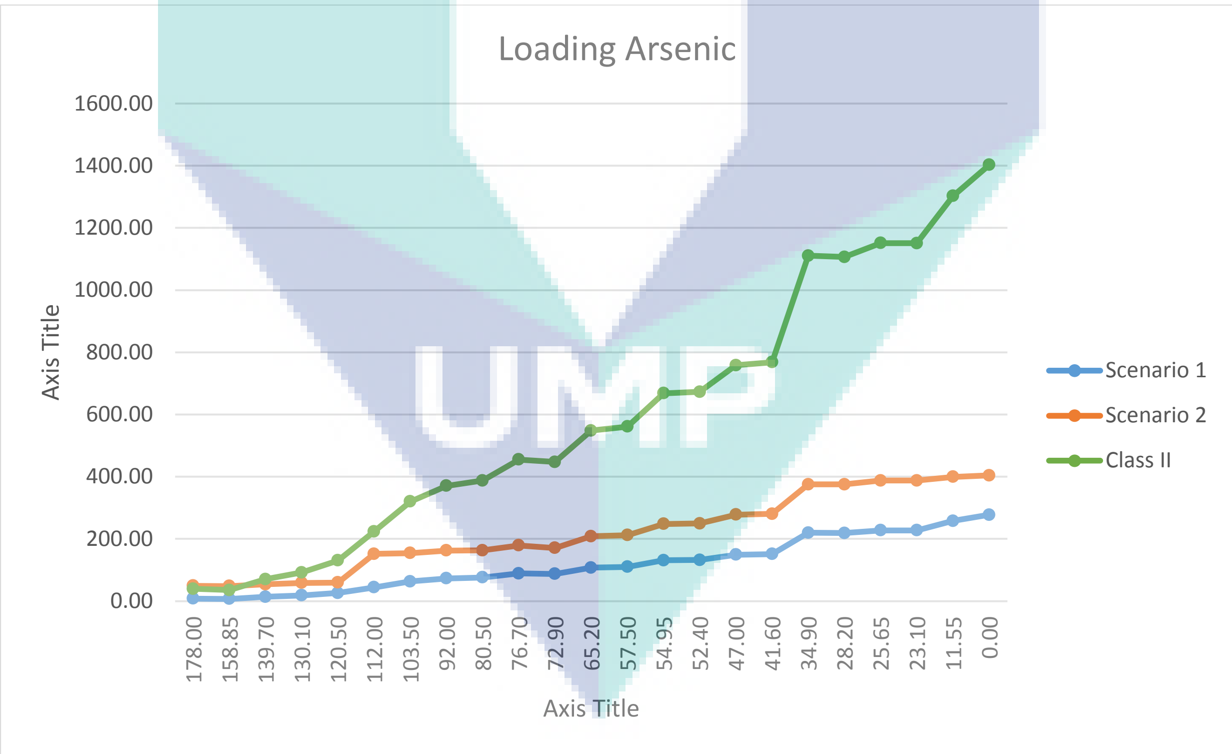


Figure 15.0: Sg Muda Arsenic (As) Spatial Trend (Loading)

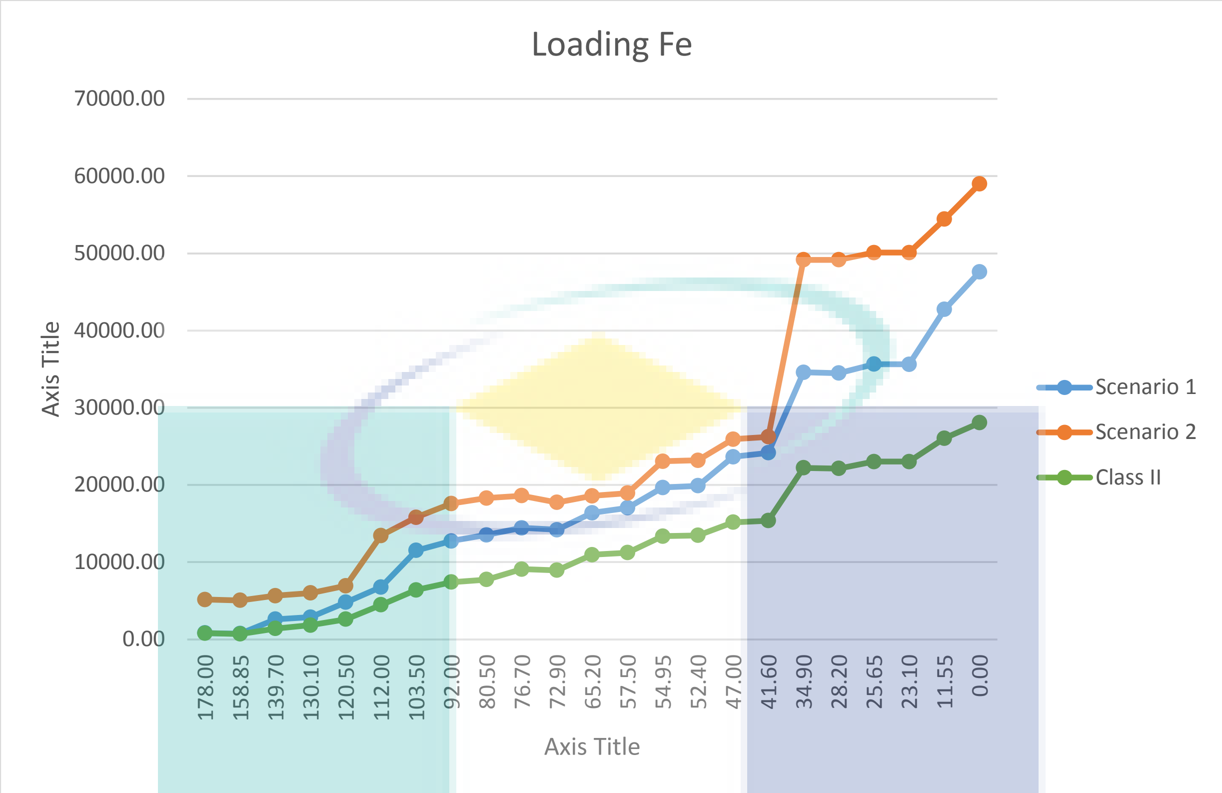


Figure 16.0: Sg Muda Iron (Fe) Spatial Trend (Loading)

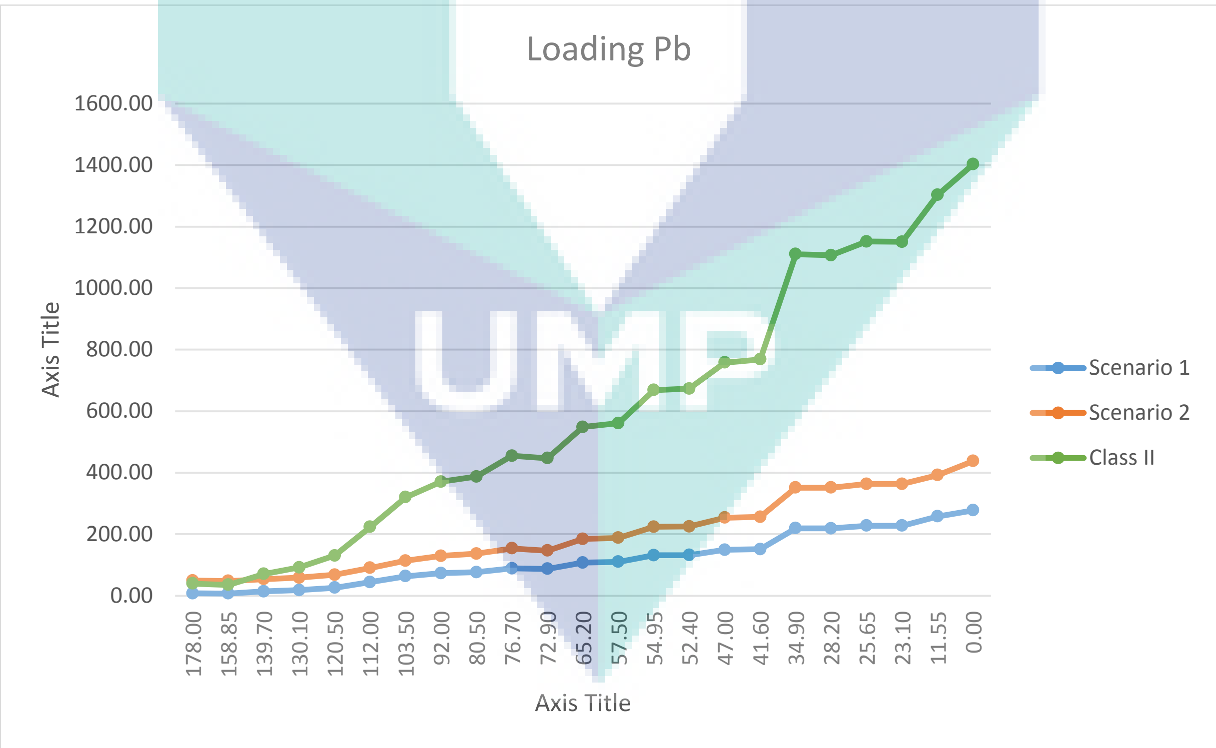


Figure 17.0: Sg Muda Lead (Pb) Spatial Trend (Loading)

4.3.2 Waste Assimilative Capacity (WAC)

Waste Assimilative Capacity (WAC) is the ability of the river to accept modest amounts of biodegradable waste. Any stream can assimilate a certain amount of waste and still maintain a level of dissolved oxygen (DO) that high enough to support a healthy population of fish and other aquatic organisms. However, if the assimilative capacity is exceeded, the concentration of DO will decrease below the level required to protect organism in that particular stream (Mills et al., 1986).

By applying this concept to the water quality study of Sg Muda, the assimilative capacity of Sg Muda was determined from the water quality proceedings. The WAC of NWQS Class II was tested. Once the baseline model has been developed, Sg Muda mainstream was able to be scrutinised to determine its WAC. Depending to the current condition of the stream whether it is within or beyond the NWQS Class II setting, the total amount of pollution load (kg/day) that the stream can sustain or need to be reduced was determined. This value is defined as the Total Maximum Daily Load (TMDL).

Table 10.0 and Table 11.0 show the TMDL of the Sg Muda mainstream and its tributaries for each parameters of concern in this study stipulated by simulation exercise. From the results obtained, it can be seen that Sg Muda mainstream is facing excess loading that exceeded the Sg Muda waste assimilative capacity of parameters such as BOD, NH_3-N, P and Iron (Fe). It is pertinent to highlight in this study that all tributaries are having excess loading of BOD that exceeded the waste assimilative capacity of the rivers and more than 80% of the tributaries are also exceeding the waste assimilative capacity for other parameters simulated.

Table 12.0 to Table 17.0 show the load reduction needed to achieve in order to attain NWQS Class II for Sg Muda mainstream both flow scenarios for all parameters simulated. Once the TMDL has been determined, the waste load allocation (WLA) and load allocation (LA) which represent point source and non-point source respectively could be able to assess.

Table 10.0: Total Maximum Daily Load and Waste Assimilative Capacity of Sg Muda Mainstream

Reach	BOD		TSS		NH_3-N		NO_3		P		As		Fe		Pb	
	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC
Mainstream	76569	48474	608136	807901	6582	4847	5726	113106	4774	3232	242	808	27649	16158	222	808

Table 11.0: Total Maximum Daily Load and Waste Assimilative Capacity of Sg Muda Tributaries

Reach	BOD		TSS		NH_3-N		NO_3		P		As		Fe		Pb	
	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC	TMDL	WAC
Sg Sok	2188	1756	20042	29264	131	176	71	4097	151	117	6	29	497	585	6	30
Sg Beris	9723	4347	1747	72456	1114	435	224	10144	142	290	100	72	6281	1449	17	66
Sg Jenen	2246	2098	31913	34967	392	210	94	4895	251	140	9	35	1081	699	9	31
Sg Chepir	10153	5419	32793	90314	648	542	482	12644	315	361	25	90	1241	1806	25	67
Sg Sungkup	9050	6939	14756	115646	590	694	809	16190	599	463	35	116	1077	2313	35	72
Sg Ketil	11747	7535	164870	125582	813	753	419	17582	638	502	32	126	3817	2512	32	103
Sg Selambau	6388	3445	28030	57414	383	344	853	8038	79	230	18	57	1605	1148	18	34
Sg Sedim	19454	14512	375637	241861	3211	1451	2732	28123	1674	967	66	242	14557	4837	66	185
Sg Karangan	8702	3039	37094	50648	800	304	234	7091	293	203	14	73	3138	1013	14	38
Sg Jerong	5936	2334	27189	38904	263	233	534	5447	398	156	10	39	729	778	10	31
Sg Korok	11548	2508	46387	41801	2953	251	203	5852	2277	167	10	42	2600	836	10	38

Table 12.0: Load Reduction of Sg Muda Mainstream During Low Flow Relative to NWQS Class II

Distance	Loading BOD	Loading BOD	Load Reduction BOD %		Loading TSS	Loading TSS	Load Reduction TSS %		Loading NH_3-N	Loading NH_3-N	Load Reduction NH3-NH_3-N %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	2379	2379	0	0	39658	3173	-1150	-1265	238	79	-200	-220
158.85	2115	1848	-14	-16	35246	2820	-1150	-1265	211	65	-223	-246
139.70	4238	3512	-21	-23	70636	23989	-194	-214	424	502	16	17
130.10	5510	3892	-42	-46	91832	38335	-140	-154	551	509	-8	-9
120.50	7830	5747	-36	-40	130492	57665	-126	-139	783	931	16	17
112.00	13422	11476	-17	-19	223694	85399	-162	-178	1342	1886	29	32
103.50	19206	16068	-20	-21	320106	134906	-137	-151	1921	2916	34	38
92.00	22236	17686	-26	-28	370598	286706	-29	-32	2224	3779	41	45
80.50	23249	16988	-37	-41	387477	296446	-31	-34	2325	3763	38	42
76.70	27289	22503	-21	-23	454816	326560	-39	-43	2729	5520	51	56
72.90	26825	21435	-25	-28	447091	321013	-39	-43	2683	5330	50	55
65.20	32894	29682	-11	-12	548231	341601	-60	-67	3289	5507	40	44
57.50	33659	28558	-18	-20	560988	347979	-61	-67	3366	5455	38	42
54.95	40104	34891	-15	-16	668400	419686	-59	-65	4010	5647	29	32
52.40	40379	39256	-3	-3	672987	424465	-59	-64	4038	5631	28	31
47.00	45493	44226	-3	-3	758210	451995	-68	-75	4549	6202	27	29
41.60	46095	47894	4	4	768253	460786	-67	-73	4610	7472	38	42
34.90	66623	78475	15	17	1110390	918227	-21	-23	6662	11110	40	44
28.20	66401	74084	10	11	1106675	915262	-21	-23	6640	10730	38	42
25.65	69086	77104	10	11	1151441	932866	-23	-26	6909	10792	36	40
23.10	69038	75565	9	10	1150636	932358	-23	-26	6904	10687	35	39
11.55	78169	93503	16	18	1302811	1008494	-29	-32	7817	17432	55	61
0.00	84149	94884	11	12	1402480	1061812	-32	-35	8415	18304	54	59

Table 13.0:

Distance	Loading NO_3	NO_3 Loading	NO_3 Load Reduction %		Loading P	P Loading	P Load Reduction %		Loading As	As Loading	As Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	5552	79	-6900	-7590	159	238	33	37	40	8	-400	-440
158.85	4934	75	-6436	-7079	141	211	33	37	35	7	-400	-440
139.70	9889	192	-5046	-5550	283	337	16	18	71	14	-409	-449
130.10	12857	263	-4781	-5259	367	425	13	15	92	18	-406	-447
120.50	18269	381	-4692	-5161	522	579	10	11	130	26	-404	-445
112.00	31317	715	-4281	-4710	895	829	-8	-9	224	44	-406	-446
103.50	44815	1034	-4235	-4658	1280	1217	-5	-6	320	63	-406	-447
92.00	51884	1411	-3578	-3936	1482	1364	-9	-10	371	73	-407	-448
80.50	54247	1659	-3170	-3487	1550	1437	-8	-9	387	76	-409	-450
76.70	63674	2208	-2783	-3062	1819	1704	-7	-7	455	89	-412	-453
72.90	62593	2263	-2665	-2932	1788	1688	-6	-7	447	87	-412	-453
65.20	76752	2841	-2602	-2862	2193	1923	-14	-15	548	108	-409	-450
57.50	78538	3062	-2465	-2711	2244	2006	-12	-13	561	110	-409	-450
54.95	93576	3376	-2672	-2939	2674	2401	-11	-12	668	131	-409	-450
52.40	94218	3452	-2629	-2892	2692	2431	-11	-12	673	132	-409	-450
47.00	106149	3918	-2609	-2870	3033	2896	-5	-5	758	149	-408	-449
41.60	107555	4159	-2486	-2734	3073	2983	-3	-3	768	151	-408	-449
34.90	155455	5235	-2869	-3156	4442	4363	-2	-2	1110	220	-406	-446
28.20	154935	5549	-2692	-2961	4427	4421	0	0	1107	219	-406	-446
25.65	161202	5786	-2686	-2955	4606	5308	13	15	1151	228	-406	-446
23.10	161089	5907	-2627	-2890	4603	5331	14	15	1151	228	-406	-446
11.55	182394	8315	-2094	-2303	5211	8684	40	44	1303	258	-405	-445
0.00	196347	9305	-2010	-2211	5610	9182	39	43	1402	278	-405	-446

Table 14.0:

Distance	Fe Loading	Fe Loading	Fe Load Reduction %		Pb Loading	Pb Loading	Pb Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	793	833	5	5	40	8	-400	-440
158.85	705	740	5	5	35	7	-400	-440
139.70	1413	2615	46	51	71	14	-409	-449
130.10	1837	2873	36	40	92	18	-406	-447
120.50	2610	4806	46	50	130	26	-404	-445
112.00	4474	6768	34	37	224	44	-406	-446
103.50	6402	11517	44	49	320	63	-406	-447
92.00	7412	12747	42	46	371	73	-407	-448
80.50	7750	13520	43	47	387	76	-409	-450
76.70	9096	14432	37	41	455	89	-412	-453
72.90	8942	14187	37	41	447	87	-412	-453
65.20	10965	16385	33	36	548	108	-409	-450
57.50	11220	17022	34	37	561	110	-409	-450
54.95	13368	19660	32	35	668	131	-409	-450
52.40	13460	19889	32	36	673	132	-409	-450
47.00	15164	23653	36	39	758	149	-408	-449
41.60	15365	24160	36	40	768	151	-408	-449
34.90	22208	34597	36	39	1110	220	-406	-446
28.20	22134	34480	36	39	1107	219	-406	-446
25.65	23029	35648	35	39	1151	228	-406	-446
23.10	23013	35618	35	39	1151	227	-406	-446
11.55	26056	42740	39	43	1303	258	-405	-446
0.00	28050	47604	41	45	1402	277	-406	-446

Table 15.0: Load Reduction of Sg Muda Mainstream During High Flow Relative to NWQS Class II

Distance	Loading BOD	Loading BOD	Load Reduction BOD %		Loading TSS	Loading TSS	Load Reduction TSS %		Loading NH_3-N	Loading NH_3-N	Load Reduction NH3-NH_3-N %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	2379	26599	91	100	39658	98985	60	66	238	982	76	83
158.85	2115	22829	91	100	35246	96854	64	70	211	896	76	84
139.70	4238	23551	82	90	70636	115354	39	43	424	1040	59	65
130.10	5510	23160	76	84	91832	131471	30	33	551	1100	50	55
120.50	7830	26756	71	78	130492	155083	16	17	783	1191	34	38
112.00	13422	37941	65	71	223694	174279	-28	-31	1342	2604	48	53
103.50	19206	48859	61	67	320106	223704	-43	-47	1921	2861	33	36
92.00	22236	50932	56	62	370598	271373	-37	-40	2224	3164	30	33
80.50	23249	50423	54	59	387477	287543	-35	-38	2325	3115	25	28
76.70	27289	58666	53	59	454816	313582	-45	-50	2729	4598	41	45
72.90	26825	54276	51	56	447091	298865	-50	-55	2683	4310	38	42
65.20	32894	64994	49	54	548231	316501	-73	-81	3289	4779	31	34
57.50	33659	63074	47	51	560988	325447	-72	-80	3366	4667	28	31
54.95	40104	73155	45	50	668400	507936	-32	-35	4010	5492	27	30
52.40	40379	77183	48	52	672987	513565	-31	-34	4038	5450	26	28
47.00	45493	86618	47	52	758210	567542	-34	-37	4549	6174	26	29
41.60	46095	89412	48	53	768253	578135	-33	-36	4610	7386	38	41
34.90	66623	115204	42	46	1110390	1216861	9	10	6662	12538	47	52
28.20	66401	109141	39	43	1106675	1217034	9	10	6640	12160	45	50
25.65	69086	113918	39	43	1151441	1250162	8	9	6909	12327	44	48
23.10	69038	111686	38	42	1150636	1250453	8	9	6904	12218	43	48
11.55	78169	126901	38	42	1302811	1342900	3	3	7817	14317	45	50
0.00	84149	145709	42	46	1402480	1461935	4	4	8415	14254	41	45

Table 16.0:

Distance	Loading NO_3	NO_3 Loading	NO_3 Load Reduction %		Loading P	P Loading	P Load Reduction %		Loading As	As Loading	As Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	5552	491	-1031	-1134	159	1182	87	95	40	49	19	21
158.85	4934	544	-807	-888	141	1156	88	97	35	48	27	29
139.70	9889	609	-1523	-1675	283	1269	78	86	71	54	-30	-33
130.10	12857	711	-1709	-1880	367	1373	73	81	92	59	-57	-62
120.50	18269	764	-2291	-2520	522	1562	67	73	130	60	-119	-131
112.00	31317	1158	-2605	-2866	895	1815	51	56	224	152	-47	-52
103.50	44815	1288	-3379	-3717	1280	2296	44	49	320	154	-108	-118
92.00	51884	1556	-3234	-3558	1482	2683	45	49	371	162	-128	-141
80.50	54247	1733	-3030	-3333	1550	2836	45	50	387	163	-138	-151
76.70	63674	2365	-2592	-2851	1819	3052	40	44	455	179	-154	-169
72.90	62593	2324	-2593	-2853	1788	2920	39	43	447	171	-162	-178
65.20	76752	3355	-2188	-2407	2193	3620	39	43	548	209	-163	-179
57.50	78538	3518	-2133	-2346	2244	3721	40	44	561	212	-164	-181
54.95	93576	5483	-1607	-1767	2674	4460	40	44	668	248	-169	-186
52.40	94218	5547	-1598	-1758	2692	4496	40	44	673	249	-170	-187
47.00	106149	5901	-1699	-1869	3033	4705	36	39	758	278	-173	-190
41.60	107555	6118	-1658	-1824	3073	4805	36	40	768	281	-174	-191
34.90	155455	11462	-1256	-1382	4442	7242	39	43	1110	375	-196	-215
28.20	154935	11830	-1210	-1331	4427	7313	39	43	1107	375	-195	-214
25.65	161202	12520	-1188	-1306	4606	7773	41	45	1151	388	-197	-217
23.10	161089	12661	-1172	-1290	4603	7800	41	45	1151	388	-197	-216
11.55	182394	13582	-1243	-1367	5211	10360	50	55	1303	399	-226	-249
0.00	196347	14215	-1281	-1409	5610	11383	51	56	1402	404	-247	-272

Table 17.0:

Distance	Fe Loading	Fe Loading	Fe Load Reduction %		Pb Loading	Pb Loading	Pb Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	793	5153	85	93	40	49	19	21
158.85	705	5042	86	95	35	48	27	29
139.70	1413	5643	75	82	71	54	-30	-33
130.10	1837	5996	69	76	92	59	-57	-62
120.50	2610	6941	62	69	130	68	-92	-101
112.00	4474	13441	67	73	224	90	-148	-163
103.50	6402	15812	60	65	320	114	-181	-199
92.00	7412	17588	58	64	371	129	-186	-205
80.50	7750	18296	58	63	387	136	-184	-202
76.70	9096	18602	51	56	455	154	-196	-216
72.90	8942	17729	50	55	447	146	-205	-226
65.20	10965	18581	41	45	548	185	-197	-217
57.50	11220	18938	41	45	561	188	-198	-218
54.95	13368	23061	42	46	668	224	-198	-218
52.40	13460	23197	42	46	673	225	-199	-219
47.00	15164	25922	42	46	758	254	-199	-219
41.60	15365	26233	41	46	768	256	-200	-220
34.90	22208	49158	55	60	1110	351	-216	-238
28.20	22134	49158	55	60	1107	351	-215	-237
25.65	23029	50096	54	59	1151	364	-217	-238
23.10	23013	50096	54	59	1151	364	-217	-238
11.55	26056	54430	52	57	1303	392	-233	-256
0.00	28050	59010	52	58	1402	437	-221	-243

4.4 Scenario Simulation of LF7Q5, LF7Q10 and LF7Q20 of Sg Muda (Scenario 3 (5), Scenario 3(10) and Scenario 3(20))

The simulation of scenarios 3; concentration and loading was pertinent in illustrating the condition of Sg Muda at the lowest average discharge over a period of one week with a current interval of 5, 10 and 20 years. The pollution loading into the Sg Muda mainstream as well as its tributaries similar as inventoried as in Scenario 1.

4.4.1 Sg Muda Mainstream - Concentration and Loading Simulation

The results obtained from the simulation of the worst case scenario depicted that the Dissolved Oxygen (DO) levels of the Sg Muda mainstream during ARI 5, 10 and 20 were still within NWQS Class II threshold. However, it can be seen that the level was predicted to decrease mid-stream until to downstream (Figure 18.0). For BOD, the upstream of Sg Muda until KM 120, no violation of NWQS Class II was predicted during ARI 5, 10 and 20. During ARI 5, the concentration increased gradually and was within NWQS Class III towards the downstream however during ARI 10 and 20, the concentration level increased to the level within the NWQS Class IV. In terms of its loading, the loads simulated are violating the waste assimilative capacity (WAC) or river carrying capacity of NWQS Class II about 35%, 47% and 58% during ARI 5, 10 and 20 respectively (Figure 19.0 and Table 18.0). For TSS, the concentration levels simulated during ARI 5, 10 and 20 were still well within NWQS Class II as illustrated in Figure 20.0. For its loading, the loads seemed far from violating the river waste assimilate capacity (WAC) of NWQS Class II (Figure 28.0 and Table 19.0). It can be seen from Figure 21.0 that Sg Muda is facing contamination of NH3-N during ARI 5, 10 and 20. Is was predicted that the loads during ARI 5, 10 and 20 breached its waste assimilative capacity (WAC) by 61%, 68% and 75% respectively as illustrated in Table 20.0. Meanwhile, in terms of nutrients; NO_3-N and Phosphorus, the concentration levels simulated were less than 1 mg/l (Figure 22.0 and Figure 23.0). Phosphorus is a key element controlling productivity of rivers (Corell, 1999); high concentrations of Phosphorus will induce eutrophication to occur in the river system (Newman, 2005). From the results obtained, there was no violation to the WAC of the Sg Muda by the NO_3-N loading (Table 21.0) however for Phosphorus, about 19%, 23% and 29% of the loads predicted to breach the WAC during ARI 5, 10 and 20 (Table 22.0). In terms of heavy metals contamination, it was predicted that no violation to the WAC by As and Pb loads (Table 23.0 and Table 25.0) and the predicted concentration levels for both heavy metals were about 0.01 mg/l which is below the NWQS Class II threshold as well as the MOH Raw Drinking Water Standard as illustrated in Figure 24.0 and Figure 26.0. In this study, as the contamination of Sg Muda with Fe concentration level has been disclosed within NWQS Class IV, Sg Muda is expected to remain being contaminated with Fe throughout the river during ARI 5, 10 and 20 (Figure 25.0). In terms of its loading, the load was predicted to breach the Sg Muda WAC of ARI 5, 10 and 20 by 35%, 34% and 34% respectively (Table 24.0).

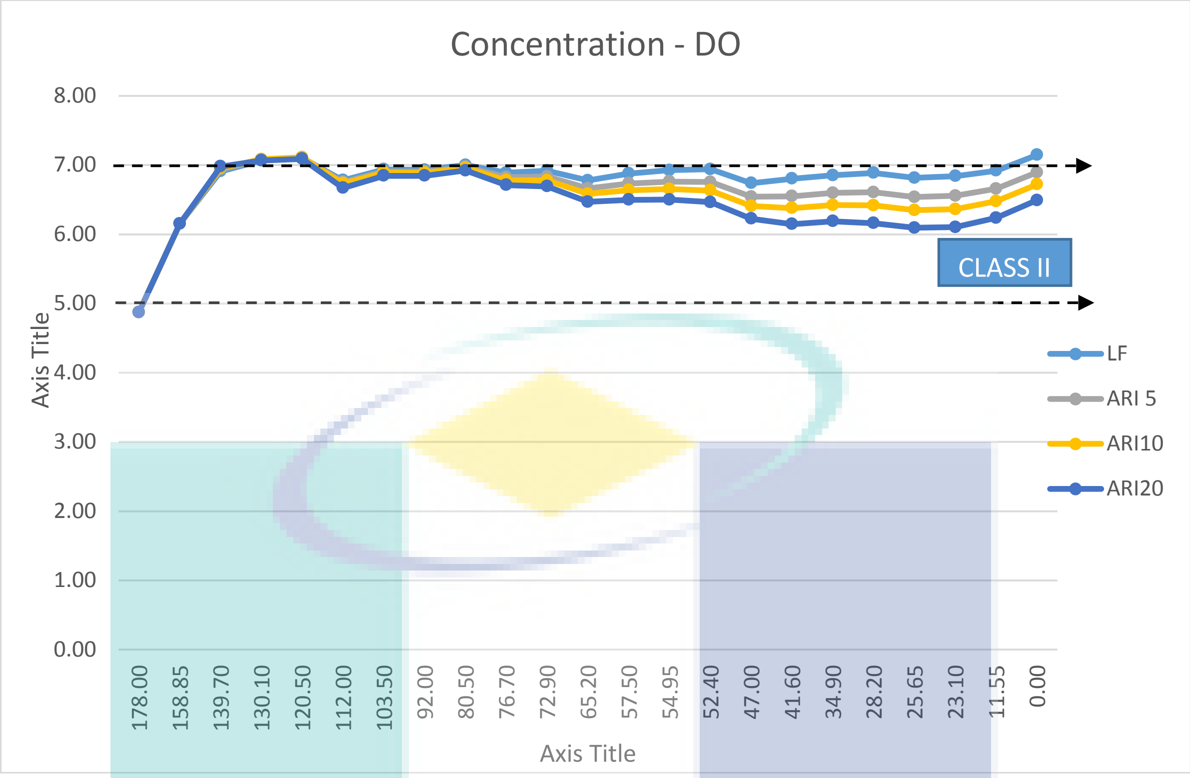


Figure 18.0: Sungai Muda Dissolved Oxygen Demand (DO) Spatial Trend (Concentration)

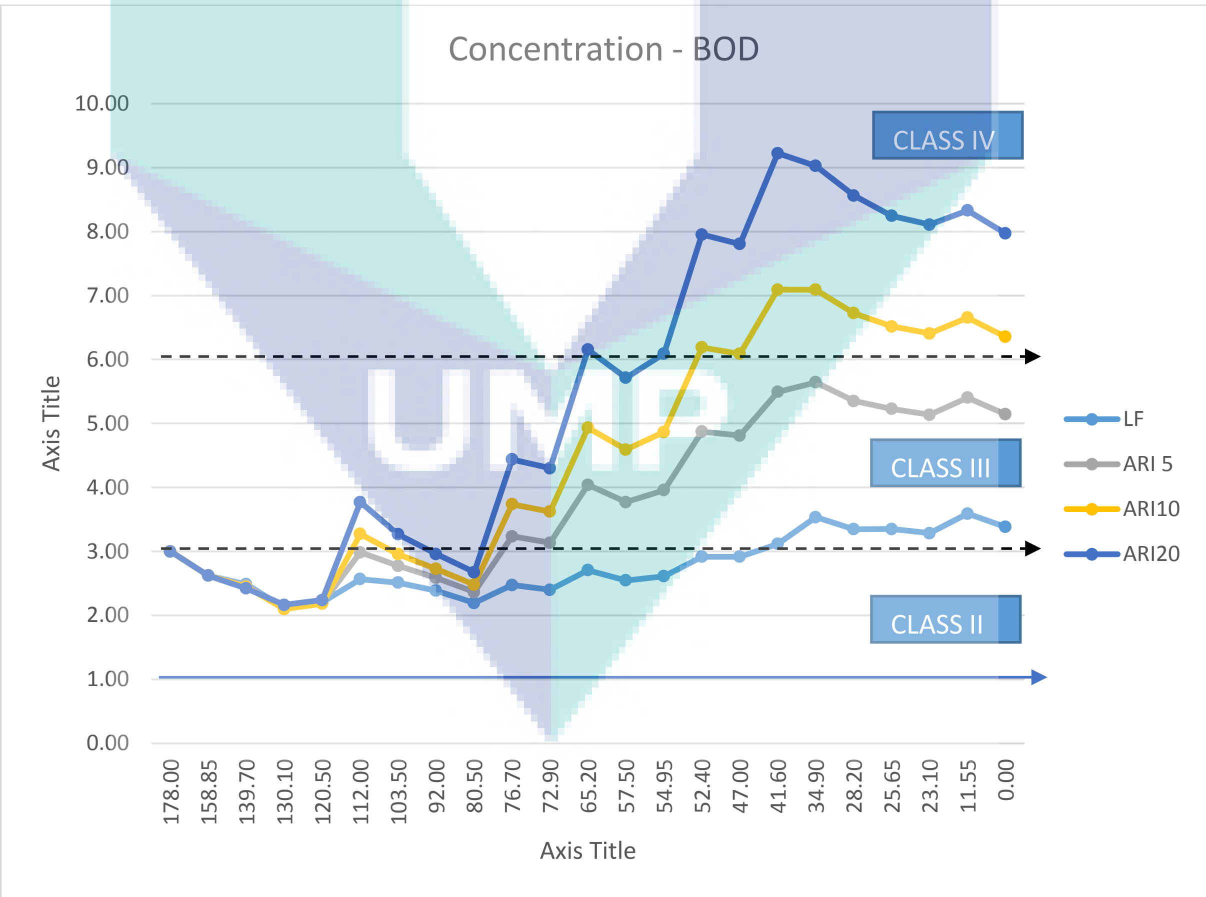


Figure 19.0: Sungai Muda Biochemical Oxygen Demand (BOD) Spatial Trend (Concentration)

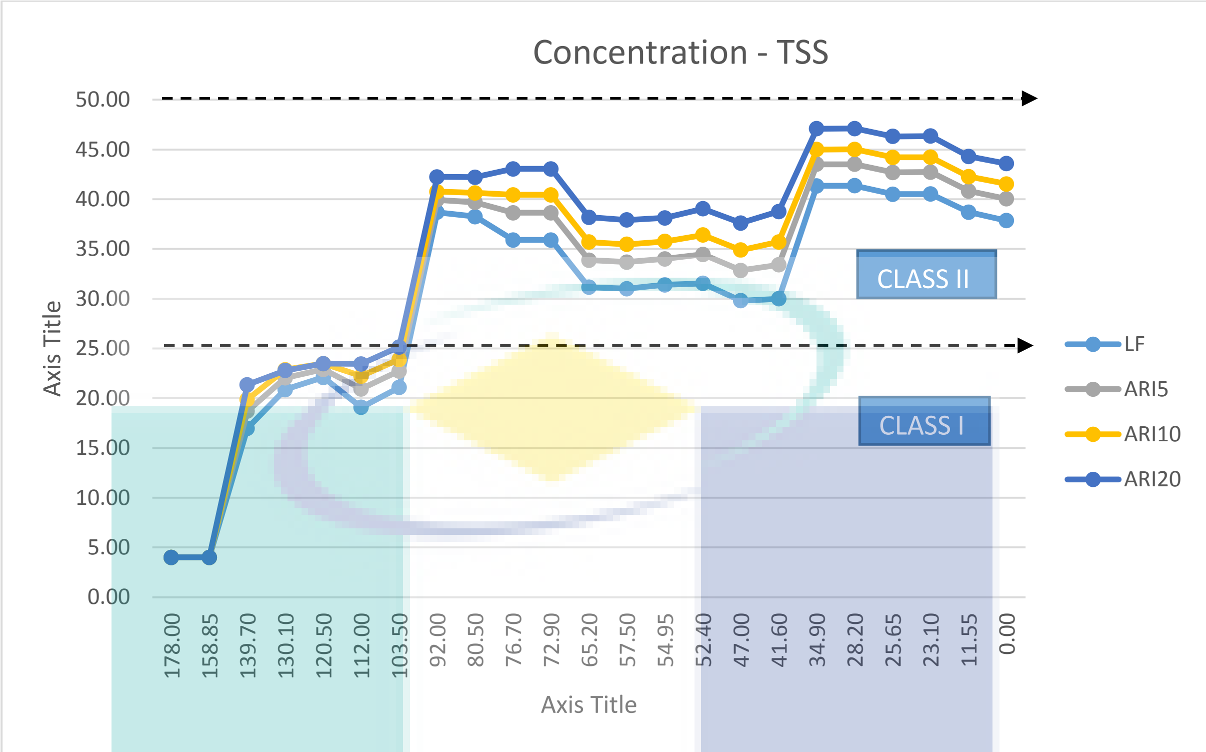


Figure 20.0: Sungai Muda Total Suspended Solid (TSS) Spatial Trend (Concentration)

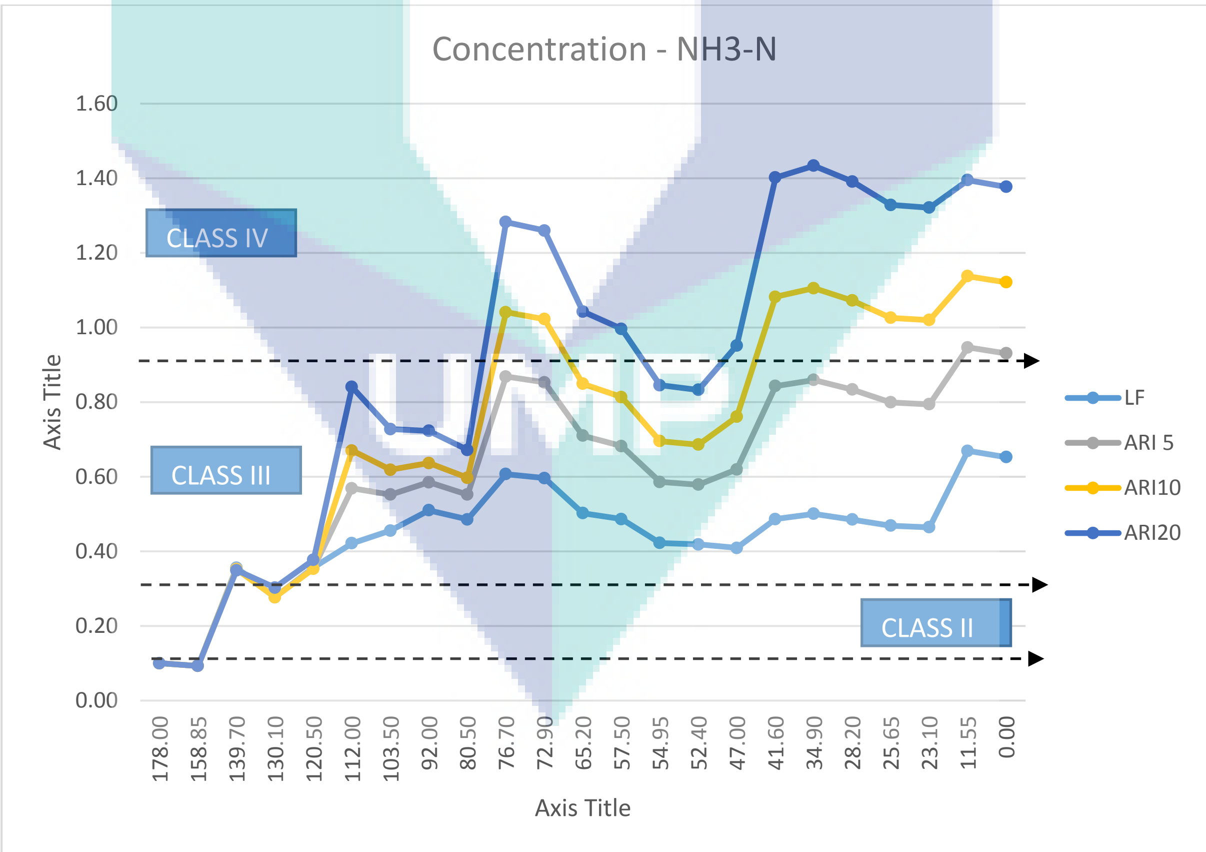


Figure 21.0: Sungai Muda Ammoniacal Nitrogen (NH_3-N) Spatial Trend (Concentration)

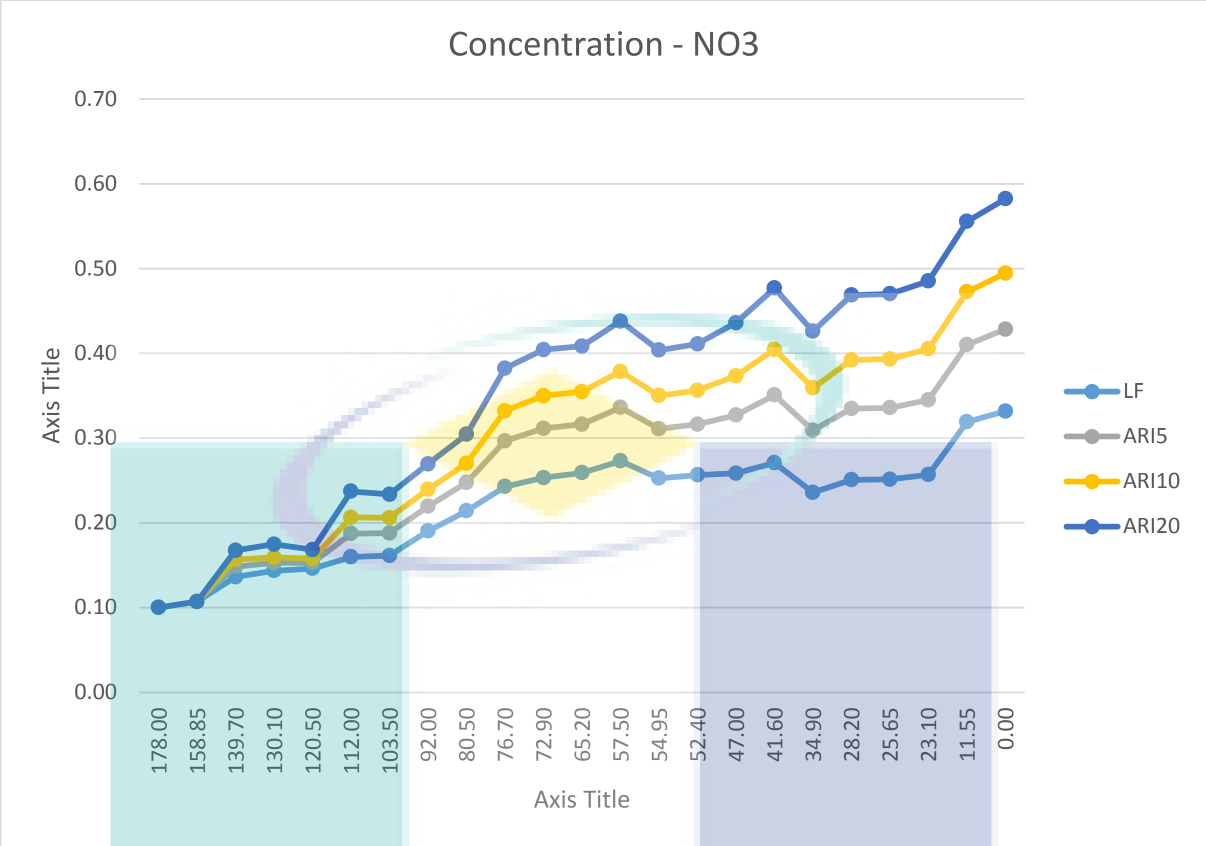


Figure 22.0: Sungai Muda Nitrate (NO_3) Spatial Trend (Concentration)

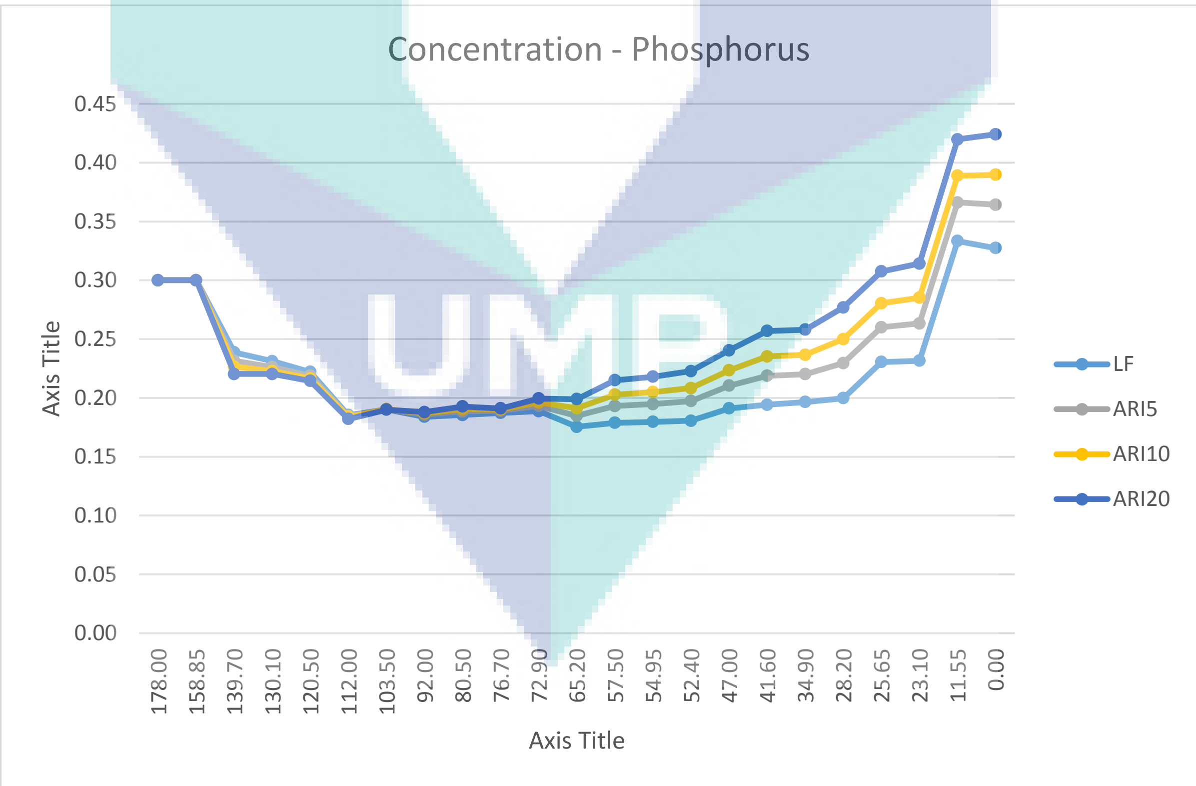


Figure 23.0: Sungai Muda Phosphorus (P) Spatial Trend (Concentration)

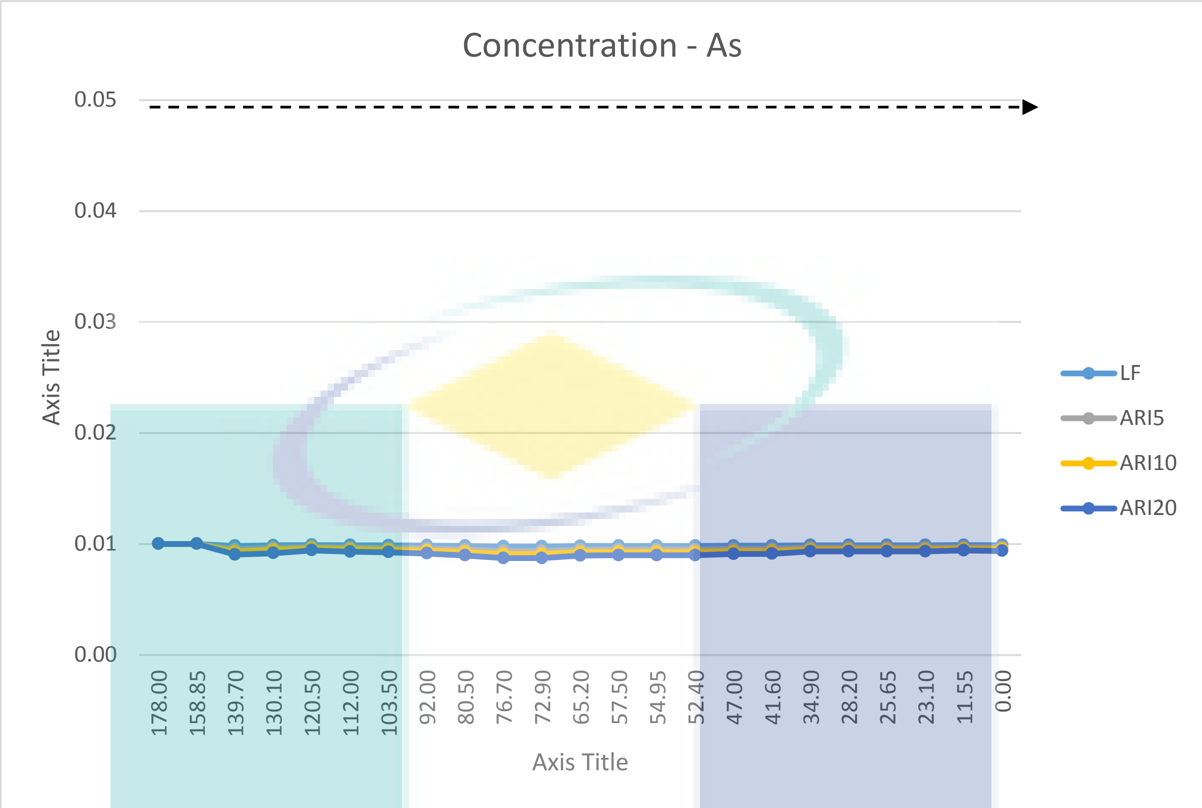


Figure 24.0: Sungai Muda Arsenic (As) Spatial Trend (Concentration)

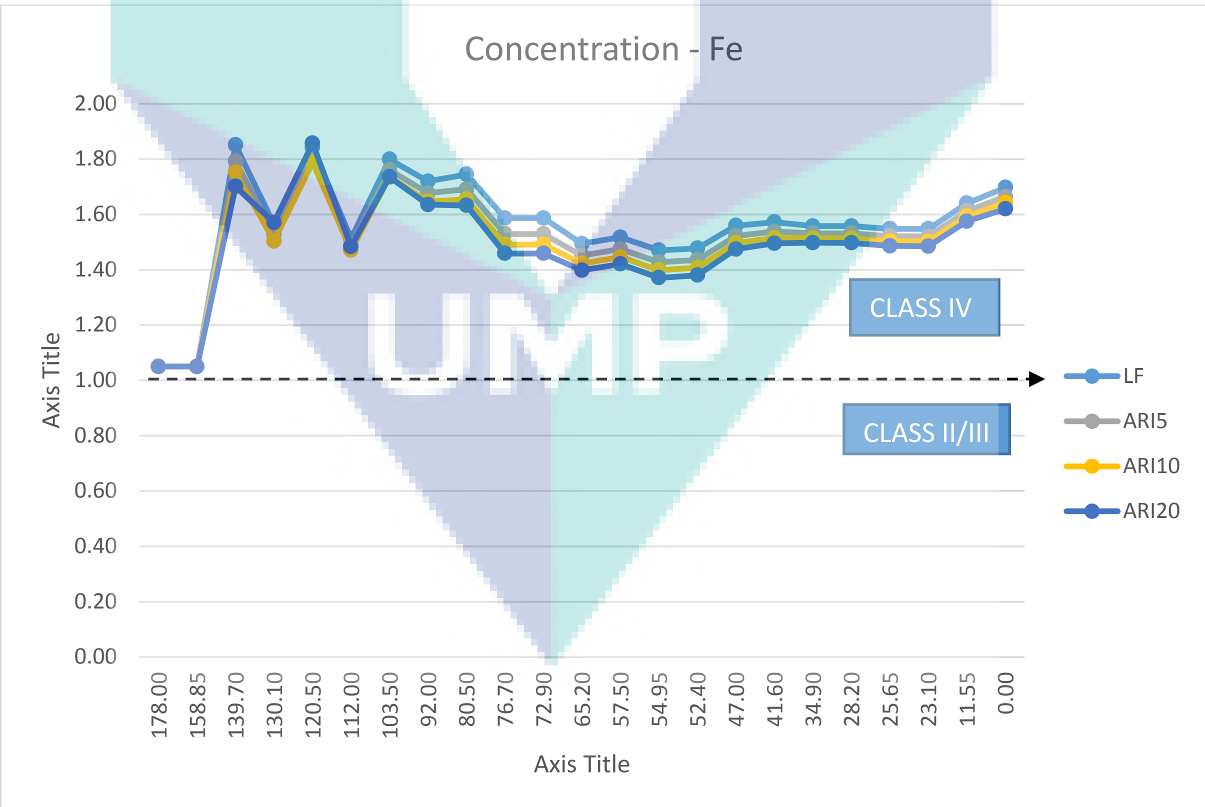


Figure 25.0: Sungai Muda Iron (Fe) Spatial Trend (Concentration)

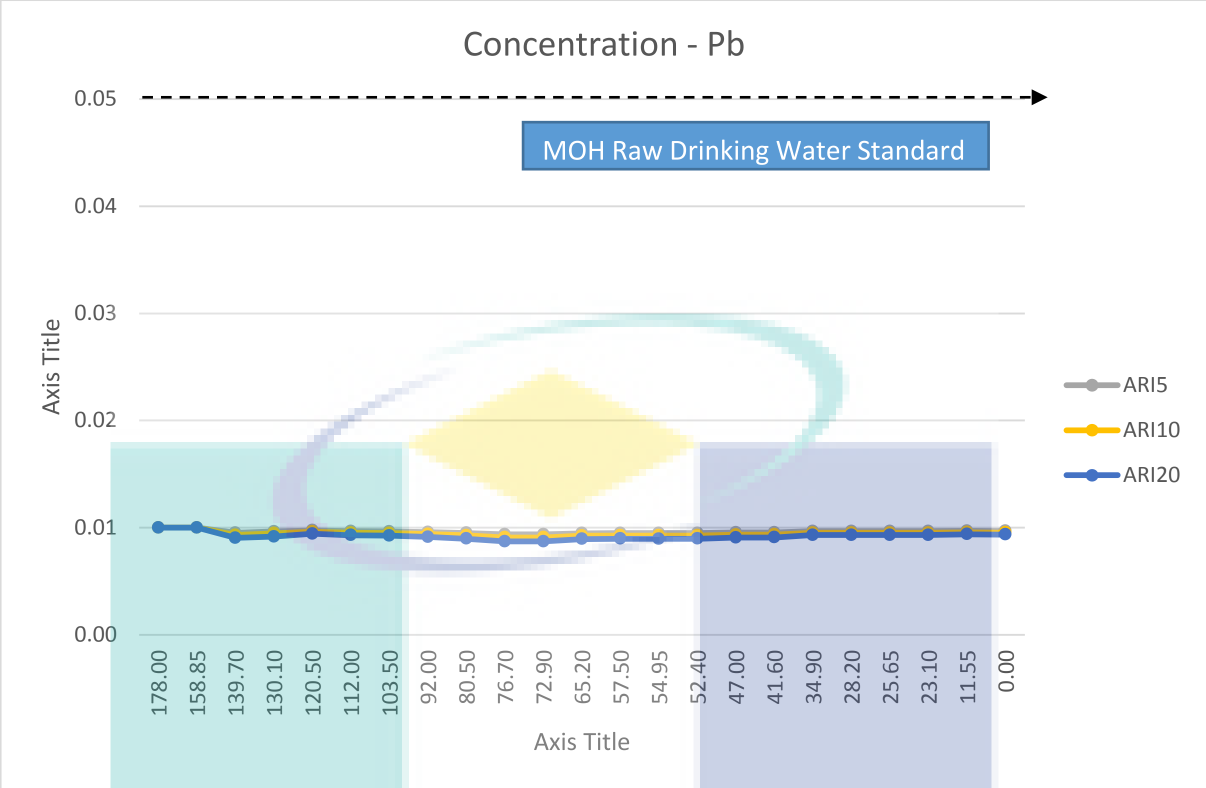


Figure 26.0: Sungai Muda Lead (Pb) Spatial Trend (Concentration)

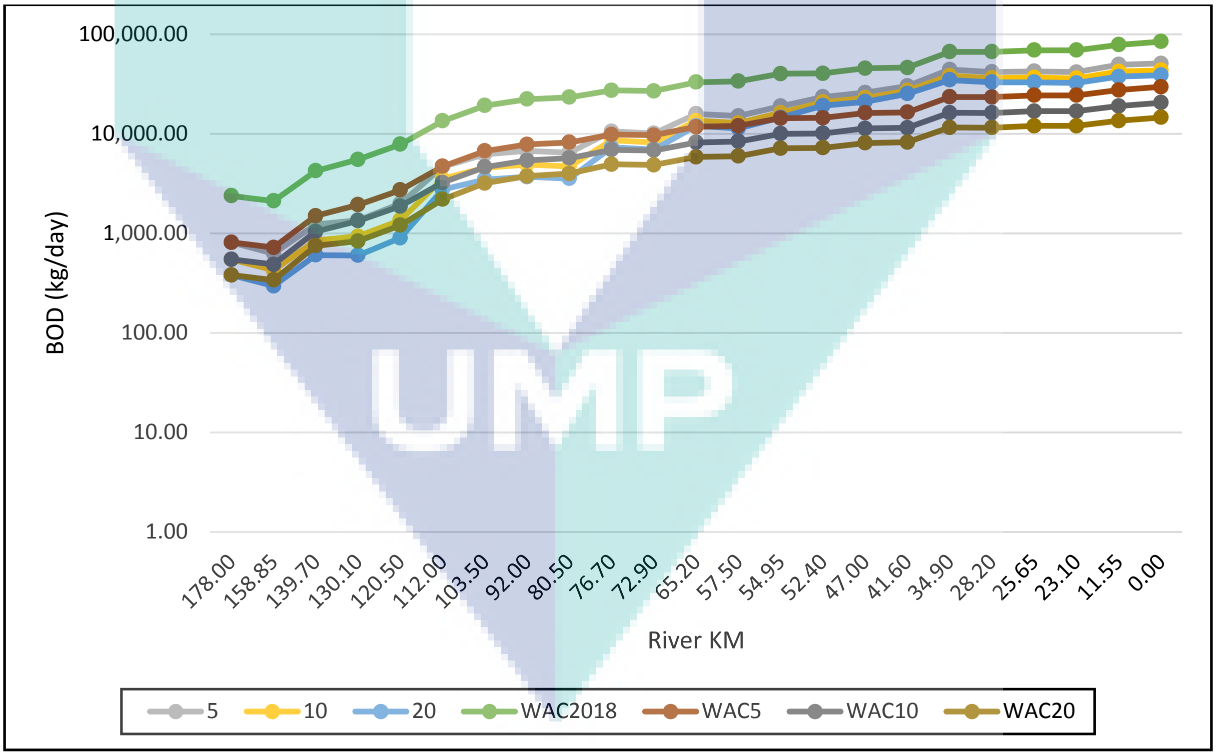


Figure 27.0: Sg Muda Biochemical Oxygen Demand (BOD) Spatial Trend (Loading)

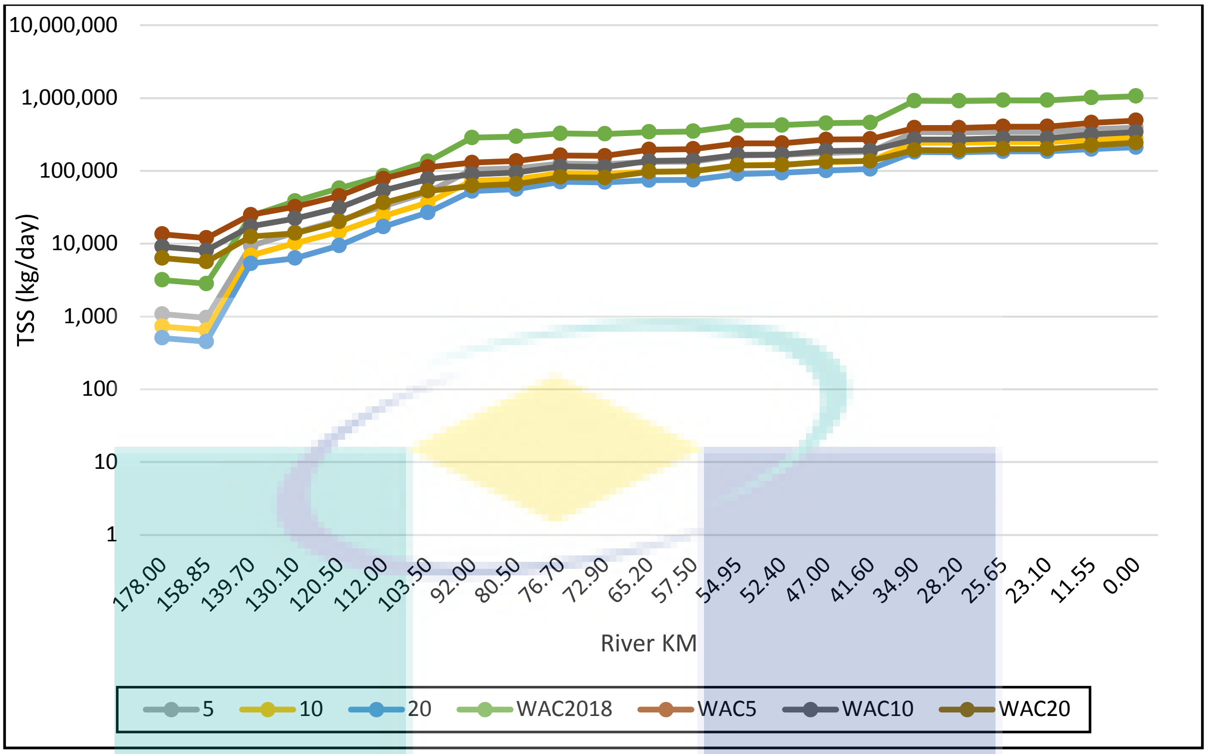


Figure 28.0: Sg Muda Total Suspended Solid (TSS) Spatial Trend (Loading)

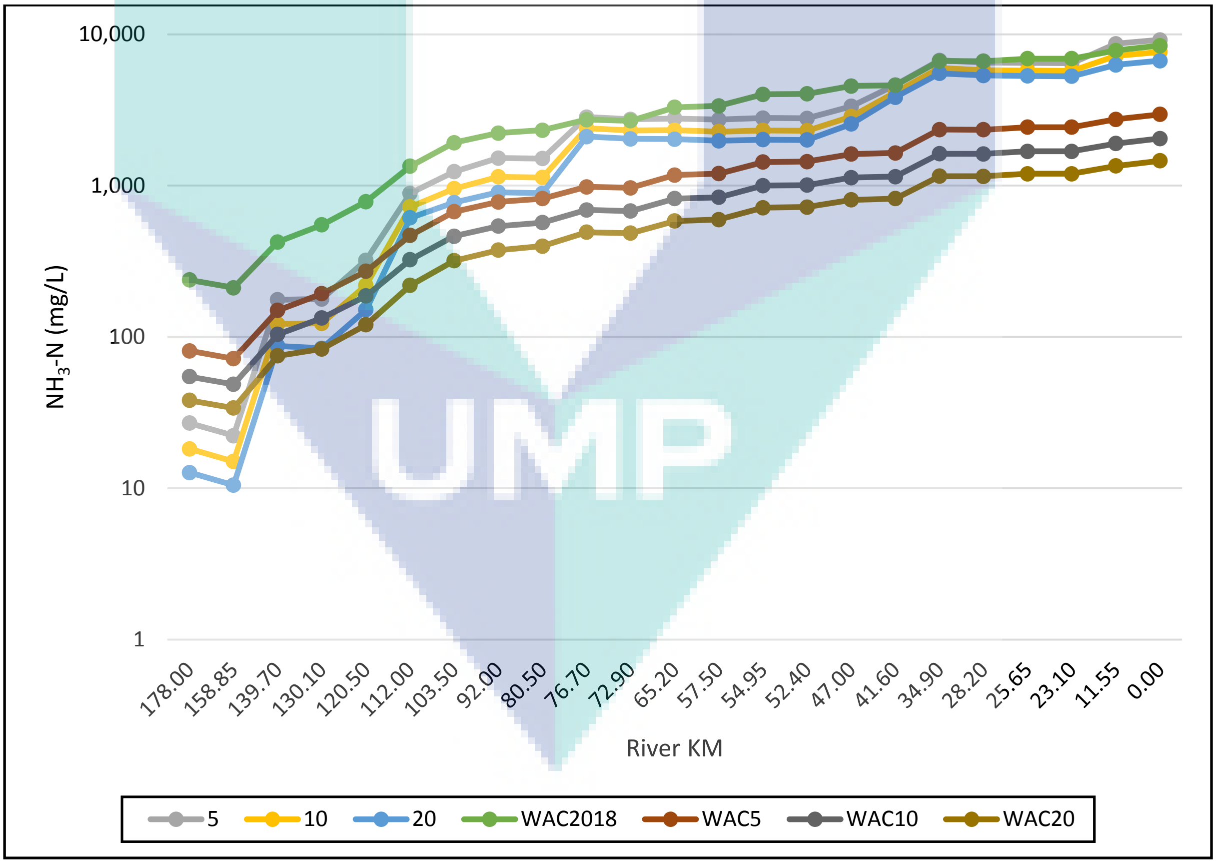


Figure 29.0: Sg Muda Ammoniacal Nitrogen (NH_3-N) Spatial Trend (Loading)

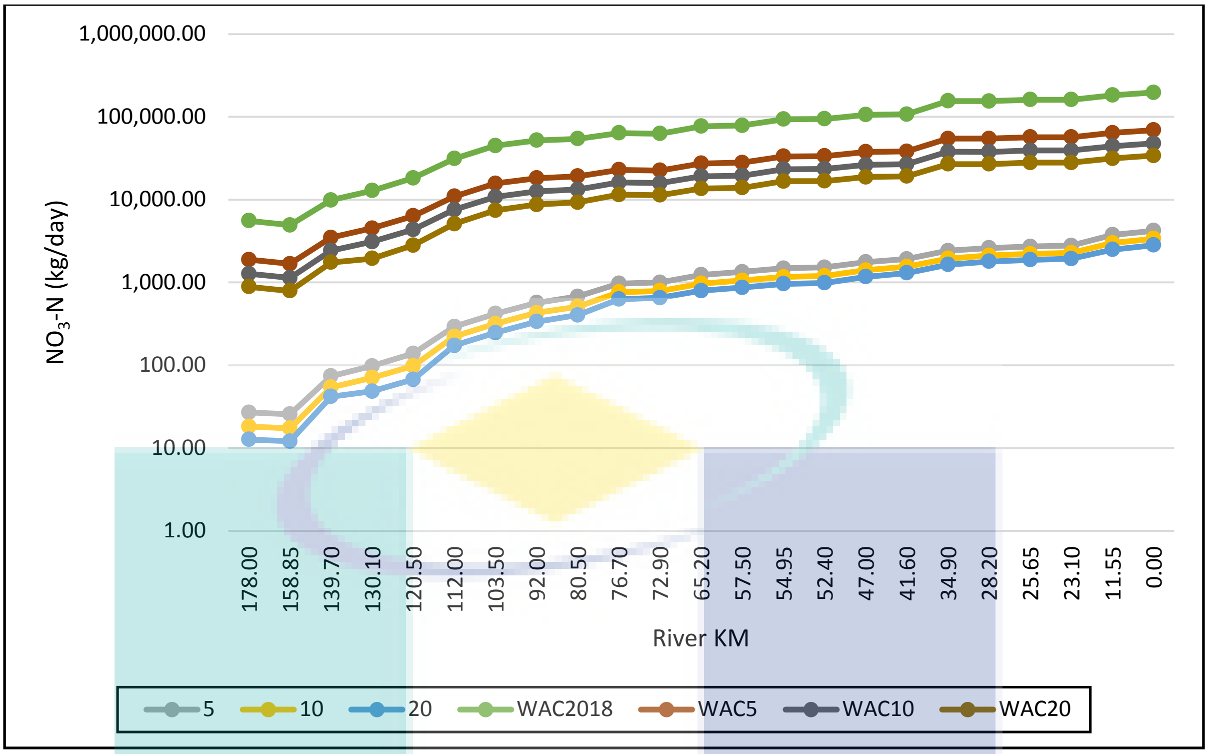


Figure 30.0: Sg Muda Nitrate (NO_3-N) Spatial Trend (Loading)

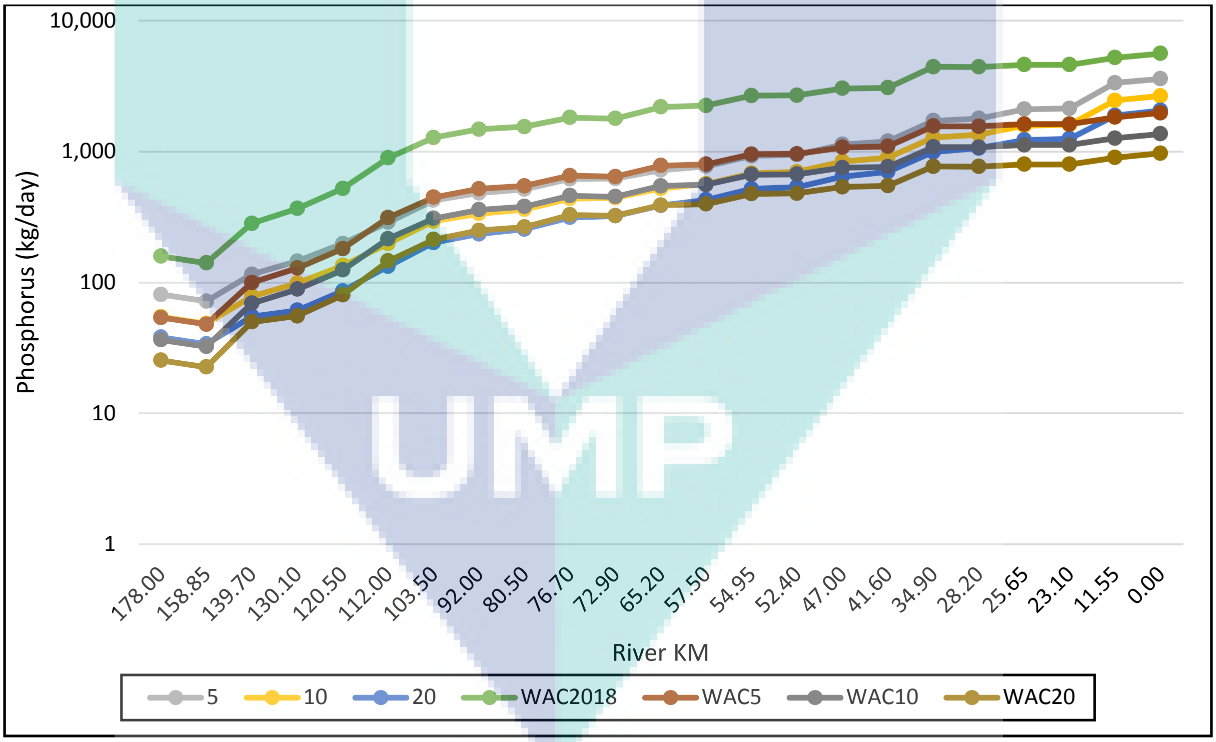


Figure 31.0: Sg Muda Phosphorus (P) Spatial Trend (Loading)

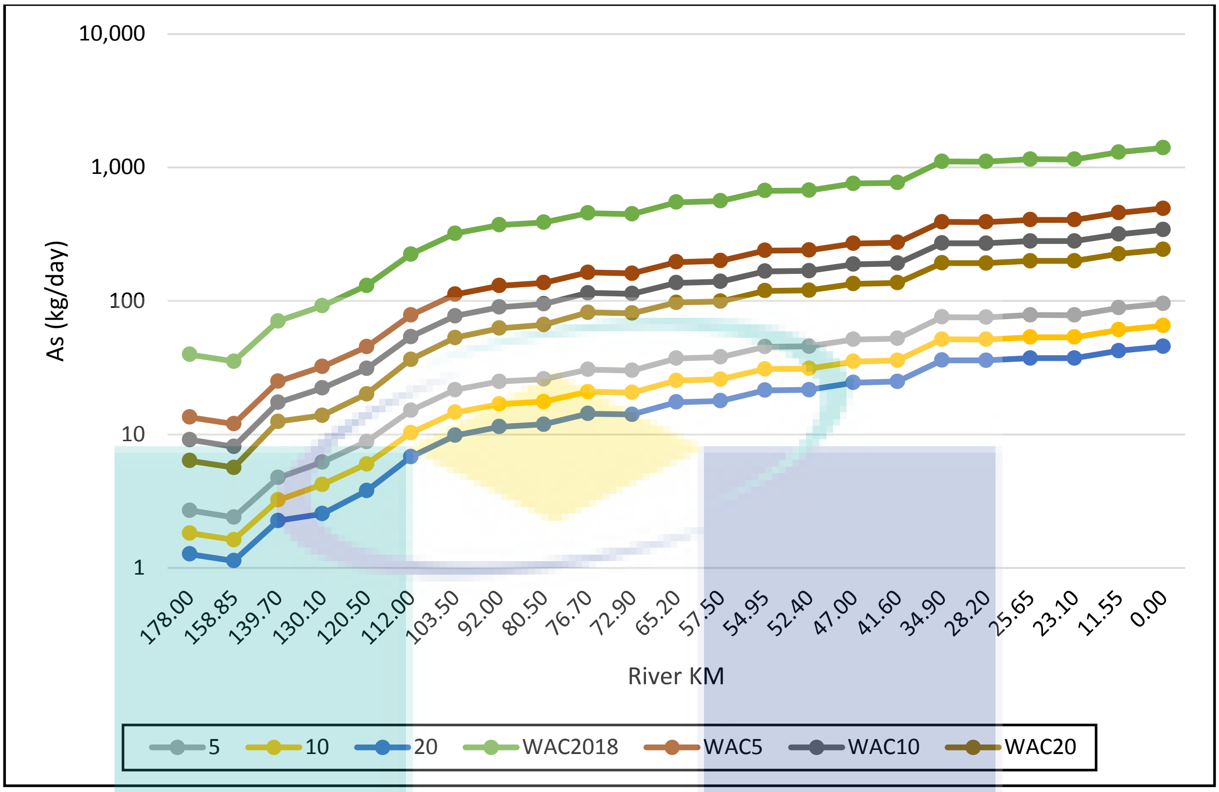


Figure 32.0: Sg Muda Arsenic (As) Spatial Trend (Loading)

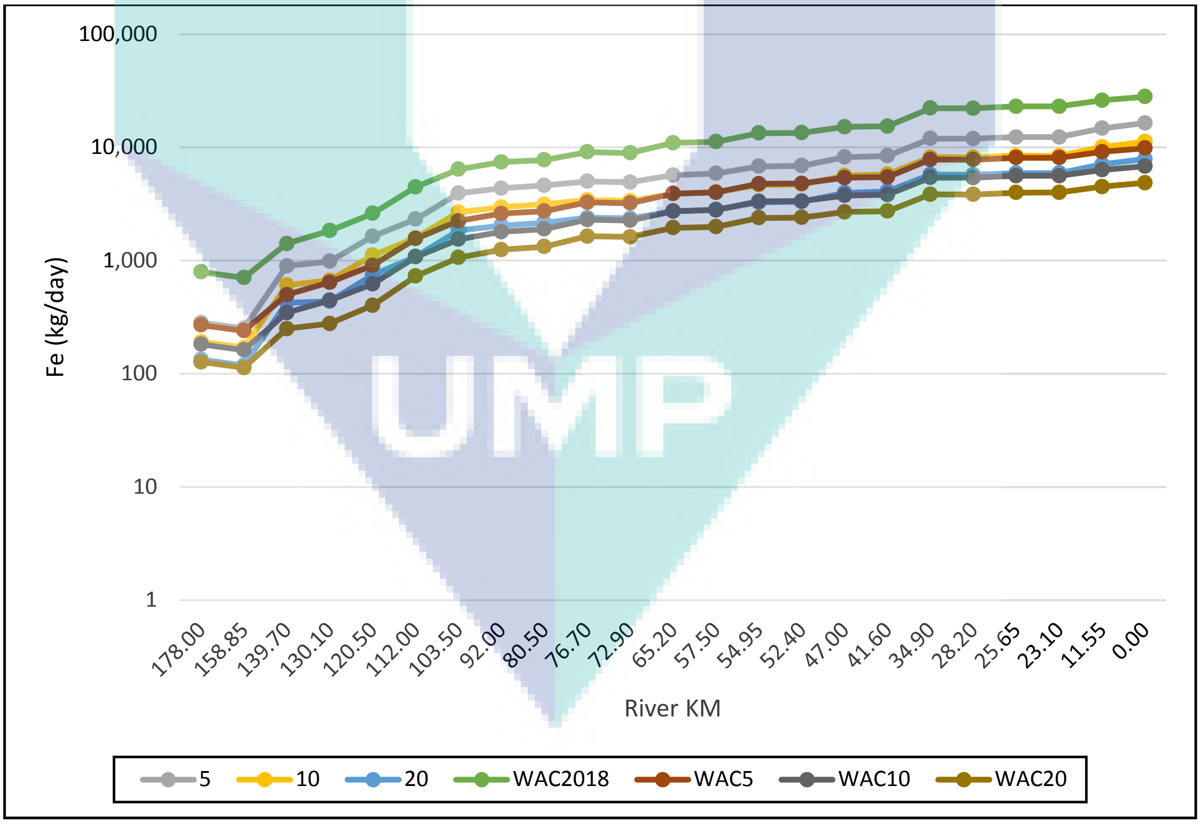


Figure 33.0: Sg Muda Iron (Fe) Spatial Trend (Loading)

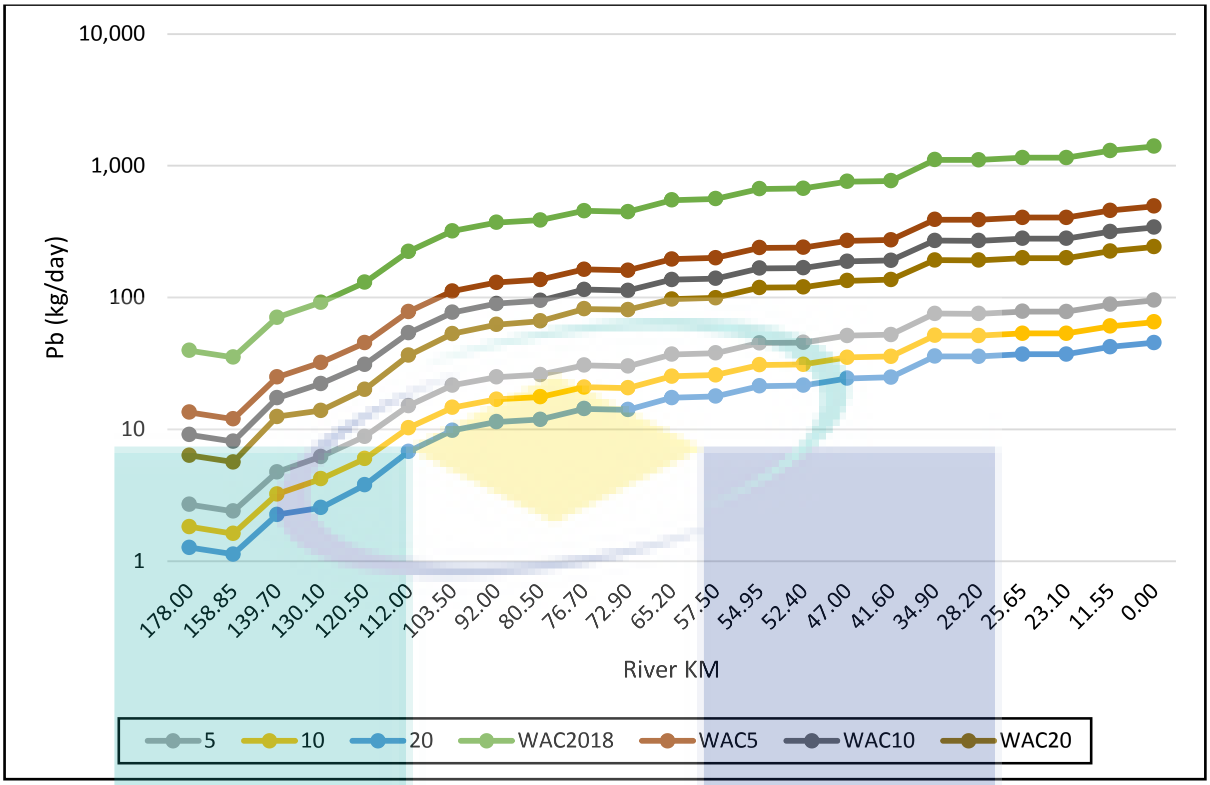


Figure 34.0: Sg Muda Lead (Pb) Spatial Trend (Loading)

Table 18.0: Load Reduction of Sg Muda Mainstream During Low Flow Relative to NWQS Class II

Distance	Loading BOD	Loading BOD	Load Reduction BOD %		Loading TSS	Loading TSS	Load Reduction TSS %		Loading NH_3-N	Loading NH_3-N	Load Reduction NH3-NH_3-N %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	2379	2379	0	0	39658	3173	-1150	-1265	238	79	-200	-220
158.85	2115	1848	-14	-16	35246	2820	-1150	-1265	211	65	-223	-246
139.70	4238	3512	-21	-23	70636	23989	-194	-214	424	502	16	17
130.10	5510	3892	-42	-46	91832	38335	-140	-154	551	509	-8	-9
120.50	7830	5747	-36	-40	130492	57665	-126	-139	783	931	16	17
112.00	13422	11476	-17	-19	223694	85399	-162	-178	1342	1886	29	32
103.50	19206	16068	-20	-21	320106	134906	-137	-151	1921	2916	34	38
92.00	22236	17686	-26	-28	370598	286706	-29	-32	2224	3779	41	45
80.50	23249	16988	-37	-41	387477	296446	-31	-34	2325	3763	38	42
76.70	27289	22503	-21	-23	454816	326560	-39	-43	2729	5520	51	56
72.90	26825	21435	-25	-28	447091	321013	-39	-43	2683	5330	50	55
65.20	32894	29682	-11	-12	548231	341601	-60	-67	3289	5507	40	44
57.50	33659	28558	-18	-20	560988	347979	-61	-67	3366	5455	38	42
54.95	40104	34891	-15	-16	668400	419686	-59	-65	4010	5647	29	32
52.40	40379	39256	-3	-3	672987	424465	-59	-64	4038	5631	28	31
47.00	45493	44226	-3	-3	758210	451995	-68	-75	4549	6202	27	29
41.60	46095	47894	4	4	768253	460786	-67	-73	4610	7472	38	42
34.90	66623	78475	15	17	1110390	918227	-21	-23	6662	11110	40	44
28.20	66401	74084	10	11	1106675	915262	-21	-23	6640	10730	38	42
25.65	69086	77104	10	11	1151441	932866	-23	-26	6909	10792	36	40
23.10	69038	75565	9	10	1150636	932358	-23	-26	6904	10687	35	39
11.55	78169	93503	16	18	1302811	1008494	-29	-32	7817	17432	55	61
0.00	84149	94884	11	12	1402480	1061812	-32	-35	8415	18304	54	59

Table 19.0:

Distance	Loading NO_3	NO_3 Loading	NO_3 Load Reduction %		Loading P	P Loading	P Load Reduction %		Loading As	As Loading	As Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	5552	79	-6900	-7590	159	238	33	37	40	8	-400	-440
158.85	4934	75	-6436	-7079	141	211	33	37	35	7	-400	-440
139.70	9889	192	-5046	-5550	283	337	16	18	71	14	-409	-449
130.10	12857	263	-4781	-5259	367	425	13	15	92	18	-406	-447
120.50	18269	381	-4692	-5161	522	579	10	11	130	26	-404	-445
112.00	31317	715	-4281	-4710	895	829	-8	-9	224	44	-406	-446
103.50	44815	1034	-4235	-4658	1280	1217	-5	-6	320	63	-406	-447
92.00	51884	1411	-3578	-3936	1482	1364	-9	-10	371	73	-407	-448
80.50	54247	1659	-3170	-3487	1550	1437	-8	-9	387	76	-409	-450
76.70	63674	2208	-2783	-3062	1819	1704	-7	-7	455	89	-412	-453
72.90	62593	2263	-2665	-2932	1788	1688	-6	-7	447	87	-412	-453
65.20	76752	2841	-2602	-2862	2193	1923	-14	-15	548	108	-409	-450
57.50	78538	3062	-2465	-2711	2244	2006	-12	-13	561	110	-409	-450
54.95	93576	3376	-2672	-2939	2674	2401	-11	-12	668	131	-409	-450
52.40	94218	3452	-2629	-2892	2692	2431	-11	-12	673	132	-409	-450
47.00	106149	3918	-2609	-2870	3033	2896	-5	-5	758	149	-408	-449
41.60	107555	4159	-2486	-2734	3073	2983	-3	-3	768	151	-408	-449
34.90	155455	5235	-2869	-3156	4442	4363	-2	-2	1110	220	-406	-446
28.20	154935	5549	-2692	-2961	4427	4421	0	0	1107	219	-406	-446
25.65	161202	5786	-2686	-2955	4606	5308	13	15	1151	228	-406	-446
23.10	161089	5907	-2627	-2890	4603	5331	14	15	1151	228	-406	-446
11.55	182394	8315	-2094	-2303	5211	8684	40	44	1303	258	-405	-445
0.00	196347	9305	-2010	-2211	5610	9182	39	43	1402	278	-405	-446

Table 20.0:

Distance	Fe Loading	Fe Loading	Fe Load Reduction %		Pb Loading	Pb Loading	Pb Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	793	833	5	5	40	8	-400	-440
158.85	705	740	5	5	35	7	-400	-440
139.70	1413	2615	46	51	71	14	-409	-449
130.10	1837	2873	36	40	92	18	-406	-447
120.50	2610	4806	46	50	130	26	-404	-445
112.00	4474	6768	34	37	224	44	-406	-446
103.50	6402	11517	44	49	320	63	-406	-447
92.00	7412	12747	42	46	371	73	-407	-448
80.50	7750	13520	43	47	387	76	-409	-450
76.70	9096	14432	37	41	455	89	-412	-453
72.90	8942	14187	37	41	447	87	-412	-453
65.20	10965	16385	33	36	548	108	-409	-450
57.50	11220	17022	34	37	561	110	-409	-450
54.95	13368	19660	32	35	668	131	-409	-450
52.40	13460	19889	32	36	673	132	-409	-450
47.00	15164	23653	36	39	758	149	-408	-449
41.60	15365	24160	36	40	768	151	-408	-449
34.90	22208	34597	36	39	1110	220	-406	-446
28.20	22134	34480	36	39	1107	219	-406	-446
25.65	23029	35648	35	39	1151	228	-406	-446
23.10	23013	35618	35	39	1151	227	-406	-446
11.55	26056	42740	39	43	1303	258	-405	-446
0.00	28050	47604	41	45	1402	277	-406	-446

Table 21.0: Load Reduction of Sg Muda Mainstream During High Flow Relative to NWQS Class II

Distance	Loading BOD	Loading BOD	Load Reduction BOD %		Loading TSS	Loading TSS	Load Reduction TSS %		Loading NH_3-N	Loading NH_3-N	Load Reduction NH3-NH_3-N %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	kg/day	Class II	Class II	+10% MOS
178.00	2379	26599	91	100	39658	98985	60	66	238	982	76	83
158.85	2115	22829	91	100	35246	96854	64	70	211	896	76	84
139.70	4238	23551	82	90	70636	115354	39	43	424	1040	59	65
130.10	5510	23160	76	84	91832	131471	30	33	551	1100	50	55
120.50	7830	26756	71	78	130492	155083	16	17	783	1191	34	38
112.00	13422	37941	65	71	223694	174279	-28	-31	1342	2604	48	53
103.50	19206	48859	61	67	320106	223704	-43	-47	1921	2861	33	36
92.00	22236	50932	56	62	370598	271373	-37	-40	2224	3164	30	33
80.50	23249	50423	54	59	387477	287543	-35	-38	2325	3115	25	28
76.70	27289	58666	53	59	454816	313582	-45	-50	2729	4598	41	45
72.90	26825	54276	51	56	447091	298865	-50	-55	2683	4310	38	42
65.20	32894	64994	49	54	548231	316501	-73	-81	3289	4779	31	34
57.50	33659	63074	47	51	560988	325447	-72	-80	3366	4667	28	31
54.95	40104	73155	45	50	668400	507936	-32	-35	4010	5492	27	30
52.40	40379	77183	48	52	672987	513565	-31	-34	4038	5450	26	28
47.00	45493	86618	47	52	758210	567542	-34	-37	4549	6174	26	29
41.60	46095	89412	48	53	768253	578135	-33	-36	4610	7386	38	41
34.90	66623	115204	42	46	1110390	1216861	9	10	6662	12538	47	52
28.20	66401	109141	39	43	1106675	1217034	9	10	6640	12160	45	50
25.65	69086	113918	39	43	1151441	1250162	8	9	6909	12327	44	48
23.10	69038	111686	38	42	1150636	1250453	8	9	6904	12218	43	48
11.55	78169	126901	38	42	1302811	1342900	3	3	7817	14317	45	50
0.00	84149	145709	42	46	1402480	1461935	4	4	8415	14254	41	45

Table 22.0:

Distance	Loading NO_3	NO_3 Loading	NO_3 Load Reduction %		Loading P	P Loading	P Load Reduction %		Loading As	As Loading	As Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	5552	491	-1031	-1134	159	1182	87	95	40	49	19	21
158.85	4934	544	-807	-888	141	1156	88	97	35	48	27	29
139.70	9889	609	-1523	-1675	283	1269	78	86	71	54	-30	-33
130.10	12857	711	-1709	-1880	367	1373	73	81	92	59	-57	-62
120.50	18269	764	-2291	-2520	522	1562	67	73	130	60	-119	-131
112.00	31317	1158	-2605	-2866	895	1815	51	56	224	152	-47	-52
103.50	44815	1288	-3379	-3717	1280	2296	44	49	320	154	-108	-118
92.00	51884	1556	-3234	-3558	1482	2683	45	49	371	162	-128	-141
80.50	54247	1733	-3030	-3333	1550	2836	45	50	387	163	-138	-151
76.70	63674	2365	-2592	-2851	1819	3052	40	44	455	179	-154	-169
72.90	62593	2324	-2593	-2853	1788	2920	39	43	447	171	-162	-178
65.20	76752	3355	-2188	-2407	2193	3620	39	43	548	209	-163	-179
57.50	78538	3518	-2133	-2346	2244	3721	40	44	561	212	-164	-181
54.95	93576	5483	-1607	-1767	2674	4460	40	44	668	248	-169	-186
52.40	94218	5547	-1598	-1758	2692	4496	40	44	673	249	-170	-187
47.00	106149	5901	-1699	-1869	3033	4705	36	39	758	278	-173	-190
41.60	107555	6118	-1658	-1824	3073	4805	36	40	768	281	-174	-191
34.90	155455	11462	-1256	-1382	4442	7242	39	43	1110	375	-196	-215
28.20	154935	11830	-1210	-1331	4427	7313	39	43	1107	375	-195	-214
25.65	161202	12520	-1188	-1306	4606	7773	41	45	1151	388	-197	-217
23.10	161089	12661	-1172	-1290	4603	7800	41	45	1151	388	-197	-216
11.55	182394	13582	-1243	-1367	5211	10360	50	55	1303	399	-226	-249
0.00	196347	14215	-1281	-1409	5610	11383	51	56	1402	404	-247	-272

Table 23.0:

Distance	Fe Loading	Fe Loading	Fe Load Reduction %		Pb Loading	Pb Loading	Pb Load Reduction %	
	Class II	kg/day	Class II	+10% MOS	Class II	kg/day	Class II	+10% MOS
178.00	793	5153	85	93	40	49	19	21
158.85	705	5042	86	95	35	48	27	29
139.70	1413	5643	75	82	71	54	-30	-33
130.10	1837	5996	69	76	92	59	-57	-62
120.50	2610	6941	62	69	130	68	-92	-101
112.00	4474	13441	67	73	224	90	-148	-163
103.50	6402	15812	60	65	320	114	-181	-199
92.00	7412	17588	58	64	371	129	-186	-205
80.50	7750	18296	58	63	387	136	-184	-202
76.70	9096	18602	51	56	455	154	-196	-216
72.90	8942	17729	50	55	447	146	-205	-226
65.20	10965	18581	41	45	548	185	-197	-217
57.50	11220	18938	41	45	561	188	-198	-218
54.95	13368	23061	42	46	668	224	-198	-218
52.40	13460	23197	42	46	673	225	-199	-219
47.00	15164	25922	42	46	758	254	-199	-219
41.60	15365	26233	41	46	768	256	-200	-220
34.90	22208	49158	55	60	1110	351	-216	-238
28.20	22134	49158	55	60	1107	351	-215	-237
25.65	23029	50096	54	59	1151	364	-217	-238
23.10	23013	50096	54	59	1151	364	-217	-238
11.55	26056	54430	52	57	1303	392	-233	-256
0.00	28050	59010	52	58	1402	437	-221	-243

5 CONCLUSION

The water quality of Sg Muda in 2016 registered NWQS Class II – Class III. This water quality notation was in accordance to the monitoring results by DOE through its 12 nos of existing Manual Water Quality Stations (MWQS) within Sg Muda Basin. From the analysis of the previous data provided, it can be presumed that the water quality of Sg Muda Basin was degraded in terms of organic and heavy metal parameters such as BOD, TSS and Fe.

During the IRBM study, thrity nine (39) of sampling stations covering Sg Muda Basin were deployed. Two (2) sampling periods were applied; 1. Low Flow (sampling conducted on 25th May 2018) 2. High Flow (sampling conducted on 29th October 2018). In addition to that, hydraulic parameters of the sampling points were also aquired. From the assessment conducted, the upper stream of Sg Muda is considered 'Clean' and registered NWQS Class II during both periods. However, during the low flow assessment, at the mid-stream of Sg Muda, the water quality of Sg Muda started to experience water quality degradation. At the downstream, severe degradation registering NWQS Class IV was observed.

Any stream can assimilate a certain amount of waste and still maintain a level of dissolved oxygen (DO) that high enough to support a healthy population of fish and other aquatic organisms. However, if the assimilative capacity is exceeded, the concentration of DO will decrease below the level required to protect organism in that particular stream. By applying this concept to the water quality study of Sg Muda, the assimilative capacity of Sg Muda was determined from the water quality simulation; in this study QUAL2K was deployed. Depending to the current condition of the Sg Muda whether it is within or beyond the NWQS Class II setting, the total amount of pollution load (kg/day) that the Sg Muda and its tributaries can sustain or need to be reduced was determined.

The simulation results obtained for Scenario 1 show that the Sg Muda Basin is experiencing occurrences of which load exceeded the river carrying capacity or Waste Assimilative Capacity (WAC) for several water quality parameters such as BOD, TSS, NH3-N, P and Fe. Sg Korok is the most river experiencing with organic loads that exceeded its WAC; BOD – 85% and NH3-N – 96%. In addition to that, Sg Korok is having 95% of P load exceeded its WAC as well as heavy metal; Fe - 49%. This was followed by Sg Jerong with BOD – 56%, P – 85% and Fe – 33%. Based on the analysis, Sg Jenen and Sg Sedim are currently having an excessive load of TSS exceeded the river WAC by 79% and 13%. These two rivers are also experiencing excessive load of BOD, NH3-N and Fe violated the river WAC.

For the worst case scenarios, simulation using the lowest discharge over a period of one week with a recurrence interval of 5 (LF7Q5), 10 (LF7Q10) and 20 (LF7Q20) years were applied in this study. The simulation results obtained show that there was an increment in terms of the pollutants load within the Sg Muda Basin which exceeded the carrying capacity of the river. The BOD load exceeded the WAC by 35%, 47% and 58% during ARI 5, ARI 10 and ARI 20 respectively. The NH3-N load exceeded the WAC by 61%,

68% and 75% during ARI 5, ARI 10 and ARI 20; the P load exceeded the WAC by 19%, 23% and 29% during ARI 5, ARI 10 and ARI 20 and the Fe load exceeded the WAC by 35%, 34% and 34% during ARI 5, ARI 10 and ARI 20.
Based on future development of Sg Muda Basin (RTD), in 2035 agriculture sector is the sector that will experiencing major expansion within most of the sub-basins. In this study, future scenario of the carrying capacity of Sg Muda mainstream as well as its tributaries were also simulated. The simulation results show that Sg Muda mainstream will experience an increment of the riverine load of BOD, TSS, NH3-N, NO3-N, P and Fe by 11%, 11%, 15%, 18% 23% and 40% from the baseline load in 2018 (Scenario 1). However, either the load exceed the river WAC is the question could be answered only with WAC determination of the river based on its intended use. In this case, again NWQS Class II is expected for all river. From the analysis, no significant changes in terms of its violation to the river WAC were simulated as compared to Scenario 1. Although the violation simulated during future development showed no increment, it does not allow the regulator to escape in overcoming the current issues in the Sg Muda Basin. It is believed that the current control approach to the various issues related to water pollution has prevalent shortcomings; blatanly, the compliance to limits in the regulations prescribed under the Environmental Quality Act, 1974, does not guarantee preservation of surface water bodies. It is time to change our control approach to something more effective. One of the options is load based control, or known as the TMDL approach. Basically, Total Maximum Daily Load (TMDL) is a regulatory term in the U.S. Clean Water Act, describing a value of the maximum amount of a pollutant that a body of water can receive while still meeting water quality standards. Calculating the TMDL for any given body of water involves the combination of factors that contribute to the problem. Bodies of water are tested for contaminants based on their intended use. Each body of water is tested similarly but designated with a specific TMDL. The size of the water body also is taken into consideration when TMDL calculation is undertaken. In essence, TMDL comprises of waste load allocation and load allocation. In case if the TMDL of any particular pollutants higher than its waste assimilative capacity (WAC), this indicate a worsening of present water quality status. TMDL calculation (Scenario 1 and Scenario 2) for all sub-basins showed that they experienced TMDL of BOD exceeded the river carrying capacity or waste assimilative capacity (WAC). From the TMDL analysis, the contributor of the pollutant loading into the Sg Muda Basin as well as its sub-basin could be able to recognise and was summarised as in Table 4.5.4 (Main Report). Initially by calculating the TMDL, the concentration of each water quality parameters simulated would be able to estimate. For BOD, all sub-basins were within NWQS Class III – Class IV; for TSS, all sub-basins were within NWQS Class II – Class IV; for NH3-N, all sub basins were within NWQS Class II – Class IV; for Fe, all sub-basins were well within NWQS Class II – Class IV.

Generally, the pollution contributor can be categorised into point source (PS) and non-point source (NPS). In this case, for Sg Muda Basin, both sources have been identified and further investigation showed that under the NPS the main contributor was agriculture activities. Meanwhile under PS several have been identified such as market, animal husbandry, restaurants and food court as amongst the activities attributed to the loading. From this IRBM study, several action plans would be able to outline and these action plans are basically based on the TMDL results.