essential to conduct an investigation on early warning system of local tsunami hazards.

2.1.8 Water Quality

Environmental baseline data collecting of water quality within the study area boundaries is performed for three types of waters, namely River, Nearshore, and Offshore.

2.1.8.1 River Water Quality

River water sampling was performed during the dry season (July – August 2012) and wet season (March – April 2013). Samples were taken from the Saengga River on the western boundary of the Tangguh LNG (SW-1) with coordinates 02° 27′ 59.8″ S - 133° 06′ 16.2 “ E and from Senindara River, east of the Tangguh LNG location (SW-3) with coordinates 02° 31′ 54.8″ S - 132° 16′ 29.3 “ E (**Map II-11**). Tidal condition during sampling is shown in **Figure II-39** – **Figure II-40**. River water sampling during the dry season at SW-1 coincided with the period approaching high tide, while at SW-3 it coincided with the period approaching lowest tide.

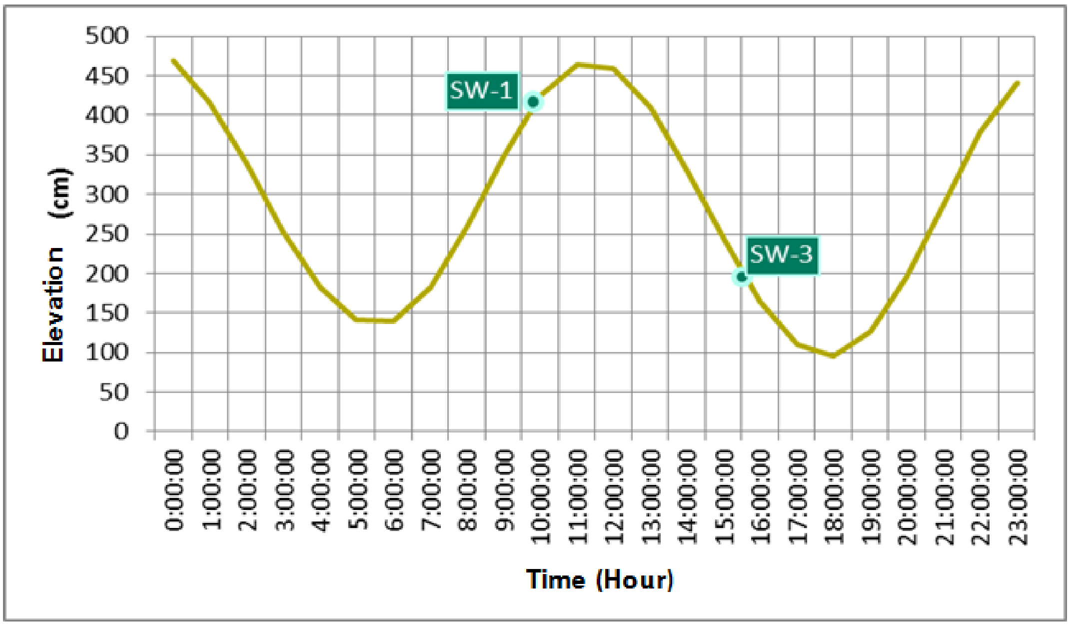


Figure II-39 Tidal Condition during Dry Season Sampling (August 9th, 2012)

Wet season sampling at SW-1 coincided with the period of lowest tide, while at SW-3 it coincided with the period approaching highest tide.

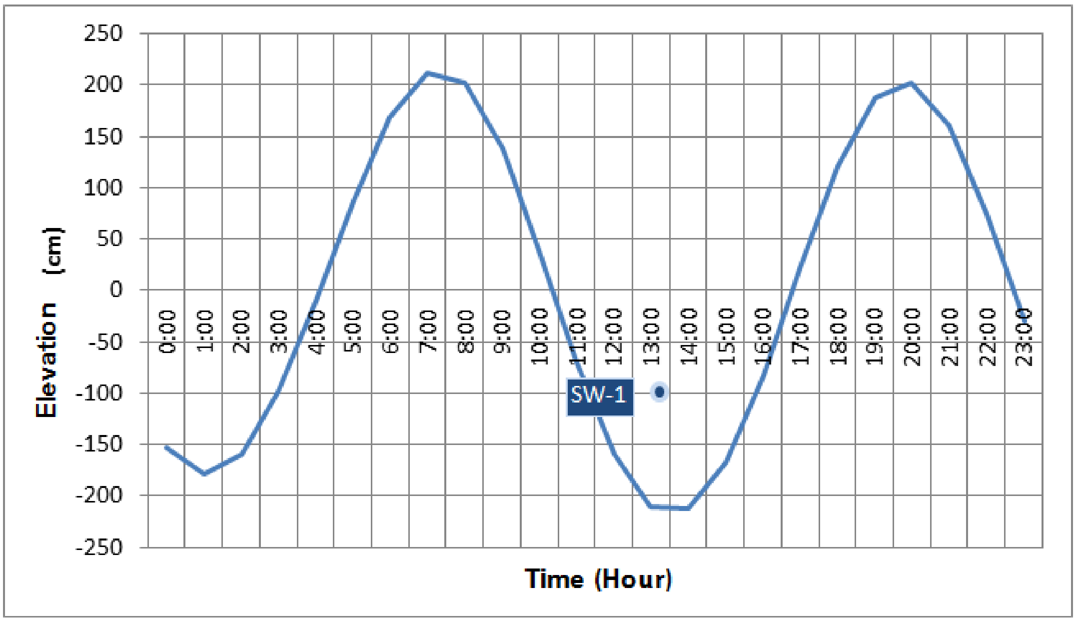


Figure II-40 Tidal Condition during Wet Season Sampling (March 12th, 2013)

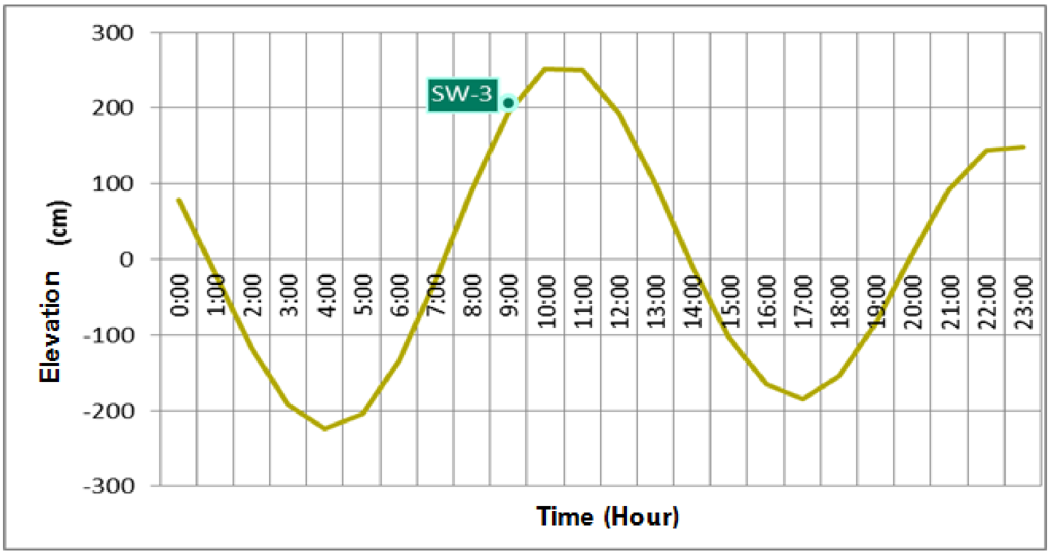


Figure II-41 Tidal Condition during Wet Season Sampling (March 17th, 2013)

The tabulation of river water quality analysis result can be seen in **Table II-29** for the fresh water quality and **Table II-30** for estuarine river water, while the certificate of the laboratory analysis results can be seen in **Appendix II-1.**

Table II-29 Laboratory Analysis Results of River Water Quality (Fresh Water Properties)

No.	Parameter	Unit	Water Quality Standard Class II[2]	SW-1 Wet Season
		Physical Test		
1	pH[1)]	-	6 - 9	6.45
2	Temperature[1)]	^{o}C	± 3	26.3
3	Total Dissolved Solids , TDS	mg/L	1,000	70
4	Total Suspended Solids, TSS	mg/L	50	129
		Anion		
1	Chloride, Cl	mg/L	-	33.0
2	Fluoride, F	mg/L	1,5	<0,02
3	Sulfate, SO_4	mg/L	-	7
4	Sulfide as H_2S	mg/L	0.002	<0.002
5	Total Cyanide, CN	mg/L	0.02	<0.005
		Nutrient		
1	Free Ammonia , NH_3-N	mg/L	-	<0.02
2	Nitrate, NO_3-N	mg/L	10	0.019
3	Nitrite, NO_2-N	mg/L	0.06	<0.001
4	Total Phosphor , P	mg/L	0.2	0.101
		Microbiological Test		
1	E.Coli	MPN/100ml	1000	40
2	Total Coliform	MPN/100ml	5000	326
		Dissolved Metals		
1	Arsenic, As	mg/L	1	0.0013
2	Barium, Ba	mg/L	-	<0.1
3	Boron, B	mg/L	1	<0.1
4	Cadmium, Cd	mg/L	0.01	<0.005
5	Chromium Hexavalent, Cr^{6+}	mg/L	0.05	<0.002
6	Cobalt, Co	mg/L	0.2	<0.02
7	Copper, Cu	mg/L	0.02	<0.01
8	Iron, Fe	mg/L	-	0.29
9	Lead, Pb	mg/L	0.03	0.002
10	Manganese, Mn	mg/L	-	0.05
11	Mercury, Hg	mg/L	0.002	<0.00005
12	Selenium, Se	mg/L	0.05	<0.0005
13	Zinc, Zn	mg/L	0.05	0.020
		Others		
1	Biochemical Oxygen Demand, BOD_5	mg/L	3	6
2	Chemical Oxygen Demand, COD	mg/L	25	28
3	Chlorine, Cl_2	mg/L	0,03	<0.01
4	Dissolved Oxygen, DO [1)]	mg/L	4	5.23
5	Oil & Grease	mg/L	1	<1
6	Surfactane, MBAS	mg/L	0.2	<0.01

No.	Parameter	Unit	Water Quality Standard Class II[2]	SW-1
				Wet Season
7	Phenol Compound, as Phenol	mg/L	0.001	<0.001

Source : Primary data, Measurement Results of the Lab Intertek, 2012 -2013
Note : 1) *Insitu measurement*
2) The quality standard in accordance with Government Regulation No. 82 Year 2001, Class II

Table II-30 Laboratory Analysis Results of River Water Quality* (Estuarine Water Properties)

No.	Parameter	Unit	SW-1	SW-3	
			Dry season	Dry season	Wet season
Physical Test					
1	pH[1)]	-	7.4	6.9	7.18
2	Temperature[1)]	^oC	26.2	27.9	29.7
3	Total Dissolved Solids, TDS	mg/L	27,700	33,200	23,400
4	Total Suspended Solids, TSS	mg/L	51	33	45
Anion					
1	Chloride, Cl	mg/L	13,800	12,600	11,700
2	Fluoride, F	mg/L	0.47	0.54	0.30
3	Sulfate, SO_4	mg/L	1,860	1,860	1,790
4	Sulfide as H_2S	mg/L	<0.002	<0.002	<0.002
5	Total Cyanide, CN	mg/L	<0.005	<0.005	<0.005
Nutrient					
1	Free Ammonia , NH_3-N	mg/L	<0.02	<0.02	<0,02
2	Nitrate, NO_3-N	mg/L	0.078	0.081	0.344
3	Nitrite, NO_2-N	mg/L	0.010	0.030	0.022
4	Total Phosphor , P	mg/L	0.074	<0.005	0.021
Microbiological Test					
1	E.Coli	MPN/100ml	47	201	23
2	Total Coliform	MPN/100ml	1550	>2,420	345
Dissolved metal					
1	Arsenic, As	mg/L	0.0012	0.0007	0.0022
2	Barium, Ba	mg/L	<0.1	<0.2	<0.1
3	Boron, B	mg/L	3.7	3.3	3.4
4	Cadmium, Cd	mg/L	<0.0001	<0.005	<0.005
5	Chromium Hexavalent, Cr^{6+}	mg/L	<0.002	<0.002	<0.002
6	Cobalt, Co	mg/L	<0.02	<0.02	<0.02
7	Copper, Cu	mg/L	<0.01	<0.01	<0.01
8	Iron, Fe	mg/L	<0.05	<0.05	<0.05
9	Lead, Pb	mg/L	<0.001	<0.001	<0.001
10	Manganese, Mn	mg/L	0.030	0.03	0.01
11	Mercury, Hg	mg/L	<0.00005	<0.00005	<0.00005
12	Selenium, Se	mg/L	<0.0005	<0.0005	<0.0005

No.	Parameter	Unit	SW-1	SW-3	
			Dry season	Dry season	Wet season
13	Zinc, Zn	mg/L	0.017	0.009	0.007
Others					
1	Biochemical Oxygen Demand, BOD_5	mg/L	<2	<2	<2
2	Chemical Oxygen Demand, COD	mg/L	<2	11	5
3	Chlorine, Cl_2	mg/L	<0.01	<0.01	<0.01
4	Dissolved Oxygen, DO 1)	mg/L	4.18	3.2	3.97
5	Oil & Grease	mg/L	<1	<1	<1
6	Surfactane, MBAS	mg/L	<0.01	<0.01	<0.01
7	Phenol Compound, as Phenol	mg/L	<0.001	<0.001	<0.001

Source: Primary data, Measurement Results of the Lab Intertek, 2012 -2013
Note:
1) *in situ measurement*
* Due to river water at SW-1 during dry season sampling , and at SW-3 both during dry and wet season were indicated as sea water quality, thus the results of the analysis in this case were neither compared with fresh water nor seawater quality standard since this is a transition zone.

In accordance with Government Regulation No. 82 Year 2001, the water encompasses all water above and below ground surface, except sea water and fossil water. Rivers that flow into Bintuni Bay are influenced strongly by tides, which during the dry season the sea water influence could reach several kilometers from the estuary. While during the wet season, sea water could be fresh water. In accordance with the provisions of Article 55 in Government Regulation No. 82 Year 2001: "in the event that water quality standard at the water source has not yet or has not been established, water quality criteria for Class II will apply".

A water body can be classified on the basis of salinity according to the *Venice System* (1958) as shown in **Table II-31** (Reid, 1961). Mixture of sea water and river water can cause changes to the cation and anion composition or water chemistry composition. The degree of seawater intrusion is usually measured from the amount of water salinity or TDS value. Seawater salinity generally ranged between 33 to $38^{0}/_{00}$ or average $35^{0}/_{00}$. While average fresh water salinity was $0,65^{0}/_{00}$ (Reid, 1961).

Table II-31 Classification of Water Body Based on Salinity* and TDS

Zone	Salinity ($^{0}/_{00}$)	TDS (mg/L) **)
Hyperhaline	>40	>40,800
Euhaline	40 – 30	40,800 – 30,600
Mixohaline	30 – 0.5	30,600 – 510
Mixoeuhaline	>30 however < around Euhaline	>30,600 however < around Euhaline
(Mixo-)polyhaline	30 – 18	30,600 – 18,360
(Mixo-)mesohaline	18 – 5	18,360 – 5,100
(Mixo-)oligohaline	5 – 0.5	5,100 – 510
Limnetic	<0.5	<510

Note :
*) Salinity 1 $^0/_{00}$ ≈ 1,020 mg/L TDS assuming that water density equals 1.02 kg/m^3
Source: Reid, 1961

The value of TDS could be associated with water salinity, in which 1$^0/_{00}$ salinity is equivalent to TDS 1,000 mg/L. In accordance with the *Venice System* (1958) criteria, Saengga River water at sampling location of SW-1 during the dry season was considered as brackish water (TDS 27,700 mg/L), and in the zone of (Mixo-) polyhaline, while in the wet season it was considered as fresh water (TDS 70 mg/L). Saengga River at location SW-1 was fresh water during the wet season, this is likely due to: (1) sampling at location SW-1 coinciding with lowest tide as shown in **Figure II-41**, (2) seawater intrusion in the wet season did not reach SW-1, as the river water current was quite strong and entered the Bintuni Bay.

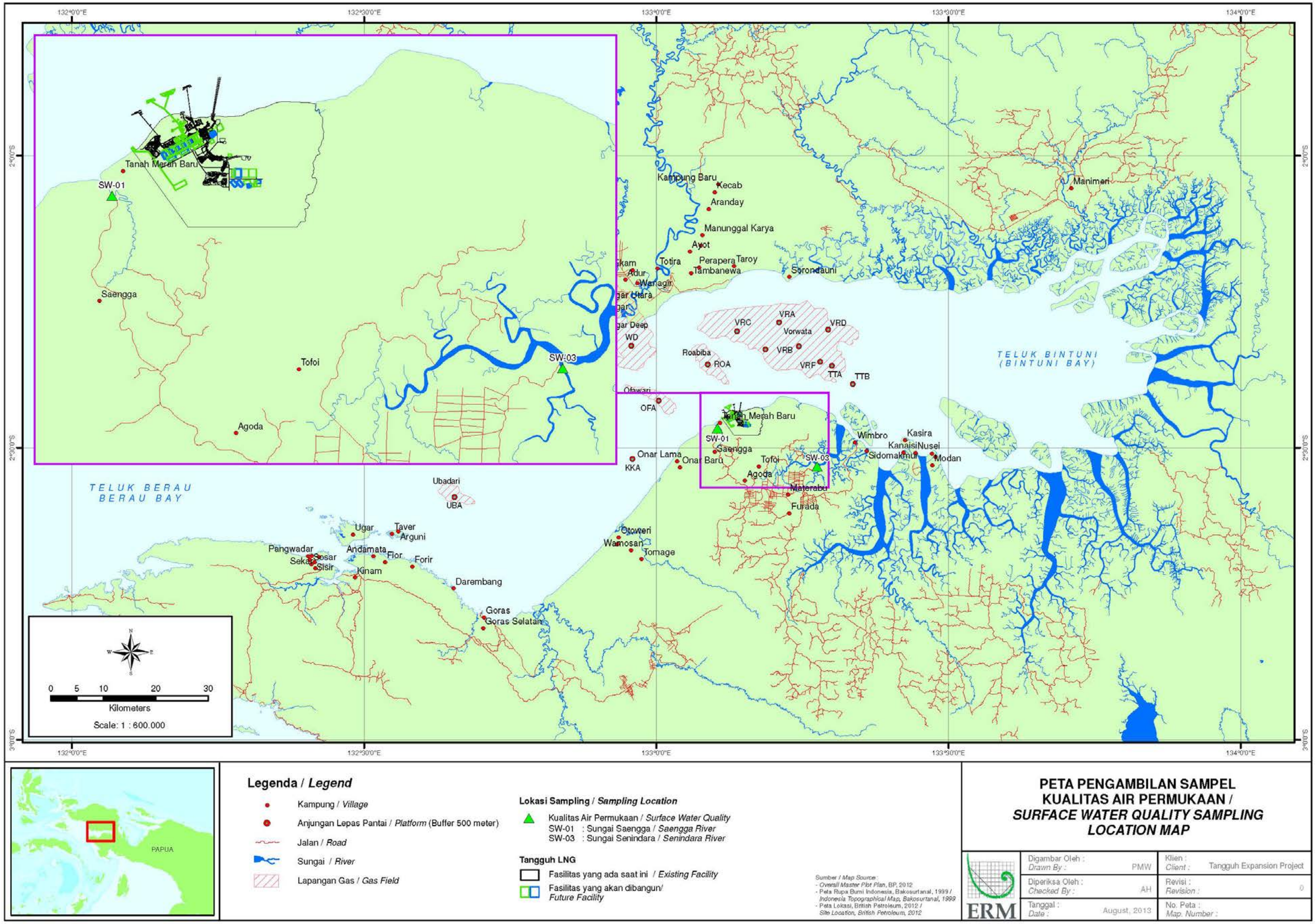
River water at sampling location of SW-3 (Senindara River) during the dry season was considered in Euhaline zone (TDS 33,200 mg/L) and during the wet season was considered in (Mixo-)polyhaline zone (TDS 23,400 mg/L).

The dominant influence of seawater in the two rivers , is shown by the high chloride and sulfate contents. Average chloride and sulfate content in seawater are respectively 19,300 mg/L and 2,700 mg/L (Anderson, 2008). Chloride content in locations of SW-1 and SW-3 in the dry season are respectively 13,800 mg/L, 12,600 mg/L and at SW-3 in the wet season is 11,700 mg/L. Similarly, sulfate content at SW-1 and SW-3 in the dry season is 1,860 mg/L and in the wet season is 1,790 mg/L. The high concentrations of chloride and sulfate indicate that the estuary of the river is greatly influenced by seawater intrusion.

Based on theabove and definition of water in accordance with Government Regulation No. 82 Year 2001, only river water in SW-1 in the wet season can be compared with Class II of water quality standard in accordance with Government Regulation No. 82 Year 2001, while in SW-1 and SW-3 in the dry season and SW-3 in wet season cannot be compared with fresh water quality standard since its quality approaches sea water quality.

In general, the water quality at SW-1 in the wet season (**Table II-31**) meets Class II of the water quality standard, except for the following parameters: TSS, BOD_5, COD. Relative high concentration of TSSwas detected due to heavy rain occurred prior to surface water sampling. High concentration of TSS (129 mg/L) indicates the amount of sediment material carried by rainwater runoff. The TSS quality standard is 50 mg/L.

Swamp and mangrove forest bed contain large amount of dissolved organic compounds as well as in colloid form (humic compound) as the result of plants decomposition. Much evidence shows that humic compounds found in water (characterized by reddish brown water) are similar to those found in soils (*Schnitzer*, 1972). Swamp and mangrove forest are quite dominant in the study area, which those are found in watersheds of Saengga and Senindara. Based on the above, rainwater runoff will carry the natural organic compounds into river waters that will cause relatively high BOD_5 and COD content (COD = 28 mg/L and BOD = 6 mg/L: COD Standard is 25 mg/L and BOD_5 is 3 mg/L). Excess organic matter content in water can decrease DO, since dissolved oxygen in water will be used by bacteria to oxidize organic substances (DO at SW-1 during wet season was detected at 5,23 mg/L, DO standard is 4 mg/L). Optimum oxygen content in fresh water at temperature of 27 ^{o}C and pressure of 1 atmosphere is around 7,8 mg/L.



Map II-12 Sampling Locations of River Water Quality

2.1.8.2 Groundwater Quality

Groundwater quality sampling was performed by taking water samples from community wells in the villages of Tanah Merah Baru (TMB) and Saengga, the nearest villages to the Tangguh LNG. The sampling was carried out in the dry season (July 2012) and wet season (March 2013). Information on the location and code of groundwater samples is shown in **Table II-32**, while sampling locations are shown in **Map II-2**. Community wells which the water samples were taken are shallow wells, with the exception of a well in Saengga (DGW 01) which is a bore well.

Groundwater quality of the samples were compared with Class I water quality classification (drinking water quality) of Government Regulation No. 82 Year 2001 regarding Water Quality Management and Water Pollution Control.

Laboratory analysis results of groundwater quality are shown in **Table II-32** and **Table II-33**, while the certificate can be found in **Appendix II**.

Generally the shallow groundwater quality of GW 01 and GW 02 (at Tanah Merah Baru) met the quality standard, except for parameters pH, and total coliform. Similarly, shallow groundwater quality of SGW 01 and SGW 02 (at Saengga village) generally met the quality standard except for parameters pH, fecal coli, total coliform. In general, deep groundwater quality (bore well , DGW 01) met quality standard in effect, with the exception of nitrite as N (N-NO_2).

Table II-32 Groundwater Sampling

Sampling Point Code	Location	Coordinates		Dry season	Wet season
		South	East		
DGW 01	Saengga village	02^0 27' 59.8"	133^0 06' 16.2"	√	√
SGW 01	Saengga village	02^0 28' 18.1"	133^0 06' 14.9"	√	√
SGW 02	Saengga village	02^0 28' 09.9"	133^0 06' 23.7"	√	√
GW 01	TMB village	02^0 27' 25.0"	133^0 06' 44.3"	√	√
GW 02	TMB village	02^0 27' 29.4"	133^0 06' 53.1"	√	√

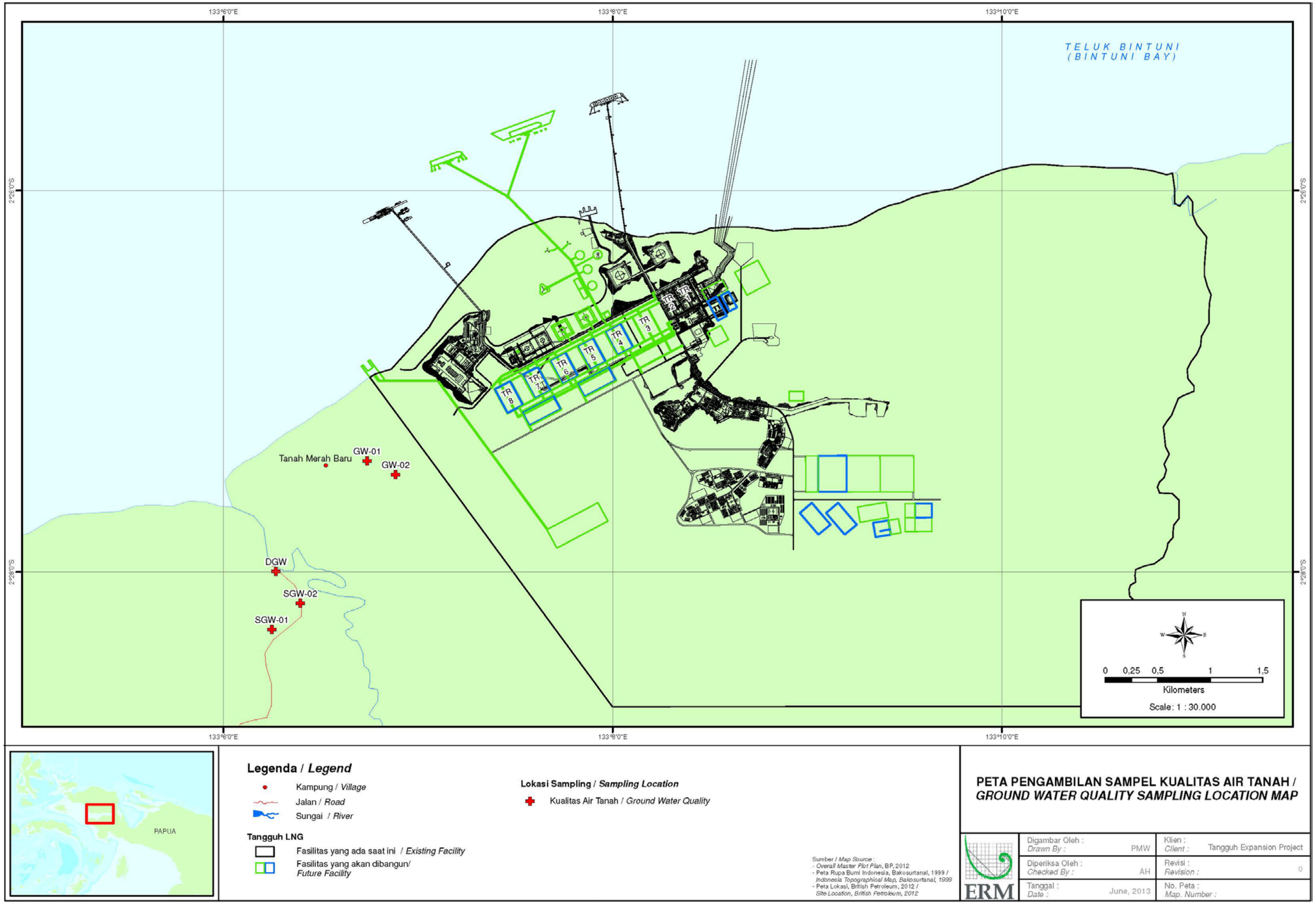
Table II-33 Laboratory Analysis Results of Groundwater Quality

No.	Parameter	Unit	Water Quality standard	DGW 01		SGW 01		SGW 02		GW 01		GW02	
				Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Physical													
1	Temperature	°C	± 3	25.0	26.9	26.1	27.3	25.8	26.9	24.6	26.4	24.7	24.7
2	Total Dissolved Solids, TDS	mg/L	1500	344	381	25	23	20	17	89	179	15	15
Inorganic Chemical													
1	pH	mg/L	6.0 – 9.0	7.93	8,32	5.51	5.39	5.24	5,95	5.75	7.14	5.79	5.79
2	Nitrate, N-NO_3	mg/L	10	0.463	0.045	<0.005	0.170	0.010	<0,005	8.63	0.223	1.45	1.45
3	Arsenic	mg/L	0.05	<0.0005	0.0010	0.0006	0.0014	0.0007	0,0005	<0.0005	0.0010	<0.0005	<0.0005
4	Selenium	mg/L	0.01	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0,0005	<0.0005	<0.0005	<0.0005	<0.0005
5	Cadmium	mg/L	0.01	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0,0001	0.0002	<0.0001	<0.0001	<0.0001
6	Chromium Hexavalent	mg/L	0.05	<0.002	<0.002	<0.002	<0.002	<0.002	<0,002	<0.002	<0.002	<0.002	<0.002
7	Copper	mg/L	0.02	<0.01	0.02	<0.01	<0.01	<0.01	<0,01	<0.01	<0.01	<0.01	<0.01
8	Iron	mg/L	0.3	<0.05	0.10	0.170	0.26	0.060	0,16	<0.05	<0.05	0.08	0.08
9	Lead	mg/L	0.03	<0.001	0.004	<0.001	0.001	<0.001	<0,001	0.002	<0.001	<0.001	<0.001
10	Manganese	mg/L	0.1	0.03	0.05	<0.01	0.01	0.03	0,03	0.03	<0.01	<0.01	<0.01
11	Mercury	mg/L	0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0,00005	<0.00005	<0.00005	<0.00005	<0.00005
12	Zinc	mg/L	0.05	0.016	0.036	0.012	0.009	0.015	0,010	0.017	0.008	0.013	0.013
13	Chloride	mg/L	600	3.4	1.0	3.8	4.7	2.6	2,7	6.9	23.8	2.6	2,6
14	Cyanide	mg/L	0.02	<0.005	<0.005	<0.005	<0.005	<0.005	<0,005	<0.005	<0.005	<0.005	<0.005
15	Fluoride	mg/L	0.5	0.02	<0.02	<0.02	<0.02	<0.02	<0,02	0.04	<0.02	<0.02	<0.02
16	Nitrite, N-NO_2	mg/L	0.06	1.37	0.765	<0.001	<0.001	<0.001	<0,001	<0.001	<0.001	<0.001	<0.001
17	Sulfate	mg/L	400	<2	<2	3	4	3	3	<2	<2	<2	<2
18	Sulfide	mg/L	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0,002	<0.002	<0.002	<0.002	<0.002
Microbiological													
1	Fecal Coliform	MPN/100 mL	100	TTD	2	1	7	13	128	TTD	TTD	1	1
2	Total Coliform	MPN/100 mL	1,000	179	187	99	548	225	>2,420	4	14	1,410	1,410
Organic Chemical													
1	MBAS	mg/L	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Source : Primary data, Measurement results of Intertek Lab 2012 -2013

Note : 1) insitu measurement

2) Quality standard based on PP 82 of 2001, Class I (as Drinking Water Standard)



Map II-13 Sampling Locations of Groundwater Quality

Figure II-42 Locations of Shallow Wells and Bore Wells in Saengga

Deep Groundwater

Based on analysis of deep groundwater, it was evident that parameters analyzed generally met the quality standard. Several parameters were in fact not detected. Only nitrite parameter did not meet the quality standard. Nitrite concentration of water samples from deep well (DGW 01 in Saengga village) was 1.37 mg/L in the dry season, while in the wet season it was 0.765 mg/L. Quality standard of nitrite for water quality classification Class I was 0.06 mg/L, however for conventional drinking water treatment, $N\text{-}NO_2$ is allowed to be smaller than 1 mg/L. The high nitrite concentration is likely caused by decomposition of organic substances into ammonia that will further become nitrite (by nitrification bacteria), the next process will likely not take place, i.e nitrite will not become nitrate as groundwater is in semi aerobic (suboxic) condition. Another possibility is that nitrate present in groundwater is denitrified by denitrification bacteria and the process does not continue from nitrite into free nitrogen.

High nitrite concentration at DGW1 Station is a natural condition and is not related to the operated Tangguh LNG activities. This is based on the following:

a) Community Well Quality

   Out of the five samples taken from community wells, Nitrite value exceeded the quality standard is only from DGW1 Station. It is a Deep Well with depth of 150 m approximately located in Saengga village. The other stations are shallow wells and based on analysis the Nitrite values met the quality standard. TDS value at DGW1 station (344 and 381 mg/L) had characteristic that differed from TDS of other wells, i.e. 13 - 179 mg/L

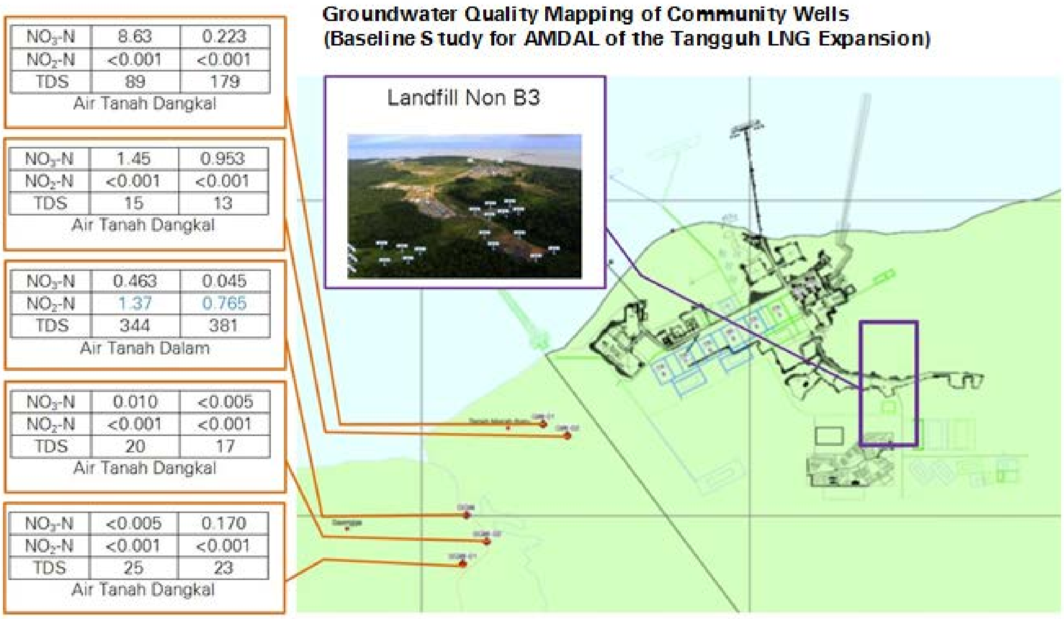


Figure II-43 Groundwater Quality Mapping of Community Wells (Baseline Study for AMDAL of the Tangguh LNG Expansion)

b) Operational Activities of the Tangguh LNG

There is no impact from the Tangguh LNG operational activities toward deep groundwater quality. Operational activity of the Tangguh LNG with potential impact on shallow groundwater quality is non-hazardous waste disposal site facility (non-hazardous waste Landfill). This facility is equipped with impermeable material (HDPE) and leachate management system. The leachate is drained to Sewage Treatment Plant and the treated wastewater is discharged into sea at -13 m LAT (located at LNG Jetty 1). There are several monitoring wells around the non-hazardous waste landfill location. Routine analysis is carried out to monitor groundwater quality around the non-hazardous waste landfill location.

Groundwater quality monitoring results at the monitoring wells around the landfill location did not indicate the existence of Nitrite concentration exceeded the applicable groundwater quality standard. This can be seen in **Figure II-44.**

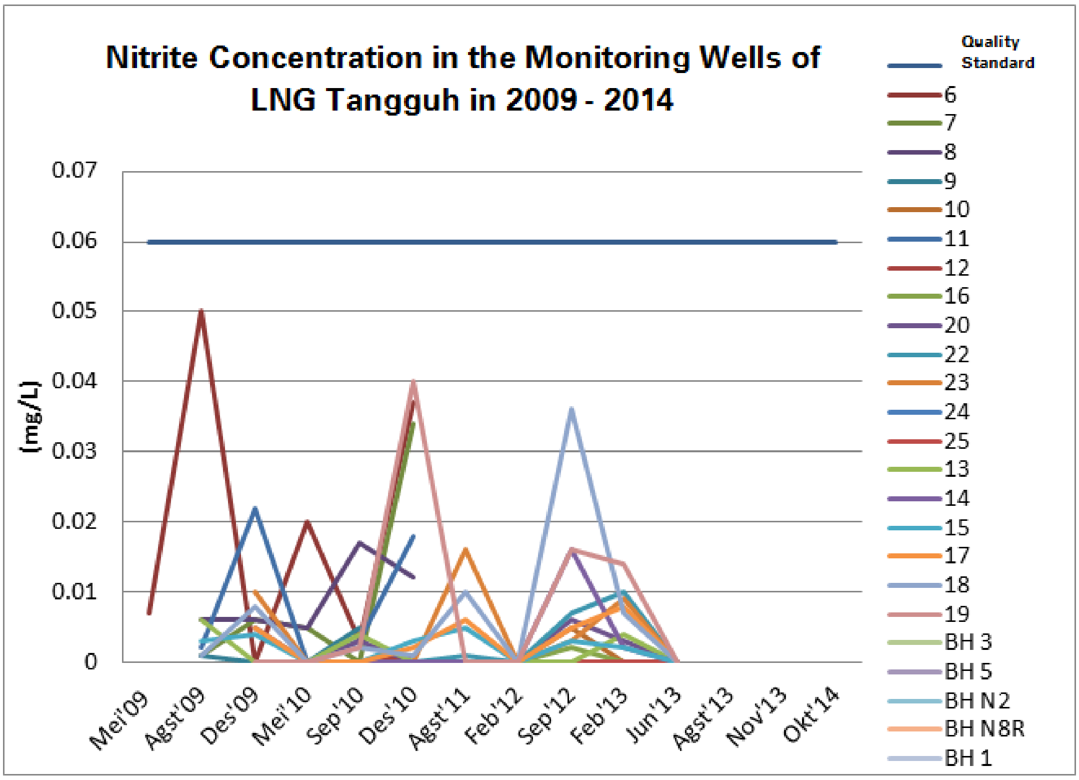


Figure II-44 Nitrite Concentration in the Monitoring Wells around the Non-Hazardous Waste Landfill Location

Total Dissolved Solids (TDS) in deep water were detected in amount of 344 mg/L in the dry season and 381 mg/L in the wet season, although the figure is still far below quality standard, i.e. 1,500 mg/L, however it appears slightly higher compared with shallow groundwater. The slightly high TDS in deep water likely originates from limestone (calcium and carbonate ions) characterized by pH of water that is slightly alkaline (7.93 - 8.32). Besides, slightly high TDS in deep water in Saengga village was not caused by dissolved chloride and sulfate ions (as indication of the presence or absence of seawater intrusion), in which the two anions were detected very low, i.e. chloride 1.0 – 3.4 mg/L and sulfate <2 mg/L. This indicated that deep well water in Saengga village does not experience seawater intrusion.

Shallow Groundwater

Based on laboratory analysis results, in general shallow groundwater quality met the quality standard. Several parameters were in fact not detected. Only parameters of pH, fecal coliform and total coliform did not meet the quality standard.

The pH values of shallow groundwater ranged between 5.24 – 5.51 in the dry season and 5.39 - 5.95 in the wet season in Saengga location. The pH value in TMB location ranged between 5.75 – 5.79 in the dry season and 5.08 – 7.14 in the wet season. The quality standard of pH is between 6 – 9. In general, pH of shallow groundwater tends to be acid, this is likely due to the acidic condition of the local soil (pH value of H_2O around 3.8 – 5.0) or simultaneously due to humic compounds (particularly fulvic acid) from decomposition of litteron the forest bed entering shallow groundwater.

Fecal coliform in SGW-02 was detected at 128 MPN/100 mL. It did not meet quality standard of 100 MPN/100mL. Fecal coli is a bio-indicator of polluted water by human and/or mammals (Homoiterm) faeces. High fecal coli was originated from public toilet (MCK) location in the proximity of wells. This was due to no walls constructed in the wells, so that contaminated rainwater by human faeces infiltrated the well water.

Total coliform refers to all types of bacteria coli that can be bio-indicators since these can survive longer than fecal coliform. Total coliform is a bio-indicator of water pollution by mammals. Total coliform did not meet quality standard in location of SGW 02 in the wet season, i.e. >2,420 MPN/100 mL and in location of GW 02 in the dry season (1,420 MPN/100 mL) and the wet season (1,410 MPN/100 mL). The quality standard for total coliform is 1,000 MPN/100 mL. The amount of total coliform indicated that well water in SGW 02, and GW 02 was contaminated by human or mammal activities.

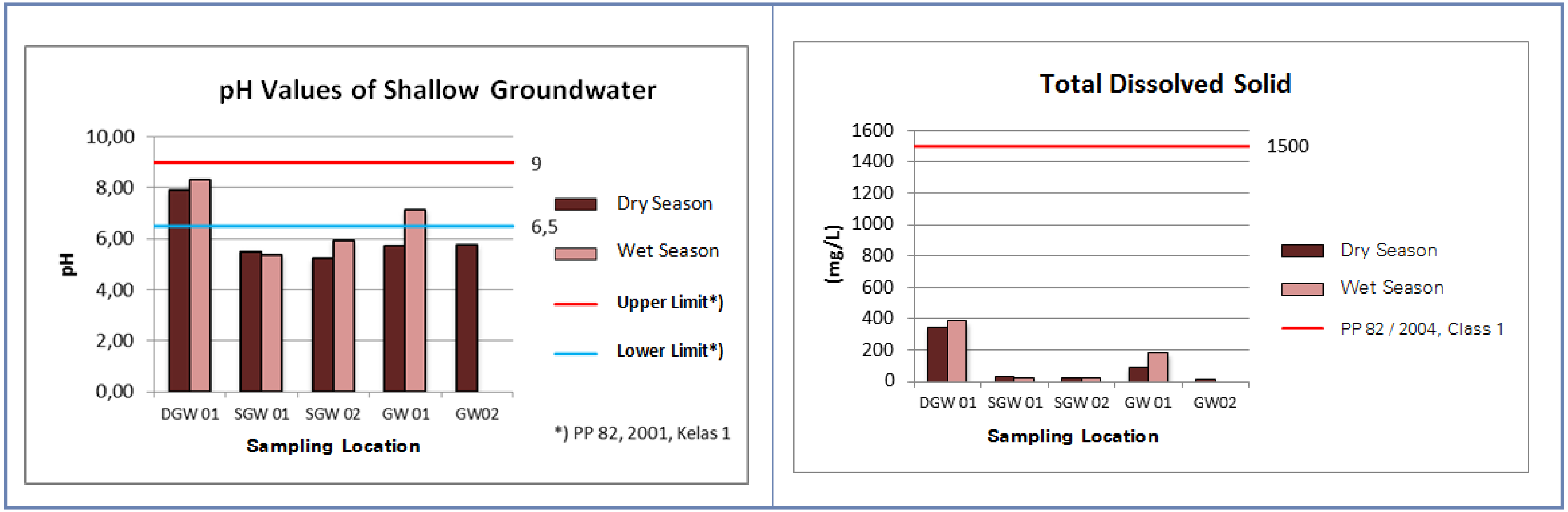


Figure II-45 Graph of Groundwater Physical Parameters

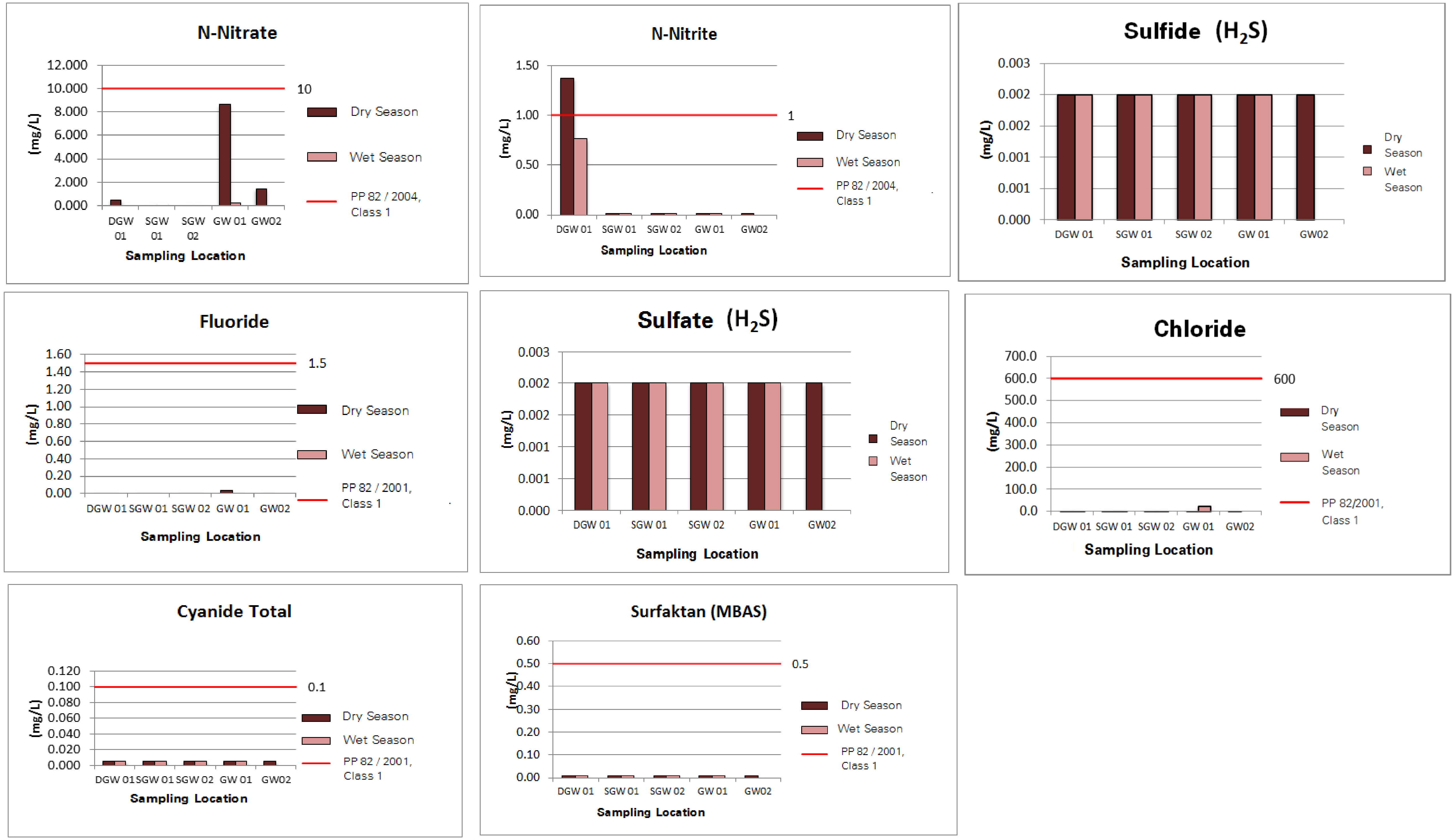


Figure II-46 Graph of Inorganic and Organic Groundwater Parameters

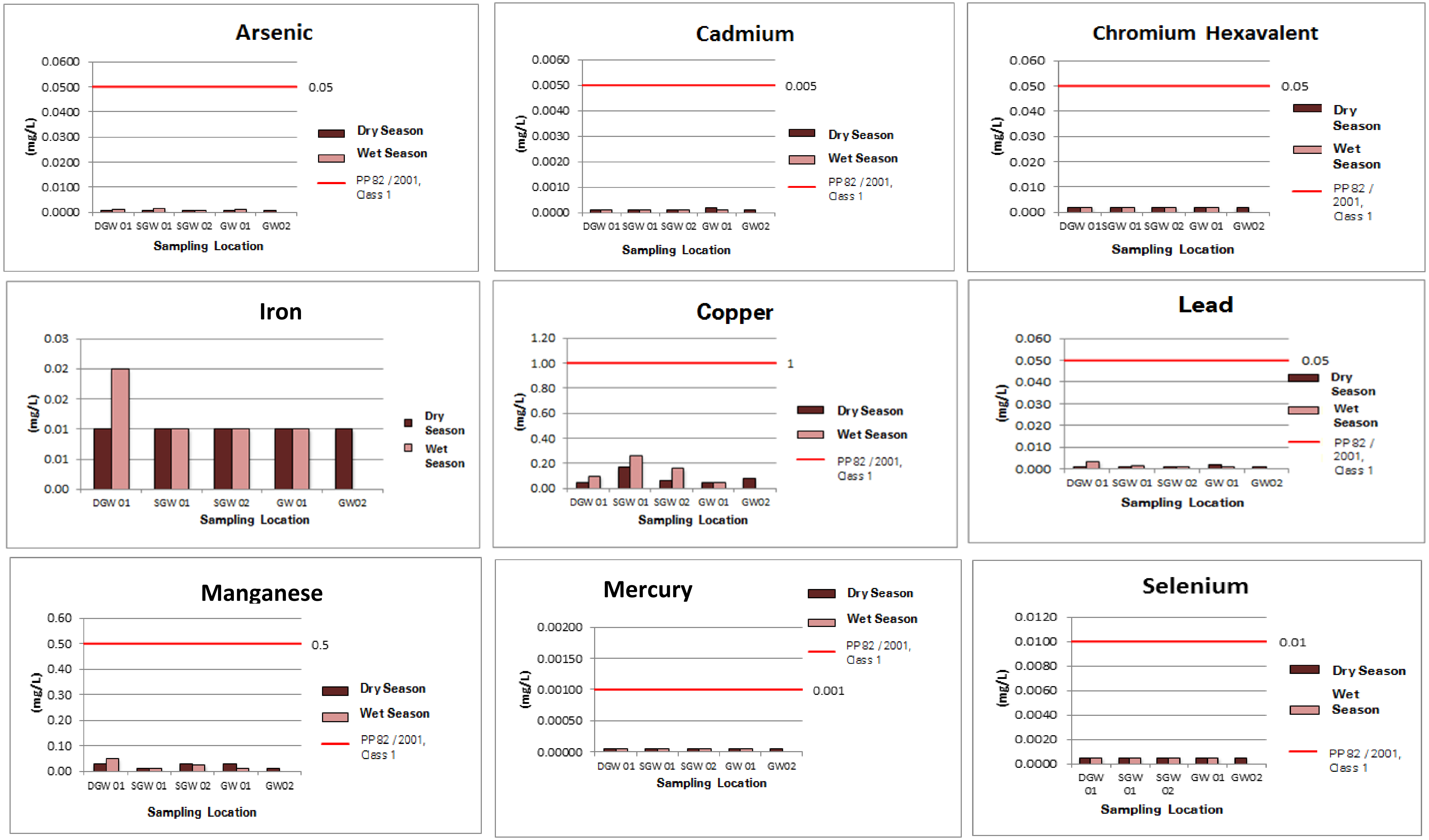


Figure II-47 Graph of Groundwater Dissolved Metals Parameters (1)

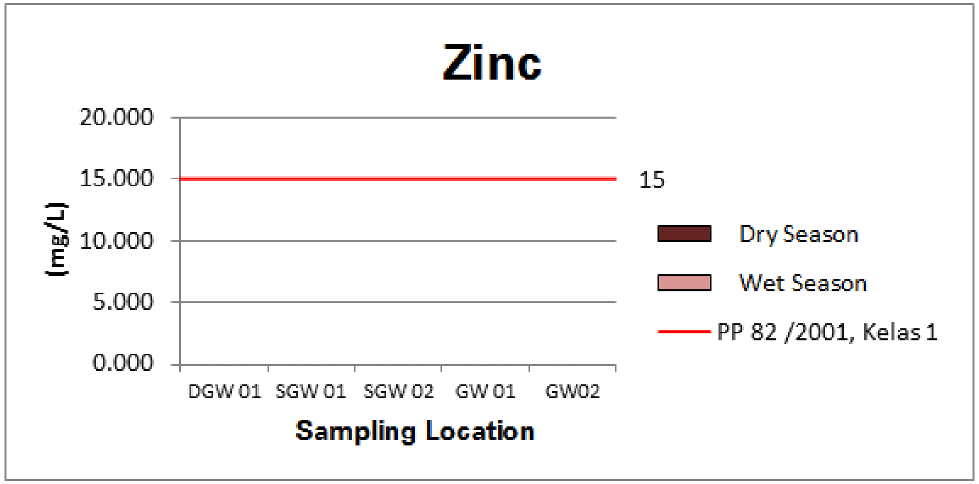
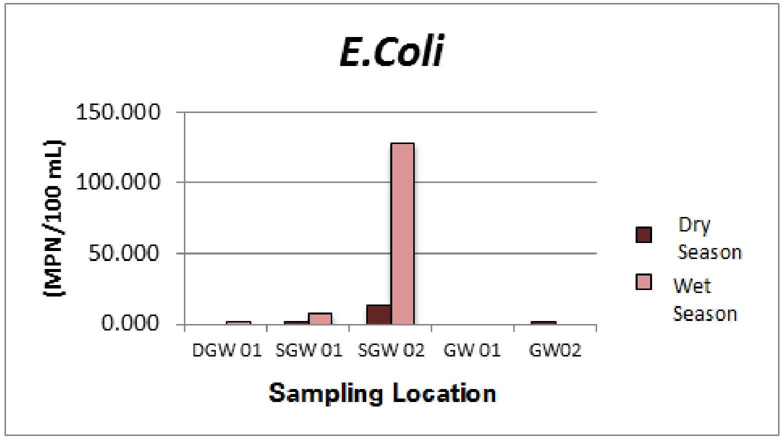


Figure II-48 Graph of Groundwater Dissolved Metals Parameters (2)



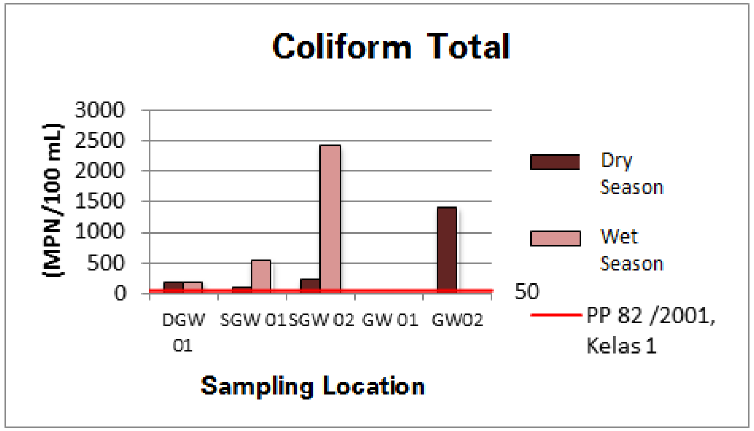


Figure II-49 Graph of Groundwater Microbiological Parameters

2.1.8.3 Seawater Quality

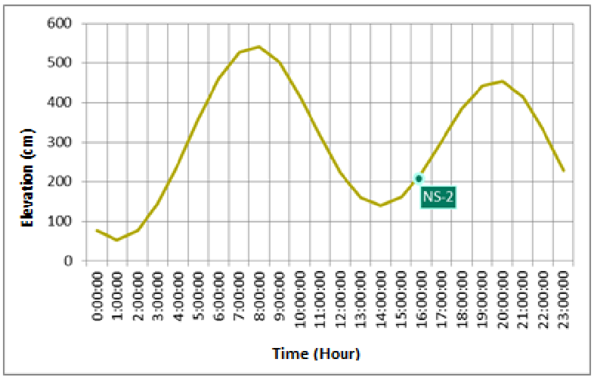
In general, Bintuni Bay indicates its water quality characteristic as estuary waters with high sediment and organic content derived from swamps and mangroves entering the bay waters through rivers. Seawater quality is in accordance with Minister for the Environment Decree No. 51 Year 2004 regarding Seawater Quality Standard, Appendix III Seawater Quality Standard for Marine Biota. Since mangrove forest is quite dominant in Bintuni Bay and there are no coral reef and seagrass fields found in the waters of Bintuni Bay, so that several water quality parameters such as Total Suspended Solids (TSS), temperature and salinity are compared with water quality standard for mangrove.

Nearshore and offshore seawater sampling were conducted in during dry season (July – August 2012) and wet season (March – April 2013). Sampling locations encompassed most of Bintuni Bay (**Table II-34** and **Figure II-50**). Tidal conditions during sampling are shown in **Figure II-50** for the dry season and **Figure II-51** for the wet season. The certificate of laboratory analysis results is shown in **Appendix II-1** and **Appendix II-2**.

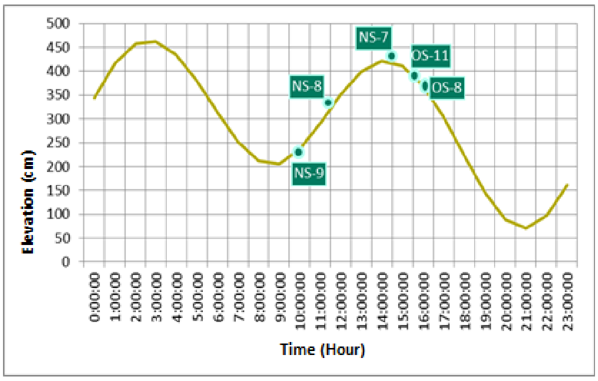
Table II-34 Sample Codes and Seawater Sampling Location

Sample Code	Coordinates		Remark
	South	East	
		Nearshore	
NS-01	02^0 39' 32.3"	132^0 32' 18.9"	Waters around Arguni
NS-02	02^0 38' 09.0"	132^0 05' 31.0"	Waters around Saengga
NS-03	02^0 25' 49.6"	133^0 07' 18.0"	Waters to the north of Tangguh LNG
NS-04	02^0 25' 13.2"	133^0 10' 51.9"	Waters to the east of Tangguh LNG
NS-05	02^0 27' 53.3"	133^0 19' 55.5"	Waters around Wimbro and Sidomakmur
NS-06	02^0 22' 19.9"	133^0 49' 15.8"	Waters at the easternmost end of Bintuni Bay (Reference)
NS-07	02^0 13' 43.3"	133^0 15' 00.9"	Waters around Sorondauni
NS-08	02^0 17' 19.0"	132^0 52' 49.1"	Waters around Weriagar
NS-09	02^0 18' 25.9"	132^0 39' 43.4"	Waters around Kalitami
		Offshore	
OS-01	02^0 20' 32.0"	132^0 57' 31.0"	Waters around WD Platform
OS-02	02^0 24' 42.0"	132^0 32' 43.0"	Waters at the westernmost end of Bintuni Bay (Reference)
OS-03	02^0 41' 50.3"	132^0 44' 40.4"	Waters at north of Goras
OS-04	02^0 34' 28.5"	132^0 39' 05.2"	Waters around UBA Platform
OS-05	02^0 20' 44.0"	132^0 48' 39.0"	Waters at south of Mogotira
OS-06	02^0 30' 42.2"	132^0 58' 32.2"	Waters around KKA Platform
OS-07	02^0 26' 01.4"	133^0 01' 22.9"	Waters around OFA Platform
OS-08	02^0 18' 58.0"	133^0 08' 17.0"	Waters around Platform VRC and eastern disposal area
OS-09	02^0 22' 36.0"	132^0 06' 39.0"	Waters around ROA Platform

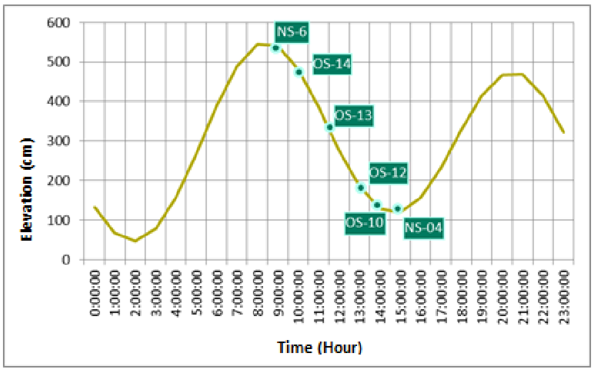
Sample Code	Coordinates		Remark
	South	East	
OS-10	02^0 22' 52.0"	133^0 11' 47.0"	Waters between the Tangguh LNG and VRB Platform
OS-11	02^0 15' 54.0"	133^0 11' 07.0"	Waters between VRC and VRA Platforms
OS-12	02^0 19' 22.0"	133^0 17' 19.0"	Waters between TTA, VRF, VRB, and VRD Platforms
OS-13	02^0 20' 06.0"	133^0 26' 20.0"	Waters at eastern of Bintuni Bay
OS-14	02^0 21' 16.0"	132^0 41' 00.0"	Waters at the easternmost end of Bintuni Bay (Reference)



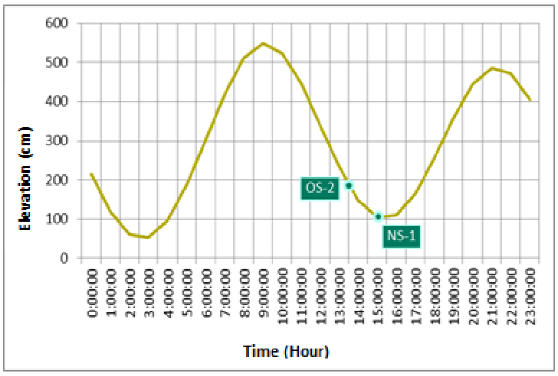
July 29th, 2012



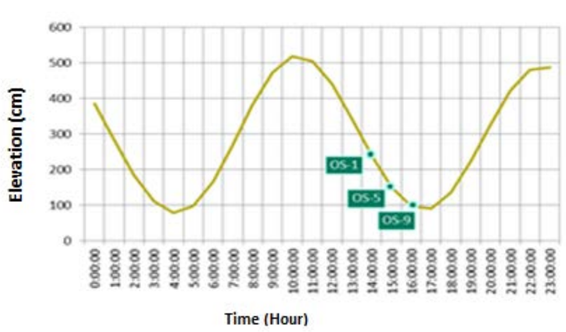
August 3th, 2012



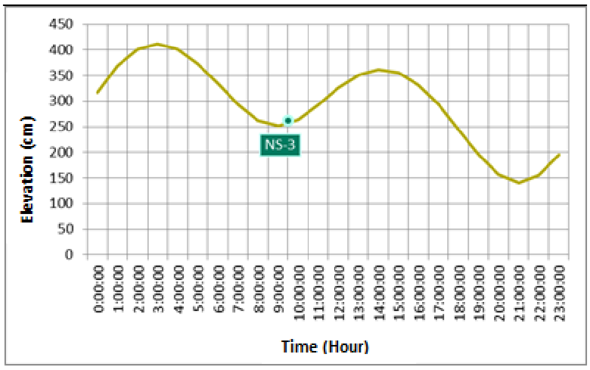
August 4th, 2012



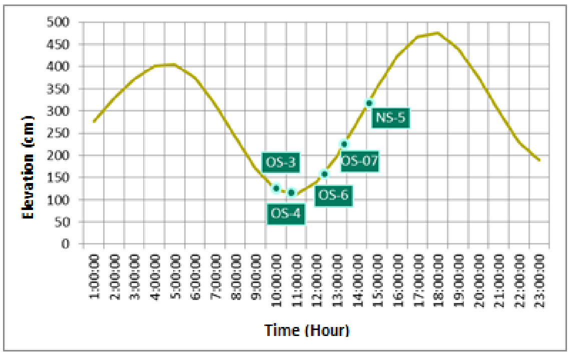
August 5th, 2012



August 7th, 2012

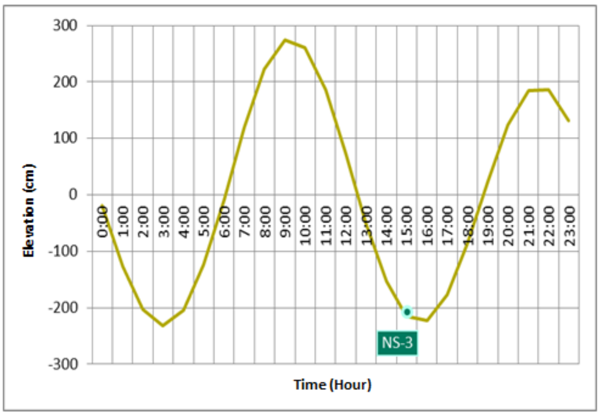


August 13th, 2012

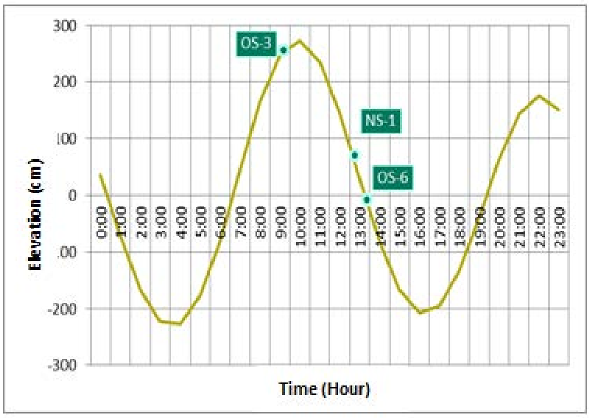


October 27th, 2012

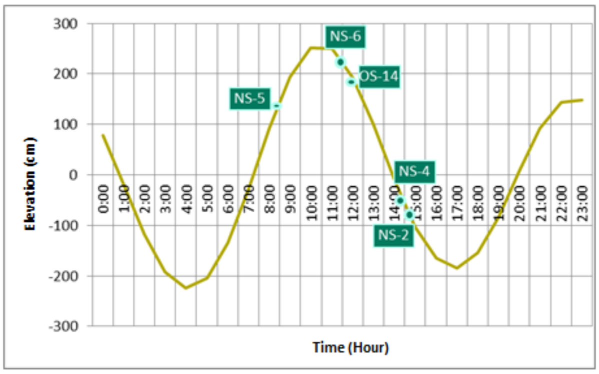
Figure II-50 Graph of Tidal Conditions during Dry season Sampling



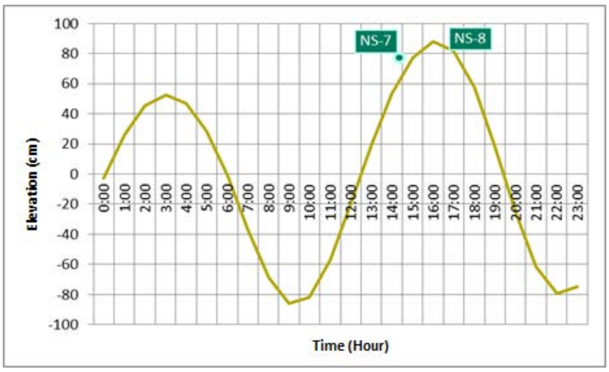
March 15th, 2013



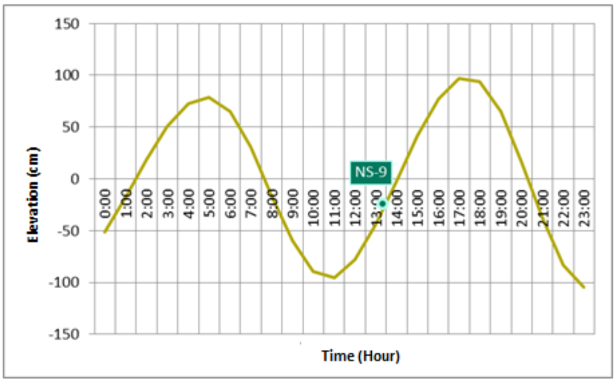
March 16th, 2013



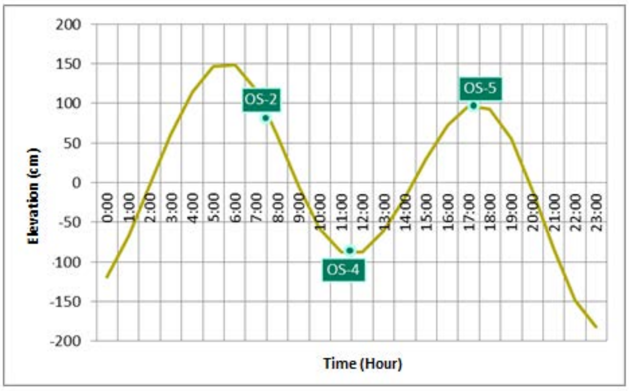
March 17th, 2013



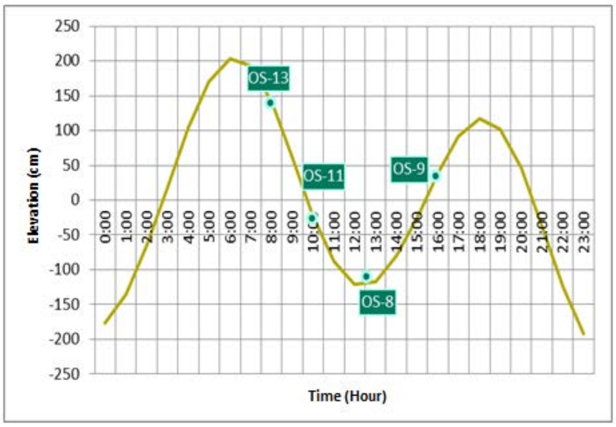
March 23rd, 2013



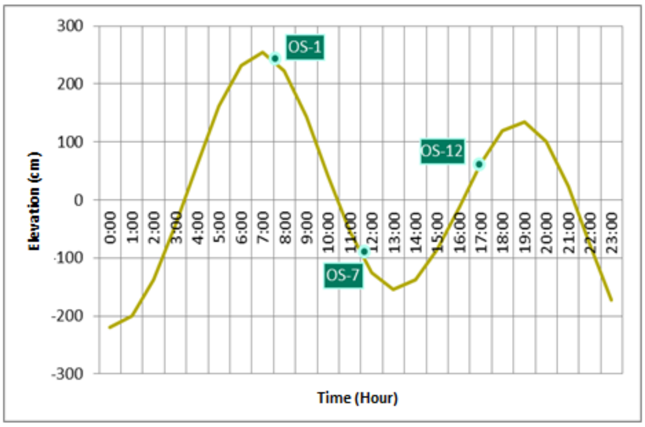
March 24th, 2013



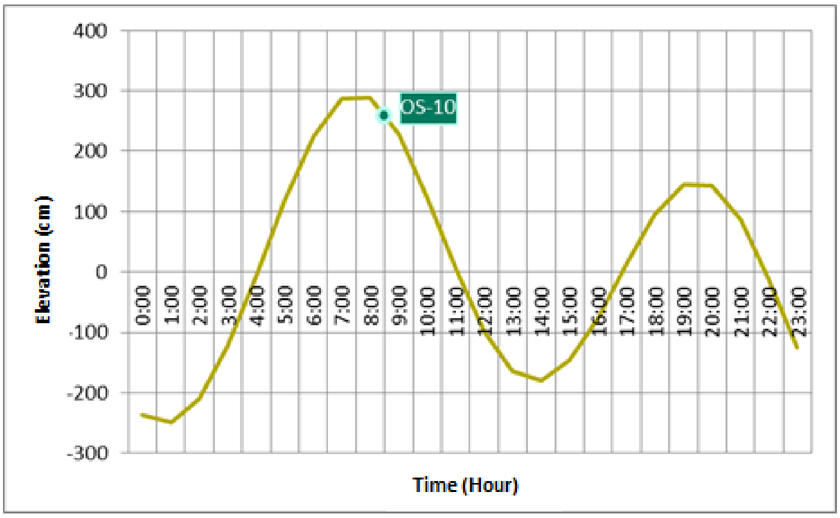
April 23rd, 2013



April 24th, 2013

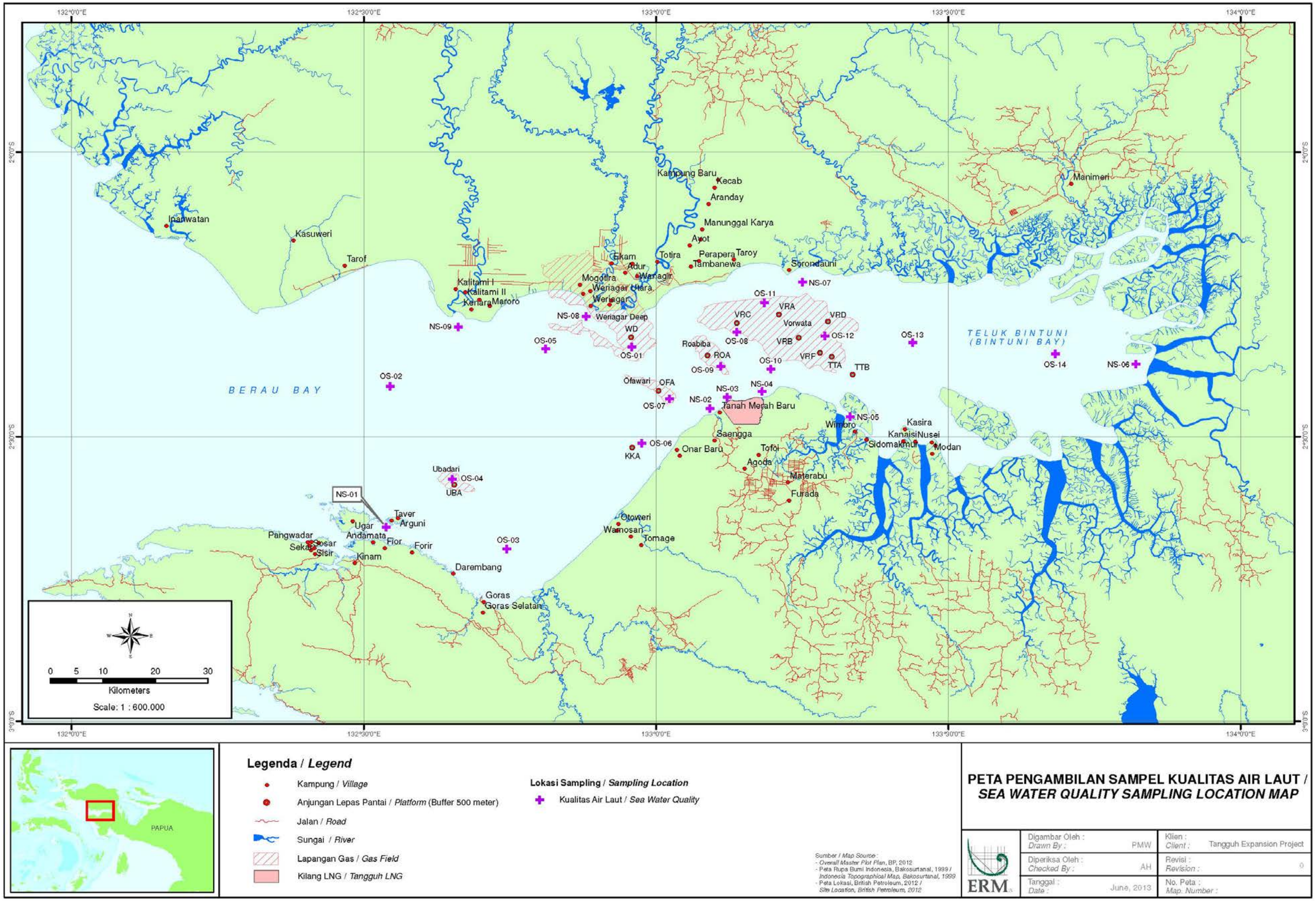


April 25th, 2013



April 26th, 2013

Figure II-51 Graph of Tidal Conditions during Wet season Sampling



Map II-14 Locations of Nearshore and Offshore Seawater Sampling

Nearshore Seawater Quality

Analysis results of nearshore seawater quality are shown in **Table II-36** and **Figure II-53** to **Figure II-59**. Based on the analysis results, the nearshore seawater quality generally met seawater quality standard (Seawater Quality Standard in accordance with Minister of the Environment Decree No. 51 Year 2004, Appendix III: Seawater Quality Standard for Marine Biota. Several parameters of seawater quality such as sulfide, total cyanide, ammonia, BOD_5, oil and grease, total phenol, surfactane (MBAS), PAH; and chromium hexavalent dissolved metal, lead, mercury as well as nickel were not detected (below equipment's detection limit) at all sampling locations both in dry season and wet season. Some other dissolved metals such as arsenic, cadmium, copper and zinc were detected at several sampling locations with very low concentrations and the values far below the threshold limits of quality standard for the metals. Several parameters that did not meet the quality standards were TSS, turbidity, nitrate, phosphor and DO.

TSS concentration that did not meet quality standard were observed in NS-02 (near the estuary of Saengga river) and NS-05 (near the estuary of Senindara river) in the dry season with respective concentrations of 193 mg/L and 86 mg/L. The high TSS concentration in NS-02 and NS-05 locations was due to the proximity of the locations to the coast dominated by mangrove and near the river estuary carrying sediments to Bintuni Bay. Sampling from the two locations were taken at the time approaching high tide, which the current flowed from west to east. Based on field records during sampling, there was rain in the both locations prior to sampling.

Periodically, once a week, concentrations of TSS are monitored by the Tangguh LNG at water intake for desalination water in the LNG Jetty 1. Monitoring results during 2011 (47 monitoring data) are shown in **Table II-35** and **Figure II-52**. Based on the monitoring results, during dry season, TSS concentration ranged between 32 mg/L to 267 mg/L with average value of 102 mg/L, while during wet season the range was between 23 mg/L to 369 mg/L with average of 139 mg/L. From 47 monitoring data of TSS, a total of 27 data or 57% of TSS monitoring results exceeded quality standard for mangrove, namely the required quality standard for TSS parameter ≤80 mg/L. This indicated that naturally the TSS concentration in nearshore activities locations was sufficiently high.

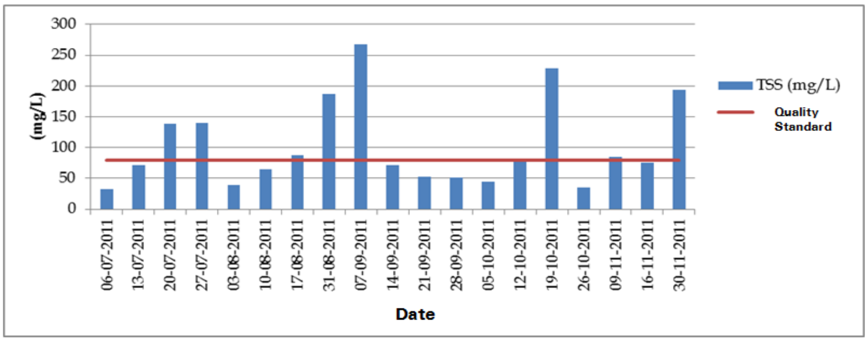
Table II-35 TSS Concentration at Water Intake in LNG Jetty 1 during 2011

Dry season		Wet season	
Date	**TSS (mg/L)**	**Date**	**TSS (mg/L)**
06-07-2011	32	5-1-2011	46
13-07-2011	71	12-1-2011	126
20-07-2011	138	19-1-2011	256
27-07-2011	140	26-1-2011	103
03-08-2011	39	2-2-2011	28
10-08-2011	65	9-2-2011	61
17-08-2011	88	16-2-2011	23
31-08-2011	187	23-2-2011	93
07-09-2011	267	30-2-2011	82

Dry season		Wet season	
Date	TSS (mg/L)	Date	TSS (mg/L)
14-09-2011	71	2-3-2011	139
21-09-2011	52	9-3-2011	229
28-09-2011	51	16-3-2011	60
05-10-2011	44	23-3-2011	289
12-10-2011	82	30-3-2011	71
19-10-2011	228	6-4-2011	88
26-10-2011	35	13-4-2011	256
09-11-2011	85	27-4-2011	266
16-11-2011	75	4-5-2011	168
30-11-2011	194	11-5-2011	68
		18-5-2011	369
		25-5-2011	34
		8-6-2011	129
		15-6-2011	38
		29-6-2011	32
		7-12-2011	233
		14-12-2011	252
		23-12-2011	255
		28-12-2011	100

Source: Primary data, Tangguh LNG. Weekly Periodic Monitoring Results.

a



b

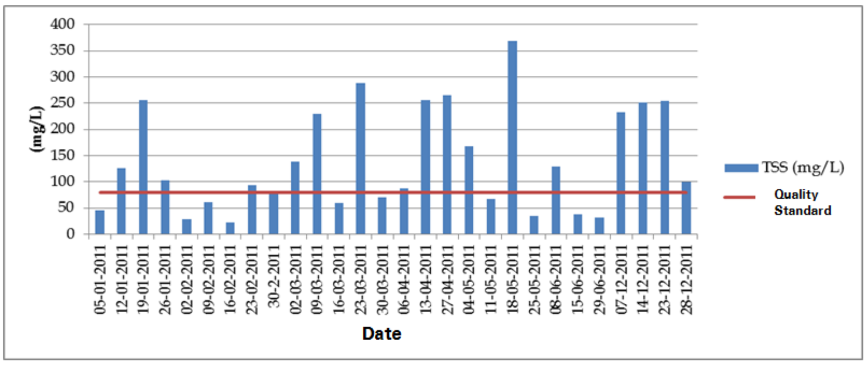


Figure II-52 Graph of TSS Concentration at Water Intake, Jetty LNG 1 in 2011. (a) Dry season, (b) Wet season

Turbidity in most of nearshore sampling locations was observed in the range of 7.7 to 183 NTU did not meet the quality standard, both in the wet season and dry season. Except in monitoring location of NS 01 (around Arguni) during the dry season turbidity was detected at 0.2 mg/L, and the turbidity in NS-07 (around Sorondauni) and NS-08 (around Weriagar) during the wet season were 1.8 NTU and 3.9 NTU respectively. The quality standard for turbidity is <5 NTU. The high turbidity level in the Bintuni Bay waters was in line with the high concentrations of TSS and low water clarity. The water clarity during the wet season and the dry season at nearshore and offshore sampling locations measured using Secchi Disk, was mostly observed less than 1 m, with the exception of the waters around Arguni (monitoring location of NS 01) in the dry season with clarity reaching 3 m. Seawater quality standard for Marine Biota in Minister of the Environment Decree No. 51 Year 2004, stipulates water clarity for coral reef is greater than 5 m, for seagrass is more than 3 m, while water clarity for mangrove is unlimited.

The low clarity figure in the waters of Bintuni Bay, prevent coral reef and seagrass from developing well, as proven by the absence of coral reef and seagrass in Bintuni Bay. Both of the marine biota require sufficient light to be able to develop, besides they are highly sensitive to high sedimentation level (TSS).

Nitrate and phosphor in seawater are nutrients required for marine primary production. Growth of phytoplankton is determined by the molarity ratio of N and P. Analysis result of N and P ratio globally for estuary and coastal aquatic ecosystem is <16:1, and could reach 100:1 for high sea (Downing, 1997). Average concentration of N in seawater is 0.8 mg/L and P is 0.07 mg/L (Korte, 1977). Nitrogen compounds dominant in seawater is nitrate (NO_3), and for phosphor compound is ortho-phosphate (PO_4). The analysis result of nitrate as N and phosphate as P in nearshore waters indicated values around 0.045 mg/L – 0.203 mg/L, and <0.005 – 0.076 mg/L respectively. Data of the analysis results indicated that nitrogen compound as N in nearshore of Bintuni Bay was in low category as it was much smaller than 0,8 mg/L, while phosphate compound as P was also low <0,07 mg/L except for the observation point of NS 02 in the dry season that was detected at 0.076 mg/L. Calculation result indicated that ratio of N:P nearshore of Bintuni Bay ranged between 3:1 to 9:1. Ratio of N:P <16:1 indicated constraint of one of the elements in seawater besides nitrogen in marine waters productivity (Downing, 1997).

Phosphor is an essential chemical element in marine primary production. The ratio of phosphor to other elements in the aquatic ecosystem is smaller than in living organisms. Phosphor is a limiting nutrient in eutrophication (process of developing nutrient-rich waters); meaning that although seawater has high concentrations of nitrate, eutrophication will not occur with low amounts of phosphate. The presence of phosphate in water greatly affects marine ecosystem balance. When phosphate content as P in water is low (<0.01 mg/L), growth of algae will be hindered, a condition known as oligotrophic (nutrient-poor waters). On the other hand, when phosphate content is high followed by balanced nitrogen compounds, growth of algae will be unlimited, a condition known as eutrophy, or nutrient-rich waters (http://id.wikipedia.org/wiki/Wikipedia_bahasa_Indonesia).

Concentration of N-nitrate in nearshore waters during the wet season and the dry season ranged between 0.045 – 0.228 mg/L and P-phosphate ranged between <0.005 – 0.076 mg/L. Based on the range values, generally nutrient concentration (N-nitrate and P-phosphate) in the waters of Bintuni Bay cannot be considered high yet; besides due to the ratio N:P in nearshore waters of Bintuni Bay <16:1, then it can be concluded that nutrient content of waters is not optimal yet. This is supported by observation results of phytoplankton in nearshore waters, which Cyanophyceae was only represented by one genus namely Trichodesmium. Trichodesmium is a member of the Cyanobacteria class with filament and commonly found in nutrient-poor marine waters.

Seawater quality standard in accordance with Minister of the Environment Decree No. 51 Year 2004 for Nitrate as N is 0.008 mg/L and for total phosphate as P is 0.015 mg/L. Empirically, according to *Korte* (1977) in marine waters, nitrogen content (0.8 mg/L) is far higher than phosphor content (0.07 mg/L) or nitrogen content of ten times higher than phosphor. In fact, according to Downing (1997) nitrogen content in offshore waters could be 100 times higher than phosphor content. On the other hand, the quality standard of Minister of the Environment Decree No. 51 Year 2004 specifies lower nitrogen content than phosphor content, or nitrogen content two times lower than phosphor content. Therefore, the quality standard determining threshold limits for N and P in Minister of the Environment Decree No. 51 Year 2004, does not accord with the above limits.

In general, concentration of DO in the dry season and wet season in all sampling locations met quality standard, with concentration of DO observed >5 mg/L, except at NS 06 (the waters in the easternmost part of Bintuni Bay as a reference location) in the dry season and wet season the DO concentration was slightly lower than the threshold limit of 5 mg/L, i.e. respectively detected of 4.87 mg/L and 4.58 mg/L. The lower concentration of DO at location NS 06, was likely due to NS 06 is located at the eastern end of Bintuni Bay (mouth of the bay), which is subject to less tidal movement or the re-aeration process is not as great as that at the mouth of the bay.

Table II-36 Analysis of Nearshore Marine Waters

No.	Parameter	Unit	Quality standard*	NS 01		NS 02		NS 03		NS 04		NS 05		NS 06		NS 07		NS 08		NS 09	
				Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
	Physical																				
1	Clarity 1)	m	*	3	2.0	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2,5	<1	2.0	<1	1,1
2	Floating Objects 1)	-	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
3	Odor 1)	-	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural
4	Oil Layer 1)	-	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
5	pH 1)	-	7 -8.5	7.89	8.06	7.89	7.89	7	7.88	7,75	7.87	8.54	7.78	7.22	7.37	7.94	7.92	7.73	8.07	7. 96	8,15
6	Salinity 1)	‰	Natural**	32.1	27.2	30.0	25.9	24	26.2	30,0	26.1	31	26.4	24.4	21.5	29.2	24.0	14.2	26.2	26.7	28,5
7	Temperature 1)	°C	Natural***	28.4	30.2	28.7	31.5	29	30.4	30,1	31.1	31.1	30.2	28.6	30.4	28.6	31.4	27.3	31.6	27.0	30,5
8	Total Suspended Solids, TSS	mg/L	****	5	11	193	51	22	47	43	44	86	46	60	19	20	17	33	11	28	15
9	Turbidity 1)	NTU	< 5	0.2	171	138	46.3	49.5	40.1	36.7	28.7	60.0	26.8	49.4	12.2	11.8	1.8	35.2	3.9	27.0	7,7
	Anion																				
1	Sulfide, H_2S	mg/L	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
2	Total Cyanide, CN	mg/L	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Nutrient																				
1	Ammonia, NH_3-N	mg/L	0.3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2	Nitrate, NO_3-N	mg/L	0.008	0.065	0.073	0.064	0.081	0.120	0.119	0.170	0.090	0.078	0.112	0.288	0.045	0.165	0.109	0.156	0.121	0.203	0.065
3	Phosphor Total, P	mg/L	0.015	<0.005	0.015	0.076	0.040	0.034	0.036	0.015	0.027	0.046	0.030	0.038	0.017	<0.005	0.018	<0.005	0.014	<0.005	0.017
	Microbiological																				
1	Total Coliform	MPN/100mL	1000	4	2	TTD	TTD	4	11	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD	33	TTD	49	TTD
	Dissolved Metals																				
1	Arsenic, As	mg/L	0.012	0.0005	0.0016	0.0011	0.0012	0.0015	0.0015	0.0007	0.0009	0.0021	0.0015	<0.0005	0.0009	0.0008	0.0012	0.0008	0.0006	0.0006	0.0015
2	Cadmium, Cd	mg/L	0.001	0.0005	<0.0005	0.0001	<0.0005	<0.0001	<0.0005	0.0001	<0.0005	<0.0001	<0.0005	0.0001	<0.0005	0.0001	<0.0001	0.0012	<0.0001	0.0001	<0.0001
3	Chromium Hexavalent, Cr^{6+}	mg/L	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
4	Copper, Cu	mg/L	0.008	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0,001	<0.001	0.001	<0.001	<0.001	<0.001
5	Lead, Pb	mg/L	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
6	Mercury, Hg	mg/L	0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
7	Nickel, Ni	mg/L	0.05	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.001	<0.02	<0.02	<0,02	<0.02	0.001	<0.02	<0.001	<0.02	<0.001
8	Zinc, Zn	mg/L	0.05	0.009	<0.005	0.010	0.008	0.008	<0.005	0.008	<0.005	<0.005	<0.005	0.014	<0.005	0.008	<0.005	0.007	<0.005	0.006	<0.005
	Others																				
1	Biochemical Oxygen Demand, BOD_5	mg/L	20	<2	<2	2	<2	<2	<2	<2	<2	2	<2	<2	<2	4	<2	<2	<2	2	<2
2	Dissolved Oxygen, DO 1)	mg/L	>5	5,.40	5.85	5.95	5.30	5.16	5.60	6.04	5.49	5.16	5.03	4.87	4.58	6.04	6.08	6.12	5.99	6.33	6.47
3	Surfactane, MBAS	mg/L	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Oil and Grease	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
5	Total Phenol Compound	mg/L	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Organic																				
1	Polycyclic Aromatic Hydrocarbon, PAHs	mg/L	0.003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00001	<0.0001	<0.00001	<0.0001	<0.00001

Source: Primary data, Lab Intertek measurement 2012 -2013

Note:

1) in-situ Measurement

2) Minister of the Environment Decree No. 51 Year 2004, Appendix III: Seawater Quality Standard for Marine Biota

* for coral reef >5 m, for seagrass >3 m, mangrove unlimited

** Change allowed until <5% average seasonal salinity

*** Change allowed until <2 °C of natural temperature

**** for coral reef: 20 mg/L, seagrass: 20 mg/L; mangrove: 80 mg/L

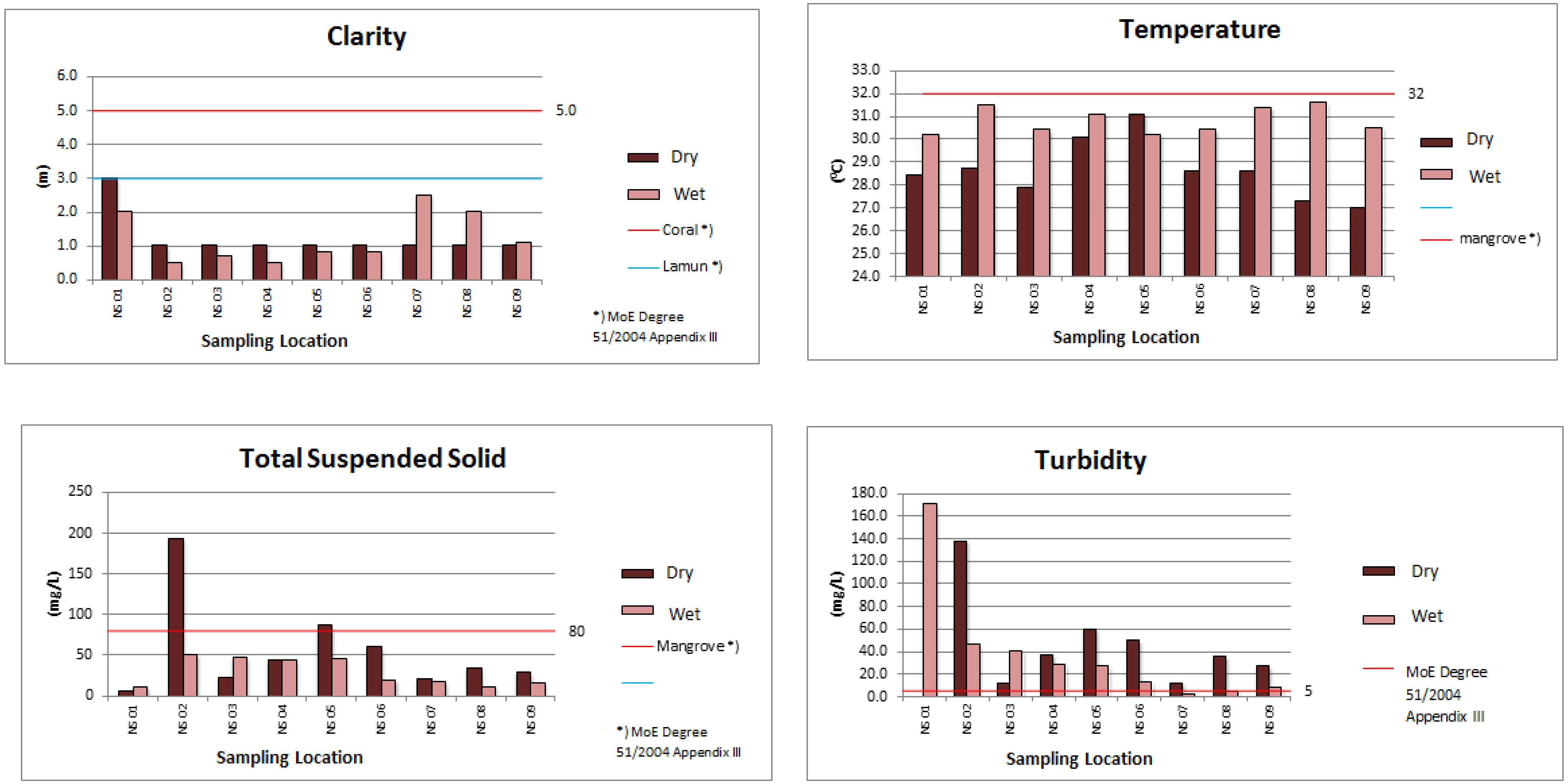


Figure II-53 **Graph of Seawater Physical Parameters (*Nearshore)***

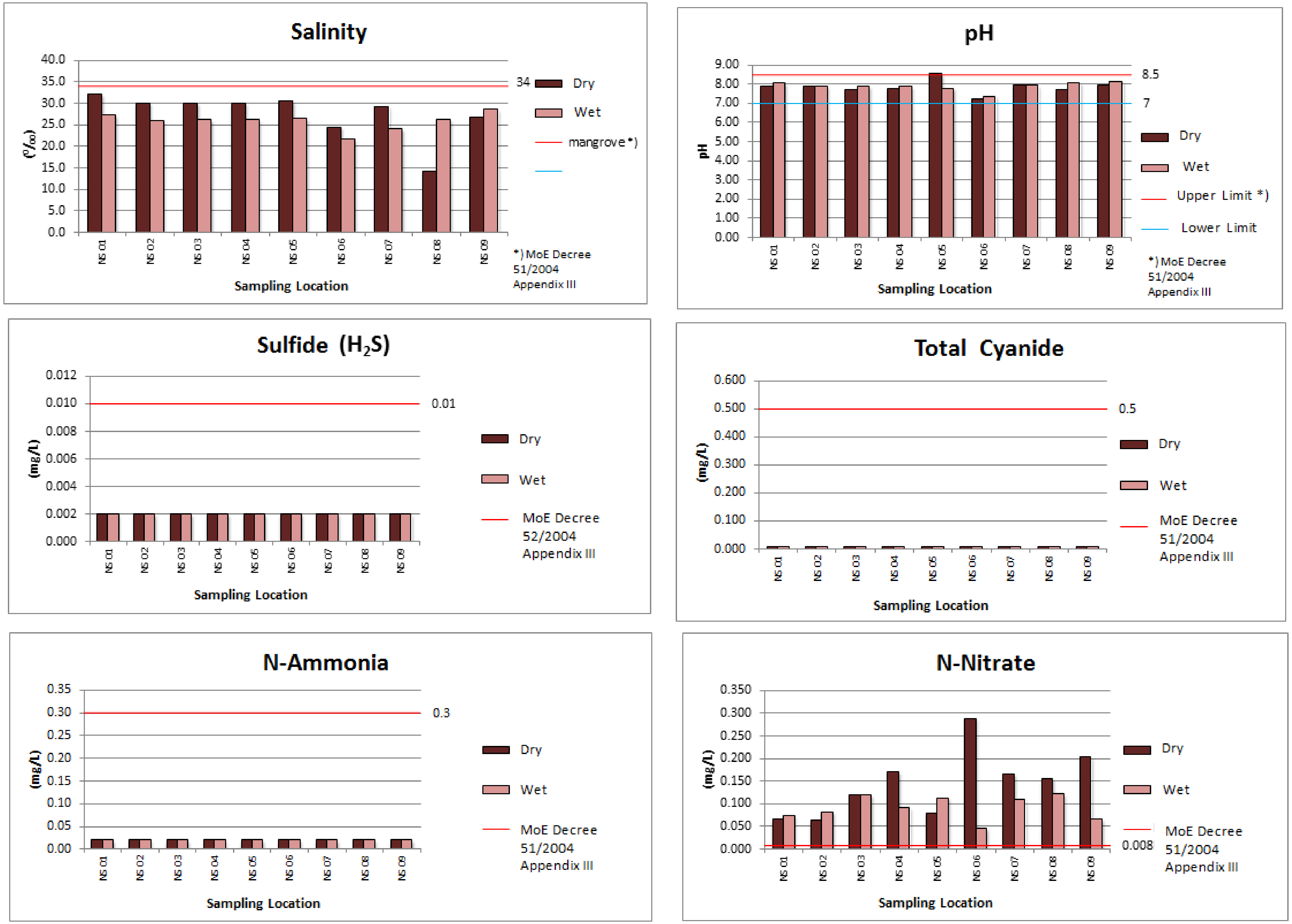


Figure II-54 **Graph of Seawater Chemical Parameters (*Nearshore*) (1)**

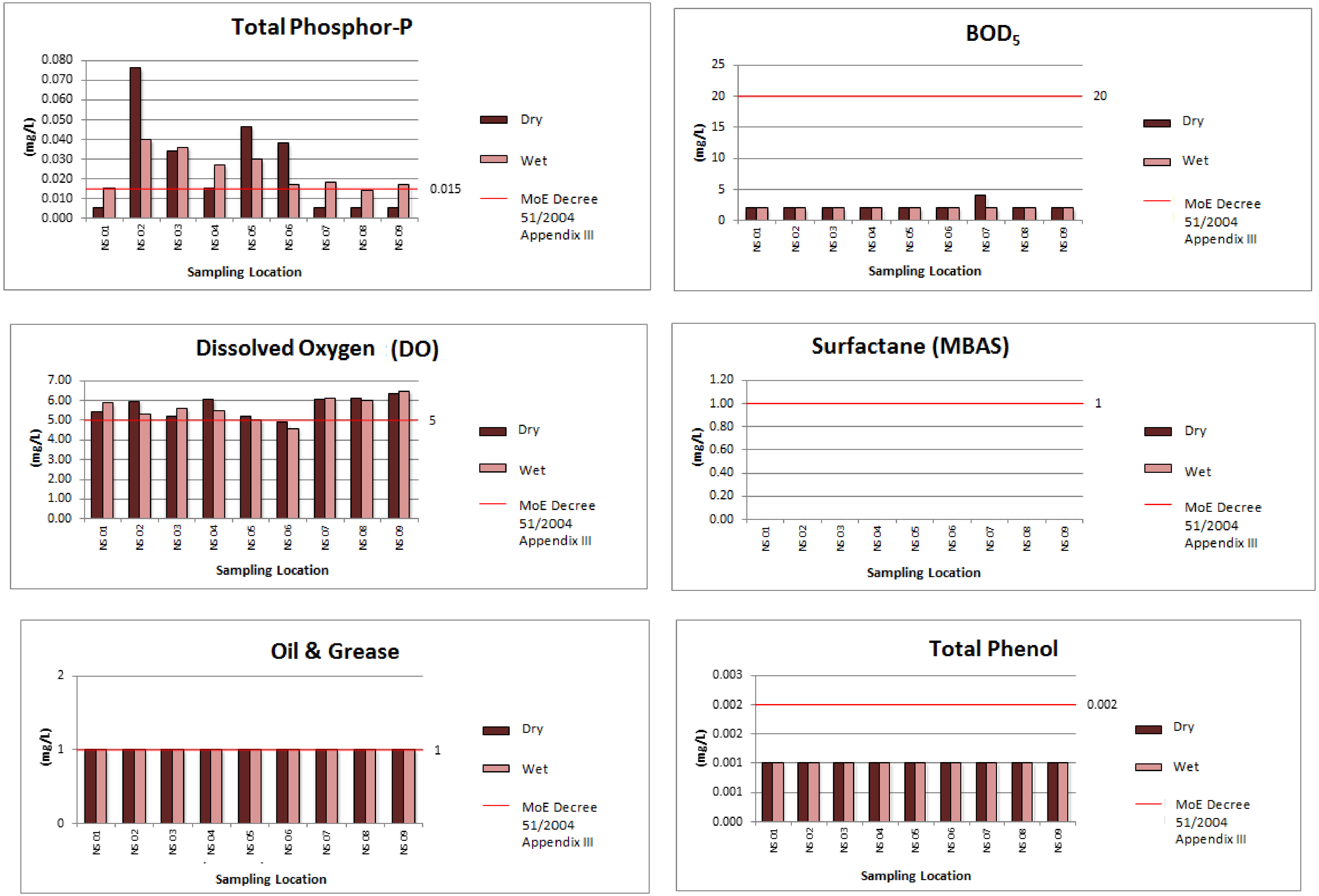


Figure II-55 **Graph of Seawater Chemical Parameters (*Nearshore*) (2)**

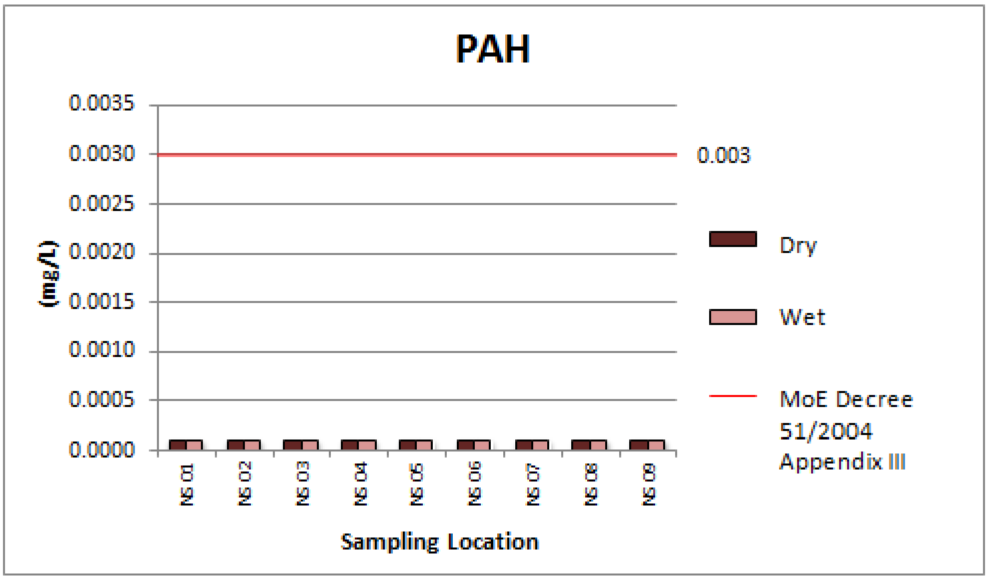
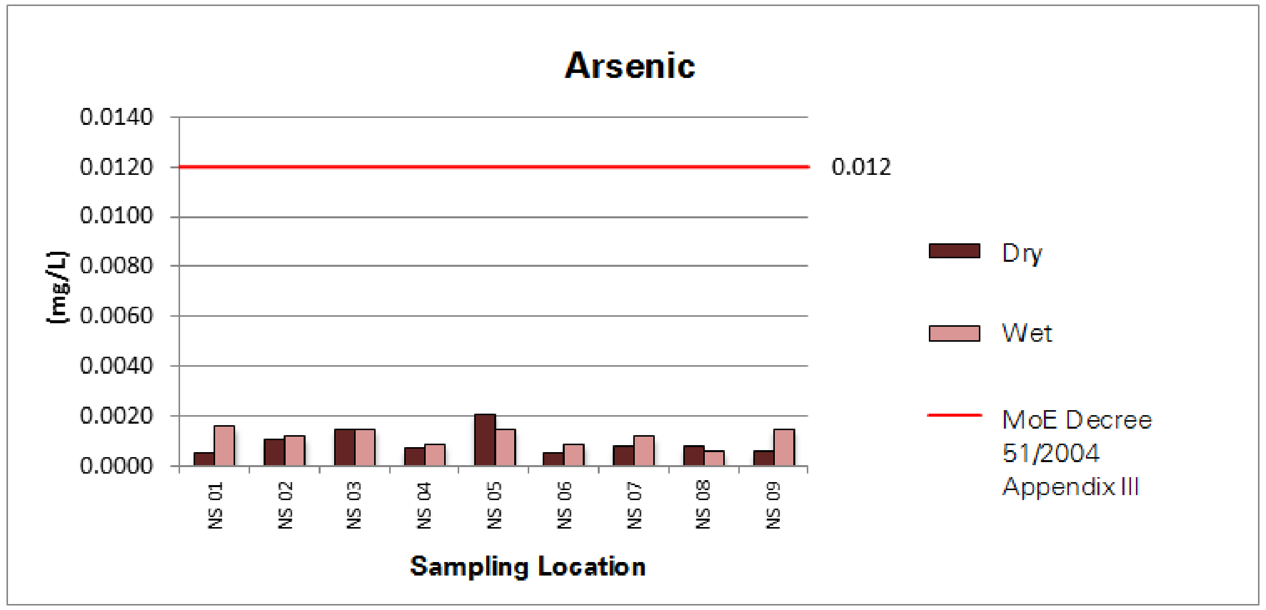
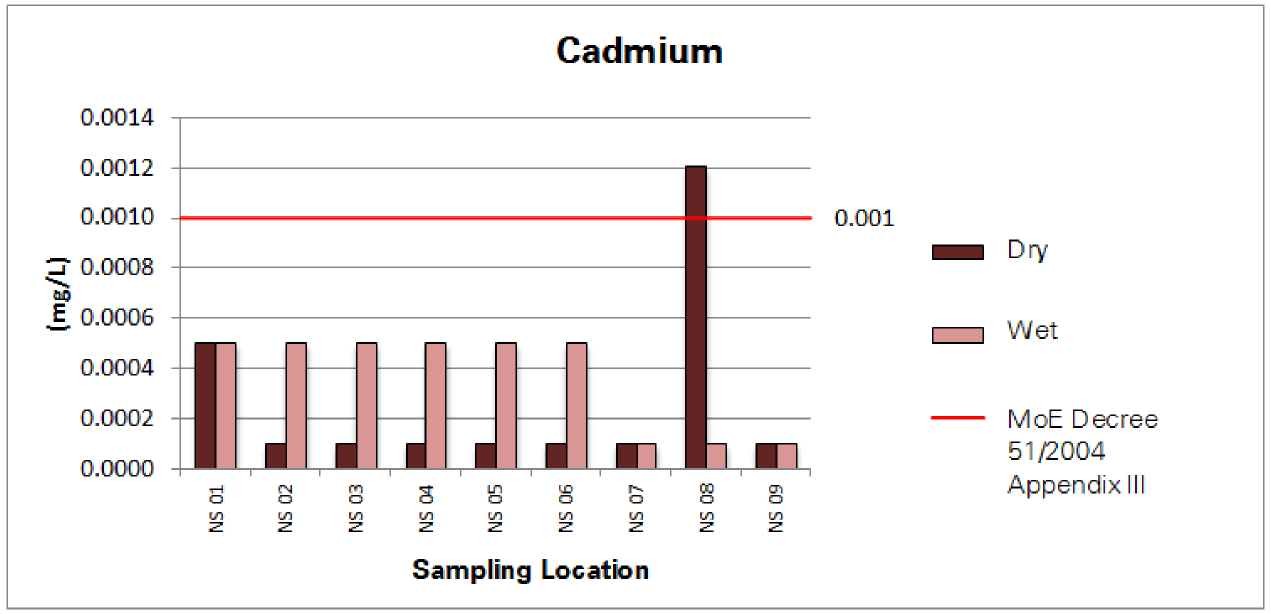
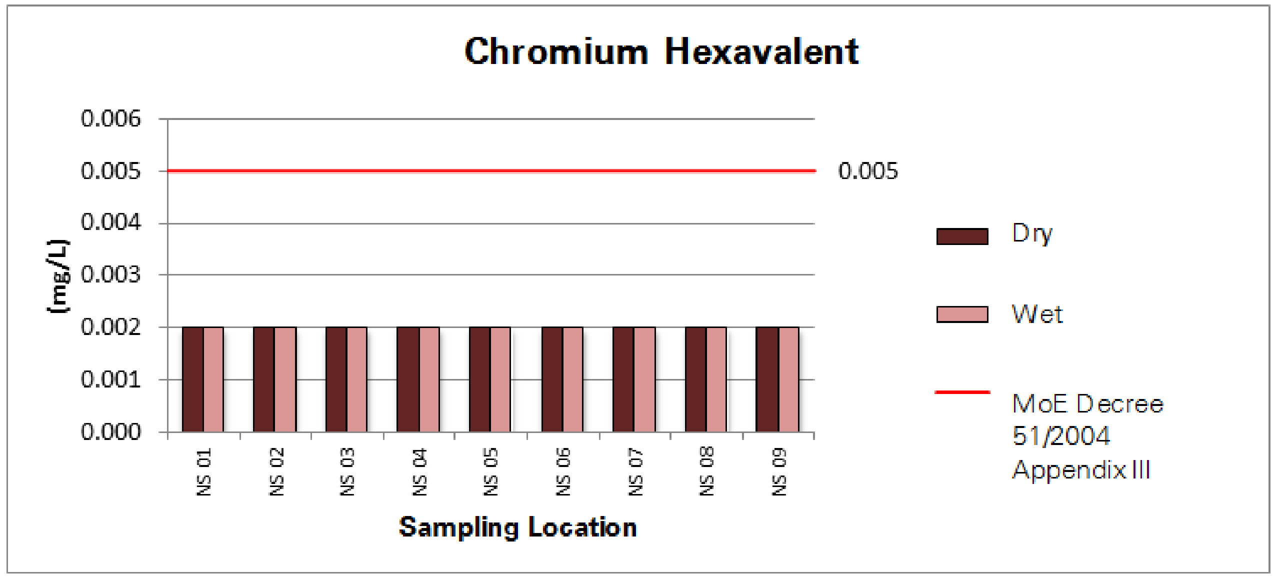
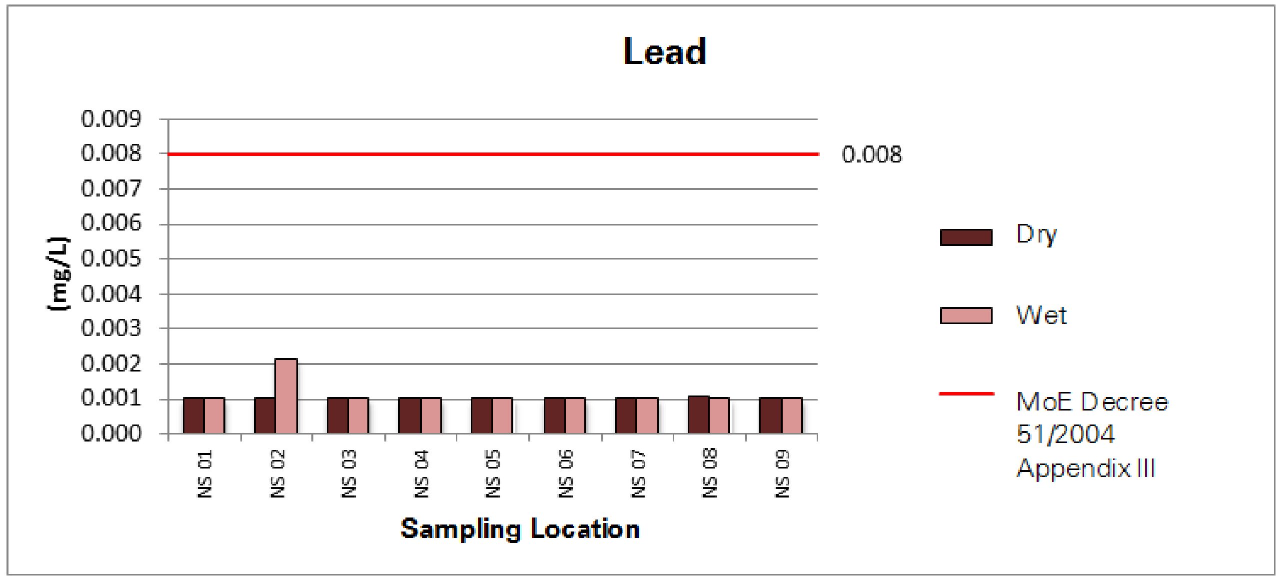


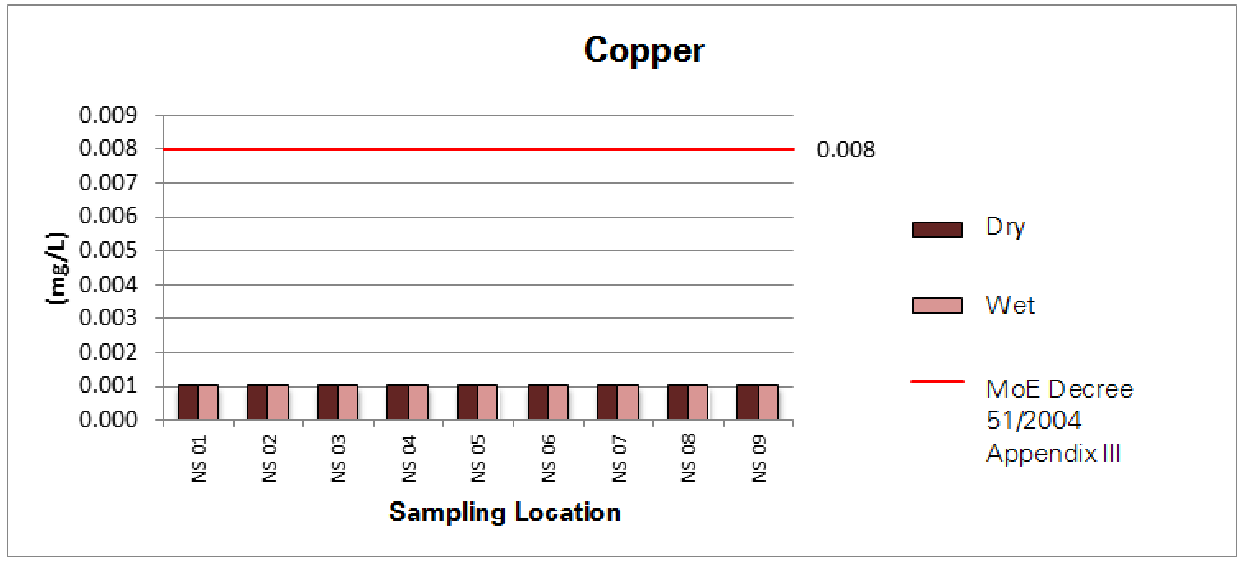
Figure II-56 Graph of Seawater Chemical Parameters (*Nearshore*) (3)











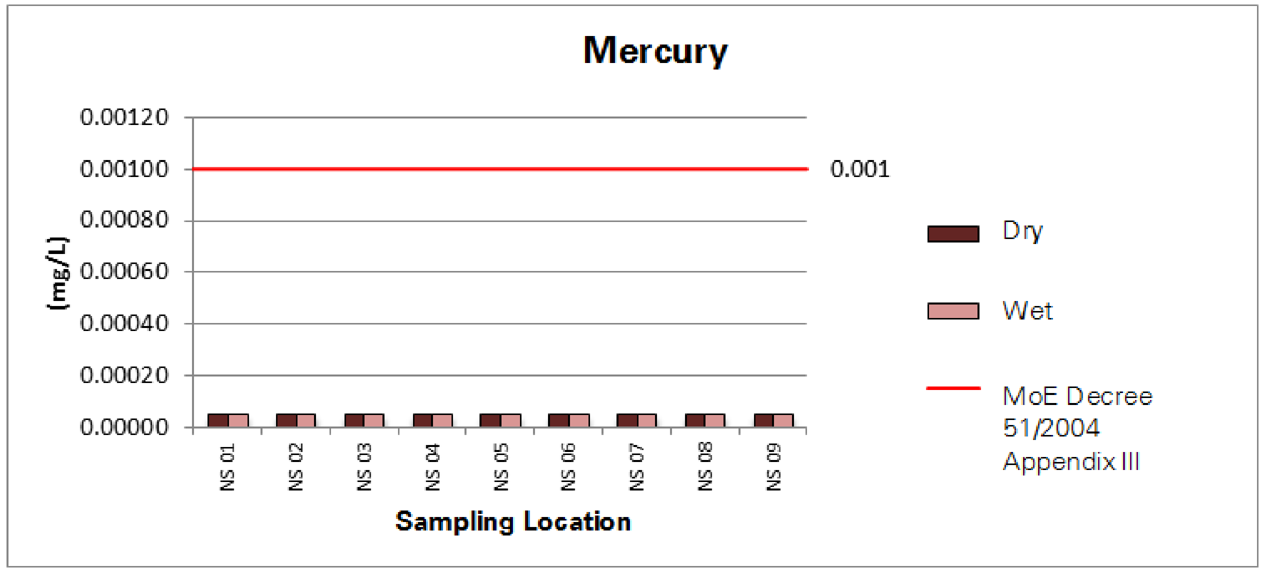
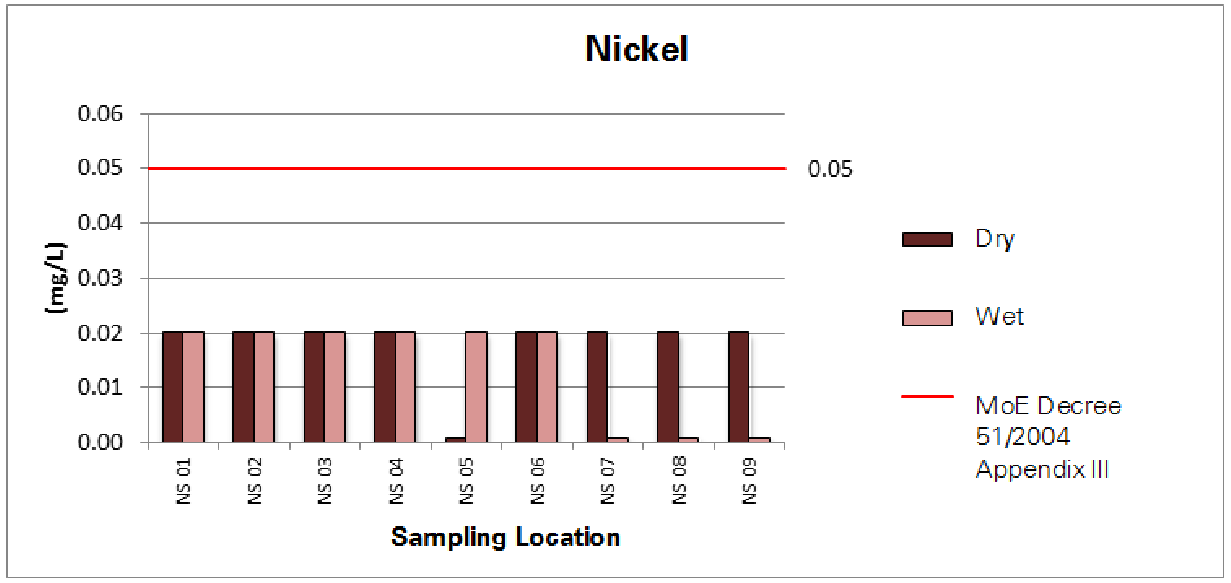


Figure II-57 Graph of Seawater Dissolved Metals Parameters (*Nearshore*) (1)



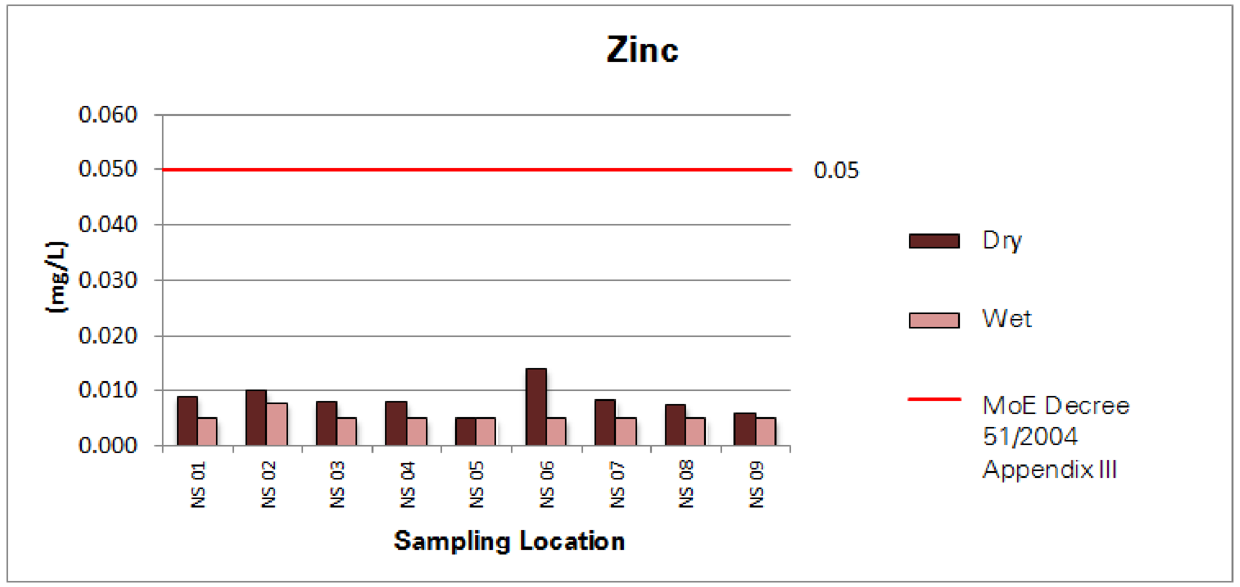


Figure II-58 Graph of Seawater Dissolved Metals Parameters (*Nearshore*) (2)

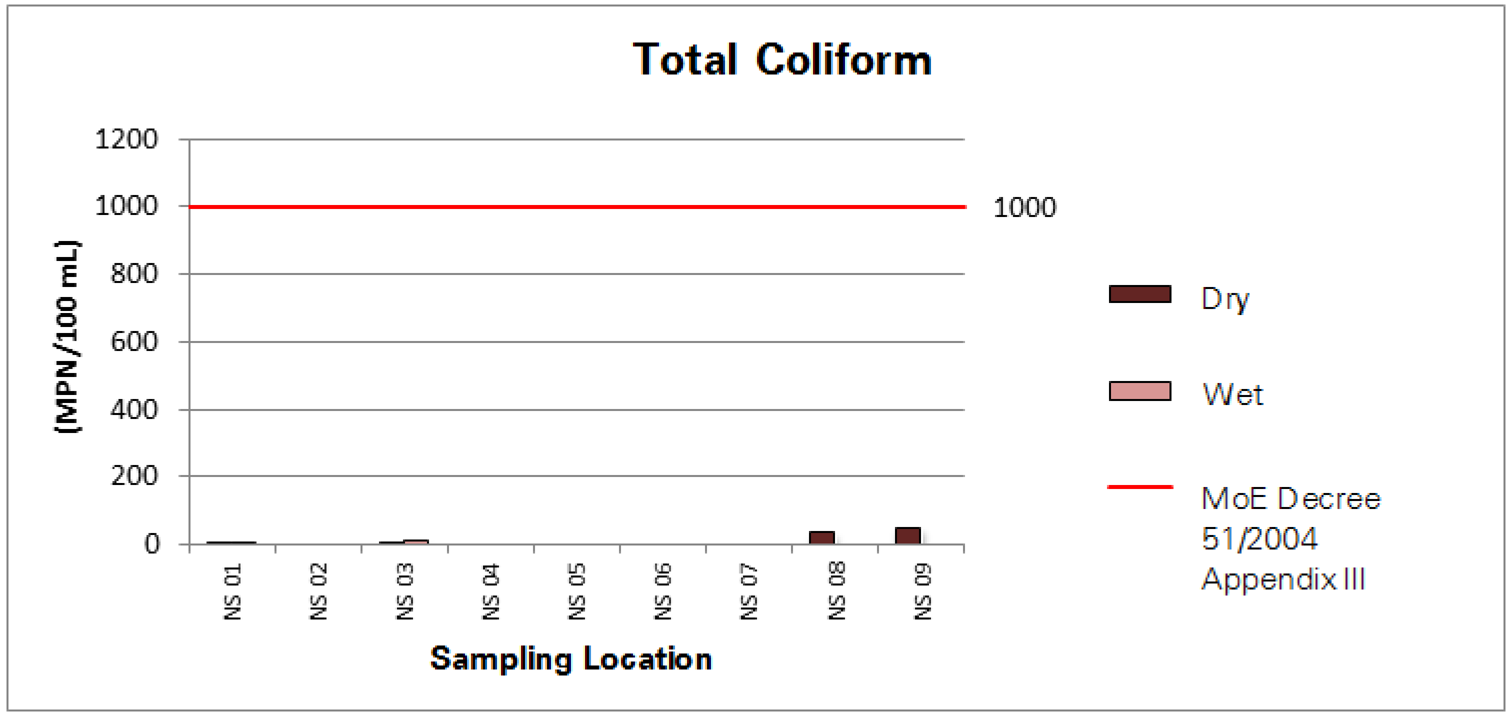


Figure II-59 Graph of Seawater Microbiological Parameters (*Nearshore*)

Offshore Seawater Quality

The analysis results of offshore seawater quality are shown in **Table II-37** and **Figure II-60** to **Figure II-66**. Based on the analysis results, offshore seawater quality generally met quality standard. Several parameters of seawater quality , i.e. sulfide, total cyanide, ammonia, BOD_5, oil and grease, total phenol, surfactane (MBAS), PAH; as well as chromium hexavalent dissolved metals, copper, lead, mercury and nickel were not detected (below instrument detection limit) in all sampling locations, in the dry season and wet season. Other dissolved metals such as arsenic, cadmium and zinc were detected in several sampling locations with very low concentrations and with far lower value than threshold limits of quality standard for the dissolved metals.

Similar to nearshore waters, except TSS, seawater quality parameters that did not meet quality standard were turbidity, nitrate, phosphor and DO.

Turbidity of offshore seawater in all sampling locations during the dry season ranged between 1.5 to 10.9 NTU. Sampling location OS 09 (waters around ROA platform), OS 10 (waters between Tangguh LNG and VRB platform) and OS 14 (at the easternmost end of Bintuni Bay, reference point) had a turbidity value exceeding threshold limit (quality standard <5 NTU) with turbidity values of 10.1 NTU, 10.9 NTU and 8.4 NTU detected respectively. While during the wet season, turbidity ranged between 1.2 to 379 NTU. Sampling location OS 03 (waters at north of Goras), OS 06 (waters around KKA platform) and OS 14 (at the easternmost end of Bintuni Bay, reference point) had turbidity values > 5 NTU, i.e. 187 NTU, 379 NTU and 16.3 NTU detected respectively. Extreme high water turbidity at OS 03 and OS 06 were likely due to the higher concentration of TSS in both of the sampling locations (TSS at OS 03 was detected 25 mg/L and at OS 06 was detected 20 mg/L) that were relatively higher than other sampling locations.

The phenomena of nitrogen compound as N and phosphate compound as P in offshore waters of Bintuni Bay were similar to nearshore waters. The analysis results of nitrate as N and phosphate as P in the dry and wet seasons in offshore waters indicated a range of values between 0.015 – 0.231 mg/L for N, and between <0.005–0.046 mg/L for P. The analysis data indicated that nitrogen compound as N in offshore waters of Bintuni Bay was categorized as low since it was smaller than 0.8 mg/L, while phosphate compound as P was also categorized as low since it was <0,07 mg/L except at observation points of OS 03 and OS 04 in the dry season that were detected at 0.128 mg/L and 0.323 mg/L respectively. The calculations showed that the ratio of N:P for offshore waters of Bintuni Bay ranged between 3:1 to 5:1. The ratio of N:P <16:1 indicated a constraint in one of the elements of seawater besides nitrogen in seawater productivity (*Downing*, 1997).

In offshore waters during the wet season and dry season, N-nitrate ranged between 0.019 -0.231 mg/L and P-phosphate ranged between <0.005 – 0.128 mg/L. Based on the range of values, generally the concentration of nutrients (N-nitrate and P-phosphate) in Bintuni Bay waters cannot be considered high yet; besides due to the ratio N:P in offshore waters of Bintuni Bay was <16:1, then it can be concluded in terms of nutrient-rich waters it was not optimal yet. This was supported by observation results of phytoplankton in offshore waters, similar to nearshore waters, which Cyanophyceae was only represented by one genus namely Trichodesmium. Trichodesmium is a member of the Cyanobacteria class with filament and commonly found in nutrient-poor seawater. The phenomena of nitrogen and phosphor concentrations in offshore waters of Bintuni Bay was similar to that of nearshore waters.

In general, the concentration of DO in the dry season and wet season in all sampling locations met quality standard, with concentration of DO observed > 5 mg/L, except at location OS 09 (in the waters around ROA platform) during the dry season the concentration of DO was slightly lower than the threshold limit of 5 mg/L, i.e. 4.86 mg/L (nonetheless the value of DO cannot be considered low).

Table II-37 Analysis of Seawater Quality Offshore OS1 – OS7

No.	Parameter	Unit	Quality standard*	OS 01		OS 02		OS 03		OS 04		OS 05		OS 06		OS 07	
				Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
	Physical																
1	Clarity[1)]	m	*	3.0	4.0	4.0	6.0	2.0	2.0	5.0	10.0	3.0	3.5	3.0	1.5	3.0	4.0
2	Floating Objects[1)]	-	nil	nil	nil	nil	nil	nil	nil	nil	nil	Nil	Nil	Nil	nil	nil	nil
3	Odor[1)]	-	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural
4	Oil Layer[1)]	-	nil	nil	nil	nil	nil	nil	nil	nil	nil	Nil	Nil	nil	nil	nil	nil
5	pH[1)]	-	7 -8.5	8	7.86	8	7.9	8.61	8.04	8.63	7.9	8	7.86	8.58	8.04	8.55	7.94
6	Salinity[1)]	‰	Natural**	31	27.7	31	28.9	31.1	25.4	31,9.	29.2	30	27.6	31.2	27.1	31.2	26.1
7	Temperature[1)]	°C	Natural***	28	29.5	28	29.8	30.2	29.9	29.8	30.8	29	30.5	30.1	30,2	30.1	31.1
8	Total Suspended Solids, TSS	mg/L	****	2	6	2	4	8	25	11	6	4	3	12	20	11	9
9	Turbidity [1)]	NTU	< 5	3.6	1.8	4	1.9	3.9	187	1.5	1.2	2.4	1.5	2.1	379	4.7	1,5
	Anion																
1	Sulfide, H_2S	mg/L	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
2	Total Cyanide, CN	mg/L	0,5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Nutrient																
1	Ammonia, NH_3-N	mg/L	0.3	<0.02	<0.02	<0,02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2	Nitrate, NO_3-N	mg/L	0.008	0.080	0.031	0.091	0.019	0.033	0.051	0.051	0.015	0.087	0.030	0.033	0.072	0.049	0.030
3	Total Phosphor , P	mg/L	0.015	0.010	0.018	<0.005	0.017	0.128	0.016	0.323	0.020	0.005	0.018	0.046	0.025	0.043	0.021
	Microbiological																
1	Total Coliform	MPN/100mL	1000	TTD	2	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD
	Dissolved metals																
1	Arsenic, As	mg/L	0.012	0.0007	0.0011	0.0011	0.0011	0.0018	0.0011	0.0018	0.0010	0.0006	0.0010	0.0015	0.0011	0.0018	0.0008
2	Cadmium, Cd	mg/L	0.001	0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0005	<0.0001	<0.0001	0.0006	<0.0001	<0.0001	<0.0005	<0.0001	<0.0001
3	Chromium Hexavalent, Cr^{6+}	mg/L	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
4	Copper, Cu	mg/L	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
5	Lead, Pb	mg/L	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0,001
6	Mercury, Hg	mg/L	0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
7	Nickel, Ni	mg/L	0.05	<0.02	<0.001	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001
8	Zinc, Zn	mg/L	0.05	0.008	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0,005	<0.005
	Others																
1	Biochemical Oxygen Demand, BOD_5	mg/L	20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
2	Dissolved oxygen, DO [1)]	mg/L	>5	6.17	5.33	5.70	5.70	5.88	5.95	5.35	6.86	5.68	6.17	5.33	5.97	5.81	6.22
3	Surfactane, MBAS	mg/L	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Oil and Grease	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
5	Total phenol Compound	mg/L	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Organic																
1	Polycyclic Aromatic Hydrocarbon, PAHs	mg/L	0.003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

1) In-situ measurement
2) Minister of the Environment Decree No. 51 Year 2004, Appendix III: Quality Standard of Seawater for Marine Biota
* For coral reef >5 m, seagrass >3 m, unlimited for mangrove
** Change allowed up to <5% average seasonal salinity
*** Change allowed up to <2 °C of normal temperature
**** For coral reef: 20 mg/L, seagrass: 20 mg/L; mangrove: 80 mg/L

Table II-38 Analysis Offshore Seawater Quality OS8 – OS14

No	Parameter	Unit	Quality standard	OS 08		OS 09		OS 10		OS 11		OS 12		OS 13		OS 14	
				Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
	Physical																
1	Clarity[1]	m	*	4.0	4.0	2.0	3.0	2.0	3.0	3.0	5.0	3.0	5.0	2.0	5.0	1.0	0.8
2	Floating Objects[1]	-	nil	nil	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
3	Odor[1]	-	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural	Natural
4	Oil Layer[1]	-	nil	nil	nil	nil	nil	Nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
5	pH[1]	-	7 -8.5	7.63	7.94	7.70	7.93	7.75	7.90	7.97	7.89	7.64	7.92	7.60	7.8	7.50	7.58
6	Salinity[1]	‰	Natural**	29.80	26.1	30.40	26.7	29.97	28.7	30.30	27.4	29.93	27.7	29.63	28.8	28.0	21.9
7	Temperature[1]	^oC	Natural***	28.90	31.1	28.70	31.0	28.97	29.9	28.20	30.5	28.93	31.3	29.00	29.9	28.5	31.3
8	Total Suspended Solids, TSS	mg/L	****	7	9	11	6	18	3	9	6	10	9	17	5	19	30
9	Turbidity [1]	NTU	< 5	4,2	1.5	10.1	1.4	10.9	2.6	2,4	0.6	3.3	0.5	5,4	< 0.5	8.4	16.3
	Anion																
1	Sulfide, H_2S	mg/L	0.01	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
2	Total Cyanide, CN	mg/L	0.5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
	Nutrient																
1	Ammonia, NH_3-N	mg/L	0.3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
2	Nitrate, NO_3-N	mg/L	0.008	0.179	0.030	0.121	0.030	0.149	0.034	0.126	0.035	0,.59	0.029	0.180	0.029	0.231	0.110
3	Total Phosphor , P	mg/L	0.015	<0.005	0.021	<0.005	0.019	<0.005	0.028	<0.005	0.021	0.006	0.021	<0.005	0.023	<0.005	0.024
	Microbiological																
1	Total Coliform	MPN/100mL	1000	TTD	TTD	TTD	TTD	TTD	23	TTD	TTD	TTD	TTD	TTD	TTD	TTD	TTD
	Dissolved metals																
1	Arsenic, As	mg/L	0.012	0.0009	0.0008	0.0007	0.0010	0.0005	0.0018	0.0008	0.0018	0.0006	0.0018	0.0007	0.0013	0.0005	0.0012
2	Cadmium, Cd	mg/L	0.001	0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0005
3	Chromium Hexavalent, Cr^{6+}	mg/L	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
4	Copper, Cu	mg/L	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
5	Lead, Pb	mg/L	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
6	Mercury, Hg	mg/L	0.001	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00014	<0.00005	<0.00005
7	Nickel, Ni	mg/L	0.05	<0.02	<0.001	<0.02	<0.001	<0.02	<0.001	<0.02	<0.001	<0.02	<0.001	<0.02	<0.001	<0.02	<0.02
8	Zinc, Zn	mg/L	0.05	0.006	<0.005	0.006	<0.005	0.006	<0.005	0.005	<0.005	0.007	<0.005	0.007	<0.005	0.009	<0.005
	Others																
1	Biochemical Oxygen Demand, BOD_5	mg/L	20	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2
2	Dissolved oxygen, DO [1]	mg/L	>5	5.94	6.22	4.86	6.58	5.13	5.57	5.85	6.12	5.35	6.71	5.13	6.36	5.13	4.85
3	Surfactane, MBAS	mg/L	1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Oil and Grease	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
5	Total phenol	mg/L	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	Organic																
1	Polycyclic Aromatic Hydrocarbon, PAHs	mg/L	0.003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

1) In-situ measurement
2) Minister of the Environment Decree No. 51 Year 2004, Appendix III: Quality Standard of Seawater for Marine Biota
* For coral reef >5 m, for seagrass >3 m, unlimited for mangrove
**Change allowed until <5% average seasonal salinity
*** Change allowed until <2 ^oC of normal temperature
**** for coral reef: 20 mg/L, seagrass: 20 mg/L; mangrove: 80 mg/L

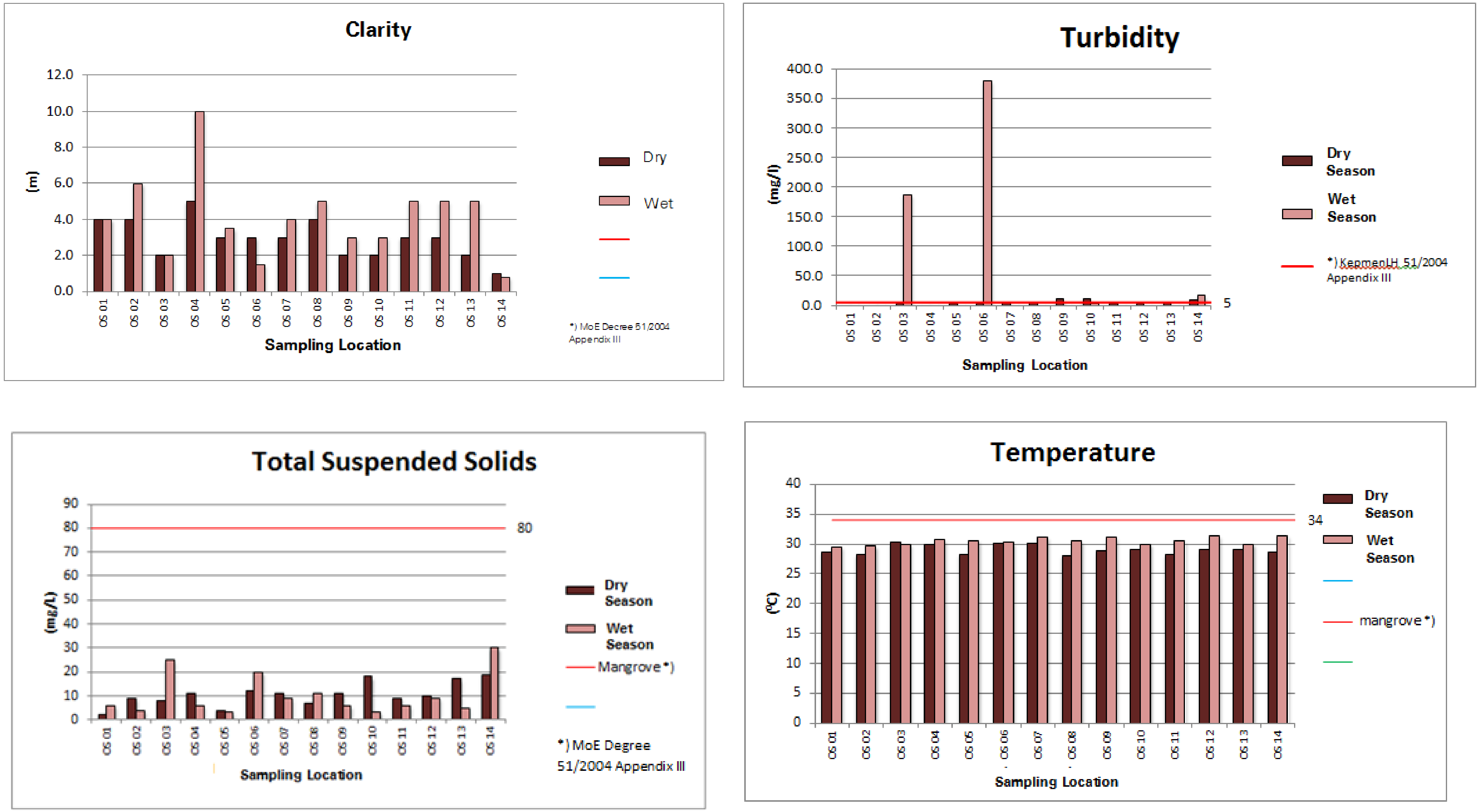


Figure II-60 Graph of Physical Seawater Parameters (*Offshore*)

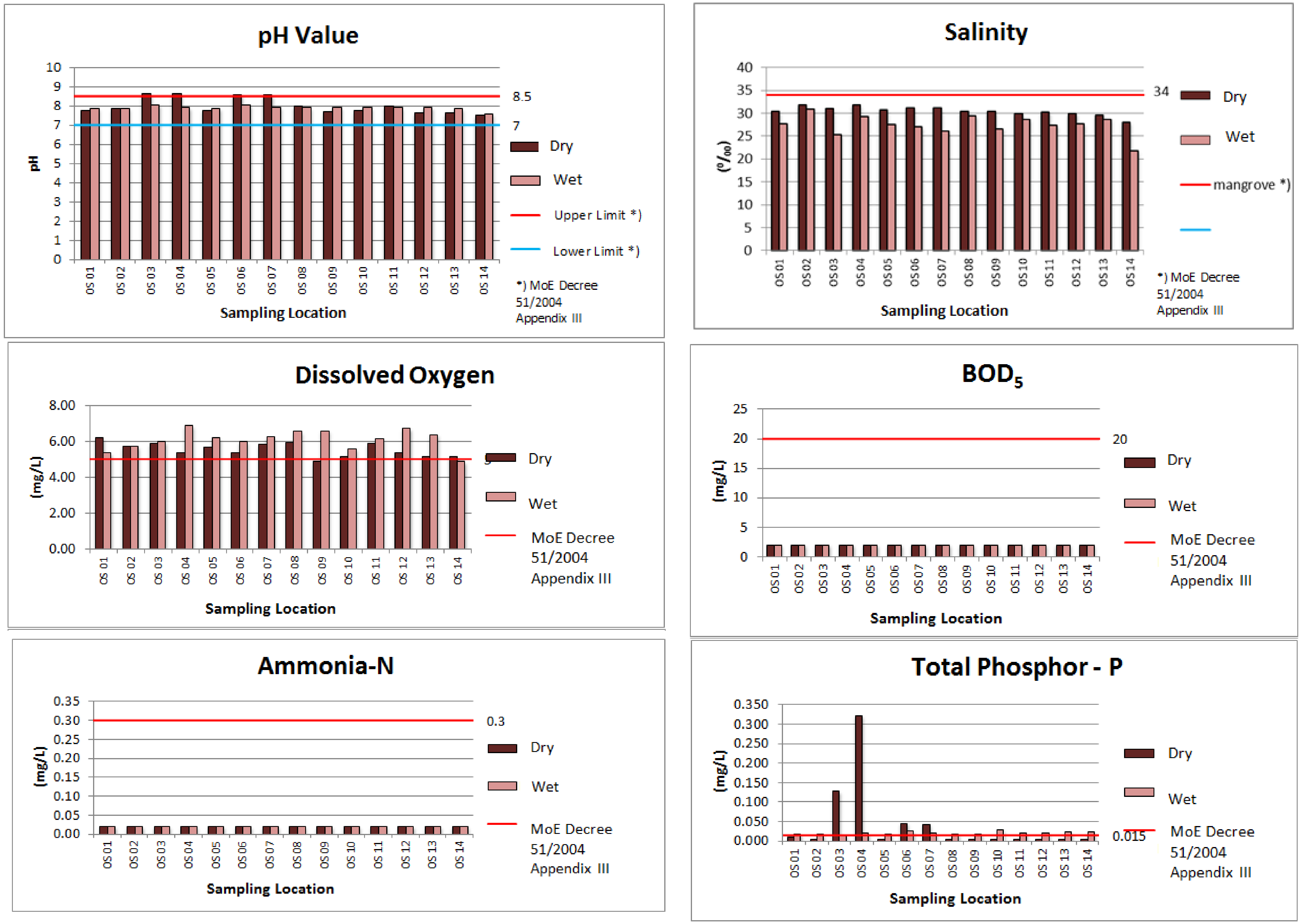


Figure II-61 **Graph of Chemical Parameters of Marine Waters (*Offshore*) (1)**

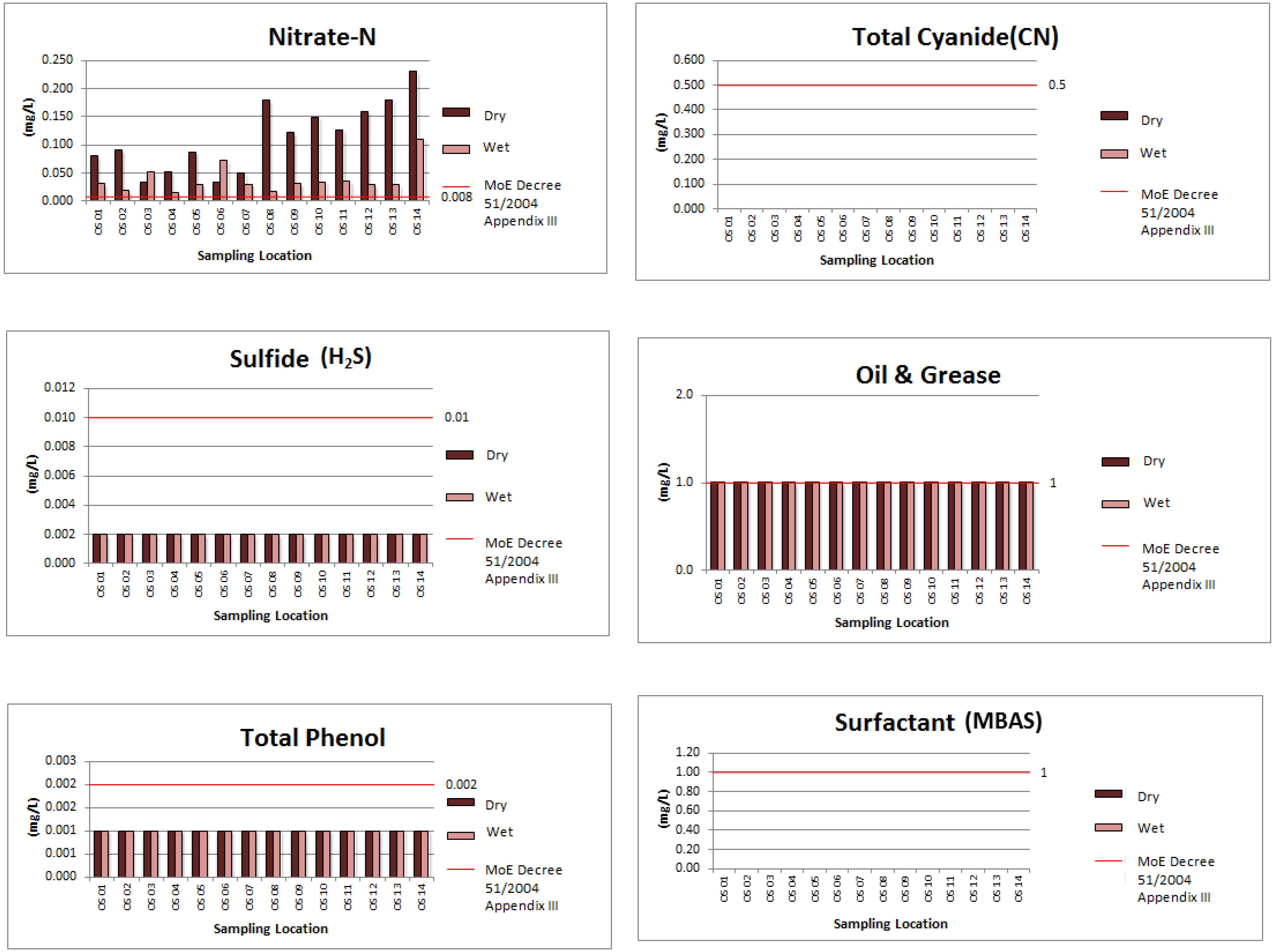


Figure II-62 Graph of Chemical Parameters of Marine Waters (*Offshore*) (2)

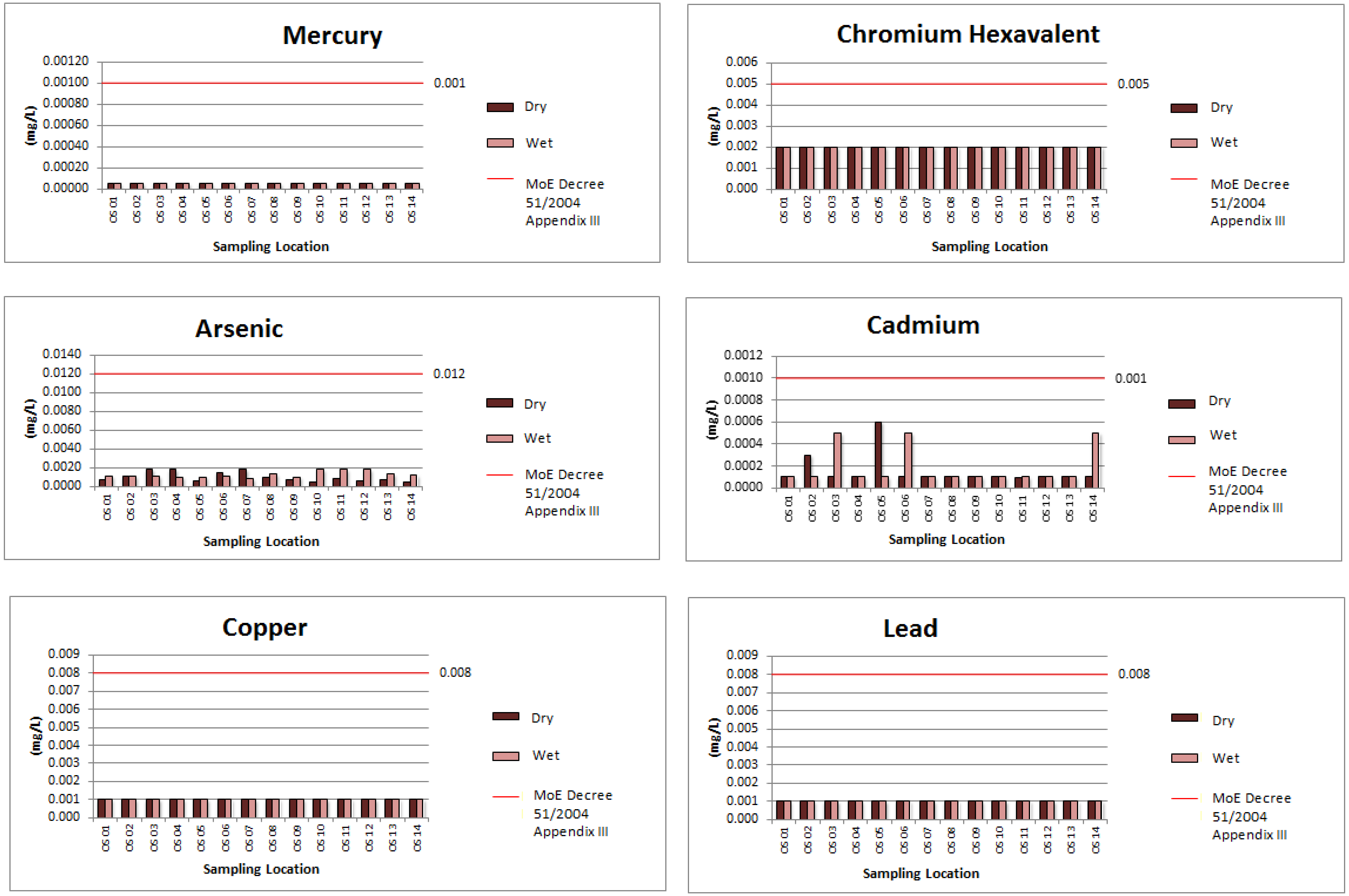


Figure II-63 Graph of Dissolved Metals Parameters of Marine Waters (*Offshore*) (1)

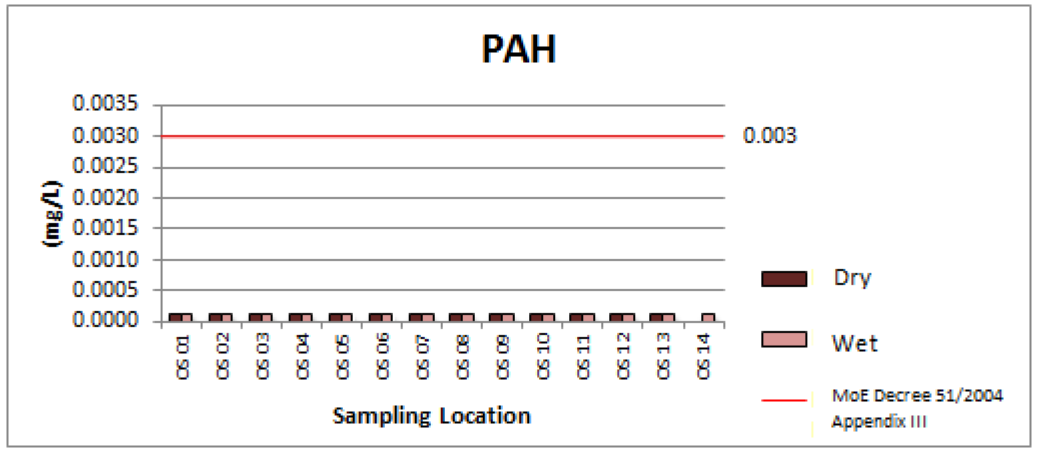
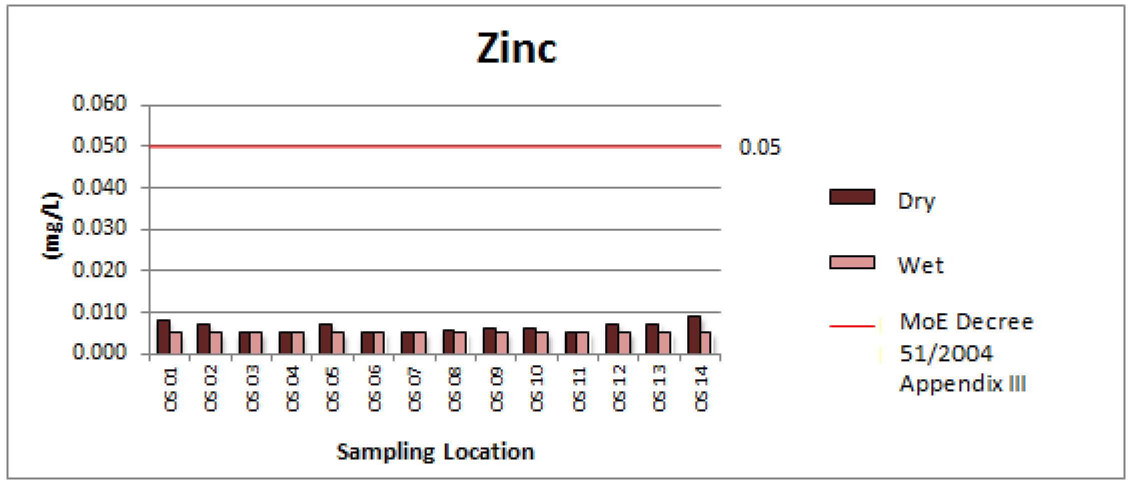


Figure II-64 Graph of Chemical Parameters of Marine Waters (*Offshore*) (3)



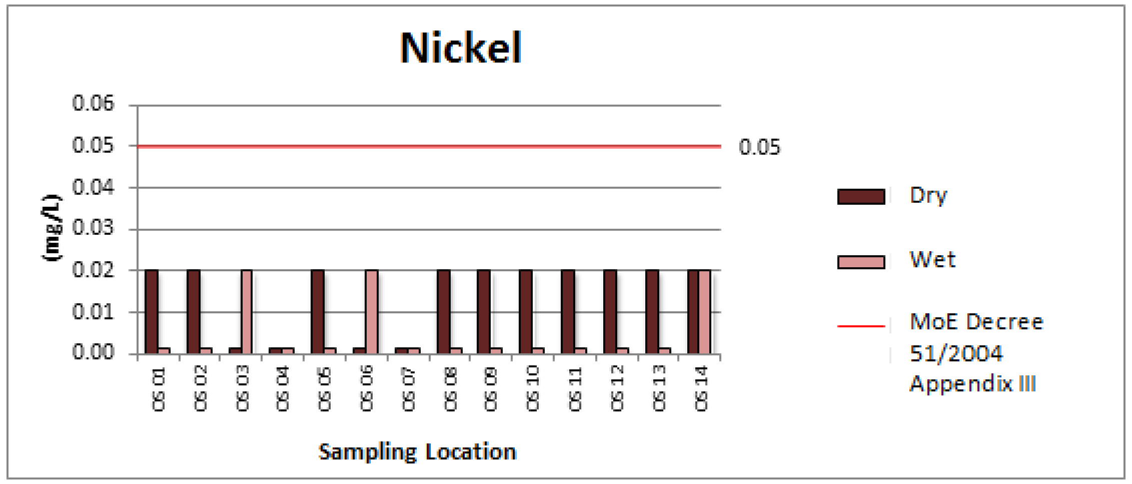


Figure II-65 Graph of Dissolved Metals Parameters of Marine Waters (Offshore) (2)

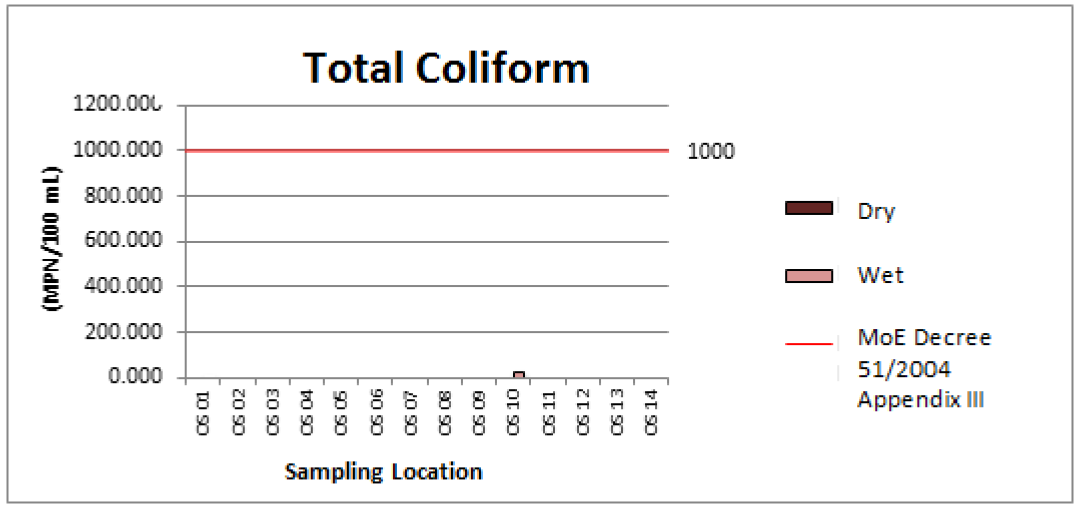


Figure II-66 Graph of Microbiology Parameters of Marine Waters (*Offshore*)

Nitrate and Phosphate concentrations of Bintuni Bay during environmental baseline study for AMDAL of the Tangguh LNG Development are provided in **Figure II-67** and **Figure II-68.**

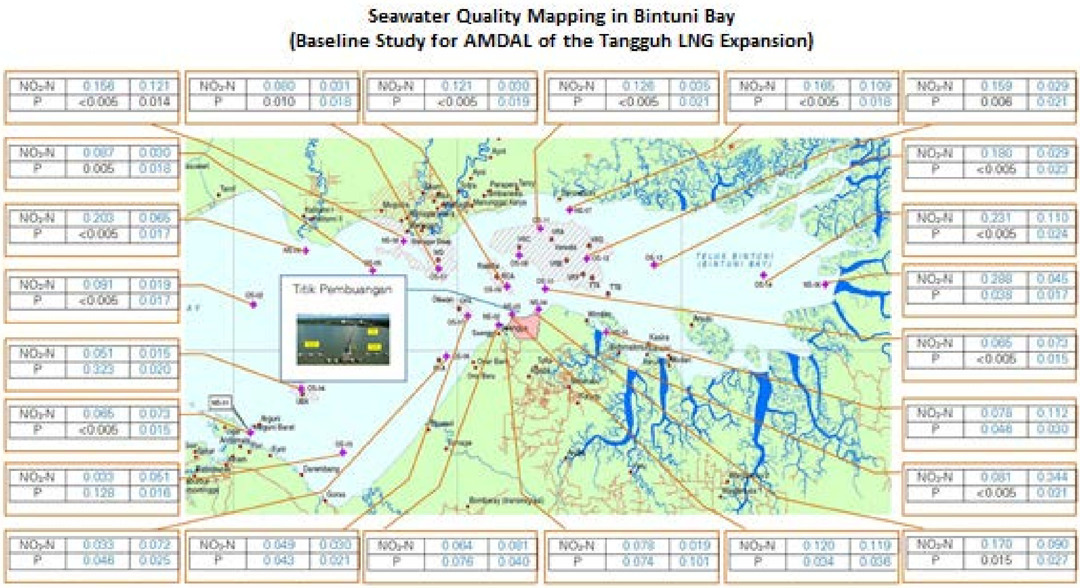


Figure II-67 Seawater Quality Mapping in Bintuni Bay (Baseline Study for AMDAL of the Tangguh LNG Expansion)

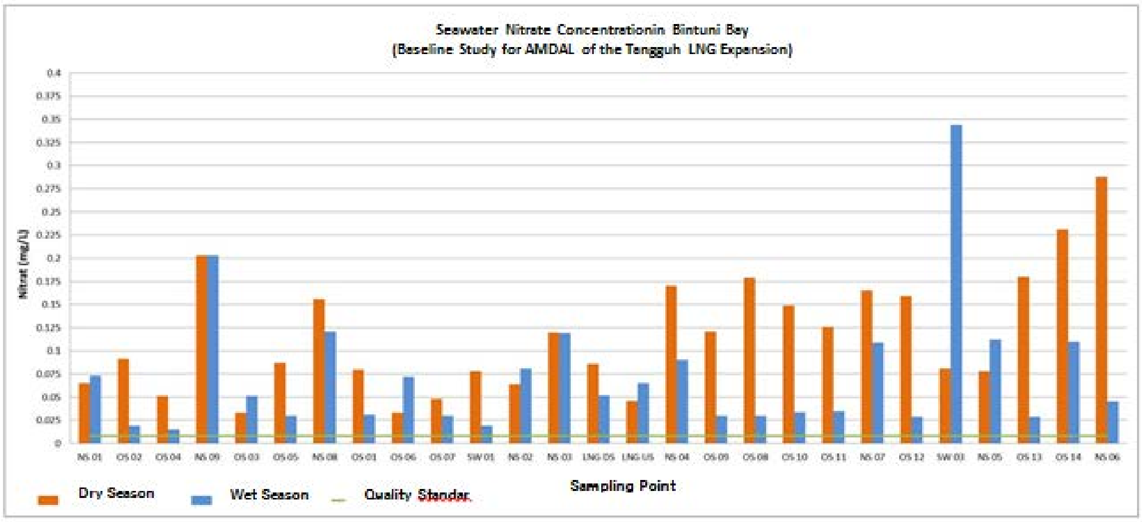
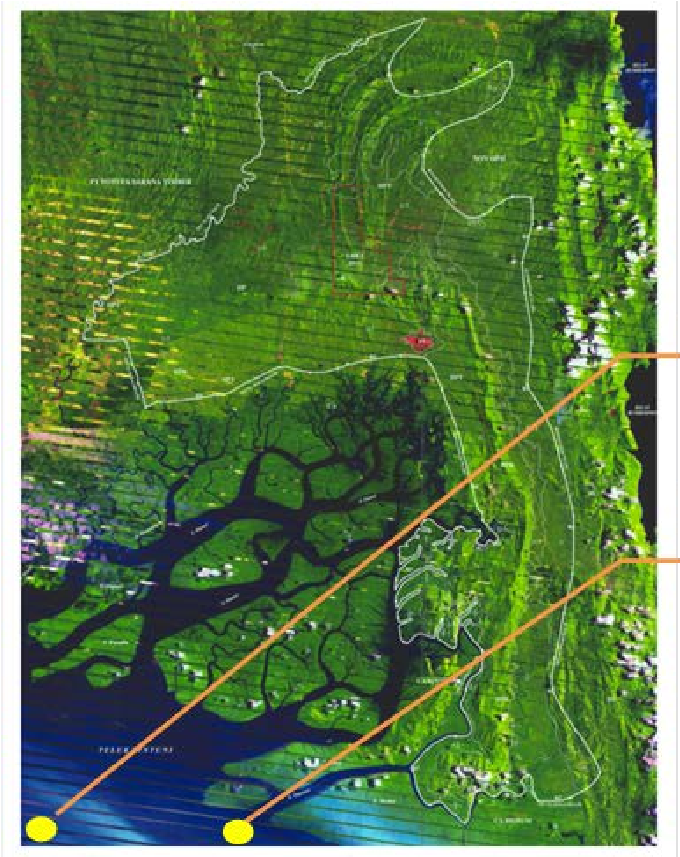


Figure II-68 Seawater Nitrate Concentrations in Bintuni Bay (Baseline Study for AMDAL of the Tangguh LNG Expansion)



Stasiun OS 14

Para-meter	Baku Mutu	Kema-rau	Hujan
NO3-N	0,008	0,231	0,110
P	0,015	<0,005	0,024

Stasiun NS 6

Para-meter	Baku Mutu	Kema-rau	Hujan
NO3-N	0,008	0,288	0,045
P	0,015	0,038	0,017

Figure II-69 Regional Condition in the Vicinity of Station NS 6 and OS 14

From the above analysis results, the following were discovered:

a) Concentrations of Nitrate and Phosphate were high in all monitoring stations. Concentration of Nitrate at nearshore locations (river estuaries) tended higher than at offshore locations

b) Concentrations of Nitrate and Phosphate at eastern of Bintuni Bay were high, i.e. at observation stations of NS 6 and OS 14 in the waters nearby Nature Reserve of Bintuni Bay approximately 80 km from the Tangguh LNG site. The Nature Reserve is a protected area and there are no large scale activities in its onshore area (see **Figure II-69**)

c) High concentrations of Nitrate and Phosphate in Bintuni Bay was a natural condition

2.1.8.4 Wastewater Quality of the Current Tangguh LNG Operations

The ongoing operations activities of the Tangguh LNG consist of two LNG trains (LNG Train 1 and LNG Train 2) to process feedgas derived from 14 production wells at two offshore platforms (VRA and VRB). The types of wastewater being managed during operations of the Tangguh LNG include:

- Produced water;

- Hydrocarbon contaminated water;
- Chemically contaminated wastewater;
- Desalination water; and
- Domestic wastewater.

The wastewater as mentioned above is treated prior to discharge overboard at the current outfall in LNG jetty at -13 m LAT. Further description of wastewater management can be seen in Chapter I of ANDAL sub chapter 1.2.3 LNG Plant activities section C7 Wastewater Management. Wastewater quality monitoring is routinely performed in accordance with provisions in the Integrated AMDAL of the Tangguh LNG that was approved in 2002 and the Wastewater Discharge Permit No.125 Year 2013 issued by Minister of the Environment. Routine monitoring results are shown in **Figure II-70** to **Figure II-75**.

a) Produced Water Quality

Produced water quality from the Produced Water Treatment during 2011 – 2013 met quality standards in accordance with the permit, except ammonia parameter. **Figure II-70** shows that ammonia concentration several times exceeded quality standard, however referring to the Wastewater Discharge Permit No. 125 Year 2013, the compliance for wastewater discharge to seawater was made toward quality standard and/or maximum load of the wastewater. The load calculation towards ammonia parameter in produced water still below the maximum load of produced water. The produced water quality can be seen in **Figure II-70** to **Figure II-75** as follows.

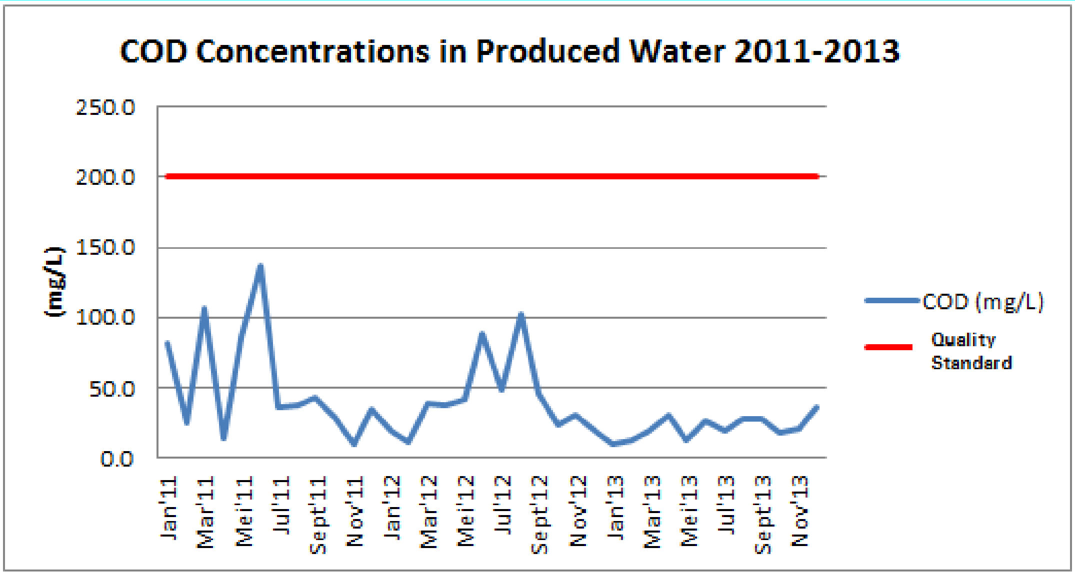


Figure II-70 COD Concentrations in Produced Water 2011-2013

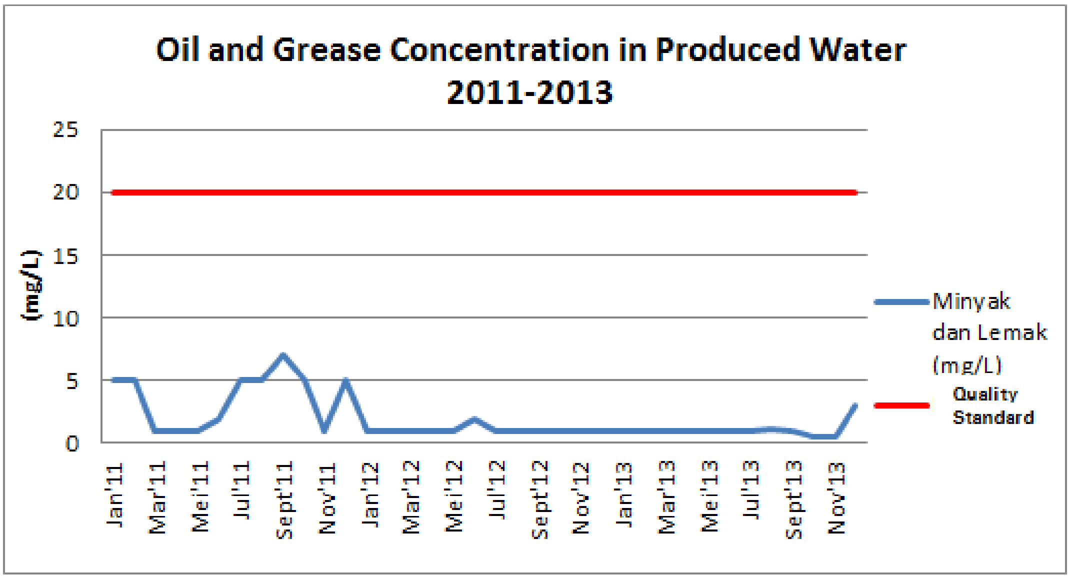


Figure II-71 Oil and Grease Concentrations in Produced Water 2011-2013

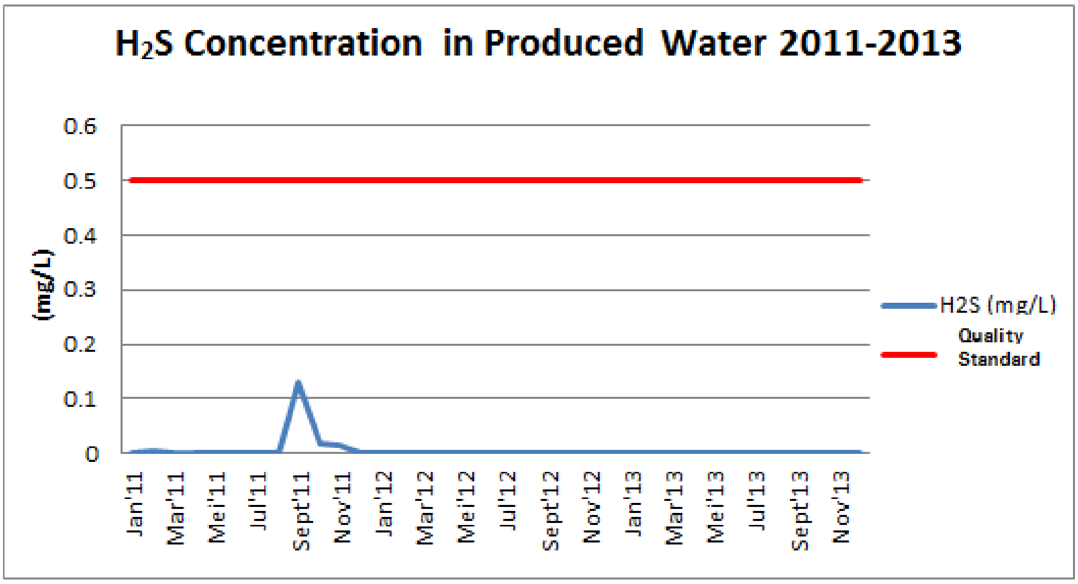


Figure II-72 H_2S Concentration in Produced Water 2011-2013

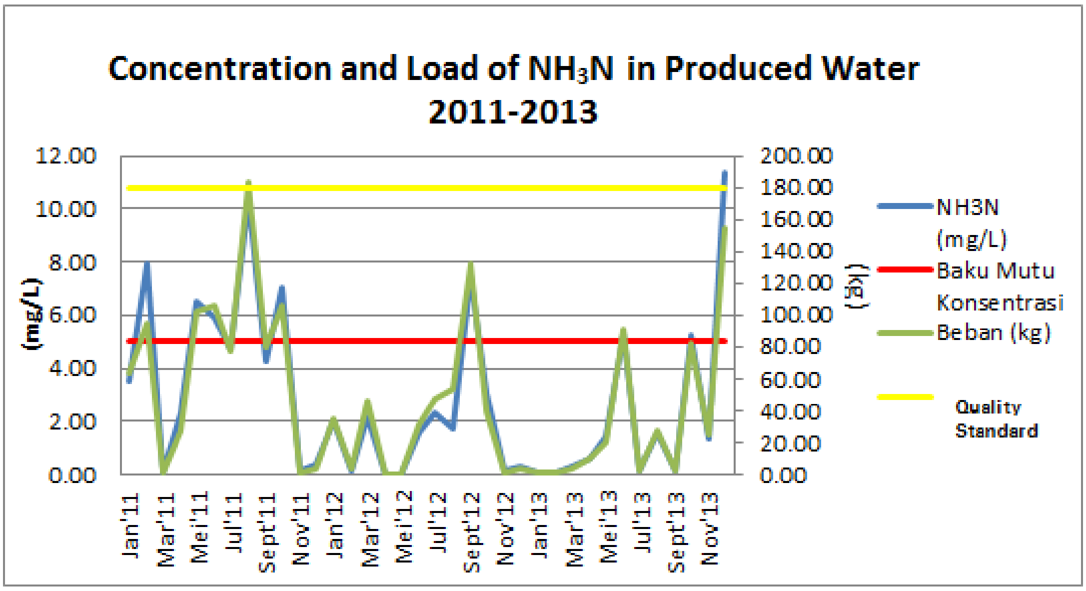


Figure II-73 Concentration and Load of NH_3N in Produced Water 2011-2013

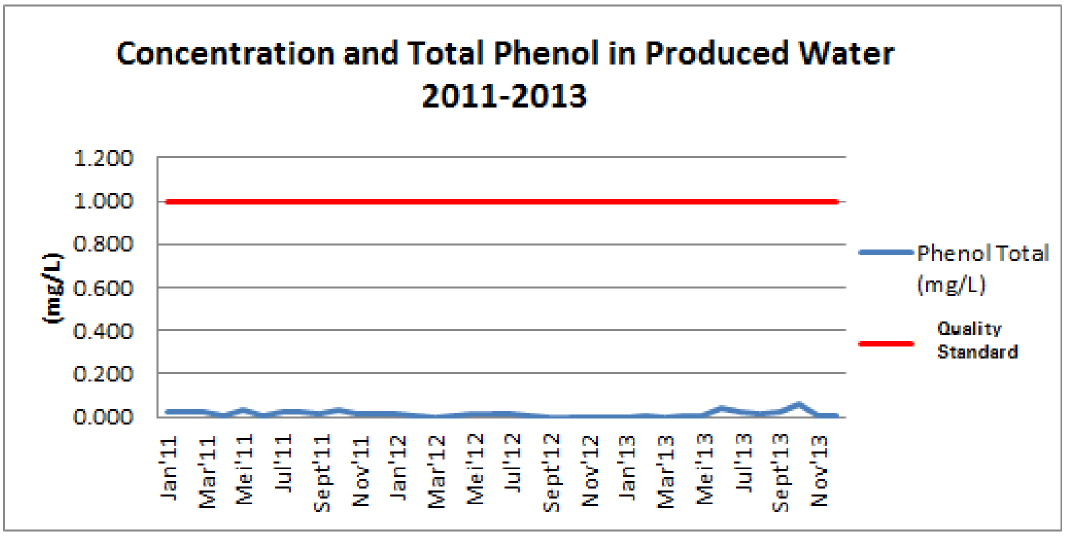


Figure II-74 Concentration of Total Phenol in Produced Water in 2011-2013

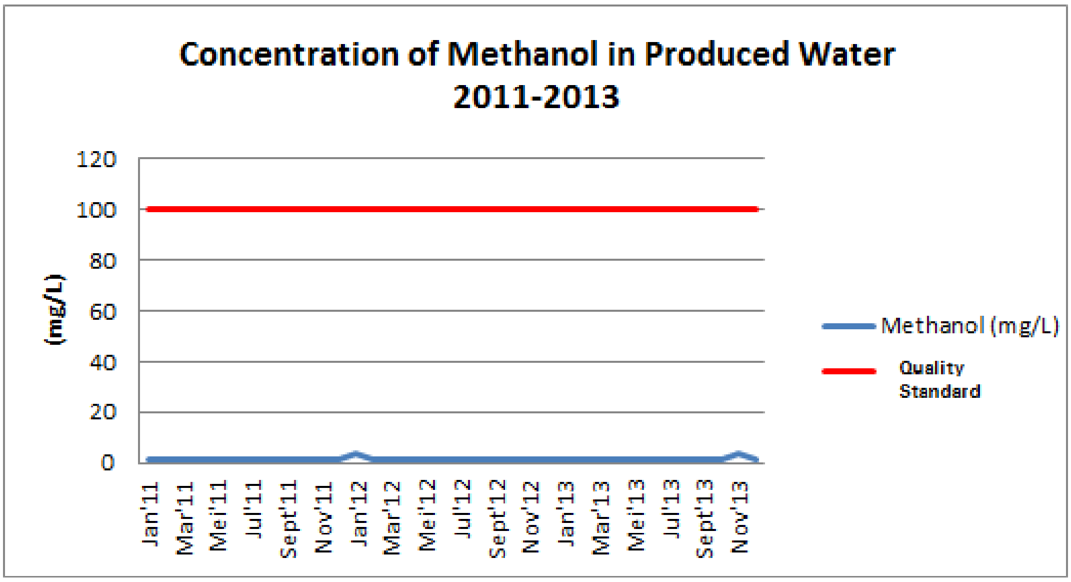


Figure II-75 **Concentration of Methanol in Produced Water 2011-2013**

b) Hydrocarbon Contaminated Water

Hydrocarbon contaminated water is treated in CPI (*Corrugated Plate Interceptor*) to reduce the hydrocarbon content. The effluents of CPI are then flown to produced water tank to be treated together with produced water. There is no discharge of hydrocarbon contaminated water treated by CPI directly into the sewerage system (discharge pipelines).

c) Chemically Contaminated Wastewater

Chemically contaminated wastewater quality during 2011 to 2013 met applicable quality standard as shown in **Figure II-76** to **Figure II-768.**

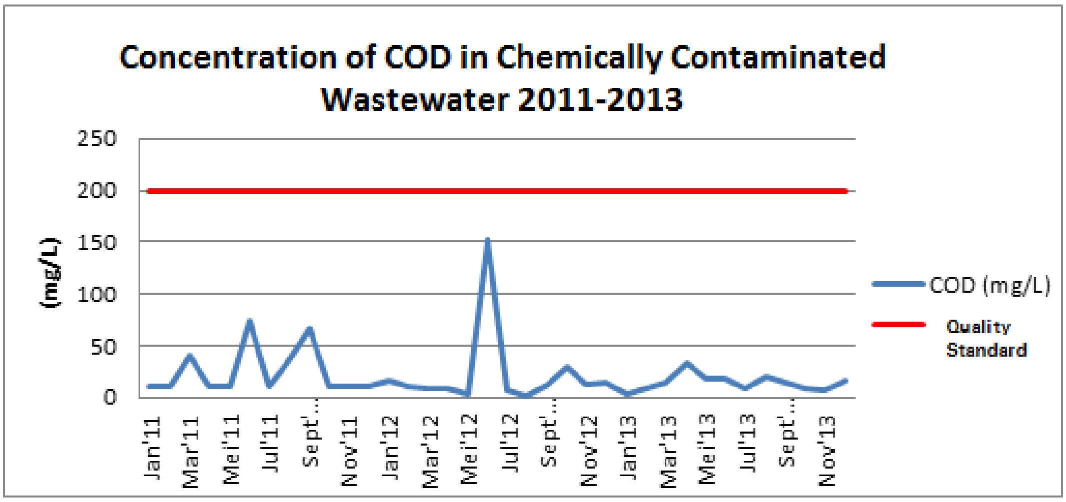


Figure II-76 **Concentration of COD in Chemically Contaminated Wastewater in 2011-2013**

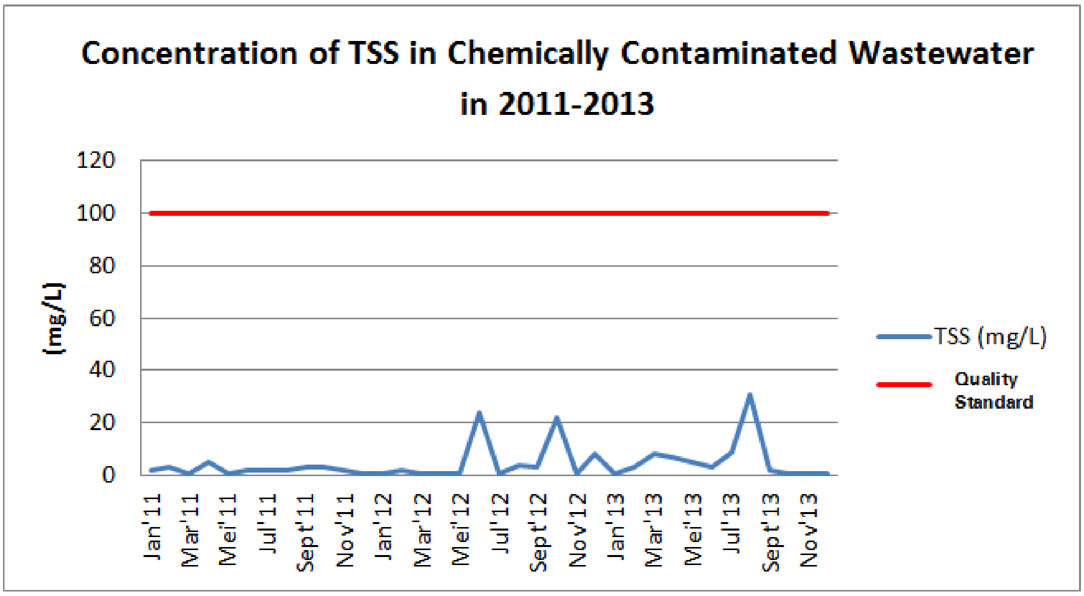


Figure II-77 **Concentration of TSS in Chemically Contaminated Wastewater in 2011-2013**

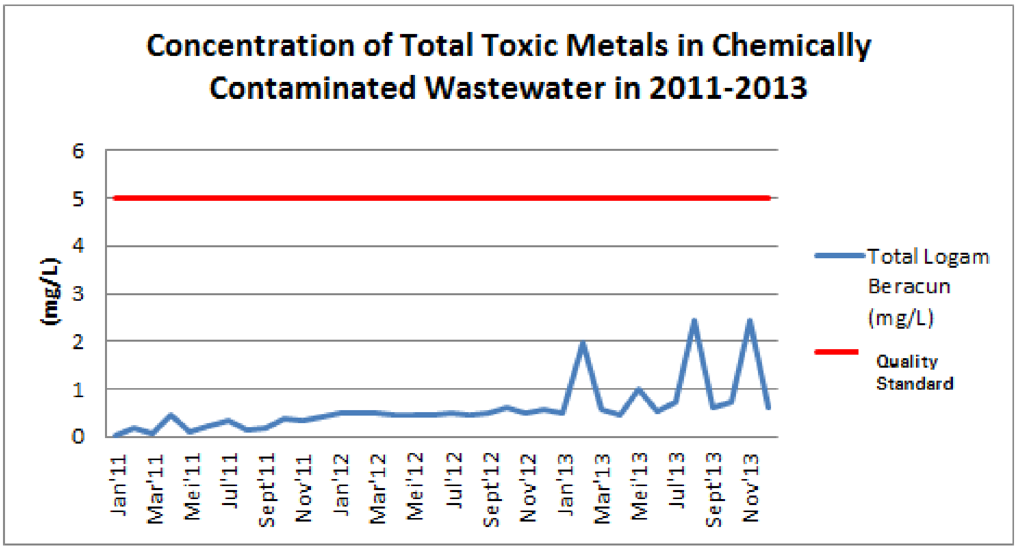


Figure II-78 **Concentration of Total Toxic Metals in Chemically Contaminated Wastewater in 2011-2013**

d) Desalination Wastewater (Brine Water Reject)

Desalination wastewater monitoring only included pH and salinity in accordance with the Wastewater Discharge Permit Number 125 Year 2013 issued by Ministry of the Environment which the quality met the applicablestandard

e) Domestic Wastewater (Sewage)

Domestic wastewater treated in Sewage Treatment Plant (STP) is routinely monitored by an accredited laboratory in accordance with the quality standard specified in the Watewater Discharge Permit Number 125Year 2013 issued by Ministry of the Environment. The monitoring results are presented in **Figure II-79** to **Figure II-81** as follows:

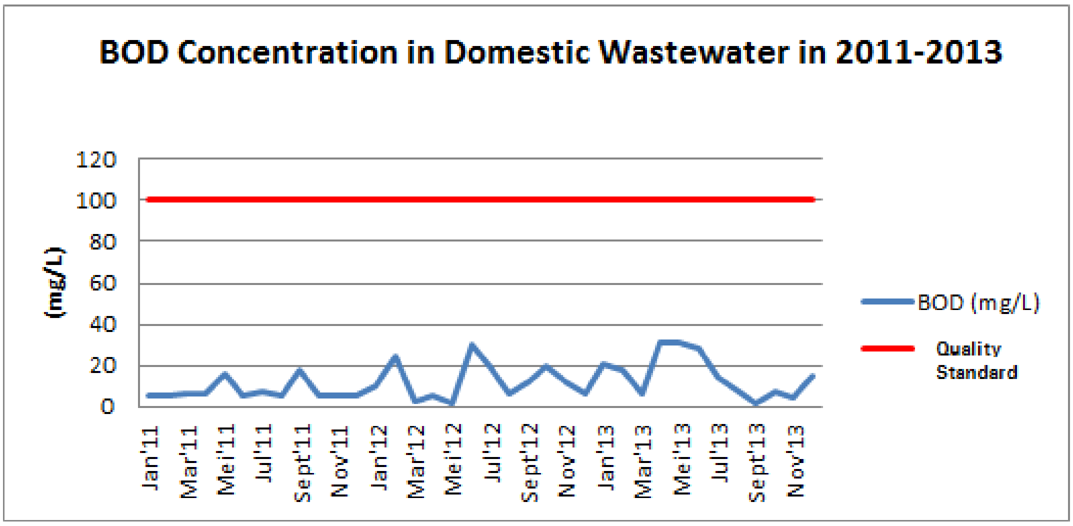


Figure II-79 BOD Concentration in Domestic Wastewater in 2011-2013

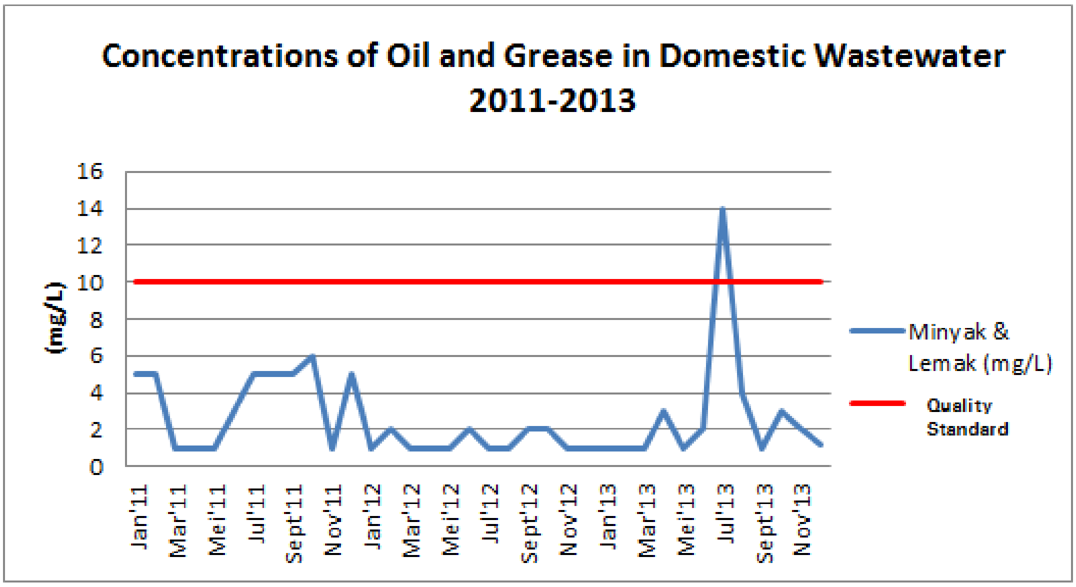


Figure II-80 Concentrations of Oil and Grease in Domestic Wastewater 2011-2013

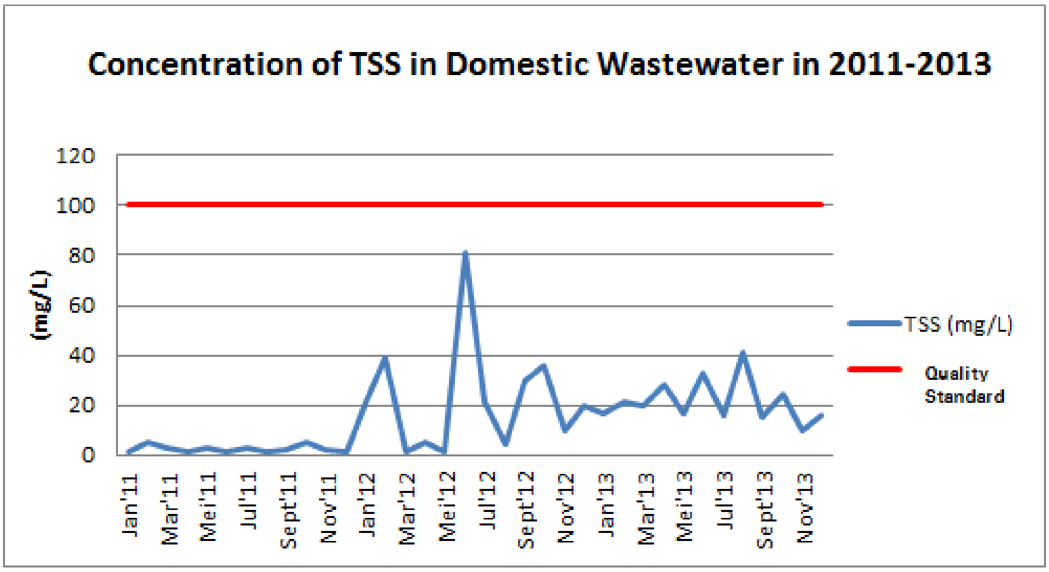


Figure II-81 **Concentration of TSS in Domestic Wastewater 2011-2013**

2.1.9 Sediment

Sea bed sediment quality samples were taken in nearshore and offshore waters of Bintuni Bay. The sampling locations were the same as seawater quality sampling locations and conducted twice, i.e in the dry season and wet season.

In the dry season between the months of August – October 2012, 11 sediment samples were taken in *offshore* areas (OS) and nine sediment samples in *nearshore* (NS) areas; while in the wet season between March – April 2013, 14 sediment samples were taken in *offshore* (OS) and eight samples in *nearshore* (NS) areas. River sediment sampling was done in the dry season and wet season with respectively two samples taken. Locations of sediment sampling were the same as those for water quality and benthos as shown in **Table II-34** and **Map II-13.**

So far, Indonesia does not have a sediment quality standard determining the threshold limits of sediment quality. For this purpose, *ANZECC Interim Sediment Quality Guidelines (ANZECC-ISQG)* Sediment Criteria has become the reference in discussion of sediment quality since West Papua lies in the Australasia *ecoregion* (**Figure II-82**). The criteria consists of Upper Limit and Lower Limit, as shown in **Table II-39**. In the study, concentrations of heavy metal in sediment analyzed consist of antimon, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc and arsenic in accordance with the ANZECC-ISQG Sediment Quality Criteria. Selenium parameter was also analyzed , however using Sediment Quality Criteria based on *Van Derveer and Canton* (1997) with lower limit of 1 mg/kg and upper limit 4 mg/kg.

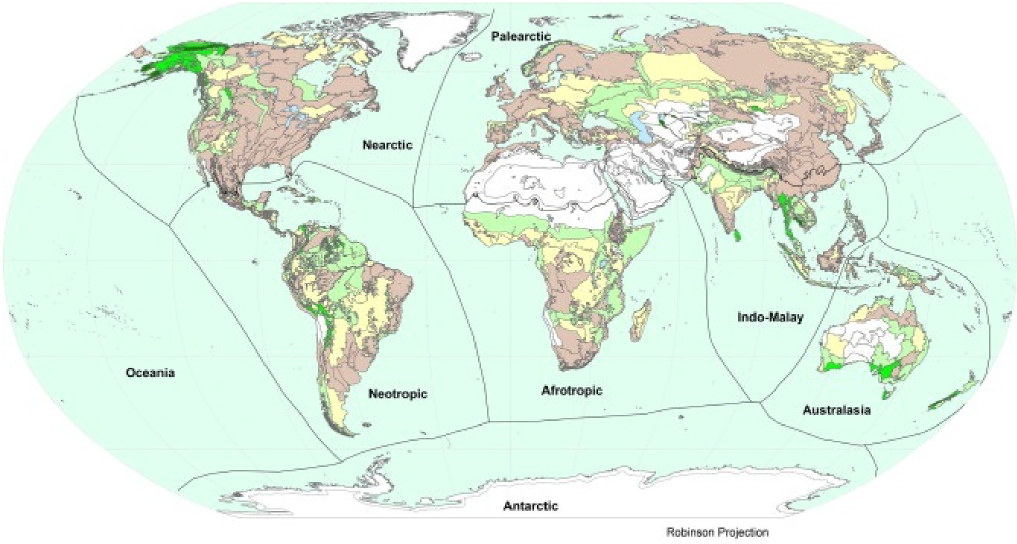


Figure II-82 Australasia Ecoregion

Table II-39 Criteria of Sediment Quality Based on ANZECC-ISQG Sediment Quality Criteria

Heavy Metals (mg/kg)	ISQG Lower Limit	ISQG Upper Limit
Antimony (Sb)	2	25
Cadmium (Cd)	1.5	10
Chromium (Cr)	80	370
Copper (Cu)	65	270
Lead (Pb)	50	220
Mercury (Hg)	0,15	1
Nickel (Ni)	21	52
Silver (Ag)	1.0	3.7
Zinc (Zn)	200	410
Arsenic (As)	20	70
Selenium (Se)*	1	4

* Selenium content based on *Van Derveer and Canton (1997),* with lower limit 1 mg/kg and upper limit 4 mg/kg.

Analysis results of heavy metals in sediment are shown in full in **Table II-41** and **Table II-42** (Offshore), **Table II-43** (nearshore) and **Table II-44** (River). **Figure II-85** and **Figure II-86** (Offshore), **Figure II-87** and **Figure II-88** (Nearshore) and **Figure II-89** and **Figure II-90** (River) show the graph of heavy metals content in sediment compared with the ANZECC-ISQG Sediment Quality Criteria, while **Figure II-91** depicts the range , median value using Whisker graph for each parameter according to sediment sampling location, i.e. offshore, nearshore and river.

2.1.9.1 Seabed Sediment of Offshore

Antimony (Sb)

In the dry season, concentrations of Sb ranged between 0.01 to 1.8 mg/kg. From 11 sampling locations, OS-01 approximately 10 km offshore Weriagar to the southeast or approximately 2 km south of the proposed location of WDA offshore gas platform (offshore platform to be built in initial phase development) has the highest sampling value (1.8 mg/kg) or approaching the lower limit of sediment criteria determined in ANZECC-ISQG, i.e. 2 mg/kg. The lowest value of Sb concentration is <0.01 originating from three sampling locations, namely OS-03, OS-08 and OS-10.

In the wet season, concentrations of Sb ranged between 0.12 to 1.7 mg/kg. Out of the 14 sampling locations, OS-06 which lies some 6 km offshore of Onar Baru to the west or at position of approximately 1 km northeast of the proposed offshore platform KKA (the offshore platform to be built in further phase development in the future) was the sampling location with highest value of Sb (1.7 mg/kg) or approaching the lower limit of sediment criteria as determined in ANZECC-ISQG, of 2 mg/kg.

Arsenic (As)

During the dry season, arsenic concentrations range between 4.2 to 86.9 mg/kg. From 11 sampling locations, two locations have the highest figure. High values are found for arsenic of 86.9 mg/kg at location OS-06 approximately 6 km offshore of Onar Baru to the west and the figure exceeds the sediment criteria as determined in ANZECC-ISQG, i.e. 70 mg/kg (upper limit), while at location OS-09 in position of approximately 30 km offshore from Inanwatan to the south or some 57 km from Arguni to the northwest the value of arsenic reached 60.9 mg/kg or almost approaching the upper limit (70 mg/kg) and far exceeded the lower limit of 20 mg/kg.

Arsenic concentrations at seven other locations, namely OS-04, OS-12, OS-07, OS-08, OS-10, OS-01 and OS-14 exceeded the lower limit of 21 mg/kg, while in the two remaining locations, namely OS-03 and OS-11 with arsenic concentration values of respectively 4.2 mg/kg and 10.3 mg/kg, which are still below the lower limit of 20 mg/kg.

In the wet season, arsenic concentrations ranged between 3.8 – 94.4 mg/kg. From the 14 sampling locations, three sampling locations had values exceeding the upper limit of ANZECC-ISQG i.e. 70 mg/kg. The highest value of arsenic was 94.4 mg/kg in location OS-07 situated some 10 km west of *Combo Dock*, while the value of arsenic in location OS-09 (approximately 30 km offshore from Inanwatan to the south or some 8 km from the Tangguh LNG location) and OS-10 (some 9 km northwest of *Combo Dock)* were respectively 73.9 mg/kg and 71.02 mg/kg.

Arsenic concentrations in Bintuni Bay's sediment during the environmental baseline study of AMDAL for the Tangguh LNG Expansion are shown in **Figure II-83**.

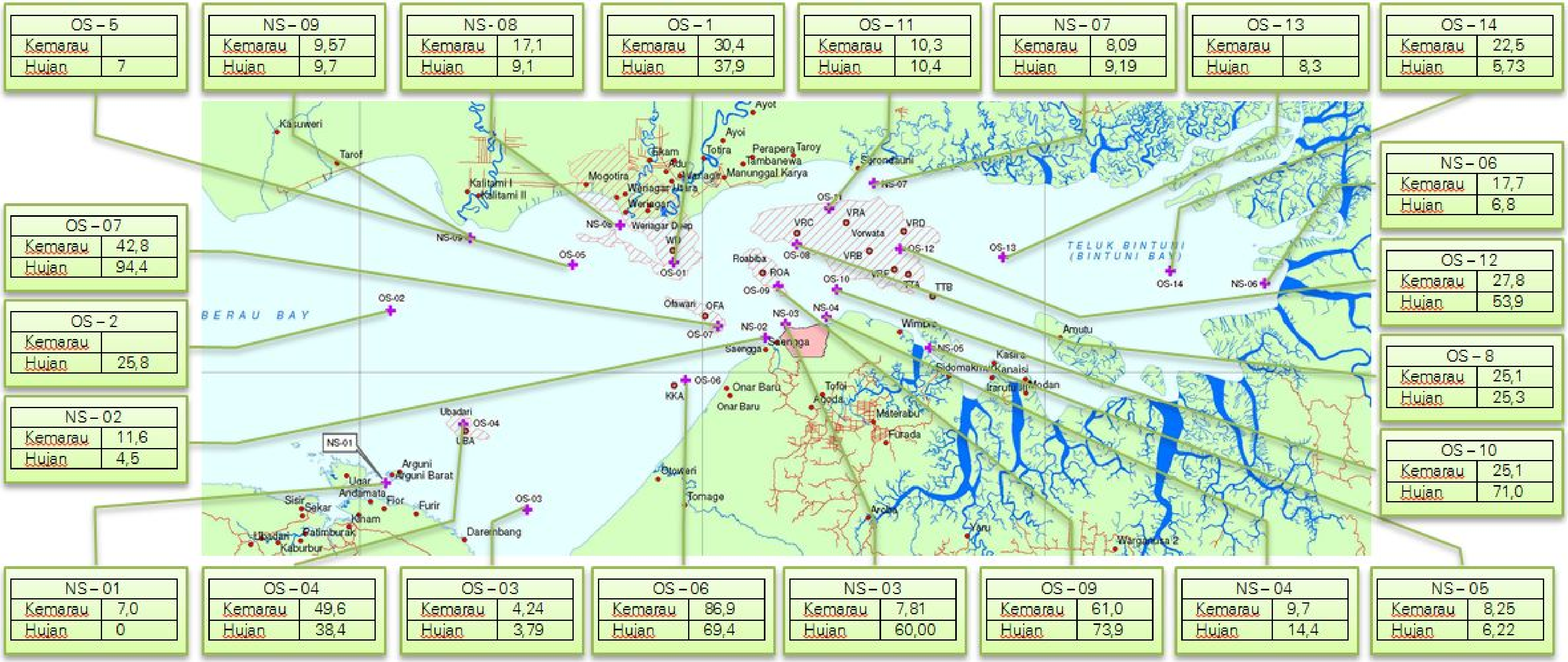


Figure II-83 Mapping of Arsenic Concentration in sediment of Bintuni Bay (AMDAL Environmental Baseline Study of the Tangguh LNG Expansion)

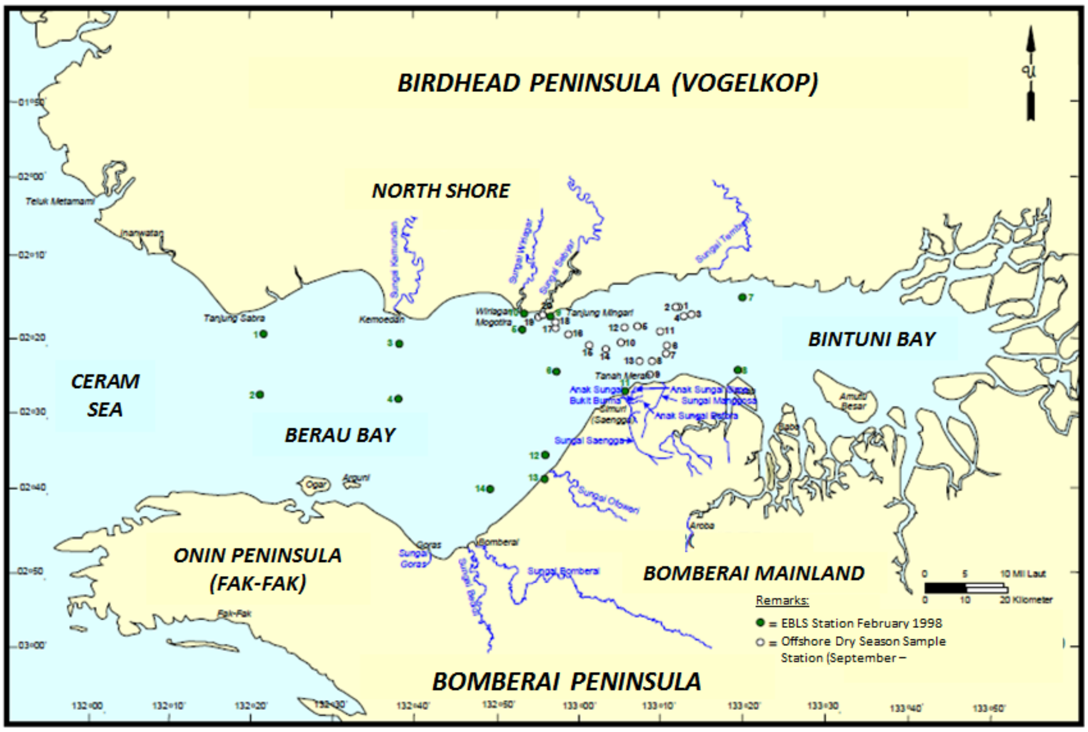


Figure II-84 **Map of Sediment Sampling in Bintuni Bay (AMDAL Environmental Baseline Study of Tangguh LNG in 2002)**

Table II-40 **Summary of Several Types of Metals Concentration in the Sediment from the AMDAL Survey Team during the Dry season in 2000 (September - October 2000)**

Element	Concentration (mg / kg)			
	Average	Maximum	Average	Standard Deviation
Aluminum (Al)	6.,659	11,400	3,880	2,267
Iron (Fe)	33,893	49,600	9,310	10,348
Manganese (Mn)	1.048	3,290	69.4	731
Barium (Ba)	33	44	<20	9
Cobalt (Co)	15,2	20	6	3.6
Copper (Cu)	5,3	11.4	2.6	2.7
Chromium (Cr)	14	25	10	4
Cadmium (Cd)	0.2	0.7	<0.1	0.1
Mercury (Hg)	0.010	0.019	0.005	0.005
Lead (Pb)	19	30	10	5
Arsenic (As)	36	74	2	20
Nickel (Ni)	31.1	42.7	14.2	7.4
Silver (Ag)	0.7	1.5	<0.4	0.3

From analysis and data presented above, the following were known:

a) Concentrations of Arsenic in sediment of Bintuni Bay had high value in nearly at all offshore locations from the survey results of 2012 and 2013.

b) Concentrations of Arsenic in sediment had high value, i.e. average value 36 mg/kg and maximum value 74 mg/kg in September - October 2000 long before Tangguh LNG commenced activities in the area. The survey activities were conducted as environmental baseline survey to prepare an AMDAL of the Tangguh LNG (currently in operation) in 2002.

c) Arsenic concentrations in Bintuni Bay had sufficiently high value prior to the presence of the Tangguh LNG activities.

Table II-41 Results of Heavy Metals Analysis in Seabed Sediment of OS 01 – OS 07 (*Offshore*)

No	Heavy Metals	Unit	ANZECC Sediment Criteria		Sampling Location													
			ISQG Lower	ISQG Upper	OS 01		OS 02		OS 03		OS 04		OS 05		OS 06		OS 07	
					K	H	K	H	K	H	K	H	K	H	K	H	K	H
1	Antimony, Sb	mg/dry kg	2	25	1.80	0.64		0.62	<0.01	0.34	0.29	0.75		0.86	0.64	1.74	0.97	0.98
2	Arsenic, As	mg/dry kg	20	70	30.4	37.9		25.8	4.24	3.79	49.6	38.4		7.0	86.9	69.4	42.8	94.4
3	Cadmium, Cd	mg/dry kg	1,5	10	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1	<0.1
4	Chromium, Cr	mg/dry kg	80	370	20	16		9	22	24	20	16		14	13	24	18	26
5	Copper, Cu	mg/dry kg	65	270	6.4	1.2		<0.2	3.7	3,9	2,1	<0.2		3,4	1,5	3.3	3,4	3,6
6	Lead, Pb	mg/dry kg	50	220	20	13		12	11	8	15	11		11	24	19	18	28
7	Mercury, Hg	mg/dry kg	0,15	1	0.032	0.008		0.006	0.032	0.018	0.023	0.005		0.022	0.015	0.008	0,.037	0.012
8	Nickel, Ni	mg/dry kg	21	52	21.2	18.5		10,3	19.6	18.8	17.1	14.6		15.0	16.3	19.4	19.1	22.8
9	Selenium, Se	mg/dry kg	1*)	4*)	0.21	0.03		<0.01	1.09	0.06	<0.01	0.04		0.08	<0.01	0.02	0.05	0.03
10	Silver, Ag	mg/dry kg	1	3,7	<0.4	<0.4		<0.4	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4	1	<0.4	<0.4
11	Zinc, Zn	mg/dry kg	200	410	53.5	42.9		26.8	46.4	48.7	35.3	36.8		44.2	37.0	56.1	42.1	67.2
									Organic									
1	TPH	mg/dry kg		0,3	<2	<2		<2	<2	<2	<2	<2		<2	<2	<2	<2	<2

K : Dry season *H : Wet season*
*) *Van Derveer and Canton (1997).*

Table II-42 Analysis of Heavy Metals in Seabed Sediment of OS 08 – OS 14 *Offshore*

No	Heavy Metals	Unit	ANZECC Sediment Criteria		Sampling location													
			ISQG Lower	ISQG Upper	OS 08		OS 09		OS 10		OS 11		OS 12		OS 13		OS 14	
					K	H	K	H	K	H	K	H	K	H	K	H	K	H
1	Antimony, Sb	mg/dry kg	2	25	<0.01	0.29	0.73	0.23	<0.01	0.69	0.98	0.12	0.84	0.44		0.71	0.48	0.48
2	Arsenic, As	mg/dry kg	20	70	25.1	25.3	61.0	73.9	25.1	71.0	10.3	10.4	27.8	53.9		8.3	22.5	5.73
3	Cadmium, Cd	mg/dry kg	1,5	10	<0.1	<0,1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1
4	Chromium, Cr	mg/dry kg	80	370	23	19	13	10	16	14	21	19	18	11		17	31	13.27
5	Copper, Cu	mg/dry kg	65	270	3,6	6,2	1.7	0.2	2,9	4.3	10.0	8.1	5.1	0.3		5.3	13.4	4.85
6	Lead, Pb	mg/dry kg	50	220	15	16	11	17	12	16	14	13	15	10		10	15	6.04
7	Mercury, Hg	mg/dry kg	0.15	1	0.022	0.027	0.004	0.005	0.022	0.014	0.054	0.032	0.032	0.005		0.023	0.027	0.02
8	Nickel, Ni	mg/dry kg	21	52	21.9	25.0	20.9	19.2	21.4	24.7	27.3	23.7	20.2	16,6		19.7	32.3	11.69
9	Selenium, Se	mg/dry kg	1*)	4*)	<0.01	0.11	0.07	<0.01	0.14	0.03	<0.01	0.08	<0.01	<0,01		0.33	0.36	0.06
10	Silver, Ag	mg/dry kg	1	3,7	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4	<0.4
11	Zinc, Zn	mg/dry kg	200	410	44.8	63.9	38.9	39.8	43.5	54.8	61.9	63.2	44.4	34.8		51.2	76.1	31.28
									Organic									
1	TPH	mg/dry kg		0,3	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	19	<2

K : Dry season *H : Wet season*
*) *Van Derveer and Canton (1997).*

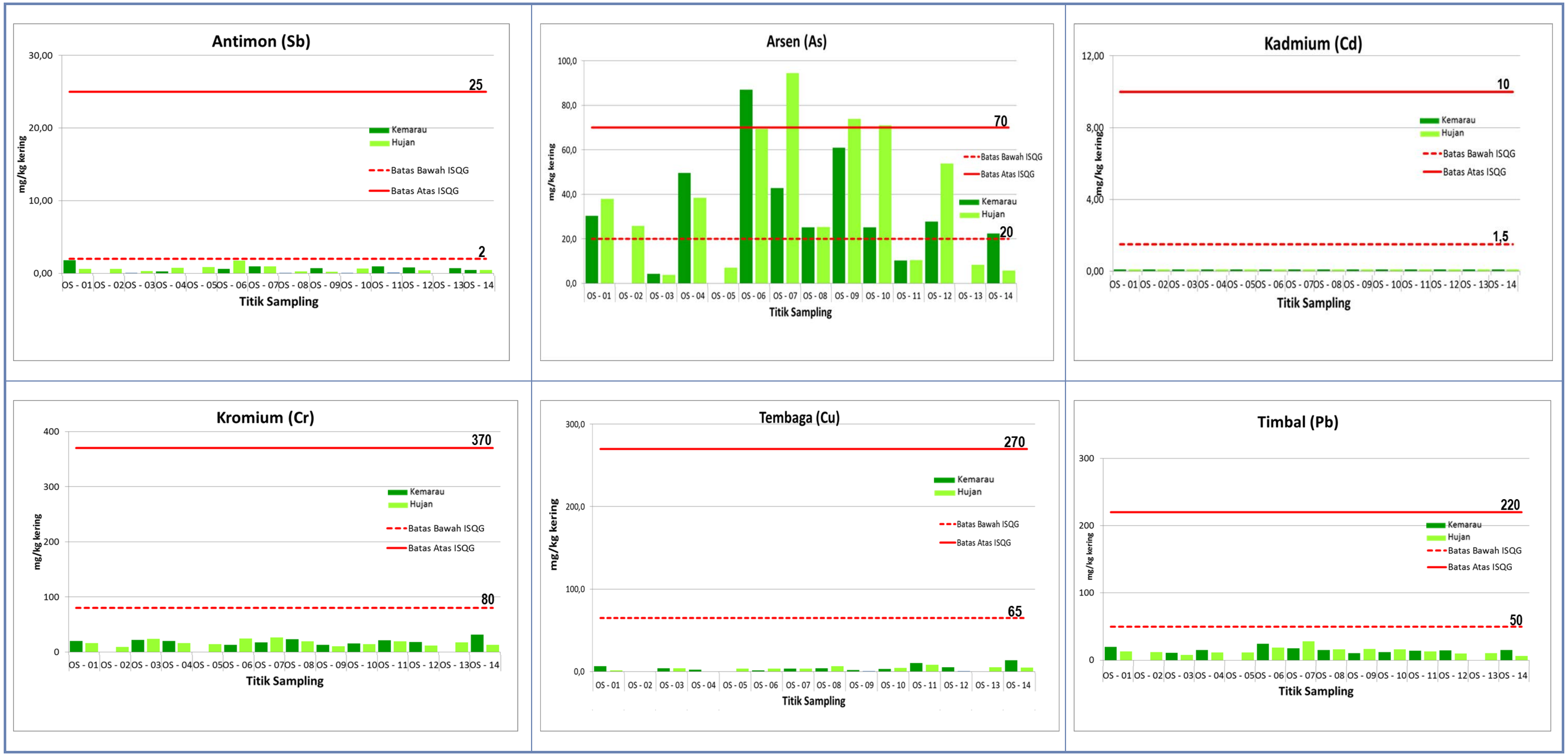


Figure II-85 Graph of Heavy Metals Content in Seabed Sediment of *Offshore* Waters Compared with ANZECC-ISQG Sediment Quality Criteria

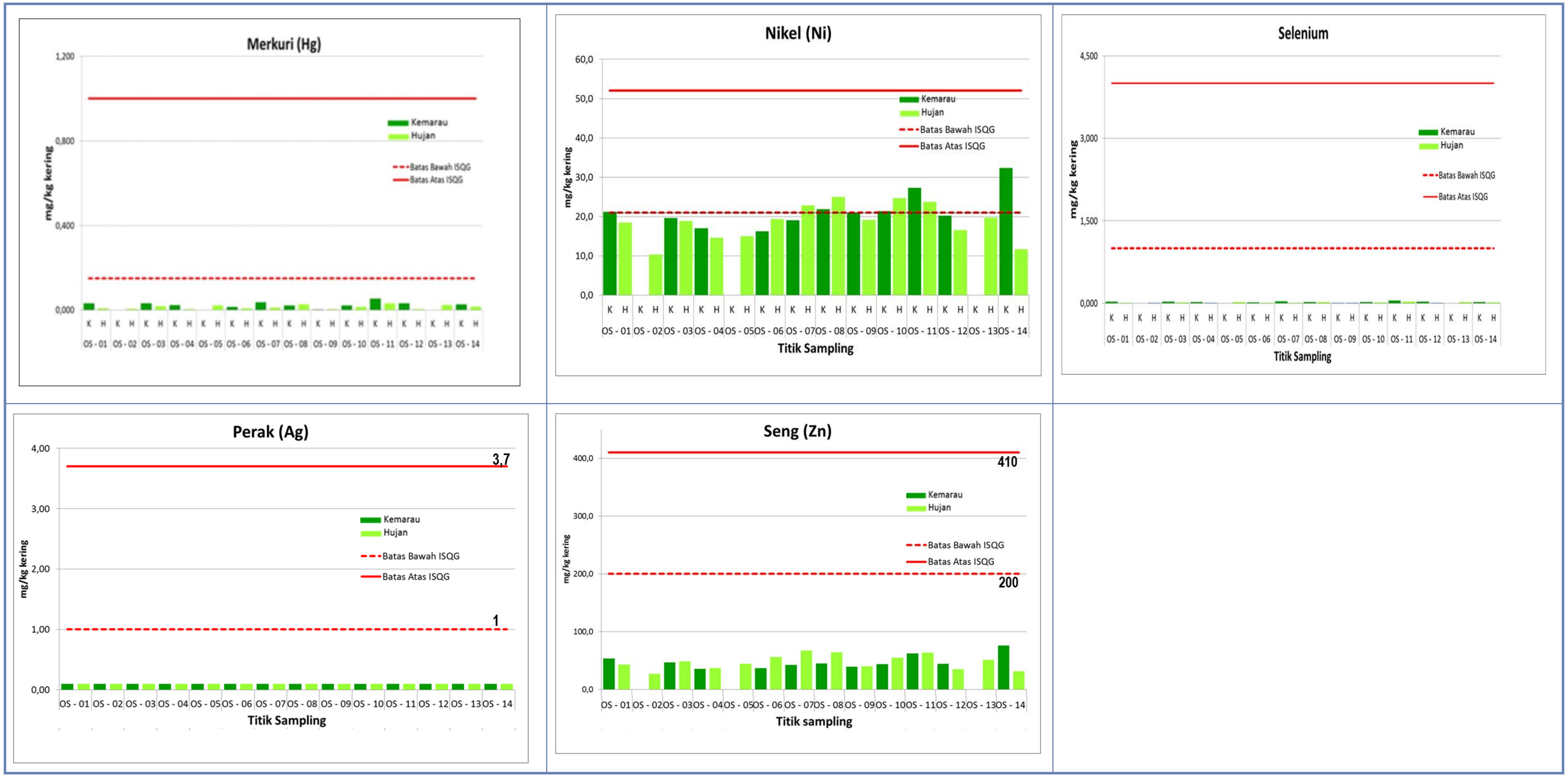


Figure II-86 Graph of Heavy Metals Content in Seabed Sediment of *Offshore* Waters Compared with ANZECC-ISQG Sediment Quality Criteria (note : for Selenium based on *Van Derveer* and *Canton*) – Continued

Table II-43 Results of Heavy Metals Analysis in Seabed Sediment (*Nearshore*)

No	Heavy Metals	Unit	ANZECC Sediment Criteria		Sampling location																	
			ISQG Lower	ISQG Upper	NS 01		NS 02		NS 03		NS 04		NS 05		NS 06		NS 07		NS 08		NS 09	
					K	H	K	H	K	H	K	H	K	H	K	H	K	H	K	H	K	H
1	Antimony, Sb	mg/dry kg	2	25	0.17		0.29	0.38	0.15	0.81	0.22	0.70	<0.01	0.55	0.32	0.44	0.22	0.17	0.87	0.39	0.34	0.46
2	Arsenic, As	mg/dry kg	20	70	7.0		11.6	4.5	7.81	60.00	9.7	14.4	8.25	6.22	17.7	6.8	8.09	9.19	17.1	9.1	9,57	9.7
3	Cadmium, Cd	mg/dry kg	1,5	10	<0.1		<0.1	<0.1	0.000	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0,1	<0.1
4	Chromium, Cr	mg/dry kg	80	370	8		30	15	19	28	26	25	17	20	34	14	34	37	22	15	27	29
5	Copper, Cu	mg/dry kg	65	270	1.2		9.1	3.9	4,6	7.7	7,7	6.7	6.0	7.3	14.0	5.2	6.0	7.6	26.2	10.4	13.1	19.7
6	Lead, Pb	mg/dry kg	50	220	0		13	7	7	12	11	12	12	9	16	7	6	6	18	11	11	15
7	Mercury, Hg	mg/dry kg	0,15	1	0.007		0.037	0.019	0.024	0.026	0.037	0.024	0,036	0.019	0.026	0.012	0.016	0.020	0.077	0.025	0,040	0.049
8	Nickel, Ni	mg/dry kg	21	52	3.8		28.9	12.5	18.2	29.7	25.0	21.5	18.2	17.9	34.6	13.2	46.4	44.8	23.9	16.3	27.2	27.4
9	Selenium, Se	mg/dry kg	1*)	4*)	0.23		0.27	0.06	0.14	0.08	0.21	0.47	<0.01	0.09	0.35	0.07	0.07	0.01	0.30	<0.01	0,17	0.03
10	Silver, Ag	mg/dry kg	1	3,7	<0.4		<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
11	Zinc, Zn	mg/dry kg	200	410	6.2		73.7	34.1	36.1	71.2	69.2	73.9	45.5	47.9	89.3	34.7	72.7	84.3	81.3	61.5	72.4	87.2
Organic																						
1	TPH	mg/dry kg		0.3	13		9	<2	<2	<2	10	<2	<2	<2	22	<2	<2	<2	18	<2	<2	<2

K : Dry season *H : Wet season*

**) Van Derveer and Canton (1997).*

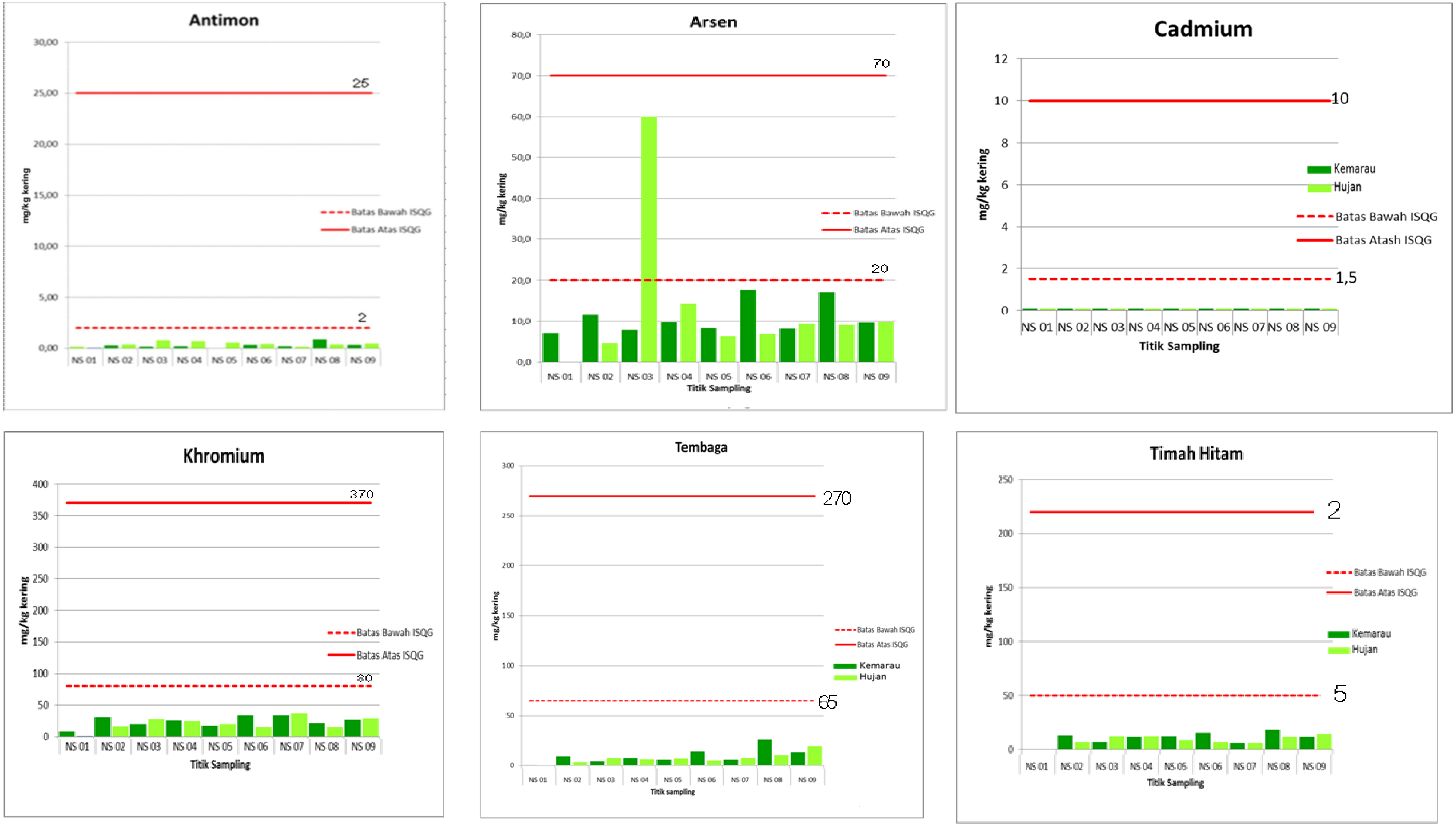


Figure II-87 Graph of Heavy Metals Content in Seabed Sediment of *Nearshore* Waters Compared with Sediment Quality Criteria of ANZECC-ISQG

Figure II-88 Graph of Heavy Metals Content in Seabed Sediment of *Nearshore* Waters Compared with ANZECC-ISQG Sediment Quality Criteria(note : for Selenium based on *Van Derveer and Canton)* – Continued

Table II-44 Results of Heavy Metals Analysis in Riverbed Sediment

No.	Heavy Metals	Unit	ANZECC Sediment Criteria		Sampling Location			
			ISQG Lower	ISQG Upper	SW 01		SW 03	
					K	H	K	H
1	Antimony, Sb	mg/dry kg	2	25	0.12	0.43	0.16	0.41
2	Arsenic, As	mg/dry kg	20	70	21.5	13.7	5.10	13.8
3	Cadmium, Cd	mg/dry kg	1.5	10	<0.1	<0.1	0.000	<0.1
4	Chromium, Cr	mg/dry kg	80	370	24	30	4	31
5	Copper, Cu	mg/dry kg	65	270	8.3	11.1	0.9	12.4
6	Lead, Pb	mg/dry kg	50	220	7	12	2	17
7	Mercury, Hg	mg/dry kg	0.15	1	0.020	0.029	0.004	0.035
8	Nickel, Ni	mg/dry kg	21	52	34.7	30.7	5.7	36.3
9	Selenium, Se	mg/dry kg	1*)	4*)	0.04	0.07	0.06	0.10
10	Silver, Ag	mg/dry kg	1	3.7	<0,4	<0.4	<0.4	<0.4
11	Zinc, Zn	mg/dry kg	200	410	64.9	75.7	12.5	91.1
Organic								
1	TPH	mg/dry kg		0.3	3	<2	<2	<2
	K	*: Dry season*	*H*	*: Wet season*				
	*)	*Van Derveer and Canton (1997).*						

K : Dry season H : Wet season

*) *Van Derveer and Canton (1997).*

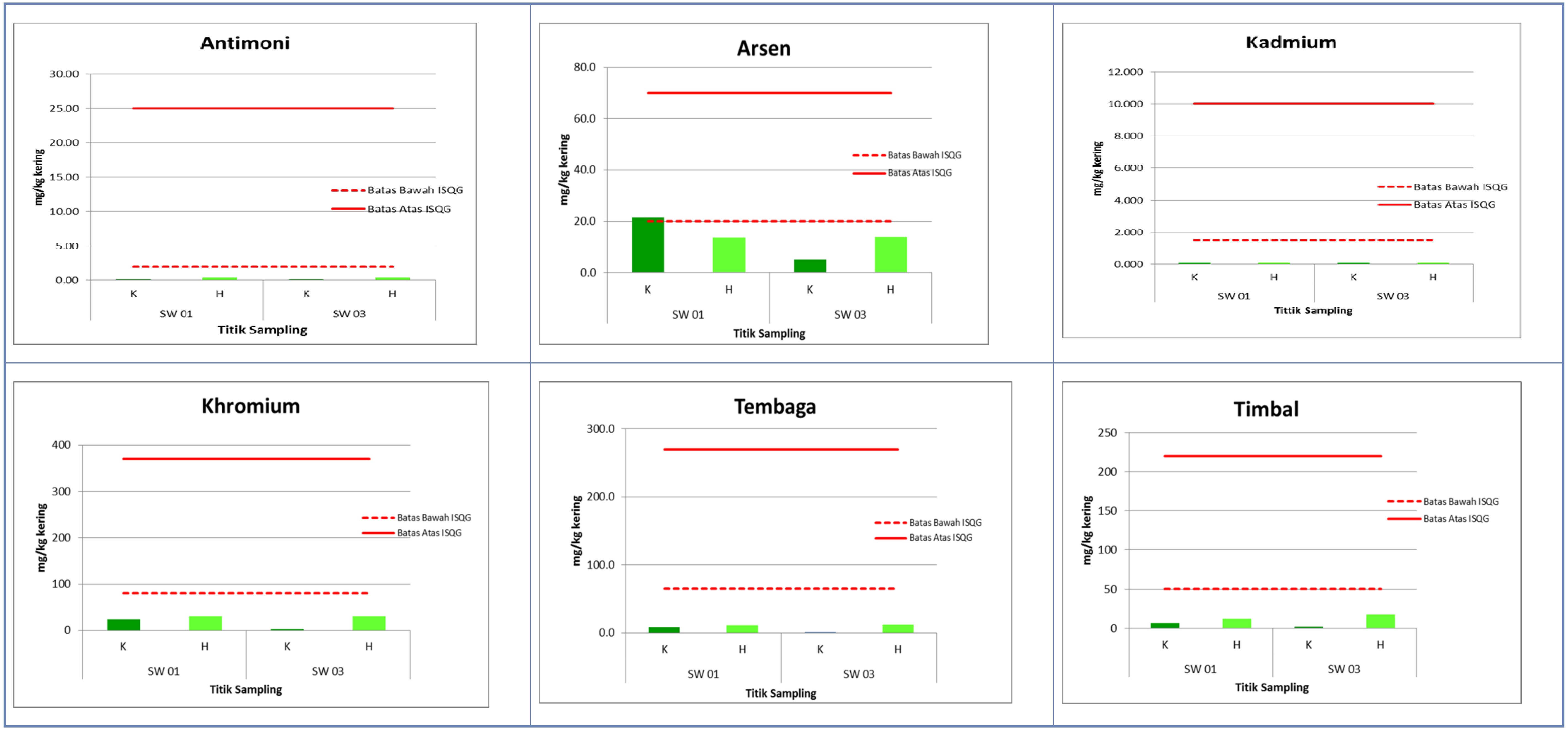


Figure II-89 Graph of Heavy Metals Content in Riverbed Sediment Compared with ANZECC-ISQG Sediment Quality Criteria

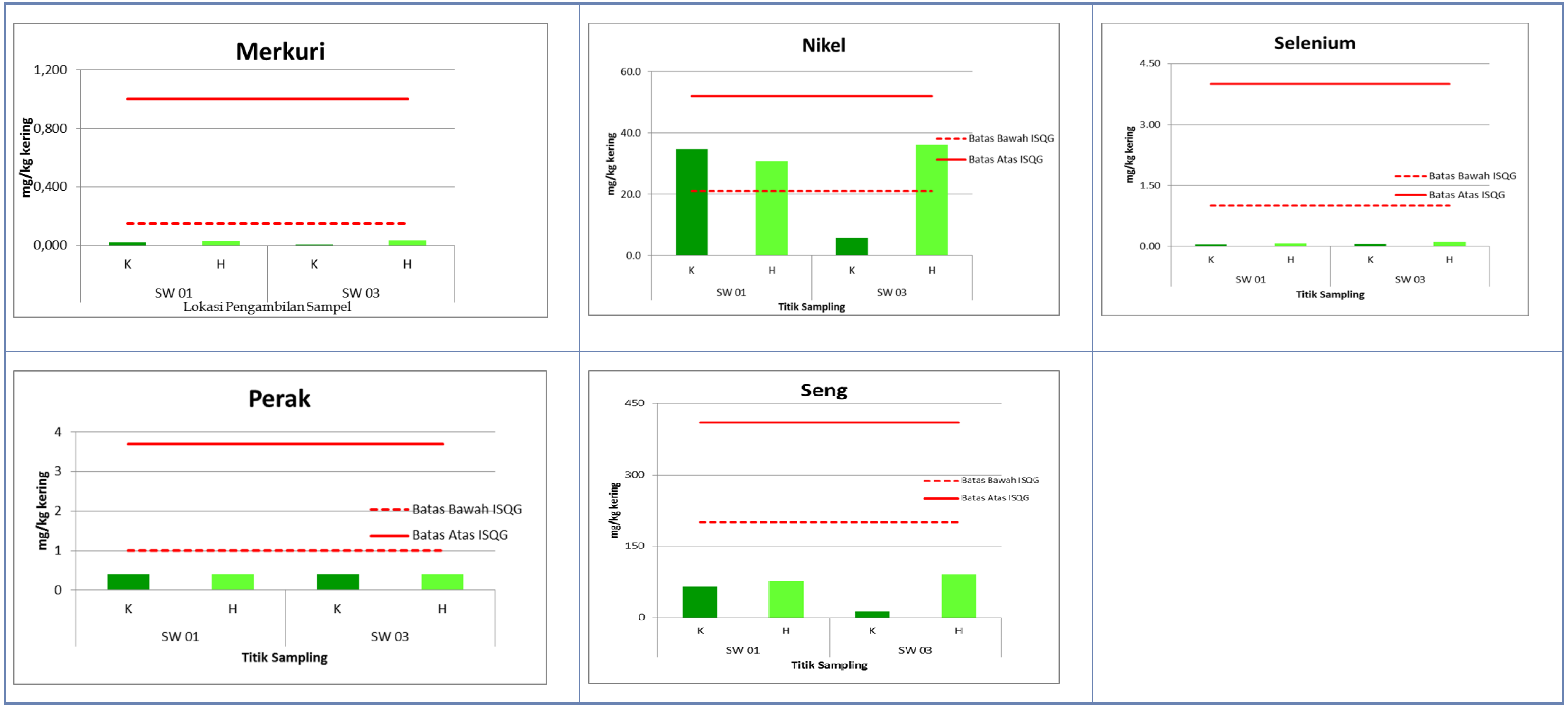


Figure II-90 Graph of Heavy Metals Content in Riverbed Sediment Compared with ANZECC-ISQG Sediment Quality Criteria (note : for Selenium based on *Van Derveer* and *Canton)* – Continued

There were also five sampling locations which Arsenic value exceeded the ANZECC-ISQG lower limit of 20 mg/kg. The five locations are OS-06, OS-12, OS-04, OS-02 and OS-08 with arsenic concentrations of respectively 69.4 mg/kg, 53.9 mg/kg, 38.4 mg/kg, 25.8 mg/kg and 25.3 mg/kg.

The remaining five locations had values below the lower limit set by ANZECC-ISQG of 20 mg/kg. The five locations i.e. OS-11, OS-13, OS-05, OS-14 and OS-03 had arsenic concentrations of respectively 10.36 mg/kg, 8.3 mg/kg, 6.9 mg/kg, 5.7 mg/kg and 3.8 mg/kg.

Cadmium (Cd)

In the dry season and wet season, concentrations of cadmium in all locations were not detected (<0.1 mg/kg), or were below instrument detection limit. Therefore, cadmium values were far below the sediment criteria according to ANZECC-ISQG of 1.5 mg/kg (lower limit).

Chromium (Cr)

In the dry season, concentrations of Cr ranged between 13 – 31 mg/kg. Location OS-14, approximately 9 km offshore from Kalitami to the south, was the site of samples with highest Cr value of (31 mg/kg) however the Cr concentration was still far below the lower limit of sediment criteria set in ANZECC-ISQG of 80 mg/kg. The lowest Cr concentration of 13 mg/kg was detected in two sampling locations, namely OS-06 and OS-09.

In the wet season, Cr concentrations ranged between values 9.2 – 26.2 mg/kg. Location of OS-07, approximately 10 km west of the *Combo Dock*, was the sampling location with highest Cr value (26.2 mg/kg) however this value was still far below the lower limit of sediment criteria set in ANZECC-ISQG of 80 mg/kg.

Copper (Cu)

In the dry season, concentrations of Cu ranged between 1.5 – 13.4 mg/kg. Location of OS-14 approximately 9 km offshore from Kalitami to the south was the sampling location with highest value of Cu (13.4 mg/kg). However the Cu concentration was still far below the lower limit of sediment criteria set in ANZECC-ISQG of 65 mg/kg. The lowest Cu concentration of 1.5 mg/kg was detected at sampling location OS-06.

In the wet season, concentrations of nickel ranged between 0.2 – 8.11 mg/kg. OS-11 was the sampling location with highest value (8.11 mg/kg) however the value was still far below the lower limit of sediment criteria determined in ANZECC-ISQG of 65 mg/kg.

Mercury (Hg)

In the dry season, concentration of Hg ranged between 0.004 – 0.054 mg/kg. Sampling location OS-11 positioned approximately 3 km northwest of the VRA offshore platform, had the highest concentration of Hg at 0.054 mg/kg however the value was far below the lower limit set by ANZECC-ISQG of 0.15 mg/kg.

In the wet season, Hg concentrations ranged between 0.005 – 0.032 mg/kg. Similar to the dry season, sampling location OS-11 in the wet season also had the highest Hg concentration of 0.032 mg/kg, however the value was still far lower than the lower limit set by ANZECC-ISQG of 0.15 mg/kg.

Silver (Ag)

In the dry season and wet season silver content in all sampling locations were not detected (<0.4 mg/kg). This indicated that in all sampling locations, Ag content was still far below the lower limit set by ANZECC-ISQG of 1 mg/kg.

Lead (Pb)

In the dry season, Pb concentration ranged between 11 – 24.5 mg/kg. Sampling location OS-06, approximately 6 km offshore from Onar Baru to the west, had the highest Pb concentration of 24.5 mg/kg however the value of Pb was still far below the ANZECC-ISQG lower limit of 50 mg/kg. Two Pb sampling locations, namely OS-03 and OS-09 had the lowest concentration of 11 mg/kg.

In the wet season, the Pb concentration ranged between 6.0 – 28 mg/kg. Sampling location OS-07 in position of some 10 km to the west of the *Combo Dock* was the sampling location with the highest value (28 mg/kg) however the value was still far below the lower limit of sediment criteria set in ANZECC-ISQG of 50 mg/kg. The lowest Pb concentration was detected at location OS-03.

Nickel (Ni)

In the dry season, nickel concentration ranged between 16.3 – 32.4 mg/kg. The highest values of 32.4 mg/kg was detected at location OS-14 approximately 9 km offshore from Kalitami to the south and 27.3 mg/kg at location OS-11 at position of some 3 km to the northwest of offshore platform VRA. At location OS-8, nickel concentration value was 21.9 mg/kg and at location OS-10 the value was 21.4 mg/kg followed by 21.2 mg/kg at location OS-01.

Nickel concentration in the five locations of OS-14, OS-11, OS-08, OS-10, and OS-01 exceeded the lowest limit of ANZECC-ISQG sediment criteria of 21 mg/kg, while four other locations namely OS-09, OS-12, OS-03 and OS-07 with nickel concentrations of respectively 20.9 mg/kg, 20.2 mg/kg, 19.6 mg/kg and 19.1 mg/kg approached the lower limit value of ANZECC-ISQG sediment criteria of 21 mg/kg, but were still below the upper limit of sediment criteria set by ANZECC-ISQG of 52 mg/kg. In other locations , namely OS-04 and OS-06, nickel concentration values were 17.05 mg/kg and 16.3 mg/kg.

In the wet season, concentrations of nickel ranged between 10.3 – 25.01 mg/kg. A total of four out of 14 sampling locations had nickel concentrations exceeding the lower limit value for sediment criteria set by ANZECC-ISQG of 21 mg/kg. The four locations are OS-08, OS-10, OS-11 and OS-07 with nickel concentration of respectively 25.01 mg/kg, 24.7 mg/kg, 23.7 mg/kg and 22.8 mg/kg.

Similarly, four locations OS-13, OS-06, OS-09 and OS-03 had nickel concentration approaching the lower limit value of sediment criteria set by ANZECC-ISQG of 21 mg/kg. The four locations respectively had nickel concentrations of 19.7 mg/kg, 19.4 mg/kg, 19.2 mg/kg and 18.8 mg/kg.

While five other locations namely OS-12, OS-5, OS-04, OS-14 and OS-02 had nickel concentration values of respectively 16.6 mg/kg, 15.01 mg/kg, 14.6 mg/kg, 11.7 mg/kg and 10.3 mg/kg.

Selenium (Se)

In the dry season, concentration of selenium ranged between 0.01 – 1.1 mg/kg. The highest selenium value of 1.1 mg/kg detected in location OS-03 (some 21 km southeast of Arguni), exceeded the lower limit of 1 mg/kg, however was still below the upper limit of 4 mg/kg based on sediment criteria of *Van Derveer and Canton* (1997). In five out of ten locations , namely OS-04, OS-06, OS-08, OS-11 and OS-12 selenium concentrations indicated values <0.01 mg/kg or below the instrument detection limit.

In the wet season, selenium concentrations ranged between 0.01 – 0.33 mg/kg. Highest selenium value of 0.33 mg/kg was detected at location OS-13 (approximately 21 km east of the VRB offshore platform), however the value was still below the lower limit of sediment criteria from Van Derveer and Canton (1997) of 1 mg/kg. A total of three out of the 14 sampling locations had selenium concentrations <0.01 mg/kg, i.e. at locations OS-02, OS-09 and OS-12.

Zinc (Zn)

In the dry season, zinc concentrations ranged between 35.3 – 70.1 mg/kg. The highest value of 70.1 mg/kg was detected in location OS-14 (some 9 km offshore from Kalitami to the south) and the lowest value of 35.33 mg/kg at location OS-04. Zinc concentrations were still far below the lower limit of ANZECC-ISQG sediment criteria of 200 mg/kg.

In the wet season, zinc concentrations ranged between 26.79 – 67.25 mg/kg. The highest value of zinc of 67.25 mg/kg was detected at location OS-07 at position of approximately 10 km to the west of the *Combo Dock* and the lowest value of 26.79 mg/kg was found at location OS-02. The value of zinc concentration was still far below the lower limit of ANZECC-ISQG sediment criteria, i.e 200 mg/kg.

Total Petroleum Hydrocarbon (TPH)

In the dry season and wet season TPH in all locations was not detected (<2 mg/kg), or was below the instrument detection limit, except at one location namely OS-14 (approximately 9 km offshore from Kalitami to the south) it was found with value of 19 mg/kg in the wet season . The criteria for upper limit concentration of TPH in sediment as set by ANZECC-ISQG is 0.3 mg/kg.

2.1.9.2 Seabed Sediment of Nearshore

Antimony (Sb)

In the dry season, concentrations of Sb ranged between 0.01 – 0.87 mg/kg. The highest value of Sb at 0.87 mg/kg was detected at location NS-08 (approximately 1 km offshore from Weriagar to the south) and lowest value of <0.01 mg/kg at location NS-05. All the sampling locations were still below the lower limit of the ANZECC-ISQG sediment criteria of 2 mg/kg.

In the wet season, concentrations of Sb ranged between the values 0.17 – 0.81 mg/kg. All sampling locations in the wet season were still below the lower limit of the ANZECC-ISQG sediment criteria of 2 mg/kg.

Arsenic (As)

In the dry season, concentrations of arsenic were detected in the range between 7.0 – 17.65 mg/kg. The highest value of arsenic of 17.65 mg/kg was detected at location NS-06 (approximately 125 km from VRB to the east) and 17.11 mg/kg at location NS-08 (approximately 1 km offshore from Weriagar to the south). The two locations approached the ANZECC-ISQG lower limit value of 20 mg/kg. A total of seven other locations had values of samples below the ANZECC-ISQG lower limit of 20 mg/kg. In the wet season, concentrations of arsenic were detected in the range between 4.5 – 60.0 mg/kg, the lowest was detected at NS-01 and the highest at NS-03. Concentrations of arsenic at NS-03 (in the *Combo Dock* area) already approached the upper limit value of ANZECC-ISQG at 70 mg/kg. The remaining arsenic concentrations in the wet season were lower than the lower limit of ANZECC-ISQG at 20 mg/kg.

Cadmium (Cd)

In the dry season and wet season concentrations of cadmium were not detected (<0.1 mg/kg) or were below the instrument detection limit. Therefore, the cadmium value was far below the sediment criteria determined in the ANZECC-ISQG of 1.5 mg/kg (lower limit).

Chromium (Cr)

In the dry season, concentrations of Cr ranged between 8 – 34 mg/kg. The highest Cr value of 34 mg/kg was detected at location NS-07 (approximately 7 km northeast of VRA) and the lowest value was 8 mg/kg at location NS-01. All sampling locations indicated values that were below the lower limit of ANZECC-ISQG sediment criteria of 80 mg/kg.

In the wet season, concentrations of Cr ranged between 14 – 37 mg/kg. All sampling locations in the wet season indicated values that were below the lower limit of the ANZECC-ISQG sediment criteria at 80 mg/kg.

Copper (Cu)

In the dry season concentrations of Cu ranged between 1.24– 26.15 mg/kg. The highest Cu value of 26.15 mg/kg was detected at location NS-08 (approximately 1 km offshore from Weriagar) and the lowest value was 1.24 mg/kg at location NS-01. All the sampling locations had values of samples that were still below the lower limit of ANZECC-ISQG sediment criteria of 65 mg/kg.

In the wet season, the concentrations of Cu ranged between 3.9 – 19.7 mg/kg. The highest Cu value of 19.7 mg/kg was detected at location NS-09 (approximately 2 km offshore from Kalitami) and the lowest value was 3.9 mg/kg at location NS-02. All the sampling locations in the wet season indicated values that were still below the ANZECC-ISQG sediment criteria of 65 mg/kg.

Mercury (Hg)

In the dry season, Hg concentration ranged between 0.007 – 0.077 mg/kg. Sampling location NS-08 (approximately 1 km offshore from Weriagar) had the highest Hg concentration of 0.077 mg/kg, this value far exceeded the lower limit value set by ANZECC-ISQG of 0.15 mg/kg and approached the upper limit value of ANZECC-ISQG at 1 mg/kg.

In the wet season Hg concentration ranged between 0.01 – 0.05 mg/kg, therefore the value of Hg concentration was far below the lower limit set by ANZECC-ISQG of 0.15 mg/kg.

Silver (Ag)

In the dry season and wet season, silver content in all sampling locations were not detected (<0.4 mg/kg), or were below the instrument detection limit. This indicated that in all sampling locations, Ag values were still far below the lower limit set by ANZECC-ISQG of 1 mg/kg.

Lead (Pb)

In the dry season, Pb concentrations ranged between 6 – 18 mg/kg. Sampling location NS-08 (approximately 1 km offshore from Weriagar) had the highest Pb concentration of 18 mg/kg however this value was still far below the lower limit set by ANZECC-ISQG of 50 mg/kg. Sampling location NS-07 had the lowest concentration of Pb at 6 mg/kg.

In the wet season, Pb concentration ranged between 6 – 15 mg/kg. Sampling location NS-09 (approximately 2 km offshore from Kalitami) had the highest Pb concentration of 15 mg/kg however the Pb concentration value was still far below the lower limit according to ANZECC-ISQG of 50 mg/kg. Similar to sampling during the dry season, in the wet season the lowest concentration of Pb was detected at sampling location NS-07.

Nickel (Ni)

In the dry season, nickel concentration ranged between 3.8 – 46.4 mg/kg. The highest value of 46.4 mg/kg was detected at location NS-07 (approximately 2 km offshore from Sorondauni), at location NS-06 (approximately 125 km from VRB to the east) was detected at 34.6 mg/kg and at location NS-02 (approximately 52 km to the east of Arguni) in the amount ot 28.9 mg/kg. Further, in location NS-09 at 27.2 mg/kg, location NS-04 at 25.03 mg/kg and followed by 23.4 mg/kg in location NS-08.

Nickel concentration in the six locations of NS-07, NS-06, NS-02, NS-09, NS-04 and NS-08 have exceeded the lower limit value of sediment criteria set by ANZECC-ISQG of 21 mg/kg, while two other locations, i.e. NS-05 and NS-03 with nickel concentration of respectively 18.23 mg/kg and 18.21 mg/kg approaching the lower limit of criteria sediment ANZECC-ISQG namely 21 mg/kg. Location NS-01 had the lowest concentration of nickel at 3.8 mg/kg.

In the wet season, nickel concentration ranged between 12.5 – 44.8 mg/kg. A total of four locations from eight sampling locations had concentration of nickel exceeding the lower limit value of sediment criteria according to ANZECC-ISQG of 21 mg/kg. The four locations are NS-07, NS-03, NS-09 and NS-04 with nickel concentration of respectively 44.8 mg/kg, 29.7 mg/kg, 27.4 mg/kg and 21.5 mg/kg.

Similarly, in two other locations of NS-05 and NS-08, nickel concentration is approaching the lower limit value of sediment criteria according to ANZECC-ISQG of 21 mg/kg. The two locations respectively had nickel concentration of 17,9 mg/kg and 16,3 mg/kg. Sampling location NS-06 and NS-02 had nickel concentration of respectively 13.2 mg/kg and 12.5 mg/kg.

Selenium (Se)

In the dry season, concentrations of selenium ranged between <0.01 – 0.3 mg/kg. The highest value of selenium was 0.35 mg/kg detected at location NS-06 and followed by location NS-08 with value of 0.3 mg/kg, however the selenium concentrations were still far below the lower limit of 1 mg/kg according to the criteria of *Van Derveer* and *Canton* (1997). The lowest selenium value of <0.01 mg/kg was detected at location NS-01. The criteria of *Van Derveer* and *Canton* (1997) were referred to since the ANZECC-ISQG criteria does not include selenium.

In the wet season, concentrations of selenium ranged between <0.01 – 0.47 mg/kg. The highest value of selenium was 0.47 mg/kg was detected at location NS-04, while the lowest concentration of <0.01 mg/kg was found at location NS-08.

Zinc (Zn)

In the dry season the concentration of zinc ranged between 6.2 – 89.3 mg/kg. There are two sampling locations with highest Zn concentration at locations NS-06 and NS-08 with values of respectively 89.3 mg/kg and 81.3 mg/kg, however the values are still far below the lower limit set by ANZECC-ISQG at 200 mg/kg.

In the wet season, zinc concentrations ranged between 34.1 – 87.2 mg/kg. Two sampling locations with highest Zn concentration were locations NS-09 and NS-07, with values of 87.2 mg/kg and 84.3 mg/kg, however these values were still far below the lower limit of ANZECC-ISQG at 200 mg/kg.

Total Petroleum Hydrocarbon (TPH)

In the wet season, TPH in all locations were not detected (< 2 mg/kg) or below the instrument detection limit. While in the dry season TPH was detected in sampling locations NS-01, NS-04, NS-06 and NS-08 with concentrations of respectively 13 mg/kg, 10 mg/kg, 22 mg/kg and 18 mg/kg. Upper limit criteria for TPH concentrations in sediment as set in ANZECC-ISQG was 0.3 mg/kg.

2.1.9.3 Riverbed Sediment

In general, concentration of heavy metal in river sediments met the Criteria of Sediment Quality based on ANZECC-ISQG, or below the lower limit, however nickel and arsenic content both in the dry season as well as wet season had tendency to exceed the lower limit of sediment criteria set by ANZECC-ISQG, similar to nearshore and offshore seabed sediment.

Nickel (Ni)

Concentrations of nickel in SW-01 and SW-03 in the dry season and wet season ranged between 5.7 – 36.3 mg/kg. In the dry season and wet season, the concentration of nickel for location SW-01 exceeded the lower limit of sediment quality criteria based on ANZECC-ISQG (21 mg/kg dry) namely 34.7 mg/kg in the dry season and 30.7 mg/kg in the wet season. Similarly, in the wet season at location SW-03, nickel concentrations in river sediment were detected at 36.3 mg/kg or exceeding the lower limit of sediment quality criteria based on ANZECC-ISQG.

Arsenic (As)

Concentrations of arsenic at SW-01 and SW-03 in the dry season and wet season ranged between 5.1 – 21.5 mg/kg. In the dry season, arsenic concentrations in location SW-01 exceeded lower limit criteria of sediment quality based on ANZECC-ISQG (20 mg/kg), i.e. 21.5 mg/kg. Moreover, sediment concentration was still below the lower limit.

Cadmium (Cd)

Concentrations of cadmium in river sediment in two locations namely SW-01 and SW-03 in the dry season and wet season were not detected or below the instrument detection limit of <0.1 mg/kg. Lower limit criteria of sediment quality based on ANZECC-ISQG was 1.5 mg/kg.

Chromium (Cr)

Concentrations of chromium in two locations namely SW-01 and SW-03 in the dry season and wet season were in the range between 4 - 31 mg/kg or below the lower limit of sediment quality criteria based on ANZECC-ISQG of 80 mg/kg.

Copper (Cu)

Copper concentrations in river sediment at locations SW-01 and SW-03 in the dry season and wet season had a range of 0.9 – 12.4 mg/kg or below the lower limit of sediment quality criteria based on ANZECC-ISQG of 65 mg/kg.

Lead (Pb)

Concentrations of lead in two locations SW-01 and SW-03 in the dry season and wet season were in the range of 2 – 17 mg/kg or below the lower limit of sediment quality criteria based on ANZECC-ISQG of 50 mg/kg.

Mercury (Hg)

Concentration of mercury in the two locations SW-01 and SW-03 in the dry season and wet season were in the range of 0.004 – 0.035 mg/kg or below the lower limit of sediment quality criteria based on ANZECC-ISQG of 0.15 mg/kg.

Selenium (Se)

Selenium concentrations in two locations at SW-01 and SW-03 both in the dry season and wet season had range between 0.04 – 0.1 mg/kg or were below lower limit concentration of selenium in sediment based on *Van Derveer* and *Canton* (1997) i.e. 1 mg/kg. The criteria of *Van Derveer* and *Canton* (1997) are referred to since the ANZECC-ISQG criteria does not include selenium.

Silver (Ag)

Silver concentrations in river sediment at locations SW-01 and SW-03 in both the dry season and wet season were not detected or were below the instrument detection limit of <0.4 mg/kg. Lower limit criteria of sediment quality based on ANZECC-ISQG was 1 mg/kg.

Zinc (Zn)

Concentrations of zinc in the two locations of SW-01 and SW-03 in both the dry season and wet season were in the range of between 12.5 – 91.1 mg/kg or below the lower limit of sediment quality criteria based on ANZECC-ISQG of 200 mg/kg.

Total Petroleum Hydrocarbon (TPH)

TPH in riverbeds was only detected at sampling location SW-01 in the dry season at 3 mg/kg, furthermore TPH was not detected or was below the instrument detection limit (<2 mg/kg). The criteria for upper limit concentration of TPH in sediment as set by ANZECC-ISQG was 0.3 mg/kg.

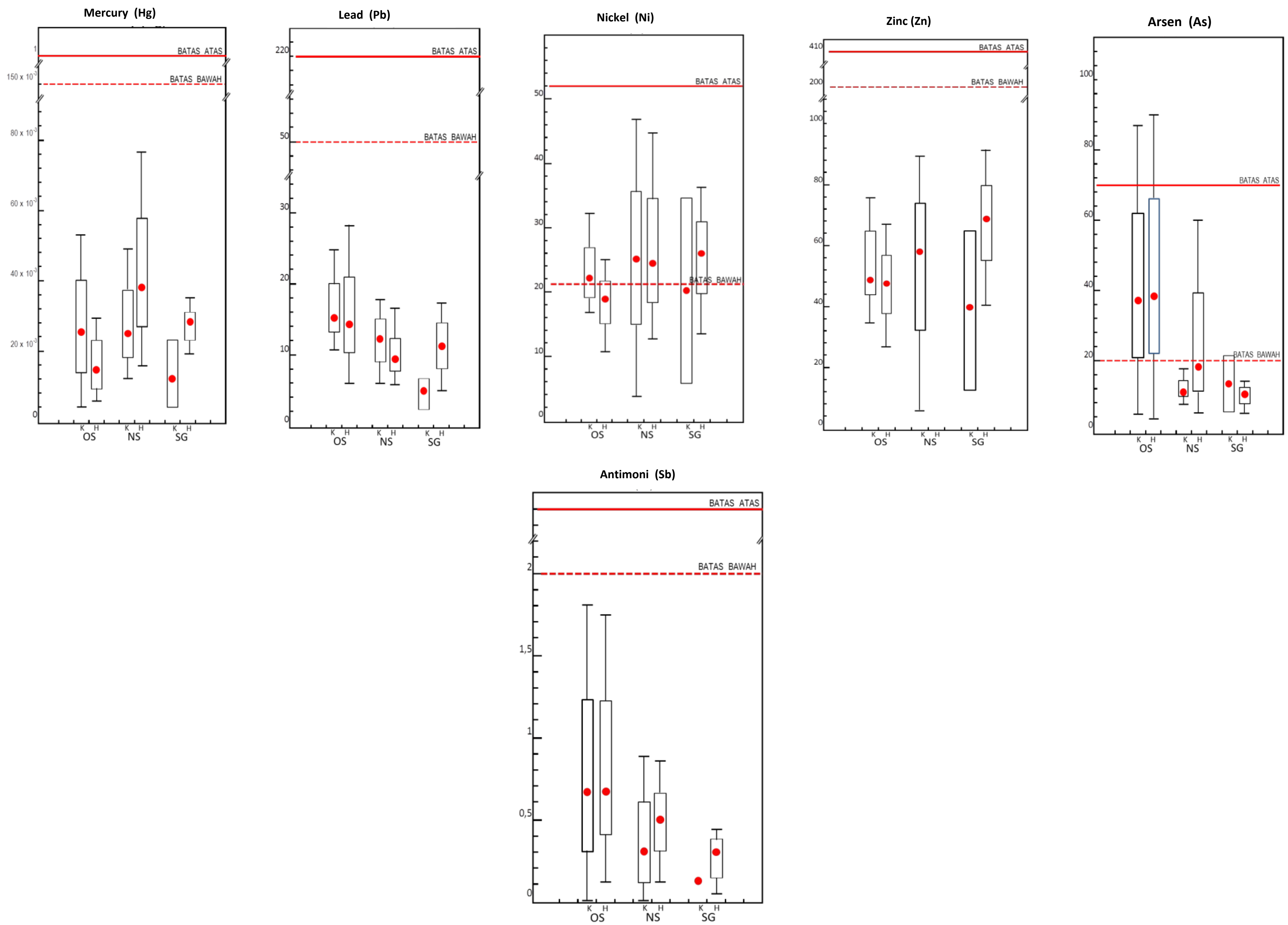


Figure II-91 **Graph of Median Value and Range Value (Minimum) of Metal Concentration in Bed Sediment of *Offshore, Onshore*, and River Waters**

Based on the above explanation, generally the heavy metals concentration in sediment from the monitoring results in the dry season (2012) and wet season (2013) complied with the criteria of sediment quality based on ANZECC-ISQG as well as *Van Derveer* and *Canton* (1997) for parameter of selenium, or was below the lower limit, however for nickel and arsenic content, in both the dry season and wet season had tendency to exceed the lower limit of sediment criteria set by ANZECC-ISQG. The monitoring results were in line with the environmental monitoring results made before and during the Tangguh LNG operation (LNG Train 1 and 2), in which the values for concentrations of nickel and arsenic exceeded the upper limit of ANZECC-ISQG sediment criteria, with the following description:

From 1996 up to 2011, totally 166 sediment samples in the waters of Bintuni Bay around the Tangguh LNG site and in areas that were sufficiently far from the Tangguh LNG activity site were taken The analysis results showed that nickel concentrations exceeded the lower and upper limits of ANZECC-ISQG sediment criteria, encompassing the metals nickel, arsenic, cadmium and mercury. Concentrations of nickel ranged between 20.3 - 348 mg/kg. The values were based on observation of samples from 1996 up to 2011, except for 2002, 2003, 2005 and 2006 in which samples were only taken in Babo. Distribution of sediment sampling from year 1966 up to 2011 are shown in **Figure II-92**.

Table II-45 Number of Samples Exceeding Sediment Criteria and Range Values (mg/kg)

Year	Location	Number of Samples	Number of Samples Exceeding Sediment Criteria and Range Value (mg/kg)																				
			As			Cd			Cr			Cu			Hg			Pb			Ni		
			Range (mg/kg)	Criteria (mg/kg)	Sample exceeding 20 mg/kg	Range (mg/kg)	Criteria (mg/kg)	Sample exceeding 1,5 mg/kg	Range (mg/kg)	Criteria mg/kg	Sample exceeding 80 mg/kg	Range (mg/kg)	Criteria mg/kg	Sample exceeding 65 mg/kg	Range mg/kg	Criteria mg/kg	Sample exceeding 0,15 mg/kg	Range (mg/kg)	Criteria mg/kg	Sample exceeding 50 mg/kg	Range mg/kg	Criteria mg/kg	Sample exceeding 21 mg/kg
1996	Weriagar	3	-	20 - 70	-	-	1,5 - 10	-	-	80 - 370	-	-	65 - 270	-	1.32	0.15 - 1	1	-	50 - 220	-	23,65	21 - 52	3
2000	Weriagar, LNG, Vorwata	45	20 - 74	20 - 70	15	-	1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	1.98	0.15 - 1	1	-	50 - 220	-	22,4 - 42,7	21 - 52	44
2001	LNG	15	30 - 64	20 - 70	2		1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	-	0.15 - 1	-	-	50 - 220	-	20,3 - 75,9	21 - 52	15
2002	Babo	2	-	20 - 70	-	-	1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	-	0.15 - 1	-	-	50 - 220	-	-	21 - 52	-
2003	Babo	1		20 - 70	-		1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	-	0.15 - 1	-	-	50 - 220	-	-	21 - 52	-
2005	Babo	2		20 - 70	-		1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	4.69	0.15 - 1	1	-	50 - 220	-	-	21 - 52	-
2006	Babo	1	-	20 - 70	-	-	1.5 - 10	-	-	80 - 370	-	-	65 - 270	-		0.15 - 1	-	-	50 - 220	-	-	21 - 52	-
2007	Vorwata - Babo LNG, Roabiba	18	-	20 - 70	-	-	1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	2.08 - 2.61	0.15 - 1	7	-	50 - 220	-	21,6 - 24,4	21 - 52	3
2008	Vorwata - Babo LNG, Roabiba	25	-	20 - 70	-	1.52 – 1.77	1.5 - 10	4	-	80 - 370		-	65 - 270	-	0.55 – 0.88	0.15 - 1	2	-	50 - 220	-	21,3 - 348*)	21 - 52	4
2009	Vorwata - Babo LNG, Roabiba	21	31.6 - 126	20 - 70	7	-	1.5 - 10	-	-	80 - 370	-	-	65 - 270	-	-	0.15 - 1	-	-	50 - 220	-	21,2	21 - 52	1
2011	Vorwata - Babo LNG, Roabiba	33	21.6 - 162	20 - 70	17	2.1 - 3.4	1.5 - 10	7	-	80 - 370	-	-	65 - 270	-	-	0.15 - 1	-	-	50 - 220	-	21,7 - 39,3	21 - 52	28
		166			41			11									12						98

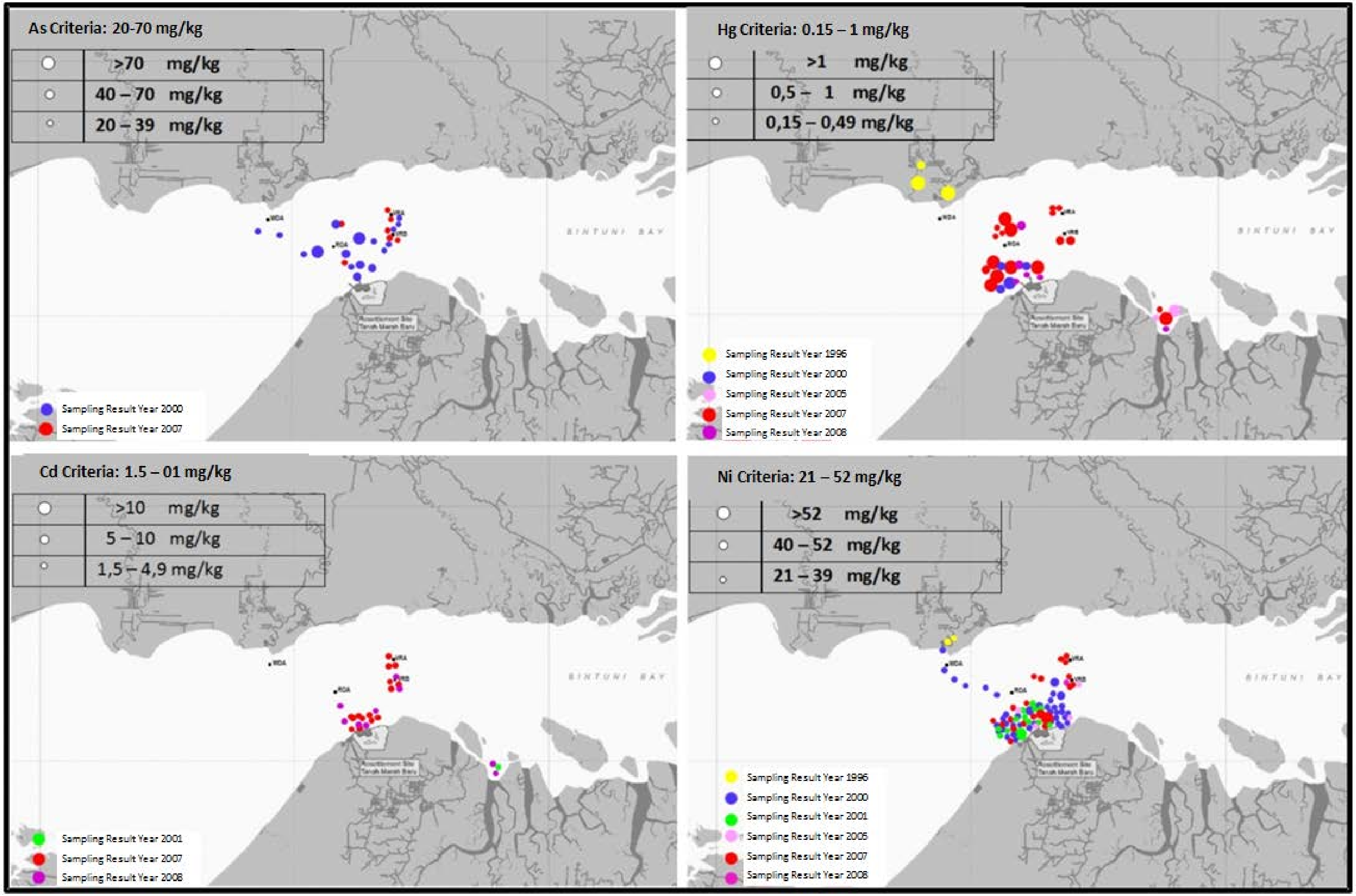


Figure II-92 Distribution of Metal Content (As, Hg, Cd and Ni) in Marine Sediment Exceeding the ANZECC Criteria

Arsenic content ranged between 20 – 162 mg/kg. The value was higher than the criteria for sediment specified in ANZECC-ISQG of 20 mg/kg (lower limit) – 70 mg/kg (upper limit). The value was based on sampling results of 2000, 2001, 2009 and 2011.

The high concentrations of nickel and arsenic in sediment are natural indicators for the Bintuni Bay seabed. In general, the presence of nickel is in areas with nickel laterite deposits in ultrabase igneous rock, while arsenic content is in intermediate igneous rock.

Nickel laterite deposits are products of advanced weathering process in *ultramafic* rock carrying Ni-Silicate. Indonesia is known worldwide as a leading producer of mine products, including nickel. Based on geological characteristic and tectonic order, several locations have potential nickel laterit deposits in Indonesia and are generally dispersed in the eastern part of Indonesia, among others: Pomalaa (Southeast Sulawesi), Sorowako (South Sulawesi), Gebe (Halmahera), Tanjung Buli (Halmahera), and Tapunopaka (Southeast Sulawesi). While several locations estimated to also possess potential nickel laterite deposits and were so far conducting exploration activities were found in small islands around Halmahera Island, among others Obi Island, Gee island, and Pakal Island.

In the West Papua area, nickel deposits are found in Waigeo Path encompassing the Bird's Head area including Gag Island located approximately 160 km from Sorong to the west *(Mines and Energy Service of Jayapura, 2004).* **Figure II-93** shows the distribution of ultabasic sediment starting from Sulawesi, North Maluku, Gag Island to Papua.

Tangguh LNG activities are not connected to the presence of nickel and arsenic in the waters of Bintuni Bay. In the industrial process, it is common that gold ore processing or pesticide industry will produce waste containing arsenic. Apart from that, in nature arsenic content in *shale and clay* rock ranges between 0.3 – 490 mg/kg and in *ultrabasic* rock ranges between 0.3 – 16 mg/kg (*National Academy of Science*, 1977).

Apart from nickel and arsenic, results of monitoring in 1996 up to 2011 also indicated that mercury and cadmium in several sampling locations exceeded the lower limit and upper limit criteria of ANZECC-ISQG. **M**ercury content in sediment recorded 10 data with indication of exceeding the ANZECC-ISQG upper limit criteria of 1 mg/kg, and two data points exceeded the ANZECC-ISQG lower limit criteria of 0.15 mg/kg. As for cadmium content, of 58 data points a total of 11 data indicated values exceeding lower limit criteria ANZECC-ISQG of 1.5 mg/kg.

Comparison with various environmental baseline data starting from 1996 gave indication of the existence in nature of several metal parameters of high concentration in Bintuni Bay.

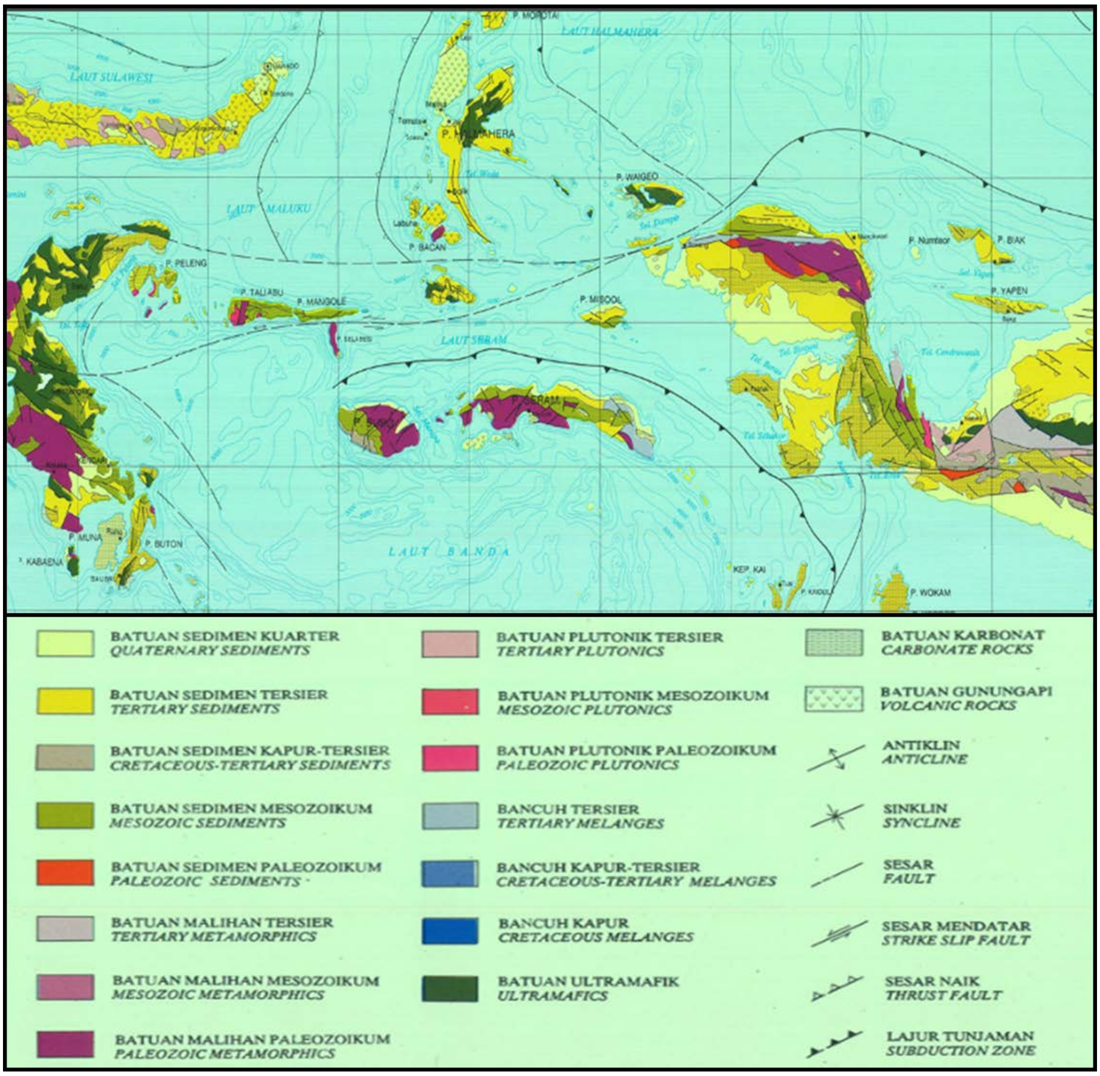


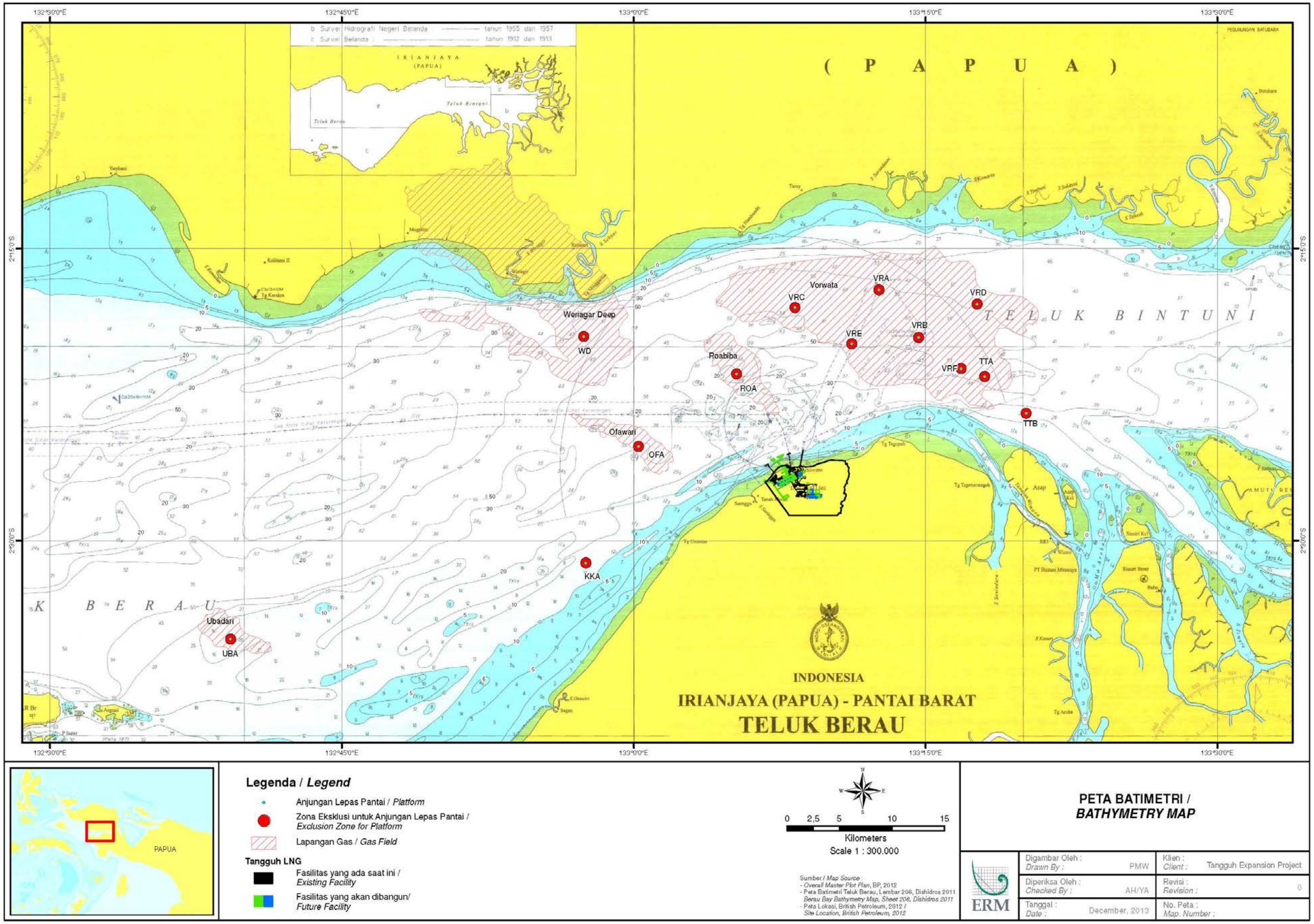
Figure II-93 Distribution of Ultramafic Rock in Sulawesi-North Maluku – Gag Island-Papua

2.1.10 Oceanography

The morphology of the Berau Bay and Bintuni Bay extends from the east to the west direction along ± 160 km with an open bay mouth in the western part that is directly connected to the waters of the Halmahera sea. The widest part of the Bintuni Bay waters reaches 50 km which is located near the bay mouth. Many rivers also empty into the bay so that the bay water salinity is lower than the sea waters in front of it.

2.1.10.1 Bathymetry

The water depth of Bintuni Bay varies from only a few meters (<5 m) along the shoreline (nearshore), up to more than 50 m in the center and near the bay mouth (**Map II-14** offshore). During seawater quality sampling, the measurement indicated that particular locations were even recorded of more than 100 m.



Map II-15 Bathymetry of the Bintuni Bay

2.1.10.2 Waves

The wave height conditions in the Bintuni Bay waters vary from <0.4 m up to >1.6 m. The wave's height surrounding the bay mouth are larger than at the inner bay as the areas around the bay mouth are more open, while the central part of the bay is more protected.

Wave data recording use the Interocean S4ADW current and wave meter equipment. This equipment records the wave height and direction. The EHI data (Evans-Hamilton International) by using the S4A equipment is installed at the western location of the LNG 1 jetty. Results of the wave data analysis is collected by PT. Calmarine during the period of March 1st up to June 30th, 2001 that is installed at the Ocean Tower location as illustrated in **Figure II-94** and **Figure II-95**.

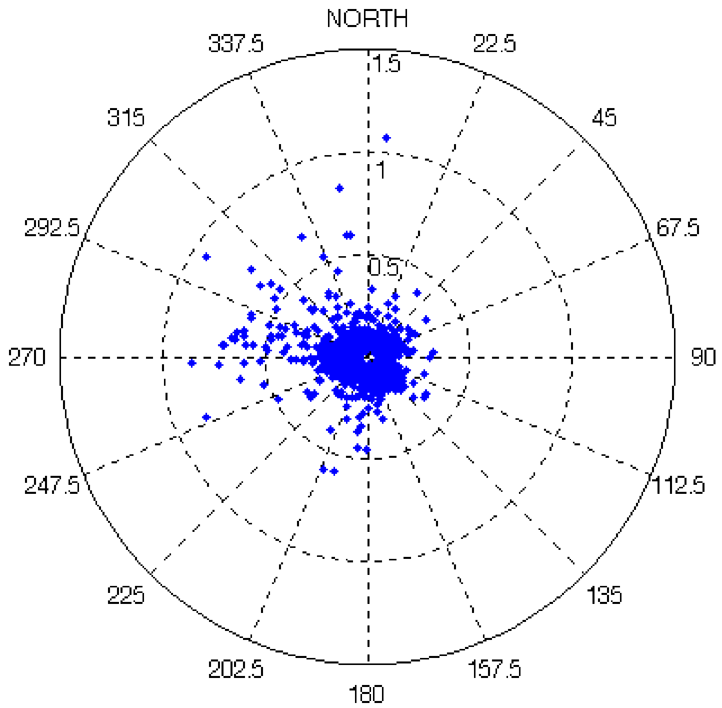


Figure II-94 Scatter Plot of the Significant Wave Height vs the Average Wave Direction in the Period of March 1st up to June 30th, 2001

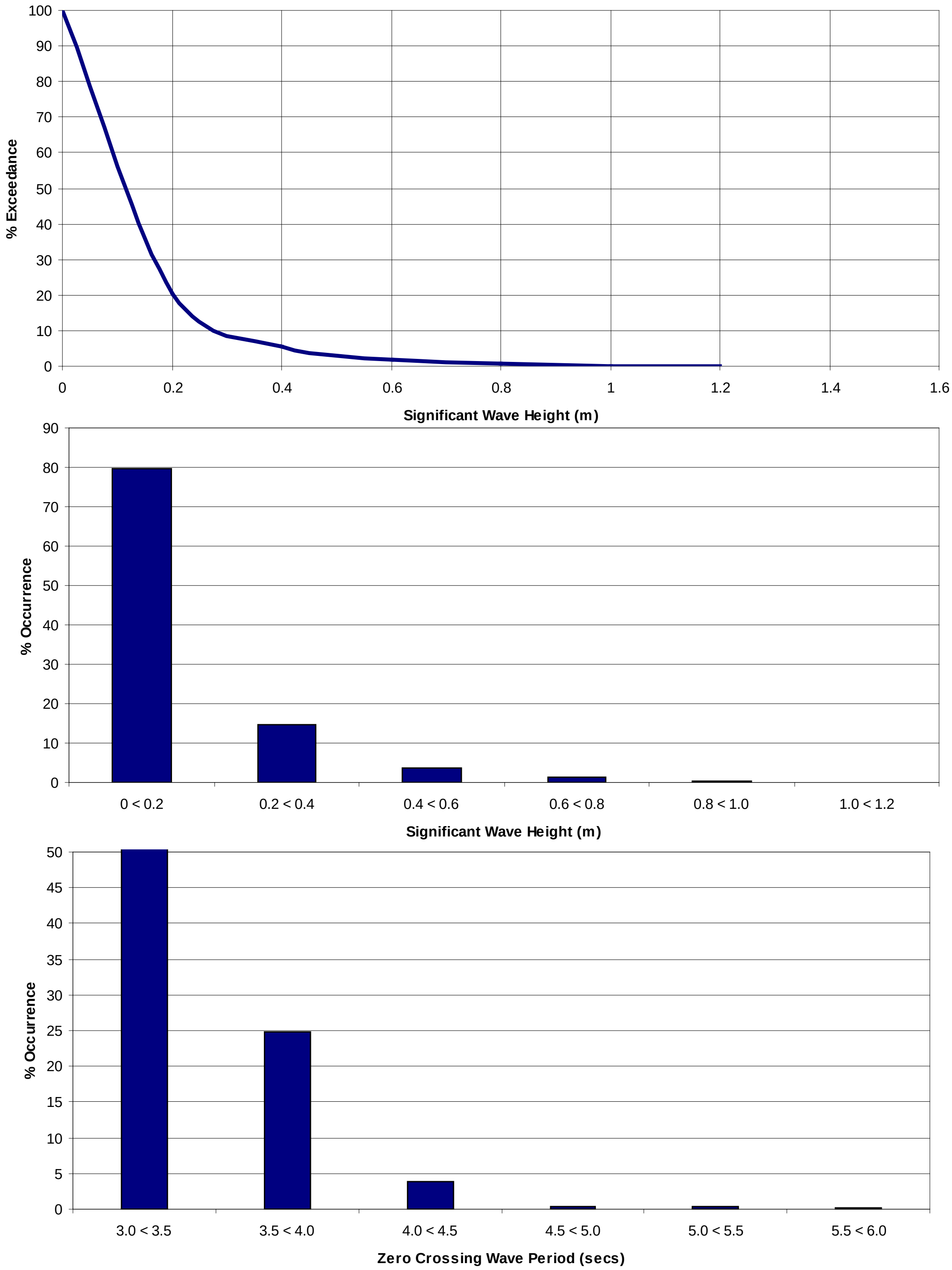


Figure II-95 **Percentage (%) of Height Occurrences (Hs) and Zero Crossing Wave (Tz) in the Period of March 1st up to June 30th, 2001**

Based on data from EHI and Calmarine in AMDAL (2002), the frequency of wave occurrences between 0 to 0.4 m are approximately 90%. This means that approximately 90% of waves heights in the bay are less than 0.4 m (40 cm) and only 1.2% wave occurrences having a significant height of more than 1.0 m.

Table II-46 Significant Wave Height and Occurrence Frequencies in the Bintuni Bay Waters

Significant Wave Height (m)	Occurrence Frequency (%)	
	Data from EHI	Data from Calmarine
0 up to 0.4	95.2	91.4
0.4 up to 0.8	4.1	7.4
0.8 up to 1.2	0.7	1.2
1.2 up to 1.6	0.06	0.1
>1.6	0.02	None

Source: EHI and Calmarine in Amdal, 2002

LAPI ITB (2013) used MuSed3D software to estimate the hydrodynamic condition in the sea around the Combo Dock. Hindcast of waves was conducted by using the NOAA wind data at 131.75° E, 02.50° S as wind data every 6-hours from 1999 to 2011. Wave estimates were performed in the waters surrounding the Combo Dock wherein the effect of the wave transformations can be ignored. This model was validated with data from an oceanography survey by Calmarine (1999) with good results.

Estimates of significant height and wave period are presented in **Table II-47**. Estimates of extreme wave heights for each return period are presented in **Table II-48**. Percentage of wave occurrences at the Combo Dock location is approximately 71%, or 21% of the sea in calm conditions.

Table II-47 The Height (Hs) and Period (Ts) of Significant Waves

	Hs (m)	Ts (s)
Significant	0.58	2.73
Max	2.88	6.16
Average	0.35	2.10
Min	0.01	0.36

Source: LAPI ITB (2013)

Table II-48 Estimates of Extreme Wave Heights

Repeated Period (Year)	Extreme Wave Heights (m)
1	1.44
2	1.63
3	1.82
5	2.03
10	2.29
25	2.61
50	2.85
100	3.08
200	3.31

Source: LAPI ITB (2013)

2.1.10.3 Tidal

Based on measurement results of sea levels performed at *Tanah Merah* in the period of October 21st, 1999 to March 3rd, 2000 by Calmarine, tidal constituents were obtained as presented in **Table II-49**. By using the tidal constituents, the Formzhal value of 0.36 can be obtained. This figure means that the tidal type at the location is mixed tide prevailing semi-diurnal.

Table II-49 Tidal Constituents at *Tanah Merah*, Bintuni Bay Waters (AMDAL, 2002)

Tidal Constituent	M2	S2	N2	K2	K1	O1	P1	M4	MS4	Z0	F
Amplitude Constituent, H (m)	0.89	0.27	0.20	-	0.45	0.27	0	0.03	0.02	2.15	0.62
Constituent Phase, g (˚)	179	272	125	-	347	313	348	322	058	-	-

Source: Analysis Data of MetOcean, Calmarine, 2002

Fluctuations of seawater surfaces at Combo Dock at a depth of +6 m LAT at the period December 24th, 2012 up to April 12th, 2013 (Fugro Geos PTE Ltd, 2013) is presented in **Figure II-96**. The maximum water height during observations recorded by devices installed at a depth of 0.5 m above average seawater level is 1.7 m that was recorded on March 31st, 2013 at 00:00 WITA. The minimum height is -2.2 m which was recorded on January 12th, 2013, at 03:10 pm WITA.

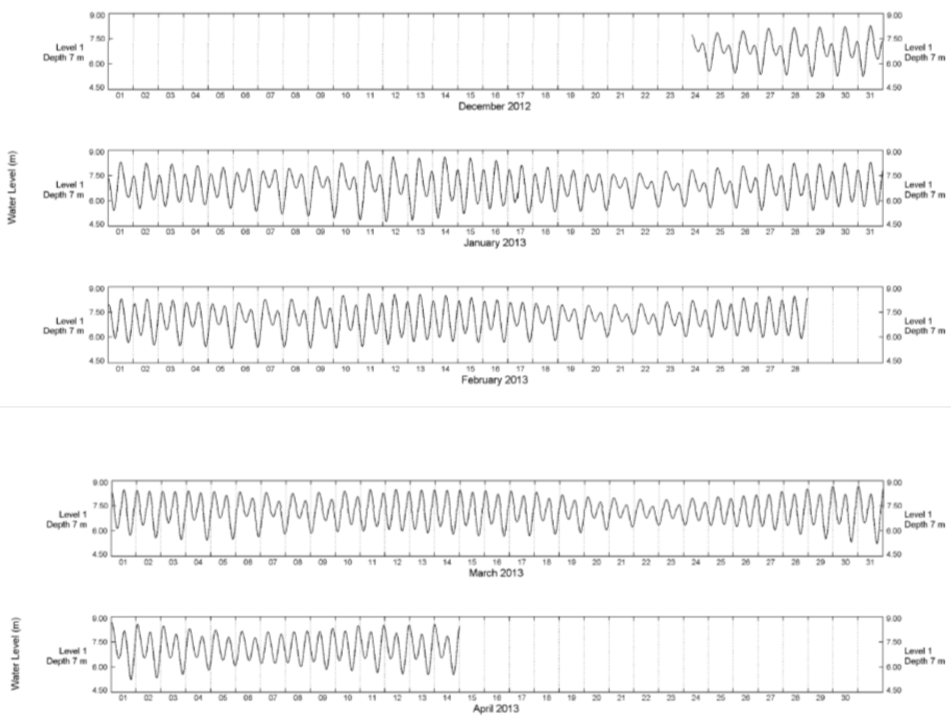
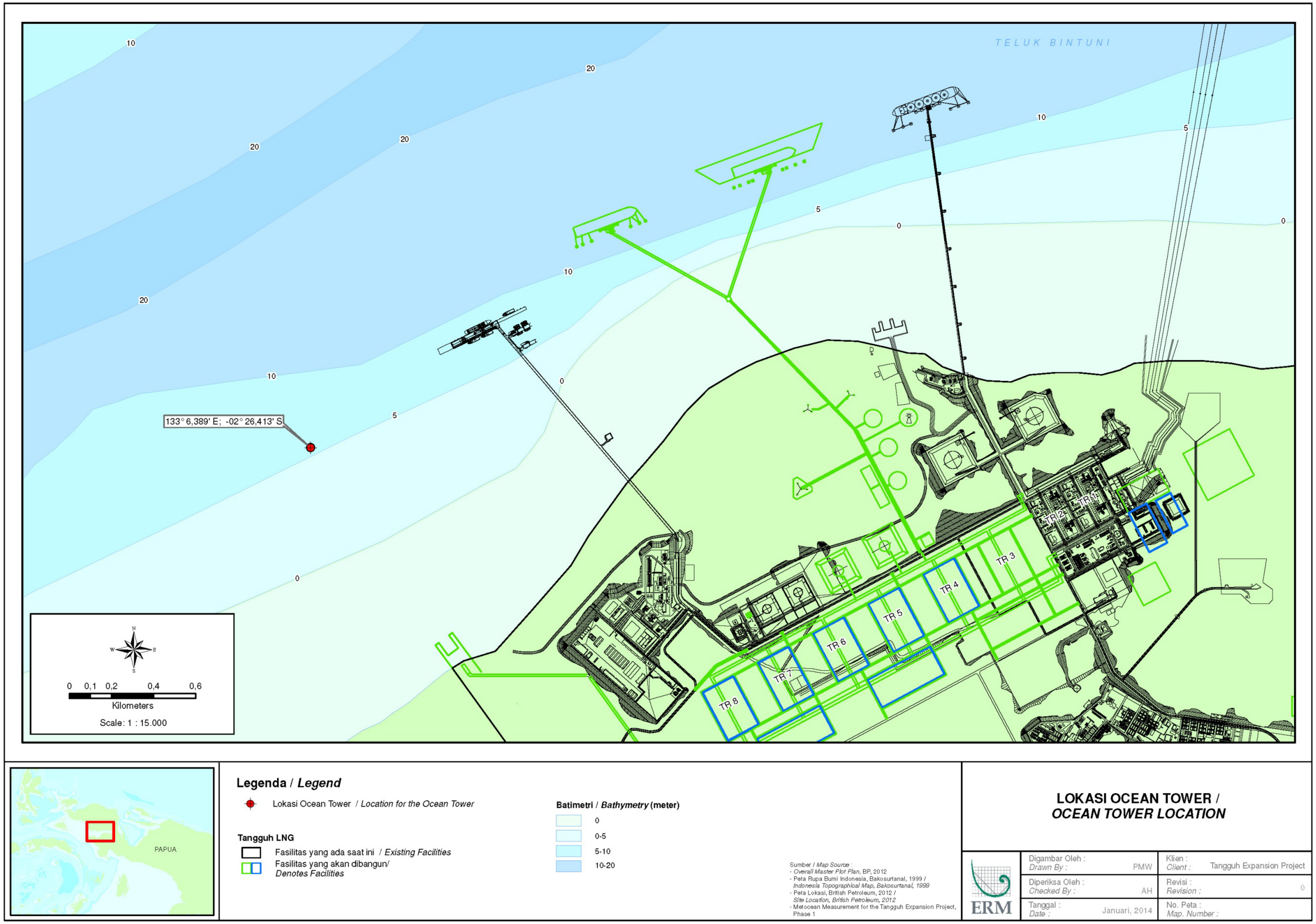


Figure II-96 Fluctuations of Seawater Level at the Ocean Tower Location in Bintuni Bay Waters



Map II-16 Ocean Tower Location

2.1.10.4 Current

Current measurement results using the mooring method at the center of narrowest bay in front of *Tanah Merah* showed that current movements were dominated by the Northeast and Southwest directions (**Figure II-97**). At the scatter plot figure, **Figure II-97** (left), it can be observed that the current spread forms an ellipse in the northeast and southwest directions. The condition indicated that the current movement direction is alternating in the northeast and northwest direction or indicated that the current movement was dominated by tidal.

Figure II-97 (right) shows the direction and velocity of the current. The maximum velocity on the major axis at the depth of 5.5 m above the seabed can reach 74.4 cm/sec, while on the minor axis is 5.0 cm/sec. At the layer of 0.5 m from the sea bed are respectively 46.0 cm/sec on the major axis and 6.1 cm/sec on the minor axis.

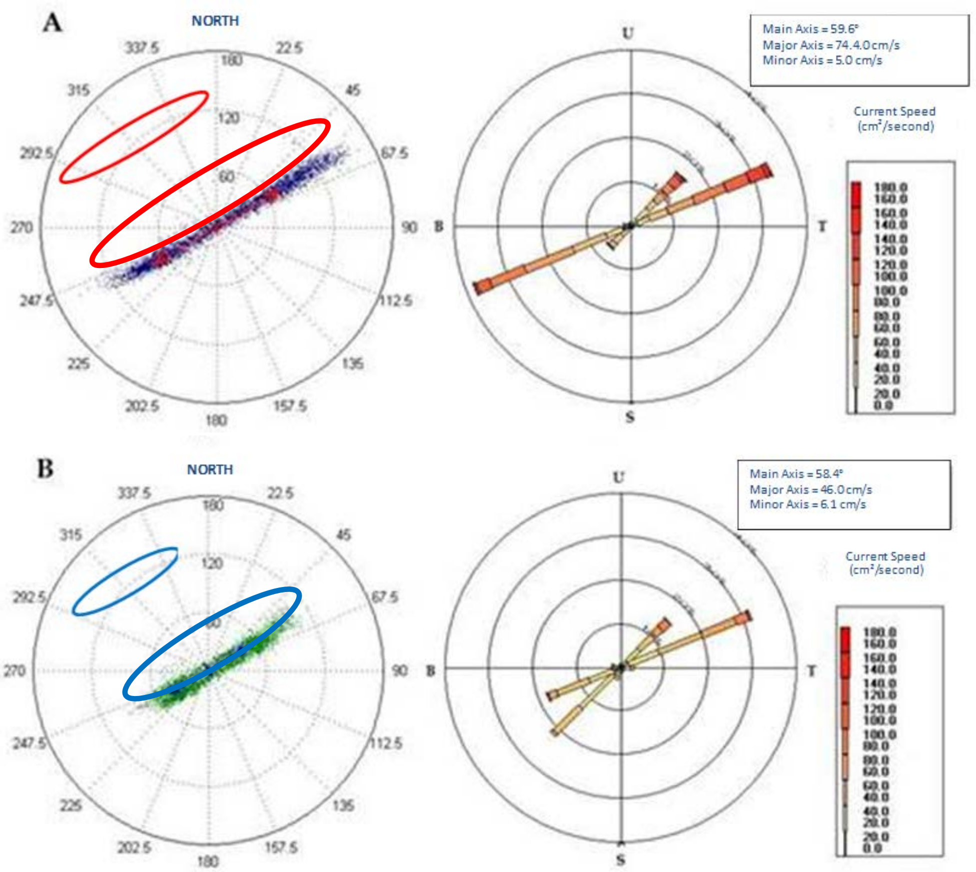
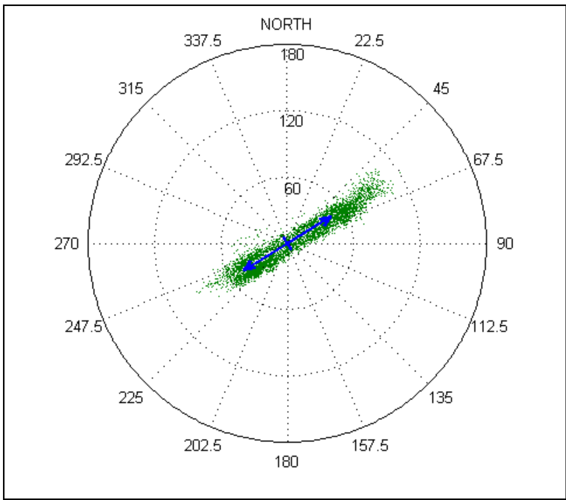
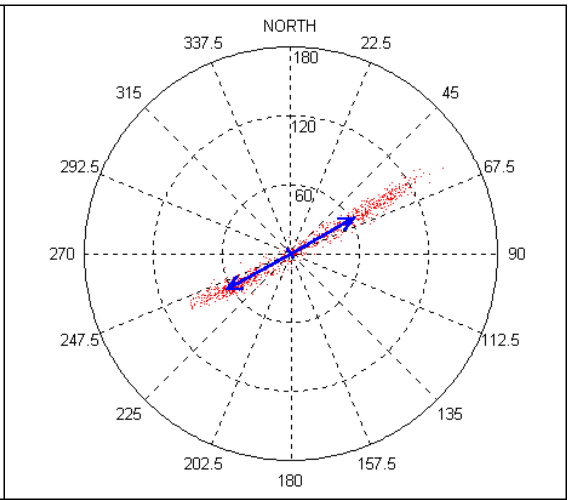


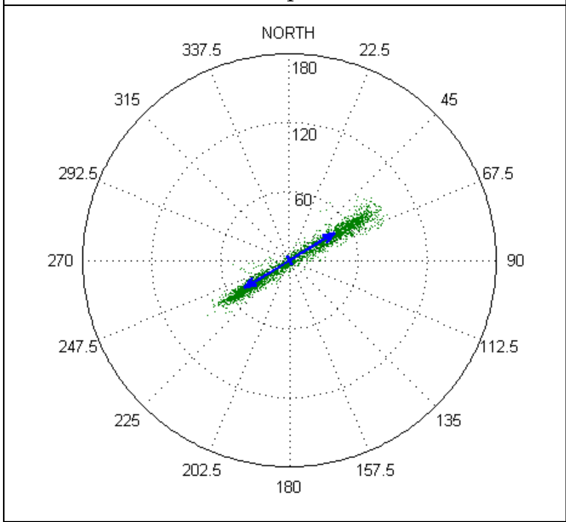
Figure II-97 **Scatter Plot and Current Rose at the Ocean Tower Location in the Period of December 7th, 1999 up to March 3rd, 2000. A-Position of current meter is at 5.5 m above the sea bed and the B-Position of current meter is at 0.5 m above the sea bed**



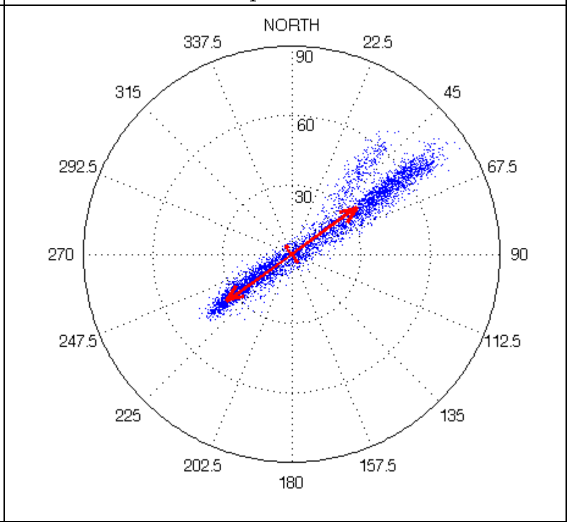
December 7th, 1999 up to March 3rd, 2000



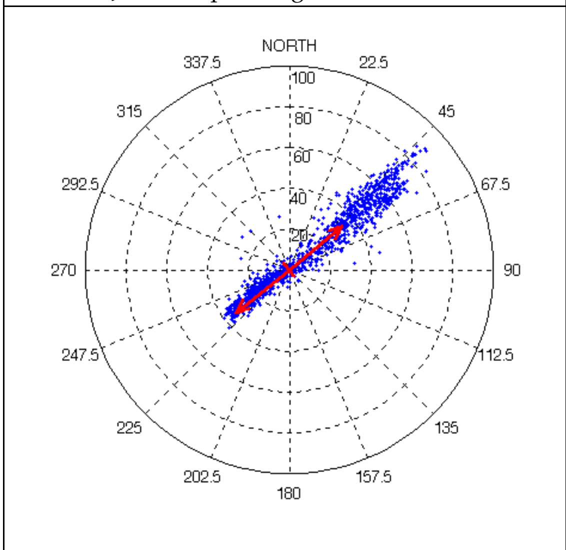
March 1st up to Mei 31st, 2000



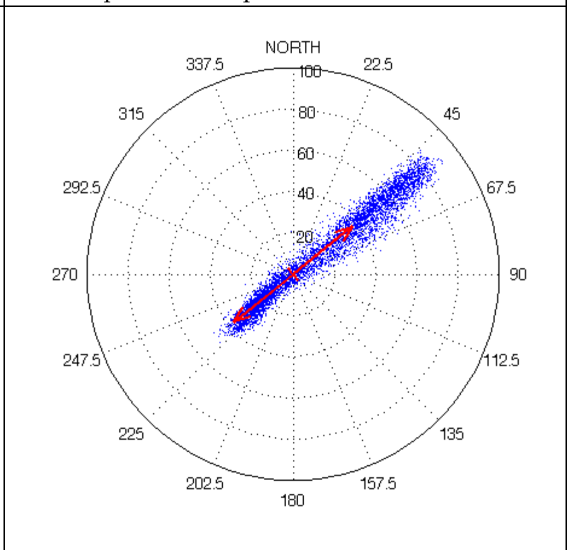
June 1st up to Augusts 30th, 2000



September 1st up to December 4th, 2000



December 1st up to February 28th, 2001



March 1st up to June 30th, 2001

Figure II-98 Scatter Plots of Each Quarter at the Period of December 7th, 1999 up to June 30th, 2001

Based on **Figure II-98**, it can be observed that the pattern of quarterly current direction during 18 months of measurement (December 7th, 1999 up to June 30th, 2001) has similar current direction pattern that is similar to the average current direction towards 45° up to 87.5° and 225° up to 247.5°. This condition explains that the current in the Bintuni Bay is very strongly affected by the tidal because of the alternating current movement direction in the northeast and northwest direction, although in different monsoons.

Current Simulation

Instantaneously current measurements in the field are not sufficient to observe the current pattern figure in the bay, but the data can be used to validate the current simulation model. A combination of the directly current measurement in the field and the simulation results can provide an understanding of the current pattern occurring in the bay spatially and temporarily.

To observe the current pattern spatially and temporarily based on the different monsoons, therefore a simulation current was performed. The input of model used in the simulation is the bathymetry, tidal (**Figure II-99**), and wind data (**Figure II-100**).

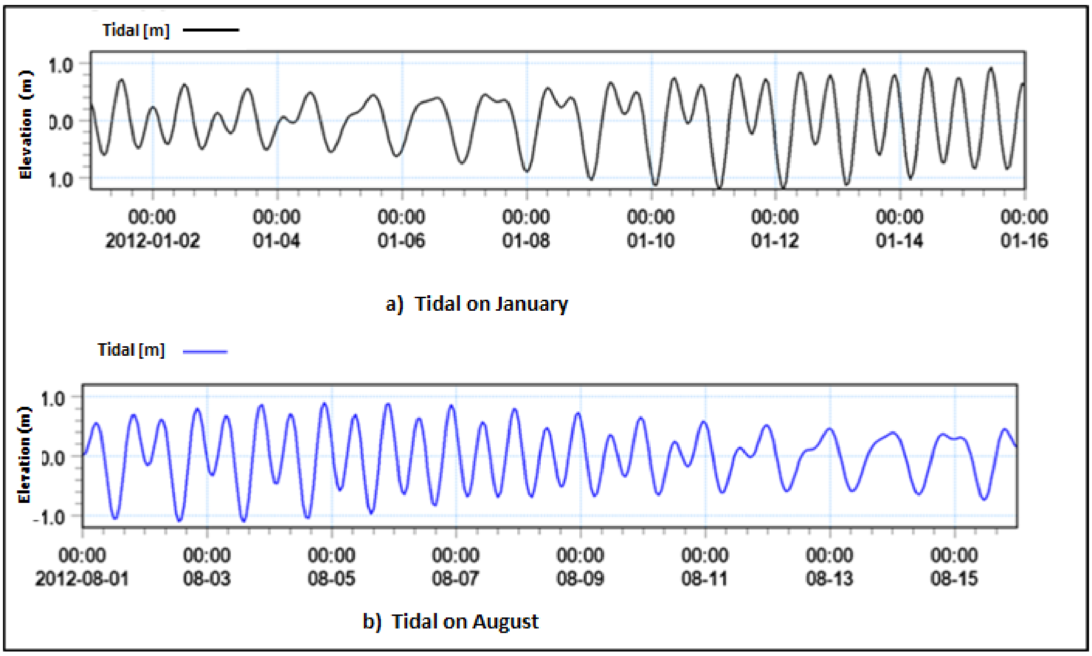


Figure II-99 **Tidal Data Used in the Current Simulation, January Represents the Northeast Monsoon and August Represents the Southeast Monsoon**

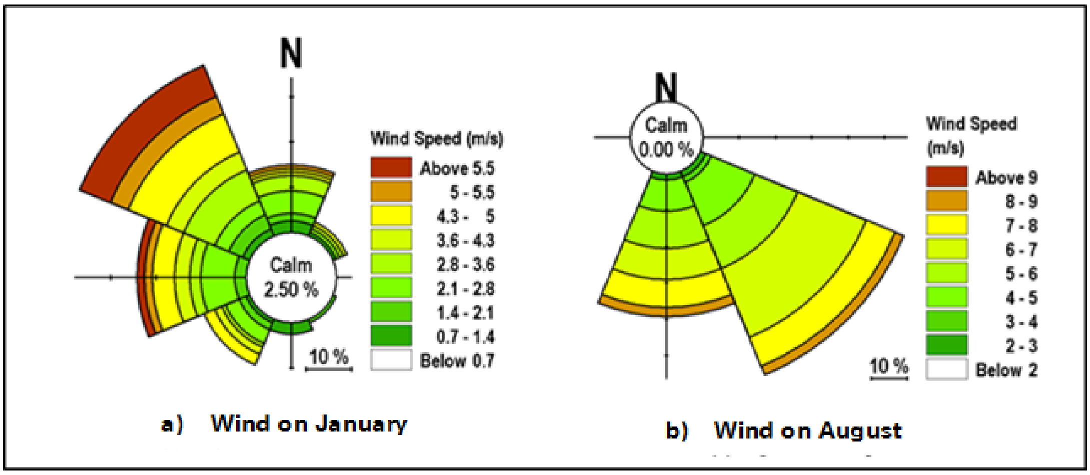


Figure II-100 Wind Data Used in the Current Simulation, January Represents the Northeast Monsoon and August Represents the Southeast Monsoon

Seawater level fluctuations for 15 days were plotted in a graphical form of the time-based seawater level elevation (**Figure II-99**), either that represents the northeast monsoon in January (upper panel) and that represents the southeast monsoon (lower panel). In general, it can be observed that the maximum tidal range within 15 days almost reaches 2 m, in particular during the spring tide.

Wind data used as input data in the simulation is the average wind data in January and October during the last ten years. In the northeast monsoon which is represented by the average wind in January during ten years, the dominant wind blows from the northwest direction with a wind velocity of > 5.5 m/sec (**Figure II-100** – left hand side).

In the southeast monsoon (June-August) or known as the Southeast Monsoon, the wind dominantly blows from the southeast and from the south with a velocity of 8-9 m/sec (**Figure II-100 –** right hand side).

Current simulation results in two different monsoons are shown in **Figure II-101** up to **Figure II-104** for the northeast monsoon, and **Figure II-105** up to **Figure II-108** for the southeast monsoon. In each monsoon, four figures of current patterns are shown which it respectively represents the seawater level position during the seawater level at MSL (Mean Sea Level) moves to the highest tide point, when the water level is at the highest tide, when the seawater level at the MSL moves to the lowest ebb point and when the water level is at the lowest ebb point.

A. Results of Current Simulation Model in the Northeast Monsoon

Based on **Figure II-101,** the current moves into the Bintuni Bay when the water level is at the MSL heading to the highest tide point, however it is not the case with the current condition in the eastern end of the bay, which there are estuaries so that the current can be observed to move in the opposite direction i.e. towards the bay mouth. The current velocity is observed to vary between 5 cm/second to approaching 100 cm/second near the mouth, in particular the inner part of the bay.

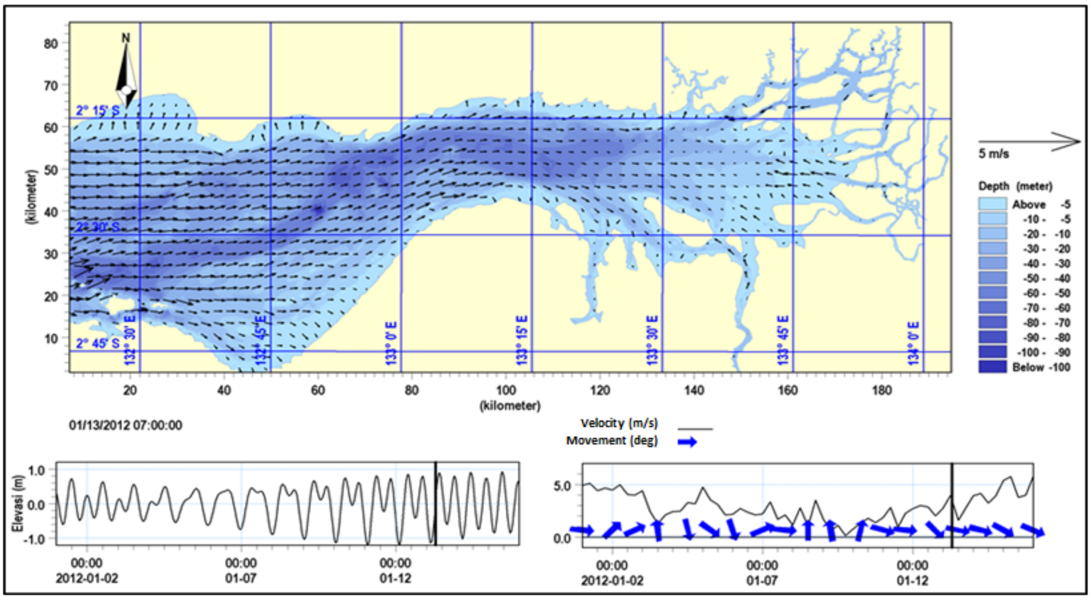


Figure II-101 Current Pattern as Simulation Result When the Seawater Level at the MSL Point Moves Towards the Highest Tide Point in January Representing the Northeast Monsoon at the Bintuni Bay

When the water level is at the highest tide point, the water movement pattern or current pattern in the bay is illustrated in **Figure II-102**. Significant changes occur in the surroundings of the bay head, the current pattern occurring is observed entering the river mouths due to during the highest tide, water masses pushing from the sea direction is extremely maximum. The current velocity at the highest tide in the deep bay are still visible to be faster of approximately 5 cm/second, while in the surroundings of the bay mouth the current velocity can reach 100 cm/second.

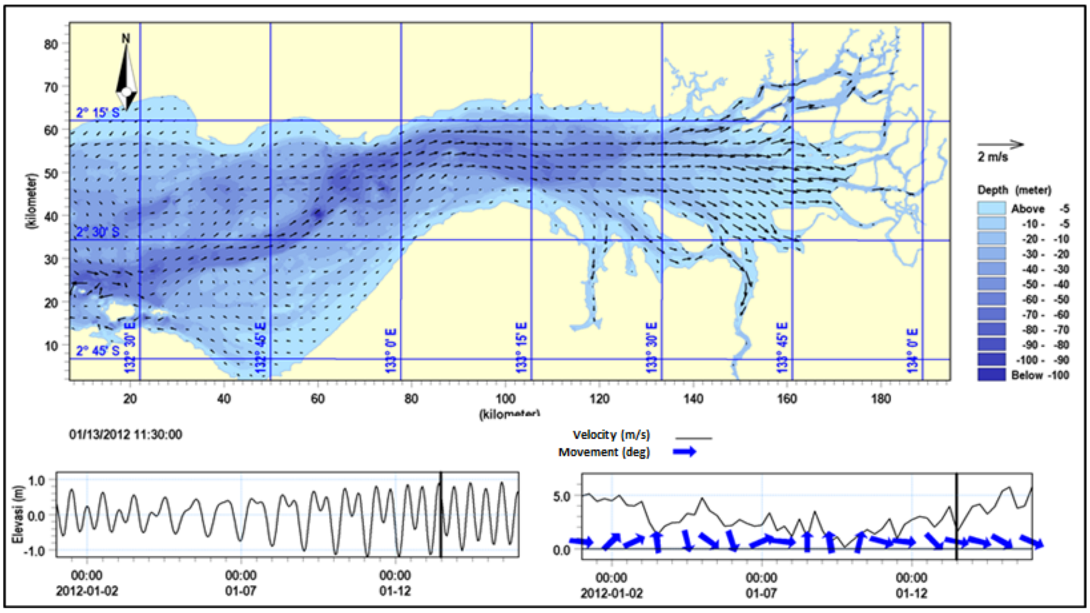


Figure II-102 Current Pattern as Simulation Results When the Seawater Level is at the Highest Tide Point in January Representing the Northeast Monsoon at Bintuni Bay

The next phase after the water level position is at the highest tide point is when the water level is at the MSL moving to the lowest ebb point. The current pattern when the water level at the MSL moves towards the lowest ebb point is illustrated in **Figure II-103**. Almost in the entire bay water mass movements are to the outside through the bay mouth. Only in a few parts it can still be observed that water mass moves to river. The current velocity when the water level position is at the MSL point heading to the ebb ranges from 5 cm/second up to nearly 100 cm/second. Similar to the previous seawater level position, current velocity is faster as observed at deeper bay (marked in dark blue colour).

Considering that the type of tide occurring in the Bintuni Bay is a mixed tide prevailing semi-diurnal, therefore after 6 hours of the tide, ebb occurs. At the time the water level is at the lowest ebb point, the occurring current pattern is illustrated at **Figure II-104**. In all the parts of the bay and river estuaries masses of water move out through the bay mouth. At the inner part, the velocity current is observed to be strong >100 cm/second, while near the shoreline it is much slower (<10 cm/second).

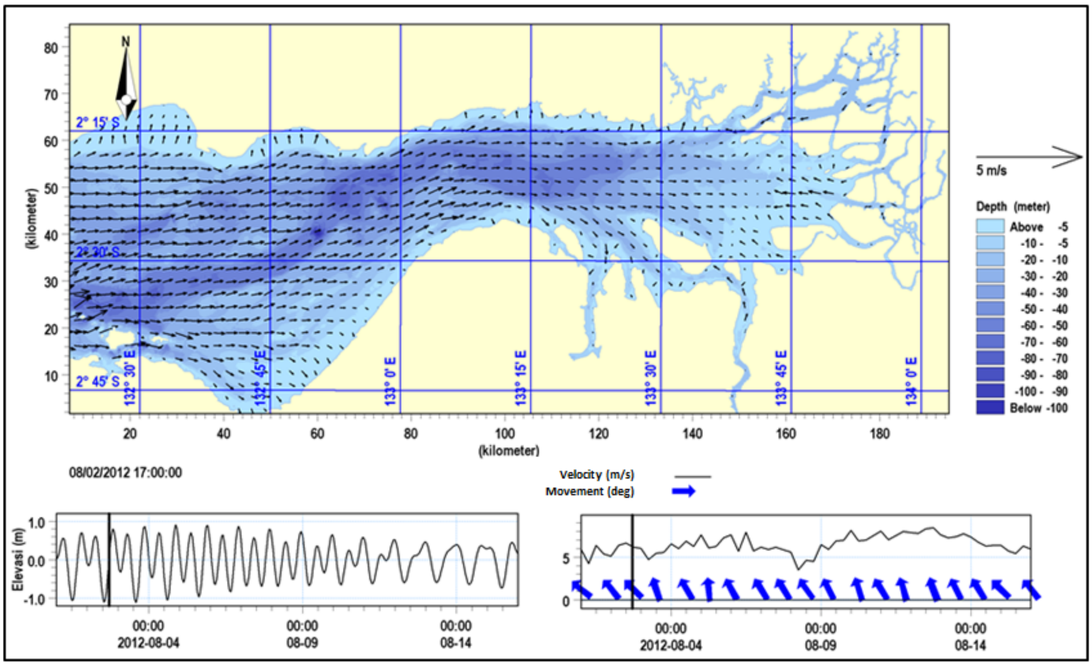


Figure II-103 Current Pattern of Simulation Results when the Seawater Level at the MSL Point Moves Towards the Lowest Ebb Point in January Representing the Northeast Monsoon at Bintuni Bay

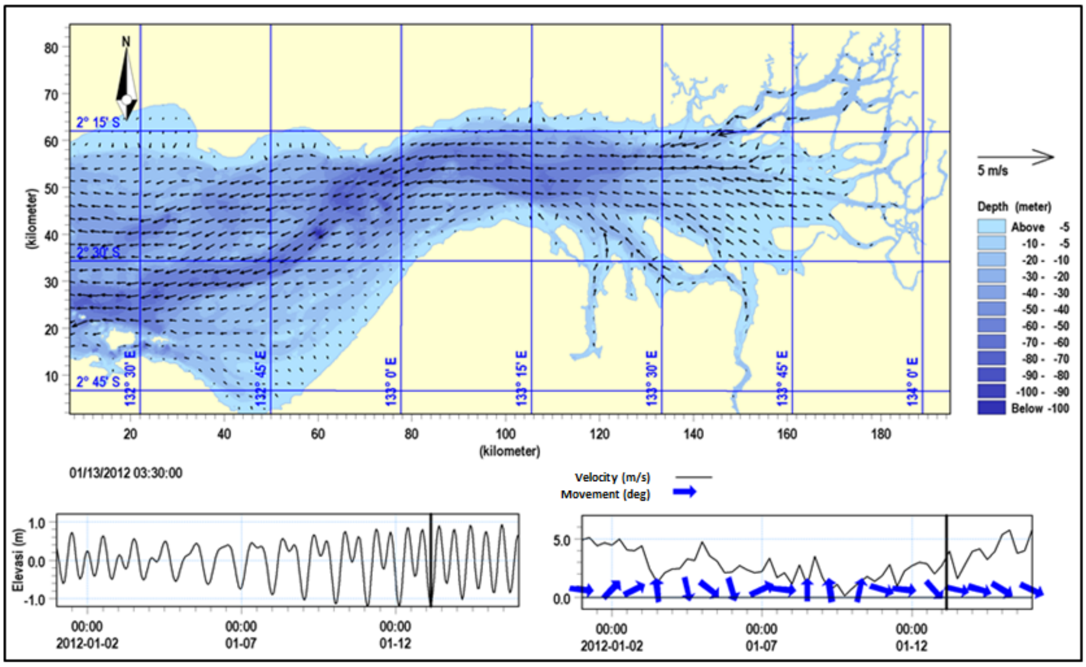


Figure II-104 Current Pattern of Simulation Results when the Seawater Level at the Lowest Ebb Point in January Representing the Northeast Monsoon at Bintuni Bay

B. *Results of the Current Simulation Model in the Southeast Monsoon*

Illustrations of current patterns occurring in the southeast monsoon can be identified by using a current simulation in August which is the peak of the southeast monsoon. Wind data used in the current simulation in the east monsoon is the average wind data for the last decade. **Figure II-105** up to **Figure II-108** are current pattern models when the water level position is at four different positions, namely when the seawater level at MSL moves towards the highest tide point, when the water level is at the highest tide point, when the seawater level at MSL moves towards the lowest ebb and when the water level is at the lowest ebb position.

The current pattern is nearly similar to when the current pattern is at the same position with the current pattern occurring in the northeast monsoon as illustrated in **Figure II-101** up to **Figure II-104**.

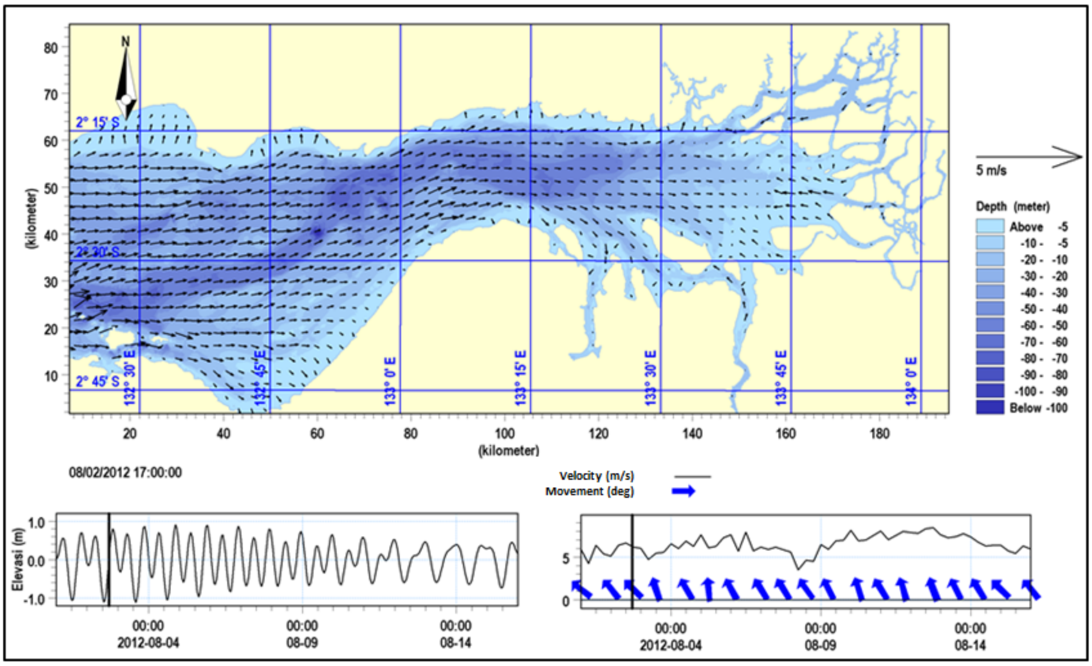


Figure II-105 **Current Pattern of Simulation Results when the Seawater Level is at the MSL Point Moves Towards the Highest Tide Point in August Representing the Southeast Monsoon at Bintuni Bay**

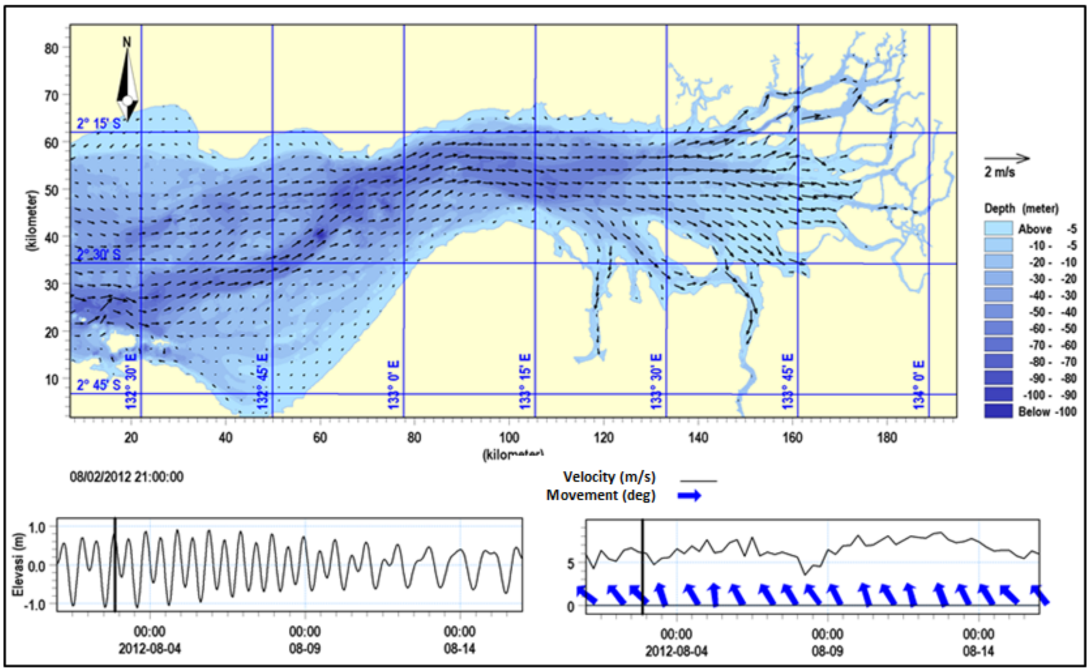


Figure II-106 Current Pattern of Simulation Results when the Seawater Level is at the Highest Tide Point in August Representing the Southeast Monsoon at Bintuni Bay

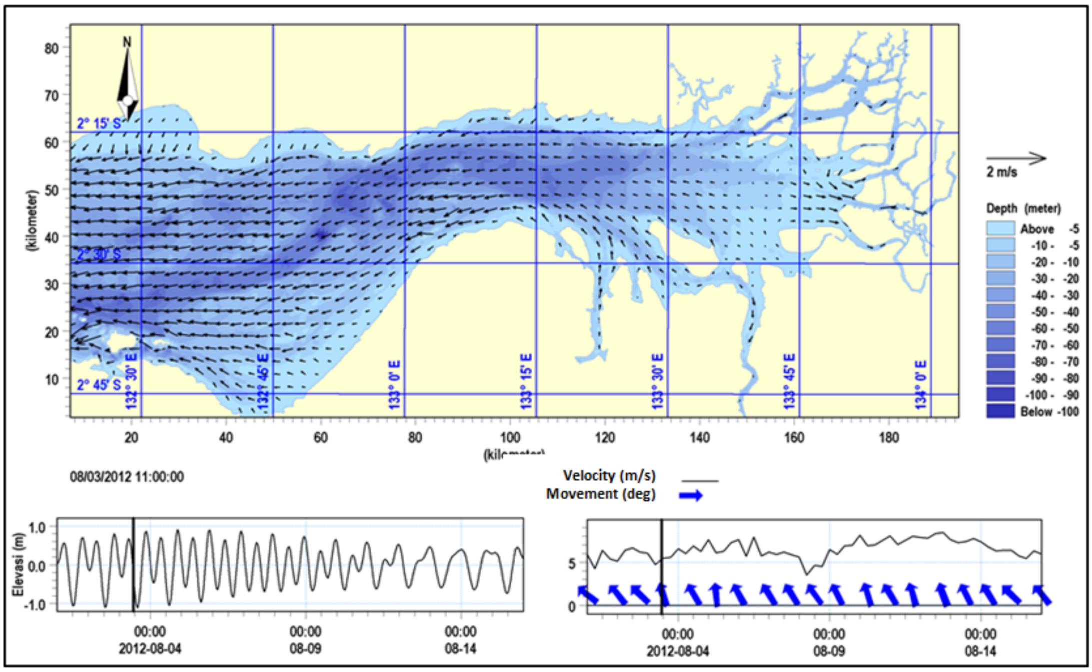


Figure II-107 Current Pattern of Simulation Results When the Seawater Level at the MSL Point Moves Towards the Lowest Ebb Point in the Representing the Southeast Monsoon at Bintuni Bay

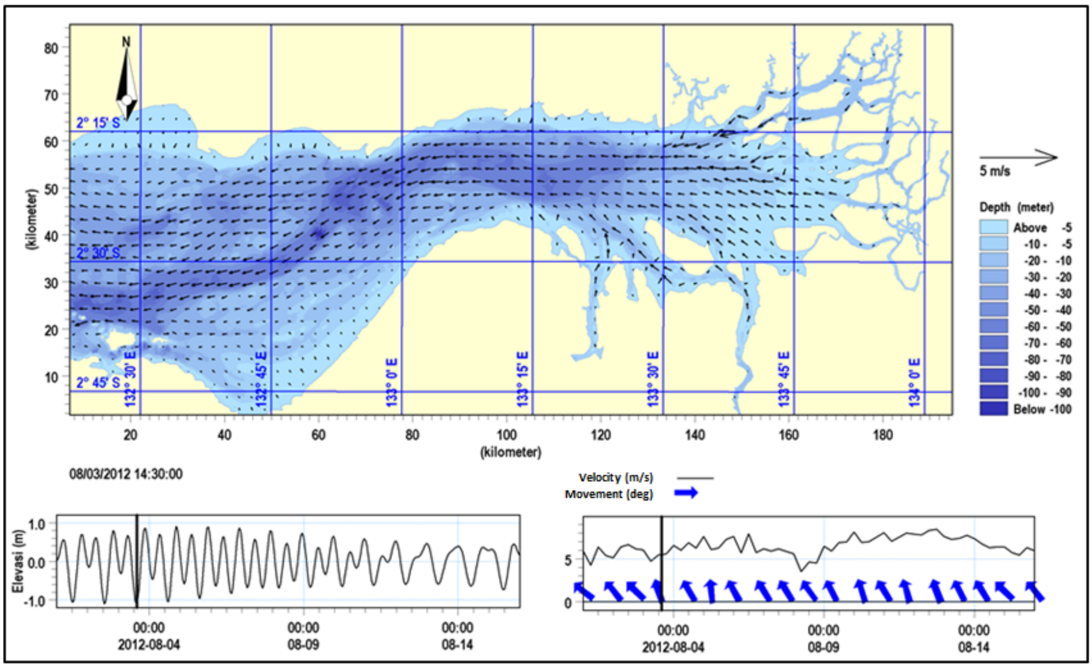


Figure II-108 **Current Pattern of Simulation Results of the Seawater Level at the Lowest Ebb Point in August Representing the Southeast Monsoon at Bintuni Bay**

C. *Model Verification*

The current model verification wass performed to identify the model conformity with the field conditions. Verification results between the model result data and measurement result data in the field are illustrated in **Figure II-109**. The Figure illustrates that the blue color is the measurement's current, while the red color is the model's current. Based on the verification it can be observed that the model's current and the measurement's current have similarities in terms of range and shape (ellipse).

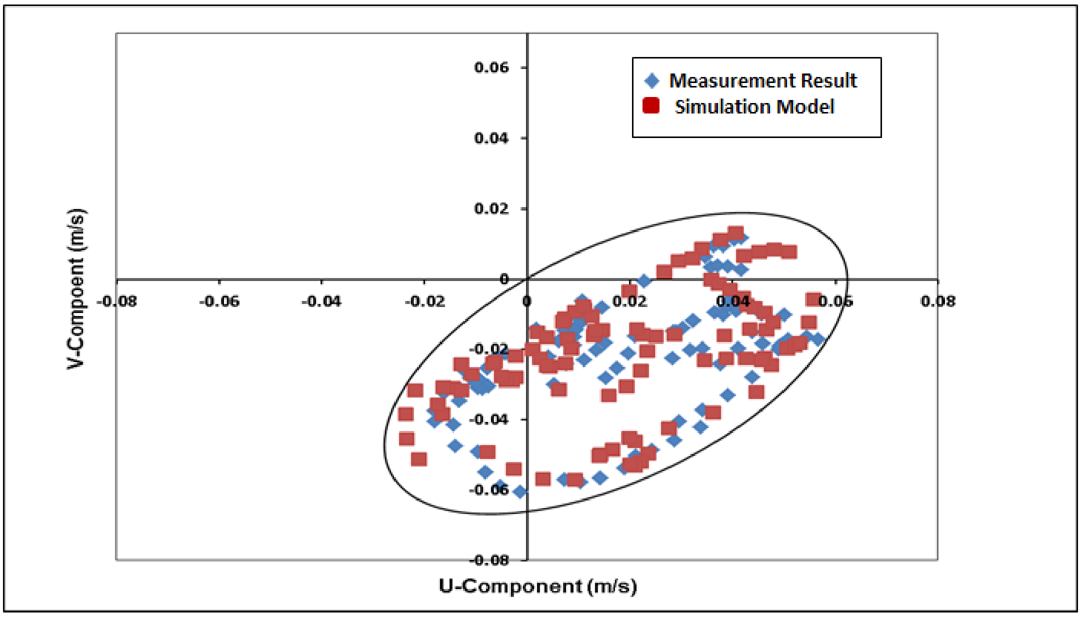


Figure II-109 **Verification Results of the Measurement Results Current Data (in Blue) and the Simulation Model (in Red)**

2.1.10.5 Profile of Temperature, Salinity and Density

Measurements of the water temperature, salinity and density were performed at 30 sampling points at the Bintuni Bay by using CTD (Conductivity-Temperature-Depth) sensors, in the northeast monsoon and the southeast monsoon (**Figure II-110**). The CTD instrument used can simultaneously record the profiles of temperature, seawater conductivity and pressure (which is automatically converted into depth) of the surface up to the seabed. Data recording settings of the instruments, data control and acquisition used PC-based programs so that data can be recorded with depth intervals of 1 meter starting at the surface up to near the seabed.

Measurement results of the temperature and sea water salinity was further presented in the form of vertical profiles, cross sections and horizontal distributions of temperature, salinity and density of the seawater.

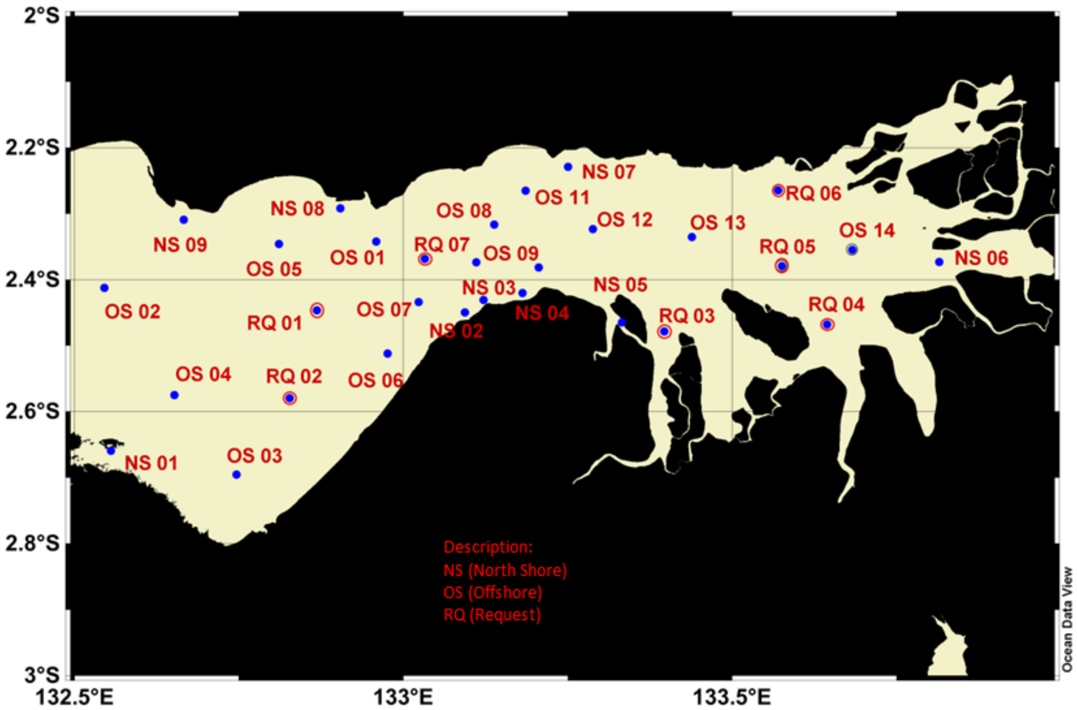


Figure II-110 Profile Measurement Location of Water Temperature, Salinity and Density at Bintuni Bay

A. Northeast Monsoon

The horizontal profile of temperature in the northeast monsoon plotted from all CTD data is illustrated in **Figure II-111**. The differences of color and symbol on the Map indicated the different locations of the CTD stations. Seawater surface temperature ranged between 29.5 ˚C up to 31.8 ˚C. At layers deeper than >50 m, the seawater temperature ranged between 29.7 ˚C up to 30.1 ˚C. No drastic temperature decrease against the depth was observed or no thermocline layers were found.

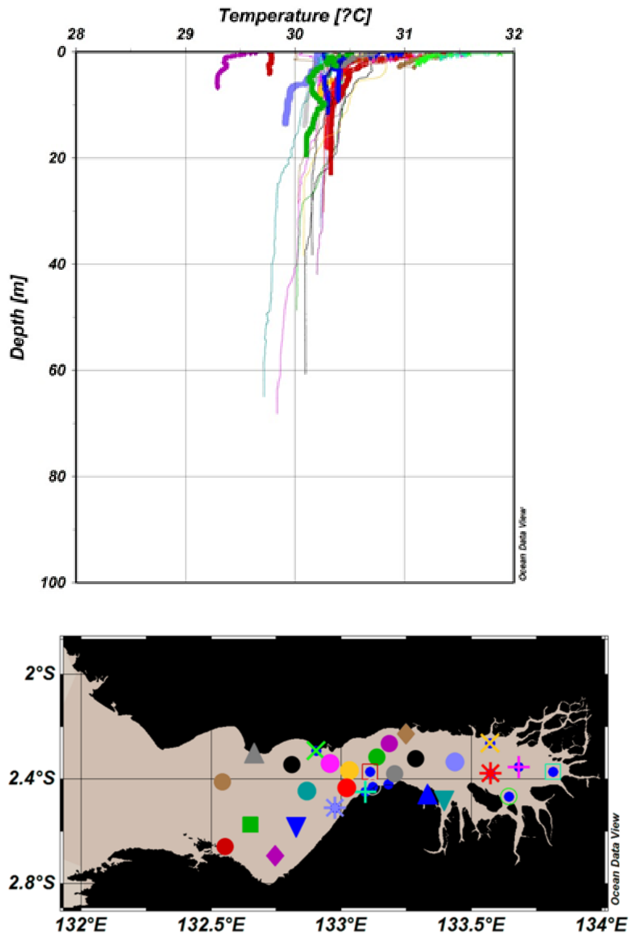


Figure II-111 Temperature Profile (˚C) against the Depth Plotted from All CTD Data Measured During the Northeast Monsoon (Colors Indicate CTD Stations)

Unlike the temperature profile, the salinity profile against depth in **Figure II-112** indicates salinity value at the surface layers is lower than at the deeper layers. The range of seawater salinity at the surface layer is 19.0 psu (equivalent to $^{o}/_{oo}$) and 28 psu. Seawater salinity lower than 20 psu was measured in the surroundings of the river estuary. Seawater salinity value increased along with the addition of depth. At water depths of >50 m, seawater salinity can reach 33 psu. In general it can be stated that water masses with a salinity of 33 psu are seawater salinity without any mixture of fresh water masses carried by rivers.

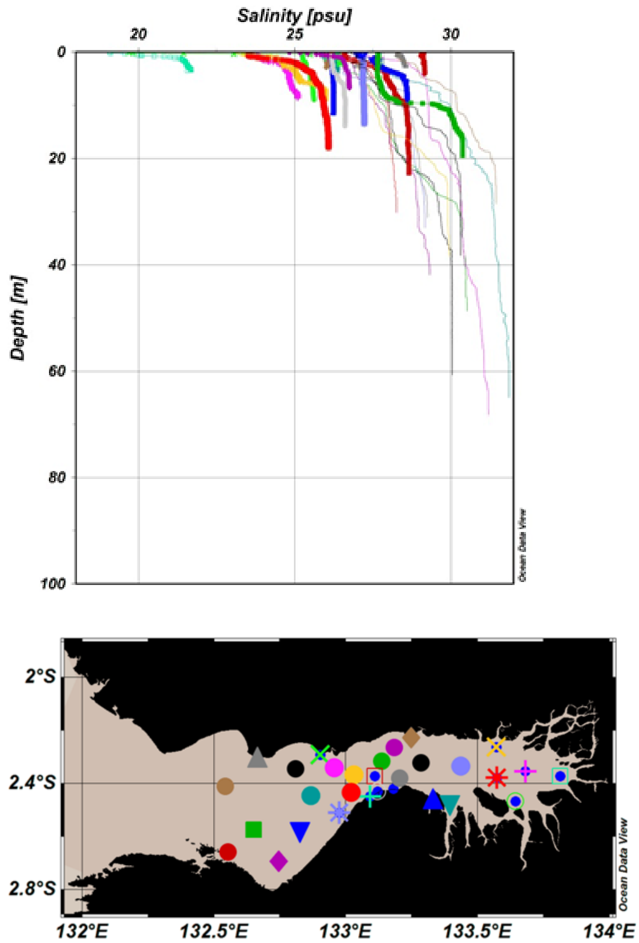


Figure II-112 Salinity Profile (psu) against Depth Plotted from All CTD Data Measured in the Northeast Monsoon (Colors Indicate CTD Stations)

Density is a derivative parameter that can be calculated from the data of salinity, temperature and pressure (in this case it is the depth). Seawater density data can illustrate the seawater physical condition, in particular on the stratification or water mass mixing in the waters. **Figure II-113** is plotted data of salinity and temperature of each station that has been converted into density. Based on the figure, it can be observed that the seawater density in the Bintuni Bay waters is more dominantly affected by salinity. This can be indicated from the vertical profile of density that more resembles the salinity profile compared to the temperature profile.

The smallest density value was measured in river estuary area i.e. 1,010 kg/m^3 with a salinity value of 19 psu and seawater temperature of 31.8 °C. At the depth of >50 m the seawater density can reach 1,019 kg/m^3.

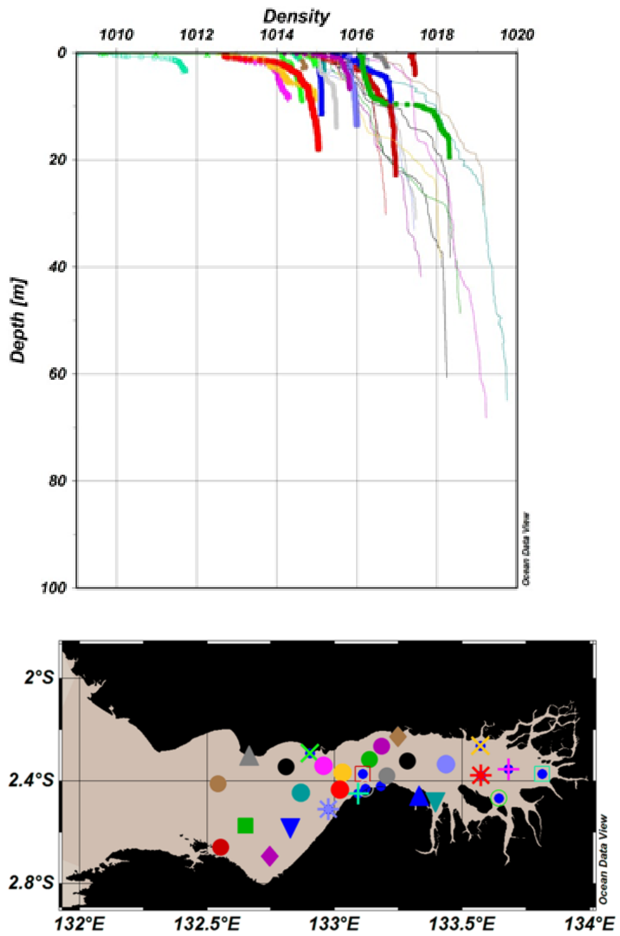


Figure II-113 **Density Profile (kg/m³) against the Depth Plotted from All CTD Data Measured During the Northeast Monsoon (Color Indicate CTD Stations)**

Figure II-114 indicates seawater surface temperature distribution plotted from all temperature data measured during the northeast monsoon. On the right side of the figure, there is a color scale in the form of bars, low temperature value is in purple (at the lower parts) and the highest sea water temperature is in red (upper part). The results of seawater temperature measurement indicate that the surface temperature at the bay head and in the surroundings of the river estuaries was higher (>31.5 ˚C) than the center parts and mouth of the bay (<31 ˚C).

Figure II-115 indicates that the surface salinity distribution pattern is opposite the horizontal distribution of the surface temperature, which a low salinity value (<22 psu) is observed at the head of bay and surface salinity is observed to gradually increase from the center part (23-24 psu) while at the mouth of bay the salinity increases to reach >28 psu.

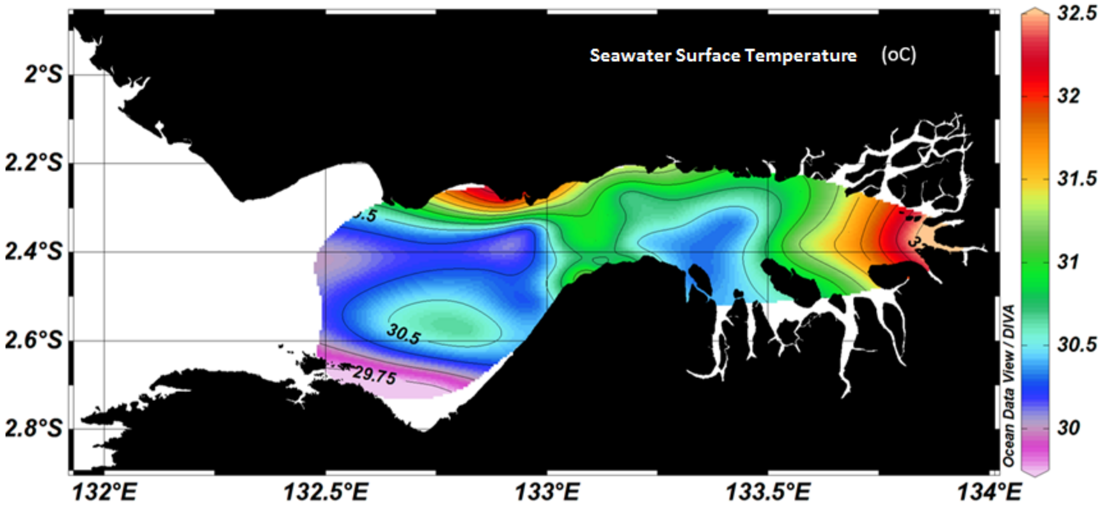


Figure II-114 Seawater Surface Temperature Distribution During the Northeast Monsoon from CTD Measurement Results

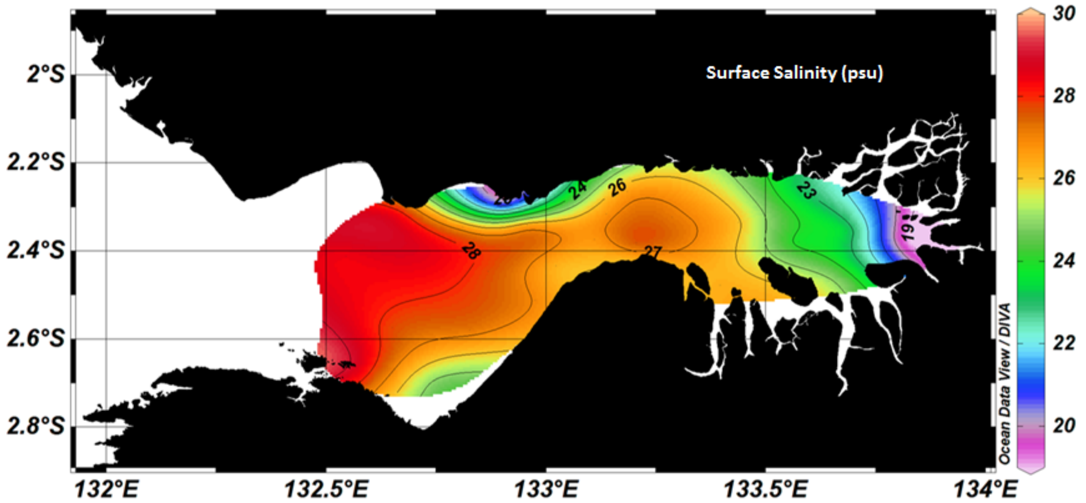


Figure II-115 Seawater Surface Salinity Distribution During the Northeast Monsoon from CTD Measurement Results

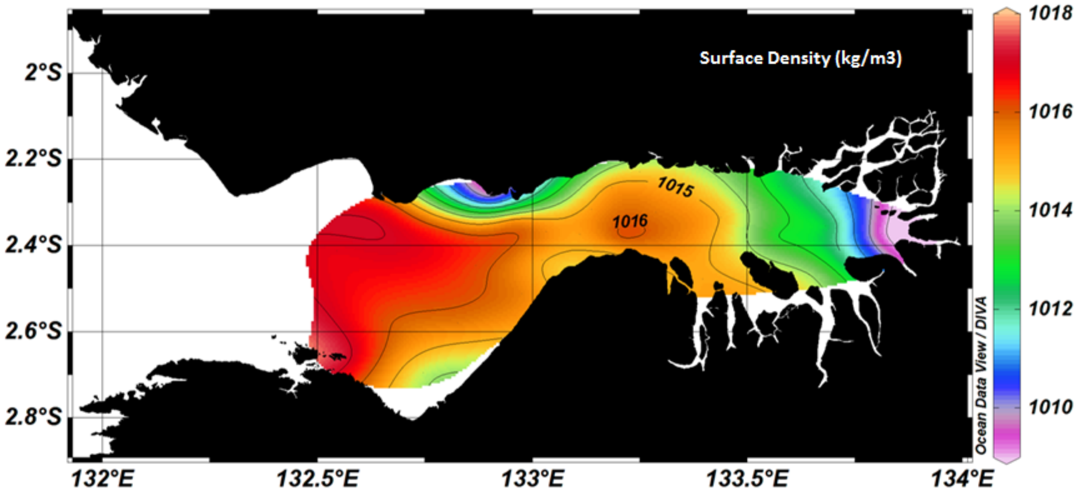


Figure II-116 **Seawater Surface Density Distribution During the Northeast Monsoon as Calculation Results from Temperature and Salinity Data Measured by CTD Sensors**

Seawater surface density calculated from data of temperature, salinity and pressure is illustrated in **Figure II-116**. The density in the Bintuni Bay waters is strongly controlled by the salinity, this can be clearly observed as the horizontal distribution pattern of seawater density is similar to the horizontal distribution of salinity. The lighter seawater mass (indicated by the lower salinity value <1,010 kg/m^3) is observed to be spread out at the bay's head, then gradually a density value increase. In the central part, the density value reaches 1,015-1,016 kg/m^3 while the highest occurs at the bay's mouth, i.e. >1,018 kg/m^3.

Cross-sections of the seawater temperature, salinity and density of the bay's mouth to the bay's head are also illustrated (**Figure II-117** up to **Figure II-125**). The y-axis of each figure indicates the water depth (m), the x-axis indicates the distance (km), while the color scale on the right hand side indicates the values of deawater temperature, salinity and density. The small figure at the lower right hand side is a location Map of the CTD temperature and salinity measurement, while the red line is a transect selected to illustrate cross-sections of the seawater temperature, salinity and density.

Cross-section distribution of seawater temperature from the bay's mouth to the head in the northeast monsoon is presented in **Figure II-117.** Higher water temperatures were measured at layers near the surface in the bay's head area. The thickness of water mass layers with higher temperatures (>31.5 ˚C) were measured to a depth of 2 m, them the sea water temperature reached 30 ˚C at a depth of 5 m. At the bay's mouth, the seawater temperature at the surface is almost similar to the temperature value at deeper depth.

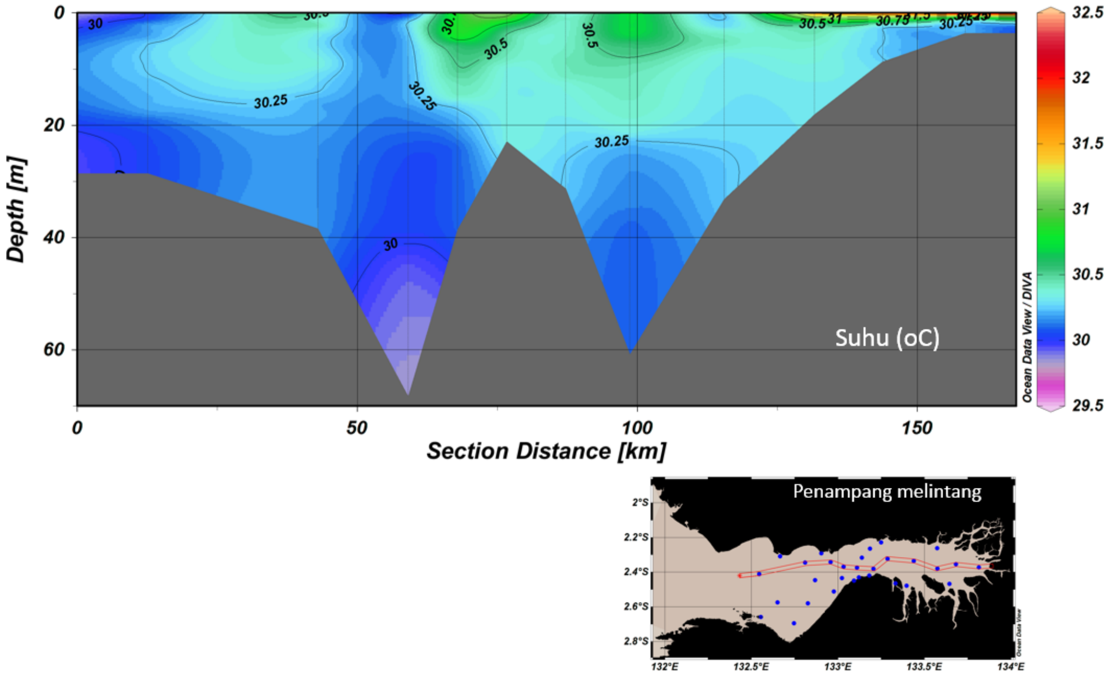


Figure II-117 **Cross Section of Temperature (˚C) from the Bay's Mouth Direction to the Bay's Head During the Northeast Monsoon**

Unlike the cross-sections of temperatures, in the cross-section of salinity clearly indicates its salinity value gradient. Water masses with low salinities (LSW = *Low Salinity Water*) were identified to fill the end of the bay head (20 psu). The more to the outer sides, the salinity was observed to increase (gradient colors of purple, blue and green with a salinity range of 22.5 psu up to 25 psu) as more seawater mass volumes were mixed with water masses flowing from rivers through the river mouths. Movements of water masses from the rivers after mixed with bay water that still have a lower salinity (27.5 to 28 psu) are on the seawater mass layers with a higher salinity (>30 psu).

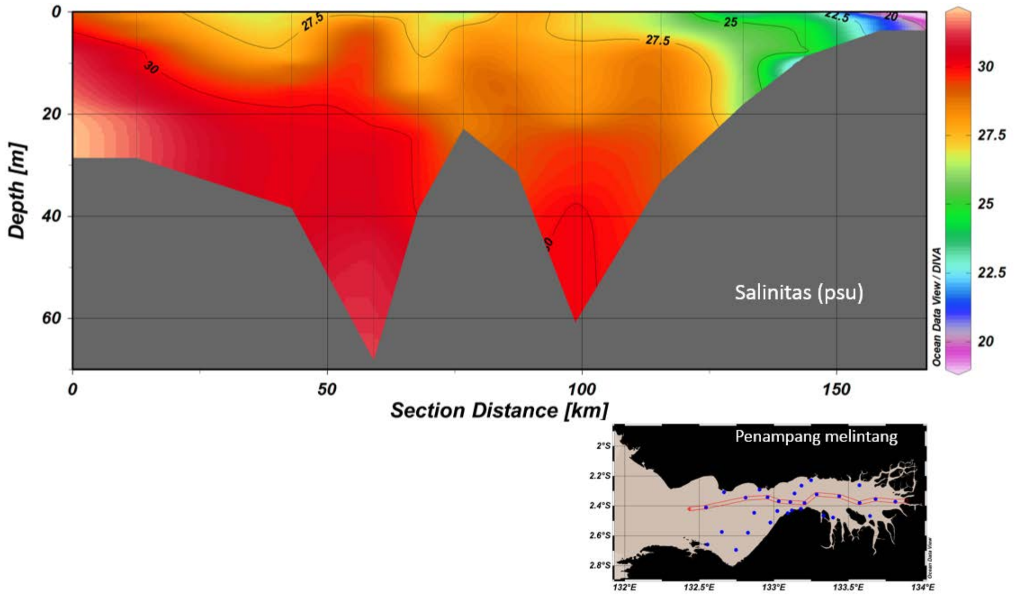


Figure II-118 Cross-Section of Salinity (psu) from the Bay Mouth Direction to the Head during the Northeast Monsoon

An interesting matter is observed from the cross-sections of seawater salinity and density (**Figure II-119** and **Figure II-122**) that have similar distribution patterns. It has been mentioned that the water density in the Bintuni Bay waters are more affected by salinity. The water density value at river mouths at the bay head are lighter (<1,012 kg/m^3) than at the central part and the bay mouth (>1,018 kg/m^3). In other words, the lighter water mass is at the upper layer (fresh water mass from the rivers that are mixed with bay water), while the heavier water masses are in the lower layers, because it is heavier. Most of the water mass volume located near the seabed originates from the sea.

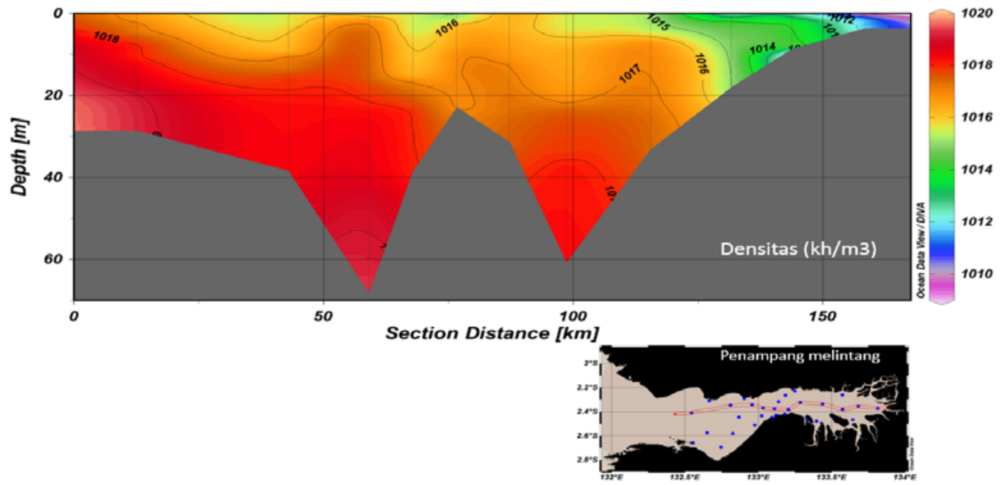


Figure II-119 Cross-Section of Density (kg/m^3) from the Bay Mouth to the Head Direction During the Northeast Monsoon

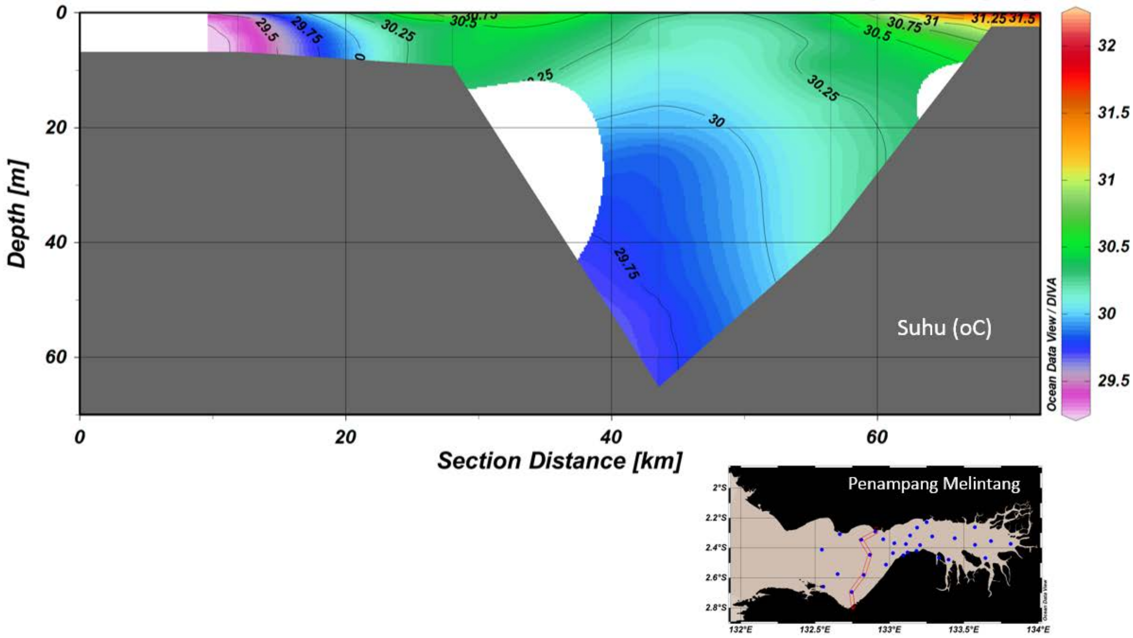


Figure II-120 Cross-Section of Temperature (°C) from the North Side to the South Side Near the Bay Mouth During the Northeast Monsoon

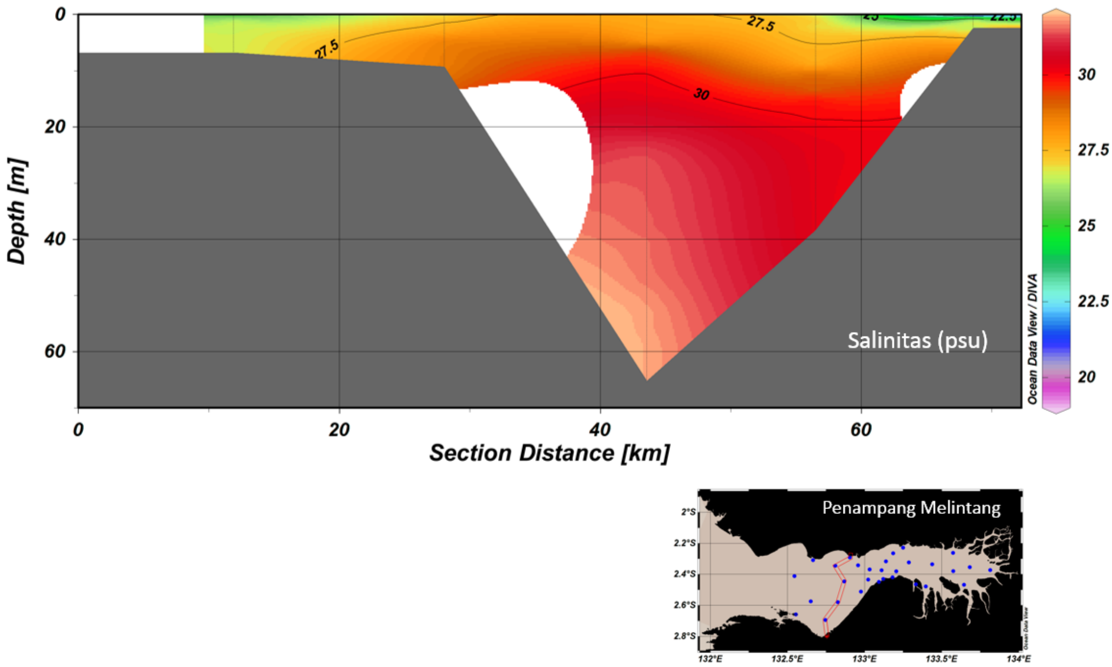


Figure II-121 Cross-Section of Salinity (psu) from the North Side to the South Side Near the Bay Mouth During the Northeast Monsoon

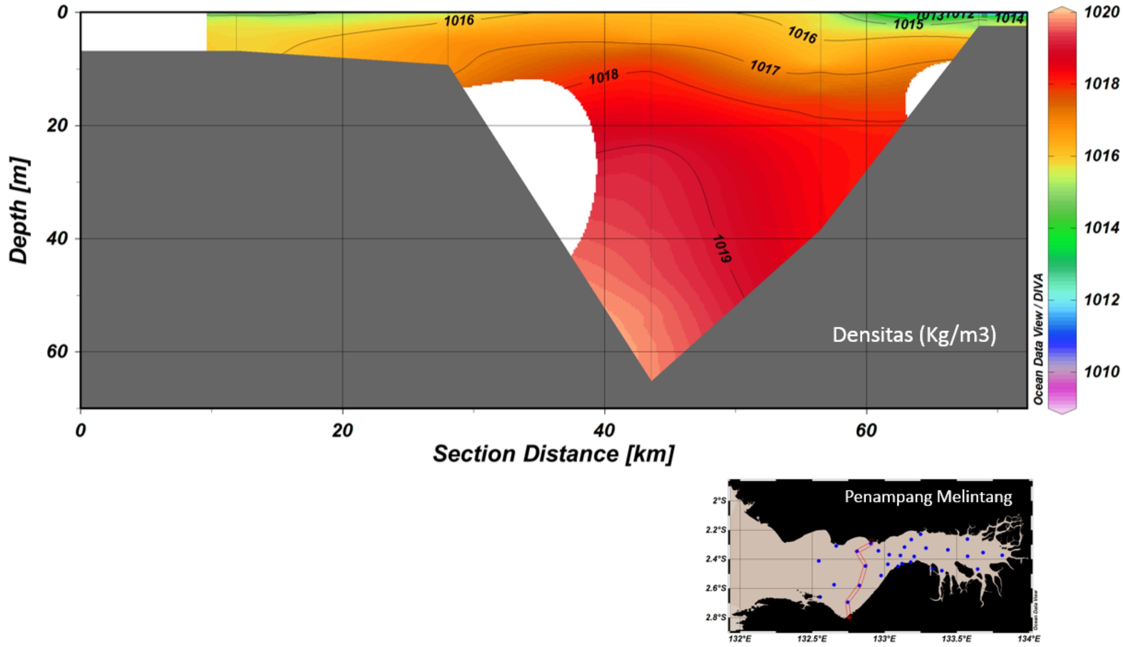


Figure II-122 Cross-Section of Density (kg/m³) from the North Side to the South Side Near the Bay Mouth During the Northeast Monsoon

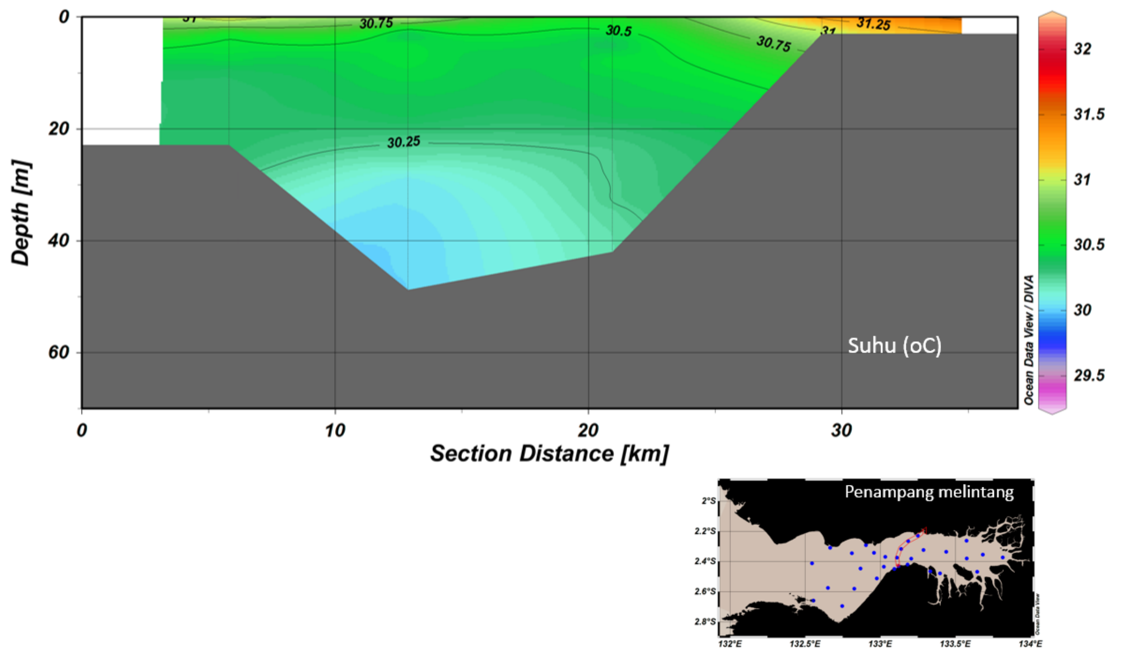


Figure II-123 Cross-Section of Temperature (°C) from the North Side to the South Side in the Bay Central Part During the Northeast Monsoon

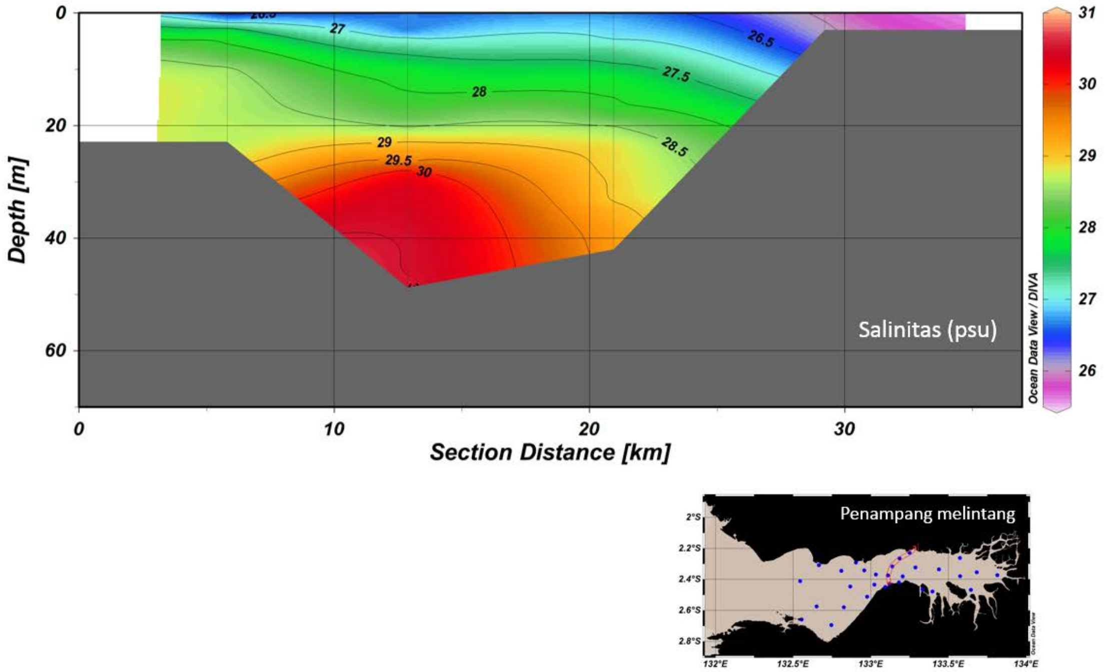


Figure II-124 Cross-Section of Salinity (psu) from the North Side to the South Side in the Bay Central Part During the Northeast Monsoon

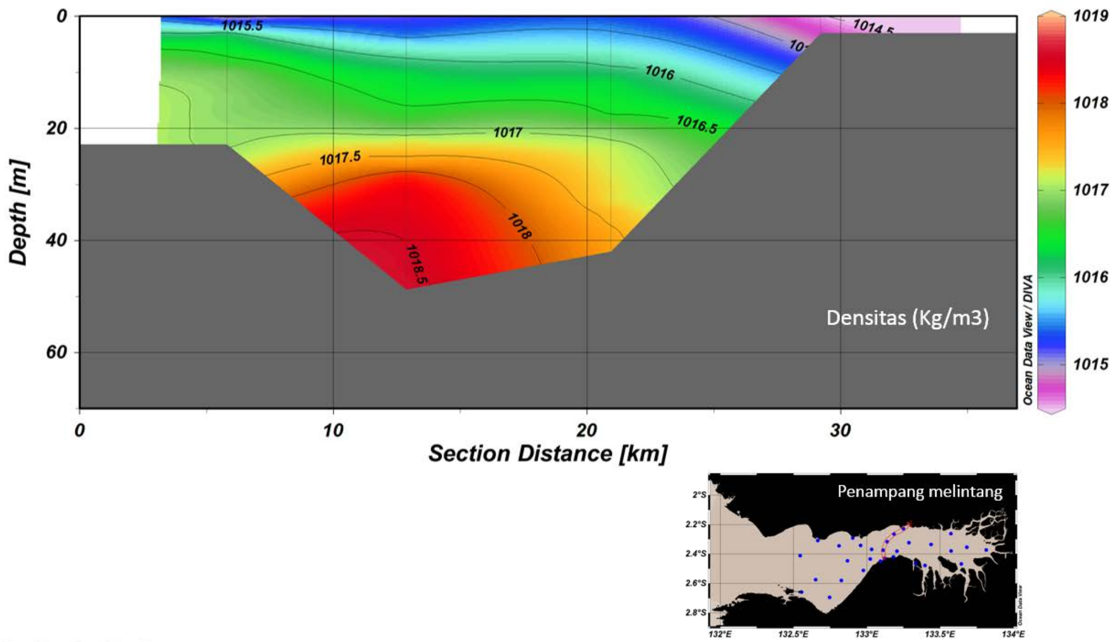


Figure II-125 Cross-Section of Density (Kg/m³) from the Bay South Side to the Central Part During the Northeast Monsoon

B. Southeast Monsoon

The southeast monsoon is a certain period (June to August) in a year which the dominant wind blows from the southeast direction (from the Australian direction) heading northwest and when passing the equator the wind direction turns towards the Pacific Ocean. During the southeast monsoon, at the Arafura Sea and Banda Sea water masses rise from the bottom layers to the upper layers (upwelling). Similar to the northeast monsoon, measurement of temperature and salinity parameter was also performed at the same location by using CTD (Conductivity-Temperature-Depth) sensors. Data analysis results, profile figures and cross-sections of temperature, salinity and density of the bay water during the southeast monsoon are presented in **Figure II-126** up to Figure **II-131.**

Temperature profiles plotted from all southeast monsoon measurement results are presented in **Figure II-126**. The surface bay water temperature range is 27.5 ˚C up to 31 ˚C. There are large temperature variations in the layer of 0 to 3 m, and thereafter at the depth layer of 5-20 m the temperature variation becomes smaller, i.e. between 28 to 30 ˚C.

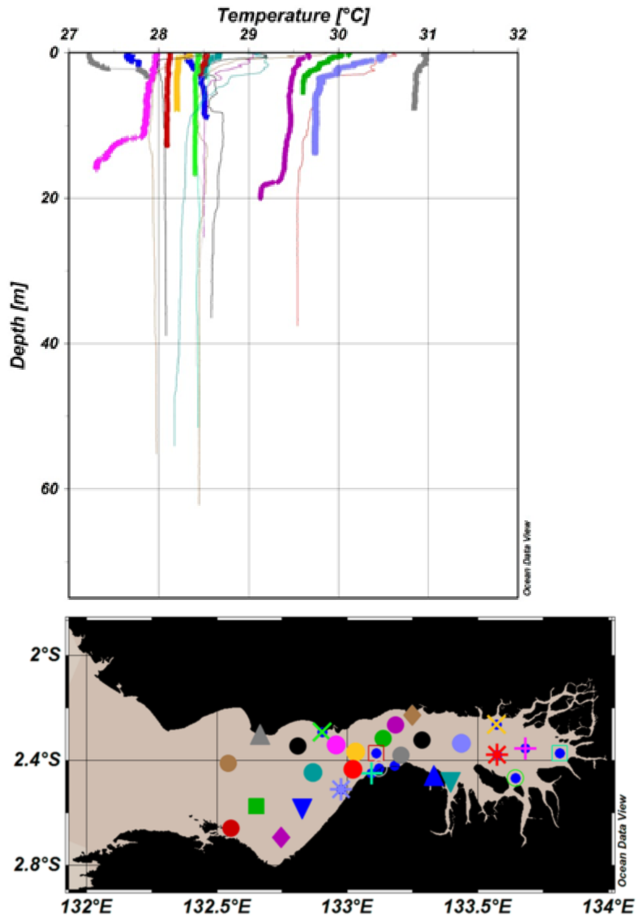


Figure II-126 Temperature Profile (˚C) against the Depth Plotted from All CTD Data Measured During the Southeast Monsoon (Color Indicates CTD Stations)

Unlike the temperature profile, the salinity profile against depth in **Figure II-127** in general indicates that the salinity value at the surface layer is lower than at the deeper layers. This salinity profile was also plotted from all salinity data available during the southeast monsoon. The range of seawater salinity at the surface layer is 19 psu and 30.5 psu. Seawater salinity closer to the bay mouth reached 30 psu, while the salinity value <20 psu was measured in the surroundings of the river estuaries. The seawater salinity value increased along with the increase of depth. At the water depth of >50 m the seawater salinity can reach 30 psu. It can be stated that at the bay floor there are water masses with a salinity of 30 psu.

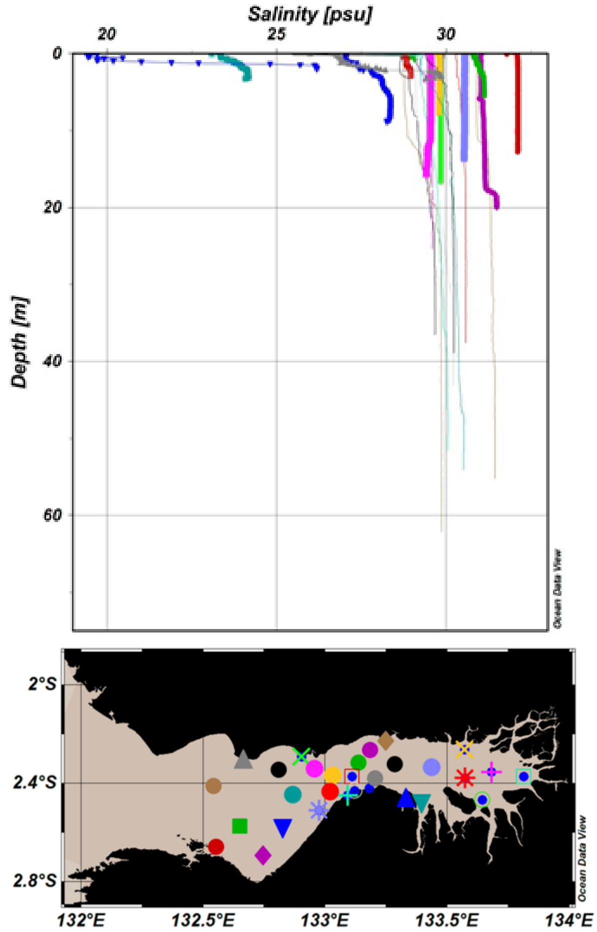
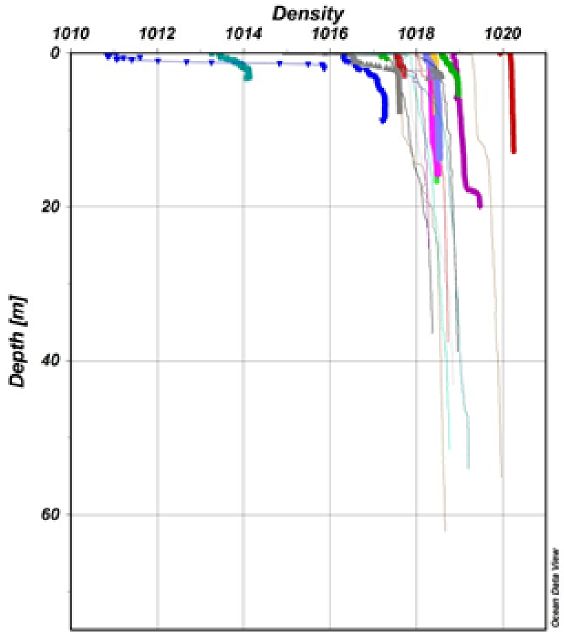


Figure II-127 Salinity Profile (psu) against Depth Plotted from All CTD Data Measured During the Southeast Monsoon (Color Indicates CTD Stations)

Figure II-128 is a plot of density data calculated from the temperature, salinity and depth at each station where temperature and salinity were measured. As the density is the function of temperature, salinity and pressure, hence masses with density profiles such as illustrated in the Figure can be said that the seawater density in the Bintuni Bay waters during the southeast monsoon are also more dominantly affected by salinity. It can be easily observed from the vertical profiles of density that are more like the salinity profile rather than the temperature profile.

The smallest density value was measured in the river estuary area, i.e. 1,011 kg/m³ which the salinity value is 19 psu and the seawater temperature is 31.8 ˚C. At the layer with a depth of >50 m the seawater density can reach 1,020 kg/m³.



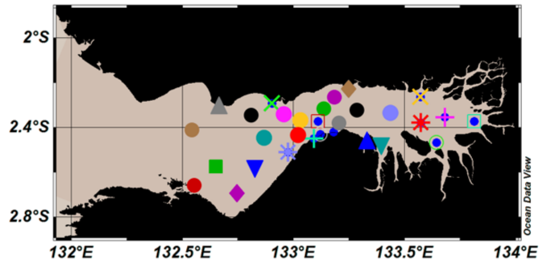


Figure II-128 Density Profile (kg/m³) against Depth Plotted from All CTD Data measured during the Southeast monsoon (Colors Indicate CTD Stations)

The distribution of the temperature, salinity and horizontal density during the southeast monsoon is presented in **Figure II-129** up to **Figure II-131.** In general distribution patterns of temperature, salinity and density during the southeast monsoon are different from the distribution pattern of same parameter during the northeast monsoon.

Temperature distribution of the bay surface during the southeast monsoon at the southern of the bay is seen to be higher (>30.5 ˚C) than at the northern of the bay. During this monsoon, the temperature in the surroundings of the bay head is seen lower, 28 ˚C (**Figure II-129**).

Salinity in the surroundings of the river mouths at the bay head part is still seen lower (<22 psu), water masses with a higher salinity (approaching 30 psu) is still seen to occupy the main bay mouth at the southern to extend to the central part of the bay (**Figure II-130**). At the central part of northern of the bay, water masses distribution with low salinities are also observed (<25 psu), that most likely large masses of fresh water flow from tributaries.

Horizontal distribution patterns of surface density in **Figure II-131** is almost equal to horizontal distribution of salinity in **Figure II-130**, it means that either the northeast monsoon and the southeast monsoon, density of bay waters is still controlled by salinity.

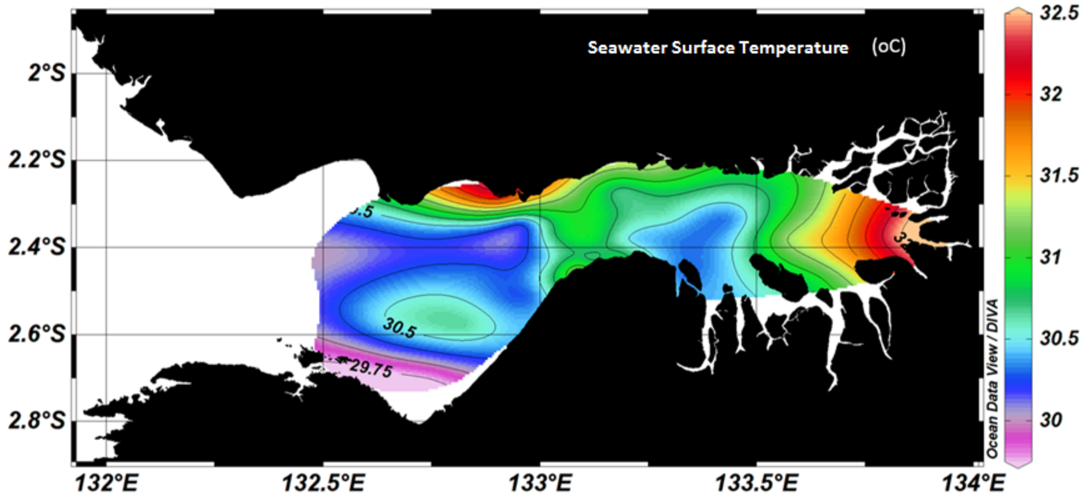


Figure II-129 Distribution of Seawater Surface Temperature During the Southeast Monsoon as CTD Measurement Results

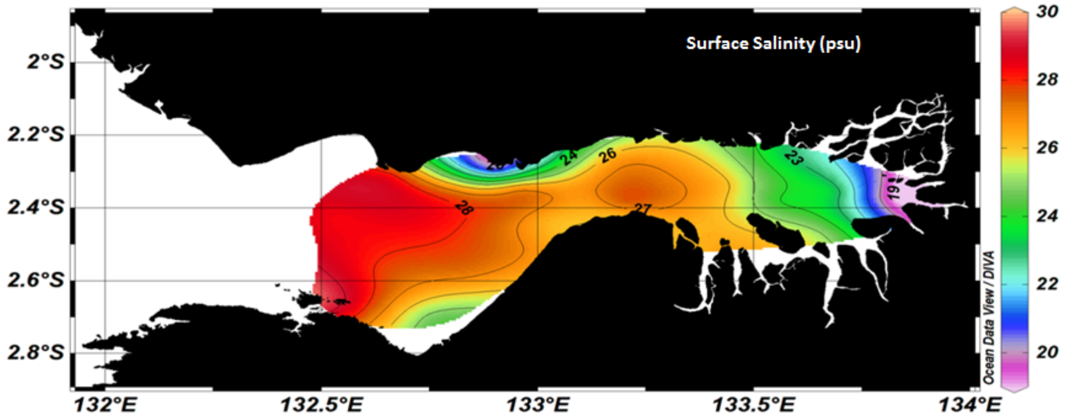


Figure II-130 Distribution of Seawater Surface Salinity During the Southeast Monsoon as CTD Measurement Results

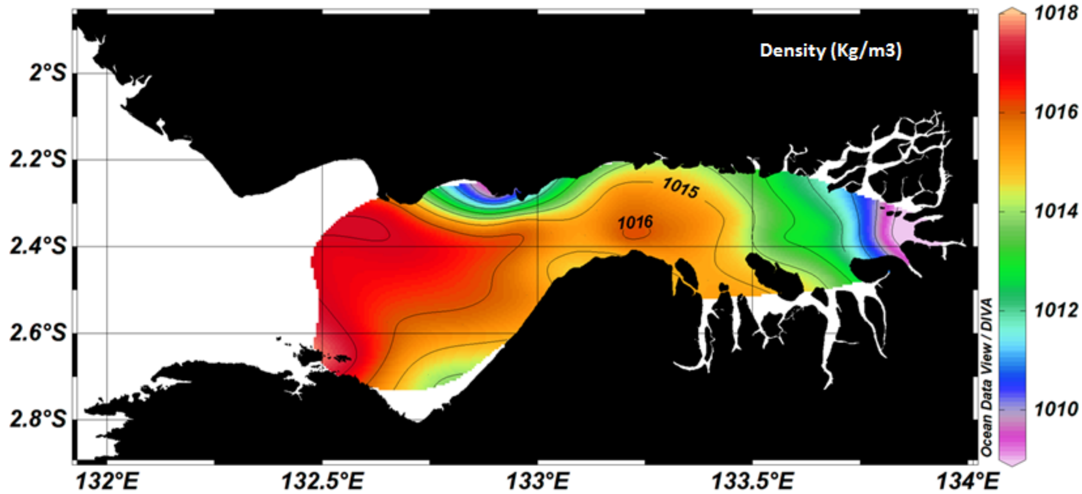


Figure II-131 Distribution of Seawater Surface Density During the Southeast Monsoon as CTD Measurement Results

Cross-section of the seawater temperature, salinity and density from the bay mouth to the bay head during the southeast monsoon is illustrated (**Figure II-132** up to **Figure II-134**). The presentation is similar to the above description for northeast monsoon, the y-axis of each figure indicates the water depth (m), the x-axis indicates the distance (km), while the color scale located at the right hand side indicates the value of the temperature, salinity and density of the seawater. The small figure at the lower right hand side is the location map of the temperature and salinity measurement with CTD, while the red line are selected transects to describe the cross-sections of seawater temperature, salinity and density.

Cross-section distribution of seawater temperature from the bay mouth to the head during the southeast monsoon is presented in **Figure II-132**. A higher water temperature was measured in the layer near the surface in the central part of the bay. The thickness of water mass layers with higher temperatures (>29.5 ˚C) were measured up to a depth of 2 m, thereafter the seawater temperature become 28.5 ˚C at a depth of 5 m. At the bay mouth, the seawater temperature at the surface is higher (28.25 ˚C) with a temperature value at a depth of 20 m is only 28 ˚C.

At the cross-section of salinity from the bay mouth heading to the bay head it is clearly visible that there are salinity gradients. The low salinity water mass (LSW=Low Salinity Water) is seen to be trapped at the end of the bay head (28 psu) due to the strong water mass pushing from the bay mouth direction. The salinity is observed to be increasing at the bay mouth part with a salinity value of >31 psu (**Figure II-133**).

Similar conditions were also observed at the cross-section of density in **Figure II-134** which is identical to the cross-section of salinity described in **Figure II-133.** The distribution pattern of both parameters is very similar which it means that the water density at the Bintuni Bay waters is controlled by its salinity. Either during the southeast monsoon and the northeast monsoon, the bay water density is dominantly controlled by salinity not by the bay water temperature. The water density value at the river mouth at the bay head is lighter (<1,012 kg/m^3) than the central part and the bay mouth (>1,018 kg/m^3).

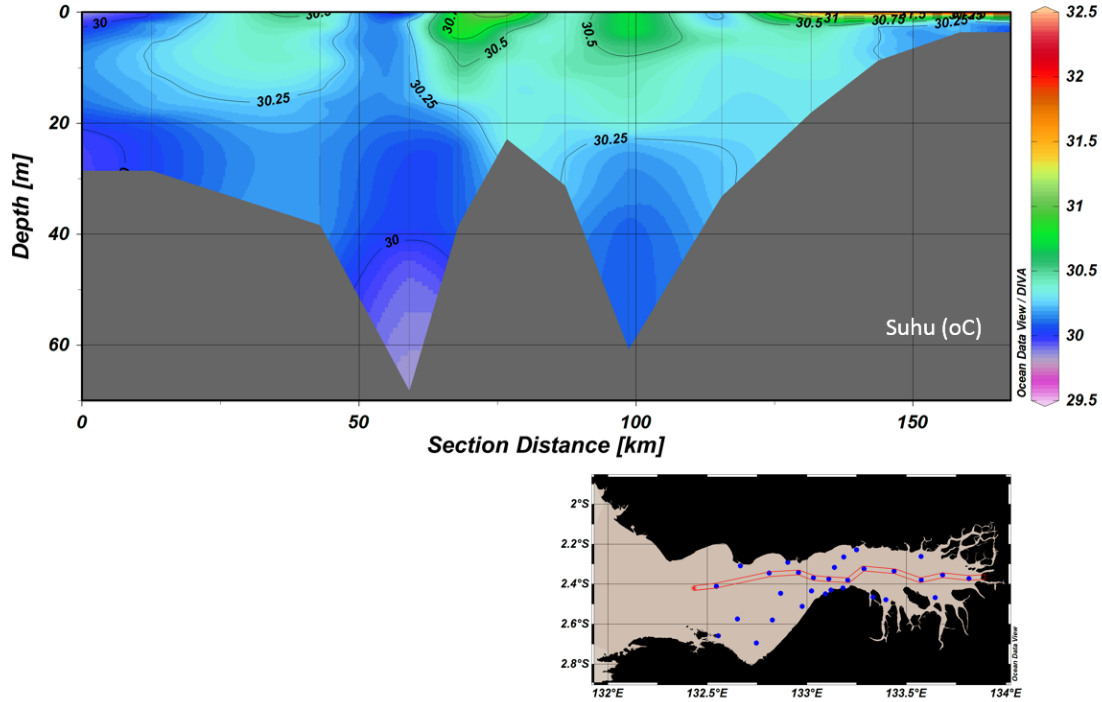


Figure II-132 Cross-section of Temperature (˚C) from the Direction of the Bay Mouth to the Head During the Southeast Monsoon

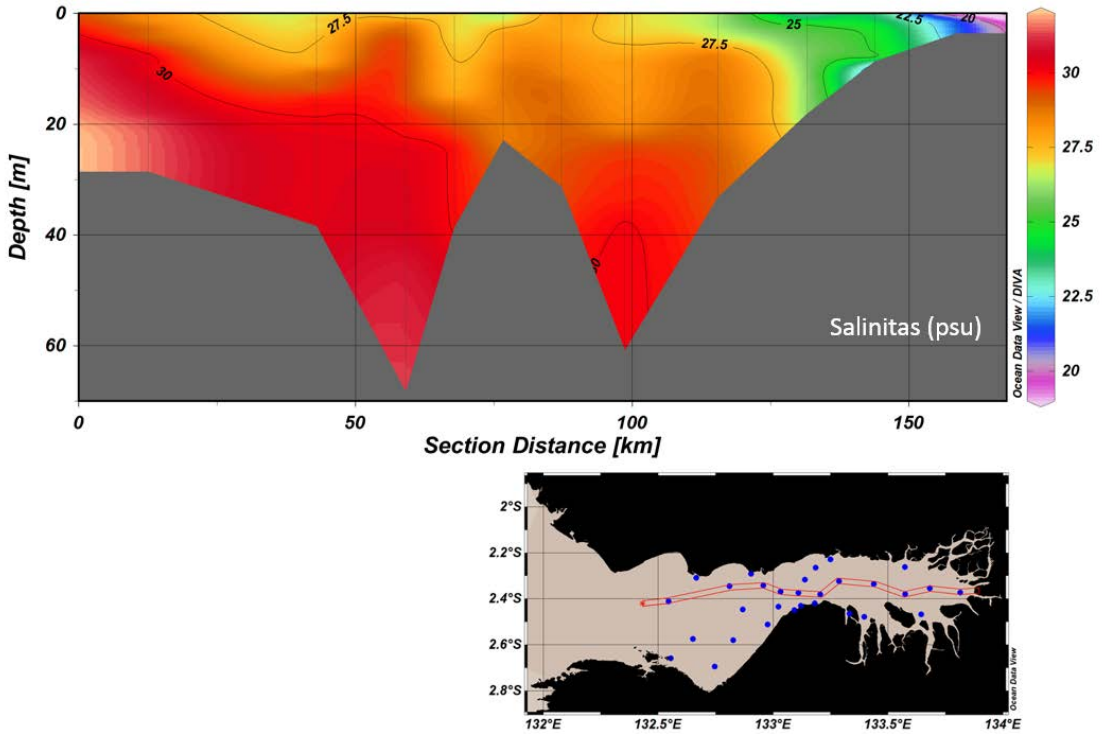


Figure II-133 Cross-section of Salinity (psu) from the Direction of the Bay Mouth to the Head During the Southeast Monsoon

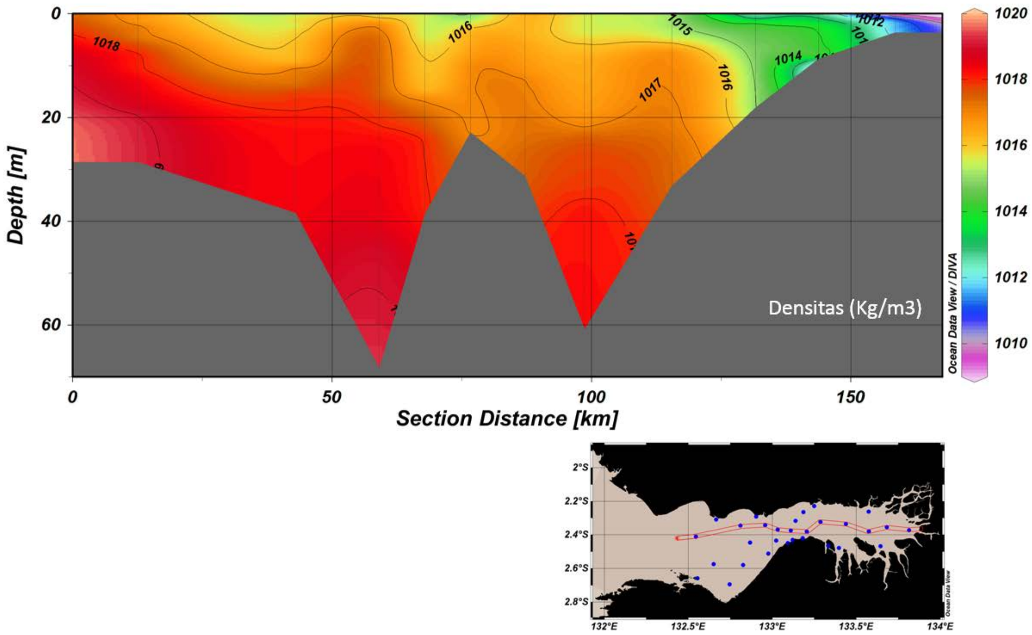


Figure II-134 Cross-section of Density (Kg/m³) from the Direction of the Bay Mouth to the Head During the Southeast Monsoon

Cross-sections of the water temperature, salinity and density also cross the bay, either at the bay mouth (**Figure II-132** to **Figure II-134**) and at the central part of the bay (**Figure II-138** up to **Figure II-140**).

Temperature conditions at the cross-section near the mouth of bay are presented in **Figure II-135**. From the left to the right hand side or south to the north side. At the north side the seawater temperature appears lower (<27.5 ˚C), while at the south side, the temperature is relatively higher (>29.5 ˚C). This condition is unlike the northeast monsoon with a temperature condition in the central part of bay being in the range of 28.0 ˚C to 29.0 ˚C.

Figure II-136 presents the cross-section of salinity near the bay mouth. In the near-surface layer at the north side of the bay mouth, water masses with a lower salinity (<28 psu) were measured. A high salinity was observed to dominate the section, in particular at the south side of the section. The salinity value can reach 31 psu. When compared to the northeast monsoon, there is a difference in the salinity distribution pattern at the cross-section of the bay. At the northeast monsoon a low salinity water mass was detected in the south side, although it was very thin.

If compared between the cross distribution of density at the cross-section and the cross distribution of salinity, then it is still clearly visible that the bay water density near the mouth is controlled by salinity. **Figure II-137** shows the similar distribution pattern to the salinity distribution in **Figure II-136**. The lighter water mass characterized by a smaller density value (<1,018 kg/m³) is trapped at the north side of the bay mouth where at the same time there is also occurred in the salinity distribution. The density value increases towards the south side which is dominated by the seawater mass entering through the inner part of the bay.

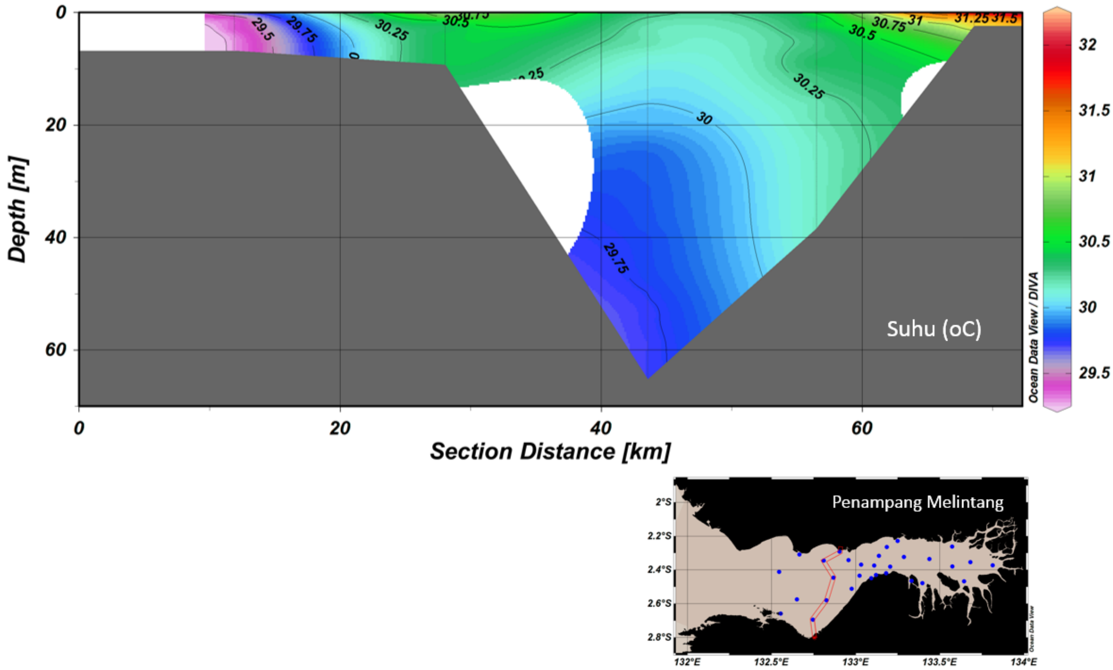


Figure II-135 **Cross-section of Temperature (˚C) from the North Side to the South Side Near the Bay Mouth During the Southeast Monsoon**

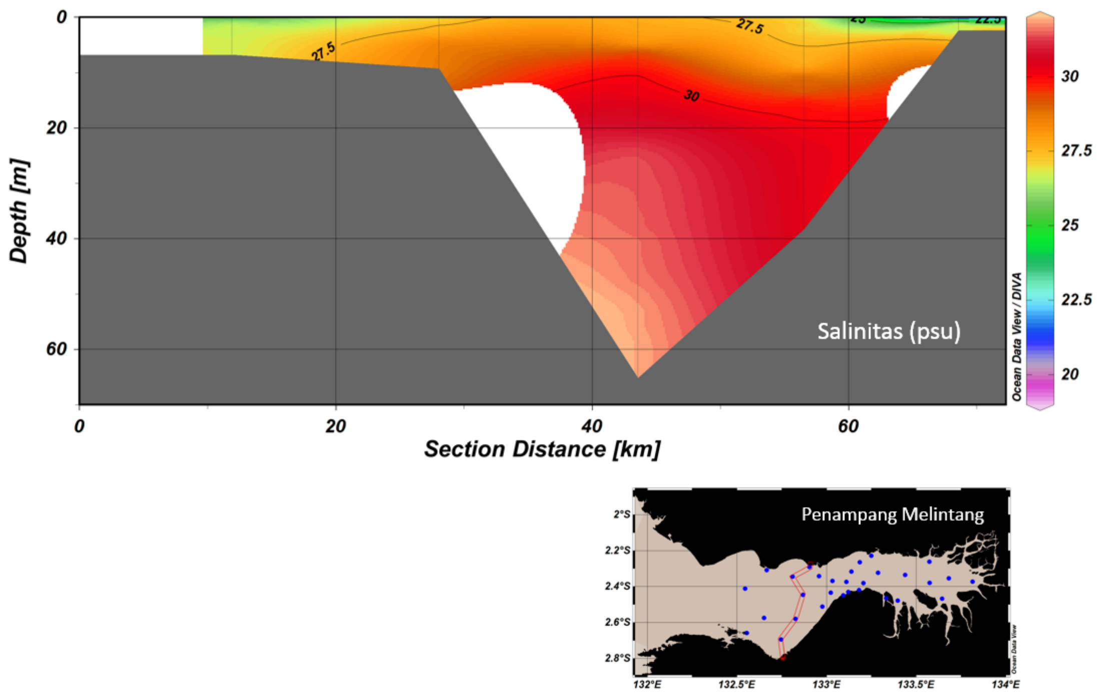


Figure II-136 **Cross-section of Salinity (psu) from the North Side to the South Side Near the Bay Mouth During the Southeast Monsoon**

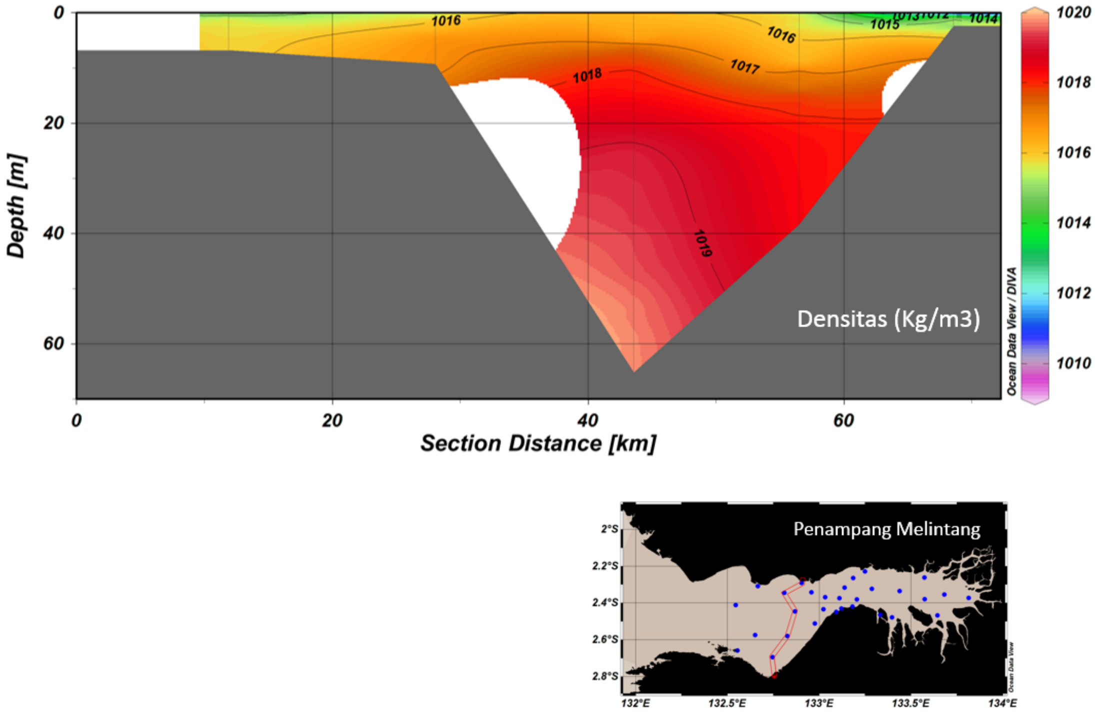


Figure II-137 Cross-section of Density (kg/m³) from the North Side to the South Side Near the Bay Mouth During the Southeast Monsoon

Cross-sections of water temperature, salinity and density of the Bintuni Bay at the central part areas during the southeast monsoon is illustrated in **Figure II-138** up to **Figure II-140**. The water temperature of the bay at the central part is relatively homogeneous which is approximately 28.5 ˚C. Only a thin layer is visible in the central part with a temperature of >28.5 ˚C.

The existence of a low-salinity water mass at the cross-section in the center of the bay is increasingly visible. **Figure II-139** shows the salinity distribution pattern at the cross-section of salinity in the central part of the bay. At the surface layer low-salinity water mass or LSW= Low Salinity Water (<29 psu) is spread out and widened to the mid sections. Mixing of low salinity and high salinity is visible starting from a depth of 5 m to a depth of 20 m which the salinity value range is at 29 psu and 29.72 psu. Thereafter, the salinity is homogeneous up to the waters floor, i.e. 30 psu.

The same distribution pattern at the cross-section of density has a high similarity with the salinity distribution pattern presented in **Figure II-140**. Physically it means that the water mass density at the Bintuni Bay during the southeast monsoon is also controlled by the salinity of bay waters. The lighter water mass density (<1,018 kg/m³) is at the northern surface layer and widens to the central part, then slowly rises to 1,018.5 kg/m³ to reach 1,018.75 kg/m³ near the central part of the bay floor.

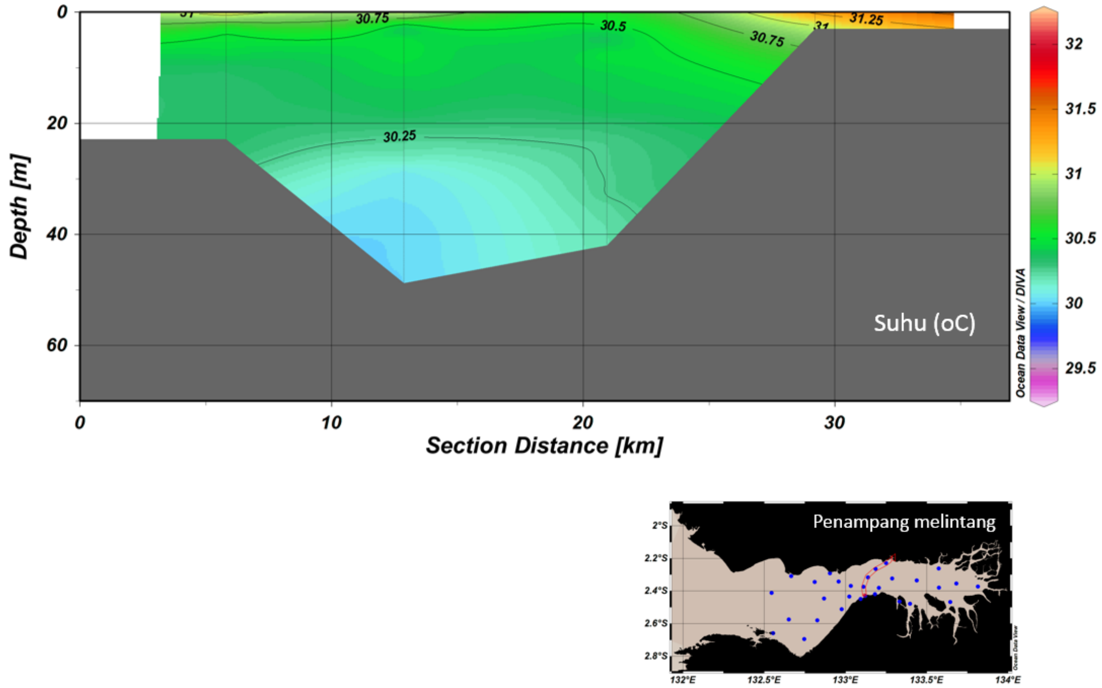


Figure II-138 Cross-section of Temperature (˚C) from the North Side to the South Side in the Bay Central Part During the Southeast Monsoon

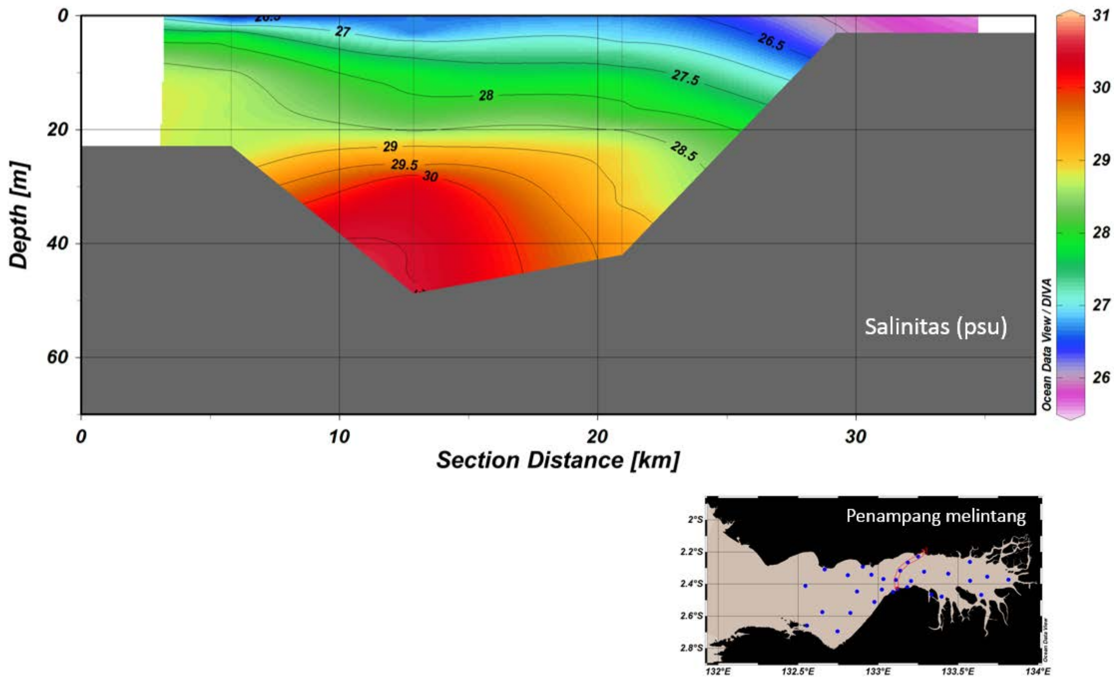


Figure II-139 Cross-section of Salinity (psu) from the North side to the South side in the Bay Central Part During the Southeast Monsoon

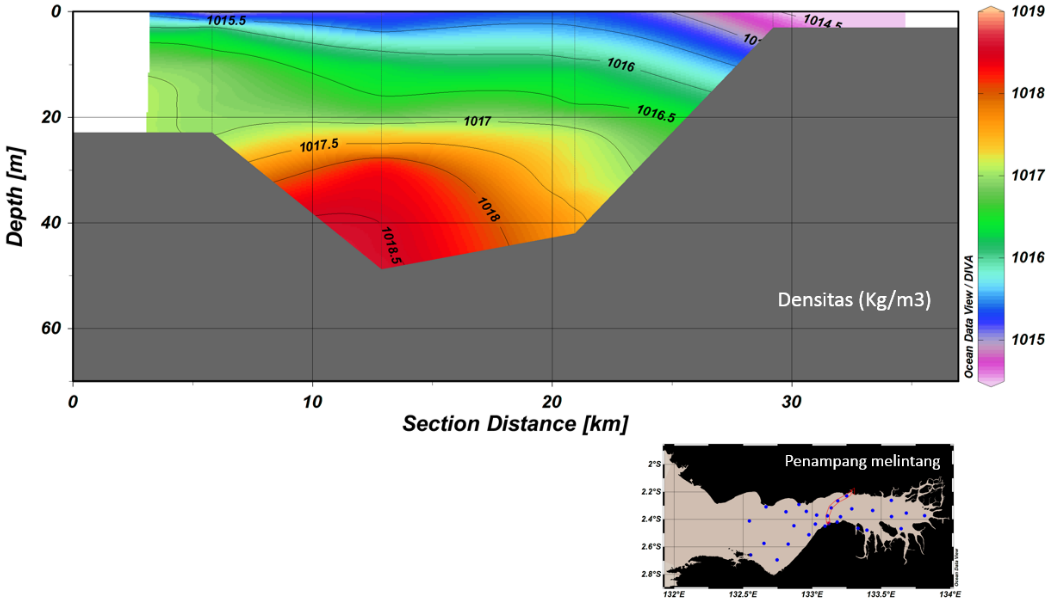


Figure II-140 Cross-section of Density (kg/m³) from the North Side to the South Side in the Bay Central Part During the Southeast Monsoon

2.2 BIOLOGY

2.2.1 Terrestrial Biology

As described in the ANDAL Terms of Reference document agreed by Minister of the Environment, the Tangguh LNG has performed several biological diversity surveys to illustrate the biological environmental conditions in the Tangguh LNG areas. The surveys are:

1. Environmental baseline study for ANDAL 2002;
2. Flora and Fauna Survey in the Tangguh LNG Project Site in 2007; and
3. Monitoring of Flora and Fauna at Tangguh LNG in 2011.

Land Cover

In the flora and fauna monitoring report 2011, it is described that in general the major forest ecosystem type at the proposed location of the Tangguh LNG Expansion Project consists of (1) mangrove forest, (2) swamp forest, and (3) lowland forest. Forest areas cleared for the Tangguh LNG activities are totally 3,266 ha, but only 365 ha (11.18%) of the area is cleared for the expansion of Tangguh LNG site and 39 ha of the area is fenced as a buffer zone. Of the cleared area, approximately 100 ha have been re-vegetated. Further, for the development of the LNG Plant facilities and its supporting facilities required as part of the Tangguh LNG Expansion Project, land clearing of maximum 500 ha is needed.