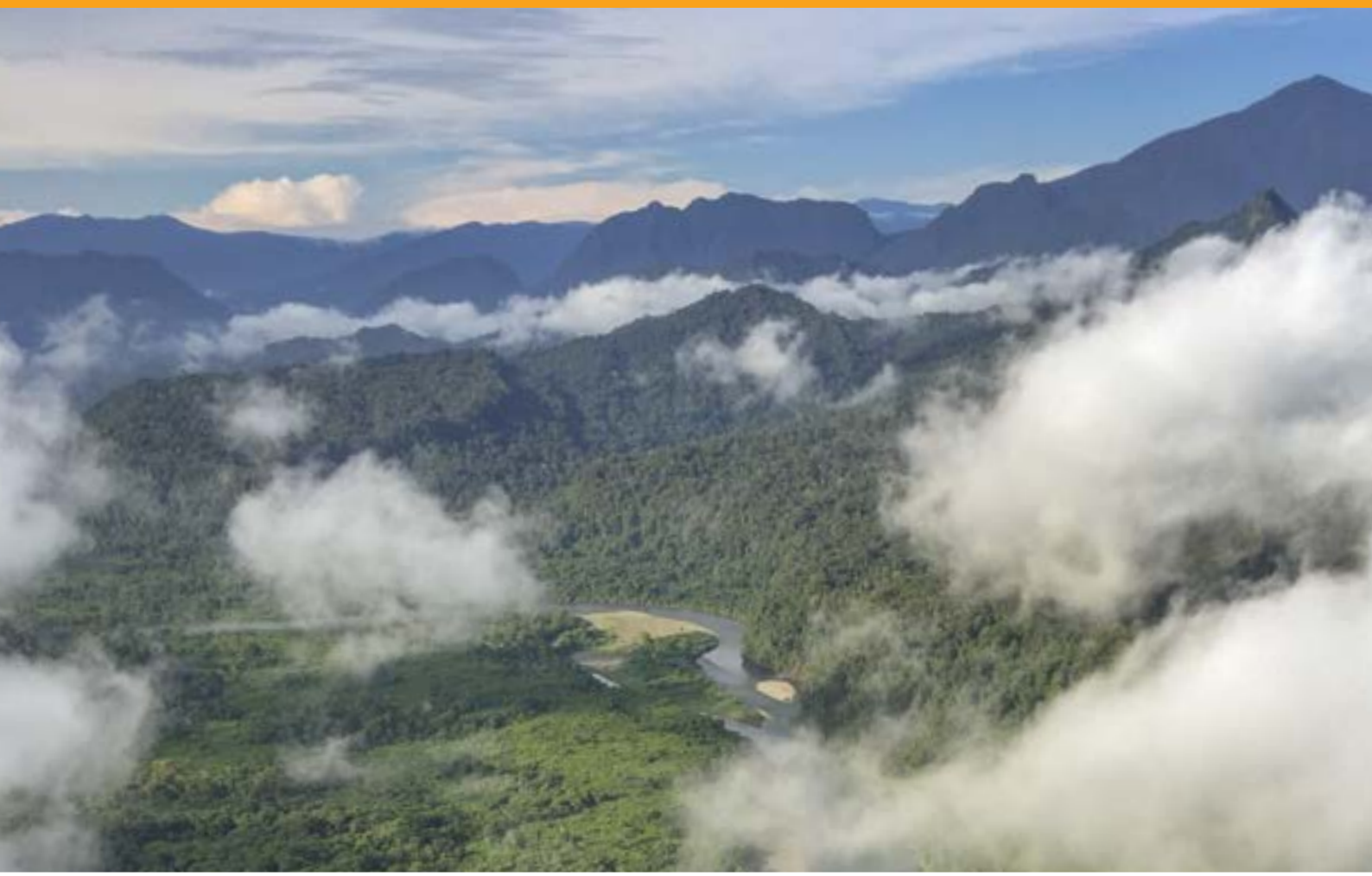
FRIEDA RIVER

Frieda River Limited
Sepik Development Project
Environmental Impact Statement

Attachment 3 – Water Quality Criteria, Guidelines and Standards

SDP-6-G-00-01-T-003-009



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A TETRA TECH COMPANY

Table A1 Drinking water quality standards/guidelines

	Units	PNG Schedule 2[A1]	PNG ECP[B1, B2]	WHO[C1]
Physico-chemical Characteristics				
Colour	Pt/Co units	50	15[B3]	15[C2,C3]
Total hardness	mg $CaCO_3$/L	600	200	-
Taste and odour	Dimensionless	Unobjectionable	Unobjectionable	Should be acceptable
Mineral oil	mg/L	0.3	-	-
Dissolved oxygen	%	-	>85% saturation[B4]	-
pH	Units	6.5 – 9.2	6.5 – 9.2	-
Total dissolved solids	mg/L	-	500	1,000[C3]
Total solids	After drying at 180 ºC	1,500	25	-
Turbidity	NTU	25 JTU[A2]	5	5[C3]
Major Ions				
Ammonia	mg NH_4/L	-	0.5[B5]	1.5[C3]
Calcium	mg/L	200	-	-
Total residual chlorine	mg/L	-	1.0	5
Chloride	mg/L	1,000	250	250[C3]
Free cyanide	CN/L	-	0.08	-
Total cyanide	CN/L	0.05	-	0.5[C4]
Fluoride	mg/L	1.5	1.5	1.5
Nitrate	mg NO_3/L	45	50	50
Nitrite	mg NO_2/L	-	3	3
Sodium	mg/L	-	-	[C5]
Sulphate	mg SO_4/L	400	250	250[C3]
Sulphide	mg H_2S/L	-	0.05	0.05[C3]
Metals and Metalloids				
Aluminum	mg/L	-	0.2[B6]	-
Antimony	mg/L	-	0.003	0.02
Silver	mg/L	0.05	0.1	[C6]
Arsenic	mg/L	0.05	0.007	0.01[C7]
Barium	mg/L	-	0.7	1.3
Beryllium	mg/L	-	-	[C8]
Boron	mg/L	-	0.3	2.4
Cadmium	mg/L	0.01	0.002	0.003
Chromium	mg/L	–	0.05	0.05[C7]
Cobalt	mg/L	–	–	–
Copper	mg/L	1.5A3	1	2 (1[C3])
Iron	mg/L	1A3	0.3	0.3[C3]
Magnesium	mg/L	150A4	–	–
Manganese	mg/L	0.5A3	0.1	0.4 (0.1[C3])
Mercury	mg/L	0.001	0.001	0.006
Nickel	mg/L	–	0.02	0.07
Lead	mg/L	0.1	0.01	0.01[C7]

Table A1 Drinking water quality standards/guidelines (cont'd)

	Units	PNG Schedule 2[A1]	PNG ECP[B1, B2]	WHO[C1]
Metals and Metalloids (cont'd)				
Selenium	mg/L	0.01	0.01	0.04[C7]
Zinc	mg/L	15[A3]	3	3
Biological Characteristics				
Total coliforms	C.F.U/100mL	0[A5] (10[A6,A7]) (3[A8])	<10[B7]	0[C9]
E. coli	C.F.U/100mL	0	–	0
Faecal coliforms	C.F.U/100mL	–	0	0

Note: Drinking water values are applied to water consumed by humans.

PNG Standards for Drinking Water

A1 Maximum allowable concentrations from PNG Public Health (Drinking Water) Regulation, Schedule 2, 1984. Values stated are the maximum permissible levels.

A2 Jacksons Turbidity Unit (JTU).

A3 Aesthetically based value.

A4 Not more than 30 mg/L, if sulphate values exceed 250 mg/L.

A5 Chlorinated water or disinfectant water supplies entering the distribution system.

A6 For water in the distribution system:

- Throughout any year, 90% of the sample shall not contain any coliform organisms in any sample of 100 mL.
- There shall be no *E. coli* in any sample of 100 mL.
- No sample shall contain more than 10 coliform organisms per 100 mL.

A7 Coliform organisms should not be detected in both or any of two consecutive 100-mL samples.

A8 No sample shall contain more than three coliform organisms per 100 mL in non-disinfected water supplies and if *E. coli* is absent.

PNG Environmental Code of Practice

B1 Water quality criteria for raw drinking water. PNG Mining Industry Environmental Code of Practice (PNG, 2000).

B2 Metal concentrations are for dissolved metals.

B3 Hazen units.

B4 Measured over at least one, but preferably several, diurnal cycles.

B5 Measured as NH_3.

B6 Maximum permissible concentration.

B7 Not detectable in >90% of samples collected over one year.

World Health Organization Drinking Water Quality Guidelines

C1 Guidelines for Drinking-water Quality. Fourth edition, incorporating the 1st addendum. World Health Organization, Geneva. 2017. Organic parameters, pesticides and radioactive parameters not included in this table. All values are health-based unless otherwise indicated.

C2 True colour unit.

C3 Aesthetically based value.

C4 A health-based value of 0.5 mg/L has been calculated for short-term exposure.

C5 No health guideline is currently considered necessary; however, concentrations above 3 mg/L may not be aesthetically pleasing to consumers.

C6 Insufficient data to set a guideline based on health considerations. Levels of up to 0.1 mg/L could be tolerated without risk to human health.

C7 Provisional guideline value.

C8 No guideline derived since chemical is considered unlikely to occur in drinking water.

C9 For large water supplies, total coliforms must not be present in 95% of samples taken throughout a 12-month period.

Table A2 Ambient water quality standards/guidelines for protection of freshwater aquatic ecosystems

	Units	PNG Schedule 1[A1]	PNG ECP[B1]	Australia/New Zealand[C1]
Physico-chemical Characteristics				
Conductivity	µS/cm	–	<1,000 mg/L (about 1,500 µS/cm)	[C2]
Colour	T.C.U	no alteration to natural conditions	<10% change in natural colour	–
Dissolved oxygen	mg/L	>6.0	>6.0 (80-90% saturation)	[C2]
pH	–	no alteration to natural pH	6.5 – 9.0	[C2]
Total suspended solids	mg/L	–	<10% change[B2]	–
Insoluble settleable residues	mg/L	–	<10% change [B2]	–
Temperature	^{o}C	less than 2^{o}C increase	<2°C increase from normal temperature	–
Turbidity	NTU	no alteration >25 NTU	<10% change [B2]	[C2]
Major Ions and Nutrients				
Ammonia (total)	mg NH_3/L	2.6[A2]	[B3]	[C3]
Free cyanide	mg CN/L	0.005 (as HCN)	0.005	0.007
WAD cyanide	mg CN/L	–	0.1	–
Fluoride	mg/L	1.5	–	–
Nitrate	mg N/L	45[A3]	–	0.7
Nitrite	mg N/L	–	–	[C2]
Phosphate	mg P/L	–	–	[C2]
Total phosphorus	mg P/L	–	–	[C2]
Sulphide (as H_2S)	mg/L	0.002 (as HS^-)	0.002	0.001[C4]
Sulphate	mg SO_4/L	400	–	–
Metals and Metalloids				
Aluminium	mg/L	–	0.1[B4]	0.055 (pH>6.5)
Antimony	mg/L	–	0.03	[C5]
Silver	mg/L	–	0.0001	0.00005
Arsenic	mg/L	0.05	0.05	0.024[C6]; 0.013[C7]
Barium	mg/L	1	–	–
Beryllium	mg/L	–	0.004	[C5]
Boron	mg/L	1	0.5	0.37[C8]
Cadmium	mg/L	0.01	<0.00066[B5]	0.0002[C9]
Total chromium	mg/L	–	0.01	–
Chromium (VI)	mg/L	0.05	–	0.001
Cobalt	mg/L	Limit of detectability	0.00024	[C5]
Copper	mg/L	1	<0.0065[B5]	0.0014[C9]
Iron	mg/L	1.0 (in solution)	1.0	[C5]
Manganese	mg/L	0.5 (in solution)	–	1.9[C8]

Table A2 Ambient water quality standards/guidelines for protection of freshwater aquatic ecosystems (cont'd)

	Units	PNG Schedule 1[A1]	PNG ECP[B1]	Australia/New Zealand[C1]
Metals and Metalloids (cont'd)				
Mercury	mg/L	0.0002	0.0001	0.00006[C10]
Nickel	mg/L	1	<0.056[B5]	0.011[C9]
Lead	mg/L	0.005	<0.0013[B5]	0.0034[C9]
Selenium	mg/L	0.01	0.005	0.005[C10]
Thallium	mg/L	–	0.004	[C5]
Zinc	mg/L	5	<0.18 [B5]	0.008[C8,C9]

PNG Schedule 1

[A1] Environment (Water Quality Guidelines) Regulation 2002. Metal concentrations are for dissolved substances, passing through a nominal 0.45-µm filter. Organic compounds and pesticides are not included in this table.

[A2] At pH 7.0 and 30°C. Values are temperature- and pH-dependent.

[A3] As nitrate + nitrite.

PNG Environmental Code of Practice

[B1] Guidelines for protection of fresh water aquatic life. PNG Mining Industry Environmental Code of Practice (ECP) (PNG, 2000). All metal concentrations are for dissolved concentrations (passing through a nominal 0.45-µm millipore medium).

[B2] From background mean seasonal values.

[B3] For total ammonia, dependent on temperature and pH.

[B5] If pH >6.5; 0.005 if pH <6.5.

[B6] Based on hardness of <50 mg/L, see Table A4 for hardness dependent values.

Australian/New Zealand Guidelines

[C1] ANZECC/ARMCANZ (2000). Australia Water Quality Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council, Agricultural and Resource Management Council of Australia and New Zealand. October 2000. Metal values are generally applied to filtered concentrations, with provision for site-specific considerations. Trigger values in this table apply to a typical slightly to moderately disturbed system. Pesticides, polyaromatic hydrocarbons and organic parameters are not included in this table.

[C2] Trigger values vary depending on ecosystem type and geographic location. Refer to source document.

[C3] Trigger value is dependent on pH and temperature.

[C3] Sulphide as un-ionised H_2S, measured as S.

[C5] Insufficient data to derive a reliable trigger value.

[C6] As(III).

[C7] As(V).

[C8] Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species).

[C9] Chemicals where algorithms have been provided to account for the effect of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to site-specific hardness.

[C10] Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.

Table A3 Ambient water quality standards/guidelines for protection of marine aquatic ecosystems

	Units	PNG Schedule 1[A1]	PNG ECP[B1]	Australia/New Zealand[C1]
Physico-chemical Characteristics				
Conductivity	µmhos/cm	–	<5% change from seasonal mean background level	[C2]
Colour	T.C.U	No alteration to natural conditions	<10% change from natural colour	–
Dissolved oxygen	mg/L	≥ 5	>6.0 mg/L (>80-90% saturation)	[C2]
pH	–	–	<0.2 pH unit change from normal pH	[C2]
Total suspended solids	mg/L	–	<10% change[B2]	–
Temperature	^{o}C	No alteration greater than 2°C from natural conditions	No alteration greater than 2°C from natural conditions	–
Turbidity	NTU	No alteration greater than 25 NTU from natural conditions	<10% change[B2]	[C2]
Major Ions and Nutrients				
Ammonia (total)	mg NH_3/L	–	[B3]	[C3]
Free cyanide	mg CN/L	0.01 (as HCN)	0.005	0.004
WAD cyanide	mg CN/L	–	0.1	–
Fluoride	mg/L	1.5	–	[C4]
Nitrate	mg N/L	45 [A3]	–	[C4]
Phosphate	mg P/L	–	–	[C2]
Total phosphorus	mg P/L	–	–	[C2]
Sulphide (as H_2S)	mg/L	0.002 (as HS^-)	0.002	[C4]
Metals and Metalloids				
Antimony	mg/L	–	0.5	[C4]
Silver	mg/L	–	0.001	0.0014
Arsenic	mg/L	0.05	0.05	[C4]
Barium	mg/L	1.0	–	–
Boron	mg/L	2.0	–	[C4]
Cadmium	mg/L	0.001	0.002	0.7[C6]
Total chromium	mg/L	–	0.05	–
Chromium (VI)	mg/L	0.01	–	0.0044 [C6]
Cobalt	mg/L	Limit of detectability	0.0009	0.0010
Copper	mg/L	0.03	0.005	0.0013 [C6]
Iron	mg/L	1.0 (in solution)	–	[C4]
Manganese	mg/L	2.0 (in solution)	–	[C4]
Mercury	mg/L	0.0002 (in solution)	0.0001	0.0004[C5]
Molybdenum	mg/L	–	–	[C4]
Nickel	mg/L	1.0	0.015	0.070[C6]
Lead	mg/L	0.004	0.005	0.0044 [C6]

Table A3 Ambient water quality standards/guidelines for protection of marine aquatic ecosystems (cont'd)

	Units	PNG Schedule 1[A1]	PNG ECP[B1]	Australia/New Zealand[C1]
Selenium	mg/L	0.01	0.07	[C4]
Thallium	mg/L	–	0.02	[C4]
Vanadium	mg/L	–	–	0.10
Zinc	mg/L	5.0	0.05	0.015[C6]

PNG Schedule 1

[A1] Environment (Water Quality Guidelines) Regulation 2002. Metal concentrations are for dissolved substances, passing through a nominal 0.45-µm filter. Organic compounds and pesticides are not included in this table.

[A2] At pH 7.0 and 30ºC. Values are temperature- and pH-dependent.

[A3] As nitrate + nitrite.

PNG Environmental Code of Practice

[B1] Guidelines for protection of fresh water aquatic life. PNG Mining Industry Environmental Code of Practice (ECP) (PNG, 2000). All metal concentrations are for dissolved concentrations (passing through a nominal 0.45-µm millipore medium).

[B2] From background mean seasonal values.

[B3] For total ammonia, it is dependent on temperature and pH.

Australian/New Zealand Guidelines

[C1] ANZECC/ARMCANZ (2000). Australia Water Quality Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council, Agricultural and Resource Management Council of Australia and New Zealand. October 2000. Metal values are generally applied to filtered concentrations, with provision for site-specific considerations. Trigger values in this table apply to a typical slightly to moderately disturbed system. Pesticides, polyaromatic hydrocarbons and organic parameters are not included in this table.

[C2] Trigger values vary depending on ecosystem type and geographic location. Refer to source document.

[C3] Trigger value is dependent on pH and temperature.

[C4] Insufficient data to derive a reliable trigger value.

[C5] Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered.

[C6] Chemicals where algorithms have been provided to account for the effect of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to site-specific hardness.

Table A4 Hardness-dependent water quality guidelines (PNG ECP)

Hardness (mg $CaCO_3$/L)	Cadmium	Copper	Lead	Nickel	Zinc
	Concentration (mg/L)				
<50	<0.00066	<0.0065	<0.0013	<0.056	<0.1800
50 – 100	0.00066 – 0.0011	0.0065 – 0.0120	0.0013 – 0.0032	0.056 – 0.096	0.01800 – 0.3200
100 – 200	0.0011 – 0.002	0.0120 – 0.00210	0.0032 – 0.0077	0.096 – 0.160	
Equation	$e^{(0.7852[lnH]-3.490}$	$e^{(0.8545[lnH]-1.465)}$	$e^{(1.273[lnH]-4.705)}$	$e^{(0.76[lnH]+1.06)}$	$e^{(0.83[lnH]+1.95)}$