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Technical Note

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Subject	NORM impact on Amungee NW-1 (vertical well) and Amungee NW-1H (horizontal well) drill cuttings disposal requirements.		

1. Recommendation

Combined drill cuttings from the Amungee NW-1 (vertical) and NW-1H (horizontal) wells do not require special offsite disposal based on the measured NORMs content and calculated activity concentrations.

2. Basis

2.1 Introduction

Minimum waste management requirements are set out in the Beetaloo Project Environmental Plan (EP) *(reference 4)*. Table 27 (section 5.7) of the EP details requirements relating to drill cutting NORMs.

"NORMs is not likely to be generated, however, if NORMs does occur a separate waste management plan will be developed for handling of NORMs material at an appropriate licensed waste disposal facility."

This technical note provides a summary of monitoring results and lists calculations used to determine the level in all drill cuttings, which were found to be below prescribed levels that would otherwise trigger additional waste management requirements.

2.2 Exemption Criteria:

Paragraph 7, part 2, of the Northern Territory of Australia Radiation Protection Regulations (see reference 2) states:

> For section 8 of the Act, radioactive material that is a mixture of radioactive materials is material to which the Act does not apply if:
>
> (a) The sum of the fractions obtained by dividing the activity of each material present by the appropriate activity value from the National Directory, Schedule 4, does not exceed 1; or
>
> (b) The sum of the fractions obtained by dividing the activity concentration of each material present by the appropriate activity concentration value from the National Directory, Schedule 4, does not exceed 1.

That is; if the threshold (<1) is not exceeded, then the Act does not apply and the material is effectively of such a low activity that it is not considered radioactive.

As per ARPANSA Regulations:

"2.7. The limits in relation to U(nat) and Th(nat) are to be applied in terms of the parent radionuclide ie. U-238 and Th-232 respectively."

Radioisotope #	Activity Concentration (Bq/g)
U_{nat}	<1
Th_{nat}	<1
K-40	<100

Table 1. Northern Territory Exemption criteria for exempt radioactive material. #U_{nat} and Th_{nat} assumes that the parents (U-238 and Th-232) are in equilibrium with the progeny.

2.3 Determining concentration of radionuclides in cuttings

Testing was carried out using a GeoFlex portable X-Ray Fluorescence (XRF) machine on the wellsite. Each test was carried out on a representative sample prepared from regularly sampled drill cuttings at 5-3m intervals.

Result summary for two wells: Amungee NW-1 (vertical) and Amungee NW1-H (horizontal). The distribution of individual radionuclide abundances, coloured by stratigraphic formation, are shown in Figures 1-6 in the Appendices.

<u>Amungee NW-1</u> (Undifferentiated Cretaceous to the lower Velkerri member):

Uranium: 0.6 - 15.55ppm (p5 - p95 range), maximum result 23.1ppm

Thorium: 8 - 29 ppm (p5 - p95 range), maximum result 44.9ppm

Potassium: 0.76 - 3.92% (p5 - p95 range), maximum result 4.8%

All drill cuttings samples containing Uranium in excess of 10ppm occur in three discrete intervals of organic rich shale within the Middle to Lower Velkerri members:

ANW-1 Velkerri Fm	Depth From (mMD)	Depth To (mMD)	Thick (m)	Uranium Concentration (ppm)		
				max	p95	p50
Zone 1	2214.8	2286.48	71.68	23.1	22.74	15.6
Zone 2	2417.64	2463.15	45.51	23.0	22.86	16.8
Zone 3	2536.9	2559.5	17.482	17.7	17.58	13.05

Table 2. List of stratigraphic intervals at the Amungee NW-1 location containing greater than 10ppm of Uranium. The inflated background levels are considered to be linked to the depositional environment, as these zones also contain abundant organic matter, up to 5% by weight, which is a proxy for a marine environment as evidenced by the main maceral type Alginate.

Amungee NW-1H (upper Velkerri to lower Velkerri members):

Uranium: 3 - 21.5ppm (p5 - p95 range), maximum result 25ppm

Thorium: 9.86 - 22.2ppm (p5 - p95 range), maximum result 25.5ppm

Potassium: 1.2 - 3.2% (p5 - p95 range), maximum result 3.6%

2.4 Activity Concentrations Calculations

Activity per gram was calculated by converting the measured mass ratio determined by XRF (represented by ppm and % notation) to percent and multiplying by the specific activity *(reference 1)* for the radionuclide in Bq/g, assuming all are naturally occurring (i.e. no isotopic fractionation of the element has occurred in the specimen and the parent radionuclides are in secular equilibrium with their decay progeny).

Note: regulations on the activity concentrations are written with respect to the parent U-238, which takes into account the presence of the U-234. Therefore, when the activity concentration limit is given as 1 Bq/g for Unat, that is worked out by the ICRP and IAEA with the assumption that it will be in equilibrium with the decay progeny including U-234. Thus, the specific activity quoted in Tables 3 and 4 of 12,370 Bq/g is the IAEA total activity of U-238.

Results shown in the tables below, indicate observed p50, p95 and maximum observed numbers.

Amungee NW-1 (vertical)		Elemental concentrations in tested cuttings						Specific Activities	Calculated Activity per gram of sample		
XRF abundance		Measured units (ppm & %)			Converted units (%)			(Bq/ g)	(Bq/g)		
		max	@ 95%	@50%	max	@ 95%	@50%		max	p95%	p50%
Uranium (nat)	ppm	23.10	15.55	3.54	2.3E-05%	1.6E-05%	3.5E-06%	12,370	0.286	0.192	0.044
Thorium (232)	ppm	44.90	29.05	17.40	4.5E-05%	2.9E-05%	1.7E-05%	4,066	0.183	0.118	0.071
Potassium (40)	%	4.79	3.92	2.65	4.79%	3.92%	2.65%	30	1.450	1.188	0.802

Table 3. Measured abundance of radioactive elements in drill cuttings in Amungee NW-1 and activity level per gram in Becquerel's. Elemental Activity's per gram values - see reference 1.

Amungee NW-1H (horizontal)		Elemental concentrations in tested cuttings						Specific Activities	Calculated Activity per gram of sample		
XRF abundance		Measured units (ppm & %)			Converted units (%)			(Bq/ g)	(Bq/g)		
		max	@ 95%	@50%	max	@ 95%	@50%		max	p95%	p50%
Uranium (nat)	ppm	25.00	21.55	13.60	2.5E-05%	2.2E-05%	1.4E-05%	12,370	0.309	0.267	0.168
Thorium (232)	ppm	25.50	22.23	12.04	2.6E-05%	2.2E-05%	1.2E-05%	4,066	0.104	0.090	0.049
Potassium (40)	%	3.62	3.19	1.43	3.62%	3.19%	1.43%	30	1.096	0.967	0.434

Table 4. Measured abundance of radioactive elements in drill cuttings in Amungee NW-1H and activity level per gram in Becquerel's. 'Elemental Activity per kg values' sourced from Royal Society of Chemistry on 31 October 2015.

The sum of activity concentrations (Tables 3 and 4) were calculated by dividing the calculated activity of each material by the relevant activity value in Table 1.

Activity Concentrations Versus Exemptions							
Dividing the activity of each material present by the appropriate activity value from the National Directory (Schedule 4)							
Activity values (Bq/g) (from ND schedule 4)		**ANW-1**			**ANW-1H**		
		Calculated activity concentration					
		max	p95%	p50%	max	p95%	p50%
Uranium	1	0.286	0.192	0.044	0.309	0.267	0.168
Thorium	1	0.183	0.118	0.071	0.104	0.090	0.049
Potassium	100	0.015	0.012	0.008	0.011	0.010	0.004
	SUM	0.483	0.322	0.123	0.424	0.367	0.221
Exemtpion threshold		1.0	1.0	1.0	1.0	1.0	1.0
Classification		Exempt	Exempt	Exempt	Exempt	Exempt	Exempt

Table 5. The sum of activities for all radioactive fractioned must be totalled and be below '1', to classify as normal waste, as per reference 3.

The combined activity concentrations of the three radioactive elemental fractions (Uranium, Thorium and Potassium) were calculated to be 0.12 Bq/g and 0.22 Bq for ANW-1 and ANW-1H, respectively, using the p50% mean abundance, as per Table 5. The 95% of the all drill cuttings brought to surface have a combined activity concentration below 0.37 and 0.32 Bq respectively.

The combined activity concentrations of the three radioactive elemental fractions were calculated to be 0.483 Bq and 0.424 Bq for ANW-1 and ANW-1H respectively, using the maximum abundance from all samples brought to surface.

2.5 Conclusions

The drill cuttings from Amungee NW-1 and NW-1H are below the Northern Territory's NORMs exemption levels: less than 1 Bq as per section 7, part 2 of the Northern Territory *Radiation Protection Regulations (see reference 3).*

3. References

	Document	Document Number
1.	IAEA Safety Standards Series - Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material Safety Guide. No.TS-G-1.1 (ST-2) http://www-pub.iaea.org/MTCD/publications/PDF/Pub1109_scr.pdf	n/a
2.	National Directory for Radiation Protection. Republished February 2014, including amendments 1-6. Radiation Protection Series No.6. Australian Radiation Protection and Nuclear Safety Agency. http://www.arpansa.gov.au/publications/codes/rps6.cfm	n/a
3.	Northern Territory Radiation Protection Regulations, 2 July 2012	n/a
4.	Beetaloo Project Environmental Plan (EP)	NT-2050-15-MP-0005

4. Appendices

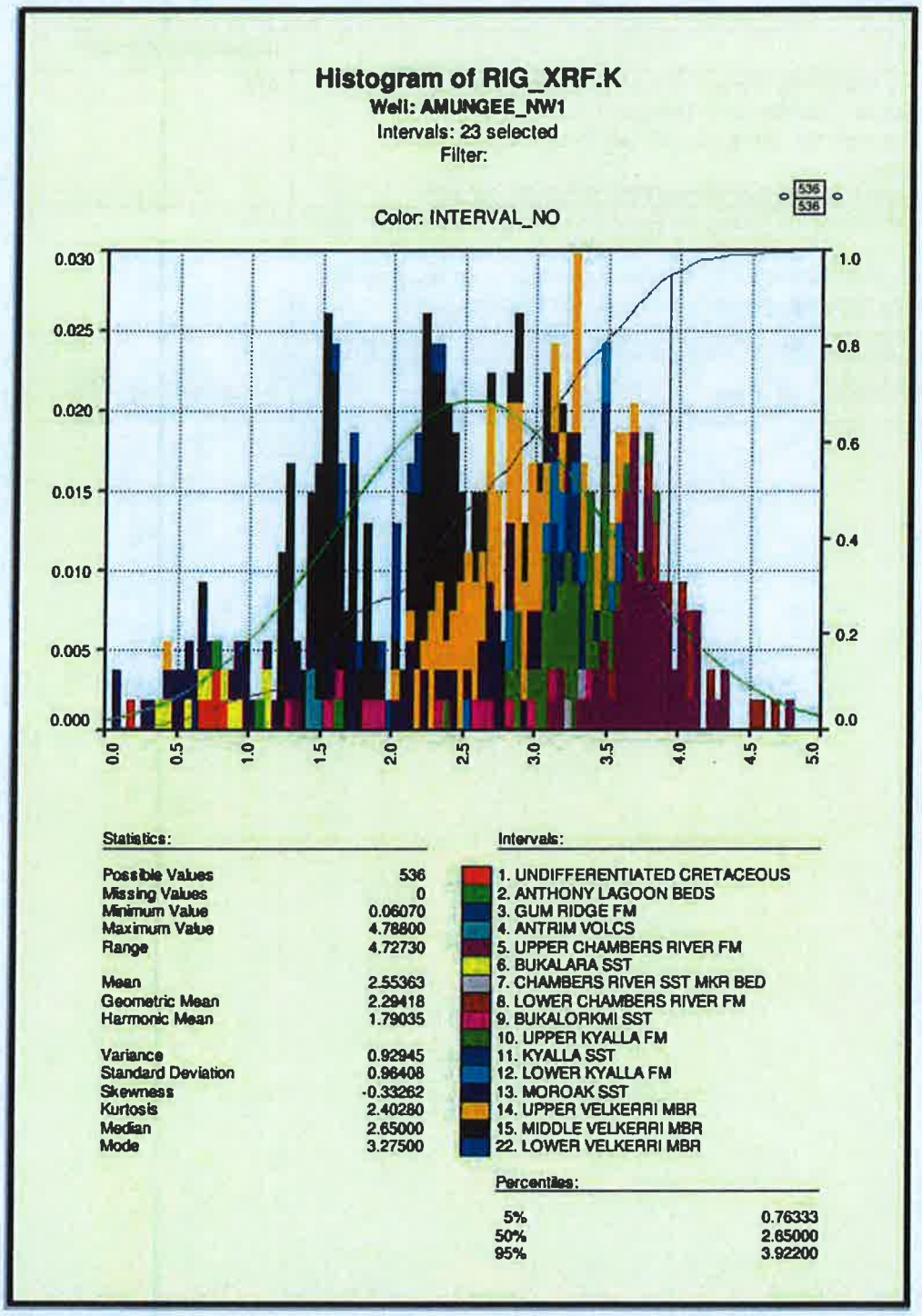

Figure 1. Frequency distribution of Potassium (0-5 weight %) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1. Colouring of data by geologic formations.

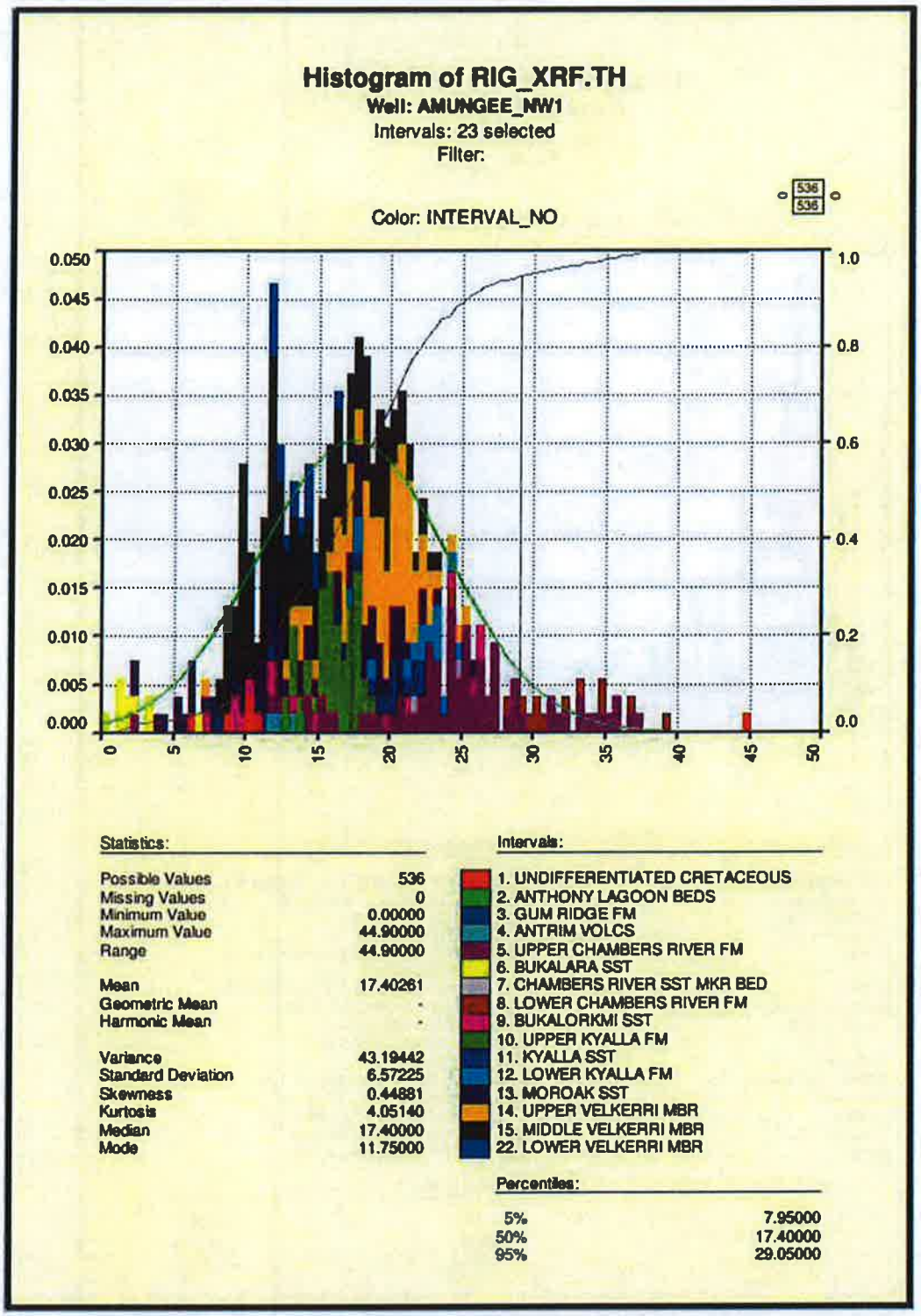

Figure 2. Frequency distribution of Thorium (0-50ppm) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1. Colouring of data by geologic formations.

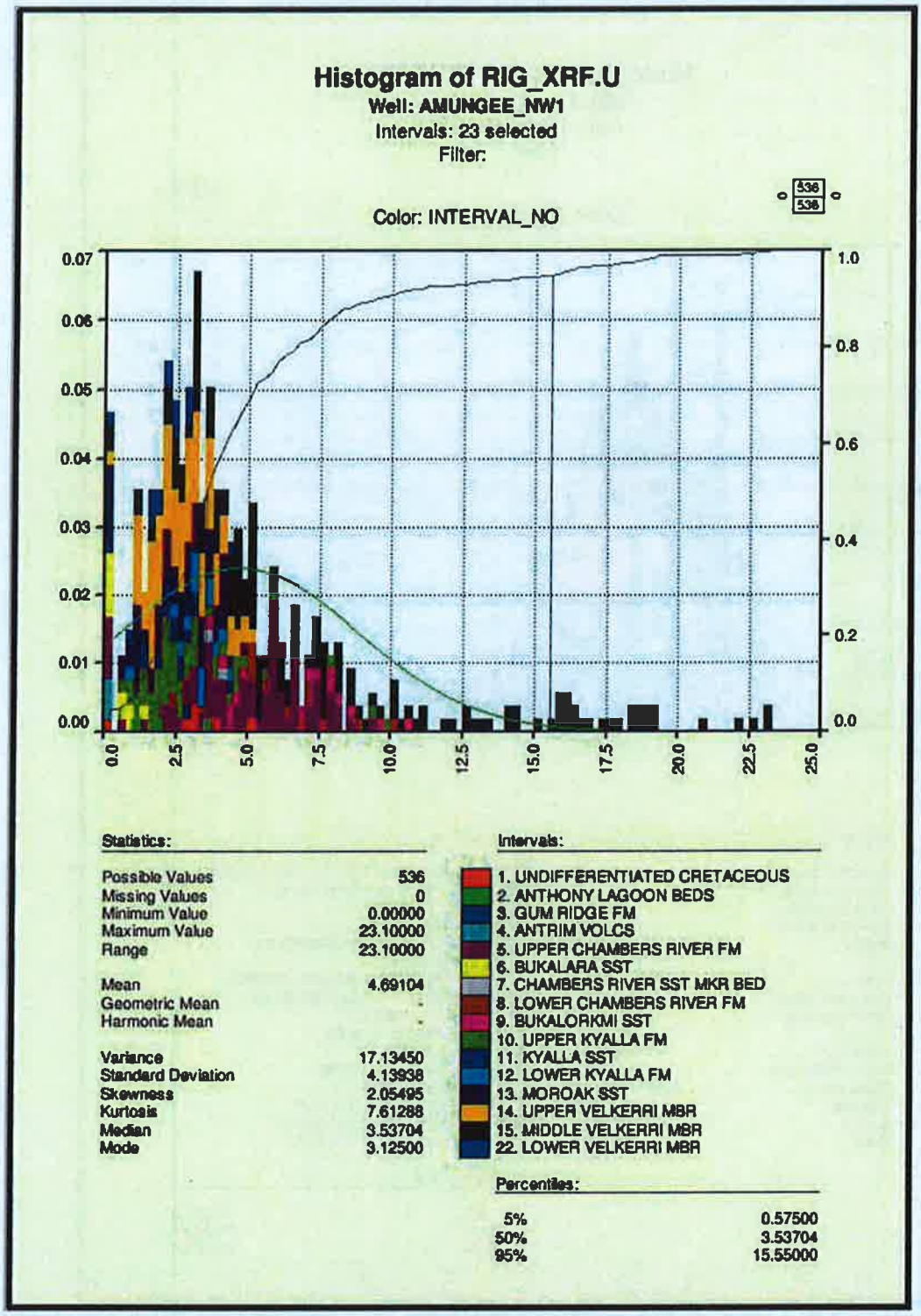

Figure 3. Frequency distribution of Uranium (0-25ppm) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1. Colouring of data by geologic formations.

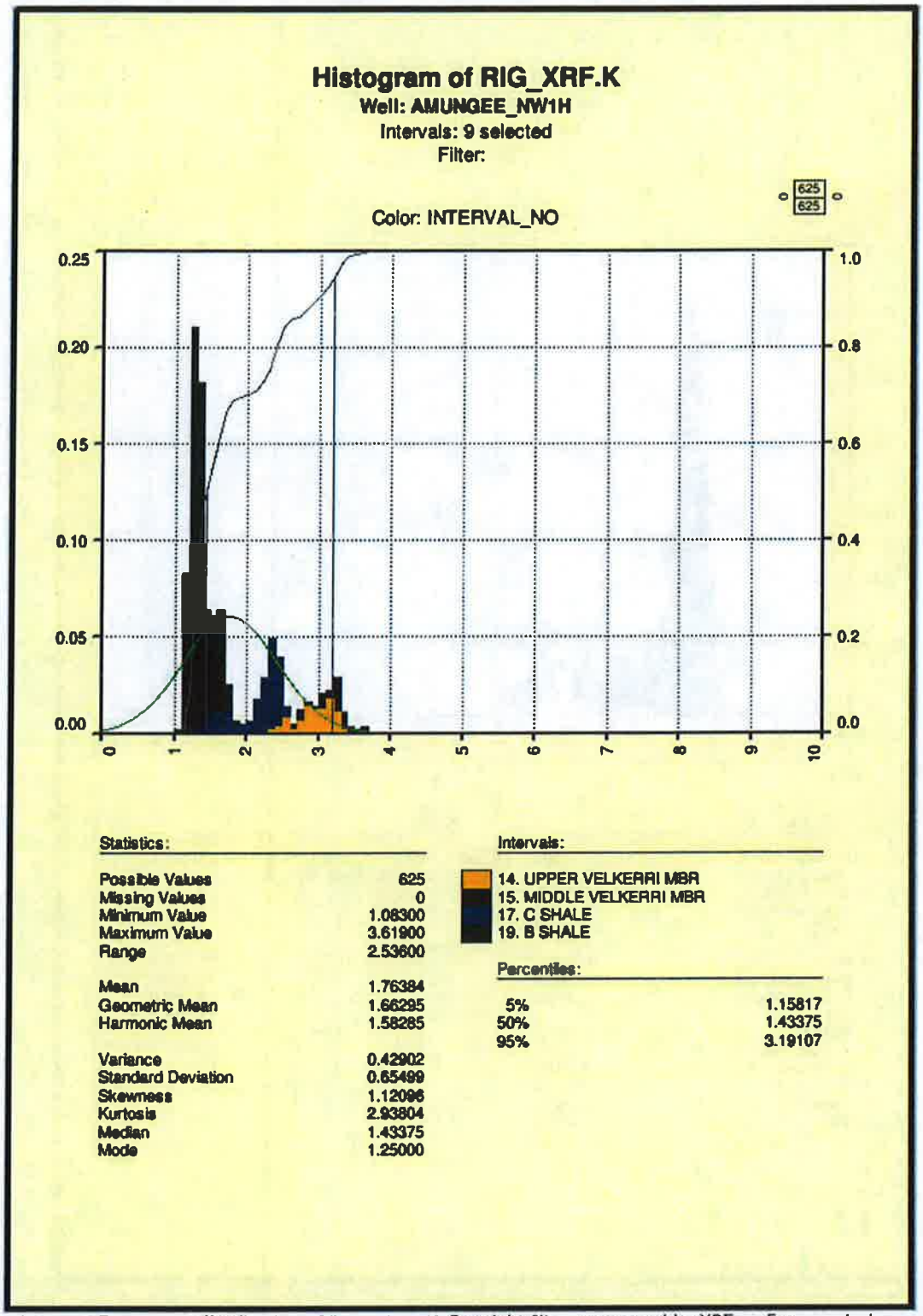

Figure 3. Frequency distribution of Potassium (0-5 weight %) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1H. Colouring of data by geologic zones recognised in the Velkerri Formation.

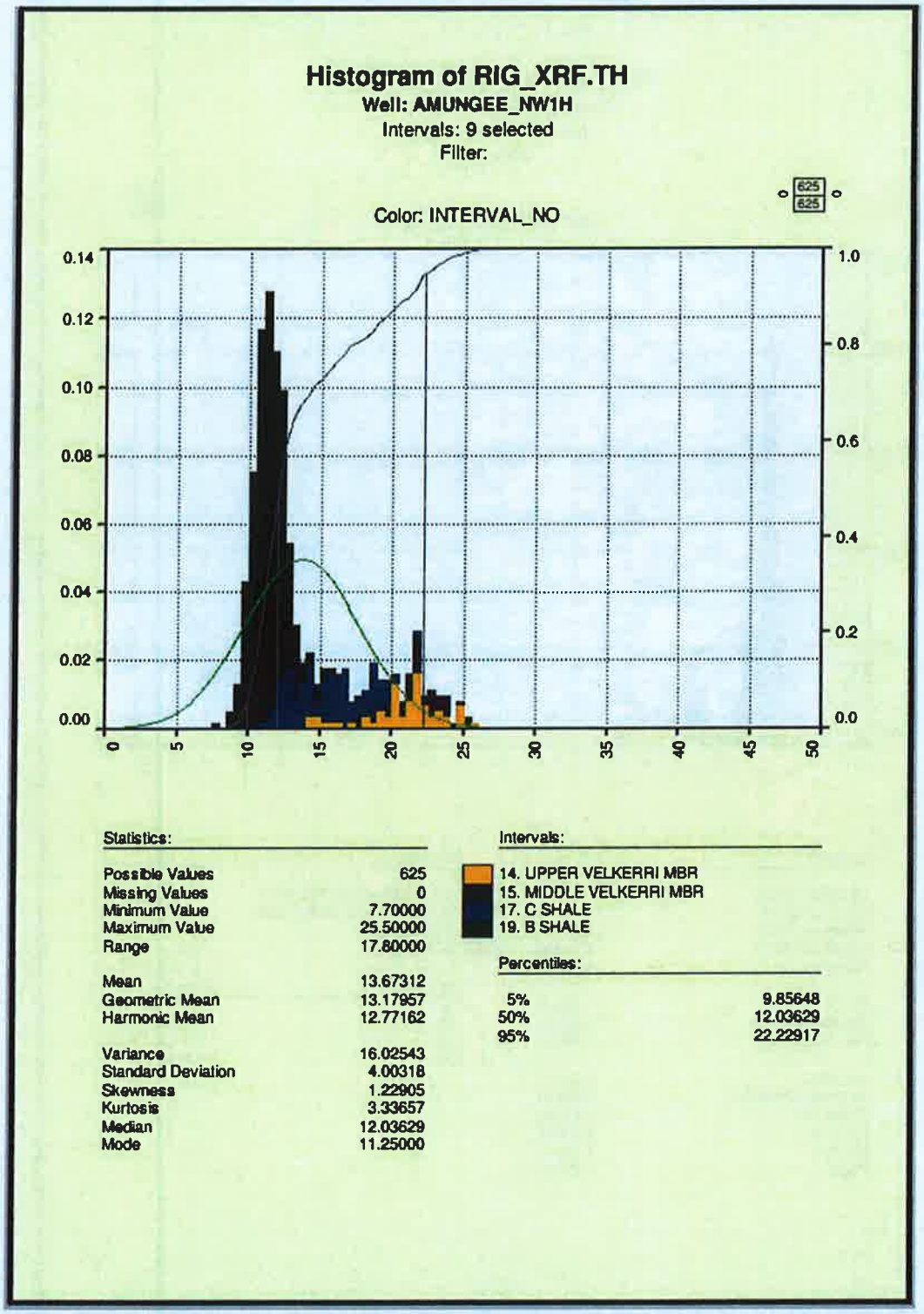

Figure 4. Frequency distribution of Thorium (0-50ppm) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1H. Colouring of data by geologic zones recognised in the Velkerri Formation.

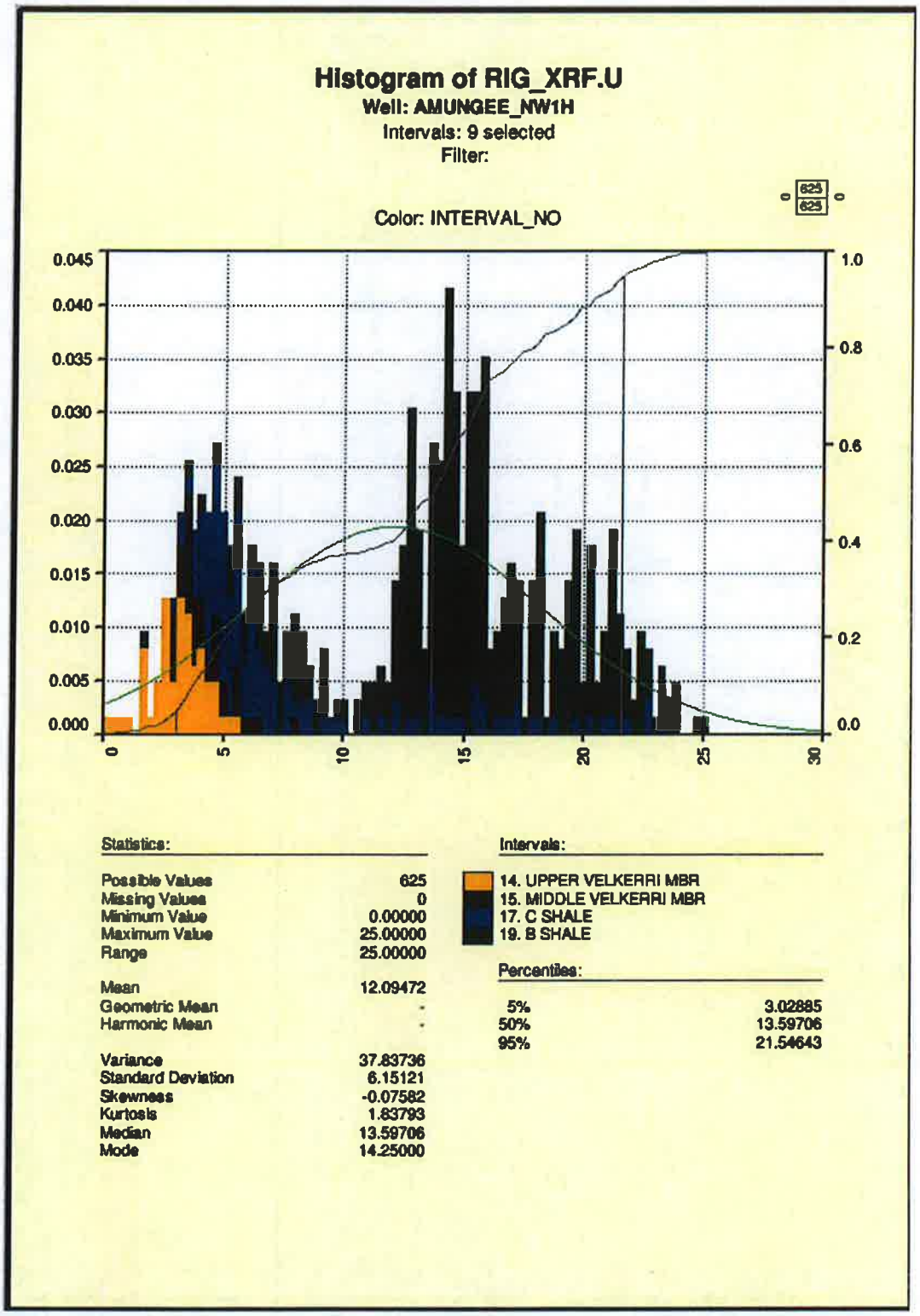

Figure 5. Frequency distribution of Uranium (0-30ppm) as measured by XRF on 5m sampled drill cuttings in Amungee NW-1H. Colouring of data by geologic zones recognised in the Velkerri Formation.