APPENDIX M11

TSF SEISMICITY ASSESSMENT 2006

ANGAS PROCESSING FACILITY

MISCELLANEOUS PURPOSES LICENSE APPLICATION 2019/0826

TERRAMIN

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Angas Zinc Tailings Dam
Strathalbyn

Seismicity Assessment

April 2006

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Tables & Figures

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This basic seismicity assessment of the proposed site for the Angas Zinc Tailings Dam (longitude 138.923° east, latitude 35.254° south), in Strathalbyn, South Australia, has been produced for Australian Tailings Consultants (reference Paul Williams), by the Seismology Research Centre (SRC), a division of Environmental Systems & Services Pty Ltd (ES&S).

The earthquake hazard calculations presented in this report take into consideration the seismicity of the area surrounding the Angas Zinc Tailings Dam site as it is currently understood.

Some nearby faults which previous studies have shown to be active have been considered however a detailed field investigation would help ascertain what (if detectible) neotectonic movement has recently occurred along other faults within the area.

This report concentrates on the earthquake ground shaking hazard. The potential hazard of fault surface rupture or liquefaction has not been considered.

This is a probabilistic hazard assessment using Cornell's (1968) methodology that employs a seismotectonic model which considers the seismicity (both historical and instrumental) and geology of the area in order to estimate seismic activity rates. The seismotectonic model allows for calculations of expected ground motion recurrence at the site, including peak ground acceleration (PGA) and response spectra. Also included are peak ground velocity (PGV) and intensity (MMI) recurrence estimates.

All calculations have been performed assuming the site is situated on bedrock geology and all results are for horizontal motion. Note that the attenuation functions used for the different calculations are not necessarily consistent - spectral and PGA calculations are produced using the Sadigh *et. al.* (1997) attenuation function, while PGV and MMI calculations have been performed using attenuation functions published by Gaull, Michael-Leiba and Rynn (1990).

3.1 Peak Ground Acceleration

The AUS5 PGA value calculated in this study (Figure 1) gives the proposed site of the Angas Zinc Tailings Dam a value of approximately 0.1 g for a return period of 500 years when considering earthquakes of magnitude 4.0 or greater.

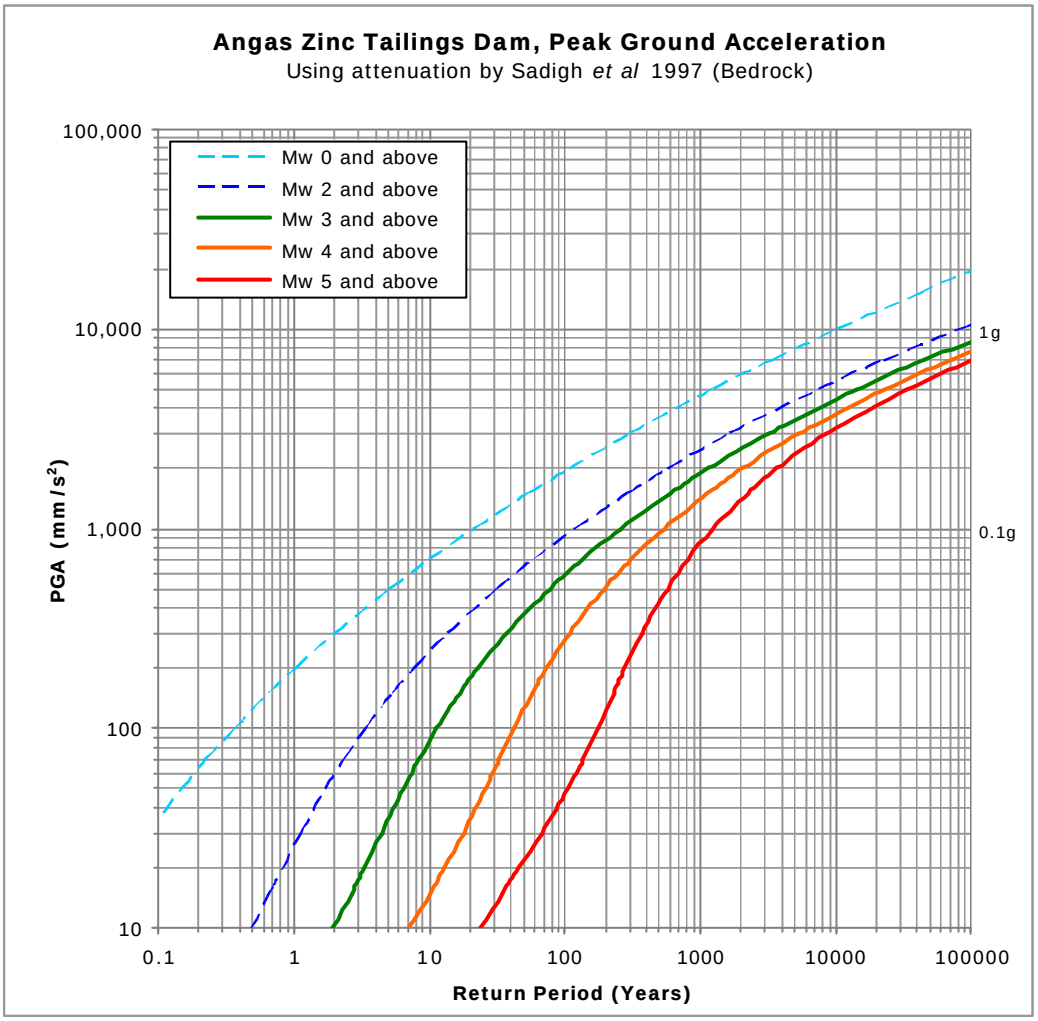

Figure 1: Peak ground acceleration recurrence

3.2 Peak Ground Velocities

The peak ground velocity plot (Figure 2) is computed using the Gaull, Michael-Leiba and Rynn, (1990) attenuation, which was derived from southeast Australian intensity data modified according to an empirical relationship with PGV.

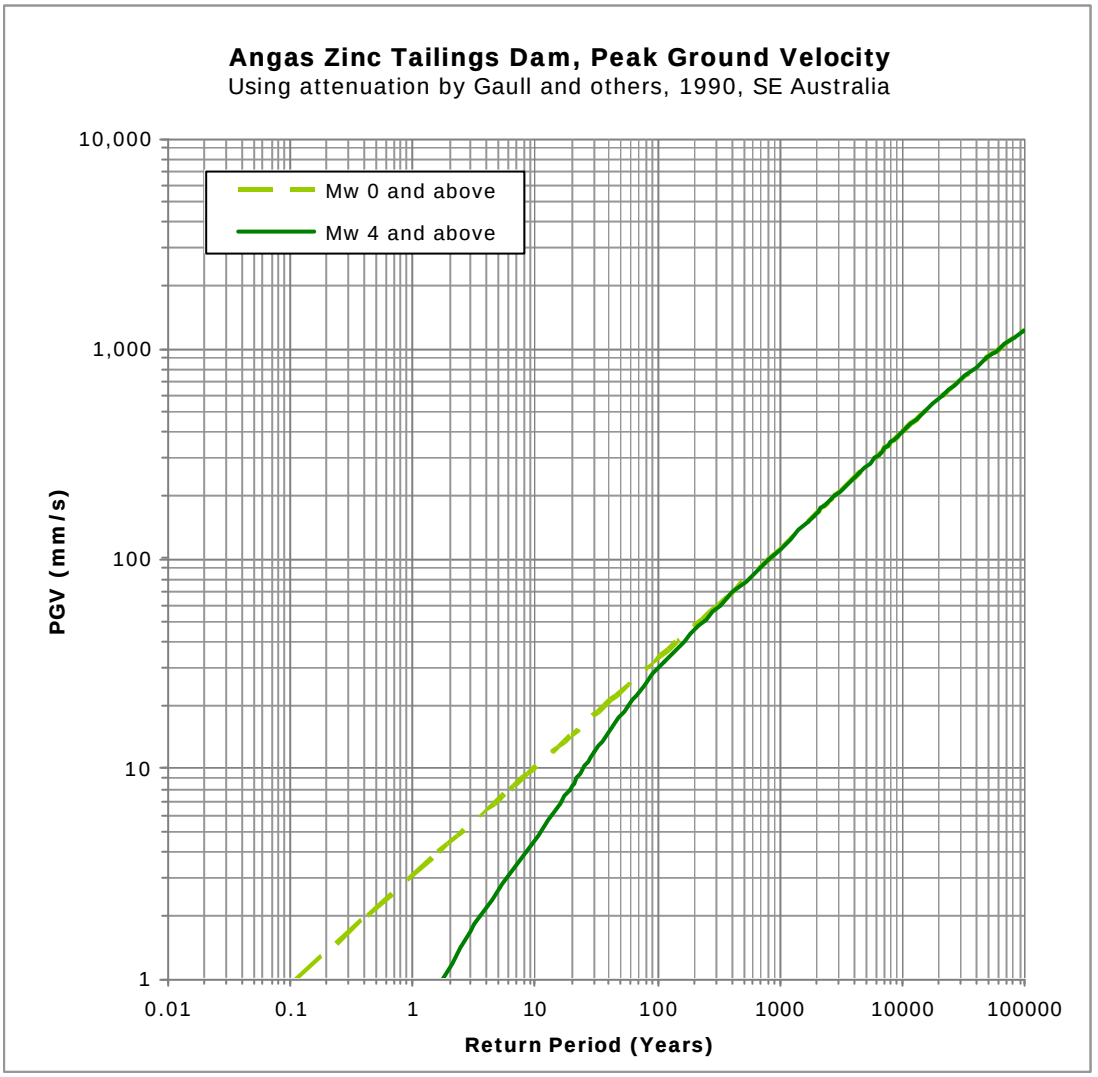

Figure 2: Peak ground velocity recurrence

3.3 Modified Mercalli Intensities

The estimated modified Mercalli intensity plot (Figure 3) has been computed using the Gaull, Michael-Leiba and Rynn, 1990 attenuation function, which was derived from intensity maps of southeast Australian earthquakes.

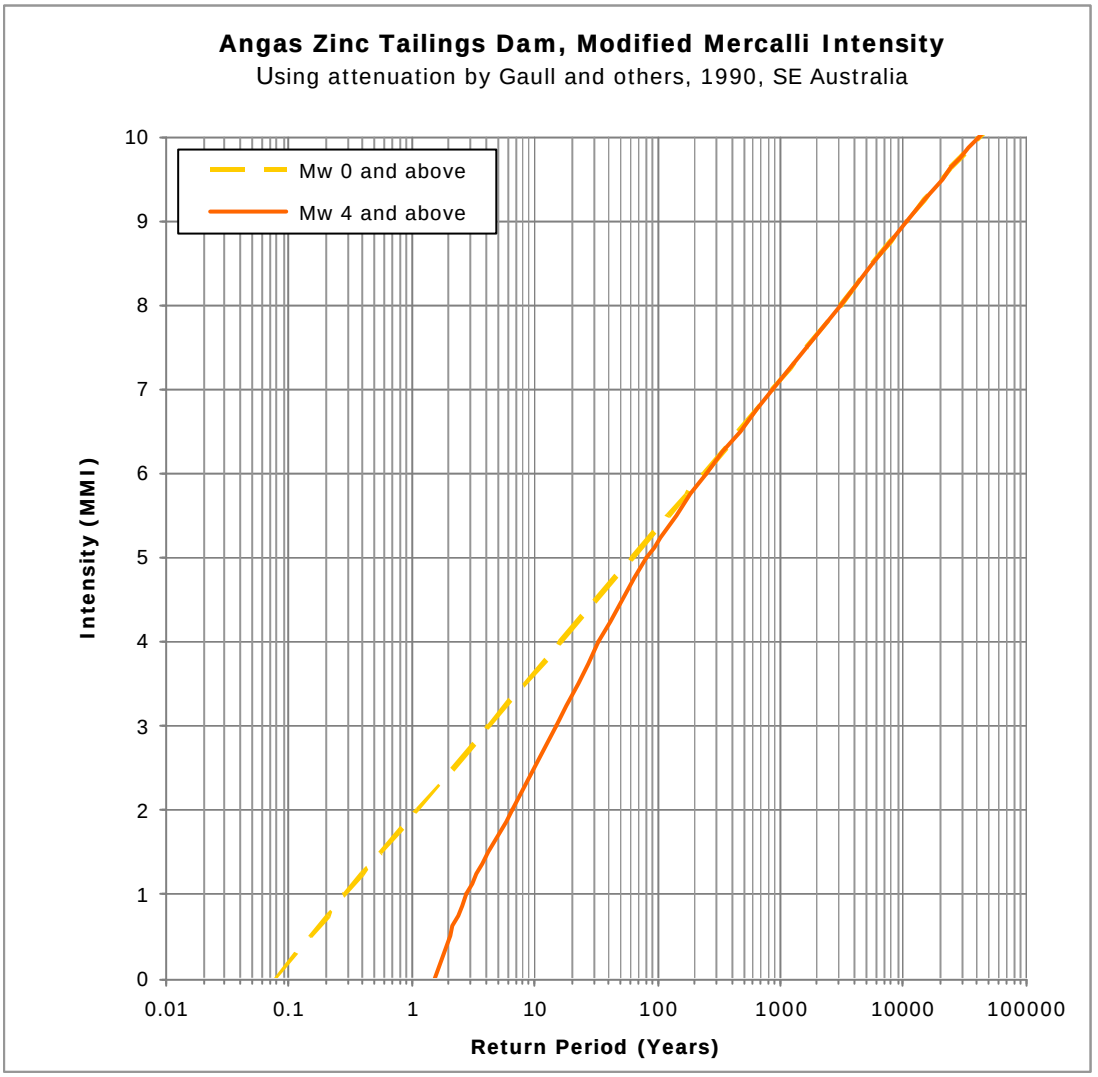

Figure 3: Modified Mercalli intensity recurrence

3.4 Uniform Probability Response Spectra

The uniform probability response spectra have been computed using the Sadigh *et. al.* (1997) relationship. For magnitudes of 4 and above, return periods of 475, 1000, 5000, 10,000 and 50,000 years have been produced, for 5% damping. These results are presented in Figures 4 to 6. Figures 4 and 5 both plot period (in seconds) versus response acceleration (in mm/s^2), on a linear-linear and a log-linear plot respectively. In Figure 6 the results have been converted to pseudo-velocity (in mm/s) and plotted versus frequency (in Hz) on a tripartite plot, with acceleration (in gravity 'g') and pseudo-displacement (mm) lines also plotted.

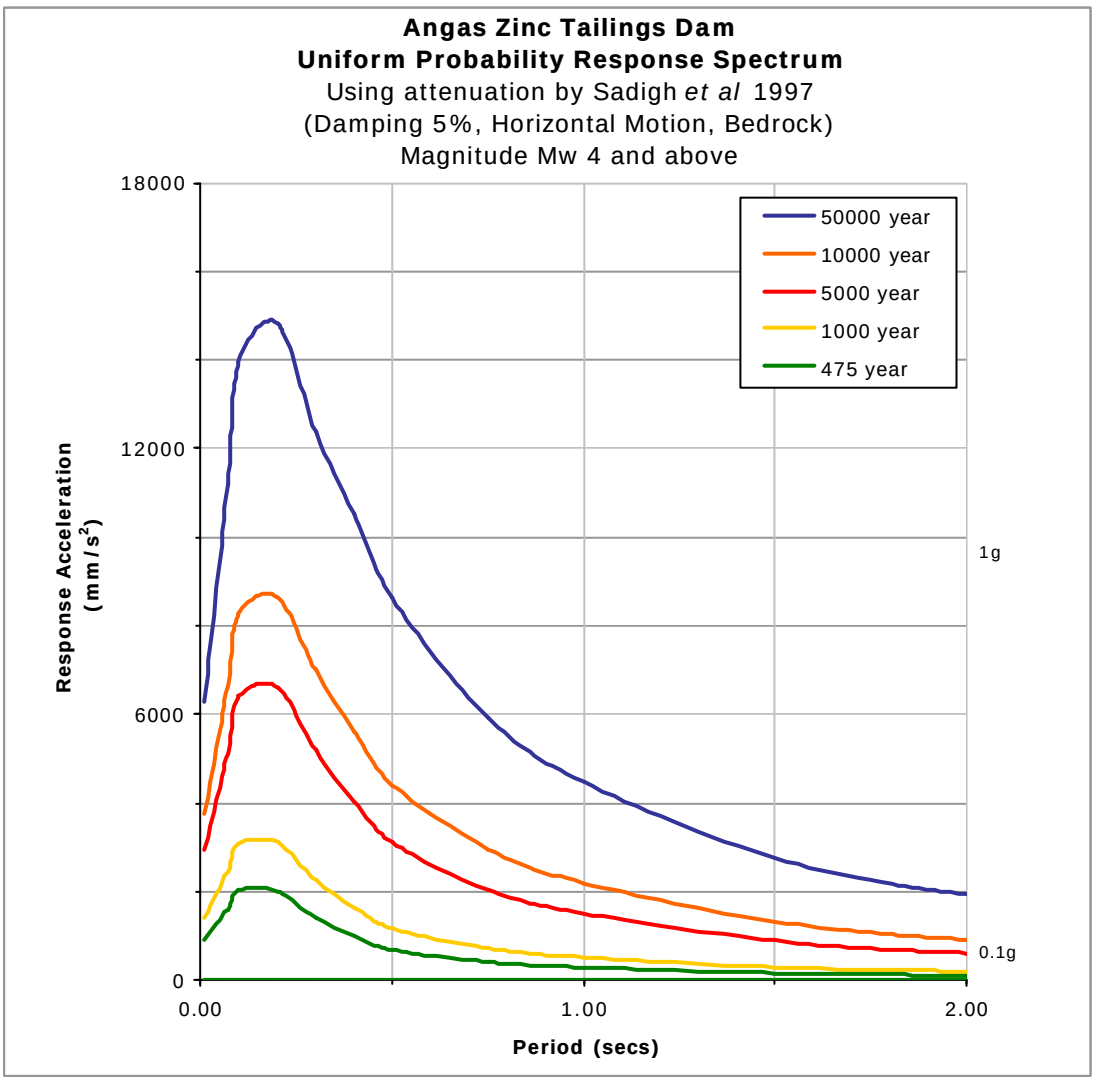

Figure 4: Response spectra acceleration (linear-linear)

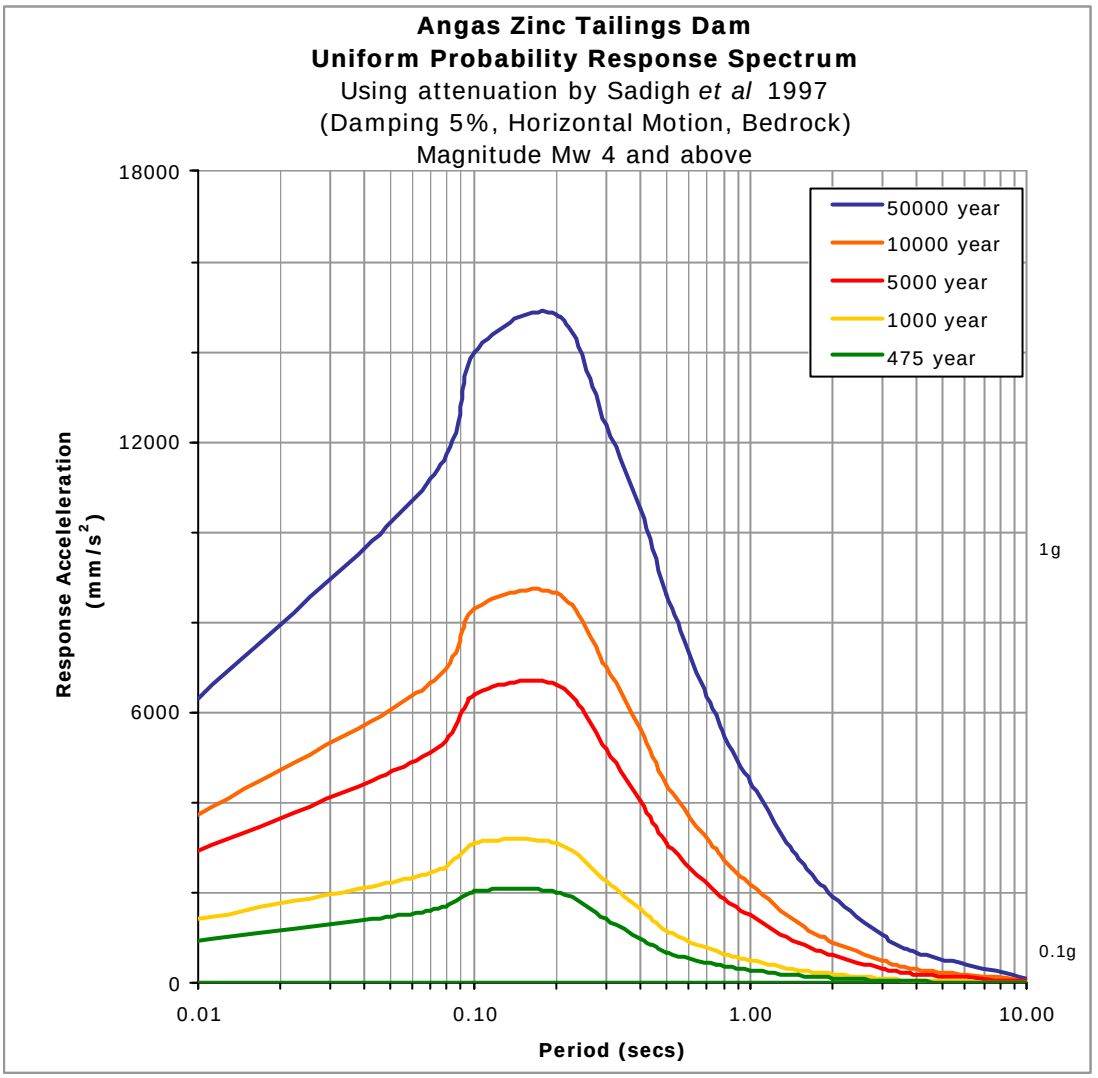

Figure 5: Response spectra acceleration (log-linear)

3 Results

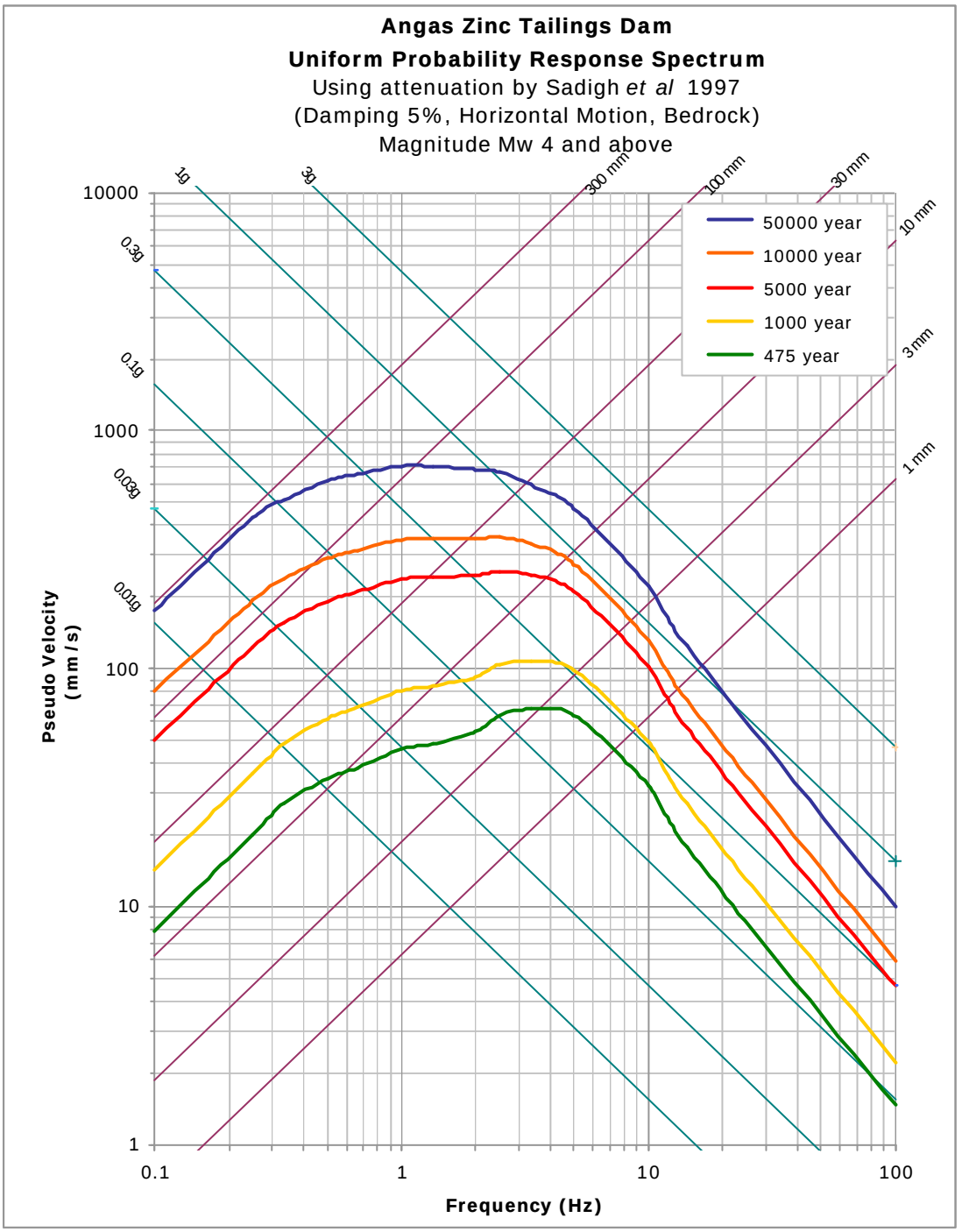

Figure 6: Response spectra pseudo-velocity recurrence

The PGA for the proposed tailings dam site has been calculated as being approximately 0.1g for a return period of 500 years (10% chance of exceedence in 50 years) when considering earthquakes of Richter magnitude ML 4 and above. This PGA value is moderately high by Australian standards and is similar to the value of Newcastle. However when considering world standards this is still relatively low; Wellington, New Zealand has a PGA for the same period of approximately 0.5g, as does Los Angeles, California.

The Angas Zinc Tailings Dam site is expected to experience earthquake intensities of MMI 6 – when standard housing starts to experience damage – approximately every 200 to 300 years.

Site response has not been considered within this report and the calculations have been made assuming the area is situated on bedrock.

We believe that the results presented in this report are in accordance with the best practices of this time.

Brown, A. and G. Gibson, 2000: *Reassessment of Earthquake Hazard in Australia*. Twelfth World Conference on Earthquake Engineering, Auckland, New Zealand, February 2000.

Cornell, C.A., 1968: *Engineering Seismic Risk Analysis*. Bulletin Seismological Society of America, 58, 5, 1583-1606, Oct.

Gaull, B.A., M.O. Michael-Leiba & J.M.W. Rynn, 1990: *Probabilistic earthquake risk maps of Australia*; Aust. Journal of Earth Sci., Vol 37, 169-187.

Sadigh, K., C. Y. Chang, J. A. Egan, F. Makdisi and R. R. Youngs, 1997: *Attenuation relationships for shallow crustal earthquakes based on Californian strong motion data*. SRL, 68(1) p. 180-189.

Appendix A – Ground Motion Recurrence Tables

PGA (mm/s^2)	Mw 0 and above Return Period (Years)	Mw 2 and above Return Period (Years)	Mw 3 and above Return Period (Years)	Mw 4 and above Return Period (Years)	Mw 5 and above Return Period (Years)
10	0.0297	0.491	1.93	7.09	24.1
15	0.0426	0.665	2.66	10.1	34.6
20	0.0558	0.824	3.31	13	45.6
30	0.0841	1.12	4.45	17.9	67.4
50	0.148	1.71	6.46	25.9	105
70	0.225	2.33	8.4	32.8	137
100	0.362	3.35	11.3	42.3	175
150	0.651	5.34	16.7	57.6	229
200	1.02	7.71	22.7	73.5	277
300	2.01	13.7	37.2	108	372
500	5.14	31.4	77.2	195	572
700	10	58	134	308	805
1000	21.3	118	258	540	1230
1500	53.5	288	594	1130	2230
2000	107	574	1140	2040	3680
3000	302	1650	3190	5340	8640
5000	1240	7440	14300	22800	33800
7000	3380	22600	45100	71700	103000
10000	10300	83800	181000	301000	439000
15000	39900	432000	1120000	2180000	3510000
20000	108000	1480000	4650000	10900000	20700000
30000	469000	9140000	38100000	129000000	356000000
50000	3310000	102000000	618000000	3500000000	19000000000

Table 1: Angas Zinc Tailings Dam PGA Recurrence results

	Response Spectra (mm/s^2)				
Period (secs)	475 Year	1000 Year	5000 Year	10000 Year	50000 Year
0.01	920.81	1402.38	2916.48	3738.70	6293.56
0.07	1607.20	2444.12	5114.62	6640.48	11181.80
0.10	2031.54	3092.88	6397.44	8284.92	13965.00
0.20	2009.00	3096.80	6618.92	8649.48	14827.40
0.30	1415.12	2251.06	5187.14	7005.04	12387.20
0.40	1001.56	1645.42	4037.60	5621.28	10515.40
0.50	680.51	1157.38	3104.64	4404.12	8618.12
0.75	404.45	710.40	2027.62	2955.68	5930.96
1.00	289.49	510.68	1497.44	2191.28	4462.92
1.50	161.01	287.73	883.57	1319.08	2757.72
2.00	108.58	194.04	605.44	911.69	1925.70
3.00	57.09	101.92	327.32	502.84	1072.12
4.00	31.76	57.01	194.04	304.39	677.18

Table 2: Angas Zinc Tailings Dam Response Spectra results (M4 and above, bedrock)

6 Appendices

PGV (mm/s)	Mw 0 and above Return Period (Years)	Mw 4 and above Return Period (Years)
1	0.112	1.750
2	0.423	3.560
4	1.63	8.43
8	6.25	19.00
12	13.7	30.3
20	36.9	56.8
32	92.3	111.0
60	310	322
100	805	805
150	1670	1670
200	2810	2810
300	5850	5840
400	9910	9900
600	21200	21200
900	48900	48800
1200	95200	95000
1500	167000	167000
2000	387000	386000
3000	1850000	1850000
6000	288000000	288000000

Table 3: Angas Zinc Tailings Dam PGV Recurrence results

Intensity (MMI)	Mw 0 and above Return Period (Years)	Mw 4 and above Return Period (Years)
0	0.077	1.520
1	0.285	2.770
2	1.09	6.51
3	4.22	14.90
4	16.1	33.2
5	62.2	81.4
6	239	252
7	874	874
8	3050	3040
9	10700	10700
10	41800	41700
11	229000	229000
12	3540000	3530000

Table 4: Angas Zinc Tailings Dam MMI Recurrence results