APPENDIX F: EARTHQUAKES IN THE CAIRNS REGION

AGSO World Earthquake Database 30-Nov-1998
Date: 01 January 1840 to 30 June 1998
Latitude: 14°S to 20°S
Longitude: 143.5°E to 147.5°E
Depth: 0 km to 100 km
Magnitude: greater than 0

Source	Date	UTC	Lat	Long	Depth	Local magnitude	Authority
RYNN	18940716	124500	-18.3	143.5	0	4	E/M
UQ	18960227	110000	-16.8	146.5	25	4.2	UQ
UQ	19000509	0	-19.3	146.8	0	2.2	UQ
UQ	19010627	0	-18.6	146.2	10	2.2	UQ
UNIQ	19131218	135400	-20	147	33	5.7	(I)
UQ	19280514	24655	-15	144	10	5.3	UQ
UQ	19420410	30000	-16.2	145.7	10	3.8	UQ
UQ	19500616	110000	-17.3	145.6	10	2.2	UQ
UQ	19500619	90000	-17.5	145.5	12	4.0	RYNN
JONES	19540504	170500	-17.7	146		3.2	(I)
RYNN	19570531	161548.1	-18.5	145.6		3.5	E/M
UQ	19571010	220349	-17.1	146.5	10	2.8	UQ
RYNN	19571109	212315.6	-18.8	146		3.5	E/M
RYNN	19571126	50539	-18.6	145.6		3.5	E/M
UQ	19580531	161554	-18.5	146.7	10	2.5	UQ
UQ	19580707	170632	-15.4	144	5	4.4	UQ
RYNN	19580730	21155	-19.2	145.7		3	E/M
RYNN	19581004	21020.1	-18.5	145.6		3.5	E/M
RYNN	19581105	51603.1	-18.7	145.5		3.5	E/M
RYNN	19581111	61222.1	-18.6	145.6		3.5	E/M
UQ	19581201	102000	-16.8	146.5	10	3	UQ
RYNN	19581201	103531	-16.5	145.5	10	4.7	(I)
UQ	19581201	103800	-16.8	146	10	3	UQ
UQ	19581201	160000	-16.8	146	10	3	UQ
UQ	19581201	180427.5	-16.8	146.5	10	3.2	UQ
UQ	19590102	194324.5	-17	146.5	10	3.4	UQ
UQ	19610227	162850	-16.5	144	10	3.7	UQ
UQ	19610624	93037	-17.8	145.6	10	2.9	UQ
UQ	19610819	22651.4	-15.8	144.7	10	4.1	UQ
UQ	19620216	121633	-14	144	5	4.4	UQ
UQ	19630328	41000	-17.6	146.2		3.2	(I)
UQ	19630328	42952.5	-17.6	146.2	7	3	UQ
UQ	19630622	195130.6	-18.15	144	15	3.4	UQ
UQ	19640115	90013.5	-18.15	144	15	4.2	UQ
UQ	19640213	73009	-18.15	144	15	2.5	UQ
UQ	19640213	74011	-18.15	144	15	2.5	UQ
UQ	19640223	122228.9	-18.2	144	15	3.5	UQ
UQ	19640224	83233	-18.15	144	15	3.1	UQ
UQ	19640224	164228	-18.15	144	15	2.8	UQ
UQ	19640225	165909	-18.15	144	15	3.1	UQ

UQ	19640831	181708	-18.15	144	15	3	UQ
UQ	19650216	124812	-18.15	144	15	3.4	UQ
UQ	19650328	73930.3	-18.8	145.8	10	2.3	UQ

Cairns earthquake catalogue (continued)

Source	Date	UTC	Lat	Long	Depth	Local magnitude	Authority
UQ	19660927	134115.5	-17.1	146.5	10	3.4	UQ
UQ	19670209	113050.1	-15.8	144.7	10	3.9	UQ
UQ	19670713	70946	-18.15	144	15	3.2	UQ
UQ	19671119	222514	-18.15	144	15	4.2	UQ
UQ	19671210	95850	-18.15	144	15	2.8	UQ
UQ	19671229	182415	-15.9	144	3	3.7	UQ
UQ	19680704	2313	-18.8	145.8		1.6	UQ
UQ	19680704	2316	-18.8	145.8		1.9	UQ
RYNN	19690111	210514	-18.3	145.7		3	E/M
RYNN	19710917	221316	-15	144	0	4	E/M
RYNN	19720505	133250	-19	146.5		3	E/M
RYNN	19740506	165511	-17.5	146	0	4	E/M
RYNN	19750405	141317	-19.8	145.7		3	E/M
RYNN	19750919	140454.5	-18.2	143.5		3.5	E/M
RYNN	19760309	101333.5	-18.2	143.5		3.5	E/M
UQ	19790613	1822	-18.1	147.2		1.9	UQ
UQ	19810226	457	-19.717	147.181		0.6	UQ
UQ	19810311	716	-19.018	147.484		1.4	UQ
UQ	19810325	628	-19.791	147.342		0.5	UQ
UQ	19810411	9	-19.459	146.981		1.1	UQ
UQ	19810508	504	-19.512	146.836		1.5	UQ
UQ	19810527	51	-19.785	147.23		0.4	UQ
UQ	19810710	153	-19.742	146.792		1.1	UQ
UQ	19810721	200	-19.197	146.776		0.9	UQ
UQ	19810807	558	-19.726	147.283		1.2	UQ
UQ	19810824	651	-19.718	147.305		1.5	UQ
UQ	19810902	650	-19.727	147.334		1.6	UQ
UQ	19810909	419	-19.711	147.296		1.1	UQ
UQ	19810930	57	-19.648	146.782		1.2	UQ
UQ	19811207	412	-19.706	147.272		1.7	UQ
UQ	19820115	2043	-19.49	146.7		1.4	UQ
UQ	19820315	2240	-19.782	147.225		1.4	UQ
UQ	19820323	425	-19.796	147.382		1.5	UQ
UQ	19820326	2225	-19.382	146.524		1.1	UQ
UQ	19820417	53	-19.444	146.943		1	UQ
GSQ	19820815	30435.6	-18.901	146.544	10	1.4	MD
UQ	19830517	1554	-19.661	144.097		1.8	UQ
UQ	19830709	1808	-18.507	146.557		1.6	UQ
UQ	19840612	1055	-18.794	147.005		1.8	UQ
UQ	19840717	620	-19.637	146.545		2	UQ
UQ	19850326	1027	-18.724	147.304		1.8	UQ
UQ	19850517	759	-19.235	147.07		1.5	UQ
UQ	19850517	800	-19.365	146.807		1.4	UQ
UQ	19850523	714	-19.555	146.975		1.3	UQ
UQ	19851108	819	-19.717	146.785		2	UQ

UQ	19860513	2224	-19.462	146.87		1.1	UQ
UQ	19861106	751	-19.79	146.437		1.4	UQ
UQ	19861214	132	-19.966	147.459		1.2	UQ
UQ	19870529	638	-19.717	146.771		1.3	UQ
UQ	19871224	917	-18.51	145.796		1.9	UQ
UQ	19890813	729	-18.969	146.794		2.7	UQ

Cairns earthquake catalogue (continued)

Source	Date	UTC	Lat	Long	Depth	Local magnitude	Authority
UQ	19890814	246	-19.055	146.738		2.9	UQ
BMR	19891116	104324.7	-17.386	146.296	5	4	BMR
QUNI	19900416	64433.4	-18.045	145.816	2	1.2	QUNI
QUNI	19900513	53524.3	-17.292	146.144	8	4.3	QUNI
QUNI	19900513	213700	-17.209	146.23	8	1.6	QUNI
QUNI	19900517	93600	-17.209	146.23	8	1.6	QUNI
QUNI	19900519	115800	-17.209	146.23	8	1.9	QUNI
QUNI	19900519	120700	-17.209	146.23	8	1.8	QUNI
QUNI	19900525	235800	-17.209	146.23	8	2	QUNI
QUNI	19900528	4200	-17.209	146.23	8	1.6	QUNI
QUNI	19900726	75800	-17.441	145.97	8	0.8	QUNI
QUNI	19900813	45200	-17.209	146.23	8	1.3	QUNI
QUNI	19900813	45500	-17.209	146.23	8	1.6	QUNI
QUNI	19900815	115643.5	-17.263	146.286	17	2.6	QUNI
QUNI	19900819	15800	-17.441	145.97	8	0.9	QUNI
QUNI	19900825	222800	-17.209	146.23	8	1.5	QUNI
QUNI	19900905	225730	-17.209	146.23	8	1.5	QUNI
QUNI	19900905	225731.5	-17.209	146.23	8	1.1	QUNI
QUNI	19900915	34100	-17.441	145.97	8	0.6	QUNI
QUNI	19900915	101604.1	-18.57	145.537	4	1.4	QUNI
QUNI	19901007	45100	-17.209	146.23	8	1.2	QUNI
QUNI	19901017	123915.2	-18.718	143.644	8	2.4	QUNI
QUNI	19901029	173032	-17.441	145.97	17	2.4	QUNI
QUNI	19901030	15900	-17.209	146.23	8	1.4	QUNI
QUNI	19901103	200131.3	-18.479	147.091	11	2.6	QUNI
QUNI	19901103	214500	-17.209	146.23	8	1.1	QUNI
QUNI	19901104	135900	-17.209	146.23	8	1.8	QUNI
QUNI	19901210	232300	-17.209	146.23	8	1.1	QUNI
QUNI	19901211	115700	-17.63	145.48	8	0.5	QUNI
QUNI	19901211	131100	-17.63	145.48	8	0.7	QUNI
QUNI	19910113	130000	-17.209	146.23	8	2	QUNI
QUNI	19910131	140200	-17.209	146.23	8	1.9	QUNI
QUNI	19910204	55100	-17.209	146.23	8	1.1	QUNI
QUNI	19910213	214400	-17.63	145.48	8	2	QUNI
QUNI	19910213	220800	-17.209	146.23	8	1.3	QUNI
QUNI	19910217	31917	-17.211	146.297	15	3.2	QUNI
QUNI	19910228	215200	-17.209	146.23	8	1.6	QUNI
QUNI	19910303	234700	-17.209	146.23	8	0.9	QUNI
QUNI	19910303	235000	-17.209	146.23	8	1.2	QUNI
QUNI	19910304	233100	-17.209	146.23	8	0.9	QUNI
QUNI	19910308	130000	-17.209	146.23	8	0.9	QUNI
QUNI	19910318	170200	-17.209	146.23	8	1.6	QUNI
QUNI	19910320	183500	-17.209	146.23	8	0.8	QUNI

QUNI	19910322	154500	-17.209	146.23	8	1.3	QUNI
QUNI	19910324	23500	-17.209	146.23	8	1.5	QUNI
QUNI	19910326	31400	-17.209	146.23	8	1.5	QUNI
QUNI	19910405	42900	-17.209	146.23	8	2.1	QUNI
QUNI	19910405	123900	-17.209	146.23	8	0.9	QUNI
QUNI	19910408	144000	-17.209	146.23	8	1.7	QUNI
QUNI	19910408	202600	-17.209	146.23	8	1.8	QUNI
QUNI	19910410	2400	-17.209	146.23	8	1.2	QUNI
QUNI	19910412	233800	-17.209	146.23	8	1.4	QUNI

Cairns earthquake catalogue (continued)

Source	Date	UTC	Lat	Long	Depth	Local magnitude	Authority
QUNI	19910414	10200	-17.209	146.23	8	1	QUNI
QUNI	19910420	202400	-17.209	146.23	8	1	QUNI
QUNI	19910425	110500	-17.209	146.23	8	1.7	QUNI
QUNI	19910502	84700	-17.209	146.23	8	1.1	QUNI
QUNI	19910502	214300	-17.209	146.23	8	1.1	QUNI
QUNI	19910509	163100	-17.63	145.48	8	0.4	QUNI
QUNI	19910522	100900	-17.63	145.48	8	0.1	QUNI
QUNI	19910606	92800	-17.209	146.23	8	1.1	QUNI
QUNI	19910607	24200	-17.209	146.23	8	1.8	QUNI
QUNI	19910611	211800	-17.209	146.23	8	2	QUNI
QUNI	19910612	82100	-17.209	146.23	8	1.9	QUNI
QUNI	19910628	85400	-17.209	146.23	8	1.1	QUNI
QUNI	19910701	231936	-17.253	146.371	8	2.7	QUNI
QUNI	19910708	800	-17.209	146.23	8	1.1	QUNI
QUNI	19910716	115	-17.63	145.48		-1	QUNI
QUNI	19910719	143000	-17.209	146.23	8	0.9	QUNI
QUNI	19910723	115200	-17.209	146.23	8	0.9	QUNI
QUNI	19910728	600	-17.209	146.23	8	1	QUNI
QUNI	19910806	141148.2	-18.222	143.506	17	4.8	QUNI
QUNI	19910809	74100	-17.209	146.23	8	1.3	QUNI
QUNI	19910823	212900	-17.63	145.48	8	1.7	QUNI
QUNI	19910920	173200	-17.209	146.23	8	1.4	QUNI
QUNI	19911003	41313.1	-17.277	146.285	8	1.8	QUNI
QUNI	19911009	94900	-17.209	146.23	8	1.1	QUNI
QUNI	19911028	231631.8	-17.191	146.37	8	1.3	QUNI
QUNI	19911029	232902	-17.367	146.279	13	1.7	QUNI
QUNI	19911130	213400	-17.209	146.23	8	0.9	QUNI
QUNI	19911205	71800	-17.209	146.23	8	1	QUNI
QUNI	19911209	134700	-17.209	146.23	8	0.6	QUNI
QUNI	19911214	133300	-17.209	146.23	8	0.8	QUNI
QUNI	19911215	2900	-17.209	146.23	8	1.1	QUNI
QUNI	19911221	211200	-17.209	146.23	8	1.6	QUNI
QUNI	19911230	143600	-17.63	145.48	8	0.1	QUNI
QUNI	19920103	70900	-17.633	145.484	0	0.7	QUNI
QUNI	19920105	43400	-17.633	145.484	0	0.5	QUNI
QUNI	19920106	104000	-17.633	145.484	0	0.9	QUNI
QUNI	19920115	131600	-17.633	145.484	0	1.5	QUNI
QUNI	19920115	134500	-17.633	145.484	0	1	QUNI
QUNI	19920116	221700	-17.633	145.484	0	1.5	QUNI

QUNI	19920117	174400	-17.633	145.484	0	1.1	QUNI
QUNI	19920117	194700	-17.633	145.484	0	0.5	QUNI
QUNI	19920117	225643.3	-17.326	146.156	8	2.3	QUNI
QUNI	19920118	74900	-17.633	145.484	0	0.9	QUNI
QUNI	19920119	234800	-17.633	145.484	0	0.1	QUNI
QUNI	19920124	51600	-17.633	145.484	0	0.5	QUNI
QUNI	19920129	120200	-17.633	145.484	0	2.7	QUNI
QUNI	19920130	140500	-17.633	145.484	0	0.9	QUNI
QUNI	19920217	225900	-17.633	145.484	0	1.2	QUNI
QUNI	19920324	185000	-17.633	145.484	0	0.6	QUNI
QUNI	19920330	2359	-17.633	145.484		-0.1	QUNI
QUNI	19920608	45433.6	-18.129	145.434	8	1.3	QUNI

Cairns earthquake catalogue (continued)

Source	**Date**	**UTC**	**Lat**	**Long**	**Depth**	**Local magnitude**	**Authority**
QUNI	19920625	104800	-17.633	145.484	0	1.5	QUNI
QUNI	19920625	144400	-17.633	145.484	0	1.1	QUNI
QUNI	19920625	221000	-17.633	145.484	0	1.5	QUNI
QUNI	19920724	4100	-17.633	145.484	0	1.6	QUNI
QUNI	19920726	173950.9	-17.425	146.239	6	2.1	QUNI
QUNI	19920731	214800	-17.633	145.484	0	1.4	QUNI
QUNI	19920827	5051.5	-17.552	144.411	0	1.6	QUNI
QUNI	19920828	11700	-17.633	145.484	0	0.8	QUNI
QUNI	19920830	55400	-17.63	145.48	0	1	QUNI
QUNI	19920901	84300	-17.633	145.484	0	1	QUNI
QUNI	19920903	12732.4	-17.482	144.725	0	1.6	QUNI
QUNI	19920910	105544	-17.324	146.174	8	1.5	QUNI
QUNI	19920914	140200	-17.633	145.484	0	0.8	QUNI
QUNI	19920922	232316.8	-17.262	146.219	8	1.9	QUNI
QUNI	19920926	141400	-17.112	145.484	0	1.3	QUNI
QUNI	19920927	135100	-17.633	145.484	0	1.3	QUNI
QUNI	19920927	143400	-17.633	145.484	0	1.2	QUNI
QUNI	19920929	13500	-17.633	145.484	0	1.6	QUNI
QUNI	19921001	174300	-17.633	145.484	0	1.4	QUNI
QUNI	19921029	82600	-17.633	145.484	0	1.3	QUNI
QUNI	19921103	80600	-17.633	145.484	0	1.6	QUNI
QUNI	19921106	40900	-17.633	145.484	0	3.5	QUNI
QUNI	19921118	163800	-17.633	145.484	0	1	QUNI
QUNI	19921221	13200	-17.633	145.484	0	1.2	QUNI
QUNI	19921221	13400	-17.633	145.484	0	0.8	QUNI
QUNI	19921222	55900	-17.633	145.484	0	1.2	QUNI
QUNI	19921224	11200	-17.633	145.484	0	1.5	QUNI
QUNI	19930419	113200	-17.633	145.484	0	1.7	QUNI
UQ	19930429	54800	-17.633	145.484	0	2.1	QUNI
UQ	19930503	185700	-17.633	145.484	0	1.1	QUNI
QUNI	19930518	190500	-17.633	145.484	0	1.5	QUNI
QUNI	19930610	110300	-17.63	145.48	0	1.1	QUNI
QUNI	19930611	105400	-17.63	145.48	0	0.9	QUNI
QUNI	19930611	111800	-17.633	145.484	0	0.6	QUNI
QUNI	19930708	104800	-17.633	145.484	0	2.2	MD
QUNI	19930717	173000	-17.633	145.484	0	1.1	QUNI

QUNI	19930727	41800	-17.633	145.484	0	1.4	QUNI
QUNI	19930812	162500	-17.633	145.484	0	2	QUNI
QUNI	19930812	162600	-17.633	145.484	0	1.4	QUNI
QUNI	19930812	193200	-17.633	145.484	0	1.5	QUNI
QUNI	19930812	232600	-17.633	145.484	0	1.3	QUNI
QUNI	19930812	235300	-17.633	145.484	0	1.3	QUNI
QUNI	19930813	52400	-17.633	145.484	0	1.8	QUNI
QUNI	19930813	232800	-17.633	145.484	0	1.5	QUNI
QUNI	19930813	232830	-17.633	145.484	0	1.8	QUNI
QUNI	19930820	220745.3	-16.859	143.762	8	2.9	QUNI
QUNI	19930821	25127.2	-17.11	144.289	8	2.5	QUNI
QUNI	19930821	60600	-17.633	145.484	0	1.7	QUNI
QUNI	19930821	81500	-17.633	145.484	0	1.5	QUNI
QUNI	19930821	90500	-17.633	145.484	0	1.6	QUNI
QUNI	19930822	82844.9	-17.057	144.143	8	2.5	QUNI

Cairns earthquake catalogue (continued)

Source	Date	UTC	Lat	Long	Depth	Local magnitude	Authority
QUNI	19930822	102700	-17.633	145.484	0	1.4	QUNI
QUNI	19930823	215300	-17.633	145.484	0	1.4	QUNI
QUNI	19930826	173200	-17.633	145.484	0	1.4	QUNI
QUNI	19930913	120700	-17.633	145.484	0	1.4	QUNI
QUNI	19931012	63900	-17.633	145.484	0	1.2	QUNI
QUNI	19931030	82100	-17.633	145.484	0	1.3	QUNI
QUNI	19940403	192414.1	-17.186	146.372	18	3.4	QUNI
QUNI	19940904	10802.1	-16.987	144.502	8	4	QUNI
AUST	19950317	174114.4	-18.25	146	5	3.2	AUST
QUNI	19951030	171842.2	-19.487	147.426	10	2.4	QUNI
QUNI	19971124	155514.1	-16.767	145.696	5	2.5	QUNI
QUNI	19971124	183847.1	-16.765	145.748	5	2.1	QUNI
QUNI	19990211	124524.0	-17.2	144.8	10	3.7	QUNI

APPENDIX G: MODIFIED MERCALLI (MM) SCALE OF EARTHQUAKE INTENSITY (after Dowrick, 1996)

MM I *People*

Not felt except by a very few people under exceptionally favourable circumstances.

MM II *People*

Felt by persons at rest, on upper floors or favourably placed.

MM III *People*

Felt indoors; hanging objects may swing, vibrations may be similar to passing of light trucks, duration may be estimated, may not be recognised as an earthquake.

MM IV *People*

Generally noticed indoors but not outside. Light sleepers may be awakened. Vibration may be likened to the passing of heavy traffic, or to the jolt of a heavy object falling or striking the building.

Fittings

Doors and windows rattle. Glassware and crockery rattle. Liquids in open vessels may be slightly disturbed. Standing motorcars may rock.

Structures

Walls and frame of building are heard to creak, and partitions and suspended ceilings in commercial buildings may be heard to creak.

MM V *People*

Generally felt outside, and by almost everyone indoors. Most sleepers awakened. A few people alarmed.

Fittings

Small unstable objects are displaced or upset. Some glassware and crockery may be broken. Hanging pictures knock against the wall. Open doors may swing. Cupboard doors secured by magnetic catches may open. Pendulum clocks stop, start, or change rate.

Structures

Some windows Type I cracked. A few earthenware toilet fixtures cracked.

MM VI *People*

Felt by all. People and animals alarmed. Many run outside. Difficulty experienced in walking steadily.

Fittings

Objects fall from shelves. Pictures fall from walls. Some furniture moved on smooth floors, some unsecured free-standing fireplaces moved. Glassware and crockery broken. Very unstable furniture overturned. Small church and school bells ring. Appliances move on bench or table tops. Filing cabinets or “easy glide” drawers may open (or shut).

Structures
Slight damage to Buildings Type I. Some stucco or cement plaster falls. Windows Type I broken. Damage to a few weak domestic chimneys, some may fall.

Environment
Trees and bushes shake, or are heard to rustle. Loose material may be dislodged from sloping ground, e.g. existing slides, talus slopes, shingle slides.

MM VII *People*
General alarm. Difficulty experienced in standing. Noticed by drivers of motorcars who may stop.

Fittings
Large bells ring. Furniture moves on smooth floors, may move on carpeted floors. Substantial damage to fragile contents of buildings.

Structures
Unreinforced stone and brick walls cracked. Buildings Type I cracked with some minor masonry falls. A few instances of damage to Buildings Type II. Unbraced parapets, unbraced brick gables, and architectural ornaments fall. Roofing Loose tiles, especially ridge tiles may be dislodged. Many unreinforced chimneys damaged, often falling from roof-line. Water tanks Type I burst. A few instances of damage to brick veneers and plaster or cement-based linings. Unrestrained water cylinders (Water Tanks Type II) may move and leak. Some windows Type II cracked. Suspended ceilings damaged.

Environment
Water made turbid by stirred up mud. Small slides such as falls of sand and gravel banks, and small rock-falls from steep slopes and cuttings. Instances of settlement of unconsolidated or wet, or weak soils. Some fine cracks appear in sloping ground. A few instances of liquefaction (i.e. small water and sand ejections).

MM VIII *People*
Alarm may approach panic. Steering of motor cars greatly affected.

Structures
Buildings Type I, heavily damaged, some collapse. Buildings Type II damaged, some with partial collapse. Buildings Type III damaged in some cases. A few instances of damage to Structures Type IV. Monuments and pre-1976 elevated tanks and factory stacks twisted or brought down. Some pre-1965 infill masonry panels damaged. A few post-1980 brick veneers damaged. Decayed timber piles of houses damaged. Houses not secured to foundation may move. Most unreinforced domestic chimneys damaged, some below roof-line, many brought down.

Environment
Cracks appear on steep slopes and in wet ground. Small to moderate slides in roadside cuttings and unsupported excavations. Small water and sand ejections and localised lateral spreading adjacent to streams, canals, lakes, etc.

MM IX *Structures*

Many buildings Type I destroyed. Buildings Type II heavily damaged, some collapse. Buildings Type III damaged, some with partial collapse. Structures Type IV damaged in some cases, some with flexible frames seriously damaged. Damage or permanent distortion to some Structures Type V. Houses not secured to foundations shifted off. Brick veneers fall and expose frames.

Environment
Cracking of the ground conspicuous. Landsliding general on steep slopes. Liquefaction effects intensified and more widespread, with large lateral spreading and flow sliding adjacent to streams, canals, lakes, etc.

MM X *Structures*
Most Buildings Type I destroyed. Many Buildings Type II destroyed. Buildings Type III heavily damaged, some collapse. Structures Type IV damaged, some with partial collapse. Structures Type V moderately damaged, but few partial collapses. A few instances of damage to Structures Type VI. Some well-built timber buildings moderately damaged (excluding damage from falling chimneys). Dams, dykes, and embankments seriously damaged. Railway lines slightly bent. Cement and asphalt roads and pavements badly cracked or thrown into waves.

Environment
Landsliding very widespread in susceptible terrain, with very large rock masses displaced on steep slopes. Landslide dams may be formed. Liquefaction effects widespread and severe.

MM XI *Structures*
Most Buildings Type II destroyed. Many Buildings Type III destroyed. Structures Type IV heavily damaged, some collapse. Structures Type V damaged, some with partial collapse. Structures Type VI suffer minor damage, a few moderately damaged.

MM XII *Structures*
Most Buildings Type III destroyed. Many Structures Type IV destroyed. Structures Type V heavily damaged, some with partial collapse some collapse. Structures Type VI moderately damaged.

Construction types

Buildings Type I Buildings with low standard of workmanship, poor mortar, or constructed of weak materials like mud brick or rammed earth. Soft storey structures (e.g. shops) made of masonry, weak reinforced concrete, or composite materials (e.g. some walls timber, some brick) not well tied together. Masonry buildings otherwise conforming to Buildings Type I–III, but also having heavy unreinforced masonry towers. (Buildings constructed entirely of timber must be of extremely low quality to be Type I).

Buildings Type II Buildings of ordinary workmanship, with mortar of average quality. No extreme weakness, such as inadequate bonding of the corners, but neither designed nor reinforced to resist lateral forces. Such buildings not having heavy unreinforced masonry towers.

Buildings Type III Reinforced masonry or concrete buildings of good workmanship and with sound mortar, but not formally designed in detail to resist earthquake forces.

Structures Type IV Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special collapse or damage limiting measures taken (mid 1930s to c. 1970 for concrete and to c. 1980 for other materials).

Structures Type V Buildings and bridges designed and built to resist earthquakes to normal use standards, i.e. no special damage limiting measures taken, other than code requirements, dating from since c. 1970 for concrete and c. 1980 for other materials.

Structures Type VI Structures dating from c. 1980 with well defined foundation behaviour, which have been especially designed for minimal damage, e.g. seismically isolated emergency facilities, some structures with dangerous or high (value) contents, or new generation low damage structures.

Windows
Type I – Large display windows, especially shop windows.
Type II – Ordinary sash or casement windows.

Water tanks
Type I – External, stand mounted, corrugated iron water tanks.
Type II – domestic hot-water cylinders unrestrained except by supply and delivery pipes.

APPENDIX H: METHOD TO ESTIMATE URBAN EARTHQUAKE HAZARD IN CAIRNS

NOTE: <u>Limitations of the earthquake hazard maps</u>

The maps were produced mainly from considerations of published geology and sparse geotechnical data. The resultant zonations are largely based on the 1:100 000 scale mapped geological units. The maps indicate the earthquake ground shaking hazard at a generalised local level. They should not be considered accurate at a site-specific level and should not be used to replace site investigations where required by building codes or local regulations.

We used a four-stage method to estimate the earthquake hazard in Cairns. We first identified an appropriate rock response spectrum to use as a basis for regional hazard estimates. Next, we prepared urban earthquake hazard maps (microzonation maps) for Cairns in a two-stage process. In the final stage, we adopted response spectra to describe the hazard in Cairns on each of the site classes in the urban hazard maps. Briefly, these site classes are rock, hard or very dense sediments, stiff sediments, and soft sediments.

A description of each of the four stages of earthquake hazard estimation is given below.

Stage 1 - Estimate the Regional Earthquake Hazard

Three estimates of regional earthquake hazard are known for Cairns. All three estimates relate to a 10% probability of exceedence in 50 years at 'firm' sites. The 10% probability of exceedence in 50 years corresponds to an AEP of approximately 1/475 if the earthquake occurrence is assumed Poissonian.

The first estimates are found in Gaull and others (1990). They estimated a Modified Mercalli Intensity (MM) of approximately MM VI, a peak horizontal ground acceleration (PGA) of approximately 0.04 g, and a peak horizontal ground velocity (PGV) of around 30 mm s^{-1}. The second estimate is found in *AS1170.4-1993*. The earthquake hazard map in *AS1170.4-1993* was compiled by an Australian Standards Committee and was a development of the work of Gaull and others (1990). The acceleration coefficient of 0.06 for a 'firm' site in the Cairns area in *AS1170.4-1993* is equivalent to a PGA value of approximately 0.06 g. The third estimate of hazard originates from QUAKES (e.g., Cuthbertson and Jaume, 1996). They estimated a significantly higher PGA of around 0.2 g on rock, in line with their estimates of PGA for Queensland 2-3 times higher than previous estimates. They also estimated a higher MMI than Gaull and others, and a similar value of PGV to the estimate of Gaull and others. A comparison of the three studies is shown in **Table H1**.

Table H1: Earthquake hazard for Cairns with a 10% probability of exceedence in 50 years

PGA (g)	PGV (mm s^{-1})	MMI	Source
~0.04	~30	~VI	Gaull and others, 1990
~0.06	-	-	*AS1170.4-1993*
~0.2	~25	V-VII	Cuthbertson and Jaume, 1996

Considerable debate has surrounded the contrasting earthquake hazard estimates of Cuthbertson and Jaume (1996) and those in *AS1170.4-1993.* We prefer to use the acceleration coefficient in *AS1170.4-1993* until new estimates of earthquake hazard for Queensland are made under the current revision of *AS1170.4-1993*. The revised standard is expected to be published within several years.

The earthquake hazard for Cairns is moderate by Australian standards. More than half the area of Australia in the earthquake hazard maps in *AS1170.4-1993,* including Cairns, has an acceleration coefficient in the range 0.05 - 0.1. The coefficient values across Australia range from a minimum 0.03 to highs of up to 0.22 in 'bullseye' areas.

Spectral values of earthquake hazard for Cairns on rock foundation can be taken from the new response spectrum proposed for the revision of *AS1170.4-1993* (Somerville and others, 1998). The elastic, 5% damped spectrum, normalised to a PGV of 50 mm s^{-1}, is shown in **Figure H1**.

The spectrum may be scaled by selecting values for peak ground acceleration, velocity, or displacement. It was derived from recordings of reverse faulting earthquakes of magnitude 6.0 ± 0.6. However, limitations on scaling will occur for scenarios where the major contribution to hazard does not arise from earthquakes of those magnitudes. For example, if larger earthquakes are being considered the long period part of the spectrum should be enhanced (Somerville and others, 1998).

Scaling the Pseudo Spectral Relative Velocity (PSRV) values in **Figure H1** by a factor of 0.6 provides spectral estimates of the earthquake hazard on rock in Cairns that may be appropriate for a 10% probability of exceedence in 50 years. This factor of 0.6 is the ratio between the PGV estimate of Gaull and others (1990) for the Cairns region of approximately 30 mm s^{-1} and the PGV of 50 mm s^{-1} of the normalised spectrum.

However, we remind the reader of the uncertainties in this estimate arising from the differences in hazard estimated by various authors.

Additional estimates of earthquake hazard for the Cairns region are required so that quantitative comparisons can be made of the earthquake risk to Cairns and the extreme wind, rainfall and inundation risks from tropical cyclones. Known estimates of earthquake hazard all refer to a 10% probability of exceedence in 50 years. Estimates of the regional earthquake hazard for AEPs of 1%, 0.1%, 0.01%, and the Maximum Probable Event would be valuable.

Stage 2 - Subdivide the City into Zones of Different Earthquake Hazard According to Site Class (see **Figure 4.6** and **Figure 4.7**).

We used the physical properties of the rocks and the mean seismic shear wave velocity to a depth of 30 m below the earth's surface (Vs) as the fundamental parameters to describe the localised earthquake hazard. Site Classes A-D defined from the combination of these factors are shown in **Table H2**.

Our site classifications are based on those developed for the 1994 provisions of the US National Earthquake Hazard Reduction Program (NEHRP). The provisions were published in FEMA (1995) and we have referred to the version reproduced by Hwang and others (1997). Many of the correlations between physical properties of the rock or sediment and the shear wave velocity were produced from extensive measurements of Vs, lithological descriptions and geotechnical testing over 20 years in San Francisco and Los Angeles. Borcherdt (1994) summarised these results. Several versions of nomenclature for the site classes are published (e.g., Borcherdt, 1994; Crouse and McGuire, 1996; Hwang and others, 1997) but they differ mainly in detail. The correlation between the physical description of the rocks and mean shear wave velocity in the top 30 m has become more rigorously defined recently but the classifications remain essentially the same.

Table H2: Site classifications for earthquake hazard maps

Site Class this study	Site Class 1994 NEHRP provisions	Description and Site Class definition[1]
A	A	Hard rock, Vs > 1 500 ms^{-1}
A	B	Rock, 760 ms^{-1} < Vs ≤ 1 500 ms^{-1}
B	C	Hard and/or very stiff soils, very dense soils, mostly gravels, and soft rock with 360 ms^{-1} < Vs ≤ 760 ms^{-1} or with either N > 50 or s_u ≥ 100 kPa
C	D	Sands, silts and/or stiff clays, some gravels, 180 ms^{-1} ≤ Vs ≤ 360 ms^{-1} or with either 15 ≤ N ≤ 50 or 50 kPa ≤ s_u ≤ 100 kPa
D	E	Profile with Vs < 180 ms^{-1} or containing at least 3 m of soft clay defined as sediment with PI > 20, w ≥ 40%, and s_u < 25 kPa
NA[2]	F	Special sites: • sites vulnerable to potential failure or collapse under seismic loading (liquefiable sediments, quick and highly sensitive clays, collapsible weakly-cemented sediments, etc.) • peats and/or highly organic clays (thickness > 3 m) • very high plasticity clays (thickness > 8 m with PI > 75) • very thick soft/medium stiff clays (thickness > 37 m)

NOTES:

[1] Modified from definitions in Crouse and McGuire (1996) and Hwang and others (1997)
[2] Special sites in Cairns have not been assessed separately
Vs = Mean shear wave velocity to a depth of 30 m
N = Mean Standard Penetration Test blow count
s_u = Mean Undrained Shear Strength
w = Mean moisture content

We have collapsed the NEHRP classifications ‘Hard rock’ and ‘Rock’ into Site Class A, simply termed ‘Rock’. The metasediments of the Hodgkinson Formation and the granitic batholiths underlying Cairns probably have shear wave velocities that would clearly mark them as ‘Hard rock’ under the NEHRP classification but we do not have the information to make the distinction.

In this study we estimated urban earthquake hazard at a localised level rather than at a site-specific level and we have not identified special sites (**Table H2**).

We used the published interpretation of the 1:100 000 scale geological map (Willmott and others, 1988) and geotechnical and geophysical information to form the zones defined by site class. No measurements of shear wave velocity were available for Cairns (few are available in Australia) and so estimates of mean shear wave velocity in the topmost 30 m were made, first for sites where geotechnical data were available, and then more broadly, largely by geological unit. The measured shear wave velocities in sediments and rock in the Los Angeles and San Francisco Bay regions, classified by type and augmented by Standard Penetration Test data, presented by Borcherdt (1994), were a valuable reference for estimating Vs in the Quaternary geological units of Cairns.

Geotechnical data from reports at approximately 40 sites were provided by Queensland Main Roads, Golder Associates, and Cairns Port Authority. These data comprised borehole, test pit, and cone penetrometer test logs and their interpretations. Some data were provided on the understanding that they would not be released in primary form for commercial in confidence reasons. The sites are shown on **Figure H2**. About 30 of the boreholes and Cone Penetrometer Tests sampled sediments consequently classified as Site Class D and, of these, about 20 were located in the City and inner suburbs. These data highlighted up to 20 m of loose/very loose sands and/or soft/very soft clays immediately underlying Portsmith, Trinity East, Parramatta Park, Cairns City, Manunda, North Cairns and Westcourt. Beneath these sediments are beds of Pleistocene alluvium up to 70 m thick interfingered with Pleistocene/Pliocene estuarine and marine sediments (Willmott and others, 1988).

Willmott and others (1988) provided a typical example of the foundation under Cairns City. They reported that a bore in Aplin Street, City, intersected 3.6 m of loose, fine to coarse sand of a former beach ridge, 0.4 m of silt-clayey marine sand, underlain by 2.4 m to 3 m of soft estuarine mud and, below this, firm, dense sandy clay at a depth of 6.4 m to 7 m. A thickness of 5 - 10 m of soft or very soft clays and/or loose to very loose sands overlying stiff clays and/or dense sands appears to be a representative foundation underneath the City. In the City area the groundwater table is probably tidal and is likely to be within 2 m of the surface (F. Baynes, written comm., 1997).

The Site Class D classification was reached for these 30 sites largely on the basis of estimated mean shear wave velocity Vs in the topmost 30 m. Where data were available, there was very good agreement between the criterion Vs < 180 ms^{-1} and the presence of estuarine muds and beach ridge sands of Holocene age (Units Qhct and Qhcb; **Table H3**.)

A further six boreholes were located in Pleistocene silty gravels, sands, silts and clays and from this limited data set there was also agreement between estimates of Vs and the physical properties for these sediments that resulted in these sediments being rated as Site Class C.

For other geological units the relation between mapped geology and site class was less clear. The Holocene alluvium of the Barron River delta (Unit Qha2) was variously rated Site Class B, C and D. The borehole and microtremor information overrode classifications made from lithological description alone. This simple example shows the limitations of producing urban earthquake hazard maps from mapped geology alone (the lowest level of hazard map) and the capacity of geotechnical, hydrogeological and geophysical datasets to improve the hazard maps.

Stage 3 - Assign Amplification Factors to the Site Classes

We next assigned amplification factors to each site class. The amplification factors describe the relative severity of earthquake shaking. The amplification factor for Site Class A, 'Rock', is unity and the peak value of the earthquake shaking on other site classes will be stronger in proportion to the amplification factor. In the absence of sufficient recordings of Australian earthquakes, our amplification factors are derived from empirical values recorded from central and southern Californian earthquakes in the years 1933-1989 (Crouse and McGuire, 1996). **Table H4** and **Table H5** present the amplification factors of Crouse and McGuire for periods of vibration T = 0.3 seconds and T =1.0 second.

In general, the amplification factors are dependent on the period of vibration of the ground during earthquakes and on the strength of earthquake input ground motion. With increasingly strong input ground motion, up to 0.4 g, the amplification factors become somewhat reduced, indicating a degree of nonlinearity in the ground behaviour.

For Cairns, we adopted the amplification factors of Crouse and McGuire (1996) at low levels of input ground motion, PGA = 0.1 g to 0.2 g. The amplification factors used in the hazard maps for Cairns are shown in **Table H6**. They are appropriate for a range of annual exceedence probabilities both larger and smaller than the AEP = ~0.2% of *AS1170.4-1993*.

Table H3: Relationship between site class and geological unit for Cairns

Site class	Geological unit[1]	Lithological Description
A	Pg, Pgt, PRg, PRgb, PRgf	Permian fine to coarse biotite granites and pegmatites
A	SDh	Silurian-Devonian argillite, slate, arenite, greywacke, quartzite, greenstone, some micaceous phyllite and schist (Hodgkinson Formation)
B	Qpfc	Pleistocene steep alluvial and colluvial fans, cones and aprons - coarse boulder deposits (on granites), silty and clayey gravel (on metasediments)
B	Qpvm	Pleistocene basaltic lava, scoria, agglutinate
B	TQvf	Pliocene- Pleistocene basaltic lava, rare limestone
C	Qa	Pleistocene-Holocene undivided creek and river alluvium in west of area
C	Qha	Mainly Holocene undivided younger creek alluvium - silt, clay, sand and gravel
C	Qha_1	Holocene younger alluvium, lowest terraces and channel deposits - gravel, sand, silt
C[2]	Qha_2	Mainly Holocene younger alluvium, intermediate terraces - silt, clay, sand and gravel
C	Qhcd	Presumed Holocene quartz sand in high vegetated dunes

C	Qhcw	Presumed Holocene thin humic sand and mud in freshwater swamps
C	Qpa	Pleistocene old alluvium of the highest terraces of the Mulgrave River - gravelly clay and silt, sand and gravel at depth
C	Qpcb	Pleistocene silty and loamy quartz sand in degraded beach ridges
C	Qpcd	Pleistocene quartz sand in high vegetated dunes
C	Qpfp	Pleistocene gentle to very gentle coalescing alluvial fans - silty cobbles and gravels grading to gravelly clay, clay and silt
D	Qhcb	Holocene silty and loamy quartz sand in degraded beach ridges
D	Qhct	Holocene mud, sandy mud of estuaries and chenier ridges

NOTES:

[1] Reference Willmott and others, 1988
[2] Some parts are rated Site Class B or Site Class D (see text)

Table H4: Amplification factors for $T = 0.3$ s, from Crouse and McGuire (1996)

Site class	Amplification factor			
	PGA = 0.1 g	PGA = 0.2 g	PGA = 0.3 g	PGA = 0.4 g
A	1.0	1.0	1.0	1.0
B	1.3	1.3	1.3	1.3
C	1.6	1.5	1.4	1.3
D	2.1	1.9	1.8	1.7

Table H5: Amplification factors for $T = 1.0$ s, from Crouse and McGuire (1996)

Site class	Amplification factor			
	PGA = 0.1 g	PGA = 0.2 g	PGA = 0.3 g	PGA = 0.4 g
A	1.0	1.0	1.0	1.0
B	1.7	1.7	1.7	1.7
C	2.0	2.0	1.9	1.9
D	2.9	2.7	2.6	2.6

Table H6: Amplification factors for Cairns hazard maps (PGA ~ 0.05 g - 0.2 g)

Site class	Amplification factor	
	T = 0.3 s	T = 1.0 s
A	1.0	1.0
B	1.3	1.7
C	1.5	2.0
D	2.0	2.9

The range of amplification factors in Table H6 could, in fact, be higher in Cairns. Hard basement rock underlying sediments will increase the amplification factors

and this may well be the case for Cairns. 'Rock' in Australia (*AS1170.4-1993)* is equivalent to 'Hard rock' in California (Hwang et al., 1997). *AS1170.4-1993* includes a Site Factor of S = 0.67 for '… rock strength Class L (low) or better', resulting in amplification factors of three between hard rock and soft sediments. Crouse and McGuire (1996) had insufficient recordings of Californian earthquakes to distinguish between 'Hard rock' and 'Rock' response and they aggregated the recordings as 'Rock' (Site Class A for Cairns). We choose to use the empirical Californian data and we note that more research is needed to develop appropriate Australian amplification factors.

Stage 4 - Produce Response Spectra Describing the Earthquake Hazard for Each Site Class

We have slightly modified the results of Somerville and others (1998) to produce response spectra for Site Classes A-D (**Figure H3**). They used the amplification factors of Crouse and McGuire (1996) to produce spectra recommended for Australia.

The rock (Site Class A) response spectrum in **Figure H3** is unchanged from Somerville and others (1998). Our spectra for Site Classes B-D are also identical to those of Somerville and others except at periods greater than T = 0.7 s. For periods T= 0.1 s to 0.7 s the amplification factors are 1, 1.3, 1.5 and 2 (**Table H6**). At periods less than T = 0.1 s the amplifications are 1, 1.15, 1.25 and 1.5. At periods greater than T = 0.7 s we adopted the amplification factors 1, 1.7, 2 and 2.9 seconds (**Table H6**). These are slightly lower than the values 1, 1.95, 2.25 and 3 that Somerville and others used. We have preferred to use the empirical factors determined by Crouse and McGuire for an input PGA of 0.1 g at a period of T = 1 s (**Table H5**) whereas Somerville and others adopted amplifications 50% greater than the amplifications in the mid-period velocity band of the spectra.

The response spectra (**Figure H3**) give estimates of the earthquake hazard in Cairns for Site Classes A-D at periods in the range T = 0.03 s to 3.0 seconds, which cover most periods of interest to designers of structures and non-structural components. As mentioned earlier, the spectra may be scaled to estimate hazard for different annual exceedence probabilities.

APPENDIX I: CAIRNS LANDSLIDES - MASTER LIST

The reference number is that in the AGSO Cairns Landslide GIS database.

1. 8 March 1878: Flood followed by severe cyclone triggered many landslides across the inlet. They could be heard distinctly in Cairns (Jones, D., 1976, p. 125).

1891: During the construction of the Cairns railway, a heavy landslide occurred during an early, heavy and prolonged wet season (Ellis, R.F., 1976).

16 April 1894: 965 mm of rain fell during the month. The railway was blocked by 20 landslides and numerous wash-outs (Broughton, 1984).

2./3. 1896: Following a prolonged wet season, large landslides blocked the line at the Springs between No. 14 tunnel and Red Bluff, and at No. 15 tunnel (Broughton, 1984).

1897-1906: Minor rock falls occurred on the Cairns railway (Broughton, 1984).

31 May 1900: Five men were killed and one buried alive for one and a half hours when a 7.6 m (25 ft) deep tramway cutting they were constructing in alluvial sandy loam, clay and gravel in a river terrace at Riverstone for the Mulgrave Central Mill caved in (Morton, 1995; Morning Post, Cairns,N.Q., 1, 8 &15 June 1900). The locality is now known as "Dead man's Gully" or Dead man's Cutting" (A. Broughton, Cairns Historical Society, written communication, 1999) and is situated 3 km WNW of Walshs Pyramid in Gordonvale.

5. 1910: There was a landslide on the Cairns railway at Surprise Creek (Broughton, 1984).

4. 15 December 1910: Landslide at Kuranda end of No. 10 tunnel on Cairns railway partly closed the tunnel for more than two months. Several episodes of sliding occurred during this time (Broughton, 1984). The line was cleared for goods traffic on 25 February 1911 and for all traffic on 6 March 1911 (*Cairns Post*, 27 February and 7 March 1911).

Early January 1911: A *Cairns Post* reporter noted that there had been small landslides at various places, but that the obstructions had been removed. The most serious fall was at the 15 Mile, but that it would be cleared quickly. Lower down the line, one or two trivial falls had also been cleared (*Cairns Post*, 4 January 1911).

Early January 1911: There were rumours of a big washaway at 3.5 miles from Cairns near Edge Hill quarry, which would be repaired in a few hours (*Cairns Post*, 4 January 1911).

6. 7 February 1911: There was a big fall on the railway at 17.75 mile near Surprise Creek (Broughton, 1984).

Ca. 13 February 1911: A landslide blocked the tramway on the Aloomba side of the Mulgrave River. It was expected to be cleared on 15 February 1911 (*Cairns Post*, 15 February 1911).

8. 3 March - 2 April 1911: A failure under the railway line between No. 11 and No. 12 tunnels was caused by heavy rain (Broughton, 1984).

4. 16 March 1911 cyclone: At No. 10 tunnel, earth and boulders from overhead fell and blocked the railway line (*Cairns Post*, 18 March 1911).

7./5. 16 March 1911 cyclone: Falls occurred on the railway line near Stony Creek bridge and at Surprise Creek (Broughton, 1984).

7. 16 March 1911 cyclone: There was a fall at 14.25 miles which temporarily blocked the line (*Cairns Post*, 18 March 1911).

6. 16 March 1911 cyclone: There was another subsidence at 17 miles 50 chains (*Cairns Post*, 18 March 1911).

9. 1 April 1911: A big landslide occurred in the Nisbet Ranges across the inlet from Cairns. The scar could be seen in photos for several years afterwards (A. Broughton, Cairns Historical Society, personal communication, 1997). The landslide brought away trees, rocks and everything else from a considerable distance up the mountain side (*Cairns Post*, 3 April 1911).

10. 31 March - 2 April 1911: On the railway at Horseshoe Bend, south of Redlynch, the formation was washed out (Broughton, 1984).

11. 31 March - 2 April 1911: Landslides covered the line near No. 6 tunnel (Broughton, 1984).

12. 31 March - 2 April 1911: On the railway, from Stony Creek to the Springs, there were wash-outs and the undermining of the embankment (Broughton, 1984).

13. 31 March - 2 April 1911: From the Springs to Red Bluff, two big landslides of about 1000 tons had blocked the line for a considerable distance (Broughton, 1984).

3. 31 March - 2 April 1911: On the Kuranda side of No. 15 tunnel, there was a large fall (Broughton, 1984).

14. 31 March - 2 April 1911: Further along, the railway line was badly undermined and scouring had left the line hanging (Broughton, 1984).

5. 31 March - 2 April 1911: Near Surprise Creek, 1500 tons of mud and rock covered the line for five chains (Broughton, 1984).

15. 31 March - 2 April 1911: Just up the line was another fall of 500 tons (Broughton, 1984).

16. 31 March-2 April 1911: At Mervyn Creek, the line was covered to a depth of 4-6 m by another large landslide (Broughton, 1984).

1912: More landslides occurred on the Cairns railway (Broughton, 1984).

30 January 1913 cyclone: There was a landslide on the range between Kuranda and Cairns (*Cairns Post*, 1 February 1913).

17. 9 February 1927 cyclone: In upper Freshwater Creek, east of Jigol Creek, boulders pounded the concrete, in which new pipes had been set, to pieces and carried away the pipes (Cairns City Council, 1927).

18. 9 February 1927 cyclone: A portion of Chirio's farm was washed away - possibly on 12 February (Cairns City Council, 1927).

19. 9 February 1927 cyclone: At Freshwater Creek, about 1 km WSW of Brinsmead, a pipe was broken near a wash-out about 1 km long (Cairns City Council, 1927). The creek here alters course (G. Haussmann, retired City Engineer, personal communication, 1997).

19A. 1932: The construction of the original above-ground hydro-electric power station at the bottom of the Barron Falls was abandoned because of major rock falls and other complications (Jones, D., 1976, p. 460).

March 1934 cyclone: At Slip Cliff Point on the Captain Cook Highway, about 200 000 tons of rock crashed down across the road, closing it. The road was relocated to a higher alignment. There are claims that the sound was heard in Port Douglas and Cairns (Richards, 1996).

19B. 1939: There were several landslides in new cuttings in Redlynch Intake Road near the last crossing on Freshwater Creek (Mulgrave Shire Council).

20. 12 January 1951: A torrential deluge of about 700 mm of rain in just under five hours, triggered debris flows over 10 km of the Captain Cook Highway between Buchan and Simpson's Points. Huge quantities of debris were swept from the mountainside on to the road and over the precipice into the sea. Boulders up to 3 m long were hurled into the Pacific like marbles. Large slabs of bitumen were tilted up from the road, and landslide debris was piled as high as 3 m. All culverts and inverts in this area were either damaged considerably or washed away entirely. The highway was not expected to carry normal traffic for at least two weeks (*Cairns Post*, 15 January 1951).

21. 5 March 1954: A large landslide in the Red Bluff area, with its head well above the railway and the toe well below it, blocked the Cairns railway from 5 March until 22 April 1954 (A. Broughton, Cairns Historical Society, personal communication, 1997).

21B. 1967: 300,000 m^3 of the hillside slipped down on to the road going to the base of the quarry face at White Rock. The quarry was closed temporarily (Don Healy, personal communication).

21A. 10 March 1970: Following about two weeks of rain at 25 mm a day, then about 200 mm of rain in two hours on 10 March, about 50 landslides occurred on hills in Whitfield - Edge Hill and other areas to the west of Cairns CBD. Hillview Crescent, Whitfield was the worst affected. A slide 50 m long, almost liquid, went under a house and on to the road in front of it. There were phone calls from residents with landslides pushing against their houses in various parts of Cairns (G. Haussmann, personal communication, 1997).

22. 1979: Following very heavy rain, a 60 m x 60 m batter and fill failure on Lake Morris Drive behind Earlville/Bayview Heights took out a section of road which was then closed for about six months. This section of road was 50% damaged again in 1981, and the road was nearly abandoned (G. Haussmann, personal communication, 1997).

23. Around 1979: A landslide near the reservoir tanks on the south side of Brinsmead-Kamerunga Road blocked the road (Member of Cairns Historical Society, personal communication, 1997).

21A. Around 1979: On Hillview Crescent, Whitfield, the hill gave way and went straight through houses. Mud went into the back of one house (Member of Cairns Historical Society, personal communication, 1997). Is this the event of 10 March 1970?

24. Around the 1980s: Mud went straight a newly completed house in Smithfield Heights. The house was not structurally damaged (*Cairns Post* employee, personal communication, 1997).

24A. 1984 or 1985: Boulders smashed the water main at No. 3 crossing on Freshwater Creek and, either before or after that, the main slipped with a mudflow which took out the anchor blocks (D'Arcy Gallop, Cairns City Council, personal communication, 1997).

25. 1988: A landslide at Sydney Street, Bayview Heights wrote off two or three building blocks.

26. 1990 or earlier: A fill failure on the NW side of Granadilla Drive, Earlville caused one lane to be closed permanently.

27. 23 December 1990 Cyclone Joy: Undercutting by a creek caused a landslide on the south side of Granadilla Drive/Comet Street, Earlville/Bayview Heights which closed this section of road permanently - only a walkway remains.

28. ?1990s: There have been slope stability problems in City View Estate, Mooroobool (Two different citizens of Cairns, personal communication, 1997).

29. ?1990s: A landslide caused part of the Rainforest Estate subdivision to be permanently abandoned (three different reports from technical consultants). The roadway and stormwater drains were broken.

30. ?1990s: A partly built house at 263 Toogood Road, Bayview Heights has a slump in talus in the excavation at the back. This landslide was reactivated by Tropical Cyclone *Justin* in March 1997.

31. ?1990s: At 5 Juno Close, Mooroobool, a house was destroyed due to batter failure at the rear, and rebuilt.

32. ?1990s: On the corner of Grandview Crescent and Barnes Street, Earlville a partly completed house was written off due to 300 mm of movement.

October 1995: A landslide in the Kuranda Range closed the Cairns railway for several days (Linda Berry, James Cook University, personal communication, 1997).

33. 1997: A debris slide about 3 m high by 2 m wide occurred in the batter on the north side of the Brinsmead-Kamerunga Road.

34. 1997: Small batter failures occurred on the hillslope to the east of Brinsmead.

36. 1997: Recent failure in weathered rock in rainforested area in Barron Gorge, estimated 20 m high x 2m wide, on opposite side of gorge to railway line.

37. 1997: Near Barron River Falls Railway Station, there are three batter failures in red, highly weathered rock. Two are 2-3 m high x 2 m wide and one is 2-3 m high x 1 m wide.

1997: In Freshwater Valley, on the Cairns Railway, there is a small batter failure about 0.7 m high x 2 m wide in weathered rock.

13. 1997: On the south side of Red Bluff, debris frequently falls, including in 1997 (Linda Berry, James Cook University, personal communication, 1997).

1997: Small batter failures occurred during this wet season along Lake Morris Drive.

23 March 1997, T.C. *Justin*: Numerous batter failures occurred along Lake Morris Drive, and the Kuranda Range Road. Batter failures were also logged along the Cairns Railway, Toogood Road, Redlynch Intake Road, Yarrabah Road, Reservoir Road, and in Rainforest Estate.

96J. 23 March 1997, T.C. *Justin*: A landslide about 600m long and 15 m wide occurred on a natural slope on the escarpment 8.5 km west of Gordonvale.

APPENDIX J : CAIRNS CYCLONE HISTORY

This list has been compiled from several sources, most notably an unpublished list compiled by Jeff Callaghan of the Bureau of Meteorology (Callaghan, 1998), a database of cyclone tracks developed by the Bureau's Severe Weather Section in Brisbane (BoM, 1997) and Appendix 1 in Harper (1998).

Cyclones which passed within 75 km of Cairns are shown with their date in **bold**; those which passed between 75 and 150 km of Cairns are shown with their dates <u>underlined</u>.

8 March 1878

An unnamed but severe cyclone (Category 3?) hit Cairns. Iron roofing was flung through the air and many properties were destroyed. The steamer *Louise* and sailing vessels *Merchant*, *Kate Conley* and *Hector Miss* were sunk in the Cairns inlet with the loss of all hands. Major debris flows occurred on the eastern side of Trinity Inlet and coastal inundation occurred.

<u>2 February 1882</u>

An unnamed cyclone (Category 2?) hit Cardwell (150 km south) with considerable damage. It is likely that Cairns was also affected by winds from this cyclone.

29 March 1890

An unnamed but severe cyclone (Category 3?) crossed the coast at Ingham (200 km south). Cairns probably experienced some effect from this cyclone.

28 January 1906

An unnamed cyclone (Category 3?) crossed the coast at Cairns causing 'devastation'.

19 January 1907

An unnamed severe cyclone (Category 3?) crossed the coast near Cooktown (170 km to the north) with 9 fatalities and severe damage. Cairns would have felt the effects of this event.

28 January 1910

An unnamed cyclone (Category 2-3?) crossed the coast around Cape Tribulation and passed within 60 km of Cairns to the west before re-crossing the coast near Townsville. It produced heavy gales and 'tremendous' seas at Cairns. Storm tide inundation of perhaps 0.7 metres was experienced. The vessel *Bombala* ran aground.

<u>10 February 1911</u>

An unnamed cyclone (Category 1-2?) passed to the east of Port Douglas and tracked down the coast passing within 80 km of Cairns. Port Douglas buildings and crops suffered with wind damage. Similar damage probably also occurred in Cairns.

16 March 1911

An unnamed, but severe cyclone (Category 3?) crossed the coast near Port Douglas (55 km north of Cairns) where there were 2 fatalities and much damage. In Cairns balconies were stripped off buildings and roofs damaged. Verandahs collapsed and some buildings were unroofed. Rainfall caused major landslides which blocked the Kuranda railway for several months.

7 April 1912

An unnamed low category cyclone (Category 1-2?) recurved to within 70 km to the east of Cairns. No damage was reported in Cairns but several houses were badly damaged in Innisfail (70 km to the south).

31 January 1913

An unnamed but severe cyclone (Category 3?) crossed the coast about 70 km north of Cairns. Damage included the front of the Stock Exchange being blown in, balconies stripped off buildings; a house lifted off its stumps; a sawmill and several sheds unroofed. Storm tide inundation of unknown depth caused damage to many boats and the sea wall was smashed. The schooner *Dancing Wave* was lost with all hands.

10 March 1918

An unnamed, but very severe (possible Category 5) cyclone crossed the coast at Innisfail (70 km to the south). The large storm tide and severe winds causing large loss of life - as many as 100 people perished in the area between Bingle Bay and South Mission Beach. Whilst the main centre of damage was in the Innisfail area, Cairns and Babinda (50 km south) and centres on the Atherton Tableland suffered widespread damage.

3 February 1920

An unnamed severe cyclone (probably Category 3) crossed the coast north of Cairns within 80 km of the town. Widespread building damage occurred throughout the district (nearly every building in Kuranda was unroofed). Storm tide inundation to approximately 1 metre above HAT was experienced in Cairns and at least one building on the coast was destroyed by the sea.

26 February 1925

An unnamed (Category 1-2?) cyclone crossed the coast near Mossman (65 km north) with building damage as far north as Cooktown. Cairns probably experienced some wind damage.

9 February 1927

An unnamed (Category 3?) cyclone crossed the coast perhaps 50 km to the north of Cairns. At least 16 buildings were totally destroyed whilst many others were unroofed or otherwise damaged.

20 January 1930

An unnamed (Category 1-2?) cyclone crossed the coast near Mossman (65 km north). No reports of damage in Cairns have been noted, but widespread flooding was caused across Queensland.

1-8 February 1931

An unnamed (Category 1-2?) cyclone entered the Coral Sea near Cooktown and moved down the coast, passing within 300 km of Cairns, and going as far south as Hervey Bay. Significant flooding was experienced in all areas.

19 January 1932

An unnamed (Category 1-2?) cyclone tracked from the Gulf to the east of Townsville producing disastrous flooding in the area from Cairns to Mackay.

22 January 1934

An unnamed (Category 1-2?) cyclone crossed the coast within 35 km of Cairns with serious flooding over a large part of the state.

12 March 1934

An unnamed (Category 3?) cyclone crossed the coast south of Cape Tribulation (about 75 km to the north of Cairns) with a 9.1 metre storm tide recorded at nearby Bailey Creek and 1.8 metres storm tide at Port Douglas. Several luggers and 75 persons were lost at sea. Cairns probably suffered damage in this cyclone given its strength and proximity.

18 February 1940

An unnamed Category 3 cyclone crossed the coast at Cardwell (150 km to the south). The worst impact was to the south of Cardwell, including significant storm tide damage in Townsville, however, some wind damage in Cairns was likely given its proximity and strength.

6 March 1940

An unnamed (Category 1-2?) cyclone crossed the coast north of Cooktown (perhaps 240 km to the north) causing significant flooding along Cape York. Some wind impact may have been experienced in Cairns.

23 March 1940

An unnamed (Category 1-2?) cyclone which formed in the Gulf of Carpentaria crossed Cape York about 300 km north of Cairns causing flooding in the north, including in the Barron River.

3 April 1941

An unnamed (Category 1-2?) cyclone recurved to within about 190 km of the coast near Cairns with high seas and coastal damage reported.

16 February 1942

An unnamed (Category -2?) cyclone crossed the coast near Cardwell (150 km south) before moving south to Mackay. Limited damage probably occurred in Cairns.

31 January 1945

An unnamed (Category 1-2?) cyclone crossed the coast near Cooktown produced floods in the Barron River.

18 March 1945

An unnamed possible Category 3 cyclone crossed the coast north of Cooktown (perhaps 200 km to the north). Major loss of life caused by the sinking of a freighter and a ketch. A storm surge of greater than 0.8 metres was reported from Cairns but no inundation.

8 February 1946

An unnamed cyclone (Category 1-2?) crossed the coast about 35 km south of Cairns. Widespread floods were reported.

2 March 1946

An unnamed Category 2 cyclone recurved over Cairns and Townsville. Considerable damage and some loss of life was experienced. A storm surge of more than 0.7 metres was reported from Cairns but apparently no inundation.

7 January 1948

An unnamed Category 1-2 cyclone, which formed in the Gulf crossed Cape York, causing heavy flooding from Cooktown to Cardwell. It recrossed the coast as a low about 60 km south of Cairns. A storm surge of around 0.5 metres was reported from Cairns but no inundation.

10 February 1949

An unnamed Category 1-2 cyclone crossed the coast north of Cooktown (perhaps 200 km to the north of Cairns) causing extensive structural damage in Cooktown. Light damage may have been experienced in Cairns.

15 January 1950

An unnamed Category 1-2 cyclone recurved near Cooktown to within about 120 km of Cairns bringing gales and floods to most coastal centres. A storm surge of 0.5 metres reported from Cairns but no inundation.

6 March 1950

An unnamed (Category 1-2?) cyclone crossed the coast near Mossman about 70 km north of Cairns. Its main impact was to produce minor flooding in the Barron River.

12 January 1951

The intense rainfall event that triggered the major debris flow at Ellis Beach reported in Chapter 5 was probably associated with a Category 1 cyclone in the Gulf, with a closest point of approach to Cairns of about 450 km.

6 March 1956

Category 3 cyclone *Agnes* crossed the coast at Townsville then moved northwards as far as Ingham before turning west. Wind gusts from the west of up to 150 km/hr recorded in Cairns with widespread damage.

20 January 1959

Category 2 Cyclone *Bertha* from the Gulf crossed into the Coral Sea between Cairns and Cooktown and passed within 20 km of the city. Widespread flooding and wind damage to banana crops was reported.

15-16 April 1964

Recurving Category 1 cyclone *Gertie* which made its closest coastal approach in the Whitsunday Group (500 km to the south-east) caused extensive damage to sugar cane around Cairns together with flooding and dislocation of both road and rail networks.

6 December 1964

Category 1 cyclone *Flora* crossed from the Gulf to enter the Coral Sea near Innisfail, passing within 40 km to the south of Cairns. Some wind damage and flooding in Cairns was likely given its proximity.

30 January 1965

Category 1 cyclone *Judy* crossed from the Gulf to enter the Coral Sea close to Innisfail. Again, wind damage and flooding in Cairns was likely.

14 March 1967

Category 1 Coral Sea cyclone *Elaine*, which approached to within 100 km of the coast near Cairns, generated a storm surge recorded as 0.5 metres in the city. There was no reported inundation.

24 December 1971

Category 3 cyclone *Althea*, which crossed the coast at Townsville, generated a 0.7 metres storm tide at Cairns whilst the cyclone was at least 250 km distant. No inundation was reported in Cairns.

4 March 1973

Category 1 cyclone *Madge*, which crossed from the Gulf just north of Cooktown (about 250 km to the north) brought widespread flooding. The Bruce Highway was cut in six places between Townsville and Cairns.

19 December 1973

Category 1 cyclone *Una*, which came within 220 km of Cairns and eventually crossed the coast east of Townsville, generated a 0.4 metre storm surge at Cairns.

6 February 1974

Category 4 cyclone *Pam*, which was about 1,700 km from Cairns at its closest point of approach, generated a storm surge measured at 0.3 metres in Cairns.

1 February 1976

Category 1 cyclone *Alan* crossed the coast near Bloomfield Mission (155 km to the north). Minor damage in Cairns is likely to have been experienced.

8 March 1977

Category 1 cyclone *Otto* crossed from the Gulf into the Coral Sea near Cape Tribulation (80 km to the north). No significant wind damage was reported by serious flooding occurred between Cairns and Ingham.

31 January 1977

Category 1 cyclone *Keith* made landfall just to the east of Cairns before moving south along the coast. Only minor wind damage to buildings was reported, however, extensive loss of banana and sugar crops occurred.

1-2 January 1979

Category 1 cyclone *Peter* approached to within 130 km of Cairns after crossing from the Gulf and degenerating into a rain depression. There was no significant wind damage, however, very intense rainfall led to serious flooding in and around Cairns (1,140 mm of rain was recorded on Mount Bellenden Ker, 50 km south, in 24 hours). There were two drowning fatalities.

26 February 1981

Category 1 cyclone *Freda* formed near Cooktown before moving away from the coast. Significant flooding occurred in the Barron River.

22 February 1985

Category 1 cyclone *Pierre* paralleled the coast about 160 km off Cairns on a southward track. Minor local flooding only was reported.

1 February 1986

Category 3 cyclone *Winifred* crossed the coast south of Innisfail (about 90 km to the south) with wind gusts in Cairns recorded at 118 km/hr. Substantial wind damage, especially uprooted trees, was reported from Cairns, mainly from westerly winds. A storm surge of 0.5 metres was measured at Cairns, however, no coastal inundation was reported.

22-25 December 1990

Category 4 cyclone *Joy* approached, and hovered, to within 120 km of Cairns before decreasing in intensity and moving south. Strongest winds in Cairns were measured at 124 km/hr on 23 December, whilst Green Island recorded a gust of 180 km/hr. A storm surge of 0.5 metres was measured at Port Douglas but no coastal inundation was reported from the area.

22 March 1997

Category 2 cyclone *Justin* made a bullseye impact on Cairns with wind gusts of 128 km/hr. About $2 million damage was done to the Cairns Marina and extensive, but relatively minor damage was done to buildings and power supply infrastructure. A peak storm surge of 0.66 metres was recorded at Cairns at about one hour before low tide. Minor sea wave and storm tide inundation of roads in northern beach suburbs occurred. The Barron River was in high flood.

11 February 1999

Weak Category 3 cyclone *Rona* crossed the coast near Cape Tribulation from the south-east. Wind damage was relatively light but heavy rain brought the Barron River to major flood levels. A storm surge of 0.6 m was measured on the Cairns tide gauge, though closer to the eye wall the surge was measured at 1.0 m at Port Douglas and 1.6 m at Mossman. Landfall was close to low tide.

APPENDIX K: STORM TIDE SCENARIO STATISTICS

Table K1: Storm tide impact on Cairns critical facilities

FACILITY	2% AEP	1% AEP	0.2% AEP	0.1% AEP	0.01% AEP
ABC Studios		C	A	A	A
ABC Transmitters					
Airport Control Tower		C	A	A	A
Airport Rescue and Fire Service		C	B	A	A
Ambulance Station Cairns		B	A	A	A
Ambulance Station Edmonton					
Ambulance Station Gordonvale					
Ambulance Station Smithfield					
Ambulance Station Yarrabah					
Ampol Fuel Depot		C	A	A	A
Bethlehem Nursing Home	C	B	A	A	A
Boral Gas Depot	B	A	A	A	A
Cairns Central	C	B	A	A	A
Cairns City Council Centre	C	B	A	A	A
Cairns City Council Works Depot		C	A	A	A
Cairns City Council Gordonvale					
Cairns Crocodile Farm			A	A	A
Cairns Hospital		C	A	A	A
Cairns Port Facilities	B	A	A	A	A
Caltex Fuel Depot	C	B	A	A	A
Calvary Hospital	B	B	A	A	A
Country Bake Bakery (Westcourt)			A	A	A
Country Bake Bakery (Bentley Pk)					
CSR Bulk Sugar Terminal	A	A	A	A	A
FARNOHA Nursing Home		C	A	A	A
Festival Faire		C	A	A	A
Fire Station Cairns		C	A	A	A
Fire Station Gordonvale					
Fire Station Smithfield					
FNQEB Cairns Substation	B	B	A	A	A

FNQEB Gordonvale Substation					
FNQEB Kamerunga Bulk Supply					C
FNQR 51st Battalion Depot		C	A	A	A
Fresha Products Cold Stores	C	B	A	A	A
Fortuna Seafood Cold Stores	B	B	A	A	A
Garozzo Agencies Wholesale Food	B	B	A	A	A
Gordonvale Memorial Hospital					
Good Samaritan Nursing Home		B	A	A	A
HMAS Cairns	B	A	A	A	A
INCITEC	B	A	A	A	A
Mobil Fuel Depot	B	B	A	A	A
Nazareth Village Nursing Home	C	B	A	A	A
Police Station Cairns	C	B	A	A	A
Police Station Smithfield					
Police Station Yarrabah					
Portsmith Cold Stores		C	A	A	A
Pyramid Retirement Centre					
Sewerage Treatment Plant		C	A	A	A

Table K1(cont.): Storm tide impact on Cairns critical facilities

FACILITY	1:50	1:100	1:500	1:1,000	1:10,000
Shell Fuel Depot	B	A	A	A	A
Smithfield Plaza					
Southern Pollution Control Centre	B	B	A	A	A
Stockland Plaza					
Telephone Exchange Cairns		B	A	A	A
Tong Sing Wholesale Fruit & Veg		C	A	A	A
Water Treatment Plant Kanimbla					
Water Treatment Plant Yarrabah					
WB Winfield Nursing Home					
Westcourt Plaza		B	A	A	A
Yarrabah Hospital					
Yarrabah Council Works Depot			A	A	A

NOTES:

A = water more than 1.0metre over floor level B = less than 1.0 metre of water over floor level

C = water on the property but not over floor level

Table K2: Impact of a 2% AEP storm tide on Cairns suburbs

SUBURB	**>1m over floor - A**	**>1m over floor - B**	**>1m over floor - C**	**<1m over floor**	**on ground only**	**roads >0.5m under (km)**	**roads .25-.5m under (km)**	**roads <.25 under (km)**	**cane fields (ha)**
Aeroglen				44	34	1.7	1.2	5.4	
Barron					1	1.2		1.1	1380
Cairns North		1		6	33	3.8	3.3	12.0	
City	2			233	135	10.7	1.4	3.5	
Clifton Beach				3	24	3.4	0.4	1.0	
Edge Hill						1.0	0.2	1.3	
Edmonton				5	1	2.1	3.0		983
Holloways Beach				8	1	1.9	0.2	2.9	881
Kamma				2	4	7.5	1.6		1091
Kewarra Beach						2.1	0.4	0.1	
Machans Beach				70	83	5.9	1.7	4.1	464
Manoora								4.7	
Manunda				93	516	7.7	8.8	12.3	
Palm Cove				21	16	3.1	0.1		
Parramatta Park				101	272	6.7	4.4	6.1	
Portsmith	3			194	51	11.7	3.6	10.5	
Smithfield					1	1.5	0.2		437
Stratford						0.2		0.6	
Trinity Beach	1			12	15	2.8	0.4	0.4	
Trinity East				8	1	5.2	4.3	0.2	4134
Trinity Park				15	17	1.2	1.8	1.7	
Westcourt				22	184	3.7	4.7	17.7	
White Rock				6	2			0.6	97
Woree				3	2	1.3	2.0	0.2	
Wright's Creek				3	2	4.2			2048
Yarrabah					9			1.6	
Yorkeys Knob		2		15	13	4.9	1.4	7.2	2255
TOTALS	6	3	0	866	1424	95.8	45.6	97.6	14007

NOTE:

A= buildings within the first 750 metres of the shoreline; B = buildings between 750 and 1,500 metres of the shoreline; C = buildings further than 1,500 metres from the shoreline.

Table K3: Impact of a 1% AEP storm tide on Cairns suburbs

SUBURB	>1m over floor - A	>1m over floor - B	>1m over floor - C	<1m over floor	on ground only	roads >0.5m under (km)	roads .25-.5m under (km)	roads <.25 under (km)	cane fields (ha)
Aeroglen				79	42	4.3	4.1		
Barron				1		1.2	1.1		1571
Cairns North		2		122	513	8.5	11.6	2.6	
City	96			287	198	13.1	2.5		
Clifton Beach	1			53	32	1.5	2.4	0.8	
Edge Hill					74	1.4	1.1	1.3	
Edmonton				6		5.1			1076
Holloways Beach	1			14	43	1.6	2.9	0.2	1329
Kamma				6	1	9.1	0.81	2.9	1350
Kewarra Beach				2	15	1.1	0.8	0.6	
Machans Beach	41			120	231	6.9	4.3	0.2	505
Manoora				6	221		6.2	1.2	
Manunda		17	16	515	897	21.1	8.7	0.9	
Mooroobool				4	56	0.5	1.1	0.6	
Palm Cove	12			26	11	3.1		0.1	
Parramatta Park		3	17	219	749	11.9	5.3		
Portsmith	74	20		263	455	18.1	7.6		
Smithfield				1	8	1.7			496
Stratford					1	0.2	0.6	1.1	
Trinity Beach	8			37	50	2.8		1.4	
Trinity East	1		3	6	3	7.3		2.1	4169
Trinity Park		1		33	142	3.3	1.5	0.7	
Westcourt			1	269	1018	13.5	14.1	3.7	
White Rock			3	6	20		1.1	0.5	116
Woree				10		3.3	0.2		
Wright's Creek			1	4		4.2	2.1	3.7	2718
Yarrabah				53	80		1.6	1.6	
Yorkeys Knob	7	2		97	307	7.2	6.6	1.2	2481
TOTALS	241	45	41	2239	5170	161.8	87.4	27.6	16130

NOTE:
A = buildings within the first 750 metres of the shoreline; B = buildings between 750 and 1,500 metres of the shoreline; C = buildings further than 1,500 metres from the shoreline.

Table K4: Impact of a 0.2% AEP storm tide on Cairns suburbs

SUBURB	**>1m over floor - A**	**>1m over floor - B**	**>1m over floor - C**	**<1m over floor**	**on ground only**	**roads >0.5m under (km)**	**roads .25-.5m under (km)**	**roads <.25 under (km)**	**cane fields (ha)**
Aeroglen	6	55	41	31	34	8.4	0.2		
Barron			1			2.3			1685
Cairns North	393	82		179	217	23.2	0.1		
City	485	52		20	24	15.7			
Clifton Beach	123			30	14	5.2			
Edge Hill			92	119	80	4.4	0.8	0.4	
Edmonton			7	2		5.1			1590
Holloways Beach	73			66	44	6.0	1.2		1634
Kamma			9			14.1			2009
Kewarra Beach	43			60	21	2.8	0.1	0.4	
Machans Beach	291	48		49	25	11.8			505
Manoora			247	168	106	7.6	0.8	0.2	
Manunda		154	1015	169	177	30.7	0.2		
Mooroobool			64	88	60	2.6	0.8	0.7	
Palm Cove	57			5		3.2			
Parramatta Park		504	47	216	222	17.2			
Portsmith	140	265	311	42	54	25.7			
Smithfield			10	1		1.7		0.4	602
Stratford			1	2	10	2.1	0.3		
Trinity Beach	129			80	27	6.2	0.3	0.1	
Trinity East	12		11	5	4	10.3	0.8	5.5	4254
Trinity Park	25	162	4	43	18	5.5		0.2	
Westcourt			1180	305	359	32.1	0.4		
White Rock			35	53	22	1.9	0.4	1.0	215
Woree			11			3.7			
Wright's Creek			7	12		14.7	1.7	0.9	3980
Yarrabah	143			21	11	4.8	0.2		
Yorkeys Knob	282	233	3	137	11	16.9	0.6		2990
TOTALS	2202	1575	3103	1927	1561	296.1	8.8	11.1	20169

NOTE:
A = buildings within the first 750 metres of the shoreline; B = buildings between 750 and 1,500 metres of the shoreline; C = buildings further than 1,500 metres from the shoreline.