University of Queensland

QUEENSLAND SEISMIC RISK STUDY

PROGRESS REPORT

TO

THE STATE GOVERNMENT OF QUEENSLAND

THROUGH

THE DIRECTOR-GENERAL OF MINES

MINES DEPARTMENT

ON BEHALF OF THE

INTERGOVERNMENTAL COMMITTEE

REPORT QSRS-1

12 AUGUST 1985 - 1 NOVEMBER 1985

Prepared by: DR. JOHN M.W. RYNN

1 NOVEMBER 1985

QUEENSLAND SEISMIC RISK STUDY

PROGRESS REPORT

TO

THE STATE GOVERNMENT OF QUEENSLAND

THROUGH

THE DIRECTOR-GENERAL OF MINES

MINES DEPARTMENT

ON BEHALF OF THE

INTERGOVERNMENTAL COMMITTEE

FOR THE PERIOD 12 AUGUST 1985 THROUGH 1 NOVEMBER 1985

REPORT QSRS - 1

Prepared by: Dr. John M. W. Rynn

.....

1 November, 1985

Submitted with the approval of

.....

Dr. G. R. Orme, Head of Department

INTRODUCTION

This is the first progress report for the Commission entitled "Queensland Seismic Risk Study" and covers the twelve (12) week period 12th August, 1985, through 1st November, 1985.

The emphasis in this initial stage has been directed towards providing the basic data set of earthquake occurrances in QueensTand. This consists of both instrumental and macroseismic data and encompasses Tasks (i), (ii) and (vi) of the Commission Brief. The remaining Tasks (iii), (iv) and (v) constitute the interperative aspects of the project and can only be undertaken once the basic data set has been faithfully compiled. Consequently these will constitute the later stage of the research project.

An interim report, Status Report No.1, was prepared and tabled at a meeting on 9th September, 1985, with the Chief Government Geologist, Mr. R. J. Allen and Dr. G. R. Orme. This report, which was to be circulated to the Steering Committee, detailed the activities on this project during the period 12th August, 1985, through 7th September, 1985. It included a detailed report on the Canberra Conferences this author attended (30th August, 1985 - 7th September, 1985) and a tentative synopsis of the proposed final publication for this project.

This report details the research currently in progress, the status to date and projections for the remainder of the one year Commission.

PROJECT STATUS IN TERMS OF COMMISSION BRIEF

Task	Description	Status	Completion
(i)	Basic Data Set		
	(a) Catalogue of Queensland earthquakes (spatial distribution-listing and map)	in progress	Dec. 1985
	(b) Earthquake zones in Queensland (delineation of zones and map)	completed	
	(c) Macroseismic data (listing and maps)	in progress	Dec. 1985
	(d) Descriptive catalogue of Queensland earthquakes	in progress	Dec. 1985
	(e) Details of other seismic phenomena	in progress	Dec. 1985
	(f) Seismograph stations in Queensland	completed	
(ii)	Magnitudes of Queensland earthquakes		
	(a) Determination of magnitudes	in progress	Dec. 1985
(iv)	Upgrading Earthquake Risk Map of Australia, Queensland Sector	in progress	Dec. 1985

The other tasks are dependent on the completion of the Basic Data Set and Magnitudes for all known Queensland earthquakes.

(i)	(g) Statistics for earthquake parameters	in progress	Feb, 1986
(ii)	(b) Magnitude-frequency relations		
(iii)	Recurrence relations for earthquakes		
(iv)	Assessment of ground motion attenuation		
(v)	Estimates of maximum ground motion acceleration, velocity and intensity for specified time periods		

At this time it is anticipated that the compilation of the entire data set for Queensland seismicity, together with the seismological statistics for this data, will be completed by December 1985. The following stage will be to undertake the interpretive aspects of the project as detailed in the Brief. As indicated in Status Report No. 1 (9 September 1985), a tentative synopsis for the Final Publication has been prepared. This will be further organised as the project progresses.

PROJECT DETAILS TO DATE

The research has been directed towards the compilation of the basic data set for Queensland earthquakes for the period 1866 through 1984 (1866 is the date of the first reported occurrance of on earthquake in Queensland). This aspect of the project covers Tasks (i), (ii) and (vi) of the Commission Brief.

The basic data set is being compiled from both instrumental and macroseismic (non-instrumental) data and will be presented as:

(a) All data:

(i) Complete listing of all known earthquakes in Queensland, a table containing:

origin time - year, month, day, hour, minute, second

epicentre - ^{o}S latitude, ^{o}E longitude

focal depth - in kilometres

magnitude - all possible values included Richter Local magnitude (ML); body wave magnitude (MB); surface wave magnitude (MS); isoseismal (macroseismic) data magnitude ML(I); estimated magnitude for the events where none of the above are available (ML E/M).

quality of the parameters for the earthquake (Q)

locality - geographical location of epicentre based on the 1:250,000 topographic Maps of Australia.

earthquake zone

macroseismic data - to include maximum assigned intensity from Modified Mercalli Scale of Intensity (Eiby, 1965) (MM); available isoseismal maps and reference to its publication.

references - where both the data and report for the particular earthquake are published.

descriptive catalogue - if particular earthquake has been described.

remarks - brief comments regarding interesting facts of the particular earthquake.

(ii) Epicentral map showing locations of all earthquakes with symbols in proportion to magnitudes of earthquakes (base map is the 1:2,500,000 Geological Map of Australia).

(iii) Map of earthquake zones.

(iv) Descriptive catalogue of earthquakes (a descriptive account of details of each particular earthquake, where applicable).

(b) Macroseismic data:

(i) Listing of earthquakes for which isoseismal maps are available, a table containing:

earthquake parameters - locality, origin time, epicentre, focal depth, magnitudes

macroseismic data - magnitude ML(I), maximum assigned intensity value MM and locality, felt area in km^2.

earthquake zone

references - published isoseismal maps, publication of accounts of particular earthquakes

(ii) Map of earthquake epicentres listed in (i).

(iii) Compendium of isoseismal maps available for Queensland earthquakes.

(iv) Corrections to earthquake parameter data given on published isoseismal maps.

(v) Listing of all macroseismic data for each earthquake given in (i), a table containing:

earthquake - abbreviated parameters locality, origin time, earthquake zone.

published isoseismal map reference

felt reports received - number of positive and negative maximum assigned intensity value (MM) and locality of assigned intensity values (MM) for each report.

(vi) Series of generalised isoseismal maps designating areas which have experienced earthquake effects in terms of assigned intensity values MM 7,6,5 and 4, and isolated felt reports.

The essence of the initial studies centres on the determination of the earthquake parameters

(a) epicentre
(b) magnitude

Note that the other parameters (origin time and focal depth) are integral parts of any determination, which the macroseismic parameters are determined from the felt report information supplied by the general public.

In the initial stages of magnitude determinations, it became apparent that the epicentres of several earthquakes in northeastern Queensland were incorrect as per the previously published data by Rynn (1984). Such epicentres had been previously determined by several earlier workers based

solely on the single station data from Charters Towers (CTA). It was obvious that these earthquakes had to be re-examined and that all epicentres prior to the 1980's should be meticulously checked.

This again highlights the major problem in seismological research in Queensland, namely, the extremely poor distribution (that is, lack of) sufficient seismograph stations in Queensland to unambiguously and accurately determine epicentres. For the record, the deployment of such stations in Queensland is given in Table 1, and shown on Figure 1. As a consequence of this, it was considered that the redetermination of earthquake epicentres be undertaken in two "general areas" centred in northern Queensland and central-south eastern Queensland based on the permanent seismograph stations data for Charters Towers and Brisbane, respectively. Further, the data had to be divided into particular "time-frames" related to the operations of existing seismograph stations. Comparisons of earthquake signatures for the early earthquakes were made with the most recent data from the microearthquake networks of the Burdekin Falls Dam and Wivenhoe Dam reservoir induced seismicity projects.

The mode of these "time-frame" analyses for the redetermination of suspect epicentres is given in Table 2.

TABLE 1

SEISMOGRAPH STATIONS IN QUEENSLAND

SEISMOGRAPH STATION		OPERATIONS		INSTRUMENTATION	INSTITUTION
NAME	CODE	COMMENCED	CEASED		
BRISBANE (City)	BRS	1937 SEP	1951 APR	Milne-Shaw horizontals	UQ
BRISBANE (St. Lucia)	BRS	1951 MAR	1963 JUN	Short period vertical; Milne-Shaw horizontals	UQ
TOWNSVILLE	TVL	1956	1965 MAY	Long period horizontal	UQ
CHARTERS TOWERS	CTA	1957 SEP	1963 MAR	Short period and long period three-component systems	UQ
KURANDA	KDA	1959 NOV	1964 SEP	Short period vertical	UQ
CHARTERS TOWERS (New Site)	CTA	1963 MAR	*	WWSSN - Short period and long period three-component systems	UQ
MT. NEBO	BRS	1963 JUN	*	Short period three-component system; Long period horizontals	UQ
CHARTERS TOWERS (High Gain)	CTA	1970 SEP	1976 JUL	High-gain long-period three-component system	UQ
CHARTERS TOWERS (ASRO)	CTAO	1976 JUL	*	ASRO digital system	UQ
WIVENHOE DAM	WDN	1977 MAR	*	Initial network of four short period verticals (MEQ)	UQ/GSQ
MT. ISA	ISQ	1979 AUG	*	Short period vertical	BMR
BOONDOOMA DAM	BODM	1980 JUL	*	Short period vertical (MEQ)	GSQ
RATHDOWNEY	RYQ	1980 DEC	1981 JAN	Short period vertical (MEQ)	UQ
BURDEKIN FALLS DAM NETWORK	BFN	1981 FEB	*	Initial network of three short period verticals (MEQ)	GSQ
AWOONGA DAM	AWMG	1981 SEP	*	Short period vertical (MEQ)	GSQ
ROMA (Test Site)	RTQ	1983 NOV	1984 AUG	Short period vertical (MEQ)	BMR/UQ
BURDEKIN FALLS DAM NETWORK	BFN	1984 FEB	*	Extended network with additional six short period three component systems (MEQ, digital)	GSQ
WIVENHOE DAM NETWORK	WFN	1984 JUL	*	Extended network with additional short period verticals (MEQ)	UQ/GSQ
ROMA	RMQ	1984 AUG	*	Short period vertical	BMR

* Currently operational in 1985
MEQ Microearthquake seismograph system for reservoir induced seismicity studies
UQ Department of Geology and Mineralogy, Seismology Group, University of Queensland
BMR Bureau of Mineral Resources, Canberra
GSQ Geological Survey of Queensland, Mines Department
BSHS Brisbane State High School

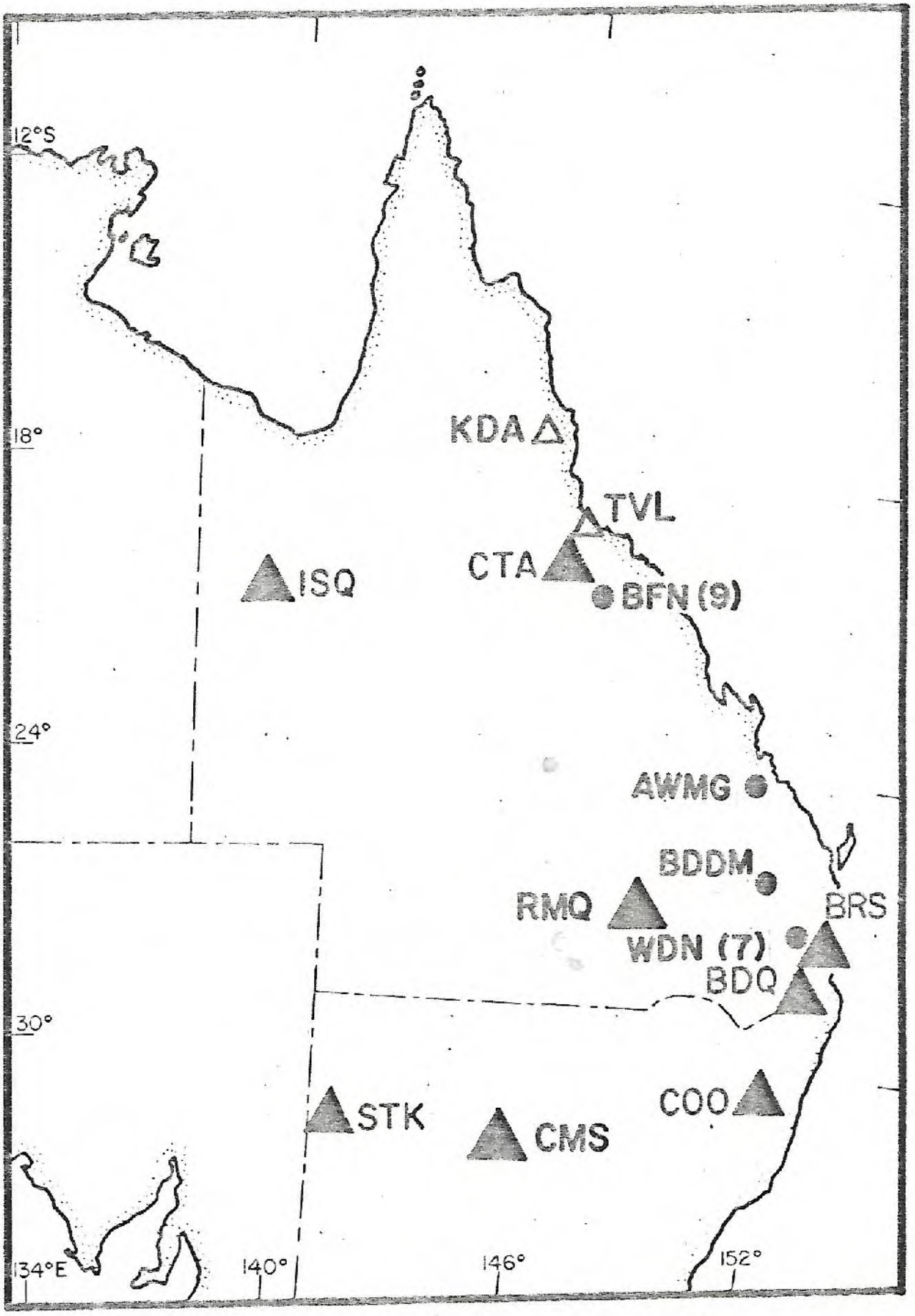

FIGURE 1 Seismograph Stations in Queensland

TABLE 2

"TIME-FRAME" ANALYSES FOR EPICENTRAL REDETERMINATIONS

TIME FRAME	SEISMOGRAPH STATION DATA		ANALYTICAL CONSTRAINTS
	PRIMARY DATA	COMPARATIVE DATA	
(a) Northern Queensland			
Pre 1957	Macroseismic		(a) Isoseismal maps (b) Isolated felt reports (c) For larger earthquakes, magnitudes greater than about 5.0: post 1909 - RIV and ISS data post 1937 - RIV, BRS and ISS data
1957 - 1981	CTA	BFN	(a) Three component short period and long period data including WWSSN data from 1963 onwards: (i) use of JB and NSK ssismic travel time tables for P,S and Lg phases (ii) azimuth of epicentre from CTA using first motion directions of short period components (iii) direction of epicentre from relative amplitudes of surface waves on short period horizontal components (b) For BFN located earthquakes recorded on CTA seismograms, a comparison of signatures for pre 1981 and post 1981 events (c) Post 1976, comparison with ASRO digital data (d) Macroseismic data where applicable
post 1981	CTA, BFN		(a) Check BFN locations using CTA data, WWSSN and ASRO seismograms (b) Macroseismic data where applicable
(b) Central and South Eastern Queensland			
Pre 1937	Macroseismic		As for Northern Queensland (a),(b) and (c)
1937 - 1963	BRS	BRS (Mt. Nebo)	(a) Identification of P,S and Lg phases from short period vertical component BRS (Brisbane) seismograms (b) Comparison of short period vertical seismograms from BRS (Mt.Nebo) and WDN for signatures (c) Use of JB and NSK seismic travel time tables for P, S and Lg phases. (d) Macroseismic data where applicable
1963 - 1977	BRS	WDN	(a) Three component short period data (i) use of JB and NSK seismic travel time tables for P,S and Lg phases (ii) azimuth of epicentre from BRS using first motion directions of short period components (iii) direction of epicentre from relative amplitudes of surface waves on short period horizontal components (b) Comparison with WDN vertical components (c) Macroseismic data where applicable
Post 1977	BRS, WDN		(a) Check WDN locations using BRS data (b) Macroseismic data where applicable
(c) Overlapping Data			
1913 - 1963	ISS		(a) Re-analysis of RIV seismograms
1957 - 1977	CTA, BRS		(a) For large earthquakes (magnitudes greater than about 5.0) recorded at both stations, epicentral determination from seismic travel time tables (to give distances) and first motions and surface wave amplitudes (to give azimuths).
Post 1977	CTA, BRS WDN, BFN		(a) As for (a) immediately above

Notes: (a) For the larger earthquakes, data is also used primarily from the BMR stations in Queensland (ISQ - post 1979; RMQ - post 1984) and northern New South Wales (COO - post 1974; STK - post 1974; CMS - post 1984).

(b) Data is also used from the other NSW, ACT, South Australia and Northern Territory stations.

Seismograph station codes: RIV Riverview College Observatory (Sydney); COO Cooney Observatory (near Armidale)
STK Stephens Creek (near Broken Hill); CMS Cobar:

Seismological data: WWSSN World Wide Standardised Seismograph Network
ASRO Abbreviated Seismic Research Observatory
ISS International Seismological Summary

Seismological tables: JB Jeffreys-Bullen Tables from Jeffreys and Bullen (1970) and Simon (1981) (World-wide data)
NSK Nuttli, Stauder and Kisslinger (1969) (Central US data)

Epicentres

As mentioned earlier, several errors were detected in previously determined epicentres subsequently published by Rynn (1984). By the very detailed analytical procedure, as given in Table 2, wherein all seismograms from CTA, BRS, KDA and TVL are being re-read, all data from the BFN and WDN networks are being re-checked and, where applicable, data from RIV and the BMR stations re-examined, such earthquake epicentres are being redetermined.

The difficulties in determing epicentres from one or two station data are clearly obvious. It was noted that the earthquake signatures as recorded at both CTA and BRS were most definitive in that clear arrivals of many P and S phases and the Lg surface were observed. This was further enhanced by the availability of horizontal component seismograms. Indeed, such horizontal components are absolutely essential to such analyses. As a consequence, it was deemed necessary that care should be taken in deciding what seismic travel time tables be used to obtain the epicentral distances between earthquake and station. Thus, a study of available published earth models was initiated.

Earth Models:

Unfortunately, definitive earth models for the seismically active areas of Queensland are not available. There are, however, several generalised and specific models available for near earthquake phases which were employed. Although it must be realised that such models are not totally applicable to the areas in question, they do allow epicentral determinations to be made, such solutions being considered as the best otainable with the available data. These earth models are detailed in Table 3.

An example of seismic ray paths and travel-time curves (from which travel-time tables are derived) for compressional or P phases for central USA is shown in Figure 2. Note that a similar situation exists for the shear or S phases wherein S-wave velocities are approximately 0.57 that for P-wave velocites.

Seismic Phase Identification:

The seismograms from Queensland earthquakes exhibit typical continental type phases. The three major P-phases (Pg, P* and Pn; refer to Figure 2) and their corresponding S-phases are usually clearly observed. In addition the continental surface wave Lg (Lehmann, 1957) is sometimes well developed. It has become clear that extreme care must be taken in identification of these continental phases. Most of the problems related to the now recognised incorrect epicentral determinations have been a result of misidentification of the Sg phase as Sn. This resulted in the epicentres being located much further from the seismograph station than they should have been.

In addition, the signature of the seismograms show clear differences related to the earthquake source. For example, the various P phases are much less attenuated for those earthquakes centred on the land than for those located in the Coral Sea. The regularity of the P- and S- phase group also indicates that the crust in Queensland is essentially two-layer with prominent discontinuities between the upper and lower crust (sometimes referred to as the "Conrad Discontinuity") and between the lower crust and upper mantle (the "Mohonovicic Discontinuity" or "Moho").

TABLE 3

EARTH MODELS EMPLOYED IN EPICENTRAL DETERMINATIONS

MODEL	P WAVE VELOCITIES		REGION APPLIED	REFERENCE	TRAVEL TIMES		QLD. AREA	
	DEPTH(KM)	VELOCITY(KM/SEC)			PUBL.	EARTHQUAKE DEPTH OF FOCUS (KM)	NORTH QLD	CENTRAL SOUTH EAST QLD
JB			World-wide	Jeffreys and Bullen (1970) Simon (1981)	X	0(surface),33	X	X
NSK	0-20	6.15	Central USA	Nuttli, Stauder and Kisslinger (1969)	X	0,5,15,25,35	X	X
	20-40	6.70						
	40+	8.18						
CRUMP (averaged)	0-2	4.50	Cape York	Finlayson (1968)		0	X	
	2-20	5.90						
	20-40	6.75						
	40+	8.00						
WDQ1	0-10	5.85	Wivenhoe Dam and E Qld.	Rynn et al.(1984-85)		0		X
	10-30	6.67						
	30+	7.95						
WDQ2	0-0.8	4.72	Wivenhoe Dam - Esk Trough	Rynn (1985)		0		WDN
	0.8-2.3	5.22						
	2.3-9.3	6.00						
	9.3-25	6.65						
	25+	7.95						
	0-0.7	5.00	Wivenhoe Dam - D'Aguilar Block	Rynn (1985)		0		WDN
	0.7-2.3	6.05						
	2.3-25	6.65						
	25+	7.95						
BFQ1	0-20	5.90	Burdekin Falls Dam	R.J. Cuthbertson (pers. comm., 1985)		0	X	
	20-40	6.75						
	40+	8.00						
BFQ2A	0-4	5.00	Burdekin Falls Dam	R.J. Cuthbertson (pers. comm., 1985)		0	X	
	4-19	6.00						
	19-35	6.70						
	35+	8.10						

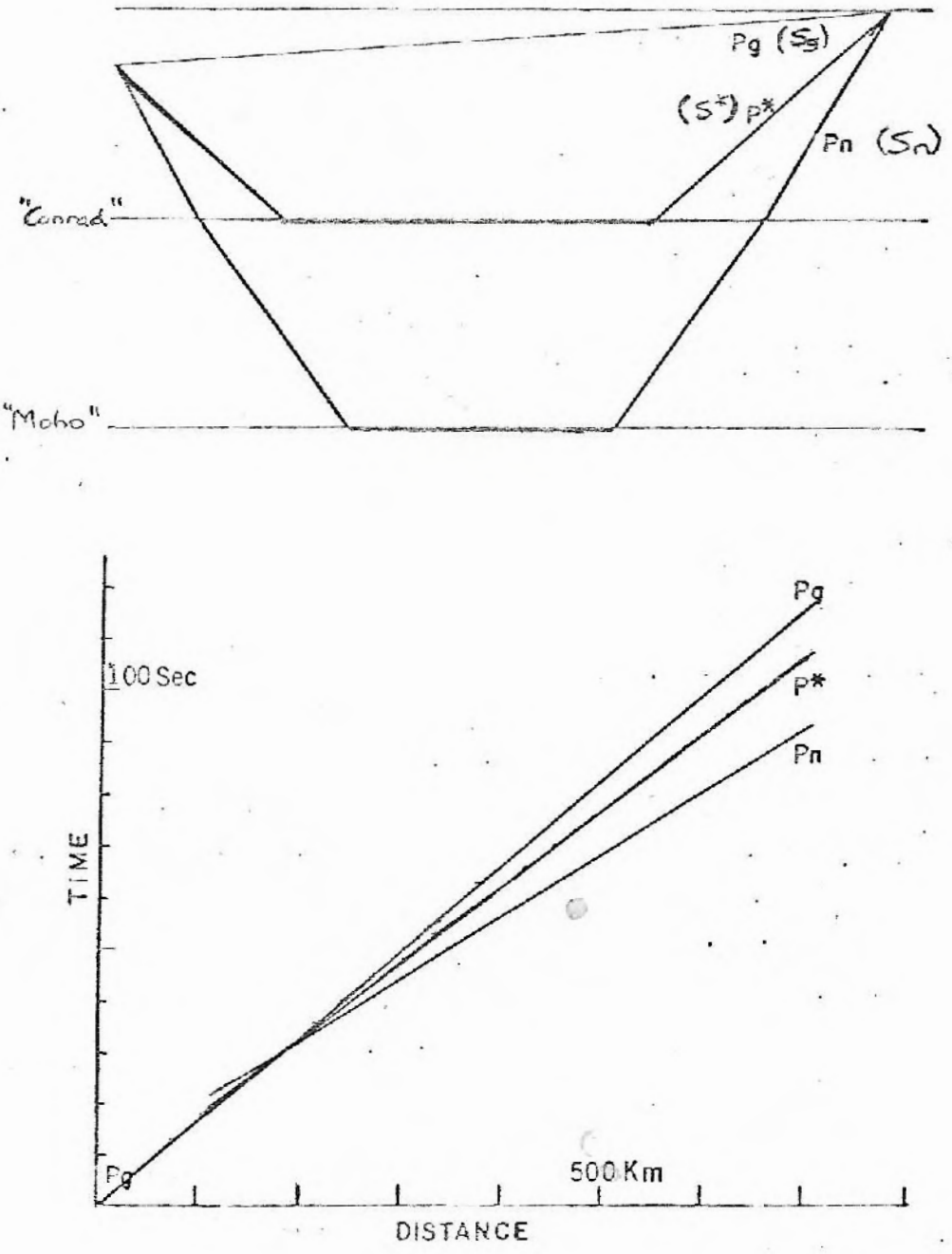

FIGURE 2 Ray paths and travel-time curves for P-waves from an earthquake near the surface. Corresponding S-waves as indicated. (After Nuttli, Stauder and Kisslinger, 1969).

Man-made Blasts:

As has been pointed out in the previous study by Rynn and Ruediger (1985), there is the need for extreme care in positively identifying natural earthquakes when studying a region like eastern Queensland. This is related to the fact that one is dealing with a region of relatively low seismic activity within a highly urbanised and industrial regime where man-made blasting is most prevalent. This has been taken into account in the Wivenhow Dam and Burdekin Falls Dam studies (Rynn, Webb, Cuthbertson; Lynam and Doherty (1984-85) and Cuthbertson (1982), respectively).

In this Commission for the northern Queensland area, such information has proven invaluable as several "earthquakes" previously shown as occurring in the southern Atherton Tableland (Rynn, 1984) have now been shown to be blasts from the Collinsville coal mine.

It is thus considered most important, indeed essential, that continuous monitoring of all major man-made blasting centres through "Blast Logs" (Rynn and Ruediger, 1985) be an integral part of the seismic monitoring of Queensland. This was proven to be the case in the Wivenhoe Dam studies (Rynn et al., 1984-85).

Focal Depths

This parameter is the most difficult one to determine and thus the most inaccurate quoted for any earthquake. For the entire region of eastern Australia, the distribution of seismograph stations and the availability of earth models are considered not sufficient to enable focal depths to be reliably determined. Denham (1976) discusses this and suggests that the focal depths of earthquakes can, at best, be considered as "crustal", that is, depths between about 0 and 30 km. This is, however, being improved as local models are becoming available.

In Queensland, focal depths have been instrumentally determined for the Wivenhoe and Burdekin Falls dams regions. The errors in the these estimations are about ± 5 to 10 km. From this current research the focal depths of some of the earthquakes pre 1981 have been estimated from the P- and S- wave arrivals using the travel-time tables of Jeffreys and Bullen (1970; Simon, 1981) and Nuttli, Stauder and Kisslinger (1969). The valves obtained have, in the main, suggested foci in the upper crust at depths between 5 and 15 km.

Magnitudes

The determination of magnitudes has been carried out according to the internationally accepted standard procedures. This has been adhered to for the following two reasons:

(a) All magnitude determinations are thereby standardised to those in other parts of the world.

(b) By this methodology, some comparisons between magnitudes for different areas can be afforded and hence the amount of seismic energy release can be clearly defined.

Several different types of standard magnitudes have been determined. These are detailed in Table 4. Further details on Australian magnitude scales can be obtained from Denham (1982) and McGregor and Ripper (1976).

Determinations of instrumental magnitudes ML,MB and MS were undertaken according to standard international procedures (See McGregor and Ripper, 1976, and references cited therein). For those earthquakes where macroseismic data only are obtainable (namely events pre 1957 for northern regions and pre 1937 for southern regions) magnitudes were either determined from such data in terms of ML(I) and ML(Io) or estimated, ML(E/M), by comparison with other earthquakes of known magnitude in the same region.

Macroseismic Data

The integrated studies on this aspect have been directed towards the cataloguing of all facits of the available information and cross-checking the earthquake parameters for the Queensland Earthquake Data File. In rechecking the earthquake data it was found that several changes needed to be made in some of the computational parameters due to corrections in instrumental data. In addition, further information was found in the Seismology Group files which has necessitated re-evaluation of the isoseismal maps for the 1935 Gayndah and 1960 Mt. Glorious earthquakes. Isoseismal maps are also being prepared for the 1964 Georgetown and 1984 Cooyar and Murgon earthquakes.

Earthquake Zones for Queensland

Based on the Queensland Earthquake Data File, the delineation of Earthquake Zones for the State has been completed. This is more detailed than that already published by Rynn (1984).

The Earthquake Zones in Queensland (shown in Figure 4) are:

1 - Wide Bay - Burnett
2 - Southeast Queensland
3 - Northeast Queensland
4 - Queensland - New South Wales Border
5 - Western Queensland
6 - Northeastern NSW
7 - Coral Sea
8 - Cape York
9 - Gulf of Carpentaria

These have been defined on the basis of the spatial distribution (epicentres) of seismicity and geological constraints related to major structural features. The essence of this result was presented at the "Intraplate and Interplate Earthquakes" Symposium held in Canberra on 28 - 29 August, 1985, in my paper entitled "Earthquakes in Queensland and Northeastern New South Wales - Is Continental Seismicity Confined Within Specific Geological Boundaries?"

TABLE 4

MAGNITUDE DETERMINATIONS FOR QUEENSLAND EARTHQUAKES

MAGNITUDE SCALE		CONSTRAINTS ON FORMULAE				REFERENCE	SEISMOGRAPH STATION DATA
TYPE	FORMULA	EPICENTRAL DISTANCE RANGE (KM)	COMPONENT OF GROUND MOTION	SEISMIC PHASE	PERIOD OF SEISMIC PHASE (SEC)		
ML Richter Local	$ML = \log A_1 - \log A_0 + \log R$	0 - 600	short period vertical	S	0.1 - 0.5	Richter (1958) McGregor and Ripper (1976) (1976)	CTA, BRS BFN, WDN, BDDM, AWMG, COO
MB Body Wave	$MB = \log \frac{A_z}{T} + Q$	> 600	short period vertical	P	actual period of phase considered (usually ~1 sec)	Richter (1958)	CTA, BRS, COO, RIV, CAN
MS Surface Wave	$MS = \log A_3 + B^1(\Delta) + P(\Delta)$	< 2000	long period horizontals	surface	20	Marshall and Basham (1973)	CTA
ML(I) Isoseismic	$ML(I) = 1.01 \ln R_p + 0.13$	Based on macroseismic data and isoseismal maps				McCue (1980)	
$ML(I_o)$ Intensity	$ML(I_o) = 1 + 0.67I_o$	Magnitudes derived from the ML - I_o relationship of Gutenberg and Richter (1956) using all available Queensland earthquake data on these parameters (as shown in Figure 3)					
ML(E/M) Estimated maximum possible	Estimate of magnitude for those events with macroseismic information only (no isoseismal maps) based on earthquakes of known magnitude in the same region.						

Symbols: For ML

A_1 = maximum mean-to-peak trace amplitude (in mm)

A_0 = tabulated by Richter (1958); trace amplitude of the reference earthquakes (magnitude zero) at the same distance

$R = \frac{\text{magnification of recording seismograph at period (T) of seismic phase}}{\text{magnification of standard Wood-Anderson seismograph at same period (T)}}$

For MB

A_2 = maximum mean-to-peak ground amplitude (in microns) of the P wave train

$= \frac{\text{maximum mean-to-peak trace amplitude (in mm)}}{\text{magnification of recording seismograph at period T of seismic phase}} \times 10^3$ (microns)

T = corresponding wave period (in sec)

Q = tabulated by Richter (1958); depth/distance factor

For MS

A_3 = maximum combined horizontal mean-to-peak ground amplitude (in nanometers) of the surface waves at period T

$= \frac{(A_N^2 + A_E^2)^{\frac{1}{2}}}{\text{magnification of recording seismograph at period T}} \times 10^6$

A_N = maximum mean-to-peak trace amplitude (in mm) of the north-south horizontal seismograph

A_E = maximum mean-to-peak trace amplitude (in mm) of the east-west horizontal seismograph

$B'(\Delta)$ = tabulated by Marshall and Basham (1978); distance correction term

$P(\Delta)$ = tabulated by Marshall and Basham (1978); path correction term
(for Queensland earthquakes, the two paths considered were totally continental for epicentres on land and mixed (oceanic and continental) for epicentres at sea)

For ML(I)

R_p = radius of perceptibility of earthquake effects enclosing the assigned Modified Mercalli Scale of Intensity value MM = 3

For $ML(I_o)$

I_o = Modified Mercalli Scale of Intensity (MM) assigned to earthquake effects at the epicentre

log — logarithm to the base 10

ln — natural logarithm for the base e

Notes: (i) In the Queensland Earthquake Date File listing, magnitudes ML, MB, MS will have noted which stations data were used to calculate the values, for example ML(CTA). The stations used are: CTA - Charters towers; BRS - Brisbane; COO - Cooney; RIV - Riverview; CAN - Canberra; WDN - averaged values for individual stations of the Wivenhoe Dam Network; BFN - averaged values for the individual stations of the Burdekin Falls Network.

(ii) RIV and CAN cite ML values for Queensland earthquakes. By the strict definition of ML in distance terms (distances less than 600 km) such magnitude values for RIV and CAN should be computed as MB as epicentral distances are greater than 600 km.

(iii) Some earlier listings of Queensland earthquakes, in particular related to the Wivenhoe Dam and Burdekin falls Dam reservoir induced seismicity studies magnitude values of MD were quoted. MD is a value based on the duration of the earthquake coda for an earthquake. The formula used was that derived for Victorian earthquakes by the Preston Institute of Technology (G. Gibson, pers. comm., 1982) and thus not strictly applicable to Queensland conditions.

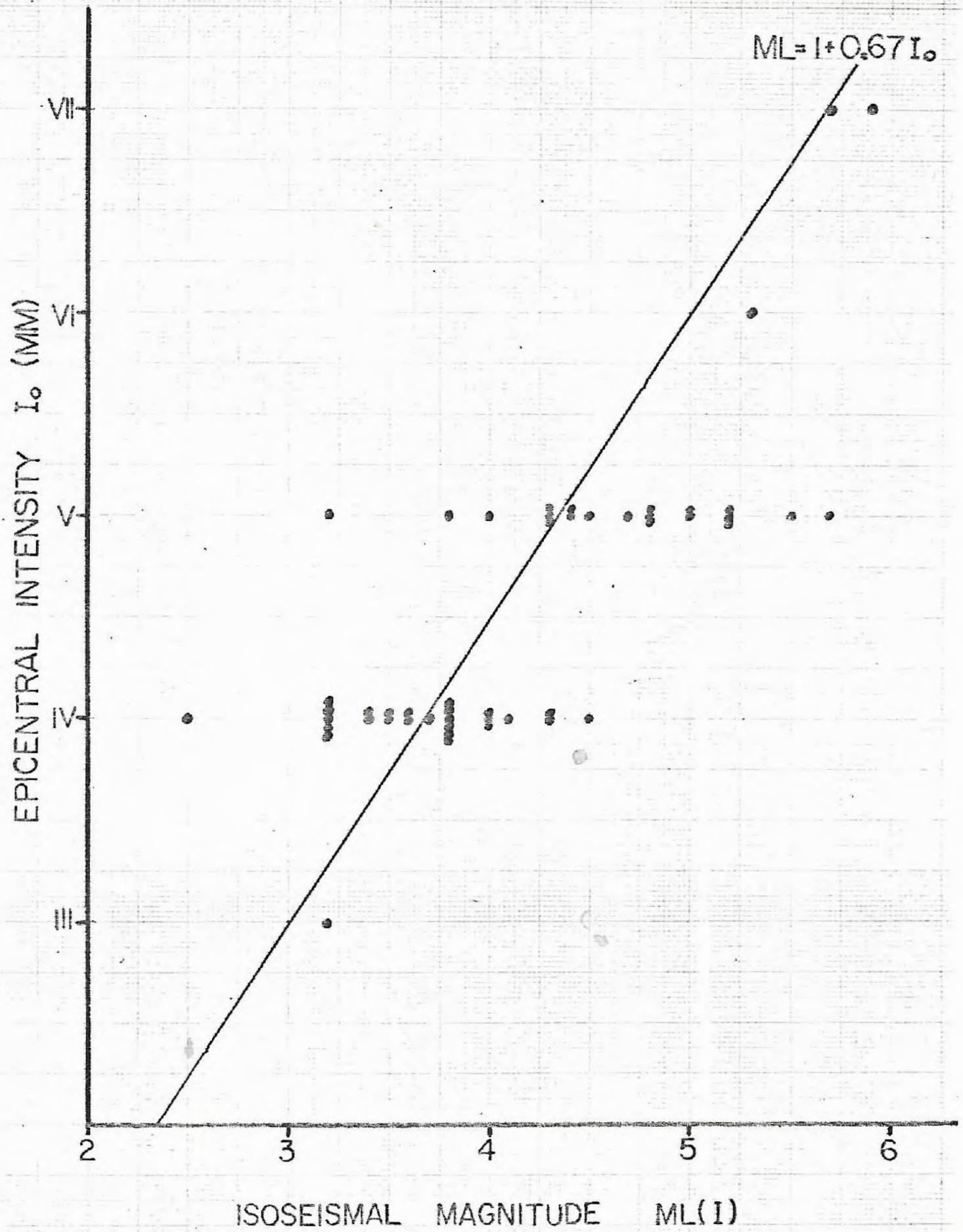

FIGURE 3 Isoseismal magnitude (ML(I)) - epicentral intensity (Io) plot for Queensland earthquakes. Gutenberg-Richter relation is shown.

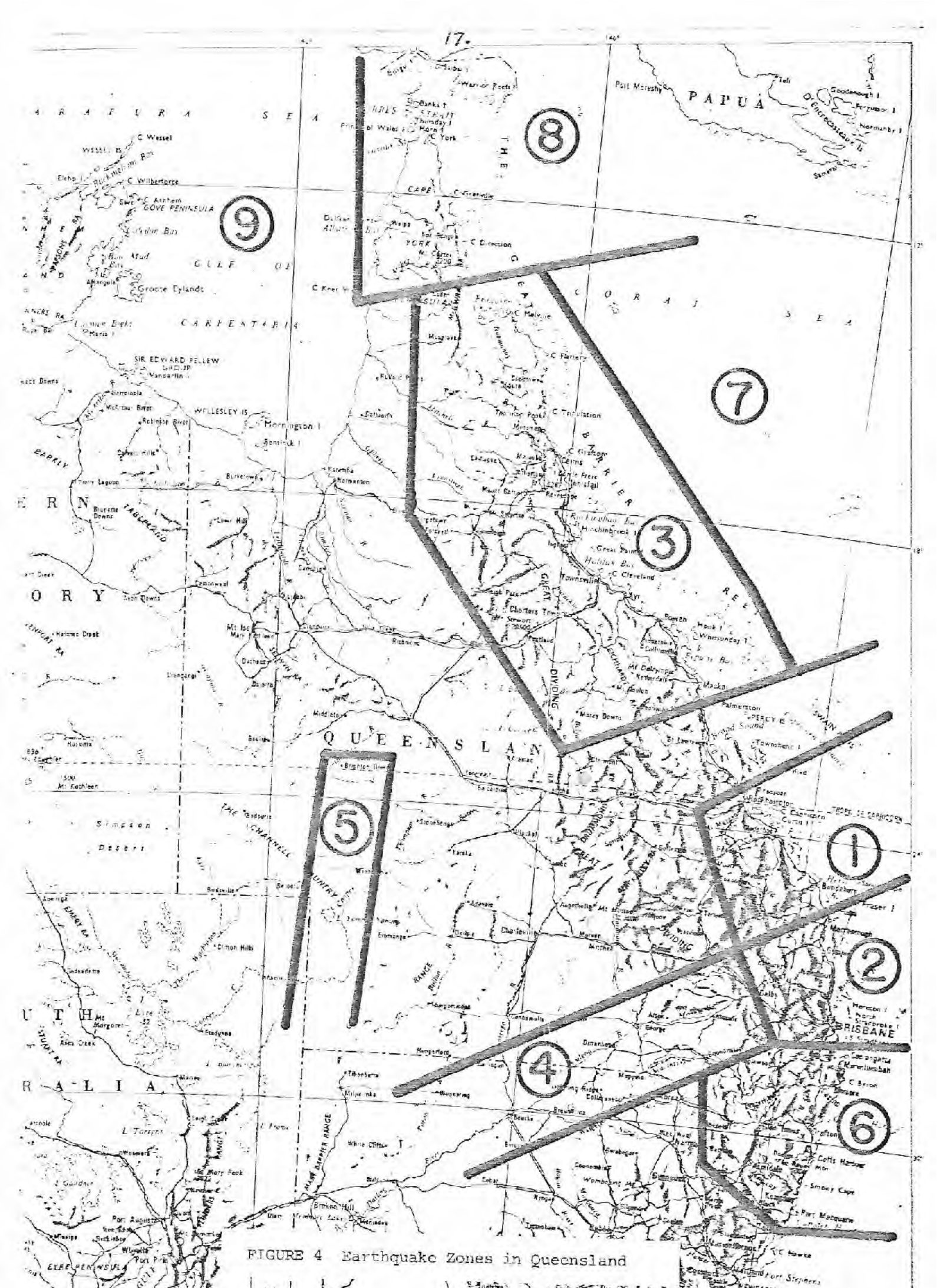

FIGURE 4 Earthquake Zones in Queensland

PROJECT EXPENDITURE

The following expenditure through October, 1985 has been incurred:

(a) University of Queensland Account 0-GEOL-DEPT. MINES-SEISMIC RISK - 822040

1985	August	Salary Dr.J.M.W. Rynn	$2024.00
	September	Salary Dr.J.M.W. Rynn	$2698.66
		Canberra Conferences	
		Airfare	$ 363.20
		Per Diem (5 days)	$ 340.00
	October	Salary Dr. J.M.W. Rynn	$2698.66
		Total:	$8124.52

(b) Department of Geology and Mineralogy, University of Queensland

To support this project, departmental costs in terms of clerical assistance (approximately 5% of total departmental time), photocopying and stores (stationary) supplies have been incurred. No absolute monetary costing was available.

(c) Personal expenses by Dr. J. M. W. Rynn

(i)	Additional expenses incurred in authorised trip to Canberra for conferences and discussions - per diem, conference registration, local travel and telephone calls	$ 320.75
(ii)	Use of private vehicle for visits to Geological Survey of Queensland, City for discussions re North Queensland data	
	3 trips (22.8.85, 28.8.85, 9.10.85) total of 60 km @ University rate of 21¢ per km.	$ 12.60
	Parking charges on 3 visits	$ 8.00
(iii)	Telephone calls from private telephone (378 7701) to B.M.R. Canberra re project data and information - 2 calls 12.9.85 total of 22min.	$ 17.60
	Total:	$ 368.95

GENERAL COMMENTS

1. For the interpretative aspects of this project, it will be essential that a package of computer programs be prepared. Of prime importance here is for the quantitative assessments of seismic risk. At this time it is intended that, again for standardisation purposes and thus comparative studies using the Queensland data, such programs will be those employed by the Bureau of Mineral Resources. In particular this will allow the lack of information now existing for Queensland in the various Australian maps to be completed with the same analytical techniques that have been employed by other researchers in Australia.

2. For several earthquakes in the period 1918 to 1937, the International Seismological Summary (ISS) bulletins show that the RIV seismograph station recorded the events. These records have to be reread in respect to checking both the epicentres and magnitudes. For several other earthquakes, magnitudes have been given in terms of ML (RIV). This is not strictly correct as the epicentral distances are greater than 600km. and thus have to be recalculated in terms of MB.

3. A paper in the first stage of this project, namely on the basic data set (instrumental and macroseismic data) has been submitted to the 8th Australian Geological Convention to be held in Adelaide in February, 1986. The title is "The Seismicity of Queensland 1866-1984".

4. Several research papers are in preparation for publication. Five relating to general aspects of the seismicity of Queensland have been submitted. Four others on the Wivenhoe Dam region are in preparation. Two others, on the 1964 Georgetown earthquakes, seismicity in the South Burnett District, are currently in preparation having emanated from this study.

5. Several people have suggested that a seminar be given (in full) on the paper presented at the Canberra Conference in August, 1985. This is being seriously considered as it is of relevance to many disciplines including seismology, geology and civil engineering.

REFERENCES

CHINNERY, M.A. and ROGERS, D.A., 1973: Earthquake Statistics in Southern New England. Earthquake Notes, 44, 89-103.

DENHAM, D., 1976: Effects of the 1973 Picton and other Earthquakes in Eastern Australia. In DENHAM, D. (Ed.) "Seismicity and Earthquake Risk in Eastern Australia" Symposium, Canberra, 5 December 1973. Bureau of Mineral Resources, Canberra, Bulletin 164, 15-31.

DENHAM, D. (Compiler), 1982: Proceedings of the Workshop on Australian Earthquake Magnitude Scales. Bureau of Mineral Resources, Canberra, Record 1982/29 (unpublished).

EIBY, G.A. 1966: The Modified Mercalli Scale of Earthquake Intensity and Its Use in New Zealand. New Zealand Journal of Geology and Geophysics, 9, 1-2.

EVERINGHAM, I.B., McEWIN, A.J. and DENHAM, D., 1982: Atlas of Isoseismal Maps of Australian Earthquakes. Bureau of Mineral Resources, Canberra, Bulletin 214.

FINLAYSON, D.M. 1968: First Arrival Data From the Carpentaria Region Upper Mantle Project (CRUMP). Journal Geological Society of Australia, 15, 33-50.

GUTENBERG, B. and RICHTER, C.F., 1966: Earthquake Magnitude, Intensity, Energy and Acceleration. Bulletin Seismological Society of America, 46, 105-145.

JEFFREYS, H. and BULLEN, K.E., 1970: Seismological Tables, British Association for the Advancement of Science, London, 50 pp.

LEHMANN, I., 1957: On Lg As Read in North America Records. Annali di Geofisica, 10, 1-21.

McCUE, K.F., 1980: Magnitudes of Some Early Earthquakes in Southeastern Australia. Search, 11, 78-80.

McGREGOR, P.M. and RIPPER, I.D., 1976: Notes on Earthquake Magnitude Scales. Bureau of Mineral Resources, Canberra, Record 1976/56 (unpublished).

MARSHALL, P.D. and BASHAM, P.W., 1973: Rayleigh Wave Magnitude Scale MS. Pure and Applied Geophysics, 103, 406-414.

NUTTLI, O.W., STAUDER, W. and KISSLINGER, C., 1969: Travel-Time Tables for Earthquakes in the Central United States. Earthquake Notes, 40, 19-28.

RICHTOR, C.F., 1968: Earthquake Seismology. W.H. Freeman and Co., San Francisco, 768 pp.

RYNN, J.M.W., 1984: Earthquake Seismology. In RYNN, J.M.W., SOKAL, Y.J. and WILLIAMS, D.J. (Compilers), Introduction to Earthquake Engineering Workshop Notes. Departments of Civil Engineering and Department of Geology and Mineralogy, University of Queensland, 1.1-1.156.

RYNN, J.M.W., DENHAM, D., JONES, T.J., GREGSON, P., SMITH, R.S. and GREENHALGH, S., 1985: Atlas of Isoseismal Maps of Australian Earthquakes. Bureau of Mineral Resources, Canberra, Bulletin 222.

RYNN, J.M.W., WEBB, J.P., CUTHBERTSON, R.J., LYNAM, C.J. and DOHERTY, J.E., 1984-1985: The Wivernhoe Dam Seismic Surveillance Project - Concepts, Methodology and Pre-Impounding Seismicity. ANCOLD Bulletins, 69, 34-42 (Part 1); 70, 39-46 (Part 2); 71, 45-58 (Part 3).

SIMON, R.B., Earthquake Interpretations. William Kanjamann Inc., Los Altos, 150 pp.