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# **An Environmental History of Uranium Mining in Australia : *A Scientific Review***

# Dr Mudd's Background ...

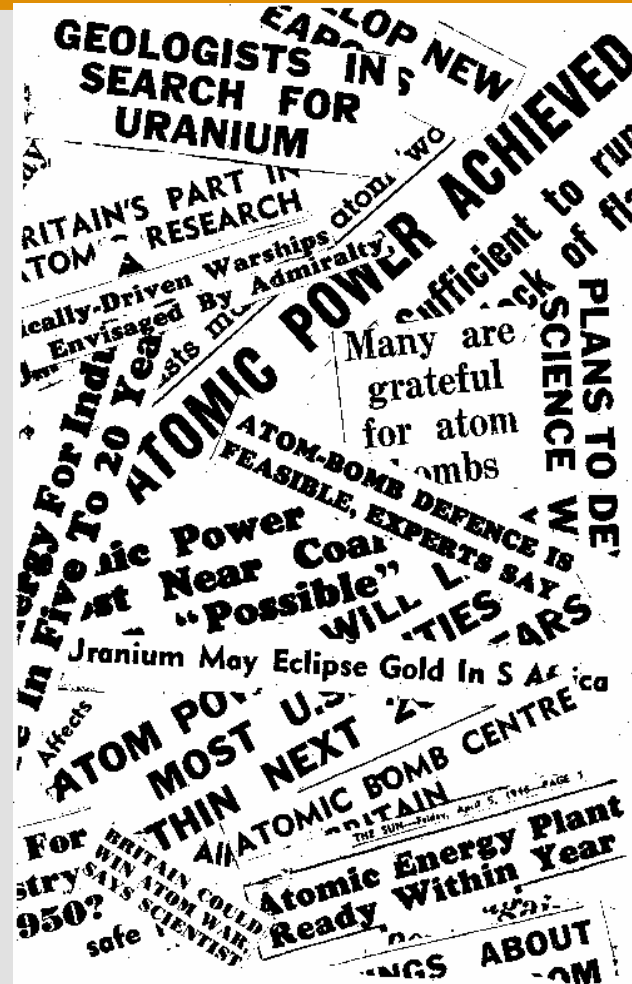
- **B Env Eng (Hons) from RMIT (1994)**
- **1995-mid 2000 PhD at Vic Uni Tech – looking at brown coal ash disposal in Latrobe Valley**
- **mid 2000-early 2002 Research Fellow in Mine Waste at Uni of Queensland**
- **Rest 2002 – Researcher/Adviser for Mirarr in Kakadu (Ranger, Jabiluka, expert witness to the Senate Inquiry) (ongoing role as adviser)**
- **May 2003 to present – Env Eng academic, Monash University**

# The Birth of the Nuclear Debate :

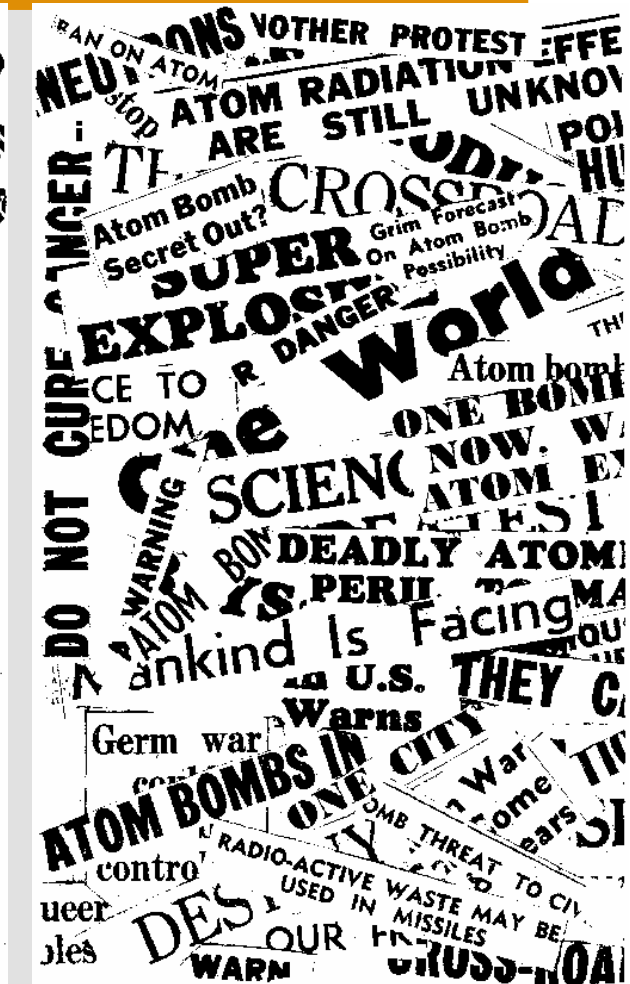
Hiroshima, Aug. 6, 1945



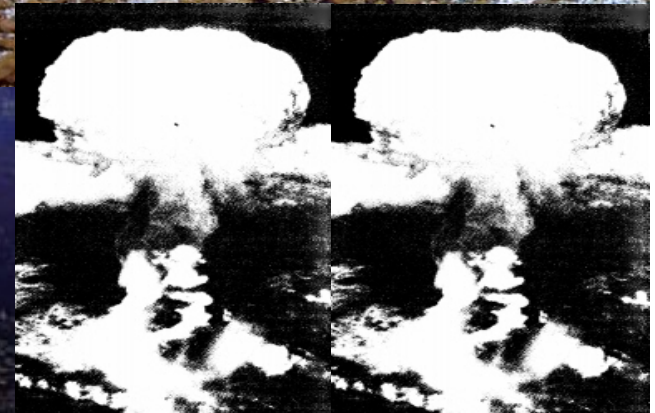
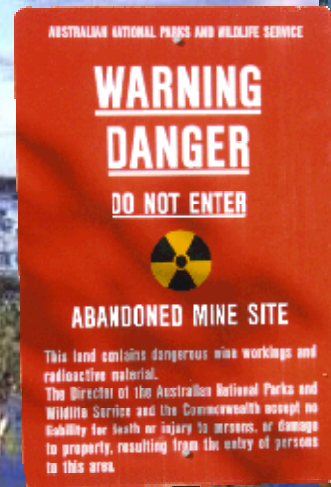
Bowker, 1948



Bowker, 1948







# Basis of this Presentation ...

- This presentation will present numerous tables, figures, photos etc.
- The sources are (mostly) noted and discussed in the extended paper prepared for this conference & House of Reps sub.
- All data and information is from the public record (including some rather obscure places and sources)

# Presentation Overview

- **Brief History of Uranium Mining** (*very brief !!*)
- **Environmental Aspects of Uranium Mining :**
  - UNSCEAR Global Radiation Doses
  - Radon Fluxes & Loads, Gamma Radiation
  - Water Quality Issues (Surface & Groundwater)
  - Future Uranium Ore Milling Issues
  - Oz Uranium Resources in Context
  - Rehabilitation
  - Environmental Issues
- ***Summary & Synthesis of Issues***





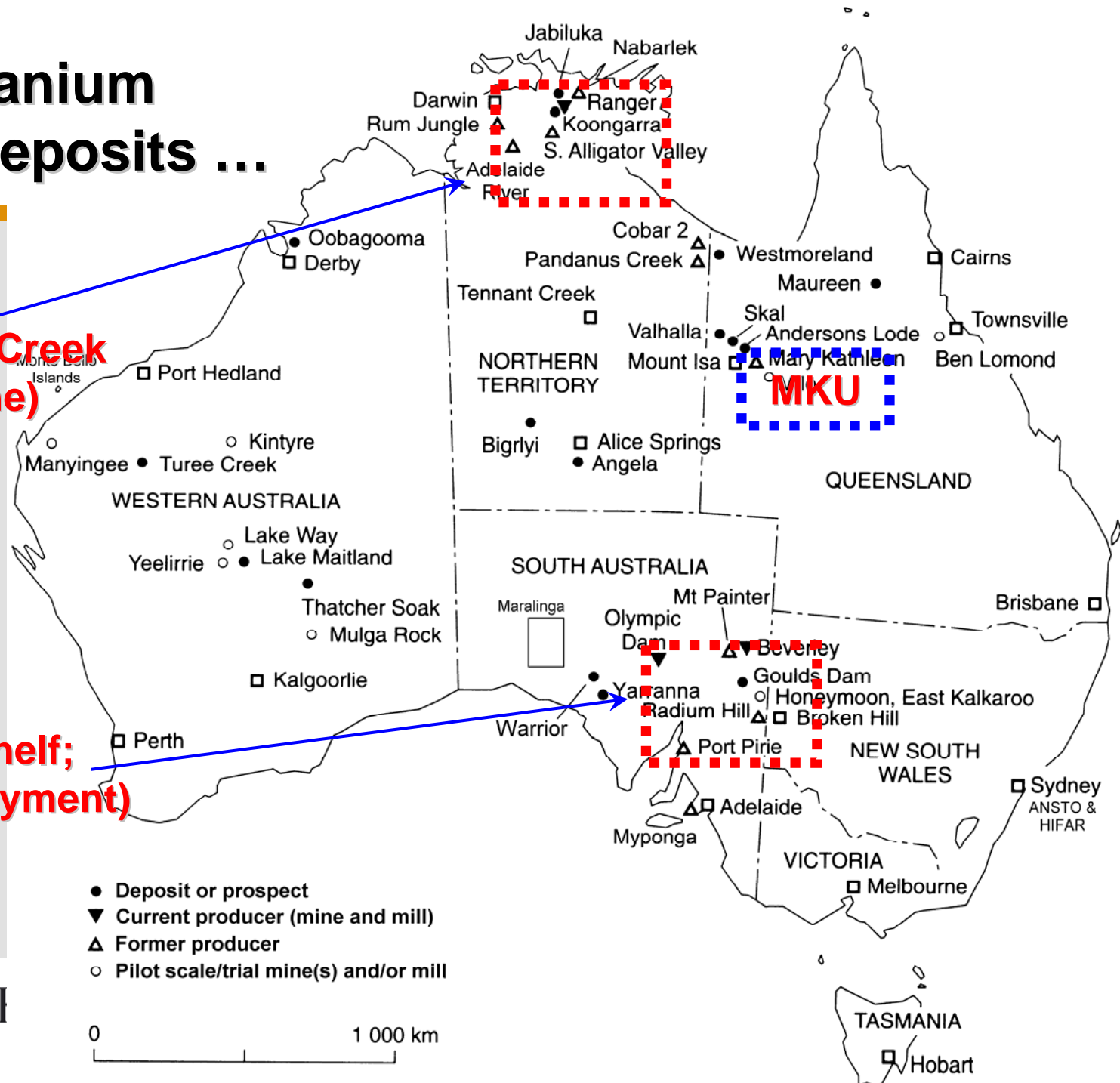
# Briefest History of Oz U Mining

- **Generally considered in two main phases, with an earlier small radium mining phase :**
  - 1906-32 – mining U ore for radium (very small U)
  - 1950's-60's – U mining & export to nuclear weapons and nuclear reactor programs (small)
  - 1970's-now - U mining & export for reactors (large)
- **Each phase has improved on environmental management over previous approaches**
- ***Env legacy is also growing with each phase***

# Aussie Uranium Mines & Deposits ...

**'Top End'  
(ARR/Pine Creek  
Geosyncline)**

**SA (Stuart Shelf;  
Frome Embayment)**



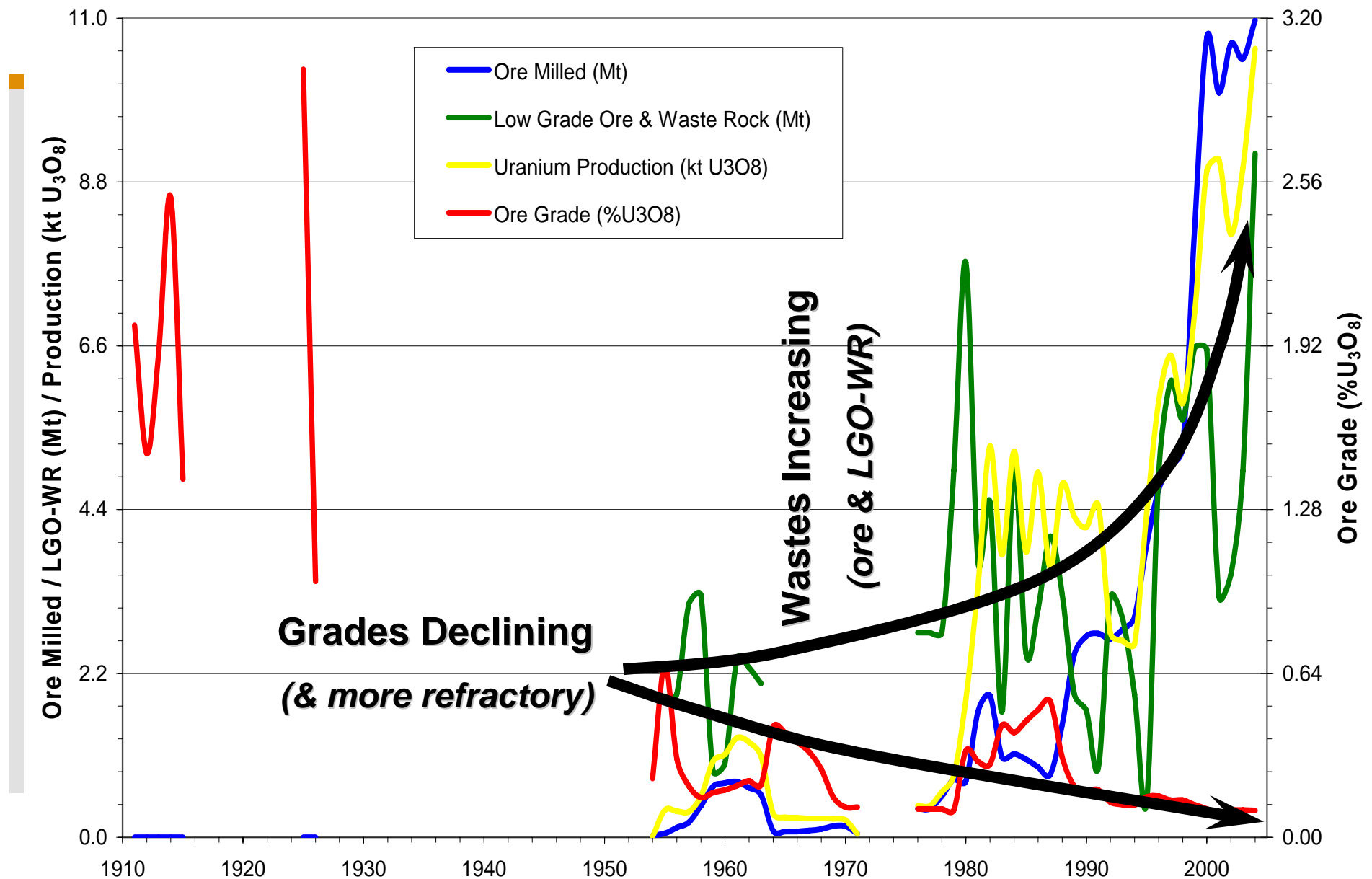


# Production Statistics to *June 2005* :

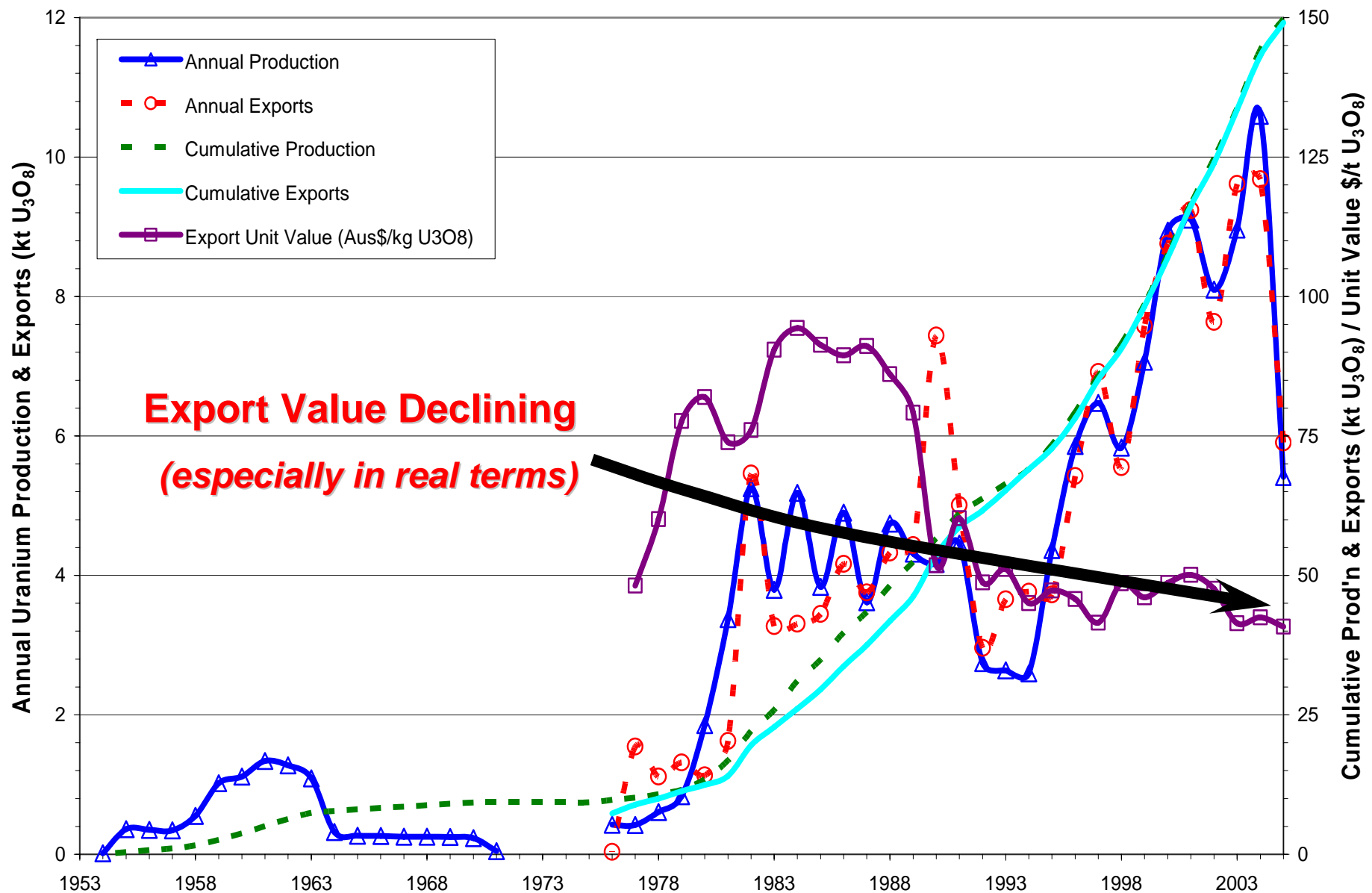
		t Ore Milled	%U <sub>3</sub> O <sub>8</sub>	t U <sub>3</sub> O <sub>8</sub>	t LGO & WR
Olympic Dam, SA	1988-	79,095,326 §	0.075% §	39,101 §	~9,750,000 §
Ranger, NT	1981-	29,609,000	0.31%	81,925	»105,500,000
Nabarlek, NT <sup>(M)</sup>	1980-88	597,957	1.84%	10,955	2,330,000
Nabarlek, NT <sup>(HL)</sup>	1985-88	157,000	~0.05%		
Beverley, SA	2000-	~24,000 ML <sup>ISL</sup> †	~0.18 <sup>ISL</sup> †	3,612	-
Honeymoon, SA <sup>P</sup>	1998-2000	897 ML <sup>ISL, P</sup> †	~0.12 <sup>ISL</sup> †	29.4 <sup>P</sup>	-
Mary Kathleen, QLD	1976-82	6,200,000	0.10%	4,801	17,571,000
Trial Mines	1978-	various		»12	»150,000
Moline, NT	1956-64	135,444	0.46%	716.0	??
Rockhole, NT	1959-62	13,155	1.11%	139.7	??
Mary Kathleen, QLD	1958-63	2,710,483	0.156%	4,091.76	4,429,764
Radium Hill, SA	1954-61	817,000	~0.005%	852.3	??
Port Pirie, SA	1955-62	152,300 <sup>C</sup>	~0.8		
Rum Jungle, NT	1954-71	1,496,641	0.35%	3,530	14,283,000
Trial Mines <sup>RJ</sup>	1953-62	9,224.9 <sup>RJ</sup>	0.92%	- <sup>RJ</sup>	??
Radium Hill, SA	1906-31	~2,130 t	1.4% ??	<7	??
Mt Painter, SA	1910-32	~933 t	~2.1%	??	??
<b>TOTAL</b>		<b>120,950,653 t</b>	<b>0.149%</b>	<b>149,775 t</b>	<b>&gt;158,500,000 t</b>

§ *Missing April-May 2005 due to the takeover of WMC by BHP Billiton*; <sup>P</sup> Pilot scale mining/milling; <sup>RJ</sup> Milled at Rum Jungle (not included in sub-totals); † In situ leach; <sup>M/HL</sup> Mill (M) or heap leach (HL); <sup>C</sup> Radium Hill concentrate; LGO – Low grade ore; WR – Waste rock.

# Production Trends Over Time #1



# Production Trends Over Time #2



# UNSCEAR Global Radiation Doses

Stage of the Nuclear Fuel Chain	Collective Effective Dose Committed per Unit Energy Generated ( person.Sv/GWe.yr)					
	UNSCEAR Report Period	(1993)	(2000) '70-79	(2000) '80-84	(2000) '85-89	(2000) '90-94
<i>Local and Regional Component</i>						
Mining, milling & tailings	1.5	0.238	0.238	0.238	0.238	0.238
Fuel fabrication	0.003	0.003	0.003	0.003	0.003	0.003
Nuclear reactor operation	1.3	3.2	0.9	0.46	0.45	0.44
Reprocessing	0.25	8.5	1.9	0.17	0.13	0.12
Transportation	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<b>Total</b>	<b>3.15</b>	<b>11.94</b>	<b>3.04</b>	<b>0.87</b>	<b>0.82</b>	<b>0.81</b>
<i>Global Component (including solid waste disposal)</i>						
Tailings (over 10,000 years)	150	7.5	7.5	7.5	7.5	7.5
Reactors	Low-level waste	5x10 <sup>-5</sup>	5x10 <sup>-5</sup>	5x10 <sup>-5</sup>	5x10 <sup>-5</sup>	5x10 <sup>-5</sup>
	Intermediate waste	0.5	0.5	0.5	0.5	0.5
Reprocessing solid waste disposal	0.05	0.05	0.05	0.05	0.05	0.05
Globally dispersed radionuclides	50	95	70	50	40	40
<b>Total</b>	<b>200.5</b>	<b>103</b>	<b>78</b>	<b>58</b>	<b>48</b>	<b>48</b>

References : Table 53, pp 200 [UNSCEAR, 1993]; Table 45, pp 284 [UNSCEAR, 2000].



# Radon Fluxes : Evidence ...

- Many uranium deposits have no surface radon expression
- Some do, varying from subtle to substantive
- Though recognised as a major worker/ community radiation risk, it remains poorly studied and reported in some ways
- For some sites, evidence suggests lower radon flux following rehabilitation, while for other sites evidence suggests increases ...

# Radon Flux ...

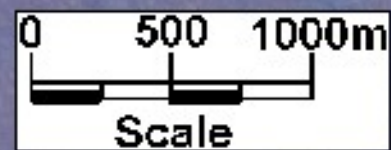
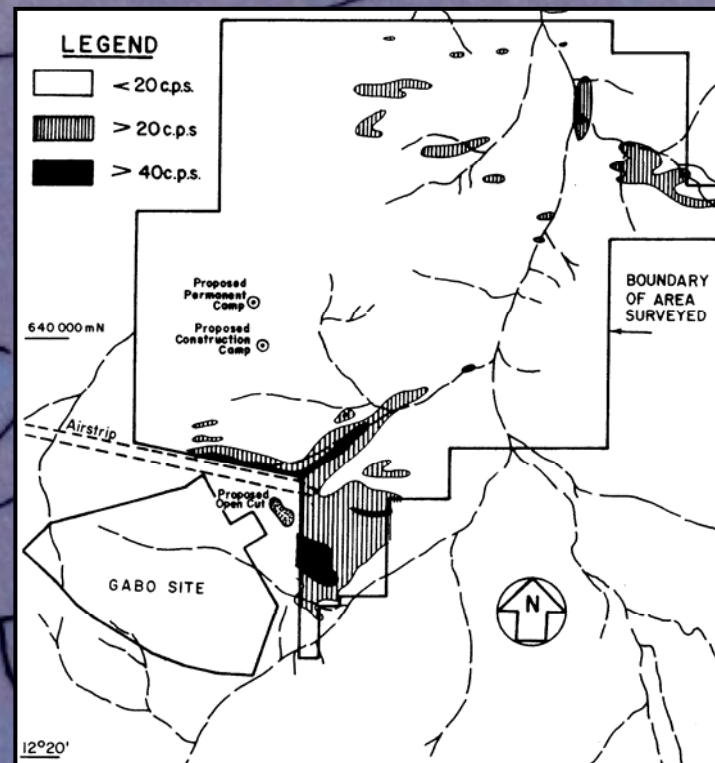
	Waste Type ‡	Area (ha)	Uranium (%U <sub>3</sub> O <sub>8</sub> )	<sup>222</sup> Rn Flux (Bq/m <sup>2</sup> /s)	<sup>222</sup> Rn Load (GBq/day)
Rum Jungle, NT	T	35	~0.086%	~2.9	88
White's (Rum Jungle), NT	WR	26.4	0.01%	1.1	25
Rum Jungle Creek South, NT	WR	21.9	0.054%	2.7	51
Rum Jungle, NT	R <sup>(P)</sup>	~500	-	0.14	-
Rockhole, NT (average)	T	~2	0.048%	<5-21.1 (~6)	10.4
Moline, NT (average)	T	~18	0.066%	<1-17.9 (~2)	31
Port Pirie, SA	T			5	130
Port Pirie, SA	R <sup>(D)</sup>	~30	~0.24%	0.12	3
Jabiluka, NT (Mine Valley)	PM	-	-	0.046	-
Jabiluka, NT (Proposed Haul Road)	PM	-	-	0.025	-
Nabarlek, NT	PM	-	-	3.7-44.0	-
Nabarlek, NT	R <sup>(D)</sup>	~5	-	1.03 ± 0.80	4.5
Nabarlek, NT	U-T	-	-	2.1	9.1
Ranger, NT	PM	245	-	1.78	377
Ranger, NT	U-T	-	-	0.9 <sup>AE</sup> / 0.1 <sup>AQ</sup>	-
Ranger, NT	R <sup>(P)</sup>	-	-	'0'	'0'
Koongarra 1, NT (Koongarra 2)	PM	12.53	-	2.43 (<0.05)	26.3
Olympic Dam, SA	PM	-	-	0.025	-
Olympic Dam, SA	Mill & T	~400	-	-	260-290
Olympic Dam, SA	U-T	75	-	1.6	103.7
Olympic Dam, SA	U-T <sup>(P)</sup>	720	-	0.2	124.4
Honeymoon, SA	PM	-	-	0.035	-

‡ U-T – UNSCEAR 1993 assumed tailings (T) data, <sup>AE</sup> – sub-aerial, <sup>AQ</sup> – sub-aqueous; WR – waste rock; PM – pre-mine (generally above ore zones); R – rehabilitated site (proposed <sup>(P)</sup> or done <sup>(D)</sup> ).

# Gamma Radiation : More Evidence ...

- **Like radon, most U deposits have no or minimal surface expression of gamma rad'n**
- **Some have major gamma signatures**
  - eg. Ranger, Yeelirrie, Mary Kathleen, etc.
- **Others have no gamma signature**
  - eg. Olympic Dam, Beverley, etc.
- **Evidence is somewhat patchy, but for most projects to date, it appears that gamma signatures have increased due to operations**

**Nabarlek**





# Water is Life : Quantity & Quality Issues

- ***Absolutely Fundamental Issue :***
- All U deposits are constrained by either water quantity or quality (or both)
- Degree of impacts on water resources are variable but always locally very significant
- Strong need for extensive high quality monitoring data – *spatially & temporally*
- Groundwater resources are often ignored or undervalued (especially for ISL)

# Water is Life : Examples & Evidence ...

- Mary Kathleen – high seepage rates from ‘rehabilitated’ tailings dam impacting on creek
  - Rum Jungle – still extensive pollutants in surface & groundwaters due to ongoing AMD
  - Jabiluka – interim water management system built
  - Ranger – clear downstream  $\text{Mg-SO}_4$  signature (U?)
  - Olympic Dam – impacts of GAB borefields on springs : mistake set to be repeated (?); *tailings ...*
  - Beverley / Honeymoon – still no real data on public record to answer scientific concerns on GW
- etc ...*

# U Ore Milling Issues : Complexity ...

- **Many potential projects are metallurgically difficult due to highly refractory U minerals or the need to use different milling techniques :**
  - ODam expansion – the 50% brannerite issue
  - QLD-SA dep's – brannerite or davidite problems
  - WA – calcrete-carnotite dep's (alkaline milling)
- **Env costs per unit U to go up ? eg.  $\text{CO}_2$   $\text{H}_2\text{O}$  ??**  
***Major energy, water, rehab'n challenges ...***

# Australian Uranium Resources in Context

- *Although Oz has plenty of U, some facts are missing from the current resources debate :*
  - Only *one new deposit* has been found since 1975
  - Most increase in resources has come from detailed drilling at known projects (esp. ODam)
  - Most future projects have major milling problems to overcome : often refractory or need to use less efficient alkaline milling
  - Almost all projects do not have EIS approvals yet
  - Markets, project scales make new mines hard ...



# Rehabilitation : Absolute Key Challenge

- Modern community expectations (& the law) demand effective rehabilitation
- Based on evidence from rehabilitation of former sites, significant questions remain over long-term performance; eg :
  - Rum Jungle : increasing infiltration on WRD's
  - Mary Kathleen : elevated seepage through tailings dam impacting on local creek
  - Radium Hill : erosion & maintenance issues
  - ***Major question of criteria/standards ...***



***Radium Hill 2001 ...***



***Rum Jungle 2004 ...***



***Yeelirrie 2003 ...***



***Ranger 2001 ...***

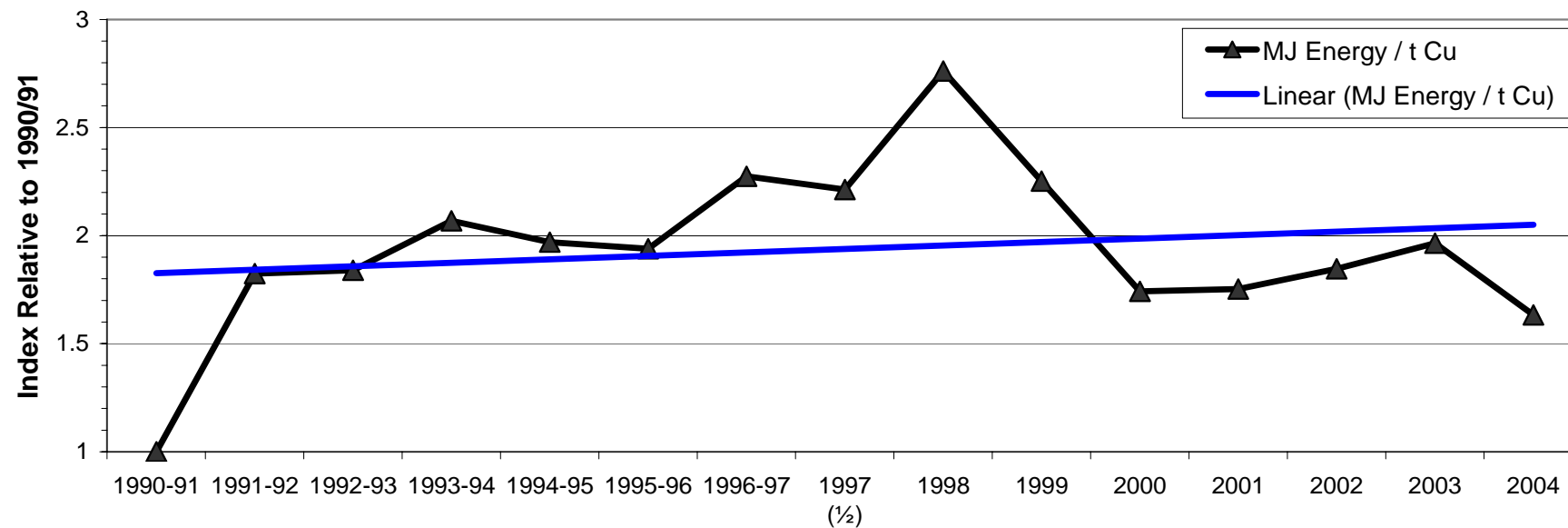
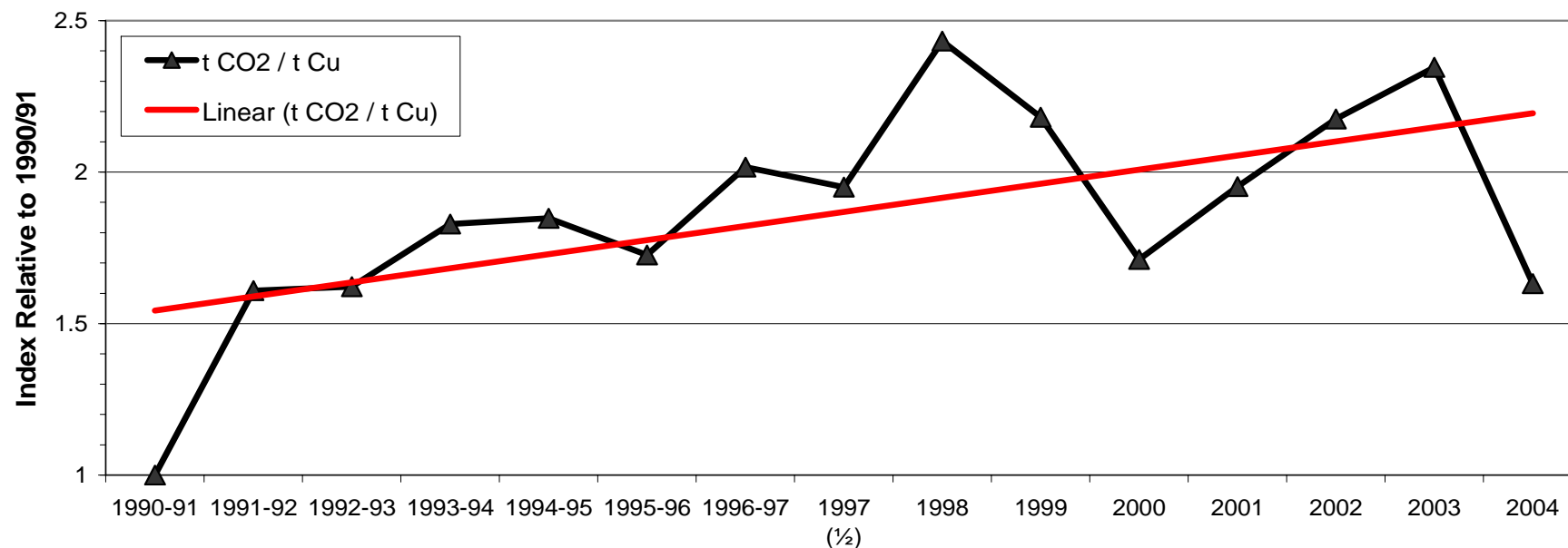




# Other Environmental Issues ...

- **Environmental Impact Assessments (EIS's)**
  - remain a valuable historical resource of data
  - fundamental to spend effort on baseline studies
- **Environmental Reporting :**
  - many U & other mining companies fail to report full mining data consistently, **esp. waste rock**
- **Financial aspects, especially rehab. Bonds**
- **State policies against new U mines ...**

# Energy & CO<sub>2</sub> 'Costs' ... eg. O Dam





# Summary & Synthesis of Issues

- Uranium mining will continue to be a major & divisive issue
- Detailed understanding of data is required by all sides : desperate need for real data (*not just hope*)
- Moral positions are legitimate
- Any potential future uranium mine in Australia will face a number of difficult challenges :
  - water, energy, rehab, significant community opposition, politics, markets, project viability, etc :

***History is a great teacher in that regard ...***



# Acknowledgements

- **Vertical Events / conference organisers**
- **Numerous colleagues (university, NGO, government, industry, etc)**
- **Numerous librarians (DME's, university, OSS, ANSTO, etc)**
- **Various Mines Departments & government groups (eg. OSS, ARPANSA)**
- **Especially Peter Diehl (WISE Uranium Project)**