Singapore Actuarial Society Mortality Investigation 1997 - 2002

A draft report by the SAS Mortality Study Work Group

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Background

- **Gap in the updated mortality table**
  - **Latest investigation for 90-95 experience do not have graduated table**
  - **Last two graduated tables of 83-88 and 88-93 are outdated**
- **Mortality Study Work Group (WG) formed in late 2001 under the auspices of SAS**
- **WG worked closely with MAS as data from individual companies are confidential**

Terms of Reference

1. To analyze the mortality experience of assured lives from 1993 to 2000 and to derive a set of graduated mortality rates
2. To compare these rates with COMSAL 1988/93 rates
3. To recommend enhancements to the raw data to enable more sophisticated analyses to be conducted (with examples of such analyses) as well as to enable analyses of annuitant mortality

Progress Since March 03

- **March 03 presentation to AGM**
  - **Presented initial work done using data from MAS303 together with some initial information on the data with and w/o CI for 99-01 for top 4 insurers**
  - **Concluded we need more data to do a proper analysis of experience w/o CI**
- **Requested for more data from top 4 insurers (AIA, GE, Prudential, NTUC Income) for year 97-98 with and w/o CI**
- **Also incorporated data from MAS303 for 2002 based on revised format and the additional request of data split by CI and w/o CI for 2002**

Progress Since March 03

- **Compiled, checked and cleaned up data collated**
- **Crude rate produced for policies without CI with curtate duration greater or equal to 2 years for all standard lives (both medical and non-medical register)**
- **Graduation carried out on the crude rate with help from Professor Beda Chan from Hong Kong University**
- **Report is almost ready to present to SAS Council for approval**

The Report

- Executive Summary
- Introduction
- The Data
- Method of Graduation
- Graduated Table
- Fit and Smoothness
- General Observations
- Lots of Appendices

The Data - Source

- **Three sets of data**
  - **Set 1: All Insurers – all policies**
  - **Set 2: Top 4 insurers – all policies**
  - **Set 3: Top 4 insurers – policies with 100% acc. CI**
- **Set 1 and set 2 breakdown by gender, medical status, curtate duration (0-5)**
- **Set 3 only breakdown by gender**
- **MAS303 and special request from MAS to the big 4**
- **Deduct Set 3 from Set 2 to derive the Cleaned Data for the analyses**

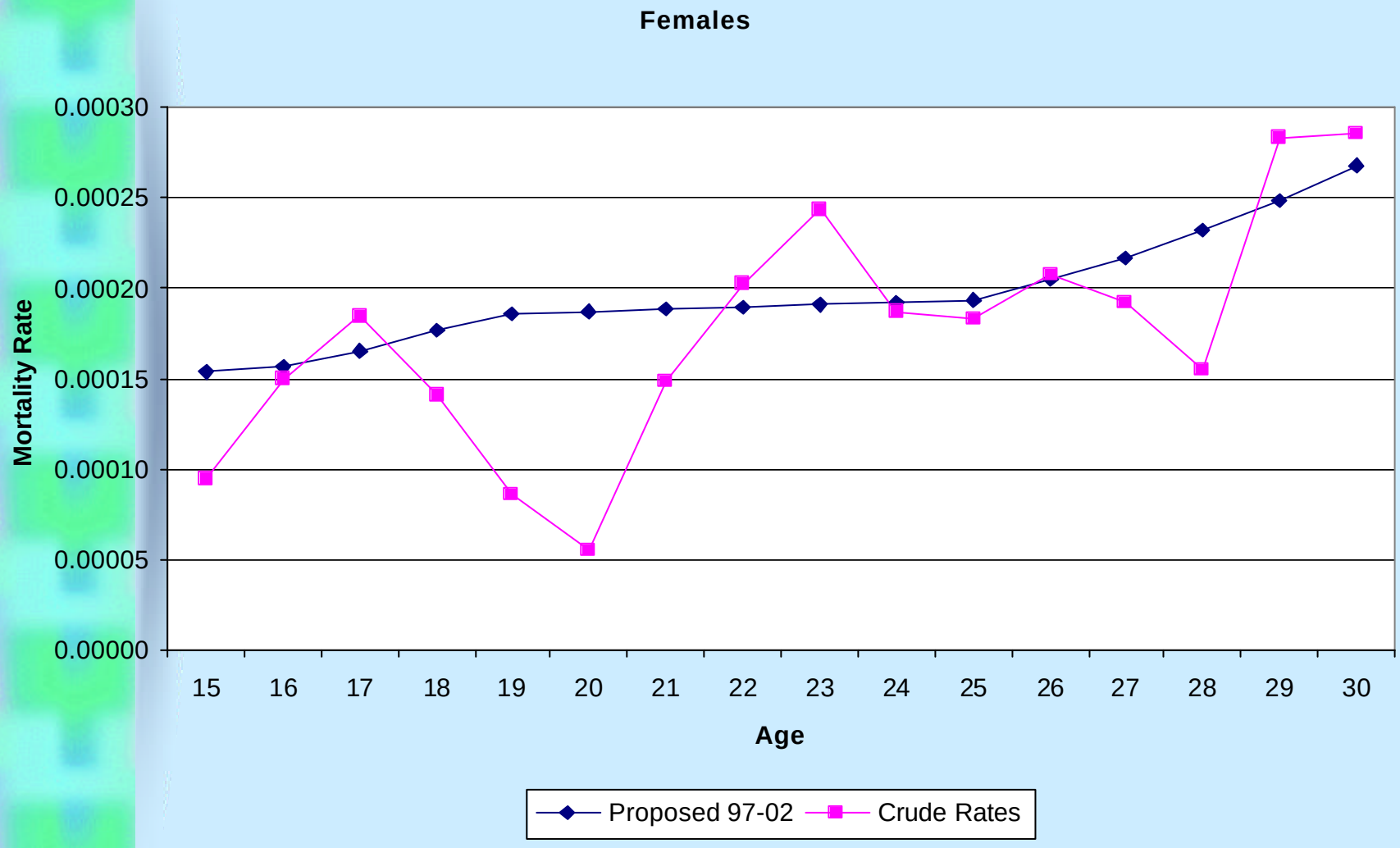
Objectives of Graduation

"To derive mortality rates that satisfy the dual criteria of providing a good fit to the underlying crude rates as well as ensuring the appropriateness of the overall shape and smoothness of the derived curves"

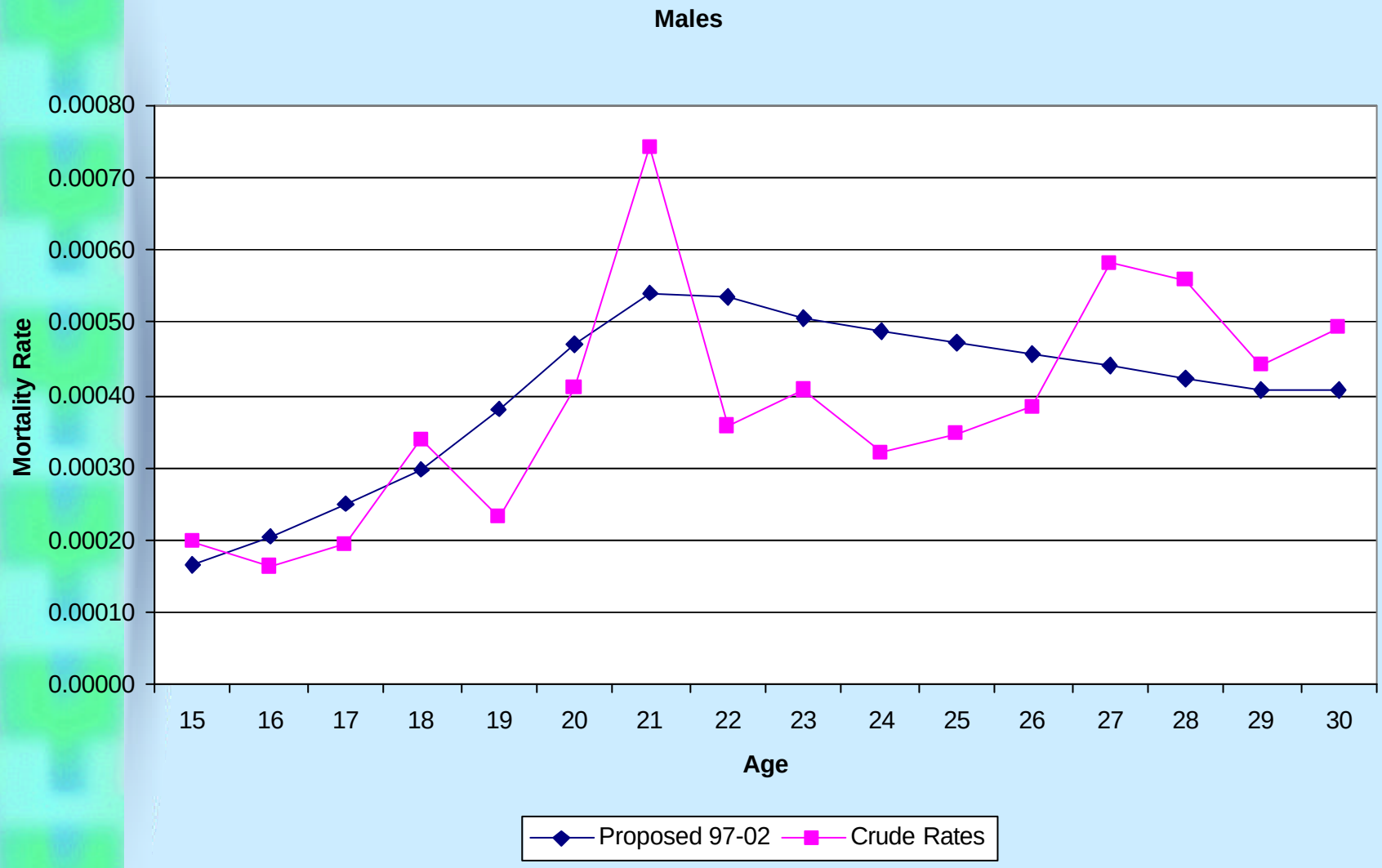
Graduation

- **Female**
  - **15 to 29: FCS with adjustments**
  - **30 to 64: FCS w/o adjustments**
  - **65+ : FCS merge into Gompertz**
- **Male**
  - **15 to 29: Combo FCS, MA7yrs, handpolish, straight line interpolation**
  - **30 to 50: FCS with small adjustments**
  - **51 to 64: FCS**
  - **65+ : FCS merge into Gompertz**

Female 15 to 29: FCS w. adj.



Male 15 to 29: various



Free Cubic Spline – Key Ages

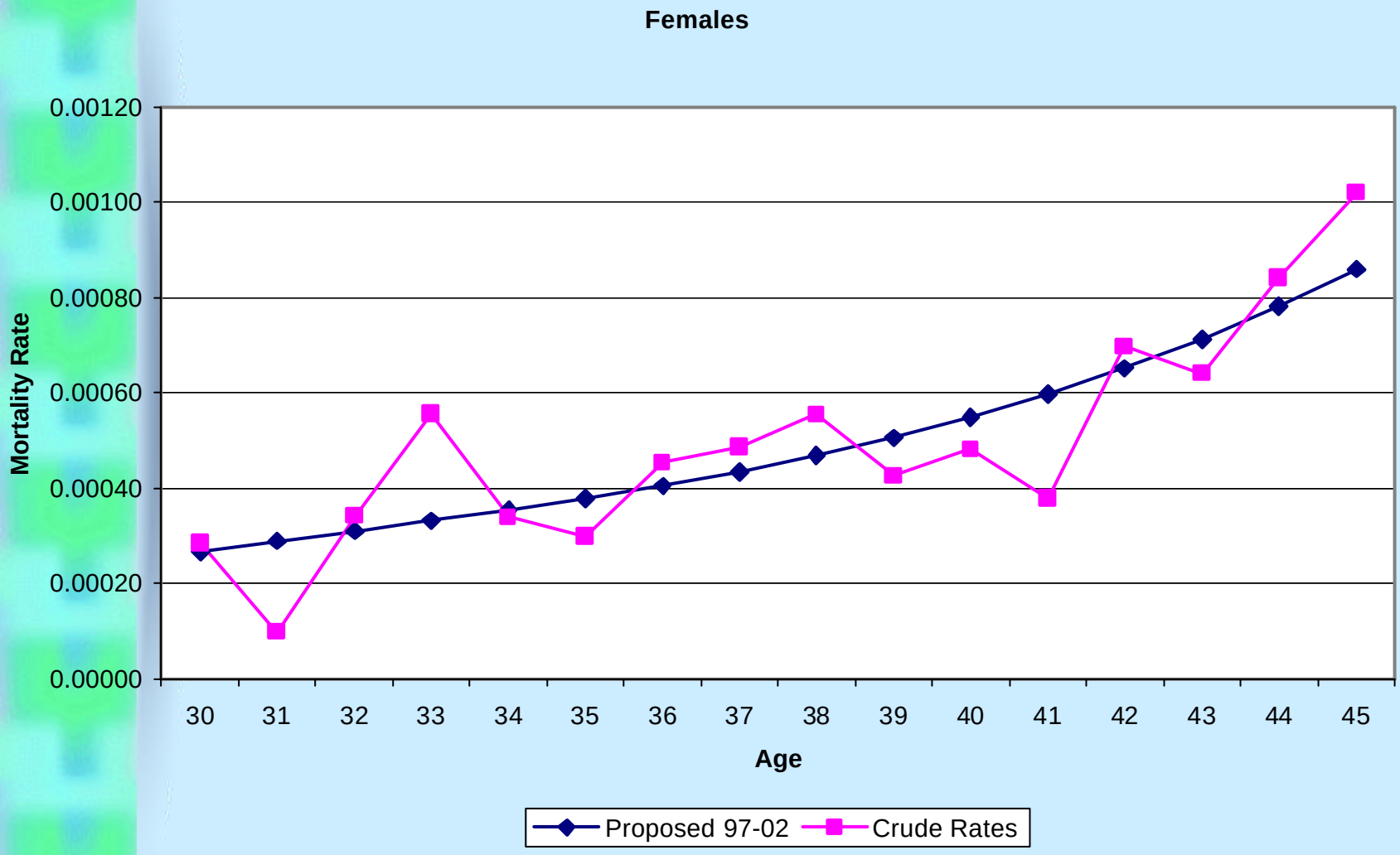
- **Formula:**

$$q_x = a_o + a_1 x + a_2 x^2 + a_3 x^3 + \sum_{i=1}^{n} b_i g_i(x)$$

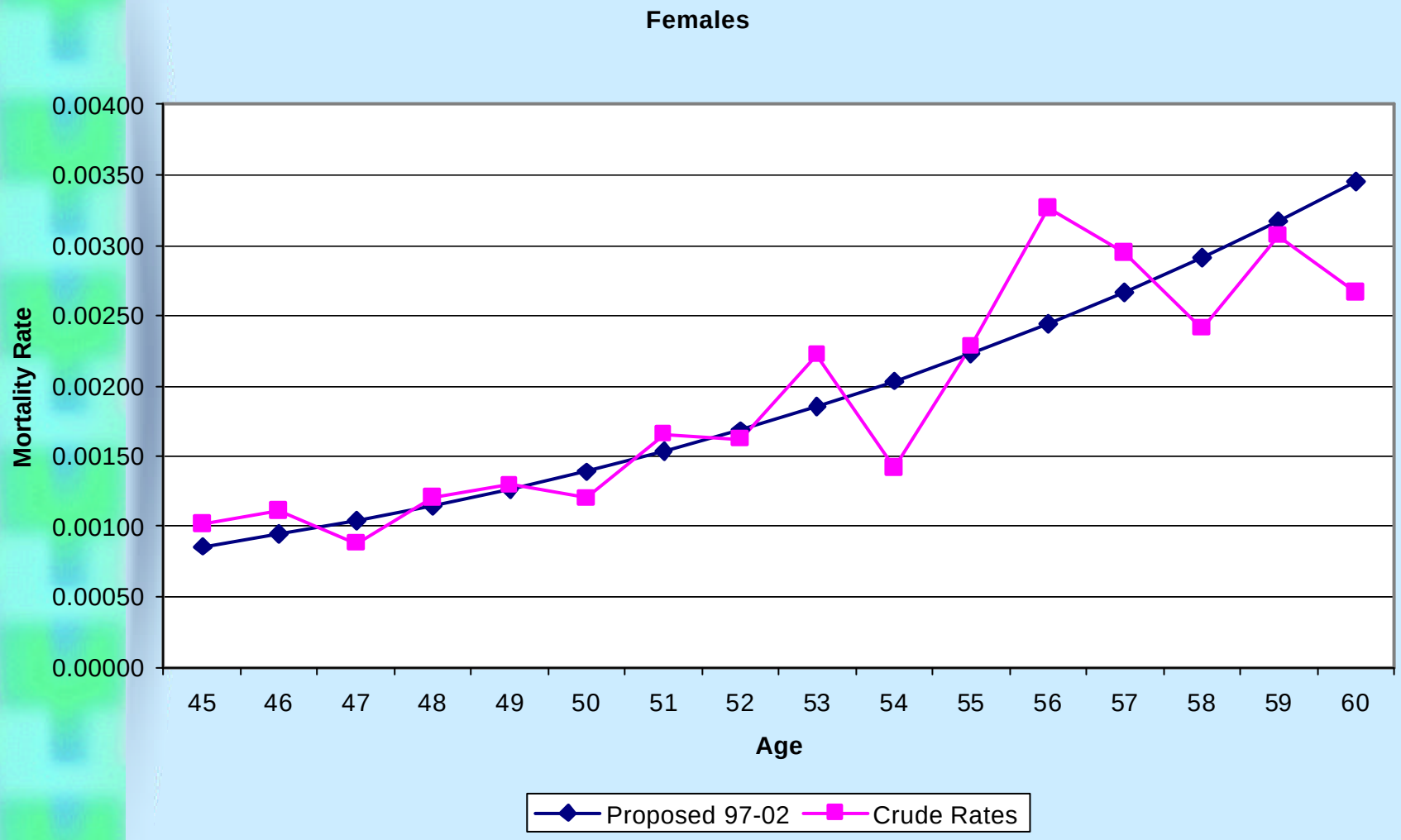
$$g_i(x) = \begin{cases} (x - x_i)^3 \ for & x \geq x_i \\ 0 \quad for & x < x_i \end{cases}$$

- **Solve using maximum likelihood method**
- **Also tried out Natural Cubic Spline and Whittaker-Henderson Methods but both would not give the balance approach that meet the objective**

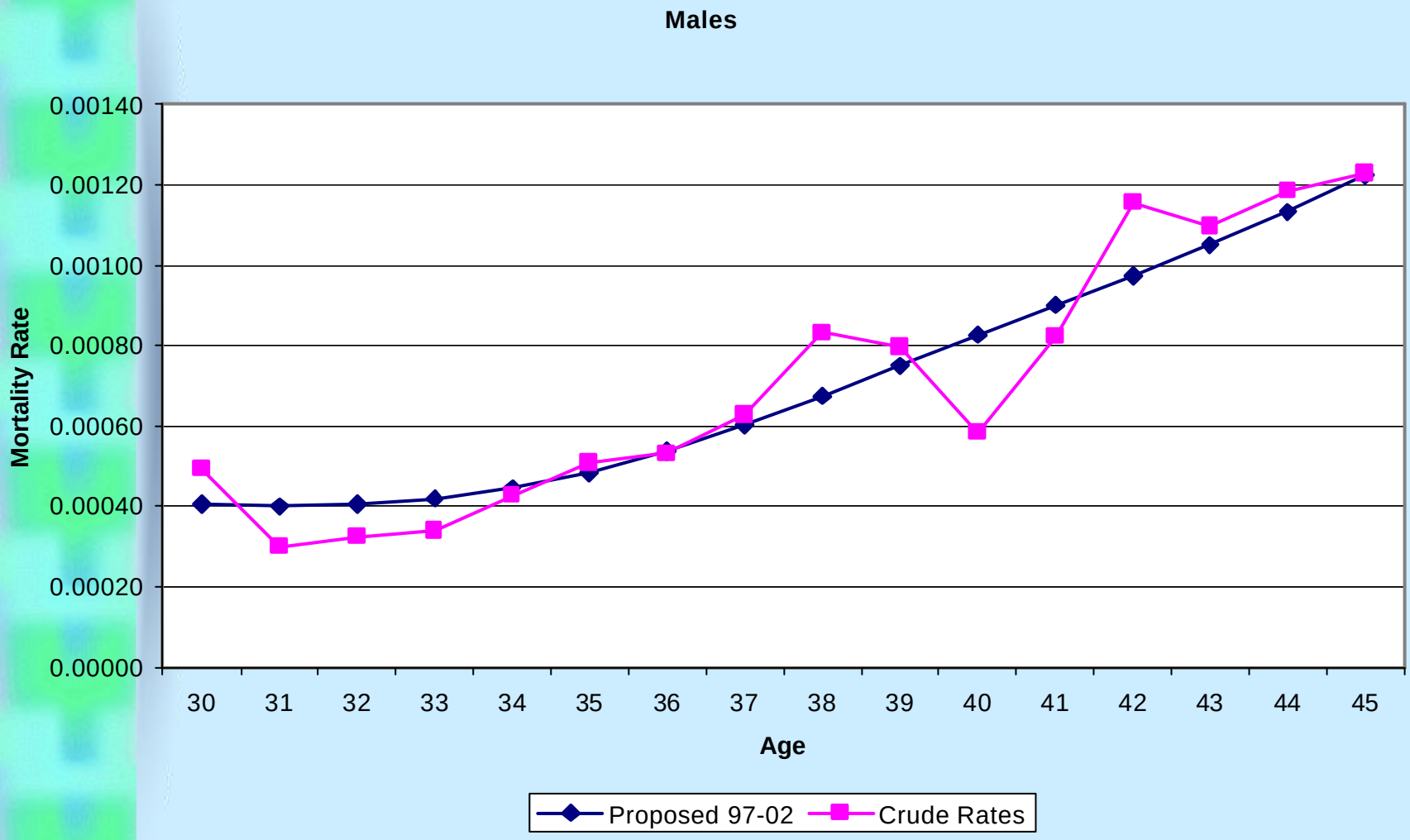
Female 30 to 45: FCS



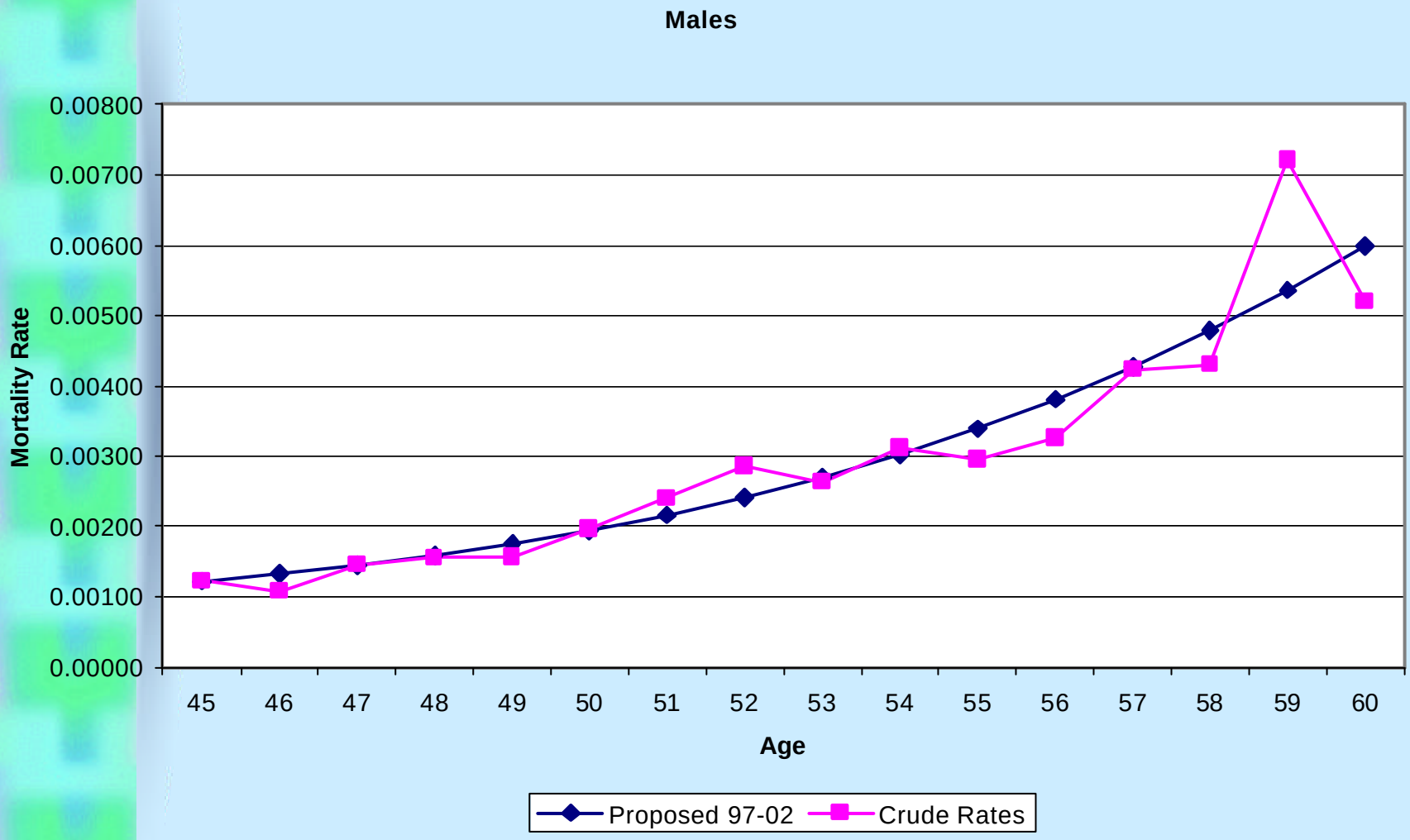
Female 46 to 60: FCS



Male 30 to 45: FCS



Male 46 to 60: FCS w. adj.



Gompertz – Old Ages 65+

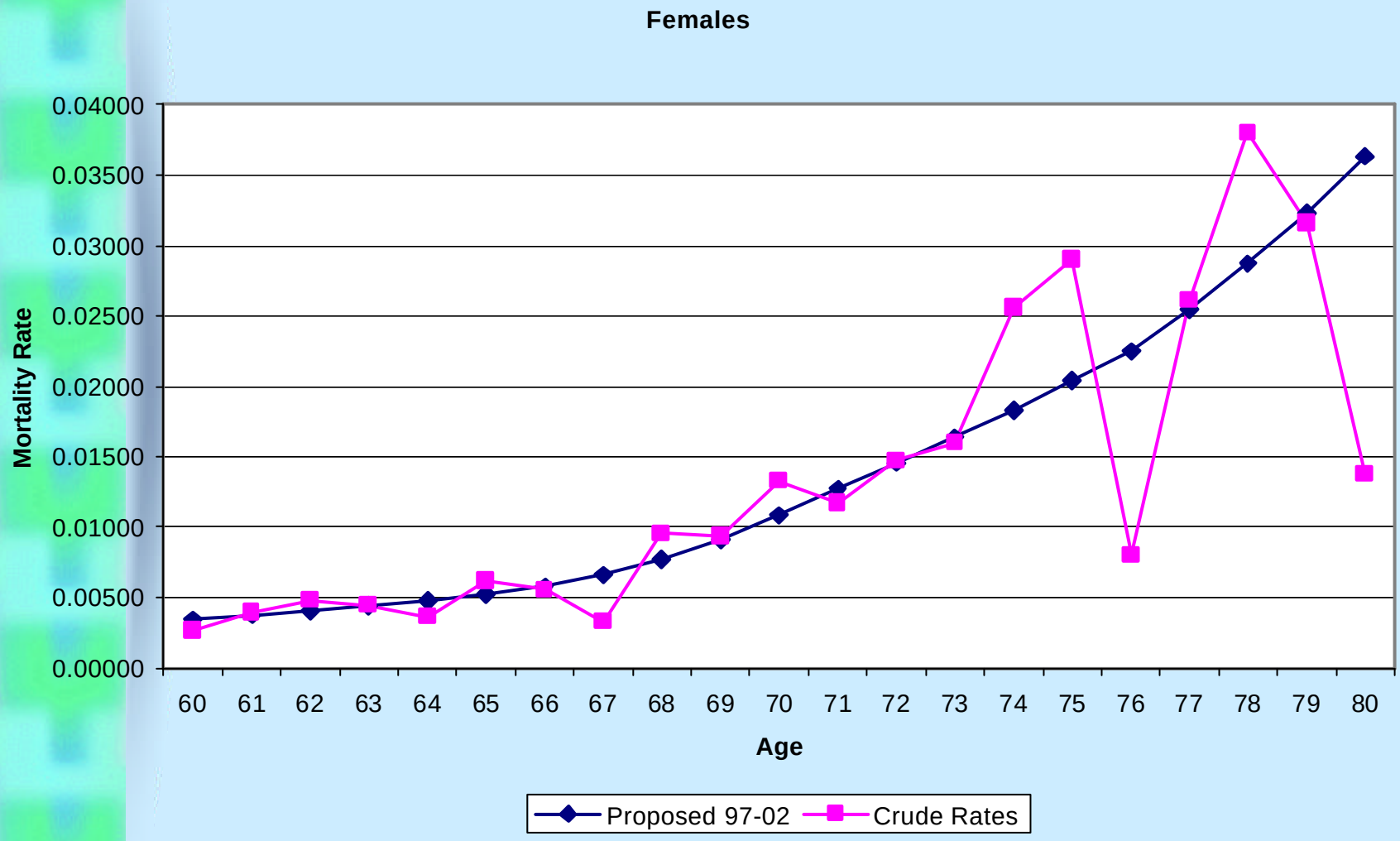
- **Formula:**

$$q_x = 1 - \exp(-m_x)$$

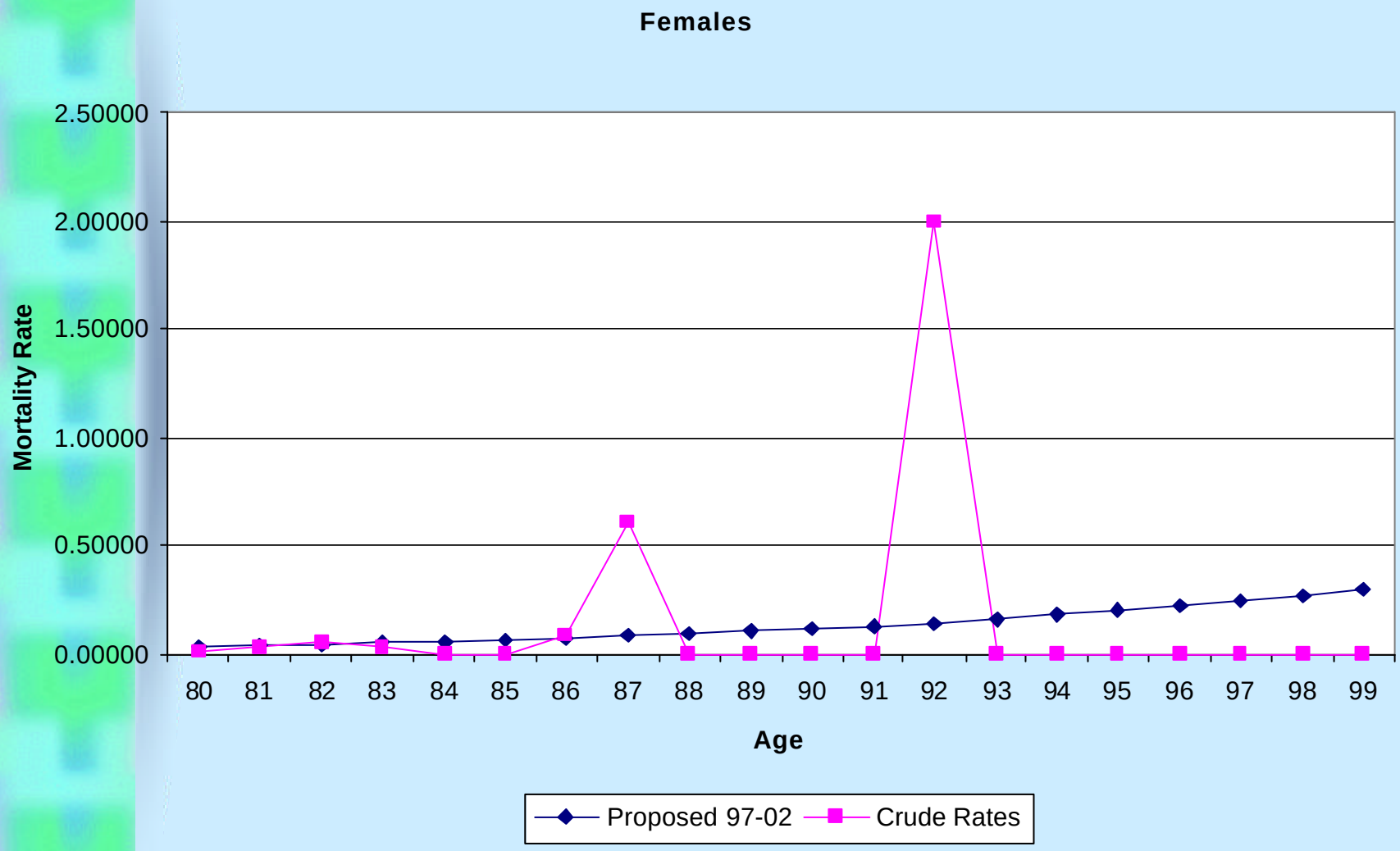
$$Log_e m_x = a + bx$$

- **Solve using least square method from age 55 to75 (female) and 55 to 80 (male)**
- **Extrapolate for the oldest ages**

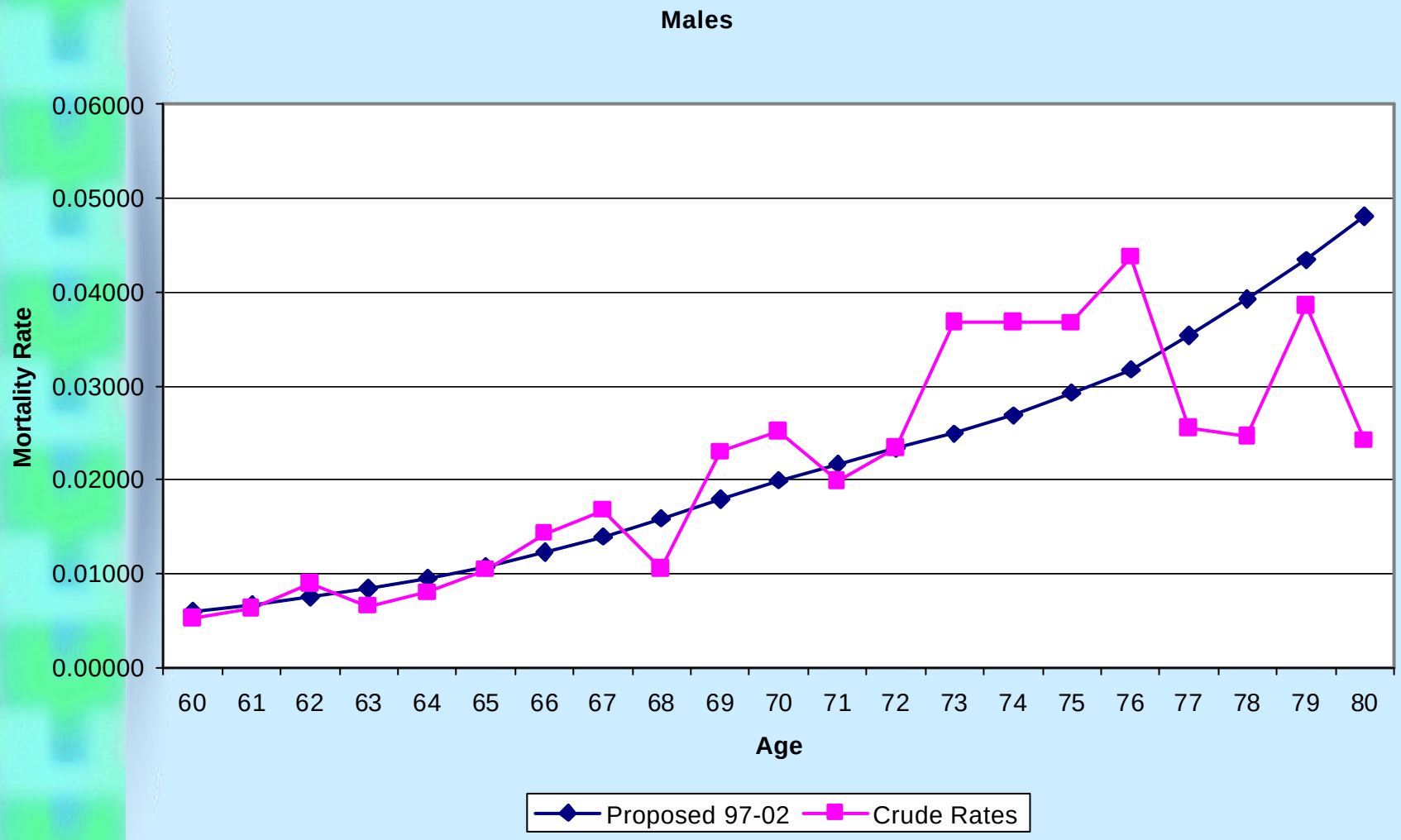
Female 60-80: FCS & Gompertz



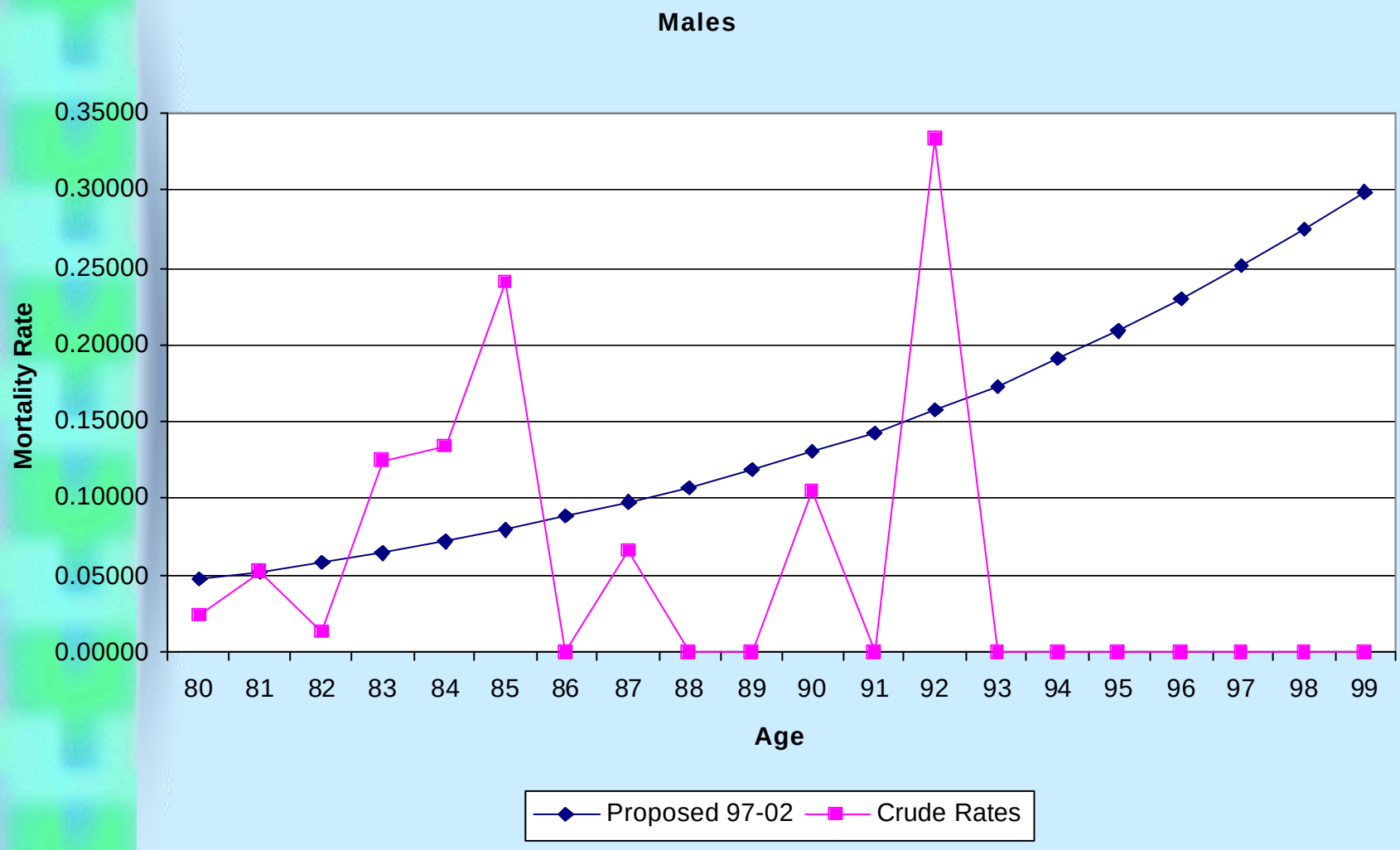
Female 80-99: FCS & Gompertz



Male 60-80


Males
Mortality Rate
0.06000
0.05000
0.04000
0.03000
0.02000
0.01000
0.00000
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
Age
Proposed 97-02
Crude Rates

Male 80-99


Males
Mortality Rate
0.35000
0.30000
0.25000
0.20000
0.15000
0.10000
0.05000
0.00000
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
Age
Proposed 97-02
Crude Rates

Goodness of Fit

Age	Males			Females		
	Actual (A)	Expected (E)	Ratio (A/E)	Actual (A)	Expected (E)	Ratio (A/E)
15 - 24	174	202	86%	70	80	88%
25 - 34	440	451	97%	302	300	101%
35 - 44	1140	1111	103%	652	680	96%
45 - 54	1580	1578	100%	895	883	101%
55 - 64	787	819	96%	457	450	101%
65 - 80	404	376	107%	177	174	101%
15 - 90	4551	4563	100%	2563	2579	99%
25 - 54	3160	3140	101%	1849	1863	99%
55 - 80	1191	1195	100%	634	625	101%

Goodness of Fit

Age	Males			Females		
	Actual Deaths	Expected Deaths	Chi-Sq	Actual Deaths	Expected Deaths	Chi-Sq
15 – 24	174	202	3.9904	70	80	1.2030
25 – 34	440	451	0.2923	302	300	0.0156
35 – 44	1140	1111	0.7412	652	680	1.1686
45 – 54	1580	1578	0.0034	895	883	0.1514
55 – 64	787	819	1.2530	457	450	0.1003
65 – 74	353	323	2.8598	151	147	0.0854
75 – 99	79	82	0.1384	37	38	0.0544
25 – 54	P-Value		0.5954			0.5129
15 – 99	P-Value		0.1585			0.8361

Smoothness

- **Smoothness test**
  - **Barnett's Rule of Thumb**
    - $[?^3 q_x] \times 7^3 < q_x$
    - $?^2 q_x$ only changes signs before and after a patch of intrinsic roughness
    - Graduation satisfies the first condition 79% of the time for male and 87% for female
    - For males $?^2 q_x$ changes sign at age: 22, 23, 70 and 73
    - For females $?^2 q_x$ changes sign at age: 76 and 77

Other Checks on the Graduations

- **Need to check for reasonableness versus previous mortality tables**
- **Is the rate of improvement too high?**

Compare to Previous Tables – Rate per Mille

Age	Males			Females		
	S8388	S8893	S9702	S8388	S8893	S9702
15 - 19	0.6870	0.5096	0.2552	0.2273	0.1881	0.1670
20 - 24	0.7403	0.7709	0.5076	0.2614	0.3261	0.1899
25 - 29	0.6240	0.5571	0.4375	0.3029	0.2744	0.2209
30 - 34	0.6248	0.4851	0.4170	0.4840	0.3229	0.3126
35 - 39	1.0462	0.7302	0.6107	0.7075	0.4653	0.4381
40 - 44	1.6503	1.1850	0.9735	0.8225	0.7695	0.6542
45 - 49	2.4577	1.8659	1.4532	1.4441	1.3234	1.0354
50 - 54	4.8730	3.2627	2.3552	2.6613	1.8316	1.6469
55 - 59	9.1834	6.4638	4.1668	5.1028	2.6570	2.6232
60 - 64	14.3092	11.0912	7.2623	8.5935	6.6693	3.9519
65 - 69	22.8337	17.8773	13.4021	13.6053	11.8955	6.4364
70 - 99	47.9092	37.0700	28.5166	27.3391	23.1866	17.6782
25 - 54	1.6469	1.1927	0.9376	0.8933	0.7052	0.6094
15 - 99	2.0488	1.5136	1.1282	1.1180	0.8596	0.7032

Compare to Previous Tables – Annualised Rate of Improvement

Age	Males			Females		
	5 Years from S8388 to S8893	9 Years from S8893 to S9702	14 Years from S8388 to S9702	5 Years from S8388 to S8893	9 Years from S8893 to S9702	14 Years from S8388 to S9702
15 - 19	6.32%	6.75%	6.60%	5.50%	0.09%	2.06%
20 - 24	-0.47%	4.54%	2.78%	-4.70%	5.90%	2.24%
25 - 29	1.62%	3.13%	2.59%	0.93%	2.48%	1.93%
30 - 34	4.85%	1.45%	2.68%	7.55%	-0.03%	2.75%
35 - 39	6.75%	1.37%	3.32%	8.42%	0.18%	3.21%
40 - 44	6.67%	1.65%	3.48%	1.91%	1.15%	1.42%
45 - 49	5.20%	2.19%	3.28%	1.29%	2.13%	1.83%
50 - 54	7.53%	2.81%	4.52%	6.30%	1.03%	2.95%
55 - 59	7.06%	4.06%	5.14%	12.73%	-0.90%	4.20%
60 - 64	5.05%	4.08%	4.43%	5.59%	4.80%	5.08%
65 - 69	4.75%	2.59%	3.37%	2.61%	6.07%	4.85%
70 - 99	5.00%	2.37%	3.31%	3.21%	2.47%	2.74%
25 - 54	6.12%	2.13%	3.57%	4.40%	1.20%	2.35%
15 - 99	5.83%	2.69%	3.83%	5.08%	1.69%	2.91%

General Observations

- **Male**
  - **Rate of improvement around 4% from S8388 and 3% from S8893**
  - **Fastest improvement around age 50-60**
  - **Extremely high improvement at 15-19**
- **Female**
  - **Rate of improvement for female around 3% from S8893 and 2% from S8893**
  - **Fastest improvement around age 60-70**

Concerns

- **Overall rates of improvement very high compared to other developed countries**
  - **New Zealand from 1985 to 1995: 2.93% pa**
  - **Australia from 1987 to 1991: 5.20% pa for males, 5.17% pa for females**
  - **Japan from 1984 to 1996: 0.67% pa for males, 0.50% for females**
  - **Japan from 1979 to 1996: 0.78% pa for males, 0.76% for females**
- **Extremely high improvement at youngest age for male**
- **Rate of improvement for 5 years from 83-88 to 88-93 is faster than the rate of improvement for 9 years from 88-93 to 95-02**

Population Mortality – Rate per Mille

Age	Males			Females		
	1984-1988	1989-1993	1998-2001	1984-1988	1989-1993	1998-2001
15-19	0.7600	0.5200	0.3750	0.3800	0.2800	0.2750
20-24	1.0600	0.7600	0.6750	0.4600	0.3800	0.2250
25-29	1.1400	0.6000	0.6250	0.6000	0.4200	0.3000
30-34	1.2600	0.9000	0.7500	0.7800	0.5600	0.4500
35-39	1.8800	1.2200	1.1000	1.1000	0.8400	0.6250
40-44	2.8800	2.1000	1.7000	1.6400	1.4600	0.9750
45-49	4.7200	3.6400	2.6250	2.8200	2.1800	1.7000
50-54	8.7800	6.7600	4.6000	5.0000	3.9400	2.7750
55-59	15.4600	12.0400	8.3250	7.9600	6.7600	4.7000
60-64	23.5800	20.3800	14.8750	13.6600	11.0400	8.2750
65-69	36.2800	30.7800	24.7750	21.7800	18.3400	14.6250

Population Mortality – Annualised Rate of Improvement

Age	Males			Females		
	5 Years from 8388 to 8893	9 Years from 8893 to 9701	14 Years from 8388 to 9701	5 Years from 8388 to 8893	9 Years from 8893 to 9701	14 Years from 8388 to 9701
15-19	7.31%	3.57%	4.92%	5.92%	0.20%	2.28%
20-24	6.44%	1.31%	3.17%	3.75%	5.66%	4.98%
25-29	12.05%	-0.45%	4.20%	6.89%	3.67%	4.83%
30-34	6.51%	2.01%	3.64%	6.41%	2.40%	3.85%
35-39	8.28%	1.14%	3.76%	5.25%	3.23%	3.96%
40-44	6.12%	2.32%	3.70%	2.30%	4.39%	3.65%
45-49	5.06%	3.57%	4.10%	5.02%	2.73%	3.55%
50-54	5.09%	4.19%	4.51%	4.65%	3.82%	4.12%
55-59	4.88%	4.02%	4.33%	3.22%	3.96%	3.69%
60-64	2.87%	3.44%	3.24%	4.17%	3.15%	3.52%
65-69	3.23%	2.38%	2.69%	3.38%	2.48%	2.80%

Ratio of Insured versus Population Rates

Age	Males			Females		
	1983 - 1988	1988 - 1993	1997 – 2002	1983 - 1988	1988 - 1993	1997 – 2002
15-19	90%	98%	68%	60%	67%	61%
20-24	70%	101%	75%	57%	86%	84%
25-29	55%	93%	70%	50%	65%	74%
30-34	50%	54%	56%	62%	58%	69%
35-39	56%	60%	56%	64%	55%	70%
40-44	57%	56%	57%	50%	53%	67%
45-49	52%	51%	55%	51%	61%	61%
50-54	56%	48%	51%	53%	46%	59%
55-59	59%	54%	50%	64%	39%	56%
60-64	61%	54%	49%	63%	60%	48%
65-69	63%	58%	54%	62%	65%	44%

General Observations

- **Male**
  - **The low insured mort rates at ages 15-19 is in line with population**
  - **Rate of improvement of 4% in line with population improvement**
  - **Ratio of insured to population seems quite stable**
- **Female**
  - **Population improvement of 4% higher than insured of around 3%**
  - **Ratio of insured to population is getting worse except for older ages**

General Observations

- **Others**
  - **Rate of improvement does look to be faster during the period 83-88 to 88-93 compared to the period 88-93 to 97-02 especially for Males**

Areas for future work

- **Gather data on per life basis rather than per policy basis**
- **Analysis of smoker and non-smoker rates separately**
- **Align and rationalise inclusion or exclusion of investment-linked policies**
- **Further study of the second mortality hump for male at late twenties**
- **Study of annuitant experience**

Next Steps

- **Present report to SAS Council**
- **Publish report**
- **Look at improving data collection for future studies (may be another workgroup?)**