A review of cancer registry data in response to concerns about a possible excess of cancer associated with the emissions from the M5 East tunnel

July 2012

Public Health Unit, South Western Sydney and Sydney Local Health Districts

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Executive Summary

In August 2010, the Public Health Units in South Eastern Sydney and Sydney were approached by a community group - Residents Against Polluting Stacks - with a list of health concerns that they felt may be linked to pollution from M5 East tunnel stack. Prominent among these concerns were reports of leukaemia. After meeting with the group to clarify concerns, the Public Health Units decided to investigate the incidence of all cancers combined, leukaemia and lung cancer in the period after tunnel opening.

Our 'screening study' examined cancer incidence in residents in the post code areas surrounding M5 East stack and portals for the 6 years post opening (2002-2007) compared to the six years immediately before opening (1996-2001). There was no increase in leukaemia over this period and a small increase in all cancers consistent with trends observed in NSW. However, we found an increase in lung cancer. This was seen in both male and female residents. Lung cancer is a common cancer and the main cause is smoking. Most of variation in lung cancer rates between areas and groups of people is due to current or past smoking. However, lung cancer is one of the few cancers where there is good evidence that air pollution is a cause.

When we more carefully examined incidence in residents by smaller geographic units that aligned closely with the area projected to be affected by additional air pollution from the stack and portals, the increase in lung cancer remained. We undertook a number of analyses to try to understand if the increase observed could have been caused by increased exposure to air pollution from the M5 East stack and portals. We also examined the available pollution monitoring data. Key observations were:

- The overall measured levels of air pollutants around the stack are consistent with background levels in other areas and appear to be dominated by sources other than the tunnel. The overall trend in air pollutants in the period has been downward.
- It would be unusual for lung cancer incidence to increase rapidly after any increase in exposure to air pollution or any other potential carcinogen, and yet a trend to higher incidence of lung cancer is seen at the time operations began.
- With the benefit of examining cancer incidence over a longer time course, the increase in lung cancer incidence in the Turrella area appears to have predated the opening of M5 East tunnel.
- An assessment of lung cancer rates in the area since 1981 showed considerable year-to-year variability, with the 6-year pre-opening period coinciding with historically low lung cancer levels.

Taken together, these make a causal association between air pollution from the M5 East tunnel and lung cancer unlikely.

Background

The M5 East motorway tunnel in Sydney's southern suburbs has been in operation since December 2001. Vehicle emissions in the tunnel are vented through a single 35m high chimney stack approximately 1km to the north in a valley approximately 30-40m deep and 400m wide surrounded by suburban residential housing on the surrounding plateaus (NH&MRC 2008). Vehicle emissions also vent from time to time through the tunnel openings (portals). The M5 East traffic tunnel has a throughput of around 100,000 vehicles per day with a significant proportion of the fleet being diesel trucks.

The effects of stack and portal emissions on acute irritant symptoms have already been the subject of a detailed investigation by NSW Health (Capon 2004) and re-analysis (NSW Health 2006). The results of this investigation were negative: higher frequencies of acute irritant symptoms were not found in areas that were considered to have a higher exposure to emissions.

In August 2010, the president of the community group Residents Against Polluting Stacks (RAPS) wrote to Directors of Public Health Units in South East Sydney Illawarra and Sydney South West with concerns about possible chronic health effects associated with emissions from the M5 East tunnel exhaust stack. These concerns were various including developmental delay in children, cardiovascular disease, and reports that one of their members had been told of seven instances of childhood leukaemia in the Arncliffe, Tempe, Turrella, Bexley, Bexley North and Earlwood areas, as well as a death in a 62 year-old man from brain tumour and the death of a 62 year-old from leukaemia, both living in close proximity to the stack.

At a meeting in October 2010 between RAPS and staff from both Public Health Units these concerns were further discussed. It was agreed that some examination of routine data sources would be feasible within current resources and the Public Health Unit at Camperdown subsequently undertook an initial screening study of cancer incidence given this was one of the stated concerns and that cancer data were recorded with a high degree of reliability.

An initial screening study was conducted to determine if there was an increase in all cancers, leukaemia or lung cancer in the area surrounding the M5 East stack using a population defined by postcode of residence. After finding an apparent increase in lung cancer, the advice of the NSW Health Air Pollution Expert Advisory Committee was sought and a second stage analysis was conducted in which the study area resident population was defined by a group of census collection districts (smaller geographic units than postcodes) that aligned more closely with pollutant dispersion modelling. Further analyses were also recommended to clarify the relationship of this observed increase in lung cancer to air pollution from the M5 East tunnel stack and portals.

In December 2011, the results from the screening study and the second stage analysis were shared with the RAPs. During the meeting it was noted that portal emissions have been less frequent in recent years. A sensitivity analysis was agreed upon to determine if there was a difference between results obtained if a different definition of the exposed population was used that only took into account emissions from the stack.

Aims and objectives

The overall aim of the current investigation was to establish whether an excess of leukaemia, lung cancer or all cancers has arisen in the population affected by pollution from the M5 East stack and portals in the years since operation of the M5 East tunnel. The approach has been iterative in response to data findings and further analysis requests as outlined above, but the more detailed objectives of the entire investigation can be stated as follows:

1. To assess whether there has been an excess of all cancers, leukaemia and lung cancer in the 6 years post operation of the M5 East tunnel compared with the 6 years pre-operation using an approximate exposed population defined by postcode (screening study).

2. To assess whether there has been an excess of all cancers, leukaemia and lung cancer in the 6 years post operation compared with the 6 years pre operation using a more refined definition of the exposed population using census collection districts (refined analysis using census collection districts).

3. To assess whether there are any similar effects or gradation of effect in an adjacent population likely to be less exposed to pollution from the M5 East stack and portals (comparison with adjacent area).

4. To assess whether any further historical analysis of cancer incidence of the exposed population is of assistance in determining baseline cancer incidence.

5. To investigate whether there are any differences in findings by choice of exposed population using the two different pollution dispersion models that, respectively, do and do not take into account portal emissions (sensitivity analysis).

6. To investigate other important exposures that may affect cancer incidence.

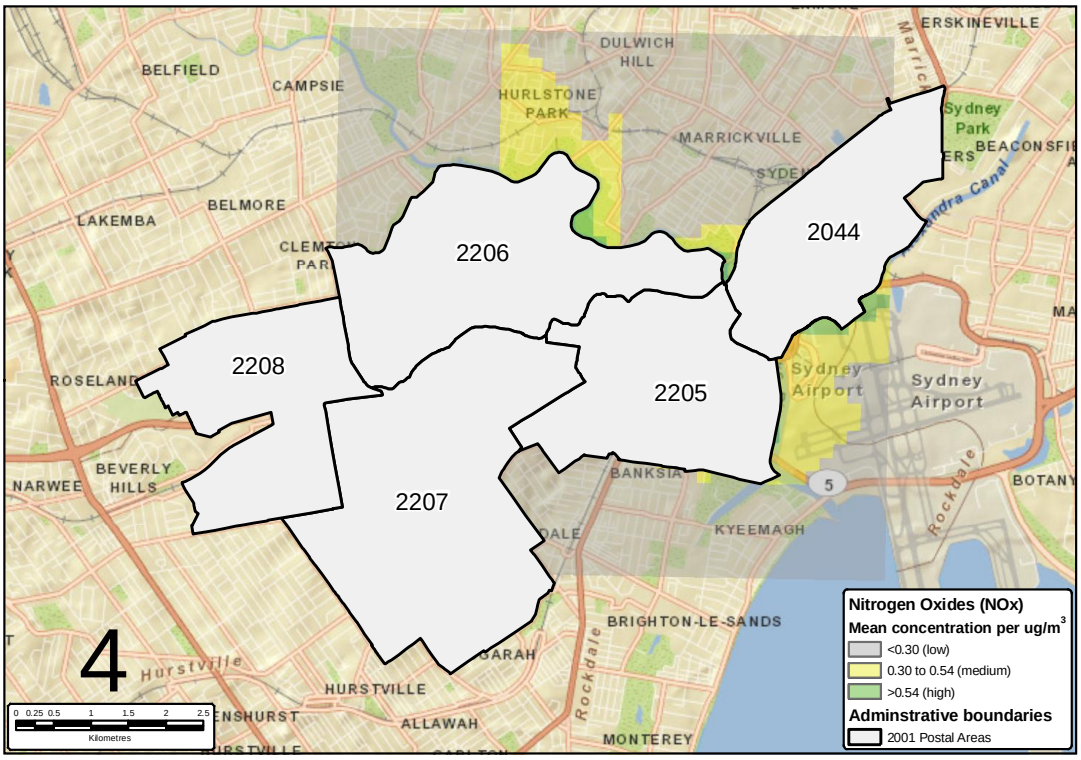
Screening Study

Method

Exposure Area

The exposure area was defined using NSW postal areas. The postcodes were selected based on the suburbs of interest identified by RAPS. The postcodes selected were 2205, 2206, 2207, 2208 and 2044. This included the following suburbs: Turrella, Arncliffe, Tempe, Bexley, Bexley North, Bardwell Park, Clemton Park, Kingsgrove and Earlwood. The 2006 resident population defined by these postcodes was 77,567. The postcodes covered an area broadly similar to the CSIRO modelling of pollutant concentrations associated with stack and portal emissions provided in the NSW Health report '*Investigation into the possible health impacts of the M5 East Motorway Stack on the Turrella Community*' (NSW Health 2006) (Map 1). East and west tunnel portals are included within these postcodes. In this report this postcode defined area is referred to as Turrella and surrounds (postcode defined).

Map 1: Map of postcodes included in analysis compared to modelled contours of average ground level concentrations of oxides of nitrogen from stack and portal emissions, and assigned exposure zones from CSIRO modelling in 2006



Analysis

De-identified aggregated data on leukaemia, lung cancer and all cancers (all age groups) were obtained from the NSW Cancer Registry data on Health Outcome Indicator Statistical Toolbox (HOIST). Data were extracted for the period 1996 to 2007 for both Turrella and surrounds and for the NSW population based on postcode of residence at diagnosis. Cancer count data were then compared to a sample of data received from the NSW Cancer Registry to ensure data accuracy.

Population data were obtained from Australian Bureau of Statistics (ABS) data on HOIST, for both the Turrella and surrounds population and the NSW population for each year from 1996 to 2007. Data on the Australian population as at June 2001 was also extracted from HOIST.

Incidence by year 1996-2007

Direct age standardisation[1] was used to compare the incidence of cancers in the subject population and the NSW population by year, 1996-2007. The June 2001 Australian population was used as the standard reference population. Crude rates per 100,000 population and direct age standardised rates per 100,000 with 99% confidence intervals were calculated using SAS version 9.2 (SAS Institute, Carry, NC, USA), for each year 1996-2007, for both males and females and for the total population. Rate ratios[2] with 99% confidence intervals were calculated using Microsoft® Excel 2007.

Comparison of incidence pre and post operation of the M5 East motorway

Direct age standardised incidence rates were calculated for leukaemia, lung cancer and all cancers for the six years pre- (1996-2001) and six years post- (2002-2007) commencement of operation of the M5 East motorway for both the subject population and the NSW population.

Results

All Cancers

There were between 313 and 437 incident cancers recorded annually for the screening study area. Incidence rates in Turrella and surrounds were lower than in the NSW population as a whole except in the year 2003 (Appendix 2: table 1).

The cancer rates for males in Turrella and surrounds were often lower but not statistically significantly different from the NSW male population in any year (Appendix 2: table 2). The cancer rates for females in Turrella and surrounds were again generally lower in any given year than the rates in the NSW female population (Appendix 2: table 3).

[1] Differences in the age structure in two populations give rise to differences in cancer incidence rates because cancer occurs more frequently in elderly people. Direct standardisation is a method of adjusting for differences in age so that rates are comparable.

[2] Rate ratios are a ratio of two rates. The ratio should be one if rates are the same in two populations.

Incidence rates for all cancer sites combined increased in both Turrella and surrounds and the NSW population over the twelve year period examined and specifically in the six years post commencement of the M5 East tunnel operations. In Turrella and surrounds the all cancer incidence rate increased by 12% in the post-operation period (rate ratio 1.12, 99%CI: 1.03-1.21). In NSW the rate increased by 7% over this period (rate ratio 1.07 99%CI: 1.06-1.07) (Table 1). Both rate ratios were significantly different from 1.

In males from Turrella and surrounds the all cancer incidence rate increased by around 16% in the post-operation period (rate ratio 1.16, 99%CI: 1.05-1.28). In NSW the rate increased by 7% over this period (rate ratio 1.07 99%CI: 1.06-1.08) (Table 1). Both rate ratios were significantly different from 1. In females from Turrella and surrounds the all cancer incidence rate increased by around 6% in the post-stack period, while the rate in NSW females increased by around 3%.

Table 1: Crude and age-standardised rates for all cancers, pre- and post-commencement of M5 East tunnel operation, Turrella and surrounds (postcode defined) and NSW

Standard population: Australian population 2001

All cancers		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standarised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	2110	450288	468.6	411.7	2398	456961	524.8	459.8	1.12*	1.03	1.21
	NSW	171722	38293560	448.4	450.3	205738	40486203	508.2	479.7	1.07*	1.06	1.07
Male	Turrella and surrounds	1165	222050	524.7	501.8	1352	225253	600.2	580.5	1.16*	1.05	1.28
	NSW	93976	19006106	494.5	545.0	115319	20068316	574.6	583.9	1.07*	1.06	1.08
Female	Turrella and surrounds	945	228238	414.0	350.6	1046	231708	451.4	373.2	1.06	0.94	1.20
	NSW	77746	19287454	403.1	583.2	90419	20417887	442.8	398.3	1.03*	1.03	1.05

* Statistically significant (confidence interval does not contain 1)

Leukaemia

The number of leukaemia cases diagnosed in those aged 15 years or less was extracted. Numbers were too small to allow comparison calculations: as there were 2 cases diagnosed between 1996 and 2001, and 4 cases diagnosed between 2001 and 2007 (Appendix 2: table 4). Therefore, leukaemia incidence rates for all age groups were calculated and compared to the NSW rates.

The number of leukaemia cases in all age groups in both males and females reported each year in Turrella and surrounds varied from 3 to 17. Consequently it is difficult to compare the rates in Turrella with the rates in the NSW population. The confidence intervals surrounding the rate ratios were wide and generally included one indicating that none of the differences in rates were statistically significant (Appendix 2: table 5). No time trend was discernable.

When comparing the post-operation (2002-2007) with the pre-operation period (1996-2001) no increase in leukaemia incidence was observed. The incidence rate decreased in Turrella and surrounds by around 20% (rate ratio 0.81, 99%CI: 0.51-1.30). This decrease was not statistically significant. For the NSW population, incidence in the pre and post operation period was similar (rate ratio 1.01, 99%CI: 0.96-1.06) indicating no change in the underlying rate. In females the incidence rate decreased in Turrella and surrounds by around 30% (rate ratio 0.68, 99%CI: 0.33-1.41) (Table 2).

Table 2: Crude and age-standardised rates for leukaemia pre- and post-commencement of M5 East tunnel operation, Turrella and surrounds (postcode defined) and NSW

Standard population: Australian population 2001

Leukaemia		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	68	450288	15.1	13.3	56	456961	12.3	10.8	0.81	0.51	1.3
	NSW	5086	38293560	13.3	13.3	5723	40486203	14.1	13.4	1.01	0.96	1.06
Male	Turrella and surrounds	35	222050	15.8	15.3	34	225253	15.1	14.9	0.97	0.52	1.82
	NSW	3011	19006106	15.8	17.4	3403	20068316	17	17.4	1.01	0.94	1.07
Female	Turrella and surrounds	33	225238	14.5	11.2	22	231708	9.5	7.6	0.68	0.33	1.41
	NSW	2075	19287454	10.8	10	2320	20417887	11.4	10.1	1.01	0.93	1.09

* Statistically significant (confidence interval does not contain 1)

Lung cancer

The number of lung cancers reported each year in Turrella and surrounds varied from 25 to 47. The confidence intervals surrounding all rate ratios were wide due to the small numbers of cancers each year and none of the differences in rates between Turrella and surrounds and the whole of NSW were statistically significant (Appendix 2: Table 8). When males and females were separately analysed (Appendix 2: Tables 9, 10) no differences between the rates in Turrella and surrounds and the NSW population were found to be statistically significant.

Lung cancer incidence increased in Turrella and surrounds by 34% in the 2002-2007 post operation period compared with the 1996-2001 pre operation period (rate ratio 1.34, 99%CI: 1.05-1.72). This increase was statistically significant. There was no change in the overall lung cancer incidence rate in NSW from 1996-2001 to 2002-2007 (rate ratio 0.99, 99%CI: 0.97-1.02) (Table 3).

Lung cancer incidence in females increased for both Turrella and surrounds (1.58, 99%CI: 0.97-2.58) and the NSW population (1.14, 99%CI: 1.09-1.20) in the post operation period. The increase in NSW females was statistically significant. Lung cancer incidence in males in NSW decreased (0.91, 99%CI: 0.88-0.95), while the incidence in Turrella and surrounds increased (1.28, 99%CI: 0.96-1.71). The decrease in incidence in the NSW male population was statistically significant (Table 3).

Table 3: Crude and age-standardised rates for lung cancer, pre-and post-commencement of M5 East tunnel operation, Turrella and surrounds (postcode defined) and NSW

Standard population: Australian population 2001

Lung cancer		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	191	450288	42.4	36.4	256	456961	56	48.8	1.34*	1.05	1.72
	NSW	16367	38293560	42.7	42.6	18310	40486203	45.2	42.4	0.99	0.97	1.02
Male	Turrella and surrounds	144	222050	64.9	61.1	183	225253	81.2	78.4	1.28	0.96	1.71
	NSW	11019	19006106	58	64.1	11472	20068316	57.2	58.5	0.91	0.88	0.95
Female	Turrella and surrounds	47	228238	20.6	16.8	73	231708	31.5	26.6	1.58	0.97	2.58
	NSW	5348	19287454	27.7	25.9	6838	20417887	33.5	29.5	1.14*	1.09	1.2

* Statistically significant (confidence interval does not contain 1)

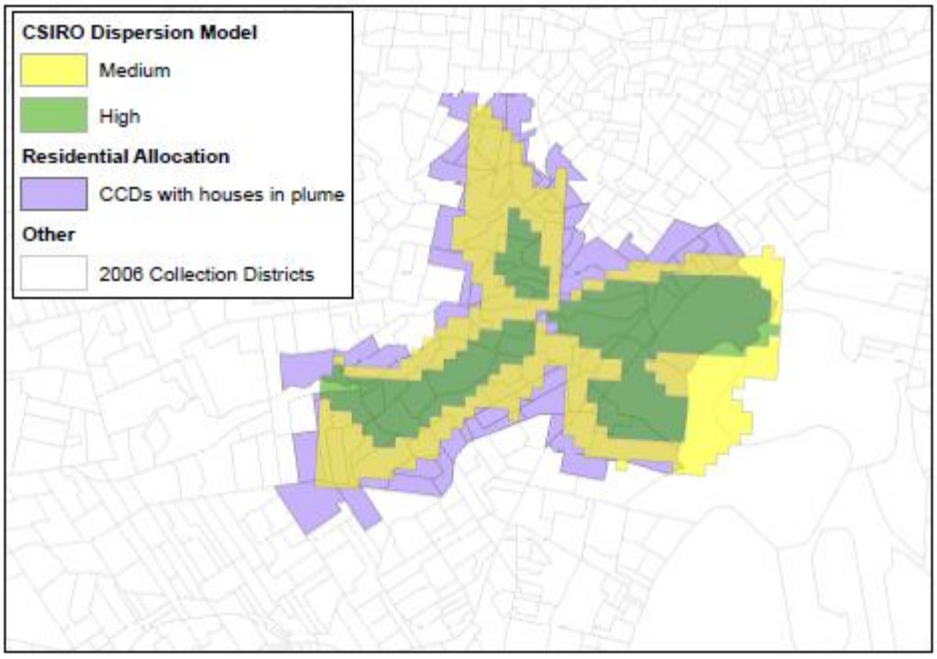
Refined Analysis using Census Collection Districts

Methods

Exposure Area

An electronic file was obtained from the NSW Ministry of Health which contained results of CSIRO plume modelling previously conducted for NSW Health for their study of acute irritant health effects (Capon 2006). This file including geocoded values of predicted average additional oxides of nitrogen (NOx) from both stack and portal emissions. Residential property locations were derived from the October 2006 release of the Geocoded National Address File (GNAF). To ensure only residential properties were used in the classification, the GNAF was intersected with land use data from 2006 mesh blocks provided by the Australian Bureau of Statistics (ABS). A census collection district (2006) was included in the study area if (i) it intersected either a medium or high (i.e. ≥ 0.30 µg/m^3) NOx emission area, and (ii) at least one residential property within the census collection district (CCD) was also within a medium or high emission plume area. The above definition included 85 census collection districts. A map of the CCD defined population can be seen below (Map 2).

Map 2: Area defined by 2006 census collection districts compared to contours of average ground level concentrations of oxides of nitrogen from stack and portal emissions from CSIRO modelling in 2006



Cancer data

A unit record file was obtained by authorised request from the NSW Cancer Institute that included all cancers in an area around Turrella for 1996 to 2007 period. This file included cancer site (including lung cancer and leukaemia) by ICD-9 code and allocation to 2006 CCD for each cancer case.

Population data

Estimated resident populations were available by CCD for years 2001 to 2008 via a single-year unit record file held by the NSW Ministry of Health. This file was aggregated into five-year age groups for ages 0–4 to 80–84 years and a single age group of ≥85 years. CCDs can change between censuses. No population data for the area defined by the 85 exposed 2006 CCDs were available for 1996 to 2000. Population data for these years were derived for 1996 by rebasing 1996 CCD populations to the 2006 CCD defined area using a geographical information system. 1996 CCDs were intersected with the 2006 CCD defined area described previously. CCDs entirely within the exposure area were assigned to that exposure area. CCDs that straddled exposure areas were split into multiple features. This multi-part feature layer was joined to a Geocoded National Address File (October 2006 release) data layer intersected with Australian Bureau of Statistics mesh block land use data and limited to residential dwellings within NSW. For each multi-part CCD the numbers of residential dwellings in each exposure area were calculated and used to proportionally assign 1996 CCD populations to the area defined by 2006 CCDs. Age and sex stratified population estimates for years 1997 to 2000 were obtained from the predicted mean values obtained by fitting generalised additive models with non-parametric spline terms (DF=3) to the age-sex stratified population series for years 1996, 2001–2008. The resulting population series were graphed and visualised to assess the adequacy of the population re-basement and imputation for years 1996 to 2000. The population defined by the 85 census collection districts was 53,264 in 2001 – around two-thirds of the postcode defined population.

Comparison of incidence pre and post operation of the M5 East motorway

Methods used to calculate incidence rates and rate ratios were identical to those used in the screening study.

Results

All Cancers

There were between 223 and 276 incident cancers recorded annually for the CCD defined area. In each year except 1997, 1999, 2003 and 2005 the age standardised cancer incidence rate was lower in the CCD-defined Turrella population than in NSW and for each year it was not statistically significantly different than the value for NSW as a whole (Appendix 3: Table 1). For males and females similar patterns were observed (Appendix 3: Tables 2 and 3).

When the post operation period (2002-2007) was compared with the pre operation period (1996-2001) an increase was observed in the incidence of cancers in the Turrella population (1.06 or increase of 6%). However, although similar to the result observed in the screening study, the increase was not statistically significant (Table 4).

Table 4: Crude and age-standardised rates for all cancers, pre- and post-commencement of M5 East motorway operation, Turrella and surrounds (CCD-defined defined) and NSW

Standard population: Australian population 2001

All cancers		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	1,434	313,991	456.7	435.0	1,570	320,737	489.5	462.3	1.06	0.97	1.17
	NSW	171,722	38,293,560	448.4	450.3	205,738	40,486,203	508.2	479.7	1.07*	1.06	1.07
Male	Turrella and surrounds	816	154,984	526.5	538.0	885	158,481	558.4	587.6	1.09	0.96	1.24
	NSW	93,976	19,006,106	494.5	544.9	115,319	20,068,316	574.6	583.8	1.07*	1.06	1.08
Female	Turrella and surrounds	618	159,007	388.7	358.4	685	162,256	422.2	374.4	1.04	0.91	1.21
	NSW	77,746	19,287,454	403.1	383.2	90,419	20,417,887	442.8	398.3	1.04*	1.03	1.05

* Statistically significant (confidence interval does not contain 1)

Leukaemia

There were between 3 and 12 incident cases of leukaemia recorded annually for the CCD defined Turrella population. In each year except 1996, 1997, 1999 and 2007 the age standardised leukaemia incidence rate was lower in the CCD defined Turrella population than in NSW. (Appendix3: Table 4).

For males and females a similar pattern was observed (Appendix 3: Tables 5,6).

When the 2002-2007 post operation period was compared with the 1996-2001 pre-operation period a decrease was observed in the incidence of leukaemia in all persons in Turrella. This decrease was not statistically significant and was similar to the decrease observed in the screening study (Table 5).

Table 5: Crude and age-standardised rates for leukaemia, pre- and post-commencement of M5 East motorway operation, Turrella and surrounds (CCD-defined defined) and NSW

Standard population: Australian population 2001

Leukaemia		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	46	313,991	14.7	13.8	37	320,737	11.5	11.0	0.8	0.45	1.41
	NSW	5,081	38,293,560	13.3	13.3	5,702	40,486,203	14.1	13.4	1	0.96	1.06
Male	Turrella and surrounds	28	154,984	18.1	18.2	20	158,481	12.6	12.8	0.71	0.33	1.51
	NSW	3,007	19,006,106	15.8	17.3	3,395	20,068,316	16.9	17.4	1	0.94	1.07
Female	Turrella and surrounds	18	159,007	11.3	9.6	17	162,256	10.5	9.5	0.99	0.41	2.39
	NSW	2,074	19,287,454	10.6	10.0	2,307	20,417,887	11.3	10.0	1	0.93	1.08

* Statistically significant (confidence interval does not contain 1)

Lung Cancer

There were between 14 and 30 incident cases of lung cancer recorded annually for the CCD defined Turrella population. In each year except 1996, 2000, 2001 and 2007 the age standardised lung cancer incidence rate was higher in the CCD-defined Turrella population than in NSW. (Appendix 3: Table 7).

In males the age standardised lung cancer incidence rate was in most years higher in the CCD-defined Turrella population than in NSW (Appendix 3: Table 8). For females in most years the age standardised lung cancer incidence rate was lower in the CCD-defined Turrella population than in NSW. (Appendix 3: Table 9).

When the 2002-2007 post operation period was compared with the 1996-2001 pre operation period an increase was observed in the incidence of lung cancer in the Turrella population (1.36, 99% CI: 1.00-1.85 or increase of 36%). This increase was statistically significant. An increase was observed in both males and females (Table 6). The proportional increase in lung cancer incidence was similar to that observed in the screening study.

Table 6: Crude and age-standardised rates for lung cancer, pre- and post-commencement of M5 East motorway operation, Turrella and surrounds (CCD-defined defined) and NSW

Standard population: Australian population 2001

Lung cancer		1996 to 2001 (pre)				2002-2007 (post)				99%CI		
		Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Events	Population	Crude rate per 100,000	Standardised rate per 100,000	Rate ratio	lower	upper
All	Turrella and surrounds	120	313,991	38.2	36.1	167	320,737	52.1	49.2	1.36*	1	1.85
	NSW	16,367	38,293,560	42.7	42.6	18,310	40,486,203	45.2	42.4	0.99	0.97	1.02
Male	Turrella and surrounds	92	154,984	59.4	59.5	123	158,481	77.6	83.6	1.4	0.98	2
	NSW	11,019	19,006,106	58	64.1	11,472	20,068,316	57.2	58.5	0.91	0.88	0.95
Female	Turrella and surrounds	28	159,007	17.6	16	44	162,256	27.1	24.5	1.53	0.82	2.84
	NSW	5,348	19,287,454	27.7	25.9	6,838	20,417,887	33.5	29.6	1.14*	1.09	1.2

* Statistically significant (confidence interval does not contain 1)

Comparison with adjacent area

Method

Exposure Area

The exposure area was again defined using the criteria outlined in the "Refined analysis using Census Collection District" section of this report. That is the exposure area included census collection districts that (i) intersected either a medium or high (i.e. ≥ 0.30 µg/m^3) NOx emission plume area, and (ii) contained at least one residential property within the census collection district that was also within a medium or high emission plume area. A map of the census collection district defined population can be seen in Map 2.

Comparison Population

The adjacent population was defined by residences within one of the 11 postcodes that included any extent of the plume, but excluded residents in any of the 85 CCDs classified as the exposure area (Map 3). The 11 postcodes were 2131, 2205, 2206, 2207, 2208, 2044, 2204, 2203, 2193, 2216, 2020. All of NSW was also used as a comparison population as previously.

Cancer data

Methods used to extract cancer data were identical to those used in the refined analysis using census collection district.

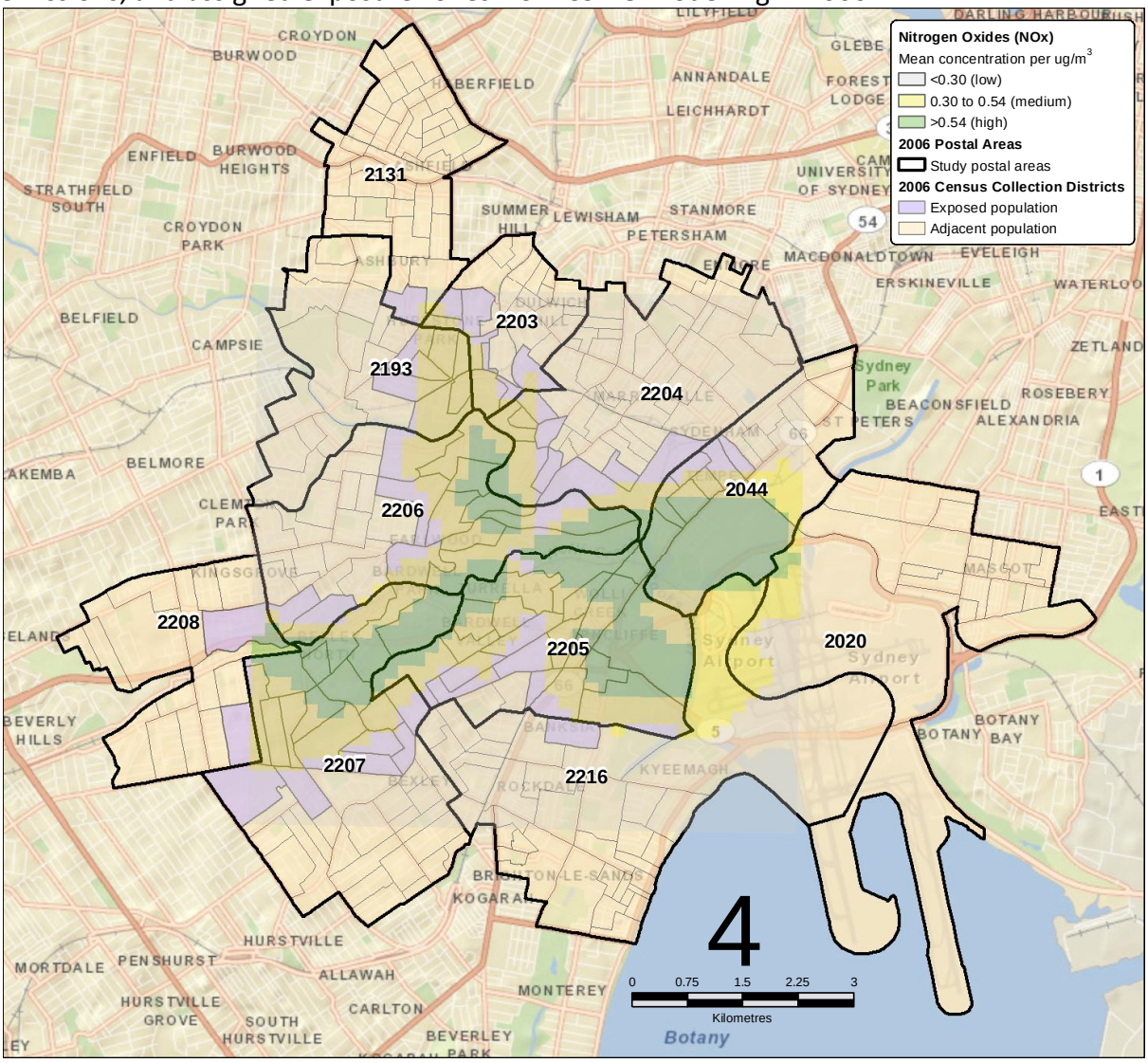
Population data

Methods used to extract population data were identical to those used in the refined analysis using census collection district.

Comparison of incidence pre and post operation of the M5 East motorway

Methods used to calculate incidence rates and rate ratios were identical to those used in the screening study.

Map 3: Map of postcodes included in adjacent population compared to modelled contours of average ground level concentrations of oxides of nitrogen from stack and portal emissions, and assigned exposure zones from CSIRO modelling in 2006



Note: This map uses the Esri Online Services World Street Map layer (http://www.arcgis.com/home/item.html?id=3b93337983e9436f8db950e38a8629af) which contains data provided by Esri, DeLorme, NAVTEQ, TomTom, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong) and Esri (Thailand). See http://downloads2.esri.com/ArcGISOnline/docs/E800_summary.pdf for terms of use.

Results

All cancers

There was a small increase in the incidence of all cancers in the adjacent postcode area from the pre-operation period to the post-operation period – similar in magnitude to that observed in the NSW population. A similar pattern was seen when male and female incidence rates were examined separately (Table 7).

Leukaemia

In the adjacent postcode comparison area leukaemia incidence was highly similar to incidence in the Turrella and NSW populations. In all three populations there was almost no change from the pre operation period to the post operation period (Table 8).

Lung cancer

In the adjacent postcode comparison area the age standardised lung cancer rate increased from the pre-operation to post-operation period by 8%. This increase was not statistically significant. The increase in lung cancer incidence in males was 14% - which was not statistically significant. There is no increase in the incidence of lung cancer in females (Table 9).

Table 7: Crude and age-standardised rates and rate-ratios for all cancers, within Turrella and surrounds (CCD-defined), adjacent postcodes and all NSW for periods before (1996-2001) and after (2002-2007) M5 East tunnel operations commenced

All Cancers		1996 to 2001 (pre)				2002-2007 (post)				99% CI		
Sex	Area	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Rate Ratio	Lower	Upper
Persons	Turrella and surrounds	1,434	313,991	456.7	435.0	1,570	320,737	489.5	462.3	1.06	0.97	1.2
	Adjacent postcodes	2,734	632,228	432.4	414.3	3,038	648,015	468.8	441.1	1.06	1.00	1.1
	All NSW	171,722	38,293,560	448.4	450.3	205,738	40,486,203	508.2	479.7	1.07	1.06	1.07
Males	Turrella and surrounds	816	154,984	526.5	538.0	885	158,481	558.4	587.6	1.09	0.96	1.24
	Adjacent postcodes	1,469	314,819	466.6	487.6	1,697	320,114	530.1	555.1	1.14	1.04	1.25
	All NSW	93,976	19,006,106	494.5	544.9	115,319	20,068,316	574.6	583.8	1.07	1.06	1.08
Females	Turrella and surrounds	618	159,007	388.7	358.4	685	162,256	422.2	374.4	1.04	0.91	1.21
	Adjacent postcodes	1,265	317,410	398.5	363.8	1,341	327,901	409.0	361.8	0.99	0.90	1.10
	All NSW	77,746	19,287,454	403.1	383.2	90,419	20,417,887	442.8	398.3	1.04	1.03	1.05

Table 8: Crude and age-standardised rates and rate-ratios for leukaemia within Turrella and surrounds, adjacent postcodes and all NSW before (1996-2001) and after (2002-2007) M5 East tunnel operations commenced

Leukaemia		1996 to 2001 (pre)				2002-2007 (post)				99% CI		
Sex	Area	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Rate Ratio	Lower	Upper
Persons	Turrella and surrounds	46	313,991	14.7	13.8	37	320,737	11.5	11.0	0.80	0.45	1.41
	Adjacent postcodes	80	632,228	12.7	12.1	84	648,015	13.0	12.4	1.03	0.68	1.54
	All NSW	5,081	38,293,560	13.3	13.3	5,702	40,486,203	14.0	13.4	1.00	0.96	1.06
Males	Turrella and surrounds	28	154,984	18.1	18.2	20	158,481	12.6	12.8	0.71	0.33	1.51
	Adjacent postcodes	50	314,819	15.9	16.8	50	320,114	15.6	17.6	1.05	0.62	1.77
	All NSW	3,007	19,006,106	15.8	17.3	3,395	20,068,316	16.9	17.4	1.00	0.94	1.07
Females	Turrella and surrounds	18	159,007	11.3	9.6	17	162,256	10.5	9.5	0.99	0.41	2.39
	Adjacent postcodes	30	317,410	9.5	8.0	34	327,901	10.4	8.9	1.10	0.57	2.14
	All NSW	2,074	19,287,454	10.8	10.0	2,307	20,417,887	11.3	10.0	1.00	0.93	1.08

Table 9: Crude and age-standardised rates and rate-ratios for lung cancer within Turrella and surrounds, adjacent postcodes and all NSW before (1996-2001) and after (2002-2007) M5 East tunnel operations commenced

Lung cancer		1996 to 2001 (pre)				2002-2007 (post)				99% CI		
Sex	Area	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Events	Population	Crude rate per 100,000	Directly Std Rate per 100,000	Rate Ratio	Lower	Upper
Persons	Turrella and surrounds	120	313,991	38.2	36.1	167	320,737	52.1	49.2	1.36	1.00	1.85
	Adjacent postcodes	293	632,228	46.3	44.5	331	648,015	51.1	48.0	1.08	0.88	1.33
	All NSW	16,367	38,293,560	42.7	42.6	18,310	40,486,203	45.2	42.4	0.99	0.97	1.02
Males	Turrella and surrounds	92	154,984	59.4	59.5	123	158,481	77.6	83.3	1.40	0.98	2.00
	Adjacent postcodes	207	314,819	65.8	69.0	239	320,114	74.7	78.4	1.14	0.89	1.45
	All NSW	11,019	19,006,106	58.0	64.1	11,472	20,068,316	57.2	58.5	0.91	0.88	0.95
Females	Turrella and surrounds	28	159,007	17.6	16.0	44	162,256	27.1	24.5	1.53	0.82	2.84
	Adjacent postcodes	86	317,410	27.1	25.2	92	327,901	28.1	24.7	0.98	0.66	1.45
	All NSW	5,348	19,287,454	27.7	25.9	6,838	20,417,887	33.5	29.6	1.14	1.09	1.20

Historical Lung Cancer Incidence Analysis

Method

Exposure Area

The exposure area was defined using the criteria outlined in the "Refined analysis using Census Collection District" section of this report.

Comparison Population

The adjacent population was defined by residences within one of the 11 postcodes that included some portion of the medium exposure extent of the plume, but excluded residents in any of the 85 CCDs classified as the exposure area (Map 3). All of NSW was used as a second comparison population.

Cancer data

Methods used to extract lung cancer data were identical to those used in the refined analysis using census collection districts except that extracted for the period 1981-2007.

Population data

The population defined by residence within the boundaries of the exposed area defined by the 85 2006 census collection districts was estimated for the 1981, 1986 and 1991 census collections (each of which had some census collection districts with different boundaries). Population data by census collection district was obtained from the Australian Bureau of Statistics (ABS) for census years 1981, 1986 and 1991. Data for these census years were only available by place of enumeration. Population data were derived for 1981, 1986 and 1991 by rebasing Census Collection District populations for these years to the 2006 CCD defined area using a geographical information system. The 1981, 1986, 1991 census collection districts were intersected with the 2006 CCD defined area described previously. As previously described in methods for 'Refined analysis using census collection districts' collection districts that straddled exposure areas were split into multiple features to proportionally assign to the 2006 CCD defined area.

Calculation of direct age-standardised rates

Age-standardised lung cancer incidence rates from 1981 to 2007 for males, females and all persons were calculated in SAS 9.2 using the Centre for Epidemiology and Research's DSTAND macro. Incidence data and population data were re-aggregated to three five year periods 1981-1985, 1986-1990, 1991-1995 for tabular presentation. A graph was then produced with a smoothed trend line fitted to the observed time-series data using the SAS/GRAPH SGPANEL procedure with a LOESS statement.

Results

The lung cancer incidence rate in males is similar in Turella to the adjacent postcode population and NSW in the 1981-1985 period, lower than the adjacent population and NSW

rates in the 1986-1990, 1991-1995, and 1996-2001 periods and then higher than the comparison populations in the 2002-2007 post-operation period (Table 10).

The lung cancer incidence rates in females appear to be lower in Turella and surrounds than either the adjacent population or the NSW population. In all three populations there appears to be a similar trend upwards.

The incident rates for all persons shows the same pattern as that observed in males.

When standardised lung cancer incidence rates are calculated for each year from 1981 to 2007 for each of the three population groups for males, females and all persons and charted (Figures 1, 2 and 3) trends are easier to visualise. As outlined in the methods a smoothed trend line is fitted to the data using a LOESS statement (or LOWESS – locally weighted scatterplot smoothing). For males this appears to show a similar trend in rates in both the Turella and surrounds and the adjacent postcode population. In both there appears to be a flattening in downward trend that begins just prior to 1995. However, in Turella and surrounds this pattern is more marked and the trend line trends upward. In contrast the rate in NSW declines consistently over this period. For females there appears to be a consistent and fairly steady increase in lung cancer incidence over this period in all three populations. For all persons a small trend upwards is apparent for the Turella population.

Table 10: Historical age-standardised lung cancer rates for Turrella and surrounds, for 1981-1985, 1986-1990 and 1991-1995

Sex	Study periods	Events	Estimated population	Crude event rate per 100000	Directly Std Event Rate per 100000	Lower 95% CI Dir Std Rate	Upper 95% CI Dir Std Rate
Males	1981 to 1985	103	132,315.90	77.8	90.7	72.95	111.25
	1986 to 1990	81	132,054.80	61.3	69.7	54.55	87.48
	1991 to 1995	81	129,552.50	62.5	68.3	53.97	85.28
Females	1981 to 1985	23	136,275.10	16.9	15	9.39	22.56
	1986 to 1990	21	134,390.80	15.6	14.3	8.79	21.92
	1991 to 1995	26	131,112.10	19.8	18.1	11.77	26.62
Persons	1981 to 1985	126	268,591.00	46.9	46.1	38.28	54.97
	1986 to 1990	102	266,445.60	38.3	37.1	30.21	45.08
	1991 to 1995	107	260,664.60	41	40.2	32.94	48.63

Table 11: Historical age-standardised lung cancer rates by sex for adjacent postcodes, for 1981-1985, 1986-1990 and 1991-1995

Sex	Study periods	Events	Estimated population	Crude event rate per 100000	Directly Std Event Rate per 100000	Lower 95% CI Dir Std Rate	Upper 95% CI Dir Std Rate
Males	1981 to 1985	208	263,085.90	79.1	92.9	80.14	107.04
	1986 to 1990	186	261,447.10	71.1	81.6	70.08	94.52
	1991 to 1995	172	258,635.20	66.5	73.9	63.1	86.07
Females	1981 to 1985	50	269,651.00	18.5	16.9	12.5	22.38
	1986 to 1990	59	264,343.90	22.3	20.5	15.53	26.46
	1991 to 1995	56	260,770.20	21.5	20	15.06	26.03
Persons	1981 to 1985	258	532,736.90	48.4	48.7	42.86	55.02
	1986 to 1990	245	525,791.00	46.6	47	41.23	53.24
	1991 to 1995	228	519,405.40	43.9	43.7	38.22	49.81

Table 12: Historical age-standardised lung cancer rates by sex for all NSW, for 1981-1985, 1986-1990 and 1991-1995

Sex	Study periods	Events	Estimated population	Crude event rate per 100000	Directly Std Event Rate per 100000	Lower 95% CI Dir Std Rate	Upper 95% CI Dir Std Rate
Males	1981 to 1985	8,557	13,335,338.00	64.2	84.2	82.34	86.16
	1986 to 1990	8,820	14,180,607.00	62.2	77.3	75.57	78.97
	1991 to 1995	8,954	14,945,168.00	59.9	71.1	69.55	72.61
Females	1981 to 1985	2,237	13,423,641.00	16.7	17.5	16.75	18.22
	1986 to 1990	3,017	14,285,268.00	21.1	21.4	20.61	22.16
	1991 to 1995	3,757	15,108,183.00	24.9	24.4	23.57	25.15
Persons	1981 to 1985	10,794	26,758,979.00	40.3	46	45.16	46.94
	1986 to 1990	11,837	28,465,875.00	41.6	45.5	44.66	46.33
	1991 to 1995	12,711	30,053,351.00	42.3	44.6	43.79	45.36

Figure 1: Lung cancer directly standardised rates for males only, for Turrella and surrounds, adjacent postcodes and all NSW, 1981-2007

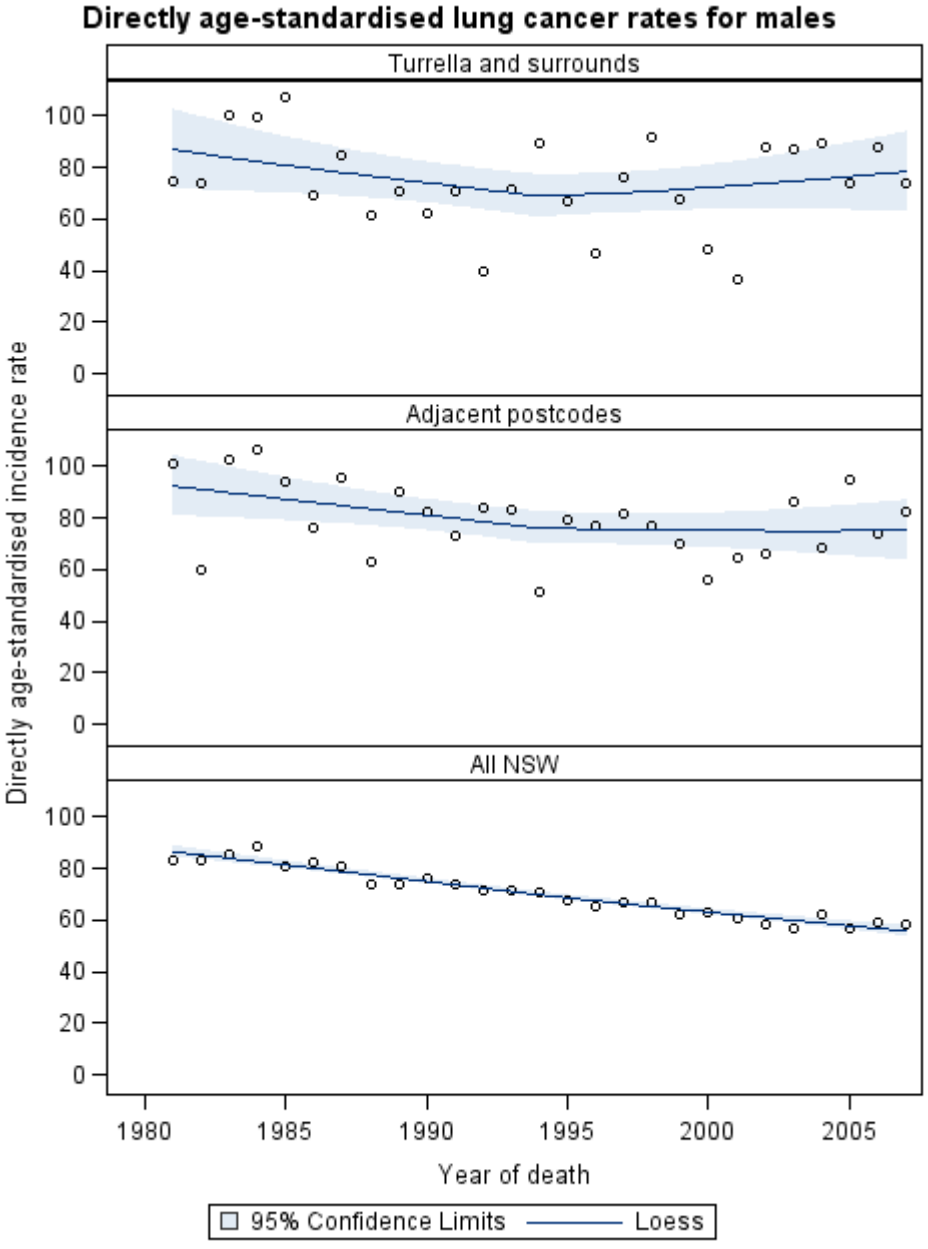


Figure 2: Lung cancer directly standardised rates for females only, for Turrella and surrounds, adjacent postcodes and all NSW, 1981-2007

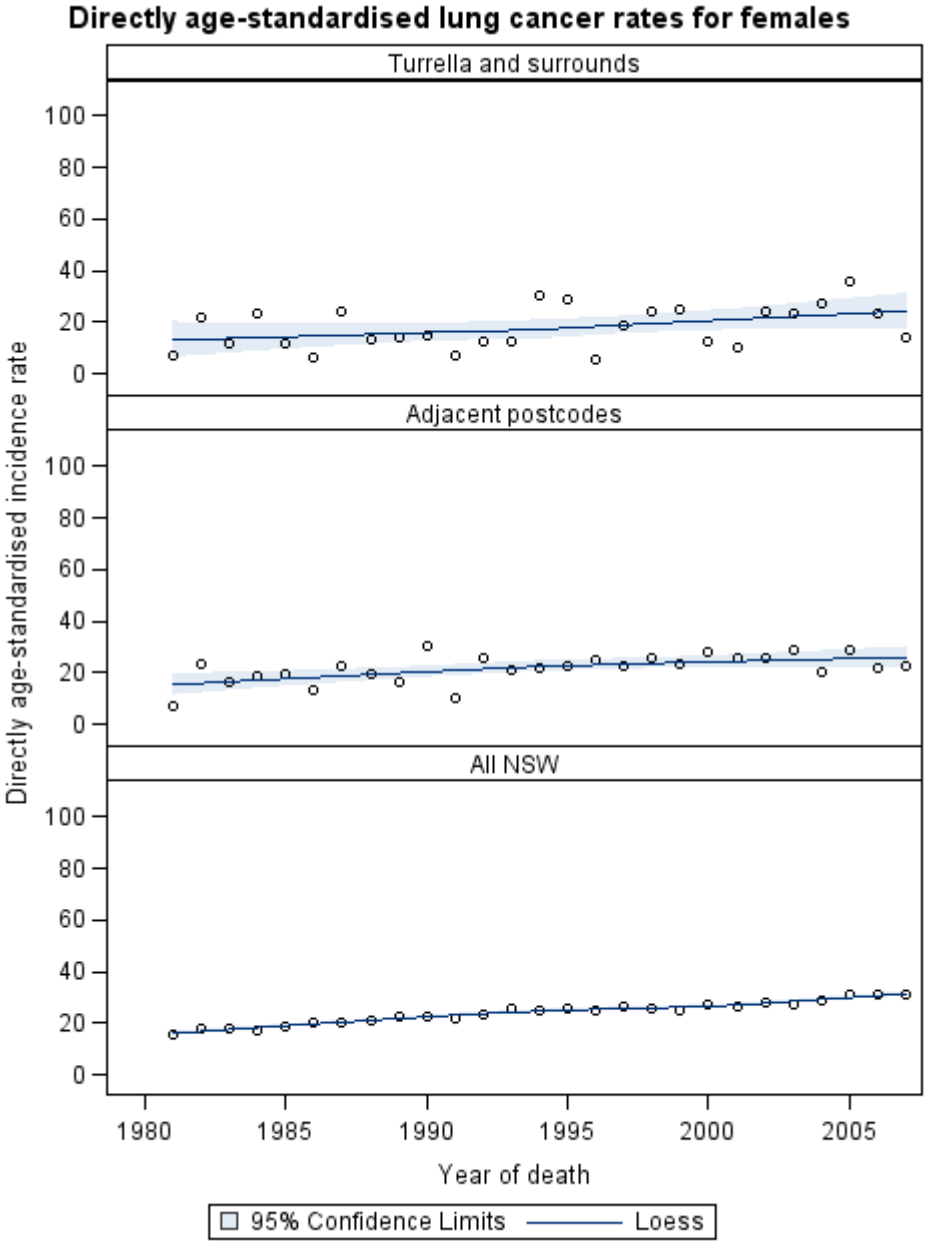
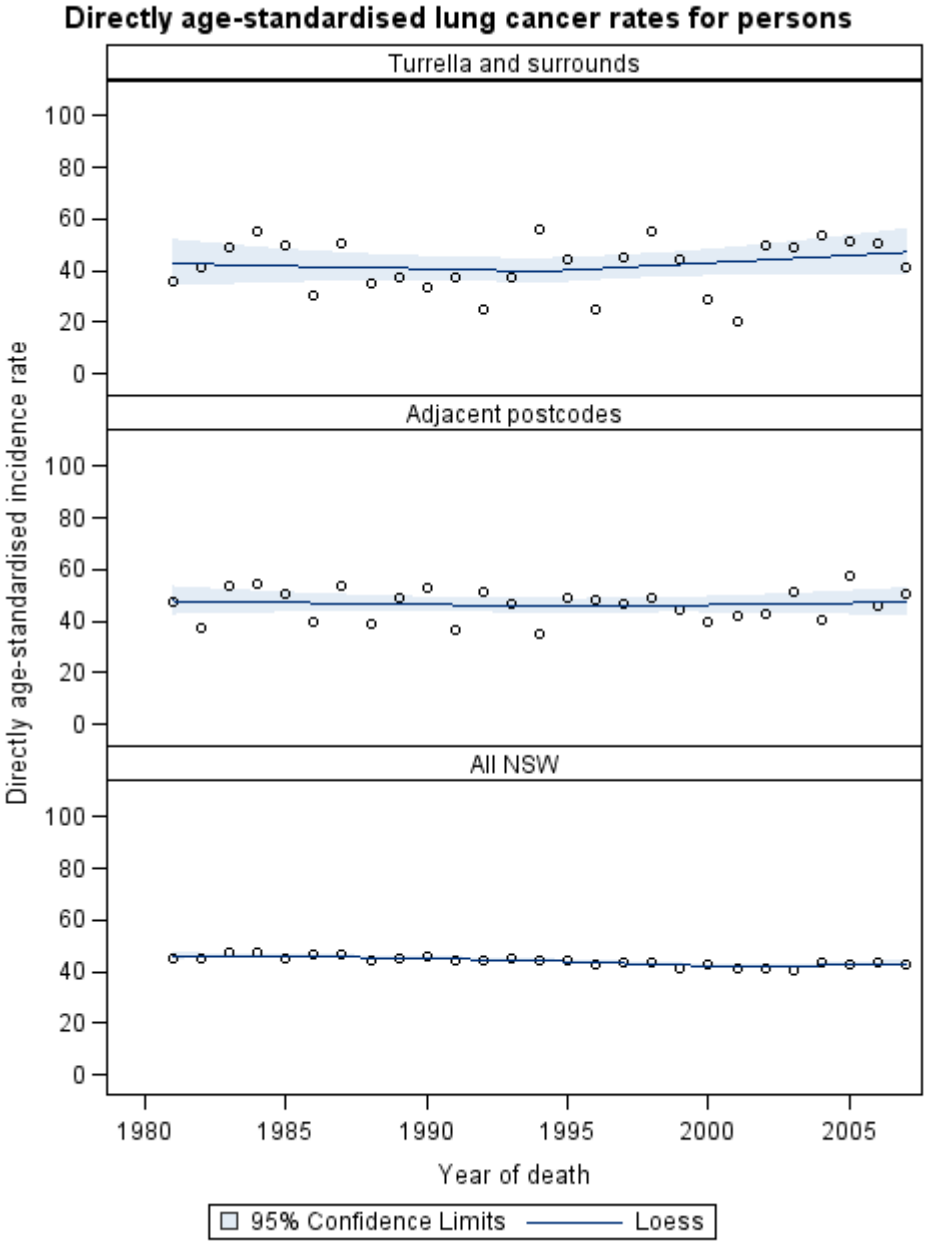


Figure 3: Lung cancer directly standardised rates, for Turrella and surrounds, adjacent postcodes and all NSW, for all persons, 1981-2007



Descriptive Analysis of Lung Cancer Type

Method

To determine the distribution of lung cancer morphology, frequencies pre- and post-commencment of the M5 East tunnel operation were calculated for Turrella and surrounds and all NSW. The methods used to define the lung cancer incidence data were identical to that described in the refined analysis by census collection district section of this report.

Results

Adenocarcinoma was the most common lung cancer morphology pre and post operation for Turrella and surrounds and for NSW. The distribution of lung cancer morphology was broadly similar in the pre and post operation periods and similar to the distribution in NSW. Increases from the pre operation period to the post operation period were seen in large cell carcinoma (25 to 41 cases) and small cell carcinoma (12 to 25 cases) (Table 13). This pattern was seen in both males and females (Table 14 and 15).

Table 13: Morphology of lung cancer in Turrella and surrounds (CCD defined) pre (1996-2001) and post (2002-2009) M5 East motorway operation periods for all persons

Morphology code (ICD-0-3)	Turrella and Surrounds						NSW	
	Pre operation period		Post operation period		Total		Total	
	n	%	n	%	n	%	n	%
Adenocarcinoma Not Otherwise Specified(NOS)	39	33	48	29	87	30	8005	23
Adenosquamous carcinoma	0	0	1	1	1	0	182	1
Basaloid squamous cell carcinoma	0	0	1	1	1	0	8	0
Bronchiolo-alveolar adenocarcinoma NOS	3	3	0	0	3	1	621	2
Carcinoma NOS	8	7	12	7	20	7	4218	12
Large cell carcinoma NOS	25	21	41	25	66	23	5905	17
Mucinous adenocarcinoma	1	1	1	1	2	1	90	0
Mucoepidermoid carcinoma	0	0	1	1	1	0	21	0
Neoplasm, malignant	5	4	5	3	10	3	1538	4
Neuroendocrine carcinoma NOS	2	2	0	0	2	1	119	0
Non-small cell carcinoma	0	0	8	5	8	3	1406	4
Small cell carcinoma NOS	12	10	25	15	37	13	4270	12
Small cell-large cell carcinoma	0	0	1	1	1	0	49	0
Squamous cell carcinoma NOS	22	18	21	13	43	15	5757	17
Squamous cell carcinoma, keratinising NOS	2	2	0	0	2	1	797	2
Squamous cell carcinoma, large cell, nonkeratinising NOS	1	1	2	1	3	1	222	1
Other	0	0	0	0	0	0	1469	4
Grand Total	120	100	167	100	287	100	34677	100

Table 14: Morphology of lung cancer in Turrella and surrounds (CCD defined) pre (1996-2001) and post (2002-2009) M5 East motorway operation periods for males only

Morphology code (ICD-0-3)	Turrella and surrounds						NSW	
	Pre operation period		Post operation period		Total		Total	
	n	%	n	%	n	%	n	%
Adenocarcinoma NOS	25	27	34	28	59	27	4773	21
Adenosquamous carcinoma	0	0	0	0	0	1	114	1
Basaloid squamous cell carcinoma	0	0	0	0	0	7	5	0
Bronchiolo-alveolar adenocarcinoma NOS	2	2	0	0	2	25	333	1
Carcinoma NOS	7	8	9	7	16	1	2691	12
Large cell carcinoma NOS	21	23	32	26	53	0	3910	17
Mucinous adenocarcinoma	1	1	1	1	2	3	60	0
Mucoepidermoid carcinoma	0	0	1	1	1	0	10	0
Neoplasm, malignant	3	3	3	2	6	2	975	4
Neuroendocrine carcinoma NOS	1	1	0	0	1	12	74	0
Non-small cell carcinoma	0	0	5	4	5	0	914	4
Small cell carcinoma NOS	9	10	17	14	26	18	2654	12
Small cell-large cell carcinoma	0	0	1	1	1	1	34	0
Squamous cell carcinoma NOS	20	22	18	15	38	1	4369	19
Squamous cell carcinoma, keratinising NOS	2	2	0	0	2	100	605	3
Squamous cell carcinoma, large cell, nonkeratinising NOS	1	1	2	2	3	0	171	1
Other	0	0	0	0	0	0	799	4
Total	92	100	123	100	215	100	22491	100

Table 15: Morphology of lung cancer in Turrella and surrounds (CCD defined) pre (1996-2001) and post (2002-2009) M5 East motorway operation periods for females only

Morphology code (ICD-0-3)	Turrella and surrounds						NSW	
	Pre operation period		Post operation period		Total		Total	
	n	%	n	%	n	%	n	%
Adenocarcinoma NOS	14	50	14	32	28	39	4773	21
Adenosquamous carcinoma	0	0	1	2	1	1	114	1
Basaloid squamous cell carcinoma	0	0	1	2	1	1	5	0
Bronchiolo-alveolar adenocarcinoma NOS	1	4	0	0	1	1	333	1
Carcinoma NOS	1	4	3	7	4	6	2691	12
Large cell carcinoma NOS	4	14	9	20	13	18	3910	17
Mucinous adenocarcinoma	0	0	0	0	0	0	60	0
Mucoepidermoid carcinoma	0	0	0	0	0	0	10	0
Neoplasm, malignant	2	7	2	5	4	6	975	4
Neuroendocrine carcinoma NOS	1	4	0	0	1	1	74	0
Non-small cell carcinoma	0	0	3	7	3	4	914	4
Small cell carcinoma NOS	3	11	8	18	11	15	2654	12
Small cell-large cell carcinoma	0	0	0	0	0	0	34	0
Squamous cell carcinoma NOS	2	7	3	7	5	7	4369	19
Squamous cell carcinoma, keratinising NOS	0	0	0	0	0	0	605	3
Squamous cell carcinoma, large cell, nonkeratinising NOS	0	0	0	0	0	0	171	1
Other	0	0	0	0	0	0	799	4
Total	28	100	44	100	72	100	22491	100

What we know about air pollution around the M5 East motorway

This section briefly reviews some of the information available about the type, distribution and scale of exposure to air pollutants in the Turrella area and especially the contribution made by air pollutants from the M5 East tunnel stack and portals.

Pollutants of interest to health

The main air pollutants of interest to health include particulate matter (PM), ozone (O_3), oxides of nitrogen (NOx) including nitric oxide (NO) and nitrogen dioxide (NO_2), sulphur dioxide SO_2, and carbon monoxide (CO).

Table 16: Summary table of pollutants of interest to health

Particulate matter (PM)	Particulate matter can be measured at different sizes and are may be reported at 10 µm or less (PM_{10}), 2.5 µm or less (fine particulates or $PM_{2.5}$) and occasionally 1µm or less (ultrafine or PM_1). PM_{10} and $PM_{2.5}$ are associated with short and long term health effects.
Ozone (O_3)	Ozone is formed in the upper atmosphere by photochemical reactions. NOx from motor vehicles contribute to ozone formation. It is associated with short and long term health effects.
NOx	Oxides of nitrogen (NOx) are frequently considered to be a reasonable proxy of traffic-derived air pollution. Vehicles are the dominant source of NOx. Emissions are predominantly NO which is oxidised to NO_2. Health effects have mainly been linked with NO_2. However, measured health effects of NOx or NO2 may be mediated by other traffic-related air-pollutants such as fine particulates.
Sulphur dioxide	Sulphur dioxide is associated with both short and long term health effects but has traditionally not been a focus of concern in Australia because of low sulphur content in fuel.
Carbon monoxide	Carbon monoxide is mainly associated with acute health effects at high concentrations.

For a relatively accessible summary of air pollutants and their health effects see '*WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide: Global update 2005'* (WHO 2006). Binding standards for air pollutants in Australia are determined by the National Environment Protection Council and published as a National Environment Protection Measure (NEPM) for ambient air quality (http://www.ephc.gov.au/nepms).

Fixed and mobile sources of air pollution in the Turrella region

As part of approval for the M5-East there was a condition placed on the Roads and Traffic Authority to investigate subregional air quality. A 2002 RTA document (Roads and Traffic Authority 2002) provides a detailed inventory of pollution sources for a 76 square kilometre area with 103,000 dwellings in the region bounded by the airport in the East, Roselands in the west, Stanmore in the north and Hurstville in the south. The Botany industrial area to the East of the airport was not included in the above area but estimates of emissions were provided in an appendix. Sources of NOx and PM_{10} were estimated for this region and scaled estimates also provided for a 13 square kilometre area within a two kilometre radius of the M5 East stack. Point sources outside the 2 km radius of the stack were scaled to zero. Summertime estimates for NOx and PM_{10} are reproduced below for the smaller region.

Table 17: Summertime sources of NOx and PM10 within a 2 km radius of the M5 East stack (taken from Table 7-1 and 7-2 of RTA 2002)

Source category	Source	NOx kg/day	PM_{10} kg/day
Mobile sources	Motor vehicles	4230	157
	Buses	47.4	1.76
	Brake and Diesel Dust	0.0	13.8
	Diesel electric locomotive	55.4	1.3
	Kingsford Smith Airport	0	0
	M5 East stack	1300	40.5
	Sub Total	5640	215
Industrial and commercial sources	Unilever	0.0	0
	Commercial cooking	0.0	8.7
	Gas combustion	15.4	1.17
	Sub Total	15.4	9.87
Domestic sources	Solid Fuel heaters	0.248	2.08
	Oil heaters	0.0578	0.00342
	Gas water heaters	11.6	0.941
	Garden maintenance	2.60	5.54
	BBQs	2.72	8.06
	Sub Total	17.3	16.6
Combined	Total	5670	241

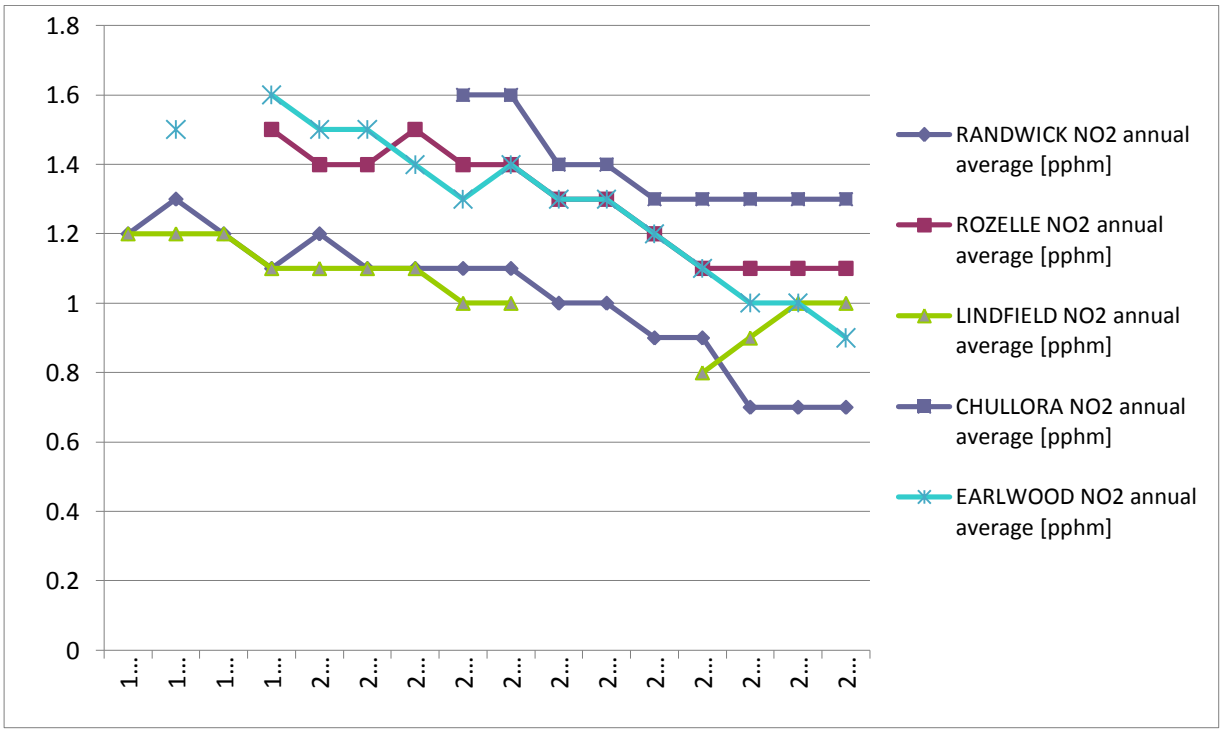
Mobile sources and particularly motor vehicles dominate summertime emissions. In winter (not shown) mobile sources again dominate but solid fuel heaters contribute importantly to

PM_{10}. In this reasonably small area, the stack is an important source of air pollution contributing approximately 23% of NOx and 17% of PM_{10}. In the sub-region (76 sq kms) the proportional contribution of the stack to regional air pollution was 3.8% for NOx and 2.2 to 3.2% for PM_{10}. Taking an even broader regional perspective, for a 2003 base year the NSW Air Emissions Inventory for the Greater Metropolitan Region (DECC 2007) estimates total annual emissions for Sydney from all sources for oxides of nitrogen at 94,353 tonnes and PM10 at 24,004 tonnes. The contribution of the M5 East stack is correspondingly 0.5% of NOx and 0.6% of PM_{10} respectively.

Temporal trends in air pollutants

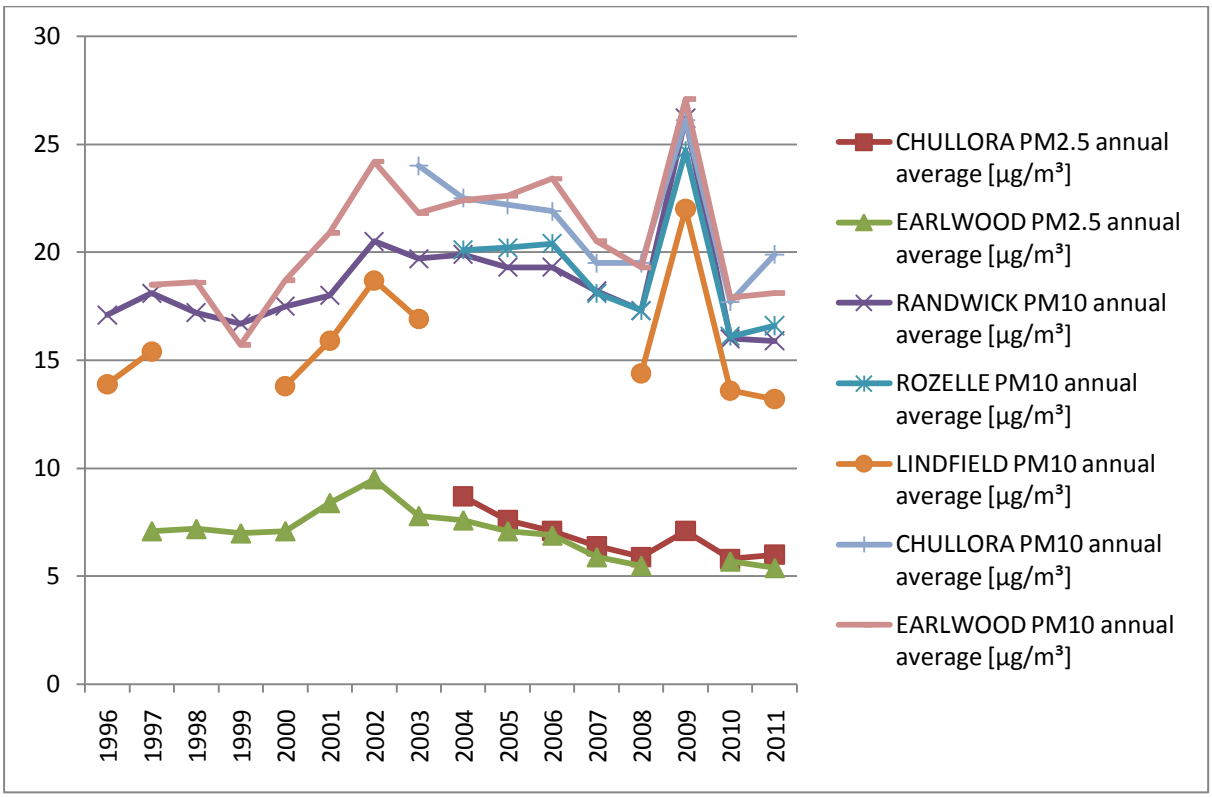
Air pollutants are measured at ground level by a network of monitoring stations run by the NSW Office of Environment and Heritage. The closest permanent monitoring station to the M5 East stack is the station at Earlwood. The general trend for NO_2 has been downward over this period. In the charts below (Figures 4 and 5) are reproduced annual average air pollutants for the Earlwood site compared with other sites in the Sydney metropolitan area for both NO_2 and PM_{10}. The overall levels of NO_2 are low. The NEPM is set at 0.03 ppm or 3 pphm – and measured annual averages are around half this[3]. A clear trend for PM_{10} and $PM_{2.5}$ is less apparent. The monitoring for PM_{10} is also frequently disturbed by large natural events including bushfires and the extraordinary dust storm of 2009.

Figure 4: Temporal trends in average NO_2 1996-2011 using data from the inner Eastern Sydney region (source: NSW Office of Environment and Heritage Air Quality Monitoring Stations - http://www.environment.nsw.gov.au/AQMS/search.htm)



[3] NSW Office of Environment and Heritage advises a conversion factor for NO_2 from parts per hundred million (pphm) to µg/m^3 of 20.5 (at 0 degrees Celsius). So an NO_2 of 1 pphm is equivalent to 20.5 ug/m3.

Figure 5: Temporal trends in annual average PM_{10} and $PM_{2.5}$ for 1996-2011 using data from inner Eastern Sydney region (source: NSW Office of Environment and Heritage Air Quality Monitoring Stations - http://www.environment.nsw.gov.au/AQMS/search.htm)



Dispersion modelling estimates of ground level concentrations of pollutants

Exposures at ground level can be estimated through plume modelling if estimates or measurements of pollutants emanating from a stack are known. Prior to the opening of the M5 East estimates of stack emissions were predicted based on fleet and tunnel characteristics and an estimated throughput of 77,000 vehicles per day. Since tunnel opening there have been direct stack measurements available.

In 2004, NSW Health undertook a multi-phase study to investigate whether there was an association between emissions from the stack and symptoms reported by local residents. Records of stack measurements of volume of air discharged and pollutant concentrations were made available to the CSIRO for the purposes of estimating relatively high, medium and low geographic exposure areas for this NSW health study. The model was developed by CSIRO using The Air Pollution Model (TAPM) to predict the ground level impact of emissions from the M5 East Stack on the region. The results of the plume model can be located as an appendix to the 2004 NSW Health Report (Capon 2004). The report modelled ground level PM_{10}, NOx, and non-methane volatile organic compounds (NMVOCS) using stack emission data for a year from February 2002 to January 2003. The pattern of dispersion around the

stack was resolved to 300m squares and showed peaks to the east and west along the valley and also north of the stack consistent with prevailing winds. The maximum annual average impact of the stack emissions in any 300m square was estimated to be 0.78µg/m^3 for NOx and 0.07µg/m^3 for PM_{10}. This was in the order of 1% of background NOx and background PM_{10}. Background emissions were estimated from the RTA monitoring stations around the site to be approximately 60.0µg/m^3 for NOx and 21.1µg/m^3 for PM_{10}. In July 2004, NSW Health was advised that portal emissions occurred during the study period (September to November 2003). The modelled exposure zone boundaries used in the study may not have been good estimates of actual exposure during the study period. As a consequence, in 2006 the initial modelling was adjusted to include the portal emissions and a re-analysis of the data collected was conducted. The modelling reproduced in the 2006 report (Hibberd 2006) was based on data obtained in September and October 2003. It also estimated portal emissions. It was specifically concerned to identify differences in geographic exposure to NOx. The highest average annual NOx concentrations were almost 10-fold higher (6.61µg/m^3) and located in fairly confined areas around the portals.

The exposure cut-offs chosen for the NSW Health study that defined low, medium and high exposures to NOx were essentially arbitrary. All levels of NOx pollution identified were reasonably low. In this study the modelling utilised to define the exposure area was the 2006 adjusted model. The same exposure cut-off was used to define an exposed population: ≥0.3µg/m^3.

There has been no update to modelling since these CSIRO reports were published. During this period there have been a number of trends that may have affected the stack emissions. Vehicle movements through the tunnel have increased well beyond 77,000 to over 100,000 per day. This increase was primarily due to an increase in the number of cars. Over this period of time there have been improvements to vehicle emissions which may have partly compensated.

Actual measurements at ground level monitoring stations

There are four ground level monitoring stations located around the stack T1, U1, X1 and CBMS (see Map 4). U1, T1 and T3 were established in June 2000 and X1 and CMBS in November 2001. T1, X1, U1 and CMBS measure both NO_2 and PM_{10}. There is another monitoring station at Finlay's Avenue that measures volatile organic compounds. Sites U1 and T1, because they were commissioned approximately 18 months prior to tunnel opening, provide some baseline data. Analyses were completed fairly soon after tunnel opening attempted to detect pollution from the stack and distinguish it from background. For example, Barnett from Holmes Air Science (Barnett 2003) compared 15 minute averages for NO_2 and PM_{10} at U1 and T1 in the year pre opening to the year post opening for certain wind directions and was unable to find a clear stack emission signature. Detailed historical

data is available from Roads and Maritime Services (RTA) website[4]. Historical daily averages and maxima for each day can be extracted from documents on the website. In the charts below data for NO_2 and PM10 for the months of March, June, September and December have been extracted for the period from June 2000 (if data was available) to the end of 2011. In general all the monitoring sites show small downward trends for both NO_2 and PM_{10} monthly averages. This small downward trend is also discernable for maxima. The maxima occasionally record pollution events. An effect post tunnel opening is not obvious from the simple presentation of data in the figures Figures 6 and 7 for sites U1 and T1.

[4] Historical data ground level monitoring stations that the RTA maintains is available from http://www.rta.nsw.gov.au/roadprojects/projects/building_sydney_motorways/tunnel_air_quality/m5_east/outside_air_quality/index.html.

Figure 6: NO_2 1 hour maximums and NO_2 monthly averages in micrograms per m^3 for March, June, September and December 2000 to 2011 for U1, T1, X1 and CBMS monitoring stations

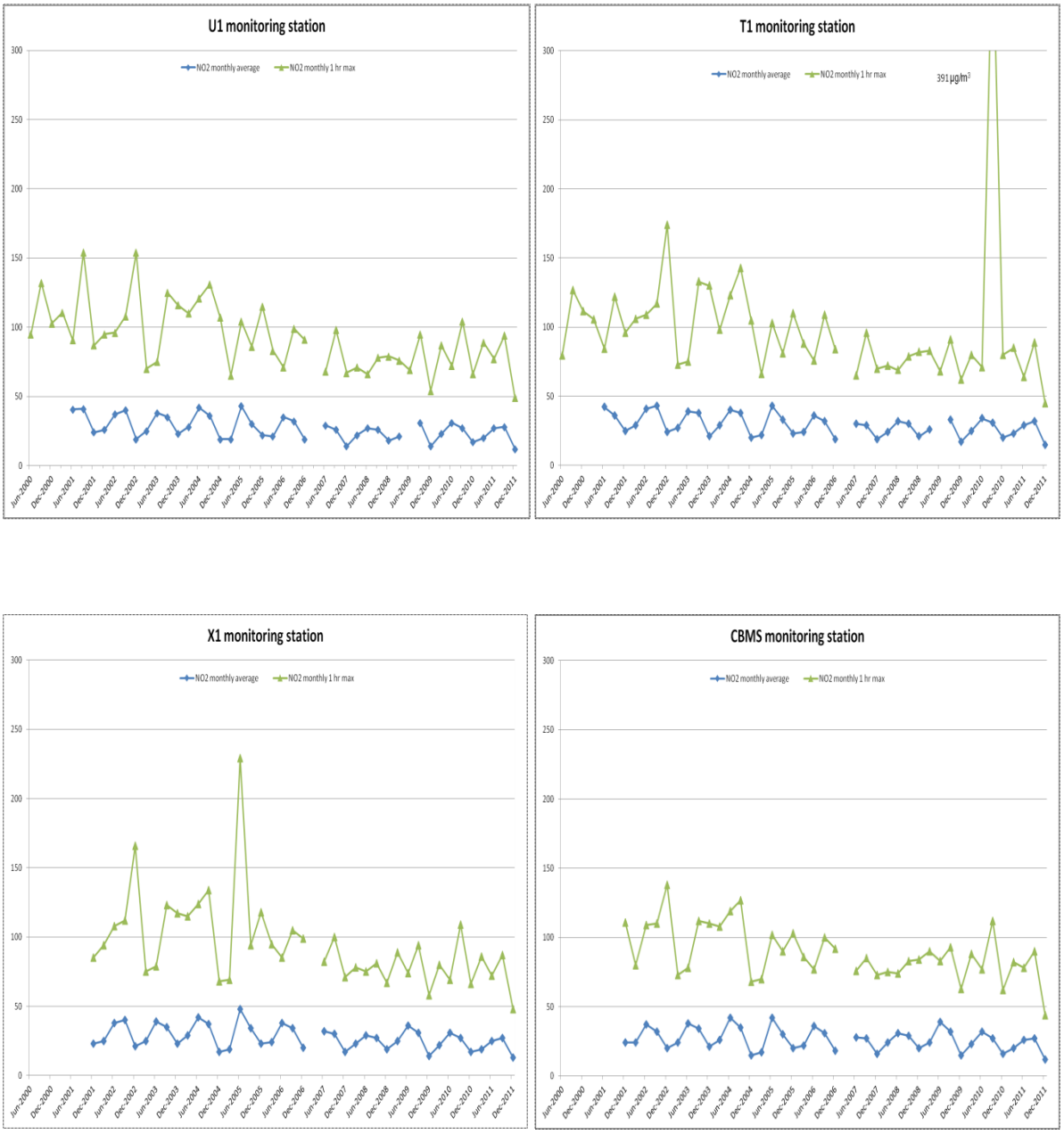
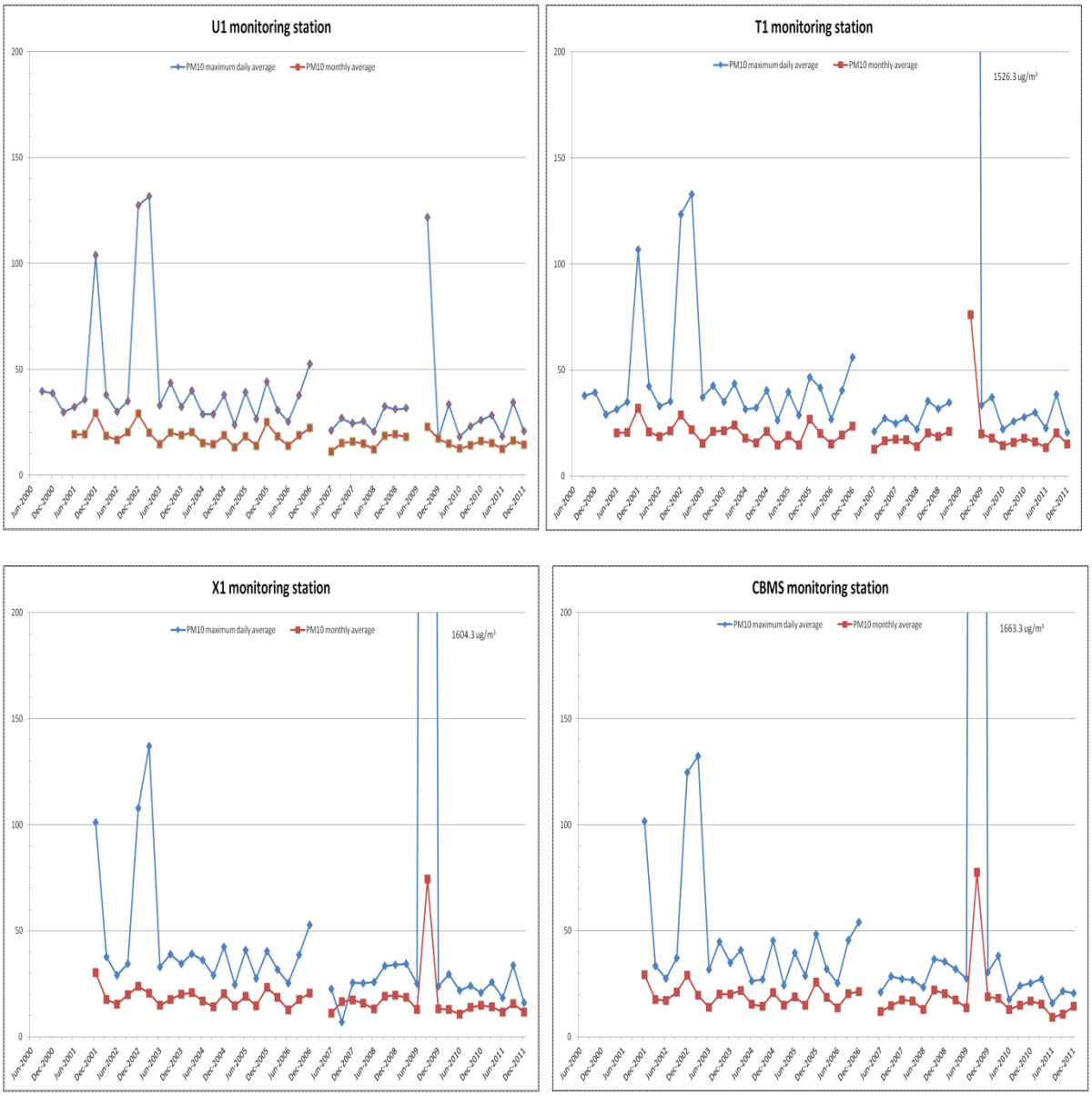
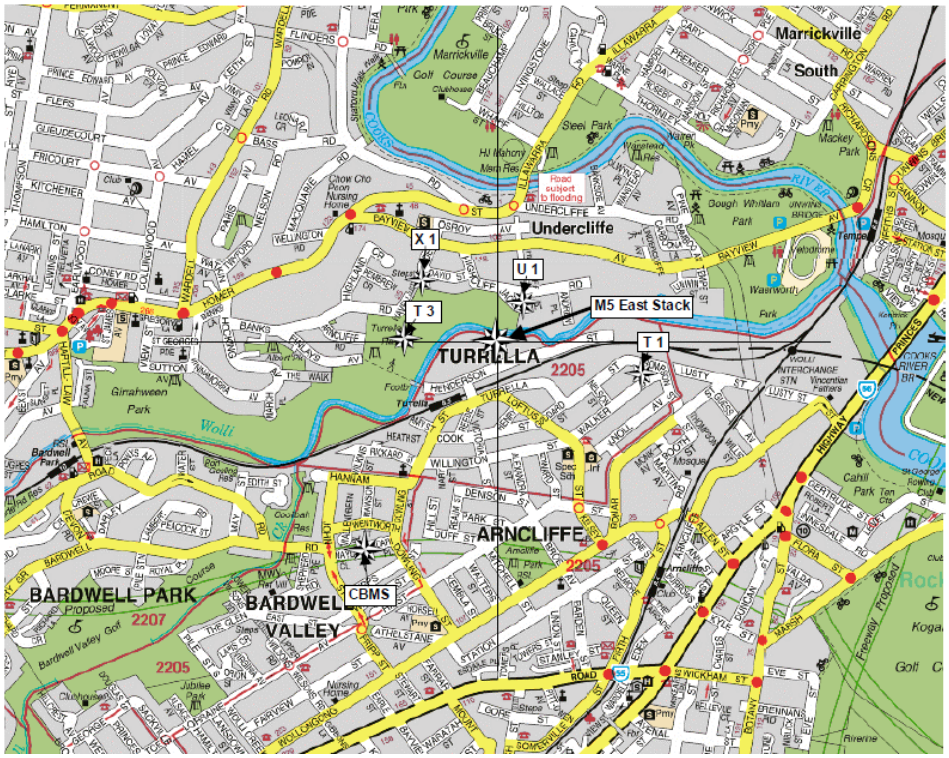


Figure 7: PM_{10} maximum daily average and PM_{10} monthly average in micrograms per m^3 for March, June, September and December 2000 to 2011 for U1, T1, X1 and CBMS monitoring stations



Map 4: Location of M5 east stack in relation to RTA monitoring stations (from Hibberd 2003)



Other secular trends – smoking prevalence and socioeconomic status

When any observation is made of a higher frequency of a health condition in one group compared to another it is important to consider a range of possible causes. The most important cause of lung cancer is tobacco smoke. There are other risk factors for lung cancer which include radon, asbestos and particulate air pollution. Smoking is both a strong risk factor for lung cancer and a common risk factor. The risk of lung cancer is approximately 20-fold-higher in current smokers compared with never smokers (Alberg 2007). Smoking has been historically common but prevalence of smoking is now decreasing quickly. However, in most populations smoking is still estimated to cause around 90% of lung cancer. Most of the variation in lung cancer incidence between areas is likely attributable to differences in historical smoking prevalence and smoking habit.

Survey data is available that estimates smoking prevalence for large populations – such as the NSW population. For example in the NSW health survey the 2010 estimate of current smoking prevalence in adults was 15.8% based on responses from 10,245 adults. However, in any small area it is likely that there would only have been a small number of respondents and current smoking prevalence cannot be accurately estimated. Even if it was available, lung cancer incidence is determined not only by current smoking but also previous smoking, smoking duration, and the amount smoked each day – information which is usually not gathered in a survey of smoking prevalence.

At a small area level proxy information is available from which we may infer relative smoking prevalence. Summary information on socioeconomic status derived from income and other measures is available as an index called the Socio-Economic Index for Areas or SEIFA index and a number of closely related indexes. This provides a simple proxy measure of smoking prevalence. For example, the 2010 Report on Adult Health in NSW shows a strong gradient in current smoking prevalence in residents from the most disadvantaged areas by SEIFA score to residents living in the least disadvantaged area. By quintile (fifth) of SEIFA score current smoking prevalence is as follows: 19.7%, 18.4%, 15.2%, 13.4%, and 12.0%. For daily smoking (which excludes occasional smokers) the difference between high and low SEIFA scores is a little greater and varies as follows: 16.0%, 14.9%, 11.8%, 10.0%, and 6.2%. Changes in socioeconomic indicators over time in the Turrella population relative to the Sydney Metropolitan or NSW population may indirectly point to changes in relative smoking prevalence.

Table 18 and 19 overleaf shows census collection districts for Turrella and Adjacent postcodes for five census periods from 1986 to 2006 grouped into quartiles according to whether they fall in the first, second, third or fourth quartile of all census collection districts in metropolitan Sydney ranked from most disadvantaged to least according to the Index of Relative Socio-economic Disadvantage. It can be seen that there are almost no census collection districts in either Turrella or Adjacent postcodes that fall into the least disadvantaged quartile. In both Turrella and Adjacent postcodes there are similar changes

from 1986 to the 2006 census. Relative to other census districts in Metropolitan Sydney there is a marked increase in the proportion of districts in the second most disadvantaged quartile and a decrease in the proportion of districts in the first and third quartiles. However, in Turrella and surrounds nearly all of this change occurs between the 1986 and the 1996 census rather than the 1996 to 2006 period which is of greater interest.

The NSW Adult Health Survey was first conducted in 1997-1998. We do not have smoking prevalence by SEIFA index from this source going back to 1986. However, if we take the smoking prevalence by SEIFA from the 2006 NSW Adult Health Survey and calculate a smoking prevalence for Turrella and surrounds after weighting smoking prevalence according to the proportions of census collector districts in each quartile of Socio-economic disadvantage then the calculated smoking prevalence in 1986 is 19.4% and in 2006 is 19.2% - a decrease of 0.2%. If the same method is followed using daily smoking then calculated smoking prevalence in 1986 is 15.5% increasing to 15.8% in 2006. Although this is a crude method of assessing possible changes in smoking prevalence, it does not seem that changes in socio-economic disadvantage in the Turrella population over this 20 year period would provide a reason for a change in smoking prevalence relative to the rest of NSW.

Table 18: Turrella and surrounds quartile distribution for Relative Socio-economic Disadvantage derived using all Census Collection Districts within the inner and outer Sydney metropolitan area (see http://www.dlg.nsw.gov.au/dlg/dlghome/dlg_regions.asp)

Relative Socioeconomic Disadvantage quartile by Census year

Disadvantage quartile	Census year					
Frequency Column Percent	1986	1991	1996	2001	2006	Total
Q1 (most)	45 36.29	41 33.33	31 32.63	20 24.10	20 23.53	157 30.78
Q2	39 31.45	50 40.65	60 63.16	55 66.27	57 67.06	261 51.18
Q3	40 32.26	30 24.39	4 4.21	8 9.64	8 9.41	90 17.65
Q4 (least)	0 0.00	2 1.63	0 0.00	0 0.00	0 0.00	2 0.39
Total	124	123	95	83	85	510 100.00

Table 19: Adjacent postcodes quartile distribution for Relative Socio-economic Disadvantage derived using all Census Collection Districts within the inner and out Sydney metropolitan area (see http://www.dlg.nsw.gov.au/dlg/dlghome/dlg_regions.asp)

Relative Socioeconomic Disadvantage quartile by Census year						
Disadvantage quartile	Census year					
Frequency Column Percent	1986	1991	1996	2001	2006	Total
Q1 (most)	121 45.83	114 43.35	102 50.50	77 41.18	60 31.91	474 42.93
Q2	85 32.20	105 39.92	91 45.05	103 55.08	110 58.51	494 44.75
Q3	56 21.21	42 15.97	9 4.46	7 3.74	18 9.57	132 11.96
Q4 (lEast)	2 0.76	2 0.76	0 0.00	0 0.00	0 0.00	4 0.36
Total	264	263	202	187	188	1104 100.00

Discussion

Screening study and refined analysis using census collection districts

Our screening study was designed to use available data to investigate whether it was likely that there was any important change in cancer incidence from the six year period before the tunnel commenced operation to the six year period after the tunnel was commissioned. We examined the age-sex standardised incidence rates of leukaemia, lung cancer and all cancers combined in the five postcodes surrounding the M5 East tunnel stack at Turrella for the period 1996 to 2007. The incidence rates for all cancers rose by 12% in the six years post commencement of operation; this increase was similar to that in NSW as a whole over the same period. The incidence rates for leukaemia in the 1996-2007 periods appeared to be unchanged. However, incidence rates for lung cancer in the period post operation of the M5 East motorway tunnel rose in the population surrounding Turrella by 34%. In contrast the lung cancer rates in NSW had been constant in the 1996-2007 periods. This deserved closer examination.

To assist in clarifying whether this finding was specific to residents affected by air pollution from the M5 East tunnel we conducted an analysis restricting the population examined to an area more closely aligned with projected pollution derived from a dispersion plume model developed by CSIRO in 2006. This analysis, using a population defined by an aggregation of 85 census collection districts, essentially verified the findings of the screening study. The finding was also seen if we used a slightly different population defined by earlier modelling that did not take into account portal emissions. Because there were fewer incident cancers in this more tightly defined population there was some loss of precision. For example, the modest increase in all cancers in the census collection district defined study population was no longer statistically significant. However, the observed increase in the incidence of lung cancer was essentially the same. In this more carefully defined population there was an apparent increase in lung cancer of 36% or some 47 cases. The result just achieved statistical significance.

Comparison with an adjacent less exposed population

We attempted to identify whether lung cancer incidence decreased consistently with increasing distance from the stack, as a proxy for decreasing exposure. The prospect of selecting several different areas with different levels of exposure (e.g. an even smaller and tightly defined high exposure area) were limited by the geography of census collection districts some of which clearly cross the ‘high’ and ‘medium’ exposure extent of the plume and by population size: the population of our CCD-defined population was only just over 50,000 and selecting a smaller population for analysis may have been limited by precision. This is well illustrated in Map 2. The comparison population outside the defined exposed population but within a broader ring of postcodes was probably negligibly exposed to pollution from the stack and portals. The change in lung cancer incidence in the adjacent

population from the pre to post operation period was +14% for males, -2% for females and +8% for all persons. No change was statistically significant and the apparent increases in the adjacent less exposed population were much less than those in the Turrella and surrounds population (+40% for males and +36% for all persons). While the increases in males and all persons in the adjacent less exposed population could be due simply to chance fluctuation of lung cancer rates in men, they might indicate some extension of whatever factors explain increased lung cancer rates in men in Turrella and surrounds.

Historical analysis of lung cancer incidence

This analysis shows that for males lung cancer incidence in the period from 1981 to 2007 appears on a downward trajectory. This is clearly shown in the NSW data and best illustrated by Figures 1 and 3. However, for both the Turrella and surrounds population and the adjacent postcodes population a downtrend is less clear. There is evidence of a point of inflexion in the mid 1990s prior to the tunnel becoming operational and trends to increase thereafter in the Turrella and surrounds population and to flatten or slightly increase in the adjacent postcodes population. It is also clear when visualising the rates in the Turrella population that the yearly rates of lung cancer in males and females post tunnel opening are not exceptionally high – just consistently higher than average. In contrast in the pre-tunnel period there are a three years where the rates were below average. When placed in this context the increase in lung cancer incidence in the Turrella and surrounds population in the post operation period appears less exceptional.

Exposure assessment, biological plausibility and study limitations

Lung cancer was not raised as a concern by the community. It was examined because it is a common cancer, contributes importantly to overall cancer trends and there is relatively good evidence of a causal association between air pollution and lung cancer. For example Pope et al (2002) estimate an 8% increase in lung cancer mortality associated with a 10µg/m^3 increase in fine particulate pollution. The absolute level of fine particulate pollution at which health effects may be observed is low and within the levels that are commonly observed in Sydney. It is likely therefore that some lung cancers are caused by or partly caused by particulate pollution. However, the finding of an apparent increase in lung cancer in any individual area should be interpreted cautiously. There are several general features of the data and some specific that could prevent a causal inference being drawn.

Firstly, as outlined in the chapter on exposure assessment, it is doubtful, on present evidence, whether the additional exposure to traffic-related air pollutants from the M5 East stack relative to other broader trends in air pollution would be sufficient to cause a detectable increase in lung cancer risk. The main pollutant associated with lung cancer is fine particulate pollution. There is certainly a reasonable quantity of particulate pollution emanating from the stack – about 41 kg per day. The best proxy of traffic-generated fine particulate pollution is probably oxides of nitrogen (NOx). The predicted additional exposure to NOx in the CSIRO modelling in even high exposure areas is very modest. The total range

of modelled additional annual average exposure to NOx in the CSIRO data that forms the plume (see map 1) is from 0.3µg/m^3 (the chosen lower cut off) to a maximum annual average value of 6.61µg/m^3 near the portals. Only approximately the top 10% of 657 data points indicate additional exposures greater than 1.0 µg/m^3. This compares with an estimated background value of 60µg/m^3 from other sources estimated from the monitoring stations around the stack (Hibberd 2003). Tunnel traffic-generated pollution should be largely the same as that generated by other main roads.

Secondly, the average latency or incubation period from exposure to cancer initiating agents to development of lung cancer is generally thought to be long – around 20 or 30 years. This is why, for example, the majority of cases of lung cancer in smokers occur in older people. While some cancer causing agents may have quite rapid effects, it would still seem unlikely that any effect on lung cancer incidence in the population surrounding the M5 East would be seen in less than a year following the opening of the tunnel; the increase in lung cancer in males was observed almost immediately in 2002.

Thirdly, descriptive epidemiologic methods are relatively weak tools to resolve these questions especially in small populations. Most importantly, we cannot adjust for other factors that may contribute to cancer. We have been comparing rates between populations. We have limited data available on individuals. We cannot adjust for important variables (like previous smoking) that may have been more or less common in people in the Turrella area and possibly contributed to an increase in the incidence of lung cancer from one time point to another. We were able to examine in an indirect way whether changes in socio-economic status over time could have contributed to a change in current smoking prevalence relative to the rest of Sydney. Although we did find changes in relative socio-economic status over a 20 year period, the changes observed could not reasonably be expected to result in a change in current smoking prevalence relative to the rest of Sydney. The other major weakness in small area studies is that the numbers of events being examined are few and apparent variation in the number of events and calculated rates from period to period or in comparison with another population can be due to chance.

Conclusion

We found a small increase in lung cancer incidence in the area surrounding M5 East tunnel and stack in the six years post opening compared to the six years immediately before opening. This was seen in both males and females resident in the geographic area projected to be affected by additional air pollution as best as we could define it. We explored the possibility that this increase or some component of it may be attributable to air pollution from the M5 East stack and portals. After close examination there are several reasons to consider that air pollution from the M5 East tunnel is not likely be the cause of this apparent increase in lung cancer. The main reasons for drawing this conclusion are as follows:

- The overall measured levels of air pollutants around the stack are consistent with background levels in other areas, appear to be dominated by sources other than the tunnel, and the overall trend in air pollutants in the period has been downward.
- It would be unusual for lung cancer incidence to increase very rapidly after an increase in exposure to air pollution or any other potential carcinogen, and yet a trend to higher incidence of lung cancer is seen at the time operations began.
- With the benefit of examining cancer incidence over a longer time course, the increase in lung cancer incidence in the Turrella area appears to have predated the opening of M5 East tunnel.

None of the above reasons would on their own completely discount the possibility of the increase in lung cancer incidence being truly associated with air pollution from the M5 East tunnel stack and portals. However, taken together they make a causal association between air pollution from the M5 East tunnel and lung cancer unlikely.

Recommendation

- The Public Health Units for the relevant health districts should continue to monitor lung cancer incidence and all cancer incidence in Turrella and the surrounding area.

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Appendix 1: Exposure area sensitivity analysis

Table 1: Comparison of changes in directly age-standardised rate-ratios for after (2002–2007) versus before (1996–2001) commencement of M5 East tunnel operations in Turrella and surrounds for 2006 (NSW Health 2006) and 2004 (Capon 2004) CSIRO plume dispersion models

Type of cancer	Sex	2006 Plume Model			2004 Plume Model			Difference
		Ratio-ratio	Lower 99% CI	Upper 99% CI	Ratio-ratio	Lower 99% CI	Upper 99% CI	2006 vs 2004
All cancers	Males	1.09	0.964	1.237	1.14	1.001	1.304	-4.60%
	Females	1.04	0.905	1.206	1.02	0.876	1.186	2.40%
	Persons	1.06	0.968	1.167	1.08	0.976	1.189	-1.30%
Leukaemia	Males	0.71	0.331	1.506	0.74	0.333	1.656	-5.10%
	Females	0.99	0.408	2.388	0.92	0.332	2.552	6.70%
	Persons	0.80	0.450	1.408	0.78	0.415	1.452	2.50%
Lung cancer	Males	1.40	0.979	1.999	1.42	0.991	2.049	-1.90%
	Females	1.53	0.822	2.843	1.24	0.672	2.272	19.10%
	Persons	1.36	1.002	1.852	1.32	0.967	1.792	3.30%

Appendix 2: Cancer incidence by type and year 1996-2007.

Table 1: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, all cancers, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	341	74819	455.77	407.44	445.67	0.91	0.80	1.05
1997	368	75034	490.44	432.25	450.41	0.96	0.84	1.10
1998	367	74896	490.01	431.73	444.26	0.97	0.85	1.11
1999	346	75037	461.11	405.82	442.05	0.92	0.80	1.05
2000	313	75124	416.64	362.94	448.53	0.81	0.71	0.92
2001	375	75378	497.49	428.89	469.33	0.91	0.80	1.04
2002	381	75330	505.78	441.66	466.85	0.95	0.83	1.08
2003	437	75604	578.01	509.63	470.78	1.08	0.95	1.23
2004	378	75631	499.80	442.15	487.04	0.91	0.80	1.03
2005	410	76124	538.60	477.86	485.92	0.98	0.87	1.12
2006	407	76705	530.60	453.74	483.31	0.94	0.83	1.06
2007	385	77567	496.35	434.29	489.96	0.90	0.79	1.02

Table 2: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, males, all cancers, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	179	36880	485.34	465.55	548.14	0.85	0.71	1.02
1997	193	36981	521.89	501.36	550.34	0.91	0.76	1.09
1998	196	36911	531.01	513.14	532.10	0.96	0.80	1.16
1999	192	37004	518.86	491.54	537.83	0.91	0.77	1.09
2000	185	37056	499.24	474.77	539.90	0.88	0.74	1.05
2001	220	37218	591.11	557.74	560.44	1.00	0.84	1.18
2002	207	37050	558.70	540.07	556.61	0.97	0.81	1.16
2003	229	37201	615.58	621.12	561.68	1.11	0.93	1.32
2004	233	37148	627.22	634.45	596.39	1.06	0.89	1.27
2005	249	37486	664.25	650.39	594.70	1.09	0.92	1.30
2006	222	37976	584.58	540.67	593.10	0.91	0.77	1.07
2007	212	38392	552.20	519.11	597.214	0.87	0.74	1.03

Table 3: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, females, all cancers, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	162	37939	427.00	368.83	373.34	0.99	0.80	1.21
1997	175	38053	459.89	384.84	381.02	1.01	0.83	1.23
1998	171	37985	450.18	378.20	383.31	0.99	0.81	1.21
1999	154	38033	404.91	346.04	373.24	0.93	0.76	1.14
2000	128	38068	336.24	284.90	382.89	0.74	0.61	0.91
2001	155	38160	406.18	342.82	403.40	0.85	0.70	1.03
2002	174	38280	454.55	380.09	400.83	0.95	0.78	1.15
2003	208	38403	541.62	442.61	401.27	1.10	0.91	1.34
2004	145	38483	376.79	316.52	402.12	0.79*	0.65	0.96
2005	161	38638	416.69	354.33	399.52	0.89	0.73	1.08
2006	185	38729	477.68	380.24	396.22	0.96	0.79	1.16
2007	173	39175	441.61	367.26	390.49	0.94	0.77	1.14

Table 4: Number of cases of Leukaemia in children (≤15 years of age) and adults (> 15 years of age) in Turrella and surround, 1996-2007

Year	Child (≤ 15 years)	Adult (>15 years)
1996	0	13
1997	1	11
1998	0	10
1999	0	17
2000	1	7
2001	0	8
2002	0	3
2003	0	9
2004	2	8
2005	0	7
2006	1	12
2007	1	13
Total	**6**	**118**

Table 5: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, all leukaemia, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	13	74819	17.38	15.42	12.80	1.20	0.55	2.66
1997	12	75034	15.99	14.52	12.05	1.20	0.53	2.76
1998	10	74896	13.35	11.60	13.06	0.89	0.41	1.93
1999	17	75037	22.66	19.70	13.86	1.42	0.67	3.00
2000	8	75124	10.65	9.70	13.77	0.70	0.32	1.55
2001	8	75378	10.61	9.16	14.23	0.64	0.31	1.35
2002	3	75330	3.98	3.83	15.06	0.25	0.12	0.52
2003	9	75604	11.90	10.09	14.01	0.72	0.34	1.51
2004	10	75631	13.22	13.02	14.04	0.93	0.42	2.05
2005	7	76124	9.20	7.27	12.92	0.56	0.27	1.17
2006	13	76705	16.95	13.99	12.47	1.12	0.52	2.43
2007	14	77567	18.05	16.48	12.20	1.35	0.60	3.06

Table 6: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, Males, all leukaemia, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	5	36880	13.56	12.58	16.53	0.76	0.28	2.11
1997	5	36981	13.52	13.86	16.03	0.86	0.29	2.55
1998	6	36911	16.26	15.81	17.06	0.93	0.33	2.59
1999	8	37004	21.62	20.16	17.30	1.17	0.43	3.14
2000	5	37056	13.49	14.23	18.31	0.78	0.28	2.17
2001	6	37218	16.12	14.87	18.65	0.80	0.31	2.05
2002	2	37050	5.40	5.64	19.20	0.29	0.11	0.76
2003	4	37201	10.75	11.32	17.85	0.63	0.23	1.78
2004	8	37148	21.54	21.94	18.76	1.17	0.43	3.16
2005	5	37486	13.34	12.26	17.09	0.72	0.27	1.91
2006	7	37976	18.43	16.68	15.57	1.07	0.39	2.95
2007	8	38392	20.84	20.68	16.36	1.26	0.45	3.55

Table 7: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, Females, all leukaemia, 1996-2007

	Turrella & surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	8	37939	21.09	15.31	9.72	1.57	0.49	5.09
1997	7	38053	18.40	14.83	8.91	1.67	0.47	5.93
1998	4	37985	10.53	7.51	9.65	0.78	0.24	2.49
1999	9	38033	23.66	18.95	11.10	1.71	0.53	5.28
2000	3	38068	7.88	5.27	10.01	0.53	0.17	1.65
2001	2	38160	5.24	5.16	10.55	0.49	0.14	1.73
2002	1	38280	2.61	2.24	11.56	0.19	0.07	0.55
2003	5	38403	13.02	8.70	10.61	0.82	0.28	2.43
2004	2	38483	5.20	5.23	10.36	0.50	0.14	1.72
2005	2	38638	5.18	3.60	9.31	0.39	0.12	1.22
2006	6	38729	15.49	12.35	10.13	1.22	0.36	4.13
2007	6	39175	15.32	13.83	8.74	1.58	0.41	6.12

Table 8: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, lung cancer, 1996-2007

	Turrella and surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100,000	Direct std rate per 100,000	Direct std rate per 100,000		Lower	Upper
1996	25	74819	33.41	28.34	42.71	0.66	0.43	1.01
1997	37	75034	49.31	42.64	43.79	0.97	0.64	1.49
1998	39	74896	52.07	45.02	43.69	1.03	0.67	1.57
1999	34	75037	45.31	38.99	41.27	0.94	0.61	1.46
2000	28	75124	37.27	32.67	42.84	0.76	0.50	1.17
2001	28	75378	37.15	30.30	41.43	0.73	0.48	1.12
2002	37	75330	49.12	42.01	41.14	1.02	0.66	1.58
2003	47	75604	62.17	54.59	40.23	1.36	0.87	2.11
2004	45	75631	59.50	52.57	43.88	1.20	0.78	1.83
2005	41	76124	53.86	47.58	42.67	1.11	0.72	1.72
2006	41	76705	53.45	45.82	43.22	1.06	0.70	1.61
2007	45	77567	58.01	50.89	43.00	1.18	0.77	1.81

Table 9: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, Males, lung cancer, 1996-2007

	Turrella and surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100,000	Direct std rate per 100,000	Direct std rate per 100,000		lower	upper
1996	19	36880	51.52	46.92	65.54	0.72	0.43	1.19
1997	30	36981	81.12	77.47	66.90	1.16	0.69	1.93
1998	31	36911	83.99	79.67	67.06	1.19	0.71	1.97
1999	25	37004	67.56	63.17	62.34	1.01	0.60	1.71
2000	20	37056	53.97	50.25	62.92	0.80	0.48	1.34
2001	19	37218	51.05	48.46	60.32	0.80	0.47	1.37
2002	21	37050	56.68	55.20	58.07	0.95	0.55	1.65
2003	34	37201	91.40	91.47	56.63	1.62	0.92	2.83
2004	32	37148	86.14	88.79	62.12	1.43	0.83	2.47
2005	33	37486	88.03	85.79	57.12	1.50	0.87	2.60
2006	30	37976	79.00	71.44	58.77	1.22	0.72	2.05
2007	33	38392	85.96	80.93	58.19	1.39	0.82	2.36

Table 10: Incidence rates for Turrella and surrounds (postcode defined) compared with NSW, Females, lung cancer, 1996-2007

	Turrella and surrounds				NSW	Rate ratio	99%CI	
Year	Events	Population	Crude rates per 100,000	Direct std rate per 100,000	Direct std rate per 100,000		Upper	Lower
1996	6	37939	15.81	12.05	25.01	0.48	0.23	1.01
1997	7	38053	18.40	15.48	26.40	0.59	0.28	1.25
1998	8	37985	21.06	16.59	25.43	0.65	0.31	1.38
1999	9	38033	23.66	19.55	24.86	0.79	0.36	1.71
2000	8	38068	21.02	17.85	27.25	0.66	0.31	1.39
2001	9	38160	23.58	19.11	26.33	0.73	0.35	1.52
2002	16	38280	41.80	34.10	27.64	1.23	0.59	2.57
2003	13	38403	33.85	31.38	27.36	1.15	0.53	2.47
2004	13	38483	33.78	26.83	28.86	0.93	0.46	1.88
2005	8	38638	20.71	18.05	31.30	0.58	0.29	1.57
2006	11	38729	28.40	24.01	30.88	0.78	0.38	1.57
2007	12	39175	30.63	25.53	31.06	0.82	0.41	1.65

Appendix 3: Cancer incidence by type and year 1996-2007 using census collection districts.

Table 1: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, all cancers, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW	99%CI		
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	227	51,207	443.30	431.76	445.65	0.97	0.82	1.15
1997	243	51,714	469.89	451.79	450.39	1.00	0.85	1.18
1998	242	52,206	463.55	441.41	444.23	0.99	0.84	1.17
1999	247	52,640	469.23	445.14	442.02	1.01	0.85	1.19
2000	234	52,960	441.84	415.44	448.51	0.93	0.79	1.09
2001	241	53,264	452.46	425.04	469.30	0.91	0.77	1.06
2002	244	52,976	460.59	435.46	466.83	0.93	0.80	1.09
2003	263	53,256	493.84	474.48	470.76	1.01	0.86	1.18
2004	238	53,160	447.71	430.28	487.01	0.88	0.76	1.03
2005	282	53,252	529.56	503.24	485.90	1.04	0.89	1.21
2006	279	53,773	518.85	480.26	483.28	0.99	0.85	1.16
2007	264	54,320	486.01	450.22	482.93	0.93	0.80	1.09

Table 2: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, males, all cancers, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW	99%CI		
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	127	25,240	503.17	526.24	548.10	0.96	0.77	1.20
1997	122	25,516	478.14	491.51	550.30	0.89	0.72	1.11
1998	134	25,777	519.84	527.54	532.07	0.99	0.79	1.24
1999	147	26,000	565.39	567.04	537.79	1.05	0.85	1.31
2000	150	26,152	573.57	581.31	539.87	1.08	0.87	1.34
2001	136	26,300	517.11	530.23	560.40	0.95	0.76	1.17
2002	132	26,091	505.92	533.10	556.58	0.96	0.77	1.19
2003	148	26,223	564.39	633.67	561.64	1.13	0.90	1.41
2004	136	26,145	520.18	576.83	596.35	0.97	0.78	1.20
2005	164	26,274	624.19	660.25	594.66	1.11	0.90	1.37
2006	154	26,719	576.37	579.21	593.06	0.98	0.80	1.20
2007	151	27,029	558.66	556.92	597.18	0.93	0.76	1.14

Table 3: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, females, all cancers, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW Direct Std Rate per 100,000	99%CI		
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000		Rate Ratio	Lower	Upper
1996	100	25,967	385.10	357.95	373.32	0.96	0.74	1.24
1997	121	26,199	461.86	426.55	381.00	1.12	0.87	1.44
1998	108	26,429	408.64	373.28	383.29	0.97	0.76	1.25
1999	100	26,640	375.38	351.16	373.22	0.94	0.73	1.21
2000	84	26,808	313.34	286.44	382.87	0.75	0.59	0.96
2001	105	26,964	389.41	357.26	403.38	0.89	0.70	1.13
2002	112	26,885	416.59	369.52	400.81	0.92	0.73	1.17
2003	115	27,033	425.41	373.47	401.25	0.93	0.74	1.18
2004	102	27,015	377.57	340.47	402.10	0.85	0.67	1.07
2005	118	26,978	437.39	393.06	399.50	0.98	0.78	1.25
2006	125	27,054	462.04	404.09	396.20	1.02	0.81	1.29
2007	113	27,291	414.06	370.30	390.47	0.95	0.75	1.20

Table 4: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, all leukaemia, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW Direct Std Rate per 100,000	99%CI		
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000		Rate Ratio	Lower	Upper
1996	11	51,207	21.48	21.32	12.80	1.67	0.61	4.52
1997	7	51,714	13.54	13.13	12.05	1.09	0.39	3.03
1998	4	52,206	7.66	6.97	13.04	0.53	0.21	1.36
1999	12	52,640	22.80	21.32	13.85	1.54	0.61	3.86
2000	6	52,960	11.33	10.21	13.77	0.74	0.30	1.85
2001	6	53,264	11.26	10.56	14.19	0.74	0.30	1.86
2002	3	52,976	5.66	5.37	14.94	0.36	0.15	0.86
2003	7	53,256	13.14	12.70	13.99	0.91	0.36	2.32
2004	7	53,160	13.17	13.27	14.03	0.95	0.36	2.46
2005	4	53,252	7.51	6.80	12.85	0.53	0.21	1.34
2006	6	53,773	11.16	10.58	12.43	0.85	0.32	2.26
2007	10	54,320	18.41	17.33	12.16	1.43	0.54	3.79

Table 5: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, Males, all leukaemia, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW		99%CI	
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	4	25,240	15.85	16.01	16.52	0.97	0.27	3.49
1997	5	25,516	19.60	20.23	16.03	1.26	0.34	4.64
1998	2	25,777	7.76	6.87	17.03	0.40	0.13	1.25
1999	7	26,000	26.92	26.45	17.27	1.53	0.46	5.10
2000	5	26,152	19.12	19.83	18.30	1.08	0.32	3.64
2001	5	26,300	19.01	19.21	18.59	1.03	0.32	3.39
2002	2	26,091	7.67	6.94	19.11	0.36	0.13	1.06
2003	4	26,223	15.25	17.85	17.85	1.00	0.26	3.79
2004	4	26,145	15.30	16.21	18.76	0.86	0.26	2.90
2005	3	26,274	11.42	10.90	17.03	0.64	0.19	2.11
2006	3	26,719	11.23	10.83	15.54	0.70	0.20	2.41
2007	4	27,029	14.80	14.35	16.30	0.88	0.26	2.97

Table 6: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, Females, all leukaemia, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW		99%CI	
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	7	25,967	26.96	22.96	9.72	2.36	0.55	10.24
1997	2	26,199	7.63	6.57	8.91	0.74	0.15	3.54
1998	2	26,429	7.57	6.32	9.65	0.66	0.15	2.88
1999	5	26,640	18.77	16.95	11.10	1.53	0.37	6.31
2000	1	26,808	3.73	2.30	10.01	0.23	0.07	0.73
2001	1	26,964	3.71	3.88	10.52	0.37	0.08	1.69
2002	1	26,885	3.72	3.77	11.42	0.33	0.08	1.38
2003	3	27,033	11.10	9.07	10.58	0.86	0.21	3.50
2004	3	27,015	11.10	11.15	10.33	1.08	0.23	5.10
2005	1	26,978	3.71	2.41	9.22	0.26	0.08	0.91
2006	3	27,054	11.09	10.64	10.08	1.06	0.23	4.90
2007	6	27,291	21.99	20.63	8.71	2.37	0.48	11.73

Table 7: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, lung cancer, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW		99%CI	
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	14	51,207	27.34	25.23	42.70	0.59	0.35	1.00
1997	24	51,714	46.41	45.00	43.79	1.03	0.60	1.76
1998	30	52,206	57.46	54.52	43.69	1.25	0.74	2.11
1999	24	52,640	45.59	43.28	41.27	1.05	0.61	1.80
2000	16	52,960	30.21	28.62	42.84	0.67	0.40	1.13
2001	12	53,264	22.53	20.53	41.43	0.50	0.30	0.83
2002	28	52,976	52.85	50.03	41.13	1.22	0.71	2.09
2003	27	53,256	50.70	49.12	40.23	1.22	0.71	2.12
2004	29	53,160	54.55	53.59	43.88	1.22	0.72	2.08
2005	29	53,252	54.46	51.09	42.67	1.20	0.71	2.03
2006	30	53,773	55.79	50.70	43.22	1.17	0.70	1.96
2007	24	54,320	44.18	41.38	43.00	0.96	0.57	1.62

Table 8: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, Males, lung cancer, 1996-2007

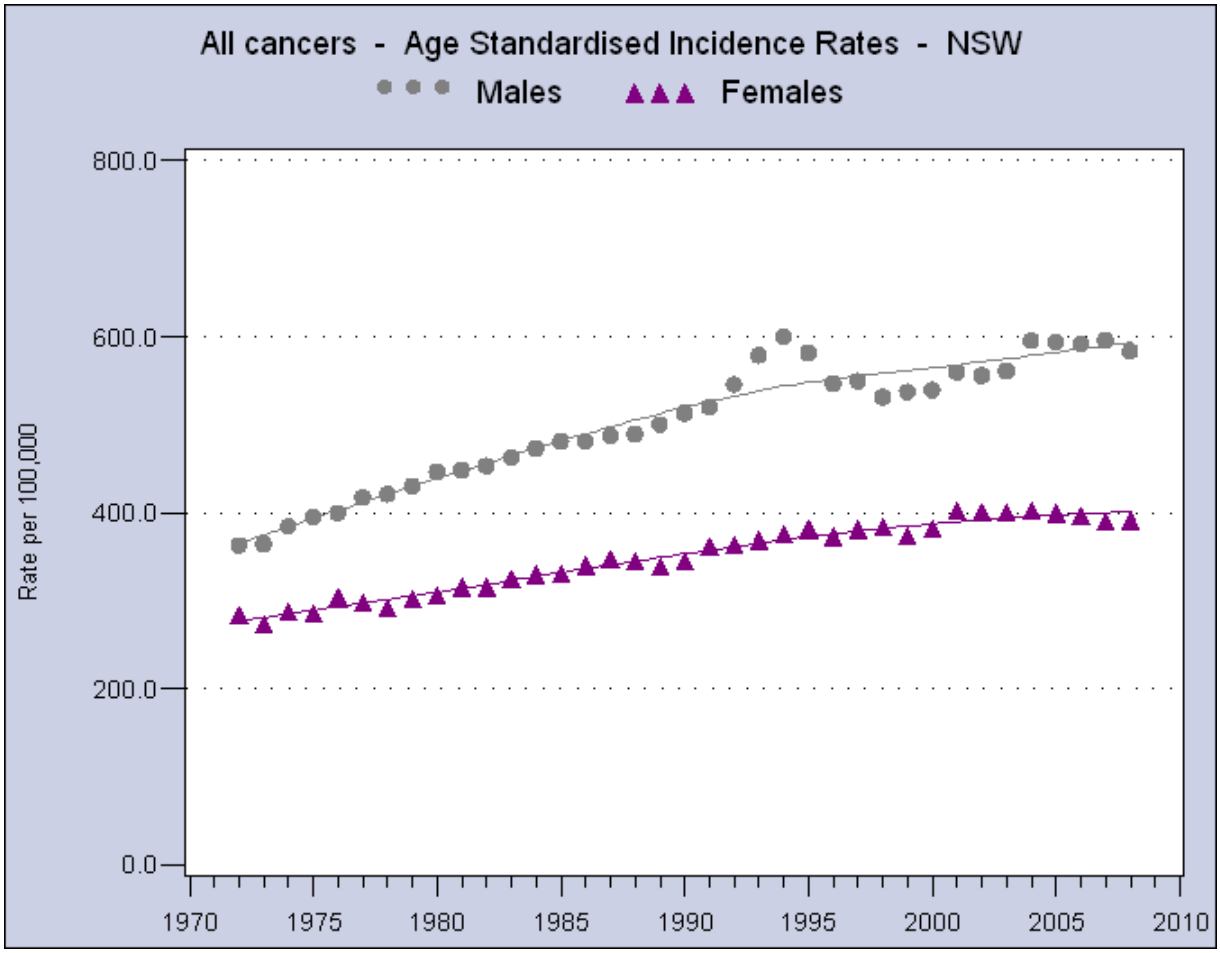
	Turrella and surrounds (CCD-defined)				NSW		99%CI	
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	12	25,240	47.54	46.62	65.54	0.71	0.38	1.34
1997	19	25,516	74.46	75.44	66.89	1.13	0.60	2.12
1998	23	25,777	89.23	88.55	67.05	1.32	0.71	2.46
1999	17	26,000	65.39	64.86	62.34	1.04	0.55	1.98
2000	12	26,152	45.89	46.11	62.92	0.73	0.39	1.39
2001	9	26,300	34.22	36.21	60.32	0.60	0.31	1.17
2002	21	26,091	80.49	88.23	58.06	1.52	0.76	3.04
2003	20	26,223	76.27	87.08	56.63	1.54	0.75	3.16
2004	21	26,145	80.32	89.27	62.12	1.44	0.73	2.83
2005	18	26,274	68.51	73.62	57.12	1.29	0.64	2.60
2006	23	26,719	86.08	87.77	58.77	1.49	0.78	2.88
2007	20	27,029	73.99	73.77	58.18	1.27	0.66	2.43

Table 9: Incidence rates for Turrella and surrounds (CCD-defined) compared with NSW, Females, lung cancer, 1996-2007

	Turrella and surrounds (CCD-defined)				NSW		99%CI	
Year	Events	Population	Crude rate per 100,000	Direct Std Rate per 100,000	Direct Std Rate per 100,000	Rate Ratio	Lower	Upper
1996	2	25,967	7.70	5.71	25.01	0.23	0.10	0.52
1997	5	26,199	19.09	18.91	26.40	0.72	0.27	1.91
1998	7	26,429	26.49	23.71	25.43	0.93	0.36	2.40
1999	7	26,640	26.28	25.08	24.86	1.01	0.38	2.70
2000	4	26,808	14.92	12.75	27.25	0.47	0.20	1.12
2001	3	26,964	11.13	10.39	26.33	0.39	0.16	0.98
2002	7	26,885	26.04	23.78	27.64	0.86	0.35	2.14
2003	7	27,033	25.89	23.63	27.36	0.86	0.35	2.16
2004	8	27,015	29.61	27.11	28.86	0.94	0.39	2.29
2005	11	26,978	40.77	35.89	31.30	1.15	0.50	2.65
2006	7	27,054	25.87	23.44	30.87	0.76	0.32	1.79
2007	4	27,291	14.66	14.18	31.06	0.46	0.19	1.08

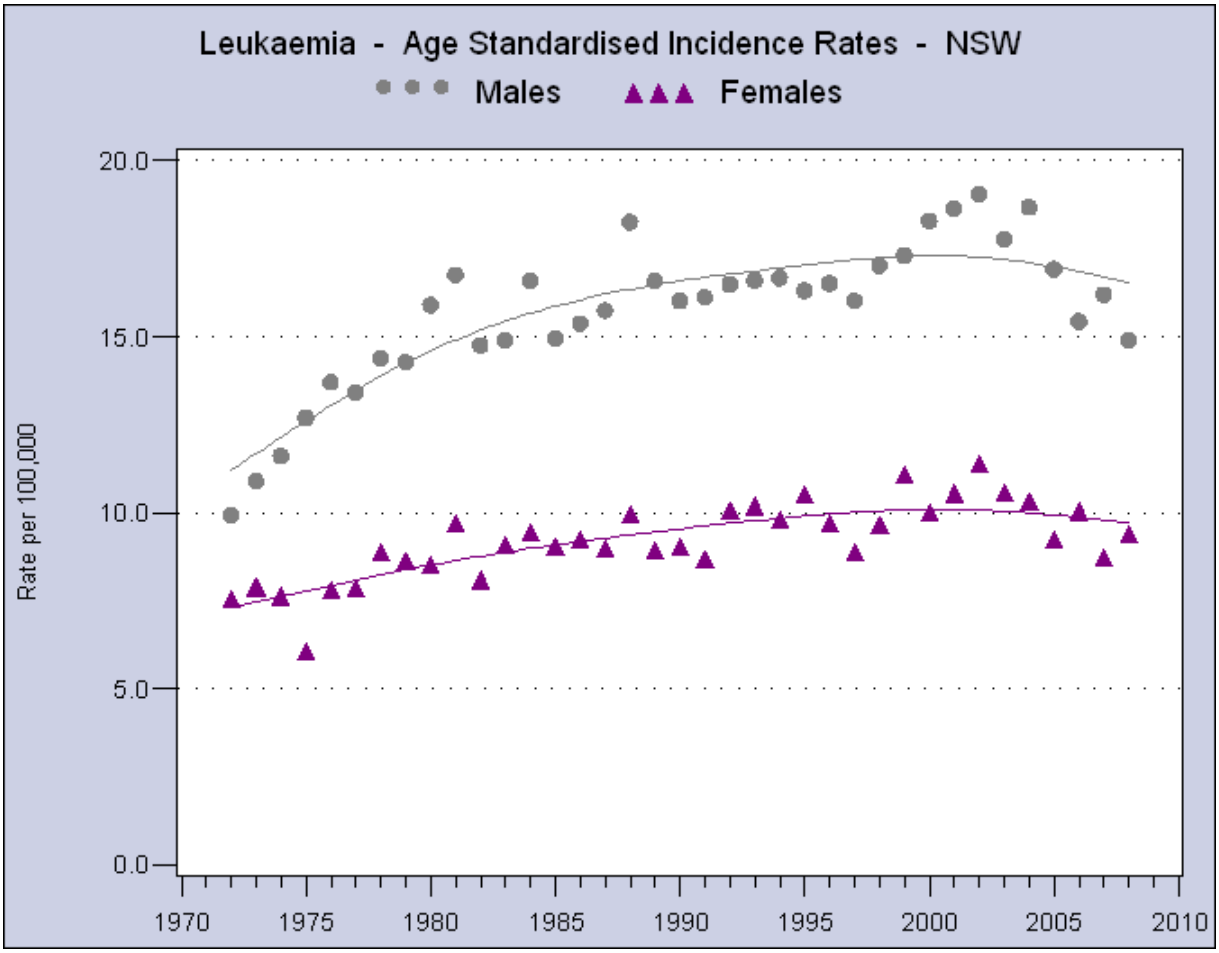
Appendix 4: Cancer registry incidence graphs

Figure 1: Age standardised incidence rates, all cancers by gender, NSW, 1970-2010



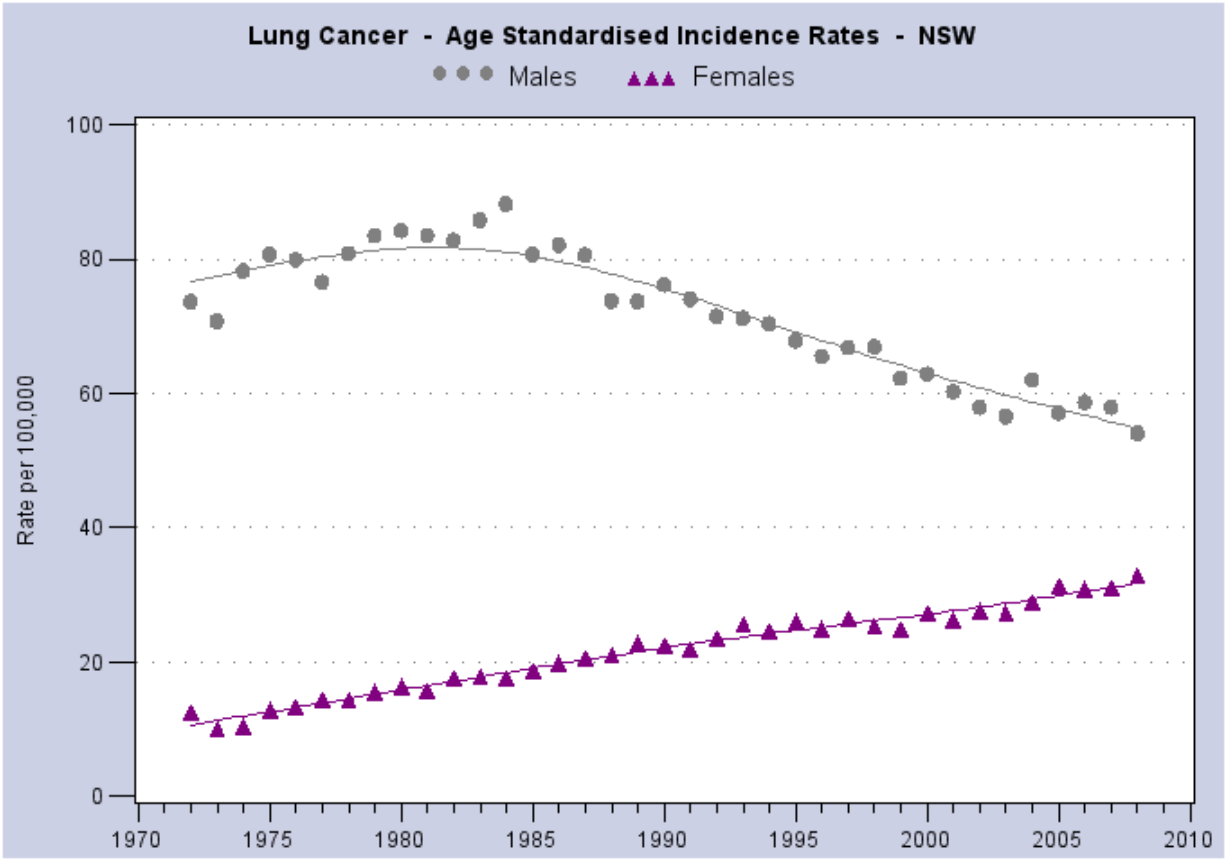
Source: NSW cancer registry
http://www.statistics.cancerinstitute.org.au/prodout/trends/trends_incid_All_extall_NSW.htm

Figure 2: Age standardised incidence rates, leukaemia by gender, NSW, 1970-2010



Source: NSW cancer registry
http://www.statistics.cancerinstitute.org.au/prodout/trends/trends_incid_All_extall_NSW.htm

Figure 3: Age standardised incidence rates, lung cancer by gender, NSW, 1970-2010



Source: NSW cancer registry
http://www.statistics.cancerinstitute.org.au/prodout/trends/trends_incid_C334_extall_NSW.htm