Evaluation of an Air Quality Screening Assessment Tool

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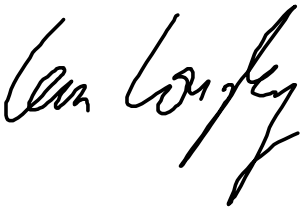

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Executive summary

We have carried out a preliminary evaluation of an air quality assessment screening tool supplied by the New Zealand Transport Authority (NZTA). The tool is web-based (http://uat.air.nzta.egressive.com/tier1) and has been designed to assess the air quality risk associated with any new road project. It is intended to be used for the *Social and Environmental Screen* (SES) phase of a road building project.

The objective of this project is to assess whether the air quality effects predicted by the tool are conservative and if so estimate by approximately how much.

The initial assessment and comparison was limited to data modelled for and monitored at two roading projects: the Northern Arterial and Queen Elizabeth II Drive in Christchurch and the Manukau Harbour Crossing in Auckland. Two additional projects have been included: the Transmission Gully in Wellington and the Cambridge Expressway in Waikato. Results from comparison of all four projects have been revised as understanding about the Tool's operation has developed throughout the comparison exercise.

For the purpose of this initial trial validation we have taken a rudimentary approach to identifying what the background and roadway contributions are to the total concentrations monitored. Because the monitoring was not undertaken explicitly for model evaluation, some of the assumptions necessary lead to uncertainties that are as large as or larger than the model results themselves. This method can be refined but it is unclear whether this would lead to more robust results without monitoring being carried out explicitly designed for model evaluation.

Subject to the caution noted on the method, the conclusions from the limited initial assessment and comparison made at these four sites are that the screening tool:

- Produces estimates for PM_{10} concentrations that compared to the Tier 3 modelling range are from a factor of seven higher down to approximately equal. I.e. the model is conservative in some cases and not in others
- Does not produce conservative estimates for NO_2 concentrations compared to Tier 3 modelling, on site real-time or passive monitoring data.

And that;

- Conclusions cannot be drawn regarding estimates for PM_{10} concentrations compared to on site monitoring data, due to insufficient sensitivity of monitoring data and large uncertainties in background concentrations relative to the magnitude of the screening tool estimate.

Because various "conservative" assumptions have to be made to prepare the monitoring data for comparison with the model output it is impossible to tell whether any apparent conservatism in the model is due to the model itself or the conservatism of the underlying assumptions.

1 Introduction

We have carried out a preliminary evaluation of an air quality assessment screening tool supplied by NZTA. The tool is web-based (http://uat.air.nzta.egressive.com/tier1) and has been designed to assess the air quality risk associated with a road project for the Social and Environmental Screen (SES).

The tool is based on the method outlined in Appendix 1 of the MfE Good Practice Guide for Assessing Discharges to Air from Land Transport (2008), which is intended to provide a conservative prediction of air quality effects. The tool assesses PM_{10}, NO_2, and $PM_{2.5}$ concentrations resulting from the project and compares them with threshold levels at the nearest sensitive receptor.

The objective of this project is to assess whether the air quality effects predicted by the tool are conservative and if so estimate by approximately how much.

The initial evaluation consisted of carrying out screening assessments for two roading projects for which full "Tier 3" assessments have been previously carried out and comparing results. A "good" screening tool should be sufficiently and reliably conservative compared to such assessments in order to have confidence in its use for decision making. We also compared the results to monitoring data collected at the sites of the two Tier 3 assessments and nearby passive monitoring of NO_2. After consultation with NZTA, comparisons were made for two further roading projects: the Cambridge section of the Waikato Expressway and Transmission Gully in Wellington. In addition the NO_2 results of the Tier 3 assessments for the Waikato Expressway and Christchurch's Northern Arterial were compared with output from NIWA's Regresson model.

The evaluation comprised four tasks:

Task 1: Use the screening tool to undertake Screening Assessment for four projects:

- Christchurch's Northern Arterial and Queen Elizabeth II Drive (NArt)
- Auckland's Manukau Harbour Crossing (MHX)
- Waikato Expressway – Cambridge Section (WECam)
- Wellington's Transmission Gully

Task 2: Compare the outputs from the screening tool with the detailed modelling presented in the four air quality assessments reports.

Task 2a. Compare NIWA Regression model with Tier 3 modelling

Task 3: Compare the outputs from the screening tool with the onsite real-time air quality monitoring results presented in the NArt and MHX assessment reports.

Task 4: Compare the outputs from the screening tool with the onsite passive NO_2 data presented in the Christchurch and Auckland air quality assessments or other NZTA reports.

2 Methods

2.1 Data requirements and Comparisons undertaken

Table 1 lists the four tools that will be used to undertake this study. Table 1 also details the data required to run these tools and the respective sources of each data type.

Table 1: Tools and data used to undertake this study. (AADT = Annual Average Daily Traffic)

Tool	Data required	Data Source
NZTA Tier 2 Screening Tool	AADT	Tier 3 assessment report for nominated study areas and from the NZTA State Highway Traffic Data Booklet or other sources within NZTA.
	% heavy vehicles	
	Average vehicle speed	
	Location of receptor	
NIWA NO_2 Regression Model	AADT	Tier 3 assessment report for nominated study areas and from the NZTA State Highway Traffic Data Booklet or other sources within NZTA
	Location of receptor	
Tier 3 Modelling	24-hour average concentrations of PM_{10} and $PM_{2.5}$ at nominated receptors	Tier 3 assessment report or modelling files for nominated study areas
On-site real-time air quality monitoring	24-hour average of PM_{10} and (if available) $PM_{2.5}$	Air quality monitoring data files for nominated study areas
On-site passive data	Annual average concentrations of NO_2	NZTA data air quality monitoring data base

Table 2 details the comparisons that will be undertaken to execute the evaluation study.

Table 2: Comparisons undertaken for the evaluation

Base data	Comparison data source	Comparison data variables
Screening Tool	Tier 3 Modelling	24-hour average concentrations of PM_{10} and $PM_{2.5}$
	On-site real-time air quality monitoring	24-hour average of PM_{10} and (if available) $PM_{2.5}$ and annual average NO_2
	On-site passive data	Annual average concentrations of NO_2
Tier 3 Modelling	NIWA NO_2 regression model	Annual average NO_2

The output of the screening tool will be compared to the relevant values from the Tier 3 modelling and from the on-site air quality monitoring.

It must be noted that the comparison between the screening model PM_{10} and $PM_{2.5}$ predicted concentrations and on-site real-time air quality monitoring will be problematic. This is because the screening model only predicts the effects of vehicle emissions, while the real-time monitoring data is a result of the cumulative effects from all sources in the area. Teasing

out the influence of vehicles from total PM_{10} monitoring will be a non-trivial task and may not produce definitive results. Because the monitoring was not undertaken explicitly for model evaluation, some of the assumptions necessary lead to uncertainties that are as large as or larger than the model results themselves. This method can be refined but it is unclear whether this would lead to more robust results without conducting monitoring explicitly designed for model evaluation.

2.2 Input for the Screening Tool

2.2.1 Northern Arterial (NArt) and Queen Elizabeth Drive project (QEII) – Christchurch

Figures 1, 2 and 3 show the sections of the Northern Arterial (NArt) and Queen Elizabeth Drive (QEII) roading project which are relevant to the Tier 2 evaluation study. Figure1 shows QE II Drive and the location of the ambient air quality monitoring station. Figure 2 shows the proposed location of the NArt in relation to Owen Mitchell Park. Figure 3 shows the Main North Road (SH74) in relation to St. Bedes College.

Figure 1: Map showing QE II Drive and the location of ambient air quality monitoring station.

Figure 2: Map showing the proposed location of the NArt in relation to Owen Mitchell Park.

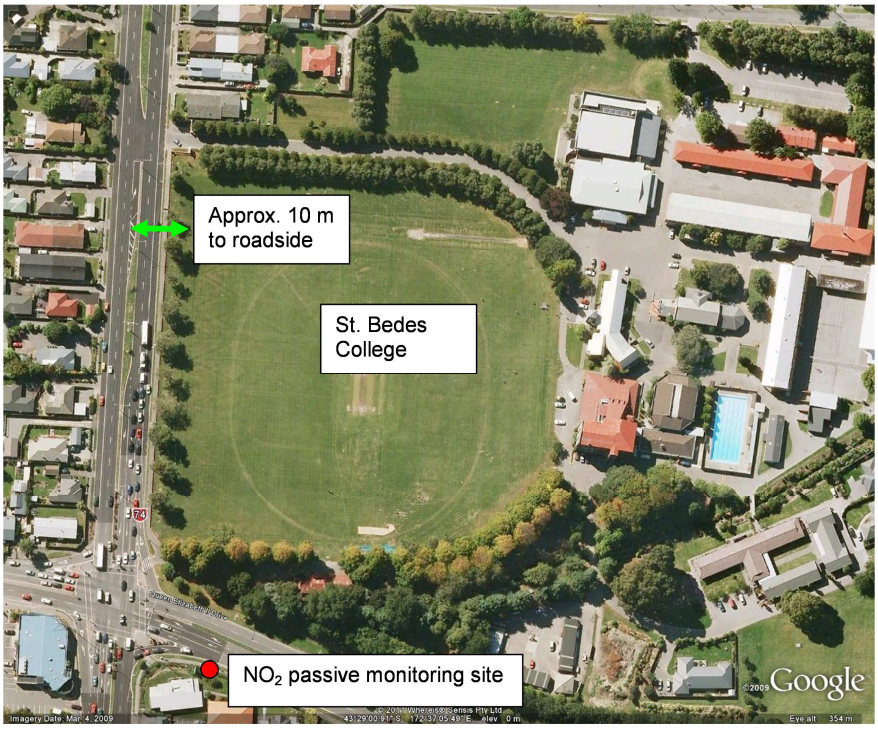

Figure 3: Map showing the Main North Road (SH74) in relation to St. Bedes College and NZTA's NO_2 passive monitoring site.

Table 3: Input for the online Screening Tool for NArt and QEII.

Link Name	AADT	%HV	Speed (km/hr)	Receptor (m from roadside)	Sensitive Receptor (m from roadside)
QE2	28,600	8	80	50	50
Main Nth Rd	34,200	8	60	10	10
NArt	34100	8	80	15	15

Table 3 shows the input for the screening tool for the Christchurch example. The AADT for the QE2 and Main Nth Rd are taken from the baseline 2006 data. AADT for NArt is taken from the 2016 projection, as the road currently doesn't exist.

2.2.2 Manukau Harbour Crossing – Auckland (MHX)

Three links were chosen from the MHX project, all along State Highway 20. Inputs for the Tool were taken from the Tier 3 assessment report (Coulson & Olivares, 2007). Sensitive receptors were named in Table A2.1. The distance of receptors from the road were estimated using Google Earth and are shown below in Figures 4-6.

Figure 4: Link 2 with sensitive receptor: Onehunga Bay Reserve.

Figure 5: Link 4 with sensitive receptor: Te Puea Marae.

Figure 6: Link 6 with sensitive receptor: Robertson rd. School.

Table 4: Inputs for the online Assessment Tool for sensitivity to speed runs.

Link Name	AADT	%HV	Speed	Receptor	Sens.Receptor
2: SH20	73050	5	?	40	40
4:SH20	68860	5	?	50	50
6: SH20	35160	5	?	30	30

No specific speed information was given in the Evidence document as the assessment modelling used NZTER which only required inputs of congestion, flow and cold starts. Thus a series of scenarios was run through the tool, varying the speed of the three links. 30km/hr, 50km/hr, 80km/hr and 99km/hr were used. (The tool does not accept 3 digit integers as speed input.) Comparisons were made with the output for 80km/hr. (N.B. These scenarios used different distances to sensitive receptors than the runs for comparison with Tier 3 assessments.) Table 4 shows the inputs for the screening tool for the Manukau example.

2.2.3 Waikato Expressway – Cambridge section (WECam)

Figure 7 shows the proposed route of the Waikato Expressway Cambridge Section (WECam) and the location of the sensitive receptors that are in close proximity to this roadway development.

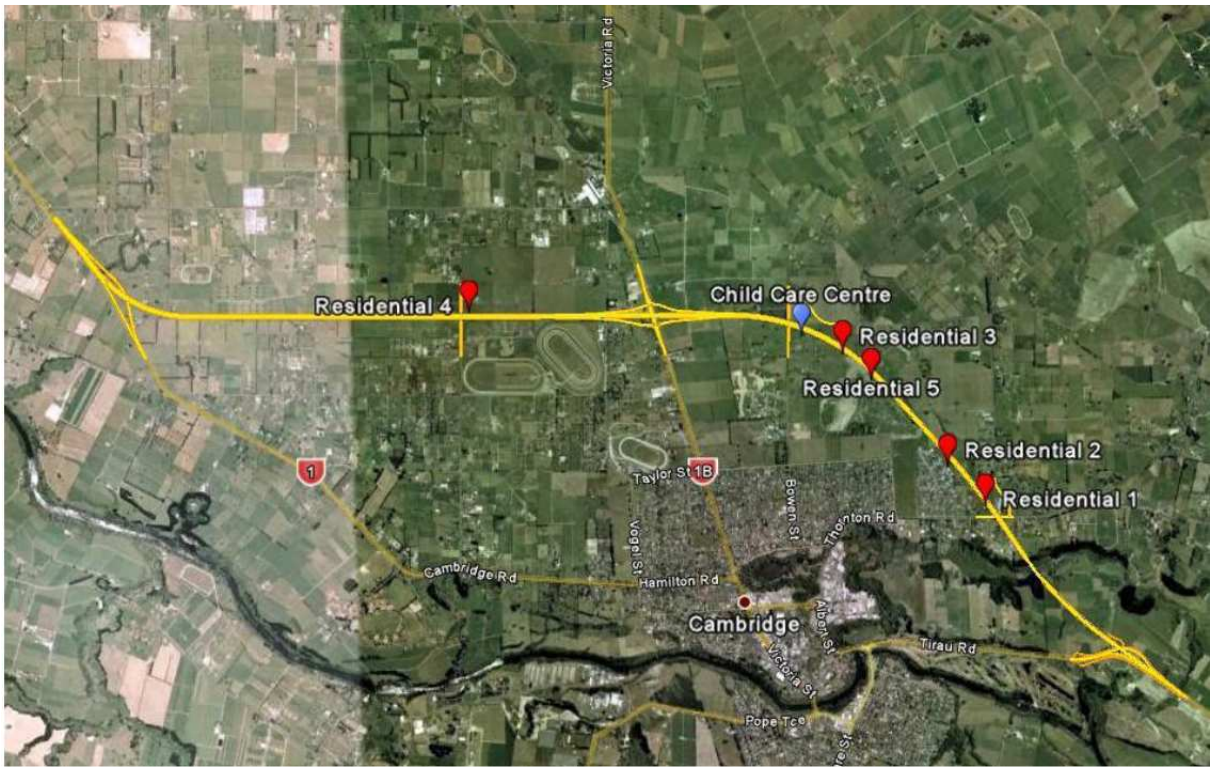

Figure 7: Proposed rout of the Waikato Expressway Cambridge Section (WECam) and the location of the sensitive receptors (SKM, 2010).

Two scenarios were chosen for comparison against the online assessment tool: State Highway 1 - 2016 without project and Expressway 2016. Table 5 shows the scenario inputs used for the online assessment tool. The inputs were taken from Section 6.2 of the assessment report (SKM, 2010).

Table 5: Inputs for the online Assessment Tool.

Road Name and scenario	AADT	%HV	Speed (km/hr)	Receptor – distance from roadside (m)	Sens.Receptor
SH1 without project - 2016	23,900 (central Cambridge)	9.3	45	20	Max grid receptor
Expressway - 2016	16,400 (west of Victoria Rd)	9.3	80	15	Max grid receptor

2.2.4 Transmission Gully – Wellington

Figure 8 shows the main alignment sections of for proposed route of the Transmission Gully project. Note north is to the left of the page.

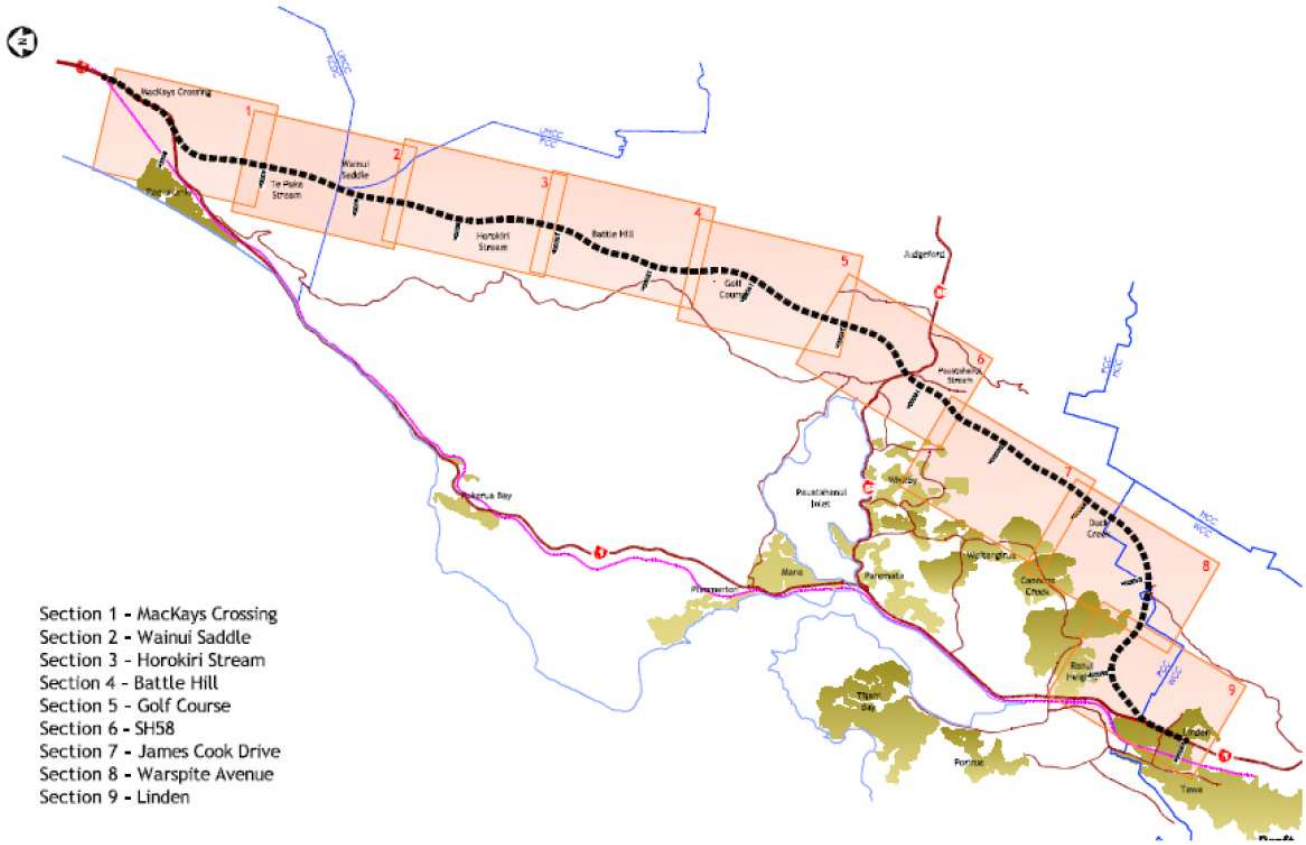

Figure 8: Main alignment sections of for proposed route of the Transmission Gully project (Beca, 2010).

Figure 9 shows details of the Linden motorway section of the Transmission Gully project, where the highest pollutant concentrations are predicted to occur. The sensitive receptors where the highest concentrations are predicted to occur are labelled R5 (Linden School Sports ground) and R6 (Linden School).

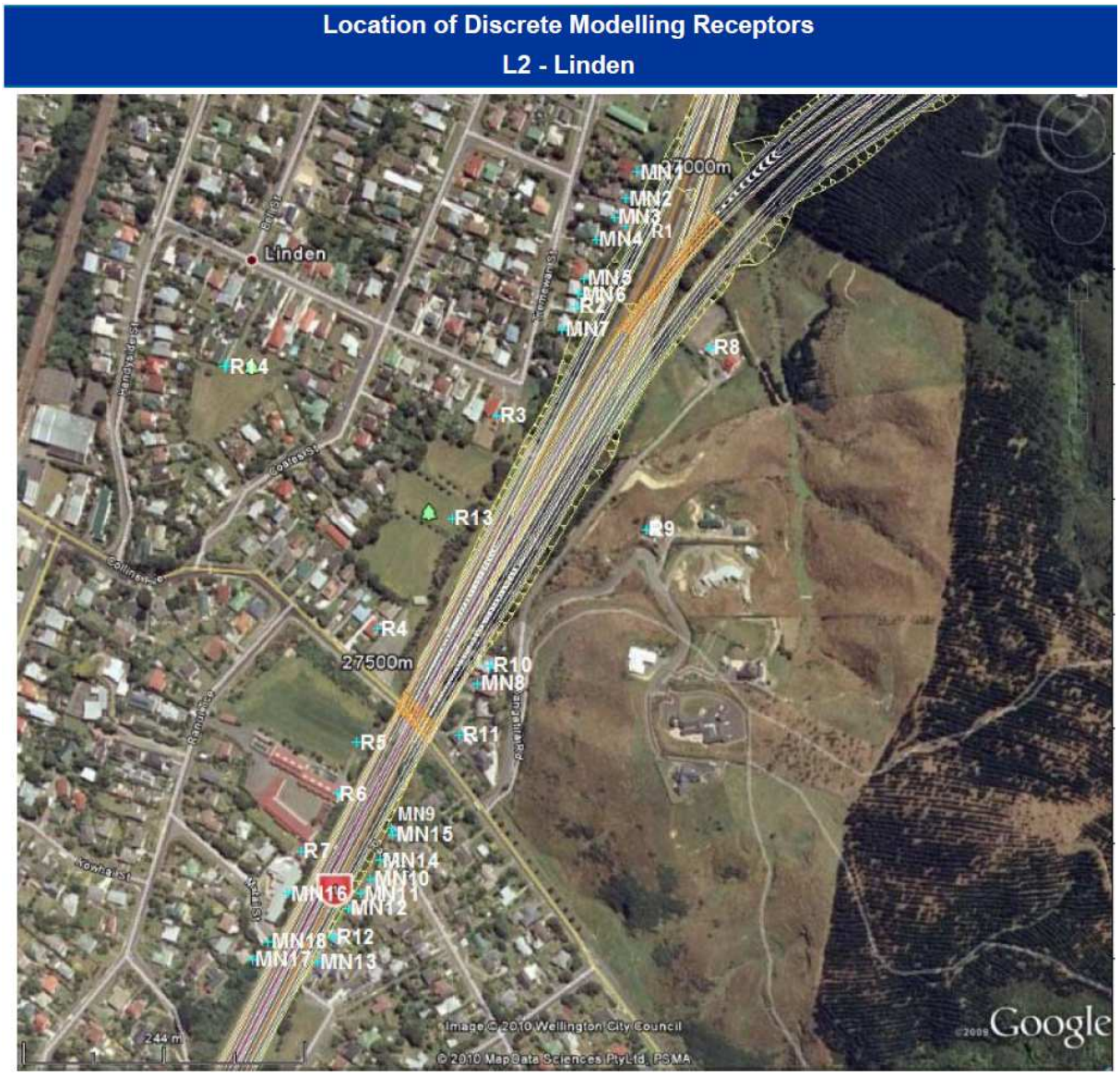

Figure 9: Linden motorway section (9) of the Transmission Gully project.

Two scenarios were chosen for comparison against the online assessment tool; 2006 and 2031 with project. Table 6 shows the scenario inputs used for the online assessment tool.

Table 6: Inputs for the online Assessment Tool.

Road Name and scenario	AADT	%HV	Speed (km/hr)	Receptor – distance from roadside (m)	Sens.Receptor
SH1 baseline year - 2006	43,900	7.2	80 (assumed)	10	R6 - Linden School
SH1 with development - 2031	65,600	7.2	80 (assumed)	10	R6 - Linden School

3 Output from the Screening Tool

Figure 10 shows a screen grab of the screening tool output for the Christchurch example. Table 7 shows the same output.

3.1.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

Link	Link Name	Air Quality Link Risk	24hr avg PM_{10} ($\mu g/m^3$)	Exceeds PM_{10} significance criteria?	24hr avg $PM_{2.5}$ ($\mu g/m^3$)	Exceeds $PM_{2.5}$ significance criteria?	Avg annual NO_2 ($\mu g/m^3$)	Exceeds NO_2 significance criteria?
1	QE2	Medium	0.9	No	0.7	No	0.9	No
2	Main Nth Rd	High	2.2	No	1.7	Yes	1.0	No
3	NA	High	2.8	Yes	2.3	Yes	1.3	No

Figure 10: Example of online output from the Screening Tool.

Table 7: Output from the Screening Tool for the Christchurch example.

	QE2	Main Nth Rd	NArt
PM_{10} (24-hour av) μgm^{-3}	1.2	2.9	2.3
$PM_{2.5}$ (24-hour av) μgm^{-3}	1.0	2.4	1.8
NO_2 (Annual av) μgm^{-3}	1.5	1.8	1.0

3.1.2 Manukau Harbour Crossing – Auckland (MHX)

Table 8: Output from the Screening Tool for Manukau Harbour Crossing for sensitivity to speed scenarios.

	Speed	30	50	80	99
PM_{10} (24-hour av) / $\mu g\ m^{-3}$	Link 2	4.4	3.4	3.3	3.9
	Link 4	**3.3**	**2.6**	**2.5**	**3**
	Link 6	2.7	2.1	2	2.4
$PM_{2.5}$ (24-hour av) / $\mu g\ m^{-3}$	Link 2	3.6	2.7	2.5	3.2
	Link 4	**2.7**	**2**	**1.9**	**2.4**
	Link 6	2.3	1.7	1.6	2
NO_2 (Annual av) / $\mu g\ m^{-3}$	Link 2	2.2	2.1	2.2	2.7
	Link 4	**2.1**	**2**	**2.1**	**2.6**
	Link 6	1.1	1	1.1	1.3

Table 8 shows the output for the four scenarios with different speeds. Link four is in bold and represents the position of the project's monitoring station. As expected the road emissions are linked with vehicle speed and show a minimum around 80 km/hr. It is expected the speed used would be just under 80 km/hr; the legal limit for the road reduced for the effects of peak congestion. Table 9 shows the output for the scenarios run for comparison with the Tier 3 assessment. No comparison could be made for average NO_2 concentrations as these were not produced for the MHX assessment.

Table 9: Output from the Screening Tool for the Manukau Harbour Crossing example.

	Link 2		Link 4		Link 6	
	2013	2021	2013	2021	2013	2021
PM_{10} (24-hour av) μgm^{-3}	9.4	7.3	3.8	3.0	4.6	3.6
$PM_{2.5}$ (24-hour av) μgm^{-3}	9.2	5.1	3.7	2.1	4.5	2.5

3.1.3 Waikato Expressway – Cambridge Section (WECam)

Table 10 shows the output of the Waikato example.

Table 10: Output from the Screening Tool for the Cambridge example.

	SH1 without project - 2016	Expressway – 2016
PM_{10} (24-hour av) μgm^{-3}	2.1	1.6
$PM_{2.5}$ (24-hour av) μgm^{-3}	1.7	1.1
NO_2 (Annual av) μgm^{-3}	0.7	0.5

3.1.4 Transmission Gully – Wellington

Table 11 shows the output of the Wellington example.

Table 11: Output from the Screening Tool for the Transmission Gully example.

	SH1 baseline year - 2006	SH1 with development - 2031
PM_{10} (24-hour av) μgm^{-3}	6.9	5.4
$PM_{2.5}$ (24-hour av) μgm^{-3}	5.7	3.7
NO_2 (Annual av) μgm^{-3}	2.2	1.0

4 Comparison of screening tool and Tier 3 Model Predictions

4.1 PM_{10}

4.1.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

Table 12 shows the comparison between the screening tool and model output from the Tier 3 Assessment. The output taken from the Tier 3 Assessment is an average of receptors relevant to the site and distance from the sensitive receptor specified in the screening tool. For the QEII link model output is an average of two receptors, for Main Nth Rd an average of five and NArt an average of three.

Table 12: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Christchurch.

	QEII	Main Nth Rd	NArt
screening tool PM_{10} (24-hour av) μgm^{-3}	1.2	2.9	2.3
Tier 3 modelling PM_{10} (24-hour av) μgm^{-3}	0.275	0.406	0.390
Most conservative estimation	Screening tool	Screening tool	Screening tool
Ratio: Screening tool to Tier 3 modelling	4.4	7.1	5.9

Conclusion: the screening tool produces PM_{10} results with a large degree of conservatism compared to Tier 3 modelling for this project.

4.1.2 Manukau Harbour Crossing – Auckland (MHX)

No baseline modelling was published for the Manukau Harbour Crossing project, so inputs were taken from the projected 2013 and 2021 do minimum scenarios and comparisons made with the Tier 3 Assessment's model output at 10m from the roadside (Roadside) and at sensitive receptors. Table 13 shows the comparison for the Manukau example.

Table 13: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Auckland.

PM10 (μgm^{-3})	Link 2		Link 4		Link 6	
	2013	2021	2013	2021	2013	2021
screening tool PM_{10} (24-hour av) μgm^{-3}	9.4	7.3	3.8	3.0	4.6	3.6
Tier 3 modelling PM_{10} (24-hour av) μgm^{-3}	8	12	15	13	6	5
Most conservative estimation	Screening tool	Tier 3 modelling	Tier 3 modelling	Tier 3 modelling	Tier 3 modelling	Tier 3 modelling
Ratio: Screening tool to Tier 3 modelling	1.2	0.6	0.3	0.2	0.8	0.7

Results for this project show an average difference of -5.0 μgm^{-3} with a range of -11.2 to 1.3.

Conclusion: The screening tool does not produce conservative PM_{10} results compared to Tier 3 modelling for this project, in contrast to the Christchurch project. The variation of differences between the two model outputs for MHX is as large as the models' output itself.

4.1.3 Waikato Expressway – Cambridge Section (WECam)

Table 14 shows the comparison for the Waikato example.

Table 14: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Cambridge.

	SH1 without project - 2016	Expressway - 2016
screening tool PM_{10} (24-hour av) μgm^{-3}	2.1	1.6
Tier 3 modelling PM_{10} (24-hour av) μgm^{-3}	2.1	1.6
Most conservative estimation	Equal	Equal
Ratio: Screening tool to Tier 3 modelling	1	1

Conclusion: the screening tool produces results comparable to the Tier 3 modelling for this project. The results are not conservative compared to the Tier 3 modelling.

4.1.4 Transmission Gully – Wellington

Table 15 shows the comparison for the Wellington example.

Table 15: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Wellington.

	SH1 baseline year - 2006	SH1 with development - 2031
screening tool PM_{10} (24-hour av) μgm^{-3}	6.5	5.4
Tier 3 modelling PM_{10} (24-hour av) μgm^{-3}	3.8	2.8
Most conservative estimation	Screening Tool	Screening Tool
Ratio: Screening tool to Tier 3 modelling	1.7	1.9

Conclusion: the screening tool produces results that are slightly conservative compared with the Tier 3 modelling for this project.

4.2 $PM_{2.5}$

4.2.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

As mentioned in the NArt Report $PM_{2.5}$ was estimated to be 0.912 of PM_{10}, calculated from the ratio of each reported in the 2006 ECan monitoring report. Table 16 shows the comparison for the Christchurch example for $PM_{2.5}$.

Table 16: Comparison of Screening Tool and Tier 3 Assessment modelling outputs.

	QEII	Main Nth Rd	NArt
screening tool $PM_{2.5}$ (24-hour av) μgm^{-3}	1.0	2.4	1.8
Tier 3 modelling $PM_{2.5}$ (24-hour av) μgm^{-3}	0.251	0.370	0.356
Most conservative estimation	Screening tool	Screening tool	Screening tool
Ratio: Screening tool to Tier 3 modelling	4.0	6.5	5.1

Conclusion: The screening tool produces conservative $PM_{2.5}$ results compared to Tier 3 modelling.

4.2.2 Manukau Harbour Crossing – Auckland (MHX)

No modelling or monitoring of $PM_{2.5}$ exists and a -$PM_{2.5}$:PM_{10} relationship will be dependent on local sources, so the relationship derived from Christchurch data may not be appropriate for Auckland conditions.

Table 17 shows the Manukau data scaled accordingly. If a ratio of 0.912 is used on the 24 hr-mean PM_{10} concentration of 1.91μgm^{-3} from the Tier 3 Assessment, then the 'model output' for $PM_{2.5}$ is 1.74 μgm^{-3}. Compared with this the Tool gives a conservative predicted concentration.

Table 17: Comparison of Screening Tool with Tier 3 'modelled' $PM_{2.5}$ outputs.

$PM_{2.5}$ (µg m-3)	Screening Tool	Tier 3 Assessment	Difference (Screening Tool – Assessment
MHX Link 2 2013 Receptor	9.2	7	2.2
MHX Link 2 2021 Receptor	5.1	11	-5.9
MHX Link 4 2013 Receptor	3.7	14	-10.3
MHX Link 4 2021 Receptor	2.1	12	-9.9
MHX Link 6 2013 Receptor	4.5	5	-0.5
MHX Link 6 2021 Receptor	2.5	5	-2.5

Results for this project show an average difference of -5.2 μgm^{-3} with a range of -10.3 to 2.2.

Conclusion: The screening tool does not produce conservative $PM_{2.5}$ results compared to Tier 3 modelling for this project. The variation of differences between the two model outputs for MHX is as large as the models' output itself.

4.2.3 Waikato Expressway – Cambridge Section (WECam)

The prediction of $PM_{2.5}$ concentrations was not undertaken for the WECam study.

4.2.4 Transmission Gully – Wellington

The assessment report for the Transmission Gully project states that $PM_{2.5}$ concentrations were calculated as 0.6 of the modelled PM_{10} concentrations. This ratio is much lower than that used for the Christchurch Northern Arterial project. Table 18 shows the comparison.

Table 18: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Wellington.

	SH1 baseline year - 2006	SH1 with development - 2031
screening tool PM_{10} (24-hour av) μgm^{-3}	5.7	3.7
Tier 3 modelling PM_{10} (24-hour av) μgm^{-3}	2.3	1.7
Most conservative estimation	Screening tool	Screening tool
Ratio: Screening tool to Tier 3 modelling	2.5	2.2

Conclusion: the screening tool produces results that are higher than the Tier 3 modelling for both the 2006 baseline scenario and 2031 with development scenario. These results suggest that the screening tool results are conservative compared with the Tier 3 modelling for this project.

4.3 NO_2

4.3.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

For the NArt Tier 3 Assessment only NO_x was modelled and NO_2 was calculated in the following manner:

> *"Estimation of nitrogen dioxide concentrations from the modelled NOx output has followed the guidelines found in the Good Practice Guide for Assessing Discharges to Air from Land Transport (MfE, 2008), which recommends using a primary NO_2 factor of 0.1 and then converting 0.2 of the NO concentration to NO_2, to account for conversion once emitted"*

Table 19 shows the comparison.

Table 19: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Christchurch

	QEII	Main Nth Rd	NArt
screening tool NO_2 (annual average) μgm^{-3}	1.5	1.6	1.0
Tier 3 modelling NO_x (annual average) μgm^{-}	5.5	7.5	5.7
Tier 3 modelling NO_2 (annual average) μgm^{-3}	1.5	2.1	1.6
Most conservative estimation of NO_2	Equal	Tier 3 modelling	Tier 3 modelling
Ratio: Screening tool to Tier 3 NO_2 modelling	1.0	0.8	0.6

Conclusion: The screening tool does not produce conservative NO_2 results compared to Tier 3 modelling.

4.3.2 Manukau Harbour Crossing – Auckland (MHX)

At the time of the AEE, only 1hr averages of NO_2 were required and so all that is presented in the Evidence is the 99.9th% concentration over that averaging period, which is unsuitable by itself for comparison.

4.3.3 Waikato Expressway – Cambridge Section (WECam)

Table 20 shows the NO_2 comparison for the Waikato example.

Table 20: Comparison of Screening Tool and Tier 3 Assessment modelling outputs - Cambridge.

	SH1 without project - 2016	Expressway - 2016
screening tool NO_2 (annual av) μgm^{-3}	0.7	0.5
Tier 3 modelling NO_2 (annual av) μgm^{-3}	0.9	1.5
Most conservative estimation	Tier 3 modelling	Tier 3 modelling
Ratio: Screening tool to Tier 3 modelling	0.78	0.33

Conclusion: the screening tool does not produce conservative NO_2 results compared to Tier 3 modelling.

4.3.4 Transmission Gully – Wellington

The prediction of annual average NO_2 concentrations was not undertaken for the Transmission Gully study.

5 Comparison of Tier 3 and NIWA regression model predictions of annual average NO_2

NIWA has proposed an alternative method of predicting annual average NO_2 concentrations. Very briefly the NIWA model uses a regression approach to model urban NO_2 concentrations based on passive monitoring data. The background to and details of the model are provided in a memo sent by Ian Longley to NZTA on 22 July 2011.

The formula of the NIWA NO_2 regression model is:

Additional NO_2 = 0.00077 * AADT * shortest distance from road centreline to receptor$^{-0.65}$

It should be noted that this regression model is designed to provide accurate estimates of the mean annual average NO_2 concentration. It is not designed to be conservative. Tables 21 and 22 show the comparisons with the Christchurch and Waikato examples.

Table 21: Comparison of NIWA NO_2 regression model and Tier 3 assessment modelling outputs - Christchurch.

	QEII	Main Nth Rd	NArt
NIWA model NO_2 (annual average) μgm^{-3}	1.5	3.8	3.2
Tier 3 modelling NO_2 (annual average) μgm^{-3}	1.5	2.1	1.6
Most conservative estimation of NO_2	Equal	NIWA	NIWA
Ratio: Regression model to Tier 3 NO_2 modelling	1	1.8	2

Table 22: Comparison of NIWA NO_2 regression model and Tier 3 assessment modelling outputs - Cambridge.

	SH1 without project - 2016	Expressway - 2016
NIWA model NO_2 (annual average) μgm^{-3}	2.3	1.8
Tier 3 modelling NO_2 (annual av) μgm^{-3}	0.9	1.5
Most conservative estimation	NIWA	NIWA
Ratio: Regression model to Tier 3 modelling	2.6	1.2

Conclusion: The NIWA NO_2 regression model produces results comparable or more conservative than those produced by the Tier 3 modelling, by up to a factor of 2.6 for these two projects.

6 Comparison of Tier 2 Predictions with Monitored Concentrations

6.1 PM_{10}

6.1.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

Comparison with monitored data is only available for the QEII link. Table 23 gives the summary statistics for the monitoring site used for this comparison.

Table 23: Summary statistics for the 24-hour average concentrations PM_{10} recorded at the monitoring site 20 May to 31 August 2010 (from NArt report).

24-hour average period	PM_{10} (μgm^{-3})
Number of days of data	104
Maximum conc. $\mu g/m^3$	62.9
*Standard or guideline conc.	50
Num. of NES exceedances	3
Average conc. $\mu g/m^3$	**19.6**

NOTE of CAUTION: As explained in section 2.1, attempting to define background concentrations of PM_{10} leads to uncertainties that are as large as or larger than the model results themselves and no conclusions can be drawn from comparisons to monitoring data.

Estimating PM_{10} Background:
Approach 1: ECan 2006 states the contribution of motor vehicles to PM_{10} emissions is 11% on weekdays and 6% on weekends. If we take the conservative value of 100% of all days having a contribution from vehicles of 11% and assigning the whole of that contribution to Queen Elizabeth Drive, then the monitored contribution from vehicle activity is 2.2 μgm^{-3} for QEII.

Approach 2: Figure 11 shows the diurnal cycle of 1 hour average PM_{10} concentrations measured at the monitoring site.

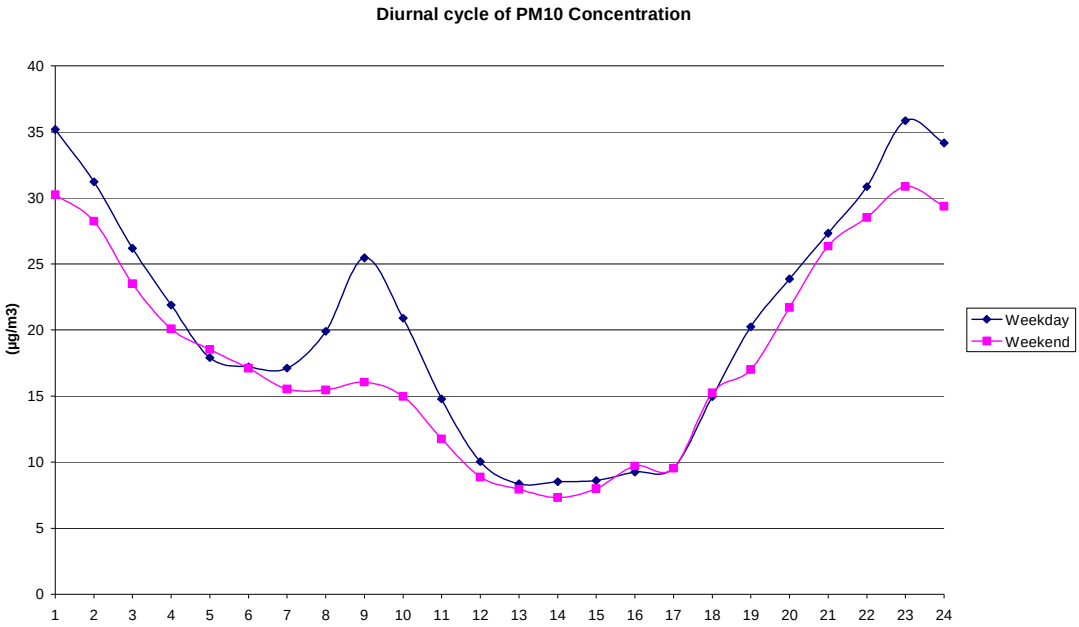

Figure 11: Diurnal cycle of PM_{10} concentrations measured at the NArt pre-development monitoring site.

The lowest diurnal concentrations are approximately 7µgm^{-3}, so this may be considered the maximum true background concentration. If this background concentration is subtracted from the total measured at the site that suggests approximately 13µg m^{-3} come from local sources. Assuming 11% of this is from vehicles on QEII then this suggests then the monitored contribution from vehicle activity is around 1.4 µg m^{-3} for QEII. Table 24 shows the comparisons.

Table 24: Comparison of Screening Tool output with Monitored Concentrations.

	PM_{10} (24-hour av) µgm^{-3}
screening tool	1.2
Monitored PM_{10}: approach one	2.2
Monitored PM_{10}: approach two	1.4
Most conservative estimate	Monitored PM_{10}: approach one
Ratio: Screening tool to Monitored PM_{10}	0.5 to 0.9

This comparison must be considered as very preliminary and treated with all due caution given the context of the limitations noted on the methods used to estimate background concentrations of PM_{10} at the site. The uncertainties involved in assigning background concentrations do not allow any definitive conclusions to be drawn.

6.1.2 Manukau Harbour Crossing – Auckland (MHX)

The 24hr-mean PM_{10} concentration from 26/10/06 to 4/1/08 was 14.62µgm^{-3} with a standard deviation of 6.15. This was relatively low when compared with annual averages from other Auckland sites as shown below in Table 25.

Table 25: 24hr Average PM_{10} measurements over Auckland measurements stations.

Location	Site type	Units	Maximum	Annual Average	Median	95th Percentile
Queen St	Traffic	µg/m³	44.2	19.2	n/a	n/a
Khyber Pass	Traffic	µg/m³	84.1	19.5	n/a	n/a
Penrose	Traffic /Industrial	µg/m³	56.3	19.3	18.7	32.7
Takapuna	Residential/ Traffic	µg/m³	51.5	16.9	16.3	27.3
Henderson	Residential	µg/m³	35.3	14.8	n/a	n/a
Mt Eden	Residential	µg/m³	33.4	12.8	12.5	21.0

Estimates of the background PM_{10} concentration are based on the diurnal cycle of concentrations found in the Evidence and shown below in Figure 12. The largest difference between background (13µgm^{-3}) and road contribution (17µgm^{-3}) occurs at 8am. At this point non-road sources represent ~ 76.5% of the total PM_{10} concentration. Therefore through the diurnal cycle 23.5% of total concentration is the largest contribution made by the road over the cycle. Applying this to the 24-hr mean gives 3.44 µg m^{-3} as a conservative maximum PM_{10} road concentration. This is in line with the estimates of the Tool for Link 4.

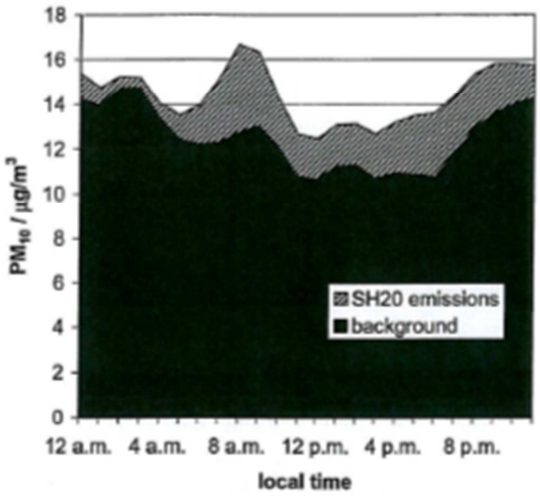

Figure 12: Contribution of PM_{10} from the road during the diurnal cycle.

Table 26 shows the comparison for Manukau example.

Table 26: Comparison of Screening Tool output with Monitored Concentrations.

	PM_{10} (24-hour av) μgm^{-3}
screening tool	3.2
Monitored PM_{10}:	3.44
Most conservative estimate	Monitored PM_{10}
Ratio: Screening tool to Monitored PM_{10}	0.9

This comparison again involves uncertainties too great to allow any definitive conclusions to be drawn on whether the tool estimates conservative concentrations, compared with measurements.

6.2 $PM_{2.5}$

Measurements of $PM_{2.5}$ were not available for either site and are derived from the PM_{10} concentrations used above. Considering the assumptions used to apportion $PM_{2.5}$ and the limitations on assigning background concentrations no conclusions can be drawn about the performance of the Screening Tool from the following comparisons.

6.2.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

No $PM_{2.5}$ monitoring was undertaken at the QEII air quality monitoring site. If the same $PM_{2.5}$:PM_{10} ratio of 0.912 is assumed, then the 'monitored' concentration of $PM_{2.5}$ is 17.88μgm^{-3}. Following the same two approaches in apportioning a background and roadway contributions to that concentration gives 1.97μgm^{-3} and 1.26μgm^{-3} respectively. (For the second approach 0.912 of the 7μgm^{-3} is removed from the total concentration as the maximum background.) Table 27 shows the resulting comparison.

Table 27: Comparison of Screening Tool output with Monitored Concentrations.

	$PM_{2.5}$ (24-hour av) μgm^{-3}
screening tool	1.0
Monitored $PM_{2.5}$: approach one	1.97
Monitored $PM_{2.5}$: approach two	1.26
Most conservative estimate	Monitored $PM_{2.5}$: approach one
Ratio: Screening tool to Monitored PM_{10}	0.5 to 0.8

6.2.2 Manukau Harbour Crossing – Auckland (MHX)

If the same ratio is used on the PM_{10} 24hr mean of 14.62 μgm^{-3} we get a $PM_{2.5}$ mean concentration of 13.33 μgm^{-3}. Assuming again that a maximum of 23.5% of this concentration is sourced from the road the $PM_{2.5}$ contribution is then **3.13μgm^{-3}**.
The Screening Tool uses $PM_{2.5}$:PM_{10} ratios which are much lower than 0.912. Table 28 shows the range seen in the sensitivity analysis of varying speeds and Table 29 shows the comparison with the monitored data.

Table 28: Ratio of $PM_{2.5}$ to PM_{10} from the Assessment Tool.

Tool's PM2.5/PM10 ratio	Speed	30	50	80	99
	Link 2	.81	.79	.75	.82
	Link 4	**.81**	**.77**	**.76**	**.8**
	Link 6	.85	.81	.80	.83

Table 29: Comparison of Screening Tool output with Monitored Concentrations.

	$PM_{2.5}$ (24-hour av) μgm^{-3}
screening tool	2.6
Monitored $PM_{2.5}$	3.13
Most conservative estimate	Monitored $PM_{2.5}$
Ratio: Screening tool to Monitored PM_{10}	0.8

6.3 NO_2 Continuous Monitoring

6.3.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

Comparison with monitored data is only available for the QEII link and is shown in Table 30.

Table 30: Summary statistics for the 24-hour average concentrations of NO2 recorded at the monitoring site 20 May to 31 August 2010.

24-hour average period	NO_2 (μgm^{-3})
Number of days of data	104
Maximum conc. $\mu g/m^3$	29.3
*Standard or guideline conc.	100
Num. of NES exceedances	0
Average conc. $\mu g/m^3$	**16.3**

NOTE of CAUTION: Attempting to define background concentrations of NO_2
It must be noted that the comparison between the screening model NO_2 predicted concentrations and on-site real-time air quality monitoring is problematic for the same reasons outlined for PM_{10}.

Estimating NO_2 Background:

Figure 13 shows the diurnal cycle of 1 hour average NO_2 and traffic counts at the monitoring site during weekdays.

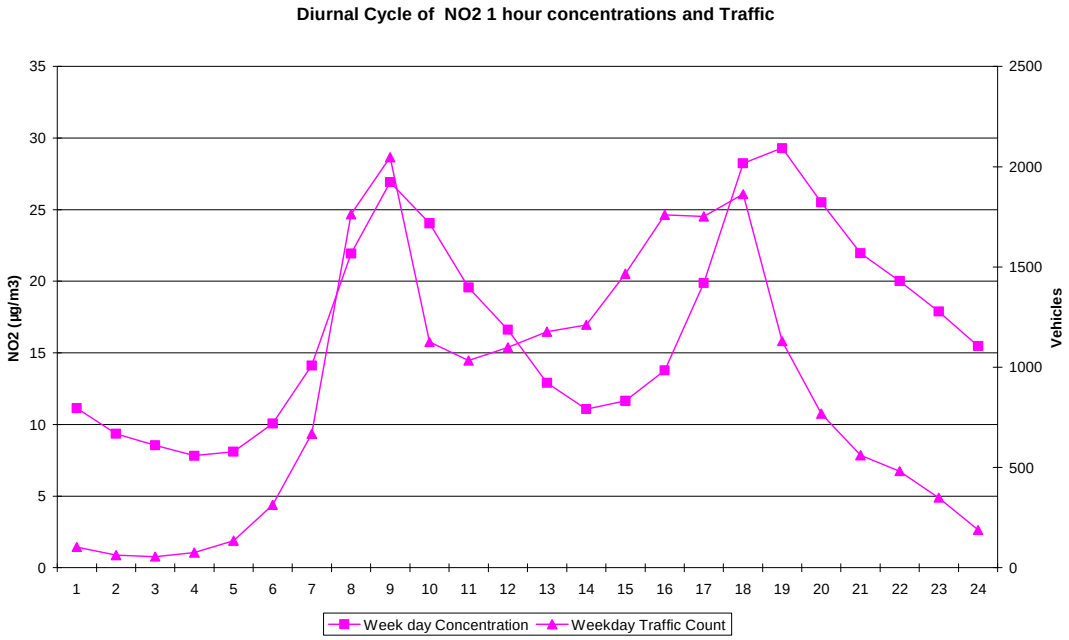

Figure 13: Diurnal cycle of NO2 concentrations measured at the NArt pre-development monitoring site.

The mean 24-hr concentration for NO_2 was 16.3 μgm^{-3} which includes the road and background contributions. The NO_2 concentration when the traffic count is lowest is 8-10μgm^{-3}. This then could be considered the background concentration and would give a 24hr average NO_2 road contribution then of 6.3 to 8.3 μgm^{-3} (see Table 31).

NB. The monitoring data for NO_2 is for a 24-hour average measured during the three winter months. Clearly this data will not represent a true annual mean value, but it can be used for a very conservative estimate of annual mean, again leading to unquantified uncertainties in the results.

Table 31: Comparison of Screening Tool output with Monitored Concentrations.

	NO_2 (annual average μgm^{-3}
screening tool	0.9
Monitored NO_2:	6.3 to 8.3
Most conservative estimate	Monitored NO_2
Ratio: Screening tool to Monitored NO_2	0.11 to 0.14

Conclusion: The screening tool does not produce conservative NO_2 results compared to on site monitoring.

N.B. This conclusion must be considered as very preliminary and treated with all due caution given the context of the limitations noted on the methods used to estimate background concentrations of NO_2 at the site.

6.3.2 Manukau Harbour Crossing – Auckland (MHX)

For the monitoring period a 24hr mean of 14.8 μgm^{-3} was recorded with a standard deviation of 7.4 μgm^{-3}. This again, is very low compared with other Auckland sites, as seen in Table 32.

Table 32: Annual mean of 1hr average NO2 Concentrations.

Location	Site type	Units	Maximum	Annual Average	Median	95th Percentile
Queen Street	Traffic	**$\mu g/m^3$**	337.4	58.4	55.6	104.0
Khyber Pass	Traffic	**$\mu g/m^3$**	263.9	50.5	38.4	136.0
Penrose	Traffic /Industrial	**$\mu g/m^3$**	101.7	29.6	29.0	61.5
Takapuna	Residential/ Traffic	**$\mu g/m^3$**	122.0	26.4	24.6	55.7
Henderson	Residential	**$\mu g/m^3$**	97.7	16.8	13.2	44.8
Mt Eden	Residential	**$\mu g/m^3$**	66.7	17.1	13.5	43.2
Musick Point	Rural	**$\mu g/m^3$**	65.5	7.7	3.9	29.9

Table 2-3. 1 hour average NO_2 measurements at Auckland monitoring sites during 2005 (NES value 200 $\mu g/m^3$)

This includes a background component which is estimated below at 10 $\mu g\ m^{-3}$ giving a road contribution of 4.8μgm^{-3}, which is double the 2.0-2.6 $\mu g\ m^{-3}$ range from the Tool (Table 33).

Table 33: Comparison of Screening Tool output with Monitored Concentrations.

	NO_2 (annual average μgm^{-3})
Tier 2 screening tool	3.4
Monitored NO_2:	4.8 (24-hr)
Most conservative estimate	Monitored NO_2
Ratio: Screening tool to Monitored NO_2	0.7

Conclusion: The screening tool does not produce conservative NO_2 results compared to on site monitoring.

6.4 NO_2 Passive Sampling

6.4.1 Northern Arterial and Queen Elizabeth Drive project – Christchurch

Diffusion tube CHR002 is located on the corner of SH74 and QEII Drive (see Figure 1). The diffusion tube is exposed to vehicles on both roadways. Table 34 shows the relevant AADTs needed for the screening tool. The screening tool only deals with one link at a time. Therefore three scenarios were run for this site, as seen in Figure 14.

Table 34: AADTs for three scenarios for passive NO_2 comparison.

Scenario	SH74 (AADT)	QEII (AADT)	SH74 plus QEII (AADT)
ADDT	34,200	28,600	62,800

Link	Link Name	Air Quality Link Risk	24hr avg PM_{10} ($\mu g/m^3$)	Exceeds PM_{10} significance criteria?	24hr avg $PM_{2.5}$ ($\mu g/m^3$)	Exceeds $PM_{2.5}$ significance criteria?	Avg annual NO_2 ($\mu g/m^3$)	Exceeds NO_2 significance criteria?
1	QEII Drive	High	6.2	Yes	5.2	Yes	1.2	No
2	NArt	High	7.4	Yes	6.3	Yes	1.4	No
3	QUEII and NART	High	13.7	Yes	11.5	Yes	2.5	Yes

Figure 14: Output for three scenarios for passive NO_2 comparison.

The annual concentration at the corresponding passive sampler was 22.2μgm^{-3} for 2009 and 23.0μgm^{-3} for 2010. Again, a background contribution is assigned as above at 8-10μgm^{-3}, giving an estimated concentration of 12.2-15μgm^{-3}. Table 35 shows the resulting comparison.

Table 35: Comparison of Screening Tool output with Passive Monitored Concentrations for three scenarios.

	SH74 (AADT)	QEII (AADT)	SH74 plus QEII (AADT)
screening tool NO_2 annual average μgm^{-3}	1.4	1.2	2.5
Passive Monitor NO_2: 2008 and (2009) μgm^{-3}	(22.2 - 23.0) 12.2-15.0	(22.2 - 23.0) 12.2-15.0	(22.2 - 23.0) 12.2-15.0
Most conservative estimate	Passive Monitor NO_2:	Passive Monitor NO_2:	Passive Monitor NO_2:
Ratio: Screening tool to Monitored NO_2	(0.06) 0.09-0.11	(0.05) 0.08-0.10	(0.11) 0.17-0.20

Conclusion: Tier 2 screening tool does not produce conservative NO_2 results compared to on site passive monitoring.

6.4.2 Manukau Harbour Crossing – Auckland (MHX)

Diffusion Tube AUC026 gives an annual mean of ~17.5μgm^{-3} from the NZTA 2007 report. This corresponds most closely to the monitoring station site for the MHX project and Link 4. Figure 15 suggests the links are in an area where the background concentration will be close to 15 μgm^{-3}. To be conservative we reduce this to 10 (the next outer contour). It is noted these concentrations are based on wintertime monitoring and so are again, conservative and lead to uncertainties in the results.

From 17.5 μgm^{-3} from the passive sampler this gives an annual mean 7.5 μgm^{-3} which is three times the range of the Screening Tool output (see Table 36).

Table 36: Comparison of Screening Tool output with Passive Monitoring.

	NO_2 (annual average μgm^{-3})
Tier 2 screening tool	3.4
Passive NO_2	7.5
Most conservative estimate	Passive NO_2
Ratio: Screening tool to Passive NO_2	0.5

Conclusion: The screening tool does not produce conservative NO_2 results compared to passive monitoring.

Figure A2.11

Spatial distribution of NO_2 concentrations in Auckland (three-month-means, July-September 2006)

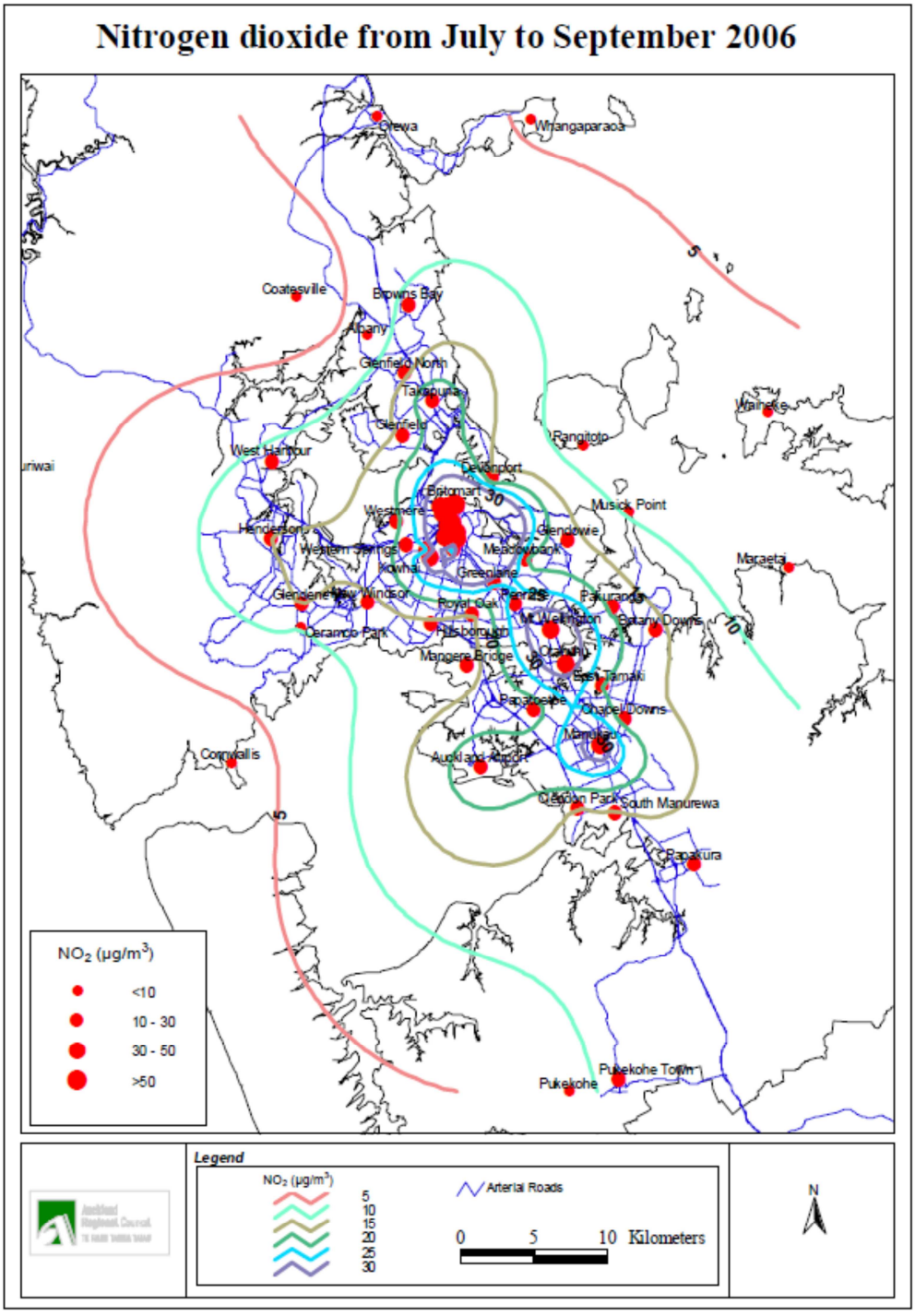

Figure 15: NO_2 concentrations in Auckland over winter 2006.

6.4.3 Addendum to Comparison with NO_2 Passive Sampling

It was noted that the MHX comparison of diffusion tube AUC026 with the Screening Tool output for link 4 may not have been appropriate, as the NZTA report ascribes the nearest main road to AUC026 to be 25m away, not the 50m used in the Screening Tool input. However running the Tool again produced the same result and at this point, a short sensitivity analysis of NO_2 concentrations to the proximity of receptors was conducted. The results were surprising:

Table 37: Input and concentration output of sensitivity test for NO_2.

LINK	AADT	%HV	SPEED	REC(m)	SENS(m)	PM10	PM2.5	NO2
1	32500	8	80	70	70	0.8	0.7	**1.1**
2	32500	8	80	30	70	2.0	1.5	**1.1**
3	32500	8	80	10	70	4.0	3.1	**1.1**
4	32500	8	80	70	10	0.8	0.7	**1.1**
5	32500	8	80	30	10	2.0	1.5	**1.1**
6	32500	8	80	10	10	4.0	3.1	**1.1**

Table 37 shows the distance from receptor (REC) determined PM concentrations but made no difference to NO_2 concentrations. Nor did distance from Sensitive Receptor (SENS). Extra runs at 100m, 150m and 500m all produced NO_2 concentrations of 1.1 μgm^{-3} for NO_2. Searching the 'help' found that annual NO_2 concentration is only calculated for a set distance, regardless of distance to receptor:

Annual average 20m from roadside NO2 (µg/m3) = 0.007 x N x EF x C

where:

N = number of vehicles in 1 hour (AADT/24)

EF = NOx emission factor in g/km

C = NOx to NO2 conversion factor, 0.2

The reasoning behind fixing the distance of the calculation is unclear, as is choosing to calculate an annual average when the averaging periods in the NES and AAQG are one and 24 hours.

7 Discussion

Screening estimates are intended to be conservative relative to the predictions of Tier 3 model results. Over the four projects used in this comparison, we found there to be a range from ‘not-conservative’ to ‘conservative’, depending upon the project, pollutant species and the individual methodologies employed in the Tier 3 assessments This indicates a variety of factors other than the performance of the screening tool may determine the outcome of such a comparison. This is highlighted by the precision of the output concentrations used in the comparison. Northern Arterial concentrations are reported to one thousandth of a microgram while the Screening Tool reports to one tenth and the Manukau Harbour Crossing modelling is reported as integers. To compare concentrations differing in precision by four orders of magnitude will lead to any differences calculated being swamped by the uncertainties surrounding the individual outputs.

Outcomes for PM_{10} ranged from being a factor of 7 over (Christchurch NArt) to a factor of 4 under (Manukau), with the Cambridge and Transmission Gully projects in between producing comparable or slightly conservative (within a factor of 2) results respectively.

The $PM_{2.5}$ results depended entirely on the Tier 3 assessment methodologies and how they differ to the screening tool in apportioning $PM_{2.5}$ as a fraction of PM_{10}. Thus, results for Transmission Gully become more conservative as the consultancy used a ratio of 0.6, while Christchurch remains very conservative using a ratio 0f 0.912. Accordingly, the $PM_{2.5}$ comparison adds no new information about the screening tool to the analysis.

For NO_2, the Tool is set at a fixed distance which makes comparison with output and monitored concentrations at varying distances from the road source difficult. Conservative predictions from the full Assessment are either equal to or greater than predictions from the Screening Tool.

Comparisons with monitored data, taking into account a conservative estimate of background concentrations, lead to even greater under-prediction by the Screening Tool. Considering that the contribution from the road can be more confidently apportioned for NO_2 than for PM and the tool is fixed at a close distance to the road and so should give very conservative concentrations, this gives cause for concern and requires further investigation.

Tier 3 results are themselves predictions based on multiple assumptions and carry inherent uncertainties. Comparison with monitoring data was proposed to verify whether this conservatism remains when compared with observations.

As highlighted throughout this report such a comparison is methodologically challenging. Not all estimate comparisons contained in this report compare like-for-like, as summarised in Table 38 below.

Table 38: Comparisons used in estimates.

	Tier 2 estimate	Monitoring-based estimate	implications
24-hour PM_{10} criterion	Annual maximum	Maximum during monitoring period	Winter bias in Christchurch data leading to possible over-estimation
NO_2 criterion	Annual average	Average during monitoring period	Winter bias in data leading to possible over-estimation
		Passive data from locations closer to road than continuous monitoring and Tier 2 receptor	Passive estimate positive bias

The conclusions of each comparison are highly sensitive to the choice of method for estimating background. In the case of PM_{10} and $PM_{2.5}$ we have made the following assumptions, each of which introduces uncertainty into the estimate:

1. The source apportionment split between traffic and non-traffic sources (11 % in Christchurch for PM_{10}, for example) applies equally at all locations throughout the city.
2. "True background", i.e. the average PM_{10} concentration in the absence of traffic sources, is approximated by minimum diurnal average PM_{10} concentrations, i.e. those occurring in the afternoon (Figure 5) despite the no-traffic assumption clearly being incorrect at this time of day.
3. "Approach 2" also attributes all of this 11% to the adjacent road, whereas in reality any given receptor will be impacted by multiple roads.

Assumption 3 is conservative and assumption 1 is also likely to be conservative at a road-impacted receptor. The resulting uncertainty in the background estimates has not been calculated, but could be of the order +/- 2 µg m^{-3} or more. Furthermore the typical accuracy of PM_{10} observations is +/- 2 µg m^{-3}. These uncertainties are then carried through to the estimate of road impact, which is itself likely to be conservative. The method then requires these estimates to be compared with the Screening Tool estimate, which is specified to +/- one decimal place.

It is not credible to assess the degree of conservatism in one estimate when compared to another estimate which itself possesses a degree of unquantified conservatism, and uncertainty of similar magnitude to the model estimate. Thus, we conclude, that the monitoring data used in this assessment has insufficient resolution or accuracy to provide a credible comparison with the Screening Tool prediction.

8 Conclusions

The objective of this project is to assess whether the air quality effects predicted by the tool are conservative and if so estimate by approximately how much.

The initial assessment and comparison is limited to data modelled for, and monitored at, four roading projects: the NArt in Christchurch, the Manukau Harbour Crossing in Auckland, the Cambridge Expressway in Waikato and transmission Gully in Wellington. For the purpose of this initial trial validation we have taken a rudimentary approach to identifying what the background and roadway contributions are to the total concentrations monitored. Because various “conservative” assumptions have to be made to prepare the monitoring data for comparison with the model output it is impossible to tell whether any apparent conservatism in the model is due to the model itself or the conservatism of the underlying assumptions.

Subject to the caution noted on the method, the conclusions from the limited initial assessment and comparison made at these four sites are that the Screening tool:

- Produces estimates for PM_{10} concentrations that compared to the Tier 3 modelling range are from a factor of seven higher down to approximately equal. I.e. the model is conservative in some cases and not in others
- Does not produce conservative estimates for NO_2 concentrations compared to Tier 3 modelling, on site real-time or passive monitoring data.

And that;

- Conclusions cannot be drawn regarding estimates for PM_{10} concentrations compared to on site monitoring data, due to insufficient sensitivity of monitoring data and large uncertainties in background concentrations relative to the magnitude of the Screening Tool estimate.

9 Acknowledgements

Thanks to the continual support and communication of peers at NZTA and Emission Impossible.

10 References

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