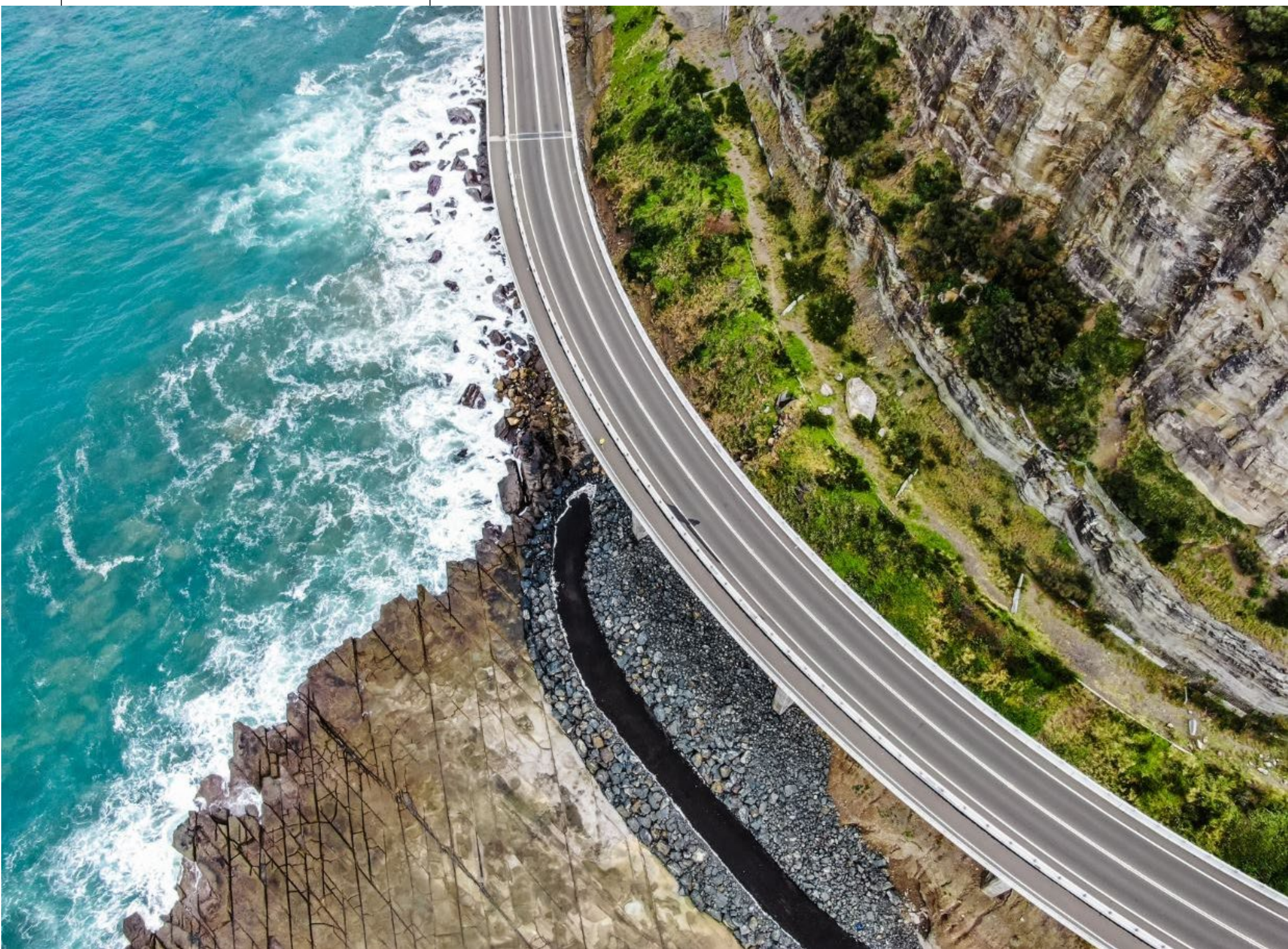
Transport for NSW

Roadside air quality screening tool guideline

October 2023



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Acknowledgement of Country

Transport for NSW acknowledges the traditional custodians of the land on which we work and live.

We pay our respects to Elders past and present and celebrate the diversity of Aboriginal people and their ongoing cultures and connections to the lands and waters of NSW.

Many of the transport routes we use today – from rail lines, to roads, to water crossings – follow the traditional Songlines, trade routes and ceremonial paths in Country that our nation's First Peoples followed for tens of thousands of years.

Transport for NSW is committed to honouring Aboriginal peoples' cultural and spiritual connections to the land, waters and seas and their rich contribution to society.

Document control

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1.0	Oct 2023	First issue

Related policy and supporting information

- Transport Environment and Sustainability Policy
- Environment & Sustainability Management Framework
- **EMF-AQ-GD-0064-TT1 Roadside air quality screening tool**

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1. Introduction

1.1 Background

Transport for NSW has developed an air quality screening tool for assessment of the operational impacts of road projects on air quality (replacing the previous *Tool for Roadside Air Quality* (TRAQ)). The new *Roadside air quality screening tool* (RAQST) reflects recent model developments in NSW and other jurisdictions. It is also designed to be consistent with the requirements of the Clean Air Society of Australia and New Zealand (CASANZ) *Good Practice Guide for the Assessment and Management of Air Pollution from Road Transport* (CASANZ Guide).

This report summarises the methodology of the RAQST and provides a guide for users.

1.2 Context

1.2.1 Air quality impact assessment in NSW

In NSW, air quality impact assessment (AQIA) is guided by the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* ('Approved Methods') (NSW EPA 2022). Section 2.1 of the Approved Methods introduces a general overall approach to assessment which has two 'Levels':

- Level 1: a simple 'screening' assessment using worst-case modelling assumptions.
- Level 2: a detailed assessment using refined modelling techniques and site-specific input data.

This approach is designed to ensure that the assessment effort is proportional to the potential scale of the impacts, with the impact estimates from Level 2 being more accurate than those from Level 1. If a Level 1 assessment demonstrates that adverse impacts will not occur, then there is no need to progress to Level 2. The Level 1 assessment, therefore, needs to be appropriately conservative. In other words, it needs to ensure that the predicted impacts are likely to be greater than the actual impacts, but not so great that projects unnecessarily require the more expensive and time-consuming Level 2 process.

The Approved Methods is designed for stationary sources. However, the two-level approach is also conceptually relevant to road projects.

1.2.2 Screening models for roads

Road projects can include new roads, significant modifications to existing roads, or new developments alongside road corridors. Screening models are often used as part of the AQIA process for these projects. Such models provide quantitative estimates of air quality impacts during project operation, typically based on straightforward calculation methods and conservative assumptions (such as 'worst-case' meteorological conditions). They are usually only applicable to simple situations for example, the existing screening models in Australia and New Zealand deal with one road link at a time. Screening models are designed to be easy to use, and present results in a format that can be easily understood by someone without detailed technical knowledge of air quality modelling.

A screening model can serve several purposes:

- A screening model can be used to establish the level of assessment that is required for air quality. Usually, if the predicted concentrations at receptors are below screening criteria, then the air quality impacts are unlikely to be material, and there will generally be no requirement for more detailed and expensive modelling. A screening assessment can provide confidence that a project will not result in material air quality impacts, despite the relative uncertainty of the predictions.

<u>Note</u> that a detailed assessment may be required for other reasons such as high existing background concentrations, near exceedance predictions, or where air quality is a sensitive issue

- Where a detailed assessment is required, a screening model can be used to refine its scope. For example, a screening assessment can be used to identify the critical roads, pollutants and air quality metrics, and where exceedances of air quality criteria are most likely to occur.

- A screening model can also inform planning proposals by linking to a risk assessment matrix.

1.2.3 CASANZ Good Practice Guide

The CASANZ Guide defines a procedure for assessing the operational impacts of a road project on air quality. The procedure has three main stages: 'scoping', 'screening' and 'detailed'. The term 'potential impact' (PI) is used in the CASANZ Guide when discussing the effects of a project on air quality. This is a broad concept that considers various factors, including the magnitude of changes in air quality, the sensitivity of people and ecosystems near the project to air pollution, and concern about air pollution in the local community.

The PI of a project is categorised as 'low', 'medium' or 'high' at the scoping stage, with the effort associated with the AQIA increasing accordingly. Low-PI projects are typically those that would clearly not result in a material change in air quality or those in areas without nearby receptors or sensitive ecosystems. High-PI projects are generally larger projects that could have a material impact on air quality for one or more reasons (e.g., project scale and area sensitivity). The 'medium-PI' category is used for projects which cannot readily be identified as low-PI or high-PI at the scoping stage, and therefore undergo screening.

Figure 1 shows the steps in the screening assessment. In NSW the screening model used is the RAQST. The procedure only applies to surface roads; it excludes sunken/elevated roads, street canyons and tunnels. The inputs include information relating to the project design, traffic, receptor locations, and background air quality. The concentrations predicted by the screening model, including the background, are then compared against screening air quality criteria.

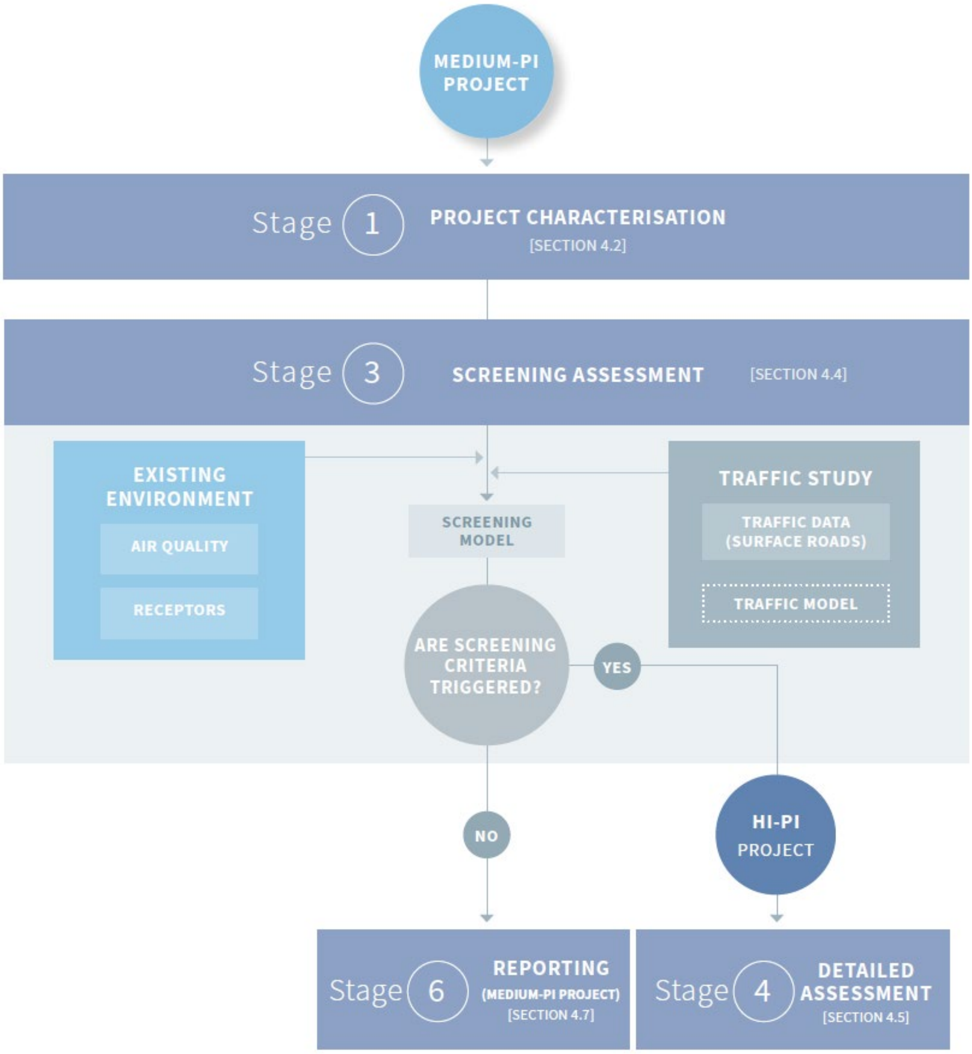

Figure 1: CASANZ Guide screening assessment procedure – operational impacts.

If the predicted concentrations at receptors are below the screening air quality criteria, then the air quality impacts are unlikely to be material and there will generally be no requirement for a detailed assessment. The screening model output will provide sufficient detail for reporting.

If the results for any of the roads affected by the project are above any of the screening air quality criteria, then the air quality impacts are potentially material and the project proceeds to a detailed assessment with more refined modelling. The user may also decide to proceed to a detailed assessment for other reasons, such as the following:

- Background concentrations are especially high (e.g., annual mean $PM_{2.5}$ concentrations are above the corresponding screening air quality criterion).
- The predicted cumulative (background plus project) concentrations are close to (but below) the screening air quality criteria.
- The precise locations of the road and the nearest receptor appear to be affecting the outcome of the screening assessment (i.e., whether the predicted concentrations are above or below screening air quality criteria).
- Air quality is a sensitive issue that could be a factor affecting decision-making on the project.

For changes to existing roads or networks, the assessment is undertaken both with and without the project so that the impacts of the project itself can be clearly established.

2. Description

2.1 Overview

The RAQST has been developed in Microsoft Excel for Office 365 (version 2202, 32-bit). The calculations are performed using macros in Visual Basic for Applications (VBA).

To calculate emissions, the RAQST relies upon the algorithms from the Link Emissions Calculator (Transport 2023). The calculation approach builds upon the algorithms and default data that were initially incorporated into TRAQ, and subsequently into the *NSW Air Quality Appraisal Tool* (PAE Holmes 2013). All these tools use a simplified version of the road vehicle emission model from the emissions inventory for the NSW greater metropolitan region (GMR). The *Link Emissions Calculator* and the RAQST also incorporate projections for the proportion of Battery Electric Vehicles (BEVs) in the fleet, based on the current Net Zero Plan policy settings (NSW DPE 2022).

The RAQST uses a single dispersion function to represent all meteorological conditions. The function was derived using the CALINE 4 model (Benson 1984), based on conservative assumptions. An empirical approach is used to calculate NO_2 concentrations.

The RAQST has the following features:

- It is a standalone, spreadsheet-based tool that is available to the public.
- It is applicable to any year between 2003 and 2050.
- It can accept traffic composition data in different formats.
- It is consistent (as far as possible) with the emission calculation methodologies being used for other applications in NSW.
- It responds quickly to user inputs.
- It will be reasonably easy to update in the future.

2.2 RAQST framework

The framework for the RAQST is shown in Figure 2, and further details of the various steps in the calculation are provided in the following sections.

The main components of the RAQST are:

- A user interface (which contains input and results sheets).
- An emission calculation.
- A dispersion calculation.
- A post-processing calculation.

The calculations are performed for a single road. The road has two directions of travel (A and B), with the user specifying the number of traffic lanes per direction, as well as a median strip if appropriate.

Based on the assessment year, road characteristics (e.g., road type, gradient) and traffic characteristics entered by the user, the RAQST cycles through the emission calculation for each lane, and then the results are carried over to the dispersion calculation.

Air pollutant concentrations are calculated for the closest receptor to the road. The direction of travel closest to the receptor is assigned as direction A. The dispersion function is applied to each traffic lane separately, and the resulting lane contributions at the receptor are added together to give a total road contribution. The road contribution for a given pollutant is then added to the background concentration for the pollutant, as selected by the user. Additional algorithms are used to determine NO_2 concentrations.

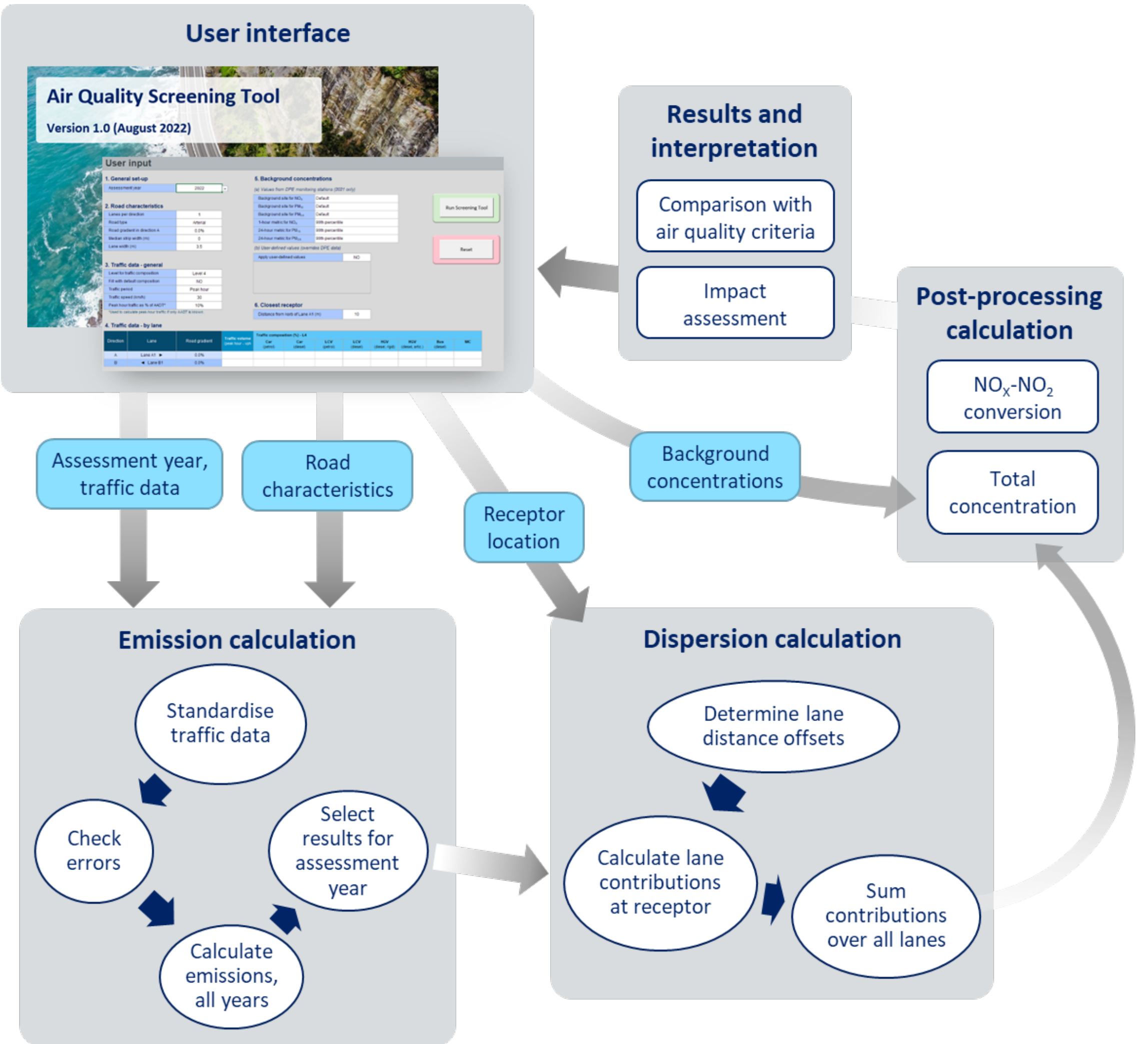

Figure 2: Roadside air quality screening tool (RAQST) framework.

The dispersion calculations are conducted fundamentally at the one-hour level. The concentrations for other averaging periods (annual and 24-hour) are therefore determined using adjustment factors.

In the final step, the results of the calculations are compared with the air quality criteria. In addition, an impact assessment is conducted using both the total concentration and the road component. This identifies whether the impact of the road on air quality at the receptor is likely to be 'negligible', 'slight', 'moderate' or 'substantial'.

2.3 Calculation methodology

The calculation methodology for the Air Quality Screening Tool is described in Appendix A,

3. User guide

3.1 Overview and structure

The RAQST has been developed in Microsoft Excel for Office 365 (version 2202, 32-bit), and uses macros in Visual Basic for Applications (VBA) to perform the calculations.

3.1.1 Sheets Visible to the User

The following sheets are visible to the user:

- **Cover:** This sheet identifies the model version and release date.
- **Notes:** This sheet provides a brief background to the RAQST the version history, contact for further information, and references.
- **Instructions:** This sheet provides the user with a step-by-step guide to using the model. These instructions are also contained in this User Guide.
- **Input:** This sheet controls the RAQST and is where the user enters general parameters, road characteristics, traffic data, background concentrations and the receptor location.
- **Results – AQ:** This sheet presents the results of the air quality calculations and recommendations on their interpretation.
- **Results – emissions:** This sheet presents the results of the emission calculations.

3.1.2 Sheets hidden from the user

Various sheets are hidden from the user to ensure the integrity of the screening tool These include the main calculation routines, the emission factors and adjustments, the dispersion calculations, the default traffic composition data, the background concentration data, the NO_2 calculations, menus, and formatting information.

3.2 Instructions

3.2.1 Macros

The user should ensure that macros are enabled in Excel (see **Developer** > **Macro Security** > **Macro settings**, and check '**Enable VBA macros**').

3.2.2 Set-up and inputs

The RAQST is controlled through the *Input* sheet. The steps to be followed are described below.

Resetting the RAQST

It is recommended that, prior to setting up a new run, or if the model needs to be reset for another reason, the RAQST is returned to the default settings. This is achieved by clicking on the 'Reset' button. The default settings in the RAQST are given in Appendix B.

Step1: General Setup

The general setup requires the following to be defined by the user using drop-down menus:

1. Select the assessment year: This can be any year between 2003 and 2050, with a default of 2022.
2. Select whether the BEV projections are included in the calculations. If 'YES' is selected, the Air Quality Screening Tool considers the projected BEV uptake for the current policy settings for Net Zero in NSW. Otherwise, no BEV uptake is assumed (and no uptake of any fuels/technologies other than petrol and diesel).

Step 2: Road characteristics

The user must set the following road characteristics:

1. **The number of traffic lanes per direction:** This can be either one, two, three or four lanes per direction (the same number of lanes is used for both directions).
2. **The road type:** Road type is selected using a drop-down menu. Each road link must be classified as residential, arterial, commercial arterial, commercial highway, or highway/freeway. The road type is defined in terms of the categories used in the NSW GMR emissions inventory (see Table 1).

Table 1: Road types in RAQST

Road type	Description
Local/residential	Secondary road with the prime purpose of access to the property. Low congestion and low levels of heavy vehicles. Generally, one lane each way, undivided with a speed limit of up to 50 km/h. Regular intersections, mostly non-signalised and low intersection delays.
Arterial	Connection from local roads to arterials. May provide a support role to arterial roads for the movement of traffic during peak periods. Distribute traffic within residential, commercial, and industrial areas. Speed limit 50-70 km/h, 1-2 lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than residential, but significant congestion impact at high volume-to-capacity ratios (V/C).
Commercial arterial	The major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to high congestion in peak periods. Speed limit 60-80 km/h, typically dual carriageway. Regular intersections, many signalised, characterised by stop-start flow, moderate to high intersection delays and queuing with higher V/C ratios.
Commercial highway	The major road for purpose of regional and inter-regional traffic movement. Provides connection between motorways and sub-arterials/collectors. May be subject to moderate congestion in peak periods. Speed limits 70-90 km/h, predominantly dual carriageway. Fewer intersections than commercial arterials with the smoother flow, but subject to some congestion at high V/C.
Freeway/ motorway	High-volume arterial roads with the primary purpose of inter-regional traffic movement with strict access control (i.e., no direct property access). Speed limits 80-110 km/h, predominantly 2+ lanes and divided. Relatively free flowing and steady in non-congested, slowing with congestion approaching V/C limit, but minimal stopping.

3. The road gradient (%) in direction A. The gradient should be specified *in the direction of travel* and *near the receptor*.
4. This can be obtained in a number of different ways, including the following:
   - It can be obtained from the relevant planning authority (e.g., for planned roads).

- It can be calculated using Google Earth or other mapping tools. For example, the 'Ruler' tool in Google Earth can be used to give the road length, and the elevation values can be obtained for the start and end points of the road.

The road gradient must be between -6% and +6%.

5. The width of any median strip. This can be any value between 0 m and 100 m.
6. The width of each lane. This must be between 2 m and 5 m. The default lane width is 3.5 m.

Step 3: General traffic data

The user must do the following to define the general traffic characteristics:

1. **Select the level for traffic composition**: The traffic composition can be defined in different ways (as 'levels') to reflect the input data that are typically available to users. The level for the traffic composition data can be either 1, 2, 3 or 4 (the default is Level 4). The available fields for vehicle categories will update according to the selection. The levels are defined as follows:
   - Level 1: all vehicles (i.e., no information on traffic composition is available to the user).
   - Level 2: light-duty vehicle (LDV) and heavy-duty vehicle (HDV).
   - Level 3: car, light commercial vehicle (LCV), heavy goods vehicle (HGV), bus, motorcycle.
   - Level 4: car, LCV, rigid HGV, articulated HGV, bus, motorcycle.

   Where traffic data are available in other formats, this would require the user to pre-process the data so that they can be used in the RAQST in one of the above formats.
2. **Fill with default composition for year and road type**: This can be used (by selecting 'YES') to fill the traffic composition using the default values for the year and road type. This approach should only be used where local data are not available.
3. **Select the traffic period**: Depending on the information available to the user, this can be either the peak hour traffic (vehicles per hour – VPH) or Annual Average Daily Traffic (AADT) (vehicles per day - VPD).
4. **Enter the traffic speed**: The average speed of traffic on the road is needed. This must correspond to the time period being modelled and can be any value between 5 km/h and 110 km/h.
5. **Define the peak hour traffic as a percentage of the average daily traffic**: This is used to calculate the peak-hour traffic if only AADT is known, or AADT if only peak-hour traffic is known. This must be between 10% and 30%. The default value is 10%.

Step 4: Traffic data by lane

For each lane of traffic, the user must do the following:

1. **Define traffic volume:** This is the total traffic volume on the road during the time period specified. For example, if the traffic period is 'AADT', then the value entered here is for the average daily traffic. The maximum traffic volume per lane is 5,000 for peak hour or 50,000 for AADT. These values are set deliberately high to provide some flexibility for the user when testing alternative inputs.
2. **Define traffic composition (if required)**: Unless the level for traffic composition is Level 1, the traffic composition must be defined in terms of the percentage of the total traffic volume that is in each vehicle type of the specified level.

Note: The user may have already applied the default traffic composition earlier when defining the general traffic composition. In this case, no further action is required here.

Note: Changing the parameters in bold once traffic data have been entered will remove the traffic data.Step 5: Background concentrations

The user defines the background concentrations for NO_X, PM_{10} and $PM_{2.5}$ according to the relevant averaging periods.

Two options are available:

1. Background data can be obtained from selected NSW Department of Planning and Environment (DPE) monitoring stations. This option only provides data for 2021. For each pollutant, the user selects the most appropriate background site, and for short-term averaging periods (1-hour and 24-hour) the statistical metric. The statistical metrics (for 2021) are the maximum concentration and 90th percentile concentration. In the case of 24-hour PM_{10} and $PM_{2.5}$, the highest concentration below the corresponding air quality criterion is also available.

   Note: Although the maximum values for short-term background concentrations are set by default, it is likely that in many circumstances this approach will be overly conservative. For example, peaks in PM_{10} and $PM_{2.5}$ concentrations are often due to natural events such as bushfires and dust storms. The user should therefore exercise professional judgement in the selection of short-term metrics. If a metric other than the maximum is selected, then some justification should be provided.

2. Background concentrations for each pollutant and averaging period can be defined by the user. These values will override the DPE data.

Step 6: Closest receptor

The user must define the distance between the closest receptor to lane A1 and the kerb of lane A1. The direction of travel closest to the receptor is assigned as direction A. The distance can be between 2 m and 200 m, with a default setting of 10 m. If the distance is less than 2 m, a detailed assessment is recommended.

Advice on the precise placement of receptors (e.g., building façade, property boundary, etc.) is available in the CASANZ Guide.

3.2.3 Running the RAQST

Once the RAQST has been set up, the calculation is initiated by clicking on the 'Run Screening Tool' button. The calculations are instantaneous.

3.2.4 Error Messages

The RAQST will return an error message for any input that is outside a valid range.

In addition, the RAQST will not run under the following circumstances:

- In the traffic data for a given lane, the traffic volume cell is empty.
- In the traffic data for a given lane, the total traffic composition does not add up to 100%.

In both cases, an error message will be returned.

3.2.5 Results and interpretation

Air quality

The results of the calculations for each pollutant and averaging period are provided on the *Results - AQ* sheet. The predicted concentrations included, where applicable, the background component, the road component, and the total.

The interpretation of the results for NO_2, PM_{10}, and $PM_{2.5}$ is based on the following steps:

- The predicted total concentrations for all averaging periods are compared with the corresponding air quality criteria.
- The predicted total concentrations for all averaging periods are compared as percentages of the corresponding air quality criteria.
- The annual mean concentrations are used to inform an 'impact assessment' which is supported by significance criteria that have been adapted from IAQM (2017).

The possible outcomes of the calculations are summarised in Table 2, and the possible recommendations are given in Table 3.

Table 2: Possible outcomes.

Outcome	Notes
Predicted concentrations	
Complies with all air quality criteria	No exceedances of air quality criteria
Complies with air quality criteria, but marginal	Concentration for any pollutant/period is >90% of the criterion
Does not comply with all air quality criteria	At least one of the criteria is exceeded
Impact assessment	
Potential impact is negligible or slight	Largest impact rating is negligible or slight
Potential impact is moderate	Largest impact rating is moderate
Potential impact is substantial	Largest impact rating is substantial

Table 3: Possible recommendations.

Recommendation	Notes
No further assessment recommended	Complies with all air quality criteria Compliance is not marginal Largest impact rating is negligible or slight
Seek advice on whether a detailed assessment should be conducted	Complies with all air quality criteria Compliance is marginal Potential impact is moderate
A detailed assessment is recommended	Does not comply with all air quality criteria Largest impact rating is substantial

Emissions

The results of the emission calculations for each pollutant and lane are provided on the *Results – emissions* sheet.

Emission rates are given for NO_X, PM_{10}, $PM_{2.5}$, exhaust CO_2 and CO_2-equivalents (CO_2-e, which considers the global warming potential of CO_2, methane and nitrous oxide).

Emission rates are given for the time period defined by the user (peak hour or day), and as both a weighted average value per vehicle (g/vehicle-km) and a traffic emission rate (g/km/h). The values are also weighted/summated across all lanes.

4. Definitions and abbreviations

Term	Definition
ADDT	Annual average daily traffic
AQIA	Air quality impact assessment
AQST	Air quality screening tool
BEV	Battery electric vehicle
CASANZ	Clean Air Society of Australia & New Zealand
DPE	Department of Planning & Environment
GMR	Greater metropolitan region
HDV	Heavy-duty vehicle
HGV	Heavy goods vehicle
ICE	Internal combustion engine
LCV	Light commercial vehicle
LDV	Light duty vehicle
LEC	Link emissions calculator
PI	Potential impact
RAQST	Roadside air quality screening tool
Transport	Transport for NSW
TRAQ	*Tool for roadside air quality*
VBA	Visual basic applications
VPD	Vehicles per day
VPH	Vehicles per hour

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Appendix A: RAQST methodology

A.1 Assessment Year

The RAQST is set up to provide predictions for any year between 2003 and 2050.

A.2 Road characteristics

The RAQST uses the following characteristics of the road:

- The number of lanes of traffic (either one, two, three or four lanes per direction).
- The road type.
- The average road gradient.
- The width of any median strip.
- The width of each lane.

A.3 Traffic data

For each lane, the RAQST calculates emissions based on the corresponding traffic data (volume, composition, and speed). The traffic data may be obtained from various sources as appropriate, including measurements, traffic models and visual observation.

A.3.1 Time period

The dispersion calculations are conducted fundamentally at the one-hour level, based on the corresponding traffic. The time period for the traffic data can be defined by the user as either the peak hour traffic (Vehicles per Hour – VPH) or Annual Average Daily Traffic (AADT) (Vehicles per Day - VPD), depending on what is available. The traffic data entered by the user corresponds to the time period that has been selected. The user can also define peak hour traffic as a percentage of the average daily traffic. This is used to calculate the peak-hour traffic if only AADT is known. The default value is 10%.

A.3.2 Traffic composition

The RAQST is configured to be flexible in terms of the traffic composition input and can be defined in several different ways to reflect the forms of data that are typically available to users. Four 'levels' of input data are available:

- Level 1: all vehicles (i.e., no information on traffic composition is available to the user).
- Level 2: light-duty vehicle (LDV) and heavy-duty vehicle (HDV).
- Level 3: car, light commercial vehicle (LCV), heavy goods vehicle (HGV), bus, motorcycle.
- Level 4: car, LCV, rigid HGV, articulated HGV, bus, motorcycle.

Where traffic data are available to the user in other formats, the user will need to pre-process the data so that they can be used in the RAQST in one of the above formats.

The emission calculations are always conducted at the level of the vehicle types in Table A.1. The RAQST also includes default traffic composition for each level, road type and year, including the proportions of BEVs if selected. These data can be used where local information on traffic composition for the roads being modelled is not available. The RAQST adjusts the traffic data for the selected Level so that it is compatible with the level of the calculation. For example, if the inputs are for Level 2, then the default values are used to subdivide LDVs into petrol cars, diesel cars, petrol LCVs and diesel LCVs.

A.4 Emission module

A.4.1 Overview

Emissions from traffic are determined using an adapted version of the *Link Emissions Calculator* (LEC) (Transport 2023). The LEC was available as a beta version[1] at the time of the study.

The scope of the emission model is summarised in Table A.1. The model includes calculations for both exhaust emissions (hot and cold start) and non-exhaust emissions. It does not include evaporative emissions, as these cannot be readily allocated to road links in a model of this type.

Emissions are calculated for the most important pollutants in relation to near-road air quality:

- oxides of nitrogen (NO_X) (used to calculate nitrogen dioxide (NO_2) concentrations)
- particulate matter with an aerodynamic diameter of fewer than 10 micrometres (µm) (PM_{10})
- particulate matter with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$).

Emissions of CO_2 and CO_2-e are also calculated.

Exhaust emission functions are defined for eight vehicle types, five road types and nine 'datum' years.

The module provides outputs in g/km/h for each lane.

Table A.1: Scope of emission model.

Aspect	Description
Pollutants	Hot and cold-start exhaust pollutants[a] • NO_X, PM_{10}, $PM_{2.5}$, CO_2, CO_2-e Non-exhaust pollutants • PM_{10}, $PM_{2.5}$
Vehicle types	Internal combustion engine (ICE) vehicles • Petrol car • Diesel car • Petrol light commercial vehicle (LCV) • Diesel LCV • Diesel rigid heavy goods vehicle (HGV) • Diesel articulated HGV • Diesel bus • Motorcycle Battery electric vehicles (for non-exhaust PM only) Car, LCV, rigid HGV, articulated HGV, bus, motorcycle
Road types	Residential, arterial, commercial arterial, commercial highway, highway/freeway
Datum years[b]	2003, 2008, 2011, 2016, 2021, 2026, 2031, 2036, 2041
Units in output	g/km/h

(a) Emissions of carbon monoxide (CO) and hydrocarbons (HC) are also calculated to support the CO_2-e calculation.
(b) The year defines the default composition of the traffic for each type of vehicle and road.

[1] The version of the LEC used in the study was based on the emission functions and data from DPE that were available in 2022. It is anticipated that that a revised version of the LEC will be available in 2023 and will incorporate up-to-date functions and data from DPE.

A.4.2 Exhaust emission functions

The RAQST is largely based upon the emission functions that were developed for the NSW GMR emissions inventory (NSW EPA 2012), as incorporated in simplified form in TRAQ and the *Air Quality Appraisal Tool*. The simplified form was retained for the RAQST. However, in recent years some of the emission factors and data have been updated[2]. Although the revised algorithms have been used in the AQIAs for some major infrastructure projects in Sydney, they have not previously been published. These changes have now been incorporated into the RAQST.

The calculation of hot running emissions uses average-speed emission functions for the cases listed in Table A.1. NSW EPA provided functions for the specific datum years. In the RAQST, the results for intervening years are obtained by interpolation, and the results for 2042 to 2050 are obtained by extrapolating the trend from 2037 to 2041.

NSW EPA did not develop any method to allow for the effects of road gradient on hot exhaust emissions. Gradient scaling factors have therefore been derived based on the emission rates in the guidance on tunnel ventilation requirements from the World Road Association (PIARC 2019).

The GMR inventory method for calculating cold-start emissions involves adjustments to the base hot emission factors to represent the extra emissions that occur during 'cold running'. This approach is incorporated automatically into the RAQST.

A.4.3 Non-exhaust emission functions

The method for calculating non-exhaust emissions of PM_{10} and $PM_{2.5}$ is taken from the *EMEP/EEA Air Pollutant Emission Inventory Guidebook* (EEA 2019) and includes tyre wear, brake wear and road surface wear. The information required on parameters such as vehicle load and the number of axles, and the assumptions used for vehicles in NSW, are taken from the GMR inventory.

For battery electric cars and LCVs, total non-exhaust emissions of PM_{10} and $PM_{2.5}$ are calculated by applying adjustment factors to non-exhaust PM_{10} and $PM_{2.5}$ from ICE vehicles. The adjustment factors were supplied by NSW DPE (2022) and vary according to road type.

A.4.4 CO_2-equivalent calculation

CO_2-e emissions are calculated as follows:

1. CO_2, CO and HC exhaust emissions are calculated using NSW EPA emission factors
2. Ultimately, all carbon-containing components[3] of the exhaust are oxidised to CO_2 in the atmosphere. This 'ultimate' CO_2 is calculated by multiplying the carbon content of the CO_2, CO and HC emission factors by 44/12, where 44 is the molecular weight of CO_2 and 12 is the atomic weight of carbon:

$$CO_{2\,(ultimate)} = [(CO_{2\,(exhaust)} \times 0.273) + (CO_{(exhaust)} \times 0.429) + (HC_{(exhaust)} \times 0.866)] \times \left(\frac{44}{12}\right)$$

Equation A.1

Where:

$CO_{2\,(ultimate)}$	=	ultimate CO_2 emission factor (g/vehicle-km)
$CO_{2\,(exhaust)}$	=	exhaust CO_2 emission factor (g/vehicle-km)
$CO_{(exhaust)}$	=	exhaust CO emission factor (g/vehicle-km)
$HC_{(exhaust)}$	=	exhaust HC emission factor (g/vehicle-km)

3. Fuel-specific emission factors for CO_2-e from the National Greenhouse Accounts Factors (DISER 2021) are used to determine the ratio between (A) the summed CO_2-e emission factors for CO_2, methane (CH_4) and

[2] For example, the NO_X emission factors were modified to reflect the improved understanding of emissions from light-duty diesel vehicles, and emission factors for primary NO_2 were developed.
[3] Particulate matter also contains carbon, although the amount is relatively small compared with the other components.

nitrous oxide (N_2O), and (B) the CO_2-e emission factor for CO_2 only (given that CO_2 has a global warming potential of one). The resulting values are shown in Table A.2.

4. The ratio between (A) and (B) from step 3 is applied to the ultimate CO_2 from step 2 to give CO_2-e.

Table A.2: Fuel energy content and greenhouse gas emission factors (DISER 2021).

Transport type and fuel	Energy content (GJ/kL)	**A:** Emission factor kg CO_2/GJ (assumed u-CO_2)	**B:** Emission factor kg CO_2-e/GJ (CO_2+CH_4+N_2O)	Ratio **B:A**
Post-2004 vehicles: petrol	34.2	67.4	67.62	1.0033
Post-2004 vehicles: diesel	38.6	69.9	70.41	1.0073
HDV (Euro IV+): diesel	38.6	69.9	70.37	1.0067

A.5 Dispersion modelling

A.5.1 Overview

The RAQST uses a single dispersion function to represent all conditions. The function was derived using the CALINE 4 model, based on conservative assumptions.

CALINE 4 is no longer supported by the United States Environmental Protection Agency (USEPA) and has been replaced by AERMOD for regulatory applications. However, it was still considered to be valid for use in the RAQST for the following reasons:

- It is actually designed as a screening model for roads, unlike other models.
- As it was used in TRAQ, this provides some consistency with TRAQ.
- It is used in the South Australia screening tool (SA DIT, 2021).
- Based on a comparison with other models (AERMOD, GRAL, CALPUFF and the New Zealand screening model), it tended to give more conservative predictions in the near-road environment.

A.5.2 Development of road dispersion function

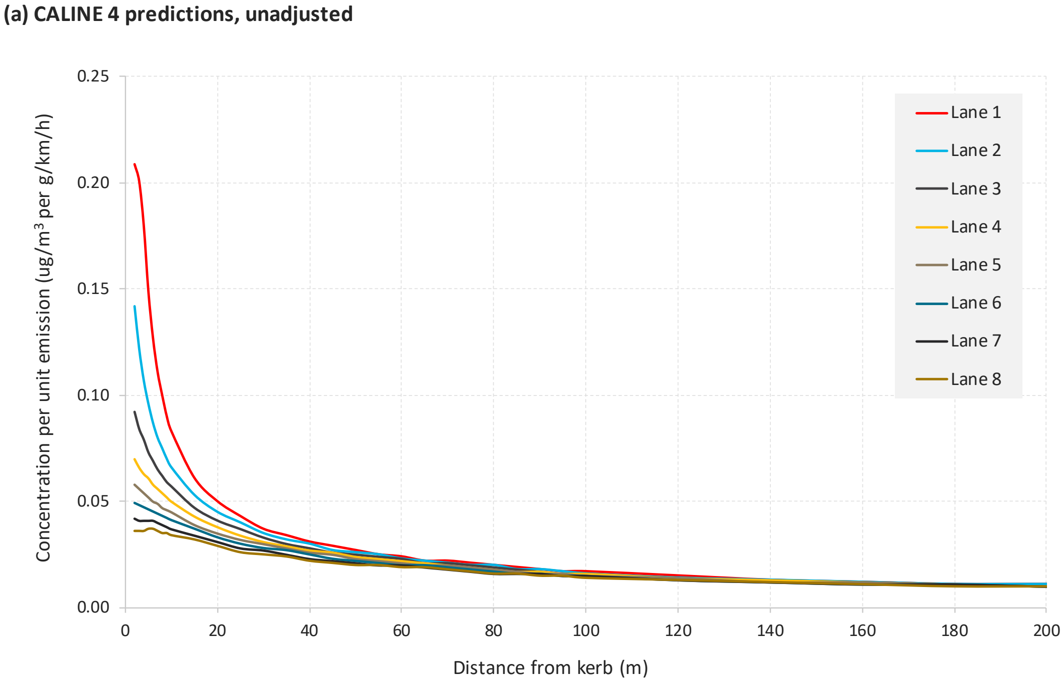
CALINE 4 Settings and Runs

CALINE 4 was used to determine the ambient peak 1-hour concentration – due to traffic – of a given pollutant (in µg/m^3) per unit emission rate (in g/km/h), as a function of distance from the kerb. The settings used in CALINE 4 were very similar to those used in the development of TRAQ and are summarised in Table A.3.

Calculations were performed for a road with eight lanes, with the same emission rate applied to each lane. The concentration profile (µg/m^3 per g/km/h) was plotted for each lane independently (Figure A.1, pane a). Each line in the figure shows the contribution of the corresponding lane to the total road concentration. When adjusted for distance from the kerb, the separate lane plots could be superimposed (Figure A.1, pane b). This illustrated that the same dispersion function could be applied separately to each lane once allowance had been made for the distance offset of the lane from the kerb.

Table A.3: CALINE 4 settings.

Variable	Setting
Pollutant type	Carbon monoxide (molecular weight 28). Conversion from ppm to µg/m^3 = 1,250.
Settling and deposition velocity (m/s)	0
Aerodynamic roughness coefficient (cm)	100 ('suburban' default)
Altitude (m)	0
Wind speed (m/s)	1
Wind angle	Worst case. The model selects wind angles that produce the highest concentrations at each receptor.
Wind direction standard deviation (deg.)	10
Atmospheric stability class	6 (F)
Mixing height (m)	1,000
Temperature (°C)	15
Number of road links	1
Road level	At grade
Road height (m)	0
Road width (m)	3.5
Mixing zone width (m)	10
Emission rate (g/vehicle-km)	1
Number of receptors	34 (aligned perpendicular to road)
Receptor locations (m from kerb)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15,20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 120, 140, 160, 180, 200
Receptor height (m)	0



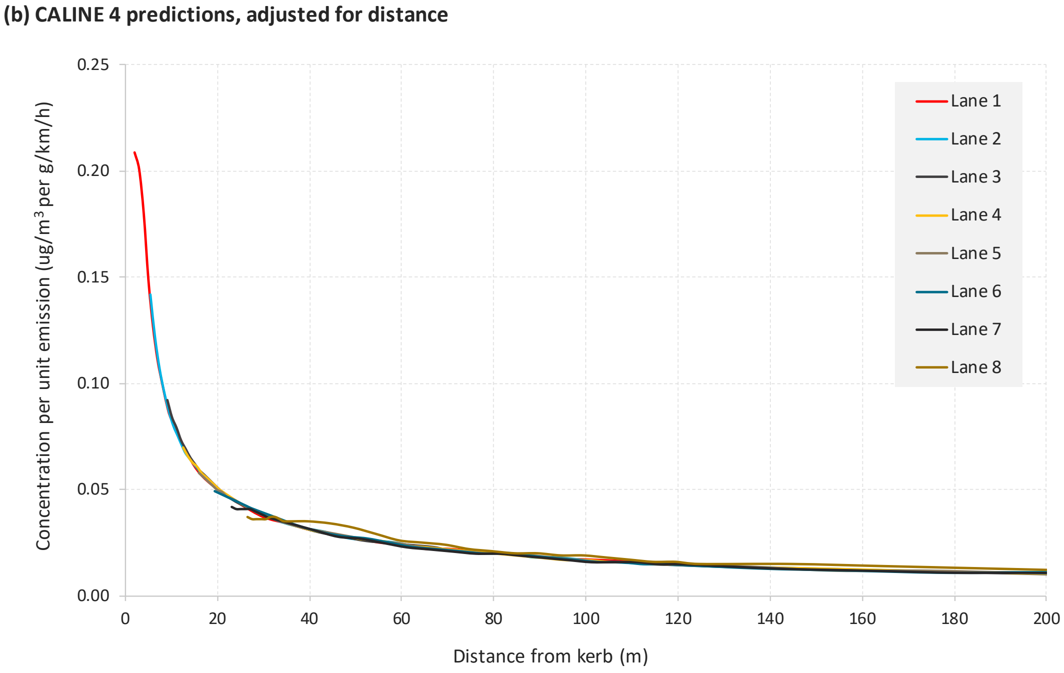


Figure A.1: CALINE 4 predictions for an 8-lane road.

Curve Fitting

The concentration-distance profile for lane 1 was taken to be representative of all lanes, and curve-fitting software was used to fit a function to the profile for use in the RAQST . Only the predictions for between 2 m and 200 m from the kerb were used for the curve fitting. The values between 0 m and 2 m were excluded because of differences between the lane profiles and the greater uncertainty in the predictions very close to the road. A reciprocal quadratic function gave a very close fit to the data (Figure A.2).

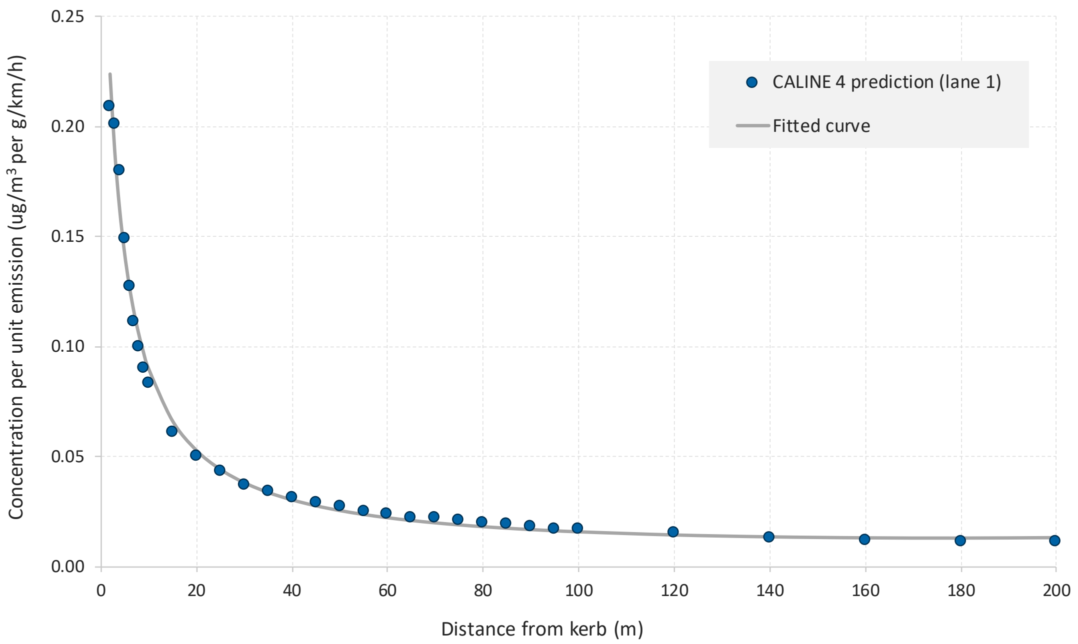


Figure A.2: Curve fit to CALINE 4 predictions

The fitted curve is described by the equation:

$$y = \frac{1}{(a+bx+cx^2)}$$ *Equation A.2*

Where:

y is the concentration per unit emission rate (µg/m³ per g/km/h)

a = 2.76177839903458

b = 0.857549125695763

c = -0.00241841175875783

x is the distance from the kerb (m)

A.5.3 Application in the RAQST

In the RAQST , the road dispersion function in Equation A.2 is applied separately to each lane and pollutant (NO_X, PM_{10} and $PM_{2.5}$). The dispersion function is independent of the time period.

To apply the dispersion function to each lane, it is necessary to calculate the distance from the receptor to the nearest edge of the lane, considering the number of lanes in each direction, the distance from the receptor to the kerb, the lane width, and the width of any median strip. The calculation of these distances is summarised in Table A.4.

The concentrations at the receptor due to the traffic in each lane are summated to give a total road contribution.

Table A.4: Distance calculations.

Lane	Lane edge to receptor (m) by number of lanes per direction[a]			
	1 lane/direction	2 lanes/direction	3 lanes/direction	4 lanes/direction
1	D_R	D_R	D_R	D_R
2	$D_R + W_L + W_M$	$D_R + W_L$	$D_R + W_L$	$D_R + W_L$
3		$D_R + (2 \times W_L) + W_M$	$D_R + (2 \times W_L)$	$D_R + (2 \times W_L)$
4		$D_R + (3 \times W_L) + W_M$	$D_R + (3 \times W_L) + W_M$	$D_R + (3 \times W_L)$
5			$D_R + (4 \times W_L) + W_M$	$D_R + (4 \times W_L) + W_M$
6			$D_R + (5 \times W_L) + W_M$	$D_R + (5 \times W_L) + W_M$
7				$D_R + (6 \times W_L) + W_M$
8				$D_R + (7 \times W_L) + W_M$

(a) Where D_R = distance from receptor to the kerb, W_L = lane width and W_M = median strip width.

A.5.4 Conversion to other averaging periods

The CALINE 4 modelling, and the resulting dispersion function, gave concentrations for a peak 1-hour period under theoretical 'worst case' meteorological conditions. For averaging times of more than one hour, the predicted concentrations for road traffic would be overly conservative. For example, it would be very unusual for the worst-case meteorological conditions to be maintained for 24 hours and, of course, a year. To predict the road traffic concentrations for 24-hour and annual averaging periods, it was, therefore, necessary to define time period conversion factors. A similar approach is used in existing guidance and screening models in Australia and New Zealand.

The time period conversion factors used in the RAQST are given in Table A.5. These values are consistent with those used in TRAQ and the South Australia screening tool (SA DIT, 2021).

Table A.5: Time period conversion factors.

Conversion	Factor
1-hour to 24-hour	0.5
1-hour to annual	0.2

A.6 Background air quality

The RAQST includes the measurements from NSW DPE's air quality monitoring network to characterise background concentrations. Values for the following in 2021 are included in the RAQST for the sites where they were measured:

- NO_X
  - Annual mean concentration
  - Maximum 1-hour concentration
  - 90th percentile 1-hour concentration

- PM_{10}
  - Annual mean concentration
  - Maximum 24-hour concentration
  - 90th percentile 24-hour concentration
  - Highest 24-hour concentration below 50 µg/m³
- $PM_{2.5}$
  - Annual mean concentration
  - Maximum 24-hour concentration
  - 90th percentile 24-hour concentration
  - Highest 24-hour concentration below 25 µg/m³

A.7 Cumulative concentration

The total road contribution for each pollutant (NO_X, PM_{10} and $PM_{2.5}$) is added to the background concentration to give the cumulative concentration.

A.8 NO_2 calculation

A.8.1 Background

Various guidance documents recommend the use of local monitoring data, where available, to estimate NO_2 from modelled NO_X. Functions have been fitted to NO_X and NO_2 monitoring data for many years, notably in the form of the ‘Derwent-Middleton’ equation (Derwent and Middleton 1996), and this continues to be the case (e.g., Podrez 2015).

Both NO_X and NO_2 have been measured for several years at a range of stations across NSW. A substantial amount of data from these stations was used to develop empirical NO_X-to-NO_2 conversion functions for several road tunnel projects in Sydney (e.g., NSW RMS 2020), with separate approaches for annual mean and 1-hour mean NO_2. One reason for the analysis was to quantify and address the excessive conservatism in some of the other methods in use, whereby exceedances of NO_2 air quality standards can be predicted for a given NO_X concentration, even where the monitoring data show that this situation is extremely uncommon for real-world locations.

An empirical approach was also adopted for the RAQST as described below.

A.8.2 Annual mean concentrations

Figure A.3 shows the relationship between the annual mean concentrations of NO_X and NO_2 at monitoring stations in NSW between 1994 and 2019. The data for background stations and road stations are shown separately. In the low-NO_X range of the graph, there is an excess of ozone and therefore NO_2 formation is limited by the availability of NO. In the high-NO_X range, there is an excess of NO, and therefore NO_2 formation is limited by the availability of ozone. The Figure also shows that there is not a large amount of scatter in the data, and for this reason, a ‘central-estimate’ approach for estimating NO_2 from NO_X was considered to be appropriate.

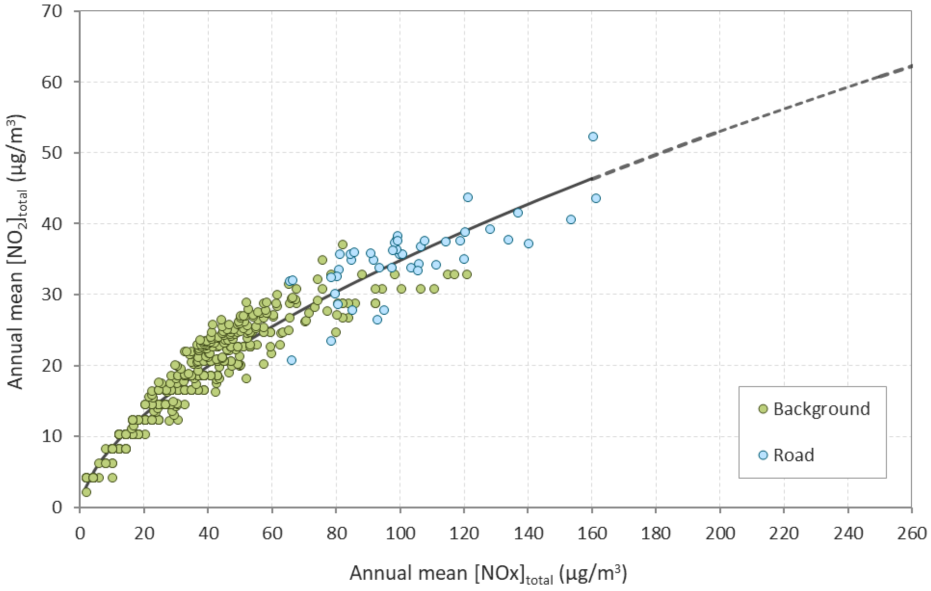


Figure A.3: Relationship between annual mean NO_X and NO_2 at NSW monitoring stations.

The solid line represents a regression model that fits the data (i.e., the central-estimate situation) which will give the most likely annual NO_2 concentration for a given annual NO_X concentration. The function giving the best fit was selected from a large number of alternatives using curve-fitting software, and is described by the following equation:

$$[NO_2] = 2.0959567 \times [NO_X]^{0.61}$$ *Equation A.3*

At very low NO_X concentrations (<=7 µg/m^3) the relationship is constrained to a NO_2:NO_X ratio of 1.

For NO_X concentrations greater than 160 µg/m^3 it has been assumed that the equation can be extrapolated (the dashed line). Given the absence of high annual mean NO_X concentrations, the extrapolation to concentrations above the measurement range is uncertain.

The use of the function could theoretically lead to exceedances of the annual mean criterion for NO_2 in NSW of 62 µg/m^3. However, a very high annual mean NO_X concentration - more than 260 µg/m^3 - would be required. This is much higher than the measurements in Sydney have yielded to date.

A.8.3 One-hour mean concentrations

For the maximum 1-hour mean NO_2 concentrations the situation is more complicated. One-hour mean NO_X and NO_2 concentrations are much more variable than annual mean concentrations. Patterns in the hourly data can be most easily visualised by plotting the 1-hour mean NO_2/NO_X ratio against the 1-hour mean NO_X concentration, as shown for the various background and road monitoring stations in Figure A.4.

This figure only includes data for monitoring stations in Sydney for 2004-2019, and not the whole of NSW, given the large quantity of data already involved (over 1.4 million points). For low NO_x concentrations, there is a wide range of possible NO_2/NO_x ratios, whereas for higher NO_X concentrations the range is much more constrained. A distinct outer envelope can be fitted to the data which includes all (or very nearly all) the measurement points, and this envelope has a strong inverse relationship with the NO_X concentration. In the envelope, the NO_2/NO_X ratio is highest (1.0) at low NO_X concentrations, representing complete, or near-complete, conversion of NO to NO_2. At the high end of the NO_X concentration range the ratio is much lower and levels out at a value of around 0.1. The highest NO_X concentrations occur mostly during the winter months when temperature inversions prevent the effective dispersion of pollution. Although not shown, the patterns for background and road locations are very similar. It was therefore considered appropriate to combine the datasets. In particular, the outer envelope of the NO_X/NO_2 ratio was very consistent, so it was also considered appropriate to define one (conservative) approach to reflect this envelope.

Several steps were taken to simplify the dataset. The data contained many low values of NO_X, and these were not considered particularly important in terms of estimating peak NO_2 concentrations. All NO_X concentrations less than 30 µg/m³ were therefore removed, as were any negative concentrations of NO_X and NO_2. All values of the NO_2/NO_X ratio greater than 1.0 were also removed.

The method then involved the following steps:

- the data were to multiple NO_X bins, at an interval of 20 µg/m³.
- for each NO_X bin the 99.9th percentile NO_2/NO_X ratio was calculated.
- a curve was fitted to the 99.9th percentile points.

The resulting data and the 99.9th percentile curve are shown in Figure A.4.

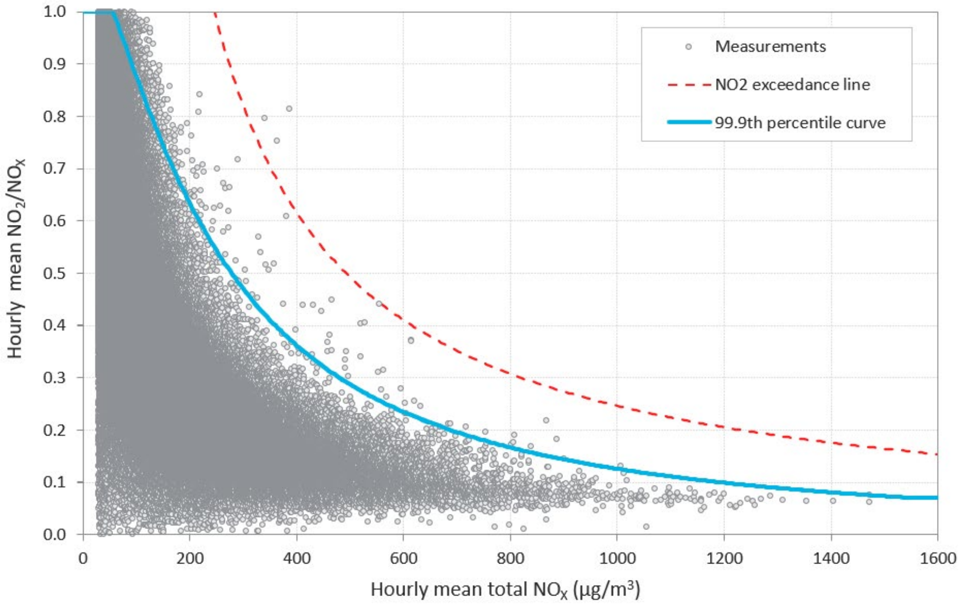


Figure A.4: Derivation of 99.9th percentile curve.

The 99.9th percentile curve was used in the RAQST and approximated to a conservative upper bound estimate of the NO_2/NO_X ratio across a wide range of 1-hour NO_X concentrations.

The curve is described by the following equations:

For NO_X values less than or equal to 55 µg/m³:

$$\frac{[NO_2]}{[NOx]} = 1.00 \quad \textit{Equation A.4}$$

For NO_X values between 55 µg/m³ and 1,555 µg/m³:

$$\frac{[NO_2]}{[NOx]} = \frac{a}{(1+(\frac{[NOx]}{b})^c)} \quad \textit{Equation A.5}$$

Where:

a = 1.12592521

b = 237.948879

c = 1.44533388

For NO_X values greater than 1,555 µg/m³ a cut-off for the NO_2/NO_X ratio of 0.07 has been assumed:

$$\frac{[NO_2]}{[NOx]} = 0.07 \quad \textit{Equation A.6}$$

Given the use of the 99.9th percentile values, for any given NO_X concentration, at least in the low-mid range, the corresponding NO_2 concentration would only be underestimated around one time in a thousand. Of course, there are very few data points at the highest NO_X concentrations, and therefore this cannot be easily demonstrated.

Figure A.4 also shows the 'exceedance line' for the 1-hour NO_2 criterion of 246 µg/m^3. It is clear that exceedances of the criterion cannot be predicted using the 99.9th percentile curve across a wide range of NO_X concentrations; a total NO_X concentration of more than 3,500 µg/m^3 is required to give an exceedance.

A.9 Calculation routine

Emission calculations

The RAQST cycles through each traffic lane in turn, and runs through the following steps:

1. Check for errors in the input data.
2. Adjust the traffic composition to the vehicle types in Table A.1.
3. Calculate emissions for each pollutant (NO_X, PM_{10} and $PM_{2.5}$ for air quality, plus CO, HC, and CO_2 for CO_2-e emissions):
   (a) Determine the base composite hot exhaust emission factor[4] for each vehicle type and datum year, based on the road type and traffic speed.
   (b) Determine the gradient correction factor for each vehicle type, based on the road gradient and traffic speed (with interpolation for both).
   (c) Based on (a) and (b), determine the gradient-corrected hot emission factor for each vehicle type and datum year.
   (d) Determine the cold-start factor (and emission) for each vehicle type and datum year.
   (e) Determine the non-exhaust emission factor (PM_{10} and $PM_{2.5}$ only) for each vehicle type and datum year.
   (f) For each vehicle type and datum year, sum the hot, cold, and non-exhaust emission factors.
   (g) Interpolate the emission factors for years between the datum years and extrapolate for 2042-2050.
   (h) Reference the emission factors by vehicle type for the assessment year.
   (i) Calculate the emissions from the traffic in the lane by weighting the emission factors according to the traffic volume and composition.
   (j) Convert the results into average g/vehicle-km.

Dispersion Calculations

1. Carry over the emission factors for each lane to the dispersion calculation.
2. Convert the values for each lane from g/vehicle-km to g/km/h, based on the traffic volume and time period.
3. Determine the distance from the lane edge to the receptor for each lane, based on the lane width and the width of any median strip.
4. Calculate the contribution of each lane to the peak hour concentration at the receptor.
5. Sum over all lane contributions to give the total peak hour road contribution to the concentration at the receptor.
6. Apply time period conversion factors to obtain the 24-hour and annual road concentrations.

Post-Processing

[4] The base composite emission factor for each vehicle type and year takes into account vehicle-kilometres of travel (VKT) by age, the emission factors for specific emission standards, and the mix of emission standards in the year.

7. Obtain background concentrations for NO_X, PM_{10} and $PM_{2.5}$ for relevant averaging periods.
8. For 1-hour NO_2:
   (a) Add road NO_X to background NO_X.
   (b) Determine NO_2/NO_X ratio.
   (c) Determine total NO_2.
9. For annual NO_2:
   (a) Add road NO_X to background NO_X.
   (b) Convert total NO_X to NO_2.
10. For PM_{10} and $PM_{2.5}$ (24-hour and annual), add road concentrations to background concentrations.

Results and Interpretation

11. Compare predicted total concentrations for all averaging periods with the corresponding air quality criteria.
12. Compare predicted total concentrations for all averaging periods as percentages of the corresponding air quality criteria.
13. Use annual mean concentrations to inform an 'impact assessment'.
14. Provide summary and recommendations for air quality.
15. Provide summary of emissions.

A.10 Error checking routines

The user inputs are restricted, as far as possible, to valid ranges. Several routines are also built into the RAQST as further checks for possible errors in the user inputs.

A.11 Quality control

The RAQST was subjected to quality control checks. This included checks of the functions and macros in the spreadsheet, and some spot checks using manual calculations.

Appendix B: RAQST default settings

Table B.1: Default settings.

Step	Parameter	Setting
General set-up	Assessment year	2022
	Electric vehicle projections	YES
Road characteristics	Lanes per direction	1
	Road type	Arterial
	Road gradient in direction A (%)	0
	Median strip width (m)	0
	Lane width (m)	3.5
Traffic data - general	Level for traffic composition	Level 4
	Fill with the default composition	NO
	Traffic period	Peak hour
	Traffic speed (km/h)	30
	Peak hour traffic as % of AADT	10
Traffic data by lane	Traffic volume	Empty
	Traffic composition	Empty
Background concentrations	Background sites	Default
	1-hour and 24-hour metrics	Maximum
	Apply user-defined values	NO
Closest receptor	Distance from the kerb of Lane A1 (m)	10