Todd Hulbert
Design Manager
Grocon Group

23 December 2016

Dear Todd,

Ribbon Development - Level 29 Pool Area Assessment

Further to your request, please find detailed below our review of air quality and meteorological data for the proposed Level 29 pool area.

Introduction

Pacific Environment has previously assessed potential air quality impacts of the Cross City Tunnel Vent (CCTV) on the proposed Ribbon Sydney development (the Development). This work includes the following studies:

- PE (2013) *Air Quality Impacts for Redevelopment of 31 Wheat Rd Revised Design*, Pacific Environment, August 2013.
- PE (2015) *The Ribbon Air Quality Assessment 2015 Revised Design*, Pacific Environment, November 2015.
- PE (2016) *The Ribbon – Air Quality Assessment, Final Report,* Pacific Environment, 11 October 2016.

These studies have involved the assessment of potential nitrogen dioxide (NO_2) impacts using conventional regulatory environmental atmospheric dispersion models (PE, 2013, 2015), with subsequent refinement using Computational Fluid Dynamic (CFD) modelling (PE, 2016). The assessment has followed a specific protocol established for the Cross City Tunnel, which applies an incremental NO_2 criterion of 150 µg/m^3 for assessment in accordance with pre-defined emission scenarios.

The Development Application (DA) conditions relevant to the assessment of potential air quality impacts within the development include the following:

- ***B29:*** *The air intakes for all mechanical ventilation systems shall be situated below a height of 60 metres above ground level. The air intakes are to be positioned following further assessment on the most appropriate location using Computational Fluid Dynamics modelling prior to issue of a Construction Certificates for Stage 4.*
- ***B30:*** *No balconies, terrraces or operable windows shall be incorporated within the building above a height of 60 metres above ground level.*

Condition B29 has been addressed within PE (2016) which assessed the potential impacts on air intakes of an enclosed building design. Since this time, Grocon are seeking to understand the nature of potential air quality impacts for an open roof design. This design would feature an open-top deck and pool area within Level 29 and Level 30 of the development (the L29 pool area). Accordingly, Pacific Environment have undertaken the following:

- A review of previous dispersion modelling and CFD analyses to infer potential air quality impacts in the vicinity of the L29 pool area.
- Preparation of a summary of existing (synthetically generated) three-dimensional data for the area to provide temperature / wind speed frequency distribution information indicative of the ambient environment at the L29 pool area.
- Augmentation of the above with any additional publicly available data (as available).

Details of this review and analysis are provided in the following sections.

Level 29 Pool Area

Attachment A1 and A2 provide an outline of the area in which the Level 29 pool area is proposed. This area is proposed to be open to the ambient environment, and spans between Finished Floor Level (FFL) extents of 80.66 mFFL and 88.36 mFFL, with a ground level of 3.2 mFFL. This translates to an area of interest between 77.4 metres Above Ground Level (AGL) and 85.1 mAGL.

Potential Air Quality Impacts on L29 Pool Area

PE (2013, 2015)

PE (2013, 2015) contain screening analyses of potential air quality impacts on the development in accordance with protocols established for the assessment of potential receptors near to the CCTV. The analysis used the CALPUFF atmospheric dispersion model in conjunction with a screening level, single wind direction meteorological dataset that has been aligned northward toward the development.

At 90 mAGL at the Development, this analysis predicted levels above the criterion, however it is noted that this analysis was primarily targeted at assessment of lower building levels, and hence adopted a wind direction that coincided with the Development footprint at a point significantly closer to the CCTV than (i.e. to the west of) the L29 pool area.

PE (2016)

PE (2016) provides a detailed CFD analysis of potential air quality impacts on the development based on 3 separate modelling scenarios. Results are presented as plume mass fraction, which in a pollution context, represent the proportion of the in-stack concentration at a given point of interest.

The modelling was undertaken for three scenarios identified as being representative of three worst case dispersion scenarios as identified through the modelling completed within the air quality assessment PEL (2015).

A summary of these scenarios is provided in **Table 1**.

Table 1 CCTV CFD modelling parameters by scenario

Parameter	Scenario 1	2	3
CCT Emission Type	High	Medium	Medium
Time of Day	6am – 10am, 3pm – 7pm	10am – 3pm	10am – 3pm
NO2 Emission Rate (g/s)	1.8	1.0	1.0
Exit Velocity (m/s)	21	11	11
In-Stack Temperature	Ambient + 5 °C (20°C)	Ambient + 5 °C (25 °C)	Ambient - 7 °C (13°C)
Wind Direction	180	180	180
Wind Speed (m/s)	1	1	1
Ambient Temperature (°C)	15	20	20
Season	Winter	Spring	Summer
Stability Class	F	B	B
Mixing Height (m)	600	1000	500

As shown in **Table 1**, Scenario 3 comprises a "negative buoyancy" scenario, where the CCTV exhaust air is cooler (and denser) than the ambient air into which it is released, thus restricting plume rise. It is noted that the adoption of a negative buoyancy assumption for a peak emission scenario is considered conservative given the buoyancy effects of vehicle waste heat that would be present when peak vehicle emissions occur.

Critical in-stack concentrations have been calculated for each scenario as presented in **Table 2**. These ratios represent the level at which the NO_2 assessment criterion would be reached.

Table 2 CFD mass fractions by scenario and elevation (mAGL)

Emission Rate g/s	Emission Rate g/s	Flow m^3/s	Concentration mg/Am^3	Mass Ratio at Criterion -
Scenario 1	1.0	303	3.3	4.5%
Scenario 2	1.0	303	3.3	4.5%
Scenario 3	1.8	602	3.0	5.0%

Note: Flow corrected to ambient temperature for the purpose of calculating mass ratio.

PE (2016) includes model results for 30, 60, 70, 80 and 90 mAGL. These are presented as contour plots for each transect. Relevant to the consideration of the Level 29 pool area are the 80 and 90 mAGL transects. Attachment B presents these results for each of the modelled scenarios, whilst Table 2 presents a summary of these mass fractions as interpreted from the figures provided in Attachment B.

Table 3 Inferred CFD predicted mass fractions by scenario and elevation

Scenario	Mass Fraction		Criterion
	80 mAGL	90 mAGL	
Scenario 1	<0.5%	<1.1%	4.5%
Scenario 2	<0.6%	<0.6%	4.5%
Scenario 3	<6.0%*	<2.5%	5.0%

Note: Values inferred from the figures provided within Attachment B. Accordingly these represent approximate values.

Based on the values outlined in **Table 2**, it can be seen that NO_2 levels at the L29 rooftop area are well below the criterion for Scenarios 1 and 2, whilst Scenario 3 predictions are approaching the criterion.

L29 Pool Area - Wind and Temperature Conditions

This section presents a brief summary of wind and temperature conditions as derived from the existing (synthetically generated) three-dimensional data wind fields from the CALMET[1] meteorological model. This data has been compiled in order to provide temperature and wind speed frequency distribution information indicative of the ambient environment at the L29 pool area.

In addition, publicly available data has been sourced from that available within (HAS, 2008) *Air Quality Impact Assessment: The Integrated Generators Project*. This data consists of a full year of monitoring records from 70 mAGL on the Millennium Towers, located on Day Street, approximately 150 m south-east of the Development. The monitoring data was collected between September 2005 and August 2006.

Calmet Wind Field Data

Figure 1 and Figure 2 present wind speed and temperature frequency distribution data for the Development location, at 80 mAGL.

It is important to note that this data is representative of the free stream meteorological conditions in the absence of physical structures. Accordingly, given the formation of stagnation and recirculation zones on a structure such as the L29 rooftop area, associated wind speeds within the L29 rooftop pool environs would be anticipated to be lower than presented here. In a similar manner, during daytime conditions, the influence of solar gain within the rooftop area may also act to elevate the L29 rooftop temperatures above those presented in **Figure 2**.

[1] The meteorological pre-processor for the CALPUFF dispersion model.

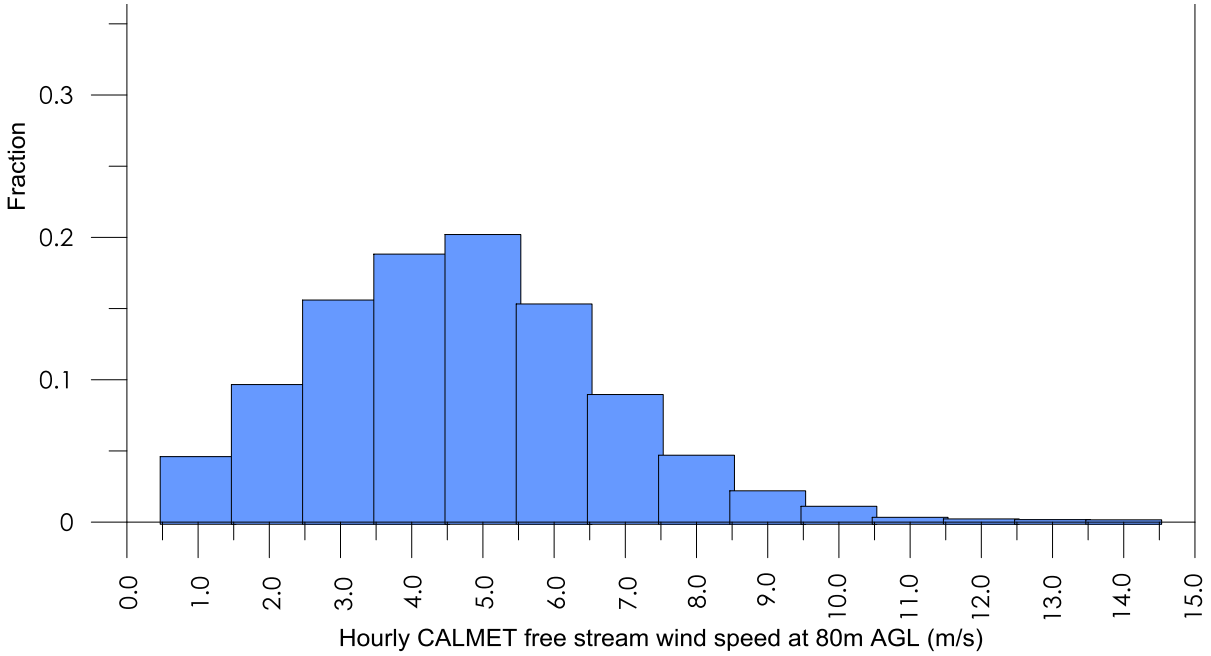


Figure 1 CALMET-generated wind speed frequency distribution for the Development location

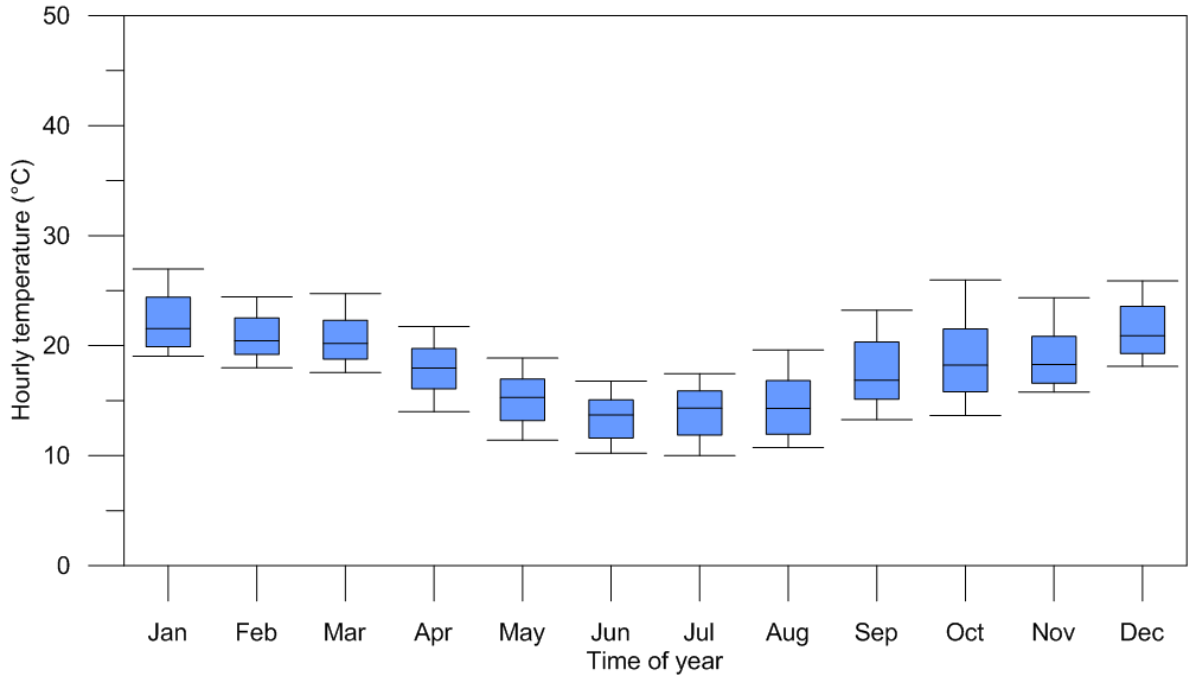


Figure 2 CALMET-generated temperature plot for the Development location (80m AGL)[2]

[2] Note: Box and whisker plot values represent 10th, 25th, 75th and 90th percentile values within each month.

Millennium Towers Data (70m AGL)

Figure 3 presents an annual wind speed frequency distribution for the Millennium Towers monitoring site. Figure 4 presents annual and seasonal wind roses for these data. HAS (2008) provides an annual average wind speed of 3.2 m/s for this location.

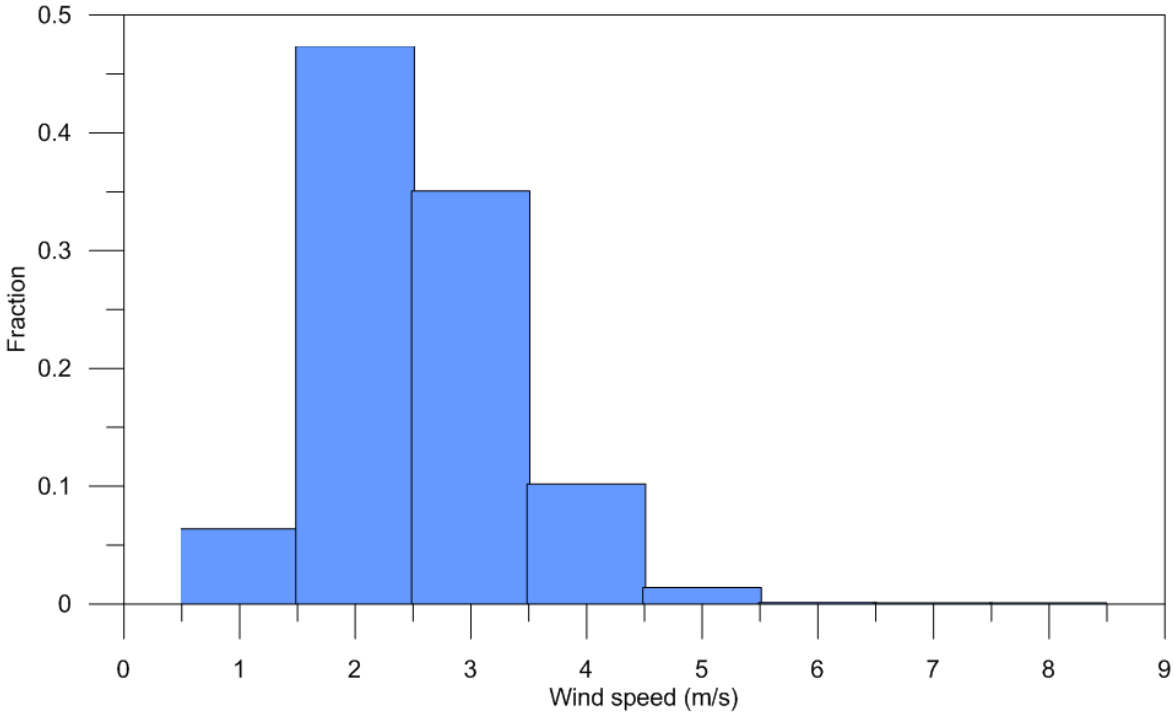


Figure 3 Annual and seasonal wind roses for Millenium Towers site (70m AGL)

As shown in **Figure 3**, wind speeds are significantly lower than those generated by CALMET, and are understood to reflect conditions at a level approximately 2 m above the rooftop.

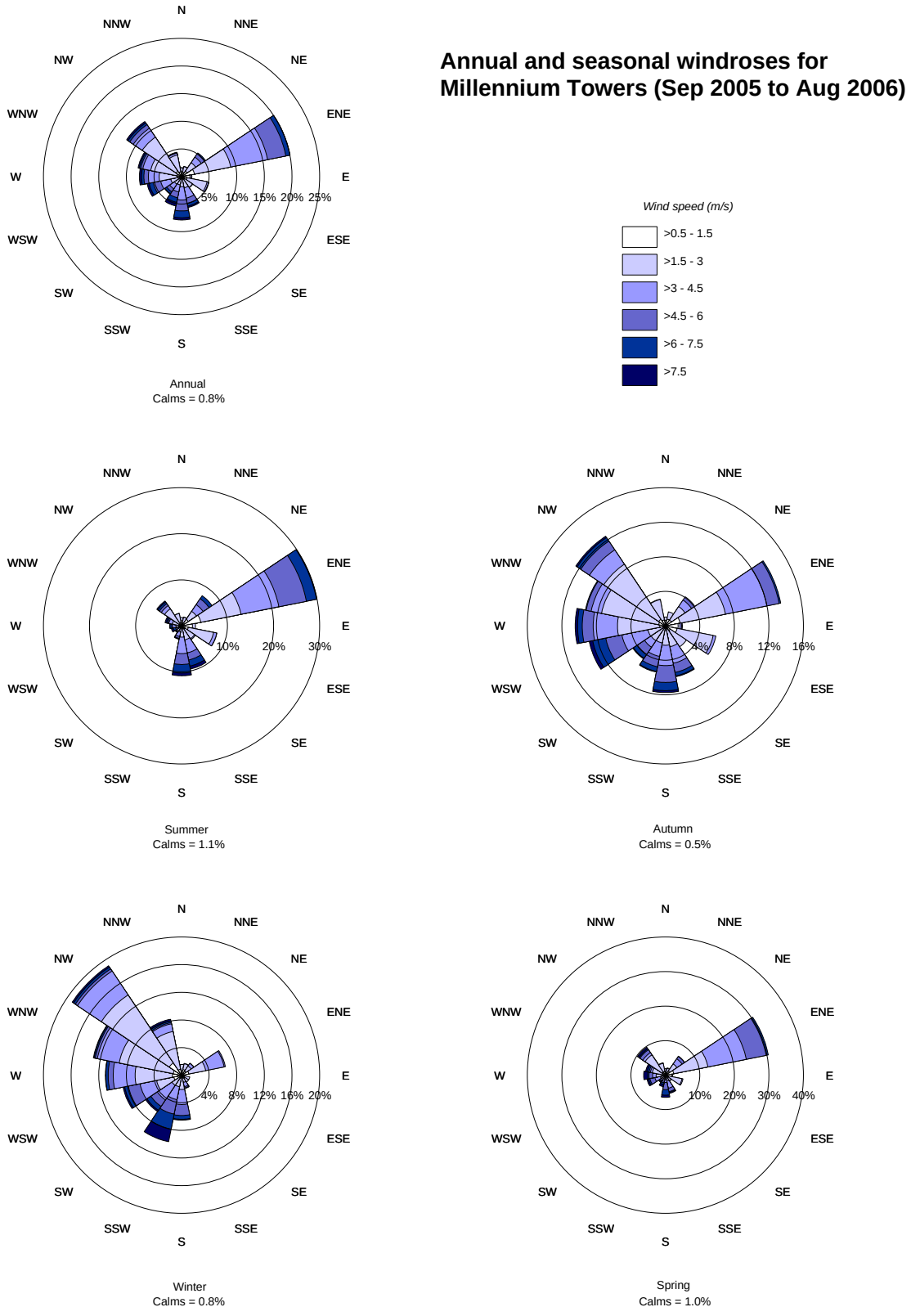


Figure 4 Annual and seasonal wind roses for Millenium Towers monitoring data (70 mAGL)

Conclusions

Within this review, previous Ribbon Development air quality studies have been used to infer potential air quality impacts on the proposed L29 rooftop pool area. On this basis, the following conclusions are made:

- At 80 and 90 mAGL, the CFD model predictions for Scenario 1 and 2 are below the CCTV impact assessment criterion for NO_2, whilst predictions for Scenario 3 are approaching the criterion.
- The application of "negative buoyancy" emission parameters in Scenario 3 are considered to provide a conservative representation of worst-case CCTV plume impacts, given that in the case of peak vehicle emissions there would also be a significant quantity of waste heat from vehicles within the tunnel, which would act to increase the buoyancy of CCTV emissions.

It is noted that the adopted CCTV emission estimates were developed in 2007, and have not been reviewed in the context of modern vehicle emission performance, or actual CCTV emission concentrations. It is expected that current NO_2 levels within the CCTV stack would be significantly lower than is reflected in the conservative assumptions used within the modelling to date (possibly by an order of magnitude).

Based on CFD analysis summarised in this review, it is considered unlikely that NO_2 levels at the L29 rooftop area would generate exceedances of the NO_2 criterion, however it is recommended that a more comprehensive analysis of risk be undertaken that includes a probabilistic analysis of potential impacts including:

- Frequency of worst case meteorological conditions;
- Frequency and magnitude of worst case CCTV emissions.
- Nature of CCTV stack emission parameters.
- Hours of occupation for the L29 rooftop area.

We hope that this meets your current requirements. Please feel free to contact me should you have any additional queries.

Yours sincerely,

Damon Roddis

Principal Consultant – Air Quality

Pacific Environment

References

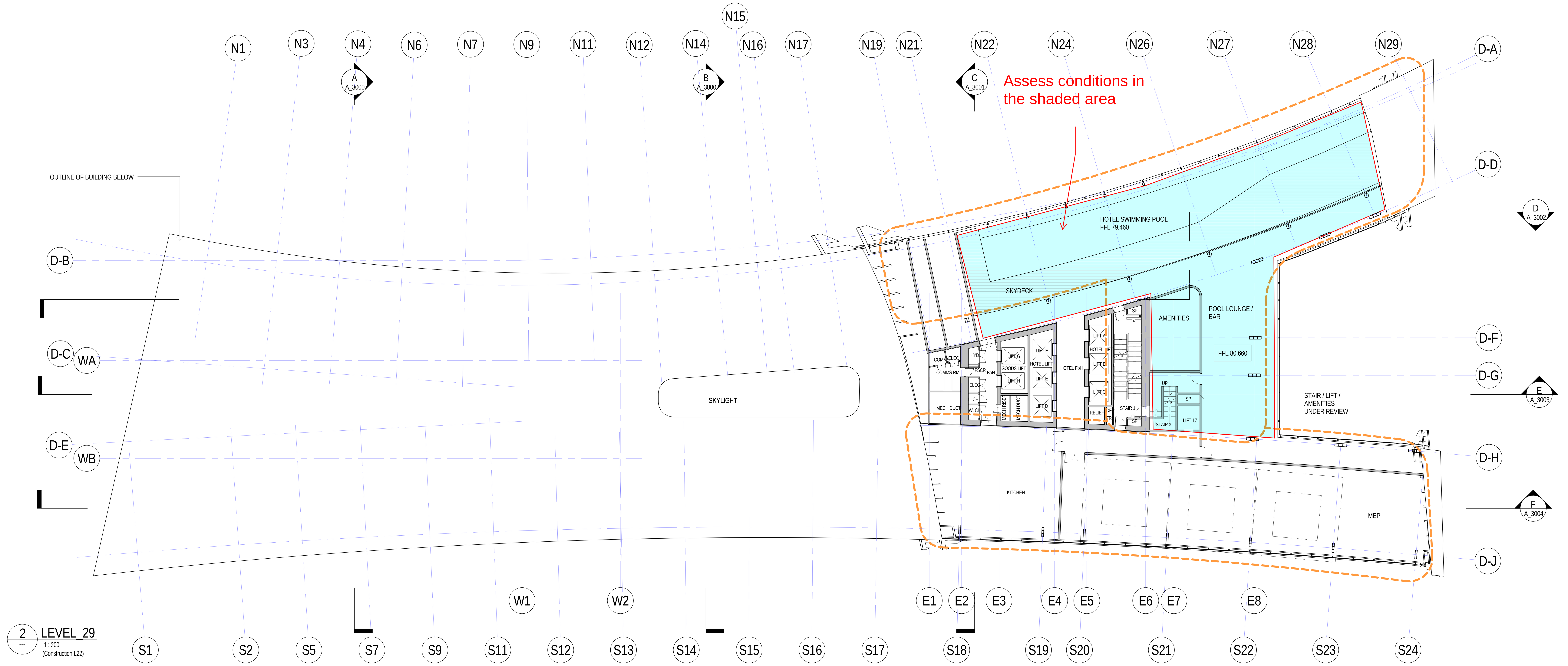
PE (2013) *Air Quality Impacts for Redevelopment of 31 Wheat Rd Revised Design*, Pacific Environment, August 2013.

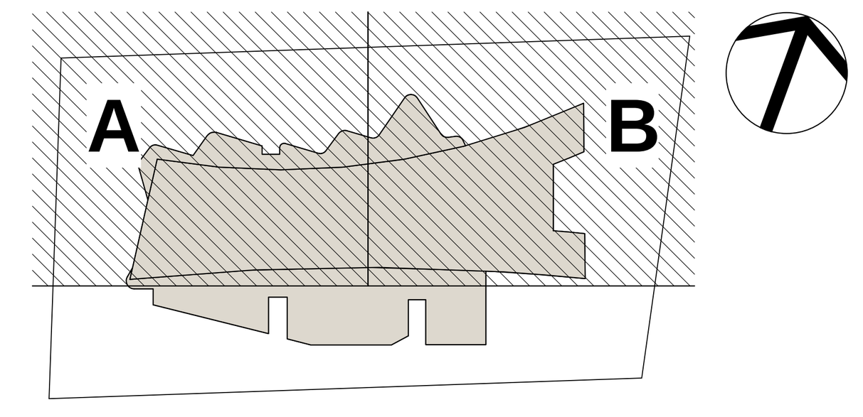
PE (2015) *The Ribbon Air Quality Assessment 2015 Revised Design*, Pacific Environment, November 2015.

PE (2016) *The Ribbon – Air Quality Assessment, Final Report,* Pacific Environment, 11 October 2016.

HAS (2008) *Air Quality Impact Assessment: The Integrated Generators Project*, Prepared for Department of Planning, Holmes Air Sciences, March 2008.

Attachment A General Layout Drawings





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GENERAL NOTES

1. DRAWINGS TO BE READ IN CONJUNCTION WITH INTERIOR DESIGN DRAWINGS AND SCHEDULES

AREA BOUNDED BY ORANGE DASHED LINE IS UNDER REVIEW

LEVEL 22 NOTES

MEP	UPDATE PENDING
DUMB WAITERS	TWO ARE TO BE ALLOWED FOR FROM LEVEL 22 TO 23
POOL	POOL EQUIPMENT ZONE PENDING

REV	DESCRIPTION	DATE
5	ISSUED FOR INFORMATION	31/10/2016
4	PRELIMINARY SERVICES COORDINATION	13/09/2016
3	INITIAL INFORMATION - DESIGN DEVELOPMENT	02/09/2016
2	ISSUED FOR SCHEMATIC DESIGN	30/06/2016
1	ISSUED FOR INFORMATION	17/06/2016
0	ISSUED FOR INFORMATION	03/06/2016

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HASSELL

CLIENT

Grocon

PROJECT

THE RIBBON HOTEL, SERVICED APARTMENTS AND RETAIL
31 WHEAT ROAD, SYDNEY

DRAWING TITLE

GA PLANS - L28 AND L29

(Construction L21 & L22)

STATUS

FOR INFORMATION

SCALE @ B1	DRAWN	CO-ORD	REVIEWED	APPROVED
1 : 200	HSL	ARC-HSL	MH	EL

PROJECT NUMBER	DRAWING NUMBER	REV
A004409	ARC-HSL- 1113	5

Original Sheet Size B1-1000 x 707mm

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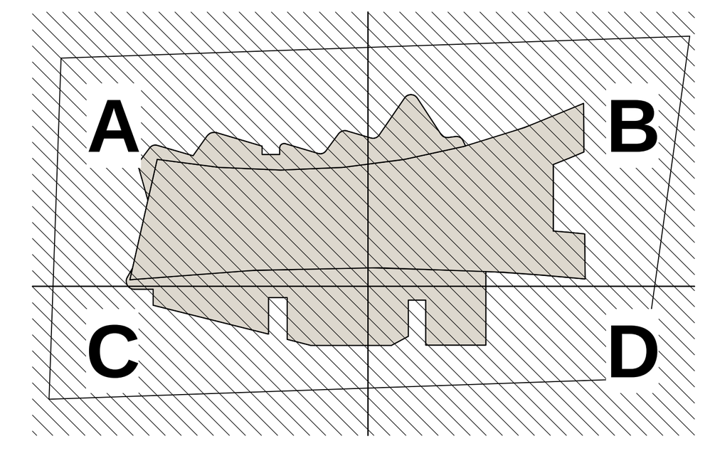
REFERENCE MAP



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GENERAL NOTES

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AREA BOUNDED BY ORANGE DASHED LINE IS UNDER REVIEW

REV	DESCRIPTION	DATE
2	ISSUED FOR INFORMATION	31/10/2016
1	ISSUED FOR SCHEMATIC DESIGN	30/06/2016
0	ISSUED FOR INFORMATION	03/06/2016

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PROJECT

THE RIBBON HOTEL, SERVICED APARTMENTS AND RETAIL
31 WHEAT ROAD, SYDNEY

DRAWING TITLE

SECTION D

STATUS

FOR INFORMATION

SCALE @ B1	DRAWN	CO-ORD	REVIEWED	APPROVED
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PROJECT NUMBER	DRAWING NUMBER	REV
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Attachment B 80m & 90m CFD Contour Plots – Scenarios 1-3

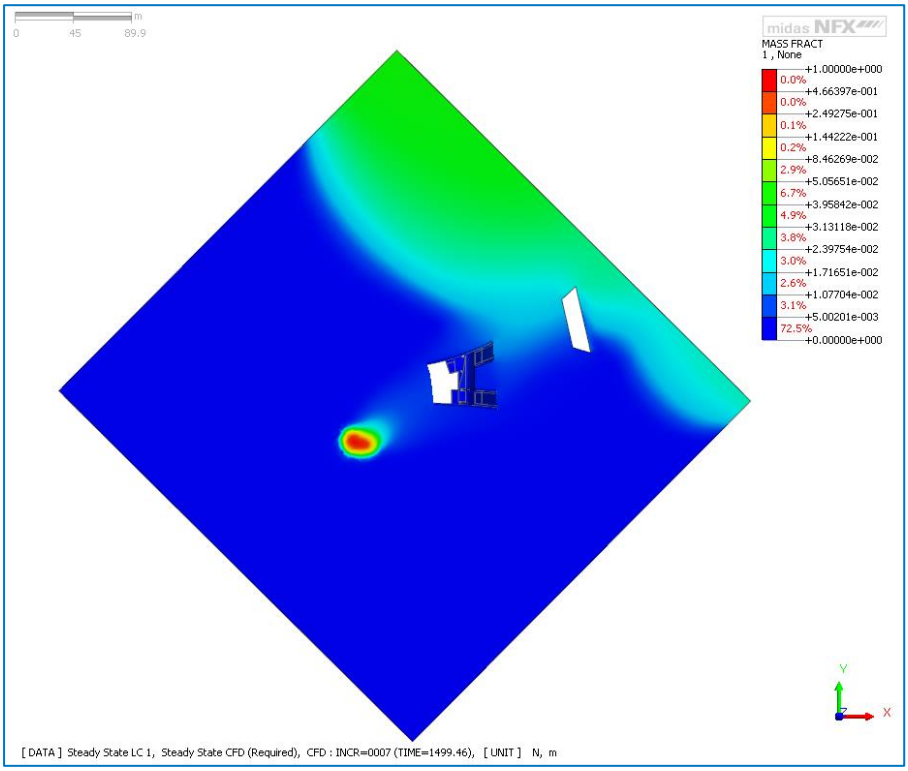

Figure B.1 CCTV mass fraction contour plot at 80 mAGL (Scenario 1)

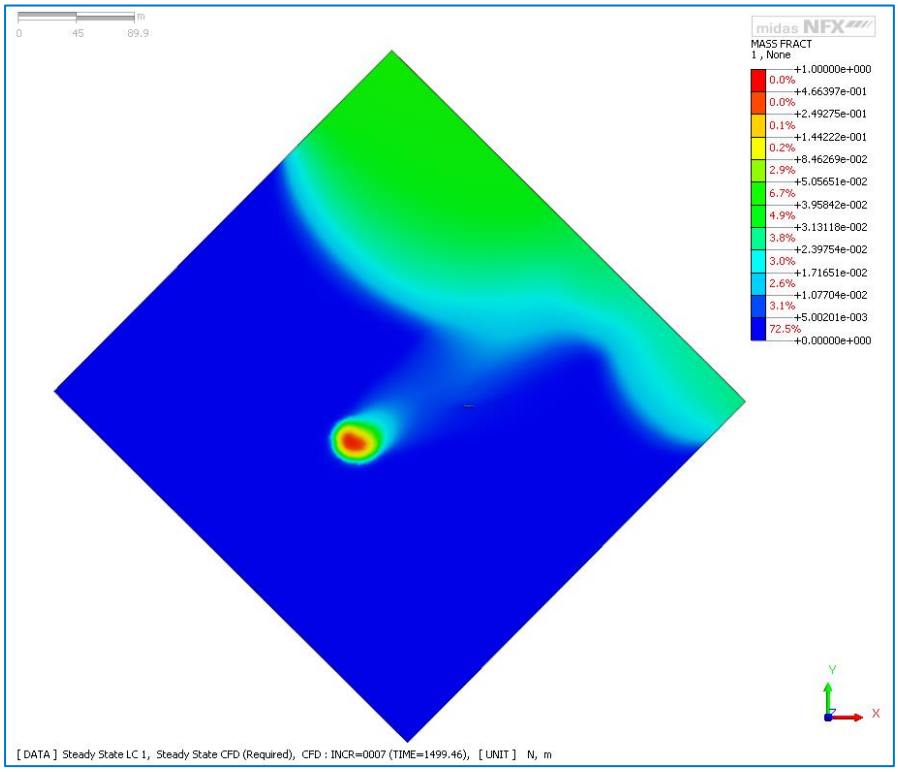

Figure B.2 CCTV mass fraction contour plot at 90 mAGL (Scenario 1)

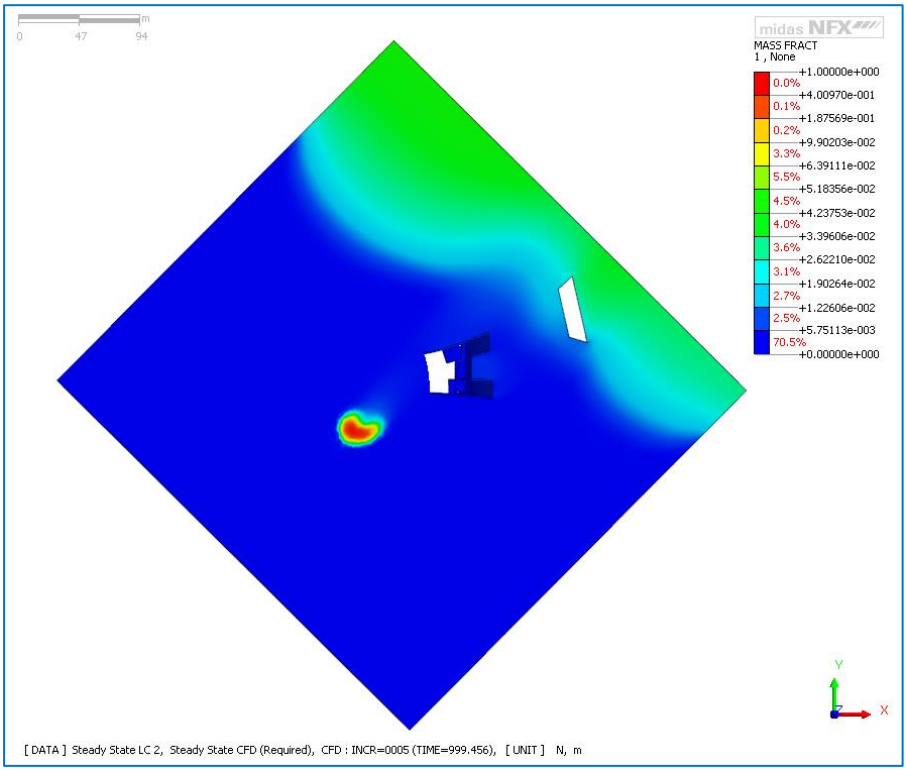

Figure B.3 CCTV mass fraction contour plot at 80 mAGL (Scenario 2)

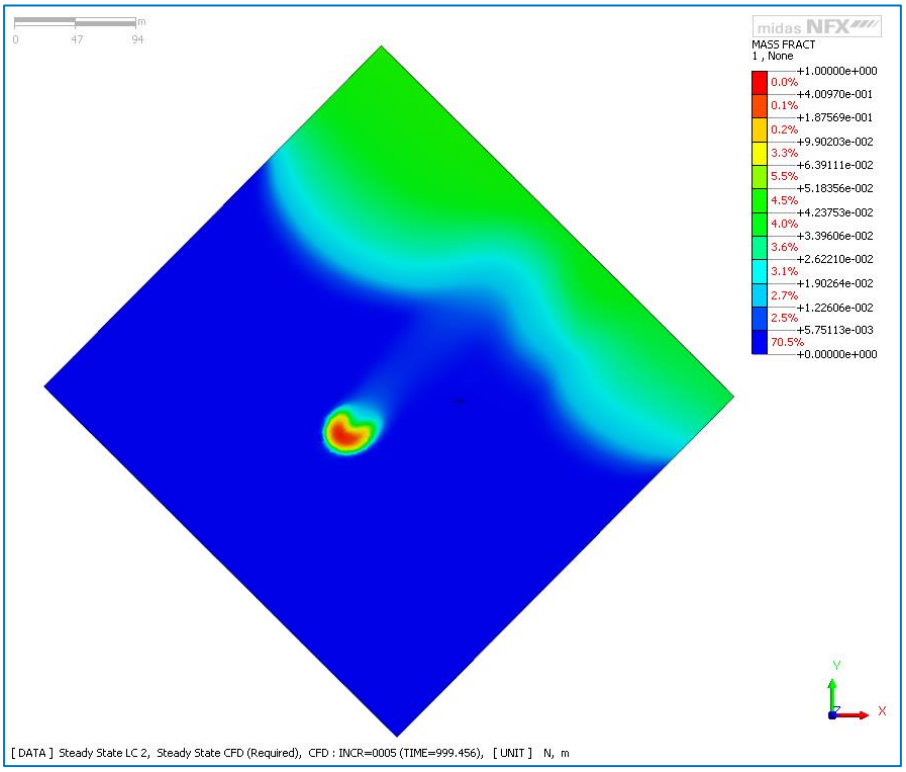

Figure B.4 CCTV mass fraction contour plot at 90 mAGL (Scenario 2)

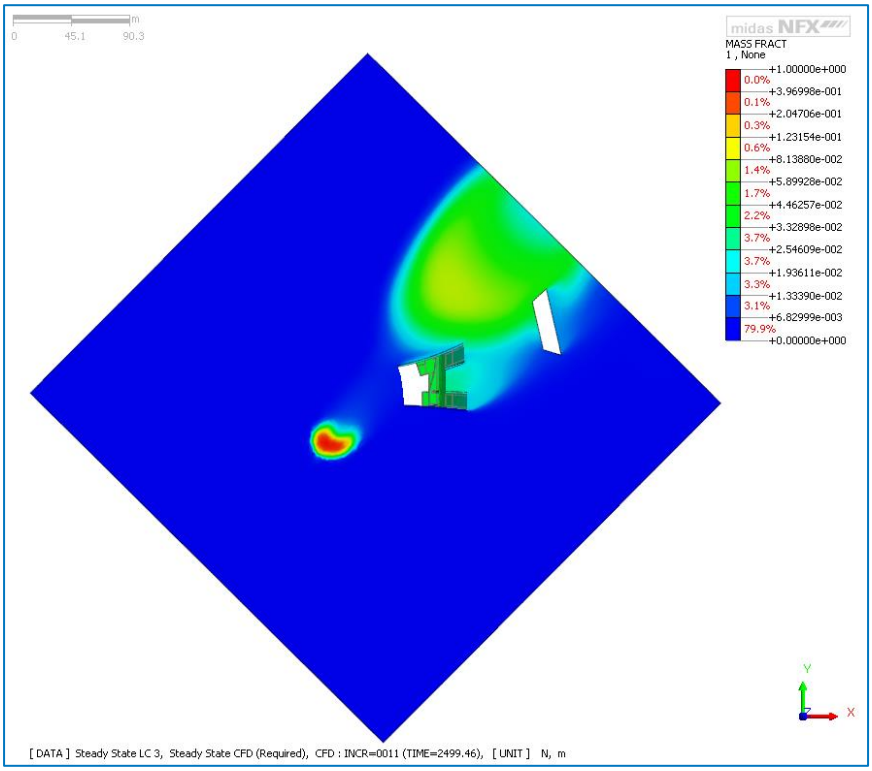

Figure B.5 CCTV mass fraction contour plot at 80 mAGL (Scenario 3)

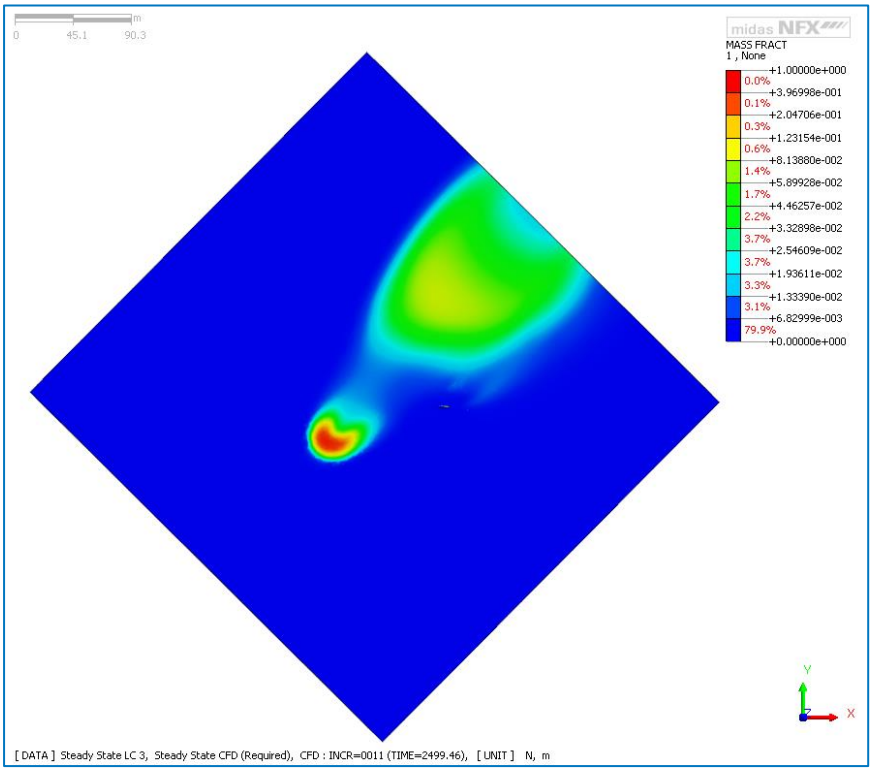

Figure B.6 CCTV mass fraction contour plot at 90 mAGL (Scenario 3)