Appendix 3.15

In-tunnel Air Quality Assessment

Calculations of NO$_2$ Concentration Inside the Two Sections of Road D2

KTD - Road D2 (normal case)

Tunnel Parameter

Tunnel length (m), L	= 214
Tunnel height (m), H	= 7
Tunnel width (m), W	= 48
Tunnel size (m2), At	= H * W 336
Equivalent diameter (m), dt	= (4*At/π)^0.5 20.68354
Effective length of the tunnel (m), Le	= L + 2*3*dt 338.1012

Emission Data

Traffic flow   =   1200 veh/hr

	Motor Cycles	Petrol PC &LGV	Taxi	Non-franchised Buses <6.4t	Non-franchised Buses 6.4-15t	Non-franchised Buses >15t	Private Light Buses <3.5t	Traffic Breakdown Private Light Buses >3.5t	Diesel PC&LGV <2.5t	Diesel LGV 2.5-3.5t	Diesel LGV >3.5t	HGV<15t	HGV>15t	Single Deck Franchised Buses	Double Deck Franchised Buses	Public Light Buses
% vehicle	0.08	0.37	0.37	0.00	0.05	0.00	0.00	0.01	0.00	0.03	0.04	0.04	0.00	0.00	0.01	0.01
NOx Emission Factor (g/mile-veh)	1.16	0.16	0.27	0.00	3.98	0.00	0.00	0.35	0.43	0.29	2.37	4.78	6.01	3.16	3.04	0.31

Total NO$_2$ emission rate   = total NO$_x$ emission factor x traffic flow x NO$_2$ conversion factor

Weighted NOX E.F. (g/km/veh)	=	0.467
Total NO$_2$ emission factor (g/m/s)	=	3.12E-05

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m	% vehicle	WxHx%veh
Motor Cycles	1.7	1.5	4.6	0.08	0.204
Petrol PC &LGV	1.7	1.5	4.6	0.37	0.941
Taxi	1.7	1.5	4.6	0.37	0.941
Non-franchised Buses <6.4t	2.5	3.5	12	0.00	0.000
Non-franchised Buses 6.4-15t	2.5	3.5	12	0.05	0.438
Non-franchised Buses >15t	2.5	3.5	12	0.00	0.000
Private Light Buses <3.5t	2	3	6.5	0.00	0.000
Private Light Buses >3.5t	2	3	6.5	0.01	0.060
Diesel PC&LGV <2.5t	2.1	1.6	5.2	0.00	0.000
Diesel LGV 2.5-3.5t	2.1	1.6	5.2	0.03	0.116
Diesel LGV >3.5t	2.1	1.6	5.2	0.04	0.120
HGV<15t	2.5	4.6	16	0.04	0.409
HGV>15t	2.5	4.6	16	0.00	0.000
Single Deck Franchised Buses	2.5	3.5	12	0.00	0.000
Double Deck Franchised Buses	2.5	4.6	12	0.01	0.128
Public Light Buses	2	3	6.5	0.01	0.034
			Nominal cross-sectional area A$_c$ =		3.389

* No dimensions for motor cycles and non-franchised buses are provided.
* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Number of lanes per direction, nl	= 2	
Equivalent cross-sectional area for each direction (m2), Av	=	6.77775
Equivalent diameter of vehicle (m), dv	= (4*Av/π)^0.5 = 2.937636	

Traffic density (traffic flow /s), N	= 0.333333
Average vehicle speed (m/s), v	= 50 km/hr = 13.88889
Head to head distance on a lane (m), l	= 2*nl*v/N = 166.6667

Diffusion Parameters

Reynolds number, Re	= (v*dv)/σ = 2615417	where σ = 15.6*10^-6

According to Figure 16 (Ohashi and Koso)

Since l / dt	= 8.057937
D / (N * dt^2 * Re^0.13)	= 0.33
Longitudinal diffusion coefficient (m2/s) , D	= 0.33 * (N * dt^2 * Re^0.13) = 321.31

Maximum Concentration of NO2

Cmax (µg/m3)	= w * Le^2 / (8 * D * At)
(without background)	= 4.1

Calculations of NO₂ Concentration inside the Two Sections of Road D2

KTD - Road D2 (worse case)

Tunnel Parameter

Tunnel length (m), L	=	214
Tunnel height (m), H	=	7
Tunnel width (m), W	=	48
Tunnel size (m2), At	=	H * W
		336
Equivalent diameter (m), dt	=	(4*At/π)^0.5
		20.68354
Effective length of the tunnel (m), Le	=	L + 2*3*dt
		338.1012

Emission Data

Traffic flow   =   1200 veh/hr

	Motor Cycles	Petrol PC &LGV	Taxi	Non-franchised Buses <6.4t	Non-franchised Buses 6.4-15t	Non-franchised Buses >15t	Private Light Buses <3.5t	Private Light Buses >3.5t	Diesel PC&LGV <2.5t	Diesel LGV 2.5-3.5t	Diesel LGV >3.5t	HGV<15t	HGV>15t	Single Deck Franchised Buses	Double Deck Franchised Buses	Public Light Buses
% vehicle	0.08	0.37	0.37	0.00	0.05	0.00	0.00	0.01	0.00	0.03	0.04	0.04	0.00	0.00	0.01	0.01
NOx Emission Factor (g/mile-veh)	1.02	0.21	0.38	0.00	5.97	0.00	0.00	0.53	0.60	0.42	3.42	7.04	8.68	5.84	5.53	0.47

(The "Traffic Breakdown" header spans across the Private Light Buses / Diesel columns)

Total NO₂ emission rate   = total NOx emission factor x traffic flow x NO₂ conversion factor

Weighted NOX E.F. (g/km/veh)	=	0.656
Total NO₂ emission factor (g/m/s)	=	4.37E-05

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m	% vehicle	WxHx%veh	Lx % vehicule
Motor Cycles	1.7	1.5	4.6	0.08	0.204	0.368
Petrol PC &LGV	1.7	1.5	4.6	0.37	0.941	1.697
Taxi	1.7	1.5	4.6	0.37	0.941	1.697
Non-franchised Buses <6.4t	2.5	3.5	12	0.00	0.000	0.000
Non-franchised Buses 6.4-15t	2.5	3.5	12	0.05	0.438	0.600
Non-franchised Buses >15t	2.5	3.5	12	0.00	0.000	0.000
Private Light Buses <3.5t	2	3	6.5	0.00	0.000	0.000
Private Light Buses >3.5t	2	3	6.5	0.01	0.060	0.065
Diesel PC&LGV <2.5t	2.1	1.6	5.2	0.00	0.000	0.000
Diesel LGV 2.5-3.5t	2.1	1.6	5.2	0.03	0.116	0.179
Diesel LGV >3.5t	2.1	1.6	5.2	0.04	0.120	0.185
HGV<15t	2.5	4.6	16	0.04	0.409	0.569
HGV>15t	2.5	4.6	16	0.00	0.000	0.000
Single Deck Franchised Buses	2.5	3.5	12	0.00	0.000	0.000
Double Deck Franchised Buses	2.5	4.6	12	0.01	0.128	0.134
Public Light Buses	2	3	6.5	0.01	0.034	0.036

Nominal cross-sectional area A_C =	3.389	m²
Equivalent length of each vehicle =	5.530	m

* No dimensions for motor cycles and non-franchised buses are provided.
* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Number of lanes per direction, nl	=	2
Equivalent cross-sectional area for each direction (m2), Av	=	6.77775
Equivalent diameter of vehicle (m), dv	=	(4*Av/π)^0.5
	=	2.937636

Distance between vehicle (m)	=	1 (worst case)
Head to head distance on a lane (m), l	=	6.530
Traffic density (traffic flow /s), N	=	0.333333
Average vehicle speed (m/s), v	=	l*N/(2*nl)
	=	0.544158

Diffusion Parameters

Reynolds number, Re	=	(v*dv)/σ where σ = 15.6*10^-6
	=	102470.3
According to Figure 16 (Ohashi and Koso)		
Since l / dt	=	0.315705
D / (N * dt^2 * Re^0.13)	=	0.15
Longitudinal diffusion coefficient (m2/s) , D	=	0.15 * (N * dt^2 * Re^0.13)
	=	95.85

Maximum Concentration of NO2

Cmax (μg/m3)	=	w * Le^2 / (8 * D * At)
(without background)	=	19.4

Calculations of NO$_2$ Concentration inside the Two Sections of Road D2

KTD - Road D2   (Overall concentrations)

Nine assessment points (ASRs AIT1-9) at the boundary of the full enclosure are chosen.
Using CALINE4 and ISCST3 model, the NO2 concentrations at the 9 assessment points at different levels are calculated.
The highest concentration among the four assessment points is assumed to be the background
NO2 concentration inside the full enclosure section.

Elevation (mAG)	NO2 Concentrations (ug/m3) at Various Levels		
	0.0	3.5	7.5
AIT1	50	47	44
AIT3	50	47	45
AIT4	61	57	48
AIT6	60	57	52
AIT7	49	48	41
AIT9	68	63	57

Therefore, the background concentration inside the full enclosure section is   68   ug/m3.

Overall Maximum NO2 concentration inside
the full enclosure section (Normal Speed)   =   4.1 + 68
                                                     =   72   ug/m3

Overall Maximum NO2 concentration inside
the full enclosure section (Worse Case)   =   19.4 + 68

                                                     =   87   ug/m3

Calculations of NO$_2$ Concentration inside the Two Sections of Road L1

KTD - Road L1   (normal case)

Tunnel Parameter

Tunnel length (m), L	=	243
Tunnel height (m), H	=	7
Tunnel width (m), W	=	9
Tunnel size (m2), At	=	H * W
		63
Equivalent diameter (m), dt	=	(4*At/π)^0.5
		8.956236
Effective length of the tunnel (m), Le	=	L + 2*3*dt
		296.7374

Emission Data

Traffic flow   =   1020 veh/hr

	Motor Cycles	Petrol PC &LGV	Taxi	Non-franchised Buses <6.4t	Non-franchised Buses 6.4-15t	Non-franchised Buses >15t	Private Light Buses <3.5t	Traffic Breakdown Private Light Buses >3.5t	Diesel PC&LGV <2.5t	Diesel LGV 2.5-3.5t	Diesel LGV >3.5t	HGV<15t	HGV>15t	Single Deck Franchised Buses	Double Deck Franchised Buses	Public Light Buses
% vehicle	0.07	0.34	0.34	0.00	0.05	0.00	0.00	0.01	0.01	0.07	0.05	0.06	0.00	0.00	0.00	0.00
NOx Emission Factor (g/mile-veh)	1.16	0.16	0.27	0.00	3.98	0.00	0.00	0.35	0.43	0.29	2.37	4.78	6.01	3.16	3.04	0.31

Total NO$_2$ emission rate   = total NO$_X$ emission factor x traffic flow x NO$_2$ conversion factor

Weighted NOX E.F. (g/km/veh)	=	0.531
Total NO$_2$ emission factor (g/m/s)	=	3.01E-05

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m	% vehicle	WxHx%veh
Motor Cycles	1.7	1.5	4.6	0.07	0.179
Petrol PC &LGV	1.7	1.5	4.6	0.34	0.869
Taxi	1.7	1.5	4.6	0.34	0.869
Non-franchised Buses <6.4t	2.5	3.5	12	0.00	0.000
Non-franchised Buses 6.4-15t	2.5	3.5	12	0.05	0.438
Non-franchised Buses >15t	2.5	3.5	12	0.00	0.000
Private Light Buses <3.5t	2	3	6.5	0.00	0.000
Private Light Buses >3.5t	2	3	6.5	0.01	0.060
Diesel PC&LGV <2.5t	2.1	1.6	5.2	0.01	0.033
Diesel LGV 2.5-3.5t	2.1	1.6	5.2	0.07	0.233
Diesel LGV >3.5t	2.1	1.6	5.2	0.05	0.166
HGV<15t	2.5	4.6	16	0.06	0.683
HGV>15t	2.5	4.6	16	0.00	0.000
Single Deck Franchised Buses	2.5	3.5	12	0.00	0.000
Double Deck Franchised Buses	2.5	4.6	12	0.00	0.000
Public Light Buses	2	3	6.5	0.00	0.000
			Nominal cross-sectional area A$_C$ =		3.530

* No dimensions for motor cycles and non-franchised buses are provided.
* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Number of lanes per direction, nl	=	1
Equivalent cross-sectional area for each direction (m2), Av	=	3.530344
Equivalent diameter of vehicle (m), dv	=	(4*Av/π)^0.5
	=	2.120136
Traffic density (traffic flow /s), N	=	0.283333
Average vehicle speed (m/s), v	=	50 km/hr
	=	13.88889
Head to head distance on a lane (m), l	=	2*nl*v/N
	=	98.03922

Diffusion Parameters

Reynolds number, Re	=	(v*dv)/σ	where σ = 15.6*10^-6
	=	1887586	
According to Figure 16 (Ohashi and Koso)			
Since l / dt	=	10.94648	
D / (N * dt^2 * Re^0.13)	=	0.33	
Longitudinal diffusion coefficient (m2/s) , D	=	0.33 * (N * dt^2 * Re^0.13)	
	=	49.08	

Maximum Concentration of NO2

Cmax (µg/m3)	=	w * Le^2 / (8 * D * At)
(without background)	=	107.1

Calculations of NO$_2$ Concentration inside the Two Sections of Road L1

KTD - Road L1   (worse case)

Tunnel Parameter

Tunnel length (m), L	=	243
Tunnel height (m), H	=	7
Tunnel width (m), W	=	9
Tunnel size (m2), At	= H * W	63
Equivalent diameter (m), dt	= (4*At/π)^0.5	8.956236
Effective length of the tunnel (m), Le	= L + 2*3*dt	296.7374

Emission Data

Traffic flow   =   1020 veh/hr

	Motor Cycles	Petrol PC &LGV	Taxi	Non-franchised Buses <6.4t	Non-franchised Buses 6.4-15t	Non-franchised Buses >15t	Private Light Buses <3.5t	Private Light Buses >3.5t	Diesel PC&LGV <2.5t	Diesel LGV 2.5-3.5t	Diesel LGV >3.5t	HGV<15t	HGV>15t	Single Deck Franchised Buses	Double Deck Franchised Buses	Public Light Buses
% vehicle	0.07	0.34	0.34	0.00	0.05	0.00	0.00	0.01	0.01	0.07	0.05	0.06	0.00	0.00	0.00	0.00
NOx Emission Factor (g/mile-veh)	1.02	0.21	0.38	0.00	5.97	0.00	0.00	0.53	0.60	0.42	3.42	7.04	8.68	5.84	5.53	0.47

Total NO$_2$ emission rate   = total NO$_x$ emission factor x traffic flow x NO$_2$ conversion factor

Weighted NOX E.F. (g/km/veh)	=	0.746
Total NO$_2$ emission factor (g/m/s)	=	4.23E-05

Vehicle Data

Nominal dimensions of vehicles are given in Transport Planning and Design Manual, Vol. 2 as:

	W /m	H /m	L /m	% vehicle	WxHx%vel	Lx % vehicule
Motor Cycles	1.7	1.5	4.6	0.07	0.179	0.323
Petrol PC &LGV	1.7	1.5	4.6	0.34	0.869	1.568
Taxi	1.7	1.5	4.6	0.34	0.869	1.568
Non-franchised Buses <6.4t	2.5	3.5	12	0.00	0.000	0.000
Non-franchised Buses 6.4-15t	2.5	3.5	12	0.05	0.438	0.600
Non-franchised Buses >15t	2.5	3.5	12	0.00	0.000	0.000
Private Light Buses <3.5t	2	3	6.5	0.00	0.000	0.000
Private Light Buses >3.5t	2	3	6.5	0.01	0.060	0.085
Diesel PC&LGV <2.5t	2.1	1.6	5.2	0.01	0.033	0.050
Diesel LGV 2.5-3.5t	2.1	1.6	5.2	0.07	0.233	0.361
Diesel LGV >3.5t	2.1	1.6	5.2	0.05	0.166	0.257
HGV<15t	2.5	4.6	16	0.06	0.683	0.951
HGV>15t	2.5	4.6	16	0.00	0.000	0.000
Single Deck Franchised Buses	2.5	3.5	12	0.00	0.000	0.000
Double Deck Franchised Buses	2.5	4.6	12	0.00	0.000	0.000
Public Light Buses	2	3	6.5	0.00	0.000	0.000

Nominal cross-sectional area A$_c$ =   3.530 m^2

Equivalent length of each vehicle =   5.743 m

* No dimensions for motor cycles and non-franchised buses are provided.
* For the purpose of this study, the dimensions of motor cycles and taxi are assumed to be the same as private car and the dimension of non-franchised buses are assumed to be the same as single deck franchised buses.

Number of lanes per direction, nl	=	1
Equivalent cross-sectional area for each direction (m2), Av	=	3.530344
Equivalent diameter of vehicle (m), dv	= (4*Av/π)^0.5	2.120136

Distance between vehicle (m)	= 1	(worst case)
Head to head distance on a lane (m), I	= 6.743	
Traffic density (traffic flow /s), N	= 0.283333	
Average vehicle speed (m/s), v	= I*N/(2*nl)	
	= 0.955317	

Diffusion Parameters

Reynolds number, Re	= (v*dv)/σ	where σ = 15.6*10^-6
	= 129833.4	

According to Figure 16 (Ohashi and Koso)

Since I / dt	= 0.752929	
D / (N * dt^2 * Re^0.13)	= 0.15	
Longitudinal diffusion coefficient (m2/s) , D	= 0.15 * (N * dt^2 * Re^0.13)	
	= 15.75	

Maximum Concentration of NO2

Cmax (μg/m3)	= w * Le^2 / (8 * D * At)	
(without background)	= 468.8	

Calculations of NO$_2$ Concentration inside the Two Sections of Road L1

KTD - Road L1 (Overall concentrations)

Six assessment points (AIT10-15) at the boundary of the Road L1 are chosen.
Using CALINE4 and ISCST3 model, the NO2 concentrations at the 6 assessment points at different levels are calculated.
The highest concentration among the four assessment points is assumed to be the background
NO2 concentration inside the full enclosure section.

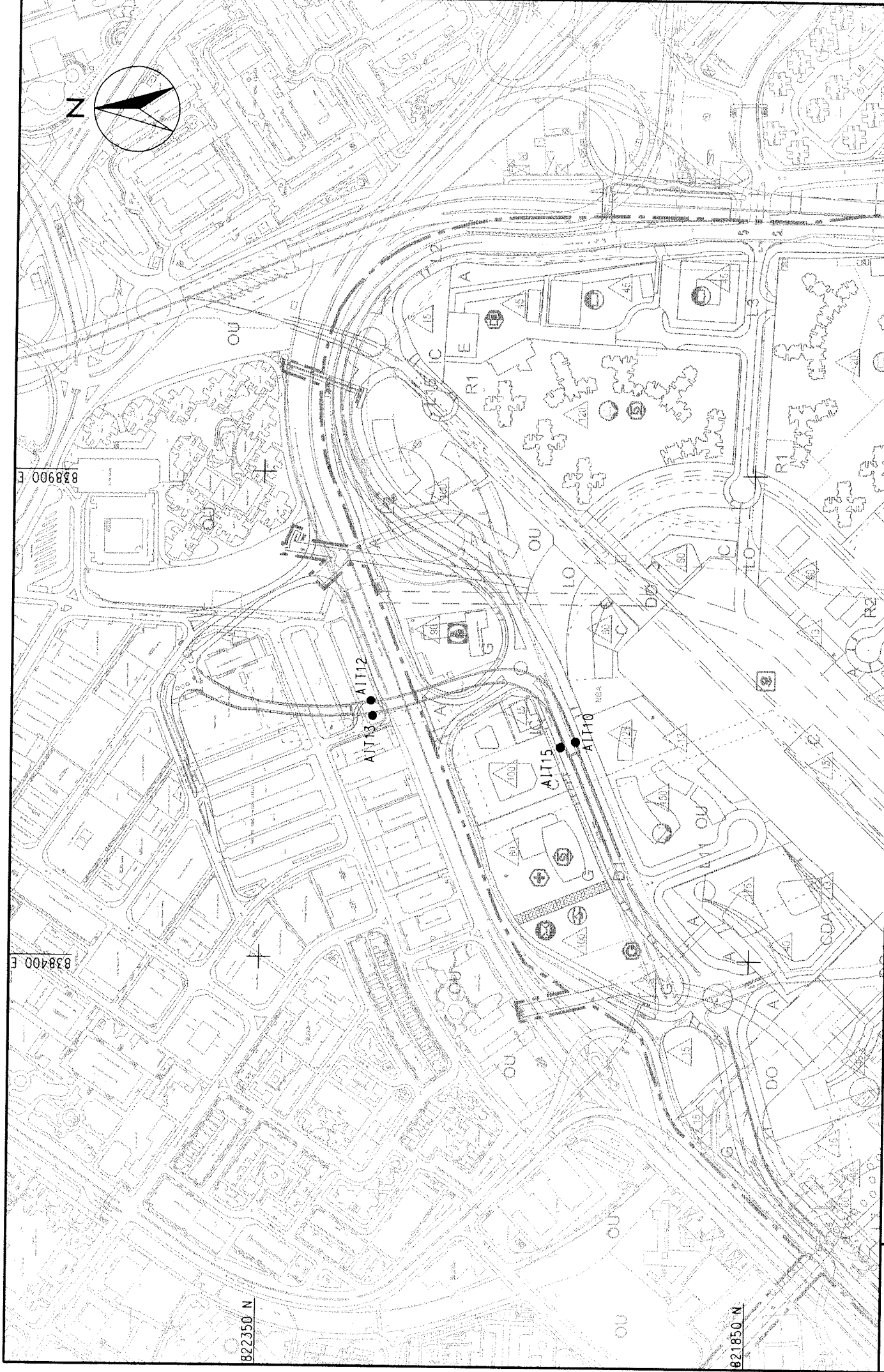| Elevation	NO2 Concentrations (ug/m3) at Various Levels		
(mAG)	0.0	3.5	7.5
AIT10	59	51	45
AIT12	58	56	53
AIT13	64	54	48
AIT15	74	62	53

Therefore, the background concentration inside the full enclosure section is   74   ug/m3.

**Overall Maximum NO2 concentration inside
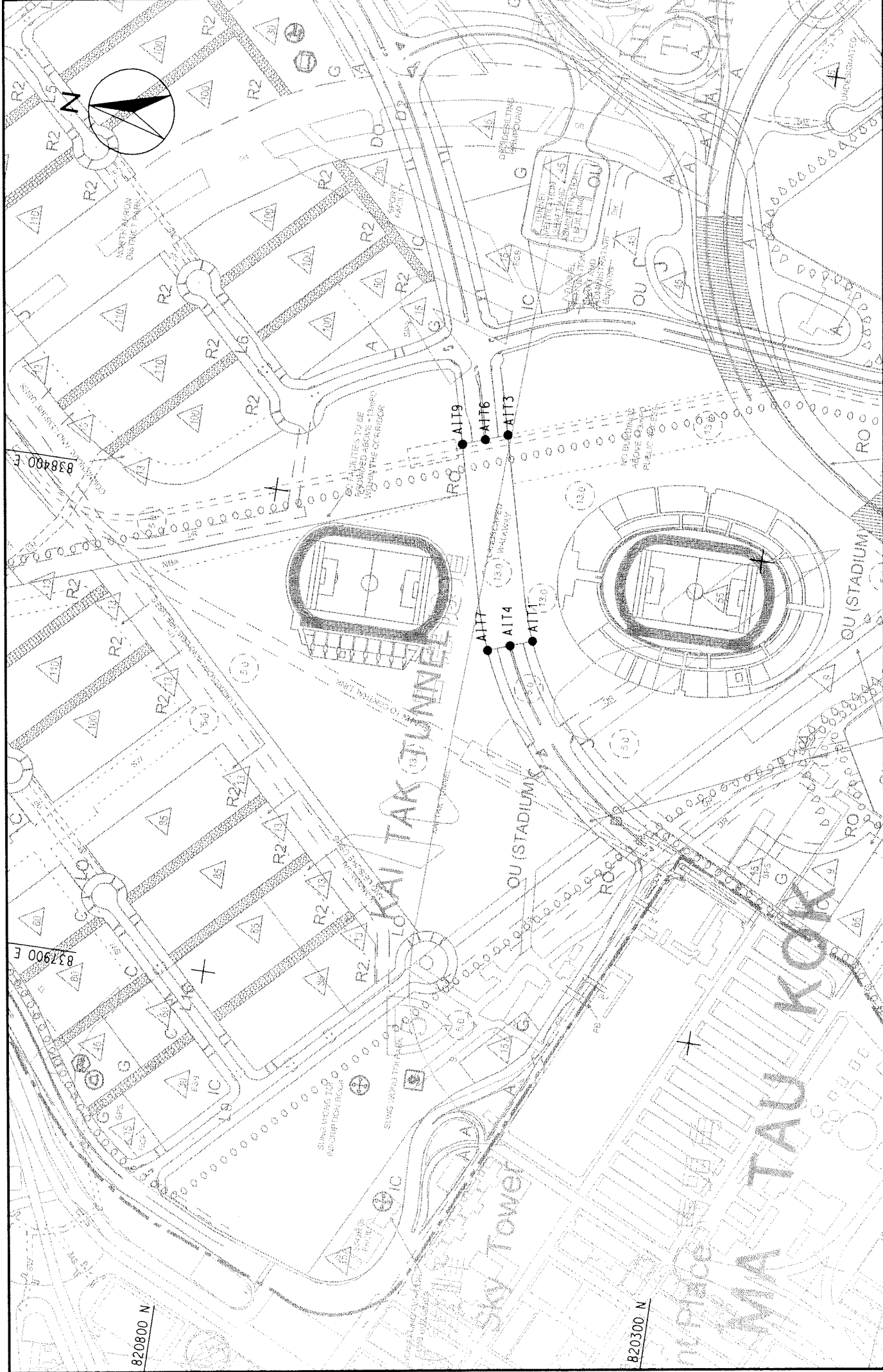the full enclosure section (Normal Speed)**   =   107.1 + 74

                                               =   181   ug/m3

**Overall Maximum NO2 concentration inside
the full enclosure section (Worse Case)**   =   468.8 + 74

                                               =   543   ug/m3

DESIGNATED ASSESSMENT POINTS FOR ROAD L1 TUNNEL

KAI TAK DEVELOPMENT ENGINEERING STUDY CUM DESIGN AND
CONSTRUCTION OF ADVANCE WORKS-INVESTIGATION, DESIGN AND CONSTRUCTION
AGREEMENT NO. CE 35/2006 (CE)

MAUNSELL AECOM

Maunsell Consultants Asia Ltd

SCALE	A4 1:5000	DATE	JUN. 2008	
CHECK		DRAWN	JY	
JOB NO.	60022503	DRAWING NO.	APPENDIX 3.15	REV -

(SHEET 2 OF 2)

AIT12
AIT13
AIT15
AIT10

N

838400 E

837900 E

820800 N

820300 N

A119
A116
A113
A117
A114
A111

KAI TAK (TUNNEL)

OU (STADIUM)

OU (STADIUM)

MA TAU KOK

Sky Tower

SCALE	DATE
A4 1:5000	JUN. 2008
CHECK	DRAWN LCR
	DRAWING NO. REV
JOB NO.	APPENDIX 3.15 –

60022503