HARBORD DIGGERS REDEVELOPMENT, FRESHWATER, NSW 2096

Fire Engineering Report

Rev 04

1/08/2017

2301602A (FEG144400)

Quality Management

Issue History

Revision	Remarks
Rev 0	Issued for stakeholder review, comments & consideration.
Rev 1	Incorporating Appendix J – Third Party Peer Review feedback.
Rev 2	Drawings updated and additional alternative solutions AS13 and AS14 included.
Rev 3	Updated incorporating FRNSW IFSR comments
Rev 4	Updated to include Peer Review comments

QA History

Revision	Rev 0	Rev 1	Rev 2	Rev 3	Rev 4
Date	5/11/2015	08/07/2016	27/01/2017	04/04/2017	01/08/2017
Prepared by	Michael Lawless	Daniel Yun	Graham Ryan	Graham Ryan	Graham Ryan
Checked by	Hay Sun Blunt	Michael Lawless (NSW C10 BPB 2726)	Dan Kirk Hay Sun Blunt	Dan Kirk	Dan Kirk
Authorised by	Wayne Bretherton	Wayne Bretherton (NSW C10 BPB 1876)	Wayne Bretherton (NSW C10 BPB 1876)	Dan Kirk (NSW C10 BPB 2952)	Dan Kirk (NSW C10 BPB 2952)
Signature					

Harbord Diggers Redevelopment, Freshwater, NSW 2096

Fire Engineering Report

Rev 04

1/08/2017

Client

Mounties Group
101 Meadows Road
Mount Pritchard NSW 2170.
c/o Cerno Management

WSP | Parsons Brinckerhoff Office

Level 27, Ernst & Young Centre
680 George Street
Sydney NSW 2000
Australia

Tel: 02 8907 0900
www.wspgroup.com.au

Registered Company

WSP Buildings (Pty) Ltd
ABN: 47 005 113 468
Sydney
www.wspgroup.com.au

WSP | Parsons Brinckerhoff Contacts

Dan Kirk
Associate Fire Engineer, NSW Team Manager
Mob: 0415 314 412
Dan.Kirk@wspgroup.com

References used in the FER

Please note that the abbreviated text enclosed in [ ] refers to a referenced document which is described in full in the Reference Section of this report (Section 21) which is noted to be presented in alphabetical order.

Executive Summary

WSP Buildings Pty Ltd has been appointed by Mounties Group to undertake fire engineering services associated with the proposed Harbord Diggers Redevelopment located at 80 Evans Street, Freshwater NSW 2096.

The objective of this Fire Engineering Report (FER) is to acknowledge any departures from the Building Code of Australia (BCA) Deemed to Satisfy (DtS) Provisions within the proposed development and to present a way forward for each, to ensure compliance with the relevant BCA Performance Requirements.

The non-compliances with the prescriptive provisions of the BCA listed in Table 1 have been identified and are to be addressed as Alternative Solutions within this report. The non-compliances listed have been identified in Section 8.3 of the BCA Report prepared by Steve Watsons & Partners as detailed in Table 5.

Table 1: Alternative Solutions addressed within this report

No.	Description of Alternative Solution	BCA Clause	Performance Requirement	BCA (A0.5)	BCA (0.9)
AS1	To permit horizontal separation of openings in the external wall of the Buildings A, B, C, D, E & F not to meet the spatial requirements given in BCA Clause C2.6 for a building of Type A Construction.	C2.6	CP2	(b)(ii)	(b)(ii) (c)
AS2	To permit glazed wall & doors to form part of a required fire wall (separation of building classifications & different fire compartments within at basement levels only) and not be provided with the required FRL.	C2.7 & C3.5	CP2 and CP4	(b)(i)	(c)
	To permit glazed elements at Lower Ground Floor Level to form part of a fire wall (separation of compartments) and be protected by a proprietary wall wetting system providing the required FRL.				
AS3	To permit unprotected openings (in Building F only) to be within 3 m of the side boundary that adjoins the public reserve by way of registering an easement or similar incumbent on the neighbouring land.	C3.2, C3.4	CP2	(b)(i)	(b)(ii)
AS4	To permit extended travel distances of up to 13 m to a single exit in lieu of the permissible 6 m in the Class 2 residential corridor areas of the development (in Buildings A, B, D, E & F).	D1.4	DP4 & EP2.2	(b)(ii)	(c)
	To permit an extended travel distance of up to 30 m in lieu of the permissible 20 m to the single exit serving the storey at the level of egress (Upper Ground Floor Level).				
	To permit Buildings A, B & D to be served by non-fire isolated stairways that do not provide a continuous means of travel by way of its own flights and landings.	D1.9(a)			
AS5	To permit the following extended travel distances to an exit in the Class 7a areas (Basement Levels 2 & 1); Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice of exits, Up to 60 m in lieu of permissible 40 m in reaching an alternative exit. Up to 95 m in lieu of the permissible 60 m between alternative exits.	D1.4(c) & D1.5	DP4 & EP2.2	(b)(ii)	(c)

No.	Description of Alternative Solution	BCA Clause	Performance Requirement	BCA (A0.5)	BCA (0.9)
	To permit an extended travel distance of 38 m in lieu of the permissible 20 m to the single exit within the loading dock area at Lower Ground Floor Level.	D1.4(c)			
	To permit an extended travel distance of 34 m in lieu of the permissible 20 m to a point of choice in the Cinema Room on Basement Level 2.				
AS6	To permit the following extended travel distances to an exit in the Class 9b areas (Lower & Upper Ground Floor Levels); Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice in exits, Up to 60 m in lieu of permissible 40 m in reaching an alternative exit. Up to 80 m in lieu of the permissible 60 m between alternative exits.	D1.4(c) & D1.5	DP4 & EP2.2	(b)(ii)	(c)
	It is noted that the travel distances identified above for the Class 9b areas have been based on guidance provided by the PCA, with the 25 m, 60 m & 80 m being the upper limitation permitted as part of the building design.				
AS7	To permit the path of travel from the discharge point of the fire-isolated stair serving Building E to pass within 6 m of the glazed facade of the Gym on the upper ground floor.	D1.7	DP4, DP5 & EP2.2	(b)(i)	(b)(ii)
	To permit the path of travel from the discharge point of the fire-isolated stairs serving Building F to pass within 6 m of the glazed facade of the Café or the Seniors Lobby on the upper ground floor.				
	To permit the fire-isolated stairs serving Buildings E & F not to discharge to an open space.				
	To permit the fire-isolated passageway which provides access to the hydrant tank and pump room to have multiple doors opening onto the passageway without the exit being pressurised.	D1.7(d)			
	To permit paths of travel on the Upper Ground Floor Level (applicable to Buildings D, E & F) to pass within 3 m of the openings associated with the Palm Gully and the Void space.	D2.12			
AS8	To permit the discharge of exits to an under croft space that is not open to the sky. This is applicable to exits that discharge into the following areas; Porte Cochere at Lower Ground Floor Level Undercroft area to the north of the club Building E overhang at Upper Ground Floor Level	D1.10	DP4 & EP2.2	(b)(i)	(b)(ii)
AS9	To permit the fire hydrant pump room not to be accessed directly from a road or open space. The fire-isolated passageway which leads to the pump room shall be accessed directly from a covered space.	E1.3 & Cl.6.4.2 of AS 2419.1	EP1.3, EP1.6 & EP2.2	(b)(i)	(b)(ii)

No.	Description of Alternative Solution	BCA Clause	Performance Requirement	BCA (A0.5)	BCA (0.9)
	To permit the Fire Sprinkler Pump & Control Valve room be located in a room that is not directly accessed from a road or open space.	Cl.6 of Spec.E1.5			
	To permit the FIP to be located in a room that is not directly accessed from a road or open space.	Cl.3 of Spec.E1.8			
	To permit the fire hydrant booster not to be shielded with FRL 90/90/90 construction from openings within 2 m of the booster.	E1.3 & Cl. 7.3 of AS 2419.1.			
AS10	To permit the fire hydrant system to be designed to have a minimum of 2 outlets (each with 10 l/s capacity) operating simultaneously in lieu of the required 3 outlets required for a fire compartment >10,000 m2 (specific to the Class 7a areas).	E1.3 & Table 2.1 of AS 2419.1	EP1.3	(b)(i)	(b)(ii)
AS11	To permit smoke detection for ventilation shutdown to be omitted from the high ceilinged indoor pool area (Aquatic Centre).	E2.2 & Spec E2.2a, NSW Table E2.2b	EP2.2	(b)(i)	(b)(ii)
	To permit the omission of fire hose reels to the indoor pool area with a view to providing additional hand held fire extinguishers.	E1.4	EP1.1		
	To permit the omission of sprinkler coverage to the indoor pool area only	E1.5	EP1.4		
	To permit the omission of a required fire wall which separates sprinklered and non-sprinklered areas	Clause 3 of Spec E1.5 inter alia AS 2118.1	CP2 & EP1.4		
AS12	To permit an impulse fan ventilation system in the basement car parks in lieu of a traditional ducted ventilation system.	E1.5, E2.2 and F4.11	EP1.4; EP2.2 and FP4.4	(b)(i)	(b)(ii)
AS13	Allow the Fire Control Centre to be located >300 mm above ground level.	E1.8 and Spec E1.8	EP1.6	(b)(i)	(b)(ii)
AS14	To permit stair 5 to indirectly connect more than four storeys	D1.12	CP2 & EP 2.2	(b)(ii)	(c)

The assessment of an Alternative Solution can be undertaken using a variety of methods which is defined in Clause A0.9 of the BCA. Compliance with Performance Requirements is undertaken in accordance with A0.5 of the BCA. Refer to Table 2 of this report for clarity on meeting the Performance Requirements and Assessment Methods for the Alternative Solutions.

Refer to Appendix A for details of the relevant BCA Clause & Performance Requirement(s) and IFEG Sub-system(s) applicable to each of the identified Alternative Solutions.

All aspects of the design are understood to be in accordance with the DtS provisions of the BCA except where modified by the Alternative Solutions above. The assessments in this FER are intended to demonstrate that the aforementioned Alternative Solutions meet the relevant Performance Requirements of the BCA subject to the requirements detailed in the Proposed Fire Safety Measures detailed in Section 6.

➢ Abbreviations used in this report

The following abbreviations are used in this report.

Abbreviation	Description
AFL	Above Floor level
PCA	Principal Certifying Authority
AHJ	Authority-having-Jurisdiction
BCA	Building Code of Australia
BOH	Back-of-house
CFD	Computational fluid dynamics
DtS	Deemed-to-Satisfy
EWIS	Emergency Warning and Intercommunication System
SSISEP	Sound Systems and Intercom Systems for Emergency Purposes
FCC	Fire Control Centre
FIP	Fire Indicator Panel
FFCP	Fire Fan Control Panel
FER	Fire Engineering Report
FEBQ	Fire Engineering Brief Questionnaire
FH	Fire Hydrant
FRL	Fire Resistance Levels
FHR	Fire Hose Reel
HRR	Heat release rate
HRRPUA	Heat release rate per unit area
HVAC	Heating, Ventilation and Air-conditioning
IFEG	International Fire Engineering Guidelines
MIUP	Management in Use Plan
POC	Point-of-choice
TD's	Travel Distances
ASET	Available Safe Egress Time
RSET	Required Safe Egress Time
RTI	Response Time Index

Table of Contents

1. Introduction

1.1 Appointment

WSP | PB has been appointed by Mounties Group to undertake a fire engineering assessment for the proposed Harbord Diggers Redevelopment located at 80 Evans Street, Freshwater NSW 2096.

1.2 Report applicability

This report addresses only the identified Alternative Solutions. All other aspects of the design, with regard to fire life safety, are assumed to be compliant with the Building Code of Australia [BCA].

This report is for the use of Mounties Group and the design team on this scheme. It should not be used in full or in part to support any other scheme and WSP | PB will not accept any responsibility for matters arising as a result of its misuse. Developments in the design of the building may invalidate the proposals of this scheme therefore the report will need to be updated if the scheme changes.

The findings and opinions expressed within this report are based on the conditions encountered and / or the information available at the date of issue of this document, and shall be applicable only to the circumstances envisaged herein.

1.3 Applicable legislation

The primary legislation applicable to the development is the BCA 2015: Building Code of Australia (BCA). The BCA provides a set of prescriptive DtS Provisions which, if adhered to, are considered to provide an acceptable level of safety and compliance with the Performance Requirements of the BCA. Deviations from the DtS Provisions must also be shown to comply with the Performance Requirements of the BCA. The analysis of these deviations is called an Alternative Solution.

The assessment of an Alternative Solution can be undertaken using a variety of methods. These are defined in Clause A0.9 of the BCA. One or more of these methods are adopted to determine whether the Alternative Solution complies with the Performance Requirements of the BCA. The relevant Performance Requirements are determined in accordance with Clause A0.10 of the BCA. Compliance with Performance Requirements is undertaken in accordance with A0.5 of the BCA. Clauses A0.5 and A0.9 are presented in Table 2 below.

Table 2: Meeting the Performance Requirements and Assessment Methods for Alternative Solutions

Clause A0.5	Clause A0.9
Compliance with the Performance Requirements can only be achieved by— (a) complying with the Deemed-to-Satisfy Provisions (b) formulating an Alternative Solution which— (i) complies with the Performance Requirements; or (ii) is shown to be at least as equivalent to the Deemed-to-Satisfy Provisions; or (c) a combination of (a) and (b)	The following Assessment Methods, or any combination of them, can be used to determine that a Building Solution complies with the Performance Requirements: (a) Evidence to support that the use of a material, form of construction or design meets a Performance Requirement or a Deemed-to-Satisfy Provision as described in A2.2. (b) Verification Methods such as— (i) the Verification Methods in the BCA; or (ii) such other Verification Methods as the appropriate authority accepts for determining compliance with the Performance Requirements. (c) Comparison with the Deemed-to-Satisfy Provisions. (d) Expert Judgement.

1.4 The fire engineering process

In accordance with the International Fire Engineering Guidelines [IFEG], the fire engineer should prepare a Fire Engineering Brief (FEB) for every project carried out. The FEB is required to include the objectives, proposed trial designs, methods of analysis and acceptance criteria for any Alternative Solutions proposed.

Following approval of the FEB, the IFEG requires that a detailed Fire Engineering Report (FER) be prepared. The FER contains all the relevant design calculations and justification to show that the Alternative Solutions contained within the FER comply with the Performance Requirements of the BCA. Once stakeholder approval is gained for this report it may be submitted to the BCA Consultant for approval.

1.4.1 Third Party Peer Review

It is not that the Alternative Solutions identified in the FER (Rev 0 issued on the 05/11/2015) for this project has been subject to a Fire Engineering Third Party Peer Review (undertaken by Olsson Fire & Risk (OFR)). WSP | Parsons Brinckerhoffs commentary of the peer review comments of the FER is discussed in Table 1 of Appendix J of this report.

1.4.2 FRNSW referral

It is noted that the FEB process has identified Category 2 Fire Safety Provisions (as defined by the EP&A Regulation 2000), and as such required a referral to the fire brigade under Clause 144 of the Regulation. Therefore, FRNSW is a referral authority for this project and a Fire Engineering Brief Questionnaire (FEBQ) for this project has been submitted to FRNSW for their review, comment & consideration.

An FEBQ application (V01) was lodged to the FRNSW on 31st of July 2015 under Clause 144 of EP&A Regulation 2000.

FRNSW has reviewed the FEBQ V01 and issued feedback via email on the 30/09/2015 by means of updating the FEBQ form to V02 to include notes and commentary on the proposal put forward. The issues raised in the FEBQ Issue V02 by FRNSW is summarised in Table 1 of Appendix B which also details WSP | PB's response and actions undertaken to each of the items raised.

1.1.1.1 Initial Fire Safety Report

An Initial Fire Safety Report (IFSR) was issued by FRNSW on the 24th August 2016 in accordance with Clause 144 of the Environmental Planning & Assessment Regulation 2000 for the proposed development which was based on the WSP | Parsons Brinkerhoff FER Rev 1 dated 8th July 2016. The issues raised in this IFSR by FRNSW is summarised in Appendix B which also details WSP's response and actions undertaken to each of the items raised.

1.5 Scope and objectives

The objective of the Fire Engineering process is to recognise variations from the DtS Provisions and to present a way forward for resolution of each, and to demonstrate compliance with the relevant BCA Performance Requirements. All design solutions are subject to formal approval by the relevant regulatory authorities.

The objective of this FER is to set out proposed solutions to the identified departures from the BCA DtS Provisions within the development using Alternative Solutions.

Unless specifically identified within this report, the design of the scheme is assumed to be commensurate with the DtS Provisions set out in the BCA.

1.6 Stakeholders

The relevant stakeholders of this scheme are listed in Table 3.

Table 3: Relevant Stakeholders

Name	Organisation	Role
c/o Grant Harding	Mounties Group	Client

Name	Organisation	Role
Grant Harding	Cerno Management	Project Manager
Jason Krzus Guiseppe Graziano	Steve Watson & Partners	Principal Certifying Authority
Jennifer Husman	Architectus	Architect
Andrew Lamond	Chrofi	Architect
Dan Kirk Wayne Bretherton	WSP | Parsons Brinckerhoff	Fire Safety Engineer Fire Safety Engineer Accredited C10 Fire Safety Engineer
Duncan Cooke Birju Ghandi	WSP | Parsons Brinckerhoff	Mechanical Engineer Fire Hydraulics / Fire Protection
Duke Ismael Darren Bofinger Shaohua Xia	FRNSW	Fire Safety Engineer
Carl Voss	Olsson Fire & Risk (OFR)	Third Party Fire Engineering Peer Reviewer

1.7 Relevant Drawings & Documentation

The relevant drawings have been assessed as part of this report are listed in Table 4.

Table 4: Relevant Drawings (overall building)

DWG No.	Drawing Name	Organisation	Date	Rev
DA002	Site Plan	Architectus+Chrofi	01/08/2014	A
A0102	Site Survey	Architectus+Chrofi	30/04/2015	B
A1000	Overall Basement Level 2 Plan	Architectus+Chrofi	14/12/2016	10
A1001	Overall Basement Level 1 Plan	Architectus+Chrofi	14/12/2016	9
A1002	Overall Lower Ground Floor Plan	Architectus+Chrofi	21/11/2016	4
A1003	Overall Upper Ground Floor Plan	Architectus+Chrofi	13/10/2016	1
A1004	Overall Level 1 Plan	Architectus+Chrofi	13/10/2016	1
A1005	Overall Level 2 Plan	Architectus+Chrofi	13/10/2016	1
A1006	Overall Level 3 Plan	Architectus+Chrofi	20/10/2016	2
A1007	Overall Level 4 Plan	Architectus+Chrofi	13/10/2016	1
A1008	Overall Roof Level Plan	Architectus+Chrofi	13/10/2016	1
WSP-ME-0-B02-100	Basement 2 – Air Conditioning and Ventilation Overall Layout	WSP | Parsons Brinckerhoff	27/02/2015	2
WSP-ME-0-B01-100	Basement 1 – Air Conditioning and Ventilation Overall Layout	WSP | Parsons Brinckerhoff	27/02/2015	3

Table 5: Relevant Documentation

Document No.	Drawing Name	Organisation	Date	Rev
REPORT 2013/1528	Harbord Diggers Redevelopment (80 Evans Street, Freshwater) - BCA Assessment Report	Steve Watson & Partners	07/07/2015	2.1
S16007 Revision PR1.0	Fire Engineering Peer Review Harbord Diggers Redevelopment (80 Evans Street, Freshwater) -	Ollson Fire & Risk (OFR)	05/11/2015	1.0

1.7.1 Figures used in this FER

It is noted that the figures presented in the Alternative Solutions within this report provide an indicative supporting mark-up of the identified non-compliances detailed in Table 1 and / or the proposed fire safety measures for each Alternative Solution as summarised in Section 6. The figures are used for illustrative purposes only and should be read in conjunction with the drawings prepared by Architectus+Chrofi for this project.

2. Assumptions and Limitations

2.1 Assumptions

The following assumptions apply to the fire engineering analysis contained in this document:

- All codes and standards referred to are assumed to be the current version at the time of design and installation, or an alternative approved edition. This also includes any buildings designed to international codes providing an equivalent or better level of safety and having been approved by the AHJ.
- All Essential Safety Measures will be maintained to the operational capacity to which they were designed, installed, commissioned and certified.
- All installations will be commissioned and maintained in accordance with the manufacturer's instructions
- All Essential Safety Measures discussed within this report are assumed to be functioning correctly during a fire situation.

2.2 Limitations

The following limitations apply to the fire engineering analysis contained in this document:

- This report addresses compliance with the Performance Requirements of the BCA relevant to fire life safety only.
- No liability is accepted for the use of the findings of this report outside the set design criteria of this report, or use by any party not engaged to undertake design, construction or commissioning work associated with this development.
- No liability is accepted for the accuracy of the design documents provided by others which form the basis of the analysis.
- Changes to the development in the future may invalidate the findings of this report. If the design changes, those changes are to be referred to the Relevant Building Surveyor and/or Fire Safety Engineer.
- The concepts outlined in this report assume a complete and operational building, and do not address protection of the building during construction, renovation or demolition.
- Drawings referred to or incorporated in this document may change resulting from design variations. Readers must ensure that they observe the referenced project related drawings, and verify that the latest Fire Engineering documentation is being used.
- The report content is limited to the consideration of the objectives outlined in the BCA. Issues relating to protection of the owners property, or business continuity are outside the scope of this report.
- Acts of malicious intent, arson or acts of terrorism are outside the scope of this report.
- Liability for re-installation and costs of any damages caused by fire is considered to be beyond the WSP | PB scope of responsibility.
- Any change in building, occupant or fuel conditions outside of those considered by this report, or any deviation in the implementation of the fire strategy outlined in this report, may invalidate the findings of this report; and must be referred to the Relevant Building Surveyor and/or Fire Safety Engineer.
- The fire-engineered proposal, in this case, does not include for stock loss, goodwill, environmental impact (in a fire situation) or any loss of trade or business interruption associated directly or indirectly with a fire in these premises.
- WSP | PB incorporates all reasonable and practical efforts into producing a fire safety strategy commensurate with the client's objectives, expectations and operations. WSP | PB cannot guarantee, in producing a fire engineering strategy, that ignition or fire will not occur.
- Where not specifically mentioned, the design is expected to meet the requirements of the BCA, relevant codes and legislation at the time of construction and / or at the time of production of this report

3. Principal Building Characteristics

3.1 Location & proximity to fire source features

The proposed Harbord Diggers Community Club redevelopment is to be located at 80 Evans Street, Freshwater NSW 2096 as illustrated in Figure 1.

No special hazards have been identified at the adjoining boundaries and given the protected location of the building, relative adjoining fire source features; the risk of fire spread between buildings is relatively low.

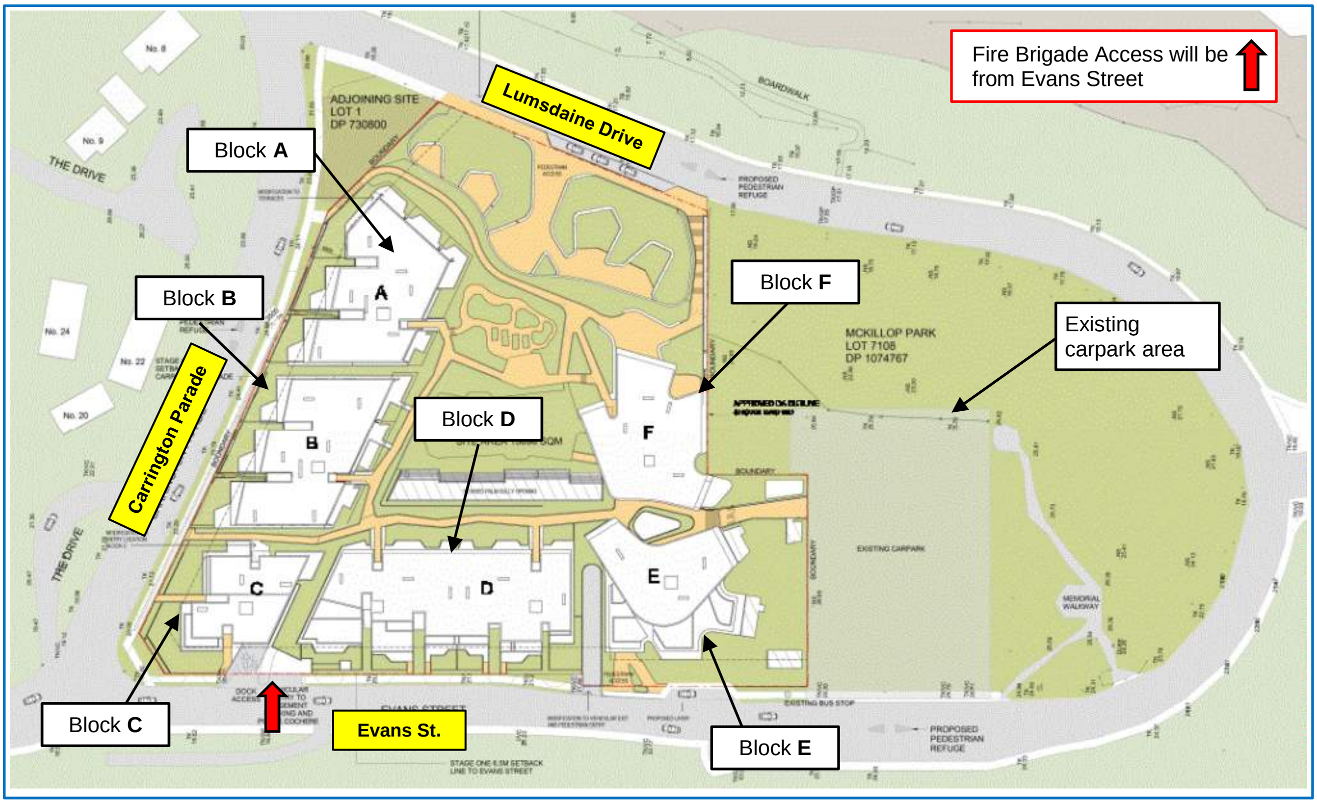


Figure 1: Site Plan of proposed Harbord Diggers Community Club Redevelopment

3.2 Building Details

3.2.1 Description of building & proposed works

The extent of the works involve the redevelopment of the existing Harbord Diggers Community Club. The proposed redeveloped community club will contain a number of areas for different uses, such as

- A Community Club
- Gymnasium,
- A Seniors Club
- Food & beverages tenancies
- Child care facility,
- An aquatic centre & ancillary amenities
- Ancillary office space
- Community recreation centre (Billiards / Gym / Cinema / Art Room)

In addition to the above it is proposed to construct 6 buildings above the podium level to accommodate 96 sole occupancy units for independent seniors living. The community club and the ancillary public use areas, as well as the residential apartments are proposed to be sited over two levels of basement car parking that serve all areas.

Table 6: Basic Building Information (refer to BCA Report for further clarity)

BCA Clause	Description	Description or requirements		
A1.1	Effective Height	The building has an effective height of 19.05 m (Bld. F 35.34 – LG Bin Area 16.40 m)		
A3.2	Building occupancy & BCA Classification	*BCA Class 7a*	Basement car parking (Basement Levels 1 & 2)[(a)(b)] Seniors Living recreation area (Basement Level 2) [(a)(b)]	
		BCA Class 9b	Aquatic Centre (Lower Ground Floor Level)	
			Childcare Facility (Lower & Upper Ground Floor Levels)	
			Gym (Upper Ground Floor Level)	
			Community Centre including the Porte Cochere area (Lower & Upper Ground Floor Levels)	
		BCA Class 2	Building A	Upper Ground Floor Level to Level 2
			Building B	Upper Ground Floor Level to Level 2
			Building C	Level 1
			Building D	Upper Ground Floor Level to Level 2
			Building E	Levels 1 & 2
			Building F	Upper Ground Floor Level to Level 4
C1.1	Construction Type	The building is to be of Type A Construction. All building elements shall have a Fire Resistance Level as listed in Table 3 of BCA Specification C1.1 at a minimum, except where addressed in this report as an alternative solution. Passive Fire Resistance Levels (structural adequacy/integrity/insulation) will be at least equivalent to the BCA DtS Provisions.		
C1.2	Rise in Storeys (RIS)	6 (number of storeys contained is 8)		
Table C2.2	Fire Compartment Floor Area and Volume	*BCA Class 7a*	The car parking levels are to be sprinkler protected and as such there are no maximum floor area or volume limitations for this area	
		BCA Class 6	Within the limits set for a Class 6 building of Type A construction	
		BCA Class 2	The Class 2 portions of the building are not subject to floor and volume limitations of BCA Table C2.2.	
Note that as per BCA clause A3.3: *(a) Where parts have different purposes – if not more than 10 % of the floor area of a storey, being the minor use, is used for a purpose which is a different classification, the classification applying to the major use may apply to the whole storey.* *(b) Plant rooms or the like must have the same classification as the part of the building in which it is situated.*				

An illustration of the different BCA Classifications at Lower Ground Floor Level (which is the main focus of the Harbord Diggers Community Club) has been indicatively illustrated in Figure 2. The Class 2 residential levels are noted to commence on the Upper Ground Floor Level (as illustrated in Figure 5).

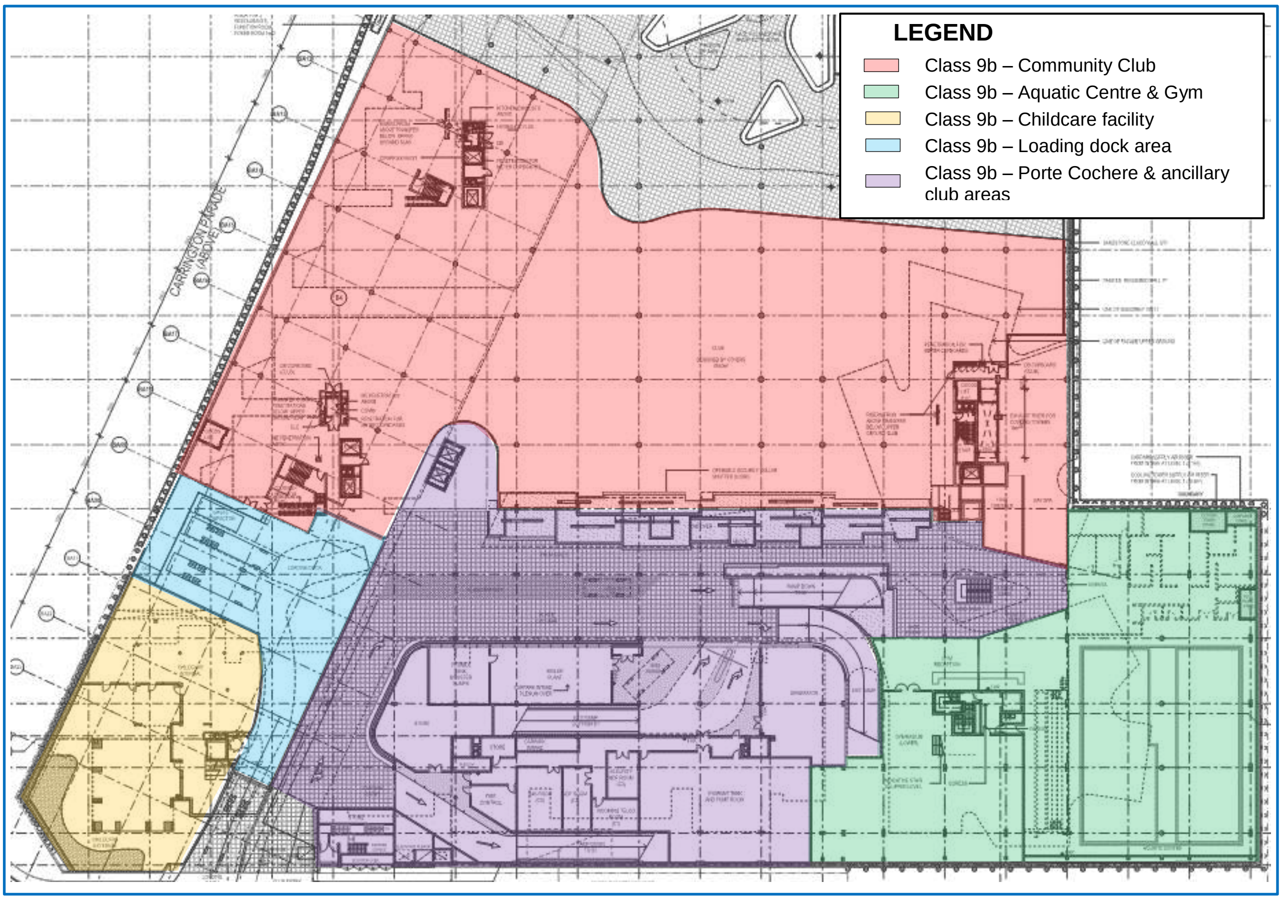


Figure 2: Overall Lower Ground Level Plan – extent of different Classifications

3.3 Means of escape

A summary of the means of escape for the development has been indicatively illustrated in Figure 3 to Figure 5. Please note that the layouts indicated are indicative sketches only and should be read in conjunction with the Architectus+Chrofi drawings listed in Table 4.

The following egress stairs serve the Basement Levels and are permitted to be non-fire-isolated stairs under the BCA Clause D1.3 as they do not connect more than 3 levels (additional level is permitted due to presence of sprinkler protection throughout the basement levels); Stair ST01, Stair ST02, Stair ST03 and Stair ST06.

The following egress stairs are also noted to be non-fire-isolated stairs and serve the residential areas of Buildings A, B & D; Stair ST-A, Stair ST-B, Stair ST-D1 and Stair ST-D2.

The following egress stairs are noted to be required fire-isolated stairs; Stair ST04, Stair ST05, Stair ST-E and Stair ST-F.

The following is a breakdown of the discharge points of the aforementioned stairs serving the building;

- Stairs ST01 & ST02 discharge towards Carrington Parade at Lower Ground Floor Level.
- Stairs ST03 & ST07 discharge towards Evans Street at Lower Ground Floor Level.
- Stair ST06 discharge towards Lumsdaine Drive at Lower Ground Floor Level.
- Stairs ST-A, ST-B, ST-D1 & ST-D2, ST04, ST05, ST06, ST07, ST-E and ST-F discharge towards the common external podium area at Upper Ground Floor Level. From here, occupants can move towards Evans Street, Lumsdaine Drive or Carrington Parade.

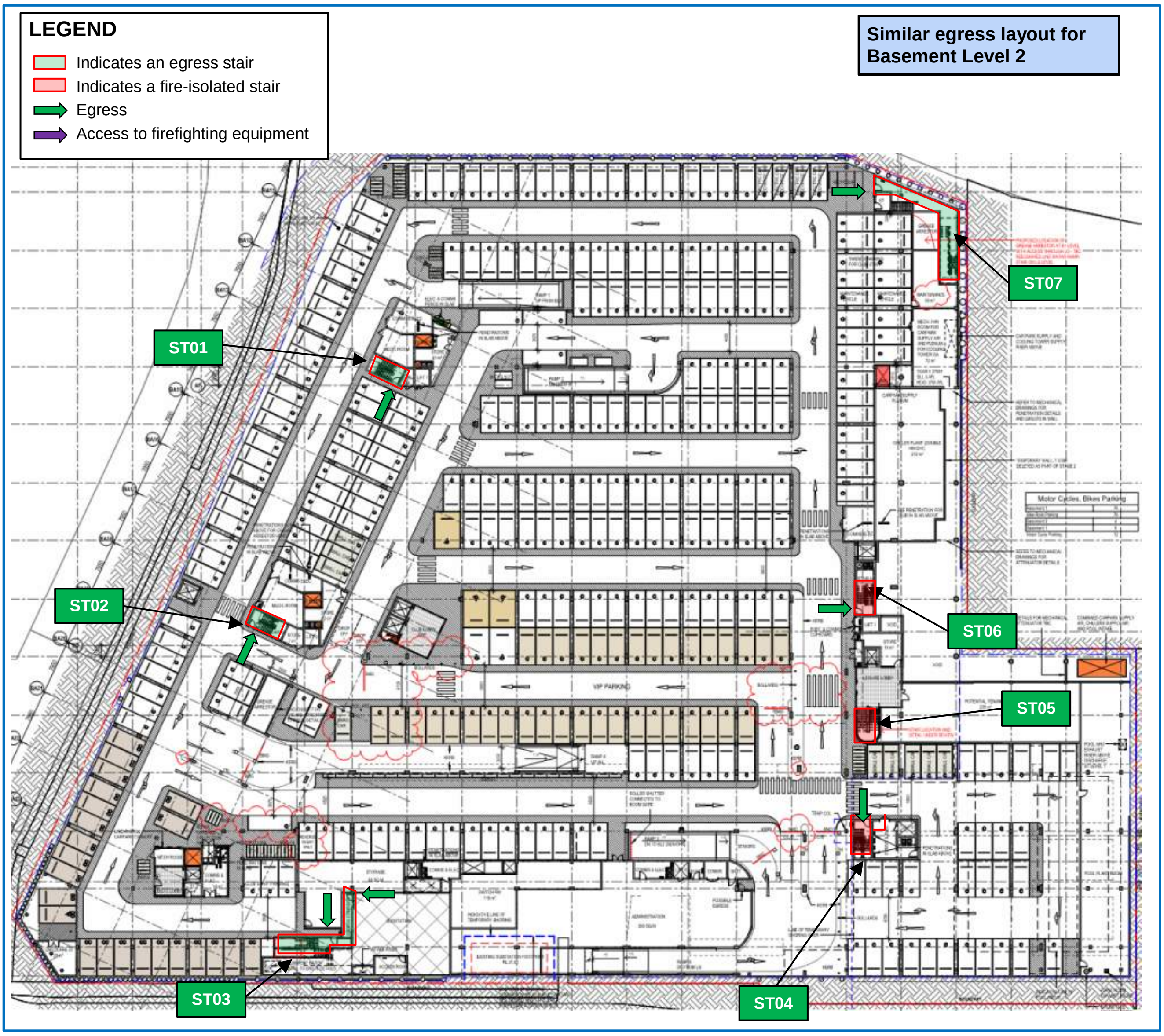


Figure 3: Overall Basement Level 1 Plan – Location of exits

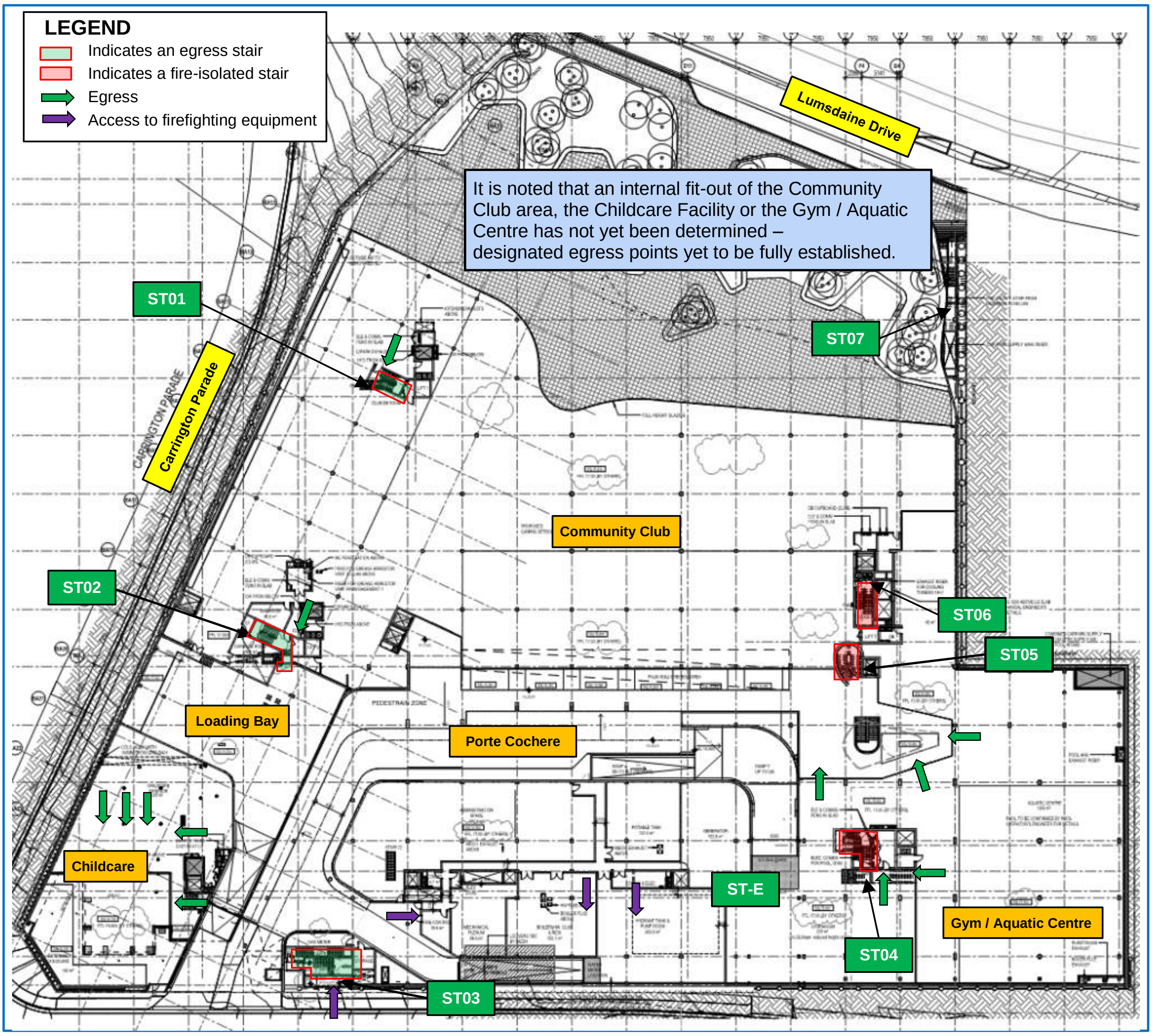


Figure 4: Overall Lower Ground Floor Level – Location of exits

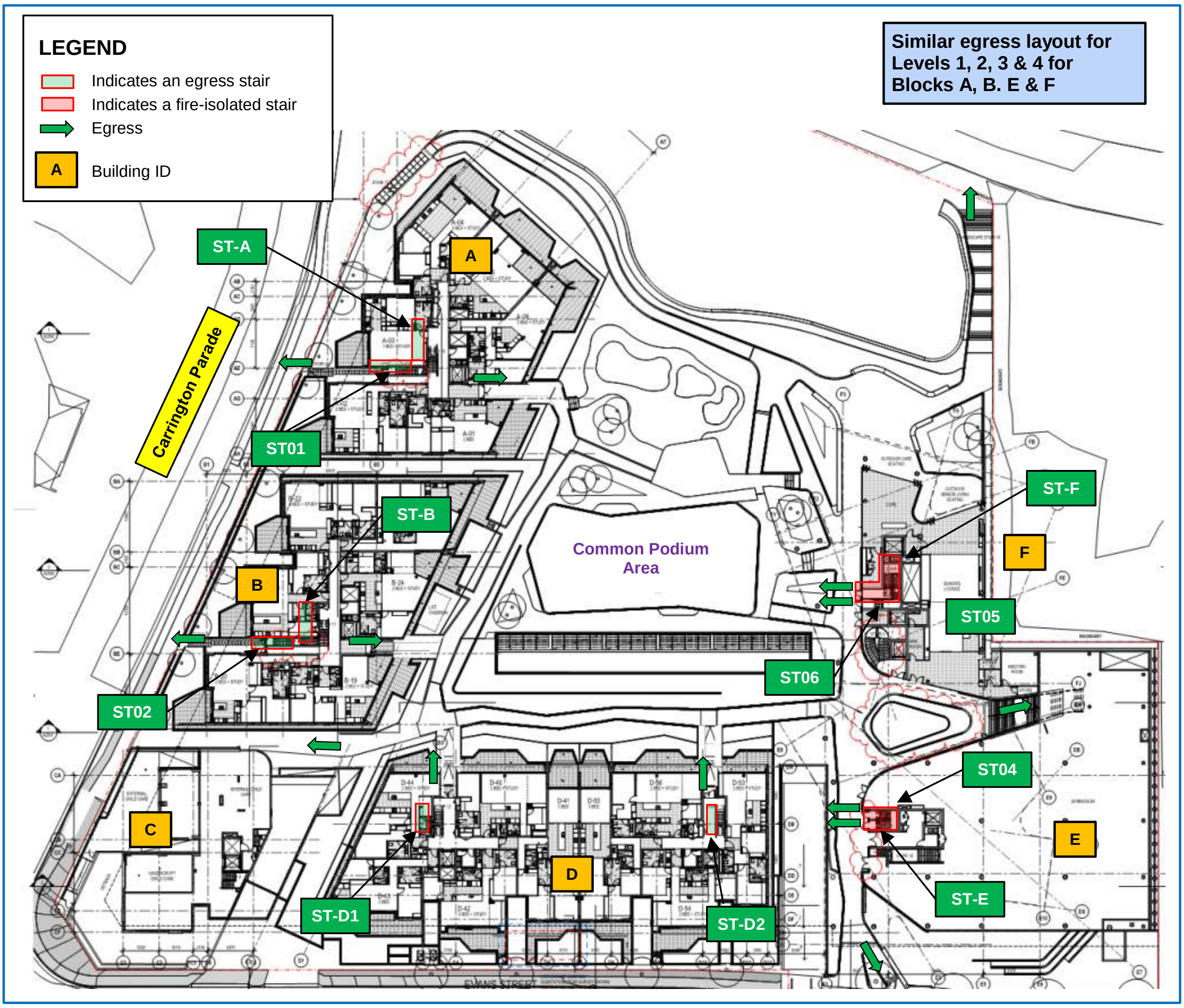


Figure 5: Overall Upper Ground Floor Level – Location of exits

4. Dominant Occupant Characteristics

4.1 Occupant characteristics

In an emergency, the characteristics of occupants and their corresponding interaction with the building environment and people around them play an important role in their ability to escape in a timely manner. It is therefore necessary to consider the characteristics of the range of occupants that can be expected in the building.

The principal occupant characteristics are listed in the table below.

Table 7: Characteristics of building occupants

Occupancy use / Location	Occupant Groups	Familiarity with surroundings	Occupied period / Occupant density	State of awareness
Class 2 (Residential Levels)	Single guests to family groups of all ages. Children accompanied by parents.	Due to simple layout, clear signage and short travel distances, able to navigate to exits	Day / Low	Awake and aware
			Night / High	Asleep, potentially impaired by alcohol
Class 9b areas	Members of the public. Single to family groups of all ages. Staff present at all times	Due to simple layout, direct exit to outside / Porte Cochere area, clear signage, familiarity with entry route and assistance from staff, able to navigate to exits	Day / High	Awake and aware
			Night / Low	Awake and aware
Carpark Levels	Single guests to family groups of all ages. Children accompanied by parents.	Due to simple and open air layout and clear signage, occupants are expected to be able to navigate to exits.	Day / High at morning & evening peaks	Awake and aware
			Night / Low	Awake and aware
Loading Dock / Plant spaces	Building maintenance personnel / occasional contractors	Familiar with building, location of exits and building alarm tones	Day / Occasionally occupied for short periods for maintenance purposes	Awake and aware

4.2 Distribution

The population to the proposed development has been detailed in Section 11.4 of the BCA Report prepared by Steve Watsons & Partners as detailed in Table 5 of the report.

The number and dimensions of the means of escape are sufficient for the identified occupant distribution as per the DtS provisions of the BCA.

4.3 State of awareness, physical attributes and level of assistance required

It is important to consider the state of awareness of occupants as it can impact on their ability to escape in a timely manner.

4.3.1 Staff to Community Centre / Aquatic Club / Gym

Permanent Staff members are expected to be present within these spaces. They are assumed to be familiar with the layout of the building and the location of emergency exits. Staff members are expected to be awake, sober and alert and be able to self-evacuate from the building in an emergency. Staff with hearing, visual or mobility impairments are assumed to have a personal emergency evacuation plan (PEEP) as part of the management strategy / health and safety requirements.

Members of staff would also be expected to assist the public, if required.

4.3.2 Visitors to Community Centre / Aquatic Club / Gym

Visitors will generally be aware of the route via which they entered the building and are more likely to evacuate the building via this route, even if other exits are closer. Most occupants, however, are expected to be mostly transient and it cannot be guaranteed that all occupants would be familiar with the building, its layout and the exit points. On this basis, it is assumed that visitors will be unfamiliar with the building, but be alert and sober.

Any hearing, visual or mobility impaired visitors are assumed to be accompanied at all times or be able to self-evacuate.

Any visitors (adults) present during an evacuation are likely to assist, but for the purposes of this assessment are conservatively assumed to be able to safely evacuate themselves from the building.

4.3.3 Class 2 residential occupants

The occupants of the residential units in the Class 2 buildings (Buildings A to F) are assumed to be familiar with the layout of the buildings and the locations of exits. Residents are not expected to have received any specific emergency training. Any hearing, visual or mobility impaired visitors are assumed to be accompanied at all times or be able to self-evacuate.

Any visitors are assumed to be accompanied by residents and if not, should be able to navigate to the exits easily due to the simple layout and clear signage.

Due to the use of the building as a residence, occupants may be sleeping and as such may be diminished in their ability to hear and react to a fire.

4.3.4 Childcare Facility (Staff & pre-school children)

Staff are expected to be familiar with the layout of the building and the location of exits and to be alert and sober. The number of staff to the childcare facility shall be based on the number of children to the childcare facility as per [NSW-392]. Staff will be expected to have received some form of emergency / first aid training as per the requirements of the [DCP 2005].

Any hearing, visual or mobility impaired staff are assumed to be able to self-evacuate or be assisted by other staff members. If a staff member requires assistance during evacuation from the building then the management of the childcare facility should account for this possibility in their staffing numbers based on the minimum required to evacuate the number of children at any given day. This must be reflected in the evacuation plan for the facility.

All children within the premises are assumed to require assistance by the staff members to evacuate. Some will need to be carried in capsules / basinets or the like (0-2 year old age group) while older children (2-5 year old age group) may be able to walk out as a group with staff members.

5. Fire Brigade Intervention

5.1 Proximity to fire stations & fire brigade Access

The site is located approximately 4.4 km (as determined by Google Maps) from the Manly Fire Station at 128 Sydney Road, Fairlight NSW 2094, as depicted in Figure 6. It is also noted that the building is in close proximity to Mossman Fire Station, Willoughby Fire Station and Belrose Rural Fire Brigade.

Table 8: Fire Stations in close proximity to the building

Station Name	Address	Station Resources
Manly Fire Station	128 Sydney Road, Fairlight NSW 2094	1 x Class 3 Pumper 1 x Bronto F27 Ladder Platform

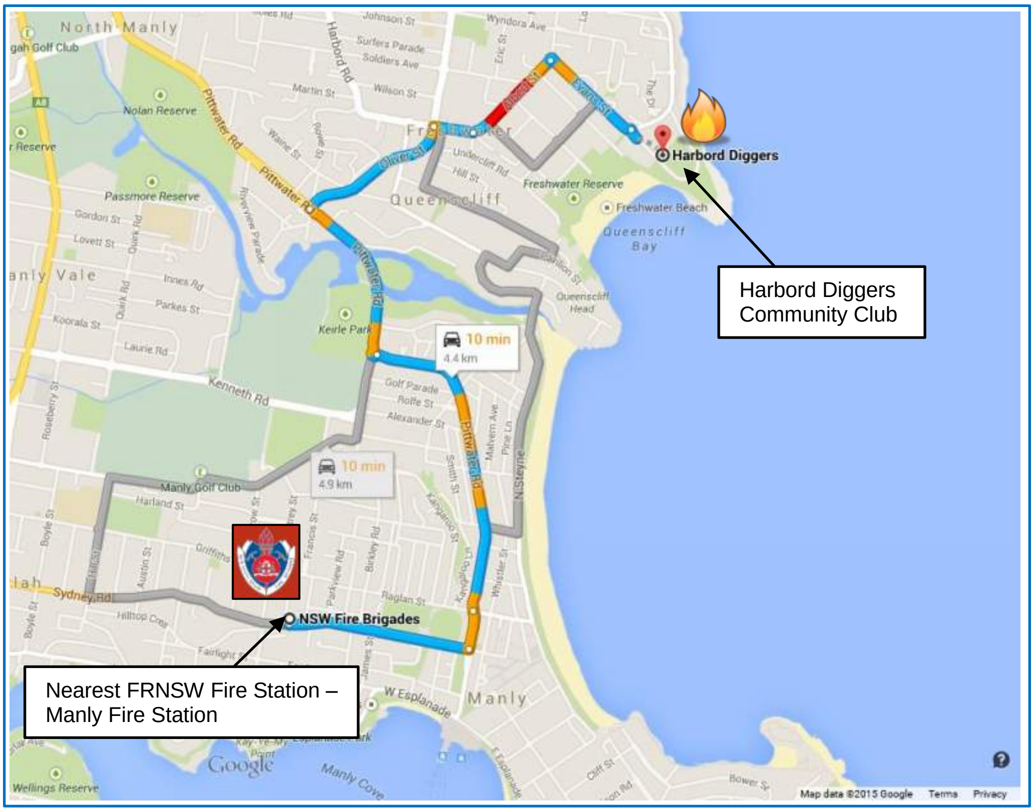


Figure 6: Nearest fire station to building – (Google Maps©2015)

5.2 Location of Fire Brigade Access and Equipment

Fire brigade access is provided direct from Evans Street as depicted in Figure 7.

The Fire Control Centre (commonly referred to as the Fire Indicator Panel (FIP)) is located at Lower Ground Floor Level in a designated room to be referred to as a 'Fire Control Room' as identified in Figure 7. It is noted that the Fire Control Room does not need to comply with the requirements of BCA Specification E1.8 as the proposed development is less than 50 m in effective height.

The Fire Hydrant Pump Room as well as the Fire Sprinkler Pump & Control Valve Room are also located at Lower Ground Floor Level and are accessed via a fire-isolated passageway as identified in Figure 7. It is noted that the FIP, including the Fire Hydrant Pump Room and the Fire Sprinkler Pump & Control Valve Room, is accessed from a covered space and not that of a road or open space which has been reviewed in AS 9 of this report.

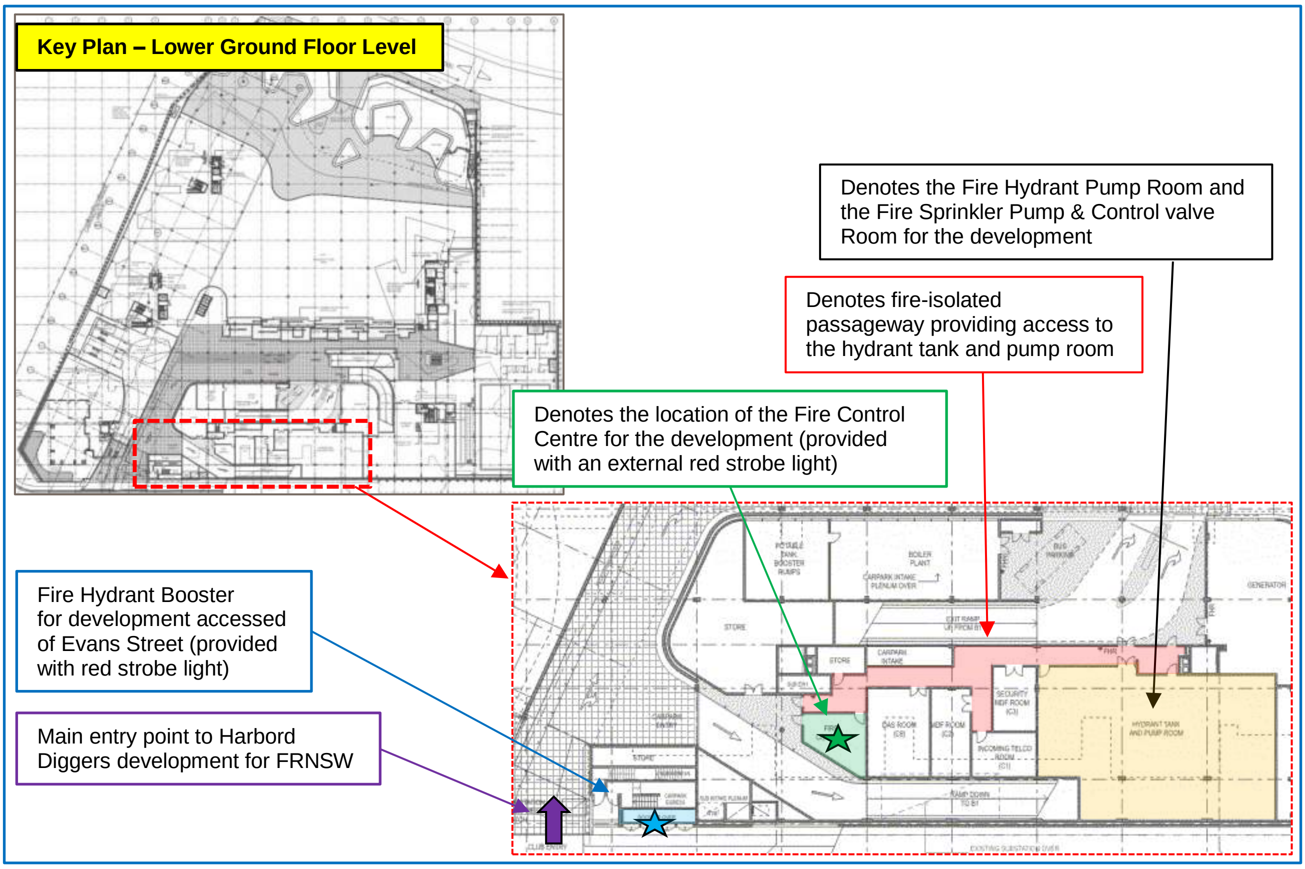


Figure 7: Fire brigade access & proposed Fire Fighting facilities for brigade upon arrival

5.3 Fire-fighting

When undertaking fire-fighting activities, the fire brigade would set up their fire hoses from the hydrants provided at the storey exits. Fire fighters would then move from the hydrants onto the floor plate under the protection of the hose stream issuing from the nozzle attached to the fire hose. Should they therefore need to retreat, they can follow the fire hose back to the exit.

It is noted that all points on the floor between the alternative exits can be adequately be covered by fire hoses attached to the hydrant at each storey exit (40 m coverage is afforded from each fire hose).

The proposed building is to be sprinkler protected in part only in accordance with AS 2118.1. Sprinklers offer an effective means of automatically controlling fire size and preventing fire spread. A fire sprinkler system will dramatically reduce the likelihood of a large fire in the building.

5.4 Fire Brigade Notification

The proposed building is to be sprinkler protected in part (as discussed in detail in Section 6) in accordance with AS 2118.1. It is noted that upon activation of a sprinkler head, the Brigade are automatically notified of a fire in the building via the Alarm Signalling Equipment (ASE) in the Fire Indicator Panel (FIP).

It is noted that upon actuation of the sprinkler system a direct alarm signal shall be automatically transmitted to a fire brigade dispatch centre enabling the earliest possible arrival of the fire brigade to the building.

It is further noted that under guidance given in BCA Clause 4 and 5 of Specification E2.2a, activation of a smoke / thermal detector in the building (designed to AS 1670.1 and AS 1668.1) shall also send an alarm to the fire brigade dispatch centre; an alarm equivalent to that of the sprinkler system discussed above.

Consequently, it is concluded that the fire brigade would be expected to start with their operations / fire suppression activities in the early stages of a fire emergency.

6. Proposed Fire Safety Measures

The building is to comply with all BCA DtS requirements except where modified by the design requirements listed below. The following should be read in conjunction with the detail contained within Appendix G of the BCA report detailed in Table 5.

6.1 Active Fire Safety Measures

- The proposed development shall be provided with an automatic fire suppression system which shall include the use of fast response sprinkler heads with an RTI of 50 $(m{\cdot}s)^{0.5}$ or less in accordance with BCA Specification E1.5 and AS 2118.1 in the following areas;
  - Basement Levels 1 & 2 (throughout), including the leisure lobby areas.
  - The Porte Cochere, Community Club areas and the Gym / Aquatic areas.
  - As per Alternative Solutions AS 5 and AS 12 of this report; Automatic sprinkler system to Basement Levels 1 & 2 as well as the loading dock area at Lower Ground Floor Level designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 modified as follows:
    - Provide fast response sprinkler heads (with an RTI of 50 (m·s)0.5 or less) in lieu of the required standard response sprinkler heads.
    - Activation temperature of the sprinklers heads within the basement carparks are to be 68°C (subject to ambient conditions).
    - The sprinklers shall be installed at a spacing of 3 m x 4 m for an Ordinary Hazard system. Sprinklers within the basement levels are to be arranged so that no heads are in the direct path of airflow from the fan to prevent potential delays in activation. For further details please refer to Appendix H of this report.
    - The sprinkler system shall be connected to and activate the building occupant warning system.
    - The activation of sprinklers in the basement car parks shall also automatically turn off the impulse fans on the fire-affected floor, activate the building occupant warning system and call FRNSW via the ASE.
  - As per Alternative Solutions AS 6 of this report; the Community Club areas (including the external covered area to the north of the club), the Gym / Aquatic centre (excluding the area directly above the swing pool), the Porte Cochere areas and the service rooms adjacent to the area and the loading dock shall be provided with fast response sprinkler heads (with an RTI of 50 $(m{\cdot}s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads.
  - As per Alternative Solution AS 11 of this report; sprinklers are to be omitted from the areas directly above the swimming pool.
- As per Alternative Solution AS 2 of this report, the proposed glazed construction at Lower Ground Floor Level (as identified in Figure 12) shall be provided with Tyco Model WS specific application window sprinklers on both sides of the glazed elements and must be installed in accordance with the manufacturer's specifications which are included in Appendix E. However, note the following key items:
  - All combustible materials shall be kept at least 50.8 mm from the glazing. This shall be implemented via a pony wall (at least 0.9 m in height, where necessary).
  - There are restrictions on the type and size of glass panels.
  - There are restrictions on depths of mullions and transoms.
  - The glass shall be at least 6 mm thick and heat strengthened or tempered glass.
  - Any section of glazing above the door or adjoining the door must also be protected with the Tyco system.

  - Glazed doors within the glazed wall are required to automatically close so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door opening mechanisms, so as not to clash with the Tyco head.
  - The flow rates required to each Tyco WS head shall be as per the manufacturer's spec sheet.
  - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system.

- As per Alternative Solution AS 14 of this report, the proposed glazed construction around Stair 5 (as identified in Figure 52) shall be provided with Tyco Model WS specific application window sprinklers on both sides of the glazed elements and must be installed in accordance with the manufacturer's specifications which are included in Appendix E.
- As per Alternative Solution AS 7 of this report, fire stairs 1 and 2 leading from the basement levels discharging at ground levels of Building A and B require that the openings within 6 m of the paths of travel are protected in accordance with C3.4. These windows shall be protected with Tyco model WS specific application window sprinklers on the SOU side of the window and must be installed in accordance with the manufacturer's specifications. The specifications of the system are contained in Appendix E.
- The proposed tyco WS drenching system(s) referred to above are required to be separated from the occupied space sprinkler system water supply by isolation valves. Isolation of both systems simultaneously (drencher system and occupied space sprinkler system) for maintenance purposes shall not be allowable. This is to be included in the management in use plan.
- The number of heads required to activate simultaneously in each area must be reviewed, with calculations carried out by the fire protection contractor to verify that the water supply available (both town main and tank supply) can achieve full flow of this system for no less than 2 hrs in the most disadvantaged area. These calculations must allow for the sprinkler system serving the occupied areas of the basement levels and the fire hydrant system to be in operation simultaneously.
- Portable fire extinguishers shall be provided throughout the building in accordance with BCA Clause E1.6 and AS 2444.
- Fire hose reels shall be provided throughout the building in accordance with BCA Clause E1.3 and AS 2441 except where modified below:
  - As per Alternative Solution AS 11 of this report, additional hazard specific portable fire extinguishers is to be provided in accordance with BCA Clause E1.6 and AS 2444 to the areas where it is proposed to omit fire hose reel coverage. An additional hand held 1x4.5 kg DCP multi-purpose extinguisher is proposed to be located in postions which fire hose reels were to be located.

6.2 Brigade requirements

- The proposed development is to be provided with a Fire Control Centre in accordance with BCA Clause 2 of Specification E1.8.
- A fire hydrant system is to be provided to the building in accordance with BCA Clause E1.3 of the BCA and AS 2419.1-2005 incorporating the following measures:
  - As per Alternative Solution AS 10; the design of the fire hydrant system is to be based on 2 fire hydrants flowing simultaneously at a flow rate of 10 L/s for a duration of at least 4 hours.
  - As per the request from FRNSW - block plans to be provided beside hydrant valves within fire stair wherever additional hydrants are deemed necessary to achieve compliant coverage on site. The intent of this requirement is to pictorially and numerically illustrate the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the AFSS.
  - The fire hydrant booster shall be shielded by a wall achieving the required FRL of 90/90/90 as per Clause 7.3 of AS 2419.1, except that the doorway openings from the egress stairs are

within 2 m of the booster and are not to be protected. Stair 07 doorway which discharges adjacent the Brigade booster assembly be fitted with a fire door despite this being to an external space.

- The fire hydrant block plan for the development (to the requirements of AS 2419.1) is to be located at the following areas;
  - At the fire brigade booster assembly at Evans St;
  - Within the fire control centre;
  - At the fire hydrant pump room.
- Red strobe lights shall be provided at the following locations:
  - At the booster assembly;
  - At the entry point to the Fire Control Room & fire isolated passageway entrance providing access to the Fire Hydrant Pump &Tank / Fire Sprinkler Pump & Control Valve room.

The red strobe lights noted above are to be activated by an alarm signal from the Fire Indicator Panel (FIP) that serves any on site automatic smoke detection and alarm system & sprinkler system.

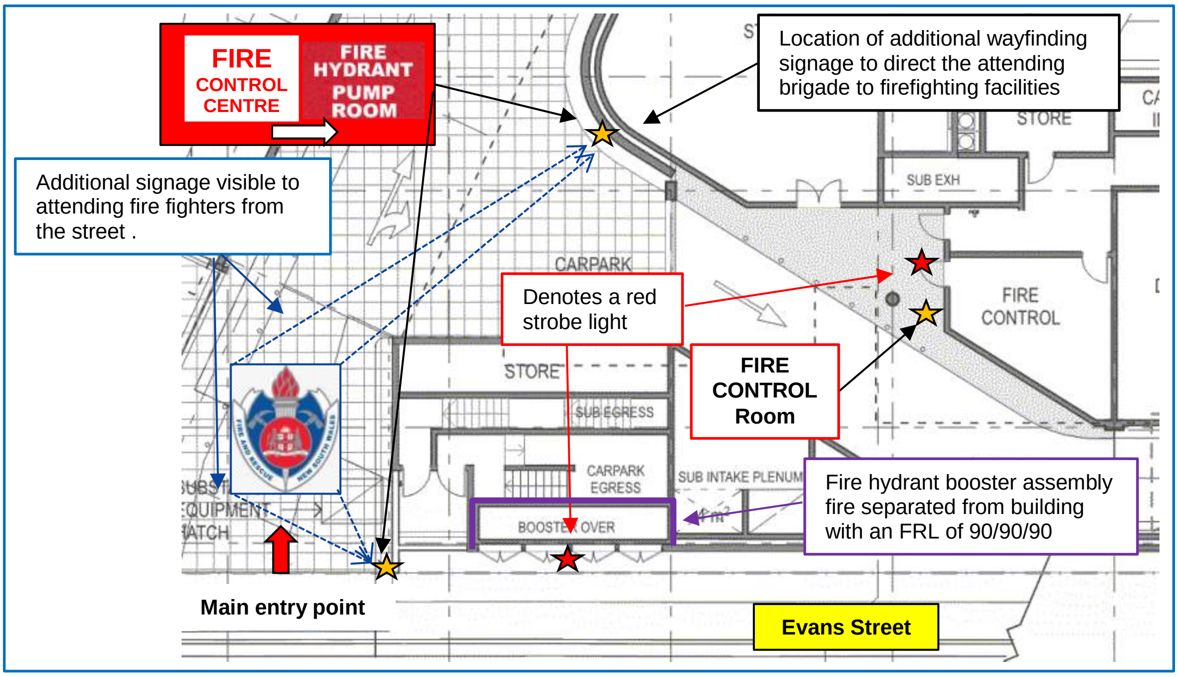


Figure 8: Proposed fire safety measures – signage & strobe lights for attending fire brigade

- Additional wayfinding signage is to be incorporated at the main entry point of the building so that it is visible from the street (as indicatively illustrated in Figure 44) to direct the attending fire brigade to the location of the Fire Control Room (including the FIP contained within) and Fire Hydrant & Pump Room for the development. The additional signage to be utilised must be fade resistant with wording in upper case letters not less than 100 mm in height in a colour contrasting with the background to which it is erected.
- The entrance door to the fire-isolated passage way to be provided with signage indicating that this door provides access to the Fire Hydrant Pump & Tank room/ Fire Sprinkler Pump & Control Valve room. Signage to be in accordance with AS 2419.1.
- As per recommendations from FFRNSW, block plans to be provided beside hydrant valves within fire stair wherever additional hydrants are deemed necessary to achieve compliant coverage on site. The intent of this requirement is to pictorially and numerically illustrate the location of the next available additional hydrant. The plans should be a minimum of A3 in size

and be orientated to reflect the floor plate as being viewed facing the door with a “YOU ARE HERE” note and be incorporated into the AFSS.

6.3 Fire detection & alarm system

- The detection and alarm system proposed throughout Buildings A, B, D, E & F is to be designed in accordance with Clause 6 of BCA Specification E2.2a. The operation of this system shall be as per the OWS Fire Matrix in Appendix L and Evaucation Strategy presented in Appendix M of this report.
- A Sound System and Intercom System for Emergency Purpose (SSISEP) system is to be installed to the Class 9b areas (Community Club / Gym & Aquatic areas) in accordance with AS 1670.4. The system is to be interconnected to the smoke detection system (AS/NZS 1668.1 and AS 1670.1) and the site’s sprinkler system (serving Basement 1 and 2 only).
- The residential levels of Buildings A, B, C, D, E & F is to be provided with an automatic smoke detection and alarm system as follows;
  - AS 3786 smoke alarms installed within each residential unit (providing a local alarm within each unit only).
  - As per Alternative Solution AS 4 of this report, heat detectors to be provided inside of each apartment (within 1.5 m of the entry door) of all residential buildings. Heat detectors to be Type A (AS 1603.1) combination fixed temperature and rate-of-rise and to be installed in accordance with AS 1670.1 and connected to the building smoke detection and occupant warning system discussed below. Activation of a heat detector to initiate a building wide fire evacuation alarm (limited to building of fire origin).
  - Smoke detectors shall be installed within the common residential corridors and other internal public spaces located in accordance with AS 1670.1. Detectors will be provided within 1.5 m of SOU doors within the common corridors. The smoke detectors are to be connected to activate the building occupant warning system and to be arranged to initiate a building wide alarm.
- As per Alternative Solution AS 6 of this report; It is proposed to modify the spacing of the smoke detectors from the required 20.4 m spacing (under Clause 4.10.5 of AS/NZS 1668.1) within the Community Club area to that of a 10.2 m grid, which resembles spacing of an AS 1670.1 system.
- Provide a smoke detection system throughout the Childcare Centre in Building C in accordance with BCA Specification E2.2a Clause 4 and AS 1670.1.
- Any required fire doors which are held open on electromagnetic locks (understood to be only applicable to Building E only) are to disengage upon activation of a fire alarm condition anywhere on site to maintain separation between the different areas.
- As per the request of FRNSW, the occupant warning system in the residential areas of the building is to achieve an A-weighted sound pressure level of 75 dB at the bedhead as stipulated in Clause 3.22 of AS 1670.1 due to the presence of smoke seals to the SOU entry doors.
- As per Alternative Solutions AS 12 of this report; the impulse fans in the basement carpark shall have built-in duct smoke detectors. These smoke detectors are required to be connected to FIP. On activation of any of these smoke detectors, all the impulse fans on the fire-affected floor shall be switched off automatically and remain switched off unless manually reset at FIP and the building occupant warning system shall be activated. This is in line with the requirments requuiested by Fire & Rescue NSW – the fire protection consultant for the project is to ensure that this requirement is met.
- Access doors along the security line (Basement Level 2) are required to failsafe open in fire mode.
- Automatic smoke detection is to be installed in accordance with AS 1670.1, the smoke detection is to be installed in a 10.2 m grid in the areas shown below in Figure 29.

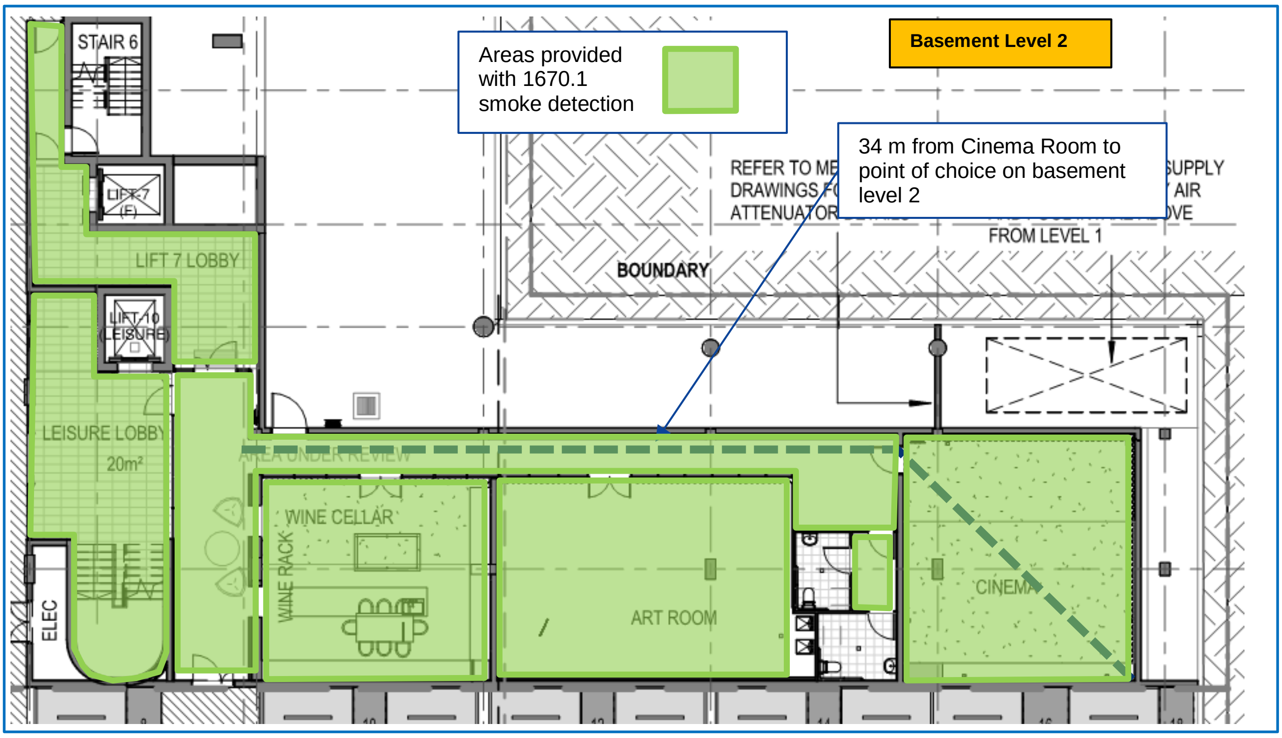


Figure 9: Basement Level 2 Cinema Room – Areas provided with AS1670.1 detection.

- The activation of smoke detector heads provided in the circulation areas of the car-parks (in accordance with AS 1670.1-2015 Figure 7.5.2.2(c)) will automatically shut down the impulse fans on all levels and activate the building occupant warning system. It is proposed for these detectors to be provided on a 15 m grid spacing basis. Sensitivity of these heads to be reduced accordingly to avoid spurious alarms.

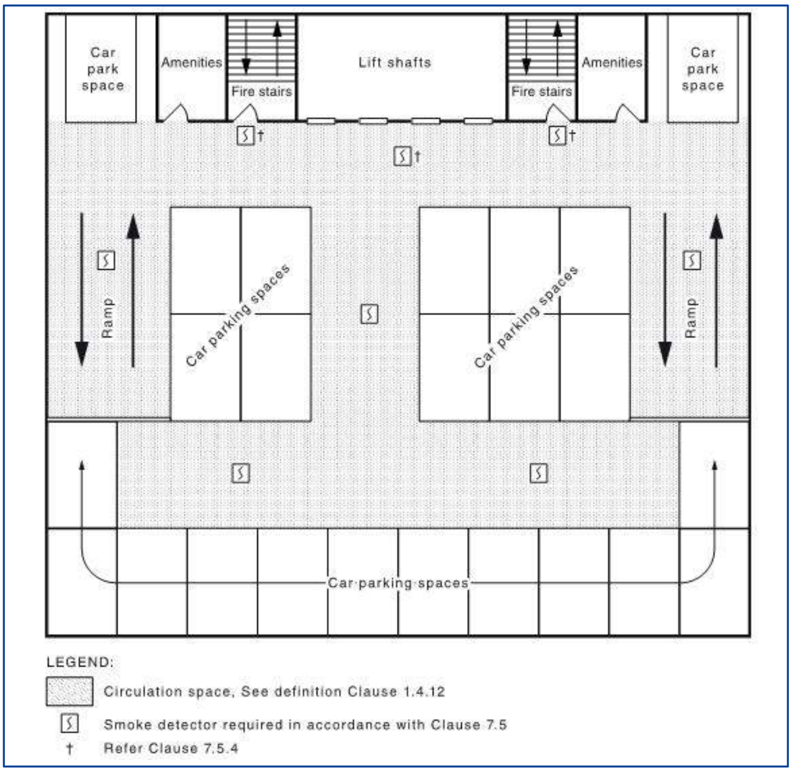


Figure 10: Figure 7.5.2.2(c) Indicative Detector Locations Example Car-Park

6.4 Mechanical Services & Smoke Hazard Management

- The mechanical ventilation system serving the basement car parks shall be designed in accordance with AS/NZS 1668.1 - 1998 and AS 1668.2 – 2012, as well as the FRNSW Fire Safety Guideline document for impulse fans in car-parks. The mechanical ventilation systems have exhaust and supply arrangements as follows:
    - On Basement 1: exhaust rate: 72 m^3/s; supply rate: 65 m^3/s and three natural supply air inlets via the vehicle ramp.
    - On Basement 2: exhaust rate: 51 m^3/s; supply rate: 45 m^3/s and four natural supply air inlets via the vehicle ramp.
    - The supply fans and exhaust fans are kept running and ramp to full speed if on variable speed drive (VSD) in the event of a fire being detected within the building (in relation to the supply/exhaust riser fans serving the basement levels – not the jet fan system).
    - Supply systems to be fitted with duct smoke detectors to switch off the supply fans if smoke is detected in the supply ducts.
- Impulse fans in conjunction with CO sensors and associated controls are proposed to be installed in the basement car parks to achieve a performance of diluting pollutants, as required by AS 1668.2 – 2012. Fantech model JIU-CPCEC-SD jet fan or other products that can produce equivalent jet flow pattern shall be installed in the basement car parks.
- The impulse fans shall be provided with duct smoke detectors. Upon activation of any of these smoke detectors or the sprinklers, all the impulse fans shall be shut down and the building occupant warning system shall be activated.
- The impulse fans should be located in driveways and access ways and not above car-parking spaces or ither areas where there are stagnant fire loads.
- The activation of smoke detector heads provided in the circulation areas of the car-parks (in accordance with AS 1670.1-2015 Figure 7.5.2.2(c)) will automatically shut down the impulse fans on all levels and activate the building occupant warning system. It is proposed for these detectors to be provided on a 15 m grid spacing basis. Sensitivity of these heads to be reduced accordingly to avoid spurious alarms.
- As per Alternative Solution AS 8 of this report; the Porte Cochere area shall be naturally ventilated by the presence of the Palm Gully Void and stair void as well as the vehicle exit ramp linking to Upper Ground Floor Level.
- A control switch shall be provided for each of the basement carpark levels to enable manual control of the impulse fans by attending fire brigade personnel. The control switches shall be incorporated in the FIP as a Fire Fan Control Panel (FFCP).
- An indicative layout of the impulse fans units for both Basement Levels 1 & 2 has been illustrated in Appendix B of the CFD report attached in Appendix H of this report which have been designed by Fantech.
- Mechanical layout plans for the basement levels are to be provided at the FIP indicating impulse fans location with numbers, as designed on the FIP. Operational instructions for the impulse fans (Auto and Manual) shall be provided at the FIP.
- Testing of the mechanical system serving the carpark level shall consist of verifying that upon activation of a fire initiating device (detector, flow switch, etc.) all jet fans shall cease operation on both carpark floors simultaneously. The carpark supply and exhaust system shall then ramp up to full speed operation, as per AS 1668.1.
- The Community Club and Gym / Aquatic Centre is to be provided with a mechanical air handling system to AS/NZS 1668.1-1998 which shall automatically shutdown the air handling systems except as modified below;

- As per Alternative Solution AS 6 of this report - It is proposed to modify the spacing of the smoke heads from the required 20.4 m spacing (under Clause 4.10.5 of AS/NZS 1668.1-1998) within the Community Club area to that of 10.2 x 10.2 m grids which resembles an AS 1670.1 system.
- As per Alternative Solution AS 11 of this report – It is proposed to permit smoke detection for ventilation shutdown to be omitted from the high ceilinged indoor pool area only (refer Figure 48 for details).

6.5 Construction

The Fire Resistance Levels (FRLs) of the new building elements must be designed in accordance with the requirements of Section C of the BCA for a building of Type A Construction, other than the following ddeviations from these requirements:

- The FRL to the carpark areas is to be in line in guidance given in BCA Specification C1.1. It is acknowledged that the carpark may have the FRL concessison detailed in BCA Table 3.9 of Specification C1.1 as it will be sprinkler protected throughout.
- The Lower Ground floor separating the carpark and the Class 9b area above shall achieve an FRL of not less than 120/120/120 which is in line with guidance given in BCA Clause C2.9.
- As per Alternative Solution AS 1 of this report – the spandrels of Buildings A to F (which deviate from the prescriptive requirements of BCA Clause C2.6 must comply with the requirements of BCA Table 3 of Specification C1.1 and achieve the required FRL of 90/90/90 (Type A Construction). The slab / horizontal projection (balcony) shall be as follows;
    - Project outwards from the external face of the wall for a minimum of 600 mm.
    - To be a minimum of 200 mm in thickness and be of non-combustible construction having an FRL of not less than 60/60/60.
    - To extends along the wall not less than 450 mm beyond the openings (see Figure 8).
- The proposed glazed construction at Basement 2 and Basement 1 Levels (refer Figure 15), and at Lower Ground Floor Level (as identified in Figure 12) shall be protected with Tyco model WS specific application window sprinklers on both sides of the glazed elements and must be installed in accordance with the manufacturer's specifications. The specifications of the system are contained in Appendix E. However, note the following key items:
    - All combustible materials shall be kept at least 50.8 mm from the glazing. This shall be implemented via a pony wall (at least 0.9 m in height, where necessary).
    - There are restrictions on the type and size of glass panels.
    - There are restrictions on depths of mullions and transoms.
    - The glass shall be at least 6 mm thick and heat strengthened or tempered glass.
    - Any section of glazing above the door or adjoining the door must also be protected with the Tyco system.
    - Glazed doors within the glazed wall are required to automatically close so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door opening mechanisms, so as not to clash with the Tyco head.
    - The flow rates required to each Tyco WS head shall be as per the manufacturer's spec sheet.
    - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system.
- As per Alternative Solution AS 2 of this report - The proposed glazed construction at basement levels shall be smoke rated in accordance with Specification C2.5 – with self-closing doors fitted with smoke seals to AS 1530.7.
- As per Alternative Solution AS 4 of this report - All doors opening onto the residential corridors are required under the BCA DtS Provisions to be fire doors with an FRL of --/60/30 and fitted with self-

closers. These doors shall be upgraded and be fitted with hot temperature smoke seals tested in accordance with AS 1530.7. This shall include the doors into the fire-isolated stairs of Buildings E & F.

- The Class 2 residential corridors shall have the following FRL requirements as detailed in Table 3 of Specification C1.1;
  - FRL of 90/90/90 for loadbearing elements and
  - FRL of -/60/60 for non-loadbearing elements.
- As per Alternative Solution AS 7 of this report - the leisure lift lobby of Building F shall be fire separated from the adjoining areas with construction having an FRL of not less than 60/60/60.
- As per Alternative Solution AS 9 of this report - The fire-isolated passageway providing access to the Fire Hydrant Pump & Tank room / Fire Sprinkler Pump & Control Valve room (as identified in Figure 29) shall have a minimum FRL of 90/90/90 with all doors opening into the passageway to be self-closing -/60/30 fire doors which shall also be upgraded and be fitted with medium temperature smoke seals capable of withstanding temperatures of 200°C for 30 minutes and tested in accordance with AS 1530.7.
- The Fire Hydrant Pump & Tank / Fire Sprinkler Pump & Control Valve room is to be fire separated from adjacent areas with fire rated walls achieving an FRL of 120/120/120 complete with self-closing -/120/30 fire doors. The doors are also to be upgraded and fitted with medium temperature smoke seals, as noted above.
- Entrance door to the fire-isolated passage way to be provided with signage indicating that this door provides access to the Fire Hydrant Pump & Tank room/ Fire Sprinkler Pump & Control Valve room. Signage to be in accordance with AS 2419.1.
- The following rooms is to be fire separated from adjacent areas with fire rated walls achieving an FRL of 120/120/120 complete with self-closing -/120/30 fire doors as per the requirements of BCA Clause C2.12 & C2.13;
  - Substation room at Basement Level 1
  - Basement 1 Main Switchroom
  - Basement 1 UPS battery storage room
  - Lower Ground Generator room
- Stair ST04, Stair ST05, Stair ST-E and Stair ST-F shall be fire-isolated stairs achieving an FRL of 90/90/90 complete with fire rated doorways achieving an FRL of -/60/30 and fitted with self-closing devices.
- The following egress stairs which serve the Basement Levels are to be fire separated from the adjoining areas with an FRL of 60/60/60 complete with self-closing -/60/30 fire doors; Stair ST01, Stair ST02, Stair ST03 and Stair ST06.
- The required non-fire-isolated stairs (Stair 03 and Stair 07) shall be fire separated from the adjoining areas at Basement Levels 1 & 2 with an FRL of 60/60/60 complete with self-closing -/60/30 fire doors.
- Stair 07 doorway which discharges adjacent the Brigade booster assembly be fitted with a fire door despite this being to an external space.
- The Porte Cochere area and its circulation areas are not permitted to have any combustible materials, such as combustible seating and linings, materials and assemblies must be as per Table 1 of Specification C1.10.
- The undercroft area to the north of the club shall be fully open at the perimeter all the times.
- Fire stairs 1 and 2 leading from the basement levels discharging at ground levels of Building A and B require that the openings within 6 m of the paths of travel are protected in accordance with C3.4. These windows shall be protected with Tyco model WS specific application window sprinklers on the SOU

side of the window and must be installed in accordance with the manufacturer's specifications. The specifications of the system are contained in Appendix E. However, note the following key items:

- Glazed doors or openable windows within the glazed wall are required to automatically close, so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door and window opening mechanisms, so as not to clash with the Tyco head.

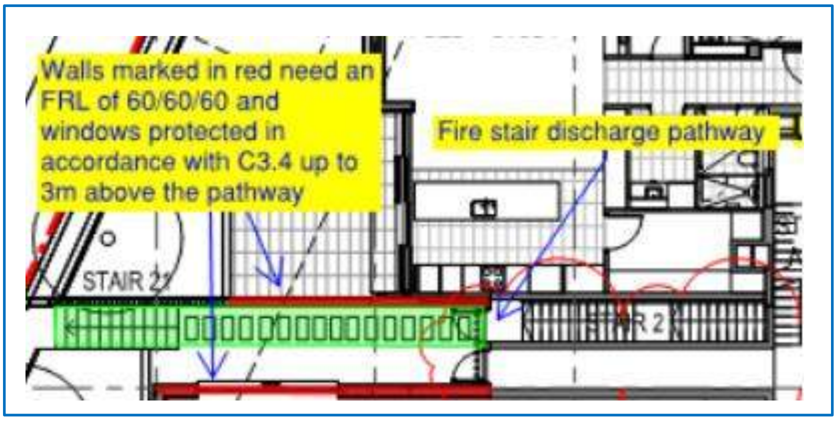


Figure 11: Openings in building A and B requiring C3.4 protection

6.6 Emergency Lighting & Signage

- Provide emergency lighting in accordance with BCA Clauses E4.2 and E4.4 and AS 2293.1.
- Provide emergency exit signage in accordance with BCA Clauses E4.5, E4.6 and E4.8 and AS 2293.1.
- As per Alternative Solution AS 2 of this report - The leisure lobby areas are required to be free of combustibles and ignition sources at all times. The following fire safety measures are to be adopted to the lobby areas at Basement Levels 1 & 2;
  - All furnishings contained within (if any, such as tables / seating) are to be of non-combustible materials as determined by AS 1530.1.
  - Shall have no combustible materials contained within and are to be designated sterile environments.
  - The leisure lobby areas and its bounding construction are to comprise of non-combustible construction.
- The lobby areas referred to in AS 2 shall have no combustible materials contained within and are to be designated sterile environments. The following supporting signage is to be erected on their walls outlining this requirement. Signage to read as follows:

  "NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA"

  The signage wording must be in capital letters not less than 50 mm in height. The lettering shall be in a colour contrasting with the background to which it is erected. The above requirement is be added to the Annual Fire Safety Statement for the building with the Building Management to inspect the leisure lobby areas on a monthly basis to ensure that the required fire safety measure is being adhered too.
- As per Alternative Solution AS 4 of this report - Directional exit signs shall be provided in the common corridors of Buildings A, B & D to clearly identify the egress route in reaching a road or open space.

6.7 Egress

Egress provisions throughout the building must comply with the requirements of Section D of the BCA except where modified by the Alternative Solutions contained herein including the following:

- As per Alternative Solution AS 4 of this report – the Class 2 SOUs (of Buildings A, B, D, E & F) have the following extended travel distances;

  - Up to 13 m in lieu of permissible 6 m in reaching the single exit (upper floors);
  - Up to 30 m in lieu of the permissible 20 m to the single exit serving the storey at the level of egress.
- As per Alternative Solution AS 4 of this report - it is proposed to permit Buildings A, B & D to be served by non-fire isolated stairways that do not provide a continuous means of travel by way of its own flights and landings.
- As per Alternative Solution AS 5 of this report – The car parking areas at Basement Levels 1 & 2 are permitted to have the following extended travel distances;
  - Up to 28 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
  - Up to 70 m in lieu of permissible 40 m in reaching an alternative exit,
  - Up to 95 m in lieu of the permissible 60 m between alternative exits.
  - Extended travel distance of 38 m in lieu of the permissible 20 m to the single exit within the loading dock area at Lower Ground Floor Level.
  - Extended travel distance of 34 m in lieu of the permissible 20 m to a point of choice in the Cinema Room on Basement Level 2.
- As per Alternative Solution AS 6 – To permit the following extended travel distances to an exit in the Class 9b areas (Lower & Upper Ground Floor Levels);
  - Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
  - Up to 60 m in lieu of permissible 40 m in reaching an alternative exit.
  - Up to 80 m in lieu of the permissible 60 m between alternative exits.
- As per Alternative Solution AS 7 – it is proposed to permit the following discharge arrangements of Buildings D, E & F;
  - To permit the fire-isolated stairs serving Buildings E & F not to discharge to an open space.
  - To permit the path of travel from the discharge point of fire-isolated stair serving Building E to pass within 6 m of the glazed facade of the Gym on the upper ground floor. The glazed facade of the Gym along the path of travel to Evans Street shall be protected with internal wall-wetting sprinklers as per Clause C3.4.
  - To permit path of travel from the discharge point of the fire-isolated stairs serving Building F to pass within 6 m of the glazed facade of the Café or the Seniors Lobby on the upper ground floor.
  - To permit the fire-isolated passageway which provides access to the hydrant tank and pump room to have multiple doors opening onto the passageway without the exit being pressurised.
  - To permit paths of travel on the Upper Ground Floor Level (applicable to Buildings D, E & F) to pass within 3 m of the openings associated with the Palm Gully and the Void space.
- Alternative egress paths shall be provided and maintained from the discharge points of exits from Buildings D, E & F. The alternative egress paths are in opposite directions to different streets. Refer to Figure 32 and Figure 33 for clarity.
- The fire-isolated passageway shall have a minimum FRL of 90/90/90 with all doors opening into the passageway to be self-closing -/60/30 fire doorsets that shall also be upgraded and fitted with medium temperature smoke seals, capable of withstanding temperatures of 200°C for at least 30 minutes and tested in accordance with AS 1530.7.
- On the Upper Ground Floor, the leisure lift lobby of Building F shall be fire separated from the adjoining areas with construction having an FRL of not less than 60/60/60.

- A designated egress pathway (with appropriate exit wayfinding signage) at least 1.5 m wide is to be provided in the Porte Cochere area, which leads directly to Evans Street and the stairs linking to Upper Ground Floor Level.
- As per Alternative Solution AS 8 of this report – it is proposed to permit the discharge of exits from Class 9b areas to an undercroft space that is not open to the sky. This is applicable to exits that discharge into the following areas: the Porte Cochere and the covered area to the north of the community club at Lower Ground Floor Level as well as Building E overhang at Upper Ground Floor Level.
- A designated egress pathway (with appropriate exit wayfinding signage) at least 1.5 m wide is to be provided in the Porte Cochere area which leads directly to Evans Street and the stairs linking to Upper Ground Floor Level.

6.8 Management in Use and Maintenance of Essential Services

- All of the relevant items listed above should be included in the essential service schedule and listed in the Annual Fire Safety Statement.
- All Alternative Solutions to be listed in the Essential Services Schedule and Annual Fire Safety Statement.
- The water supply to the wall-wetting drencher system to be separately valved and independent to the sprinkler system serving the fire compartments concerned. Suitable management provisions to be included in the Management-In-Use plan documentation to ensure that both the sprinkler and wall-wetting drencher systems are not isolated at the same time during maintenance works.
- As per Alternative Solution AS 3 of this report - it is noted at present that the proposed Building F elevation currently overlooks the existing carpark and McKillop Park public reserve. However, if the adjoining carpark / public reserve is to become part of a future development (under a separate owner), this proposed Alternative Solution is to be reassessed to ascertain if the identified unprotected openings identified are required to be protected from thermal radiation emitted from a fire in the adjoining property. An agreement is to be created, where the Consent Authority is required to give written notice to the owner and/or occupier of the subject building. The trigger for this written notice is the receipt of a Development Application for development of the adjacent allotments. On receipt of this written notice the level of fire protection for the openings identified are to be re-assessed by a qualified fire engineer.
- Monitoring of the neighbouring carpark and McKillop Park public reserve as per the above requirement is to form a Critical Fire Safety Measure for the proposed development and is be added to the Annual Fire Safety Statement (AFSS) for the building.
- Commissioning and integrated function testing of all fire safety and protection systems including interfaces to ensure proper function must be undertaken.
- All essential services are to be maintained and tested by reputable contractors in accordance with the requirements of relevant regulatory requirements and relevant Australian Standards. It is recommended that the [AS 1851] be adopted as maintenance standard for the upkeep of the essential fire protection systems in the building to ensure their continued ‘as designed’ performance throughout the life of the building.
- In order to enhance the safety of occupants and to facilitate the upkeep of the essential fire safety systems, it is recommended that a Building Maintenance Manual (BMM) must be developed for use by the Building Manager. The BMM must include *inter alia*:
    - Operation and Maintenance (O&M) Manuals of all installed fire services.
    - Registers of fire safety equipment. Fire safety equipment to be provided in situ with permanent and unique identification numbers corresponding to those contained in the equipment registers.
    - Maintenance records of systems and equipment.
    - Records of test activities.

- Where services are modified as part of an alternative solution, these must be included in the maintenance and annual certification.

7. AS 1 – Review of Spandrel Separation

7.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 9: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit horizontal separation of openings in the external wall of the Buildings A, B, C, D, E & F not to meet the spatial requirements given in BCA Clause C2.6 for a building of Type A Construction.	C2.6	CP2	SS-C	(b)(ii)	(b)(ii) (b)(c)
Approach and assessment method used - *The approach used in this solution will be deterministic and comparative in nature utilizing quantitative and qualitative assessment methods.*					

NOTE: It is acknowledged that at the time of preparing this FER, WSP | PB Fire has not been provided with completed spandrel details for Buildings A to F. It is noted that this solution will vary depending on the proposed spandrel arrangements put forward. WSP | PB Fire has addressed non-compliant horizontal projections only and compared against a permissible vertical spandrel arrangement satisfying BCA Clause C2.6(a).

7.2 Description of non-compliance with DtS Provisions

It is proposed to provide a minimum 600 mm deep horizontal apron projection in lieu of a required 1100 mm horizontal projection to achieve the equivalent level of separation as a 900 mm high spandrel to openings in some areas of the external walls of Building A to F (as illustrated in Figure 13). The minimum details of the proposed horizontal aprons in the development have been indicatively illustrated in Figure 12.

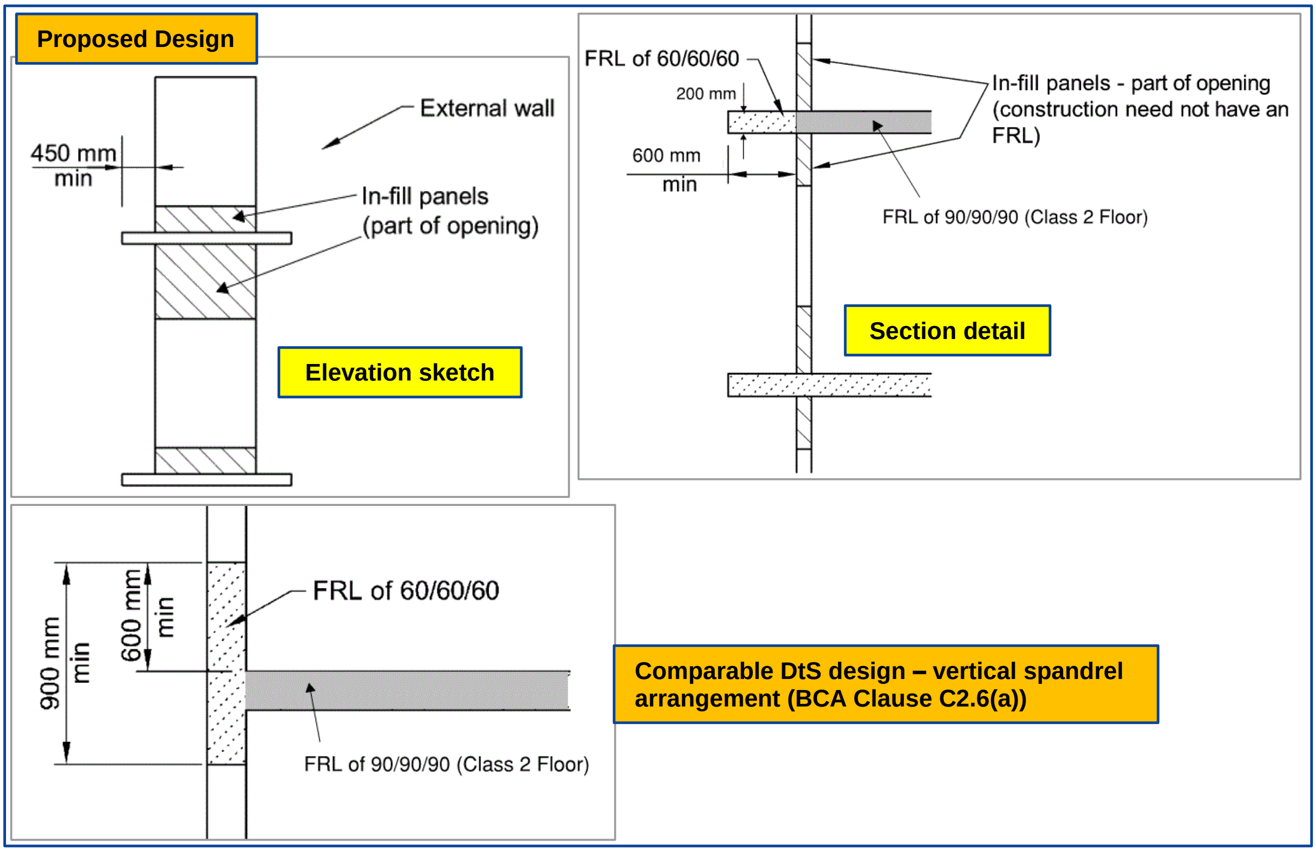


Figure 12: Proposed spandrel design (in parts only) to the residential levels of the building

7.3 Acceptance Criteria

To determine whether the Alternative Solution is considered to meet the BCA Performance Requirements, it will be demonstrated that the proposed building in its current design prevents vertical fire spread between floors to at least the extent of a DtS compliant design.

It will be demonstrated that the radiation incident on the window located in the storey above the fire-affected room window is less if a horizontal projection of 600 mm is used compared to a DtS equivalent design using a vertical spandrel of 900 mm.

7.4 Hazards

The hazard associated with the separation distance between vertical openings in external walls not meeting the dimensions prescribed in the BCA is that there is an increased risk that vertical fire spread between the openings may occur.

7.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution have been detailed below and indicatively illustrated in Figure 12;

- The floor slabs to the residential areas must comply with the requirements of BCA Table 3 of Specification C1.1 and achieve the required FRL of 90/90/90 (Type A Construction). The slab / horizontal projection (balcony) shall be as follows;
    - Project outwards from the external face of the wall for a minimum of 600 mm.
    - To be a minimum of 200 mm in thickness and be of non-combustible construction having an FRL of not less than 60/60/60.
    - To extend along the wall not less than 450 mm beyond the openings.

7.6 Method of Analysis

It will be demonstrated that the proposed minimum 600 mm deep horizontal projection achieves at least an equivalent level of fire separation to that of a DtS Compliant 900 mm high spandrel. The approach used in this solution has been deterministic and comparative utilising quantitative and qualitative assessment methods. It is demonstrated that the inclusion of the apron in the proposed design limits the flame height when compared with a DtS complaint spandrel of 900 mm between openings.

It is noted that a comparative assessment is undertaken. Any of the SOU’s in Buildings A to F can be assessed as the same layout / compartment dimensions. The only difference when compared with a comparable DtS design is the incorporation of the spandrel arrangement of 900 mm, as illustrated in Figure 12.

7.7 Assessment

7.7.1 Qualitative Assessment

The level of protection from vertical fire spread afforded by a horizontal projection is considered to be more effective than that by vertical spandrels. Refer to the following extract from the Fire Engineering Design Guide [FEDG]; note the term ‘apron’ used which is the same as a horizontal projection:

> *“Aprons are often not desirable architecturally or because they reduce the allowable floor area of a building on a site. Vertical spandrels may be so deep that they severely restrict window openings. Horizontal apron projections are much more effective, with a 600 mm apron reducing incident radiation from flame projections by 50 % from that just above an unprotected opening, the same reduction that is achieved with a 2.5 m deep spandrel.”*

In support of this statement, a comparison is made of the DtS requirements of various international building codes which have – contrary to the provisions in the BCA – a much larger spandrel height requirement than a horizontal projection depth. This is as shown in Table 10.

Table 10: Spandrel or horizontal projection requirements in various international codes

Vertical separation	International Building Code [IBC]	NZ C/AS2	BCA
Apron depth	0.762 m	0.600 m	1.100 m
Height of spandrel beam	0.914 m	1.500 m	0.900 m

From the table, it is clear that it is recognised internationally that horizontal projections are more effective than spandrel panels in preventing exterior vertical fire spread between openings.

7.7.2 Quantitative Assessment

In support of this qualitative discussion, the flame length and its temperature on the window on the floor above has been calculated. Refer to Figure 9 for a pictorial representation of the proposed building solution which is compared with a DtS compliant spandrel design.

The calculation method as given in [Eurocode 1] was used to calculate the flame height, flame length and variation in flame temperature along the flame axis. The variation in radiant flux along the axis of the flame to the upper window could then be calculated. The calculations are given in Appendix G.

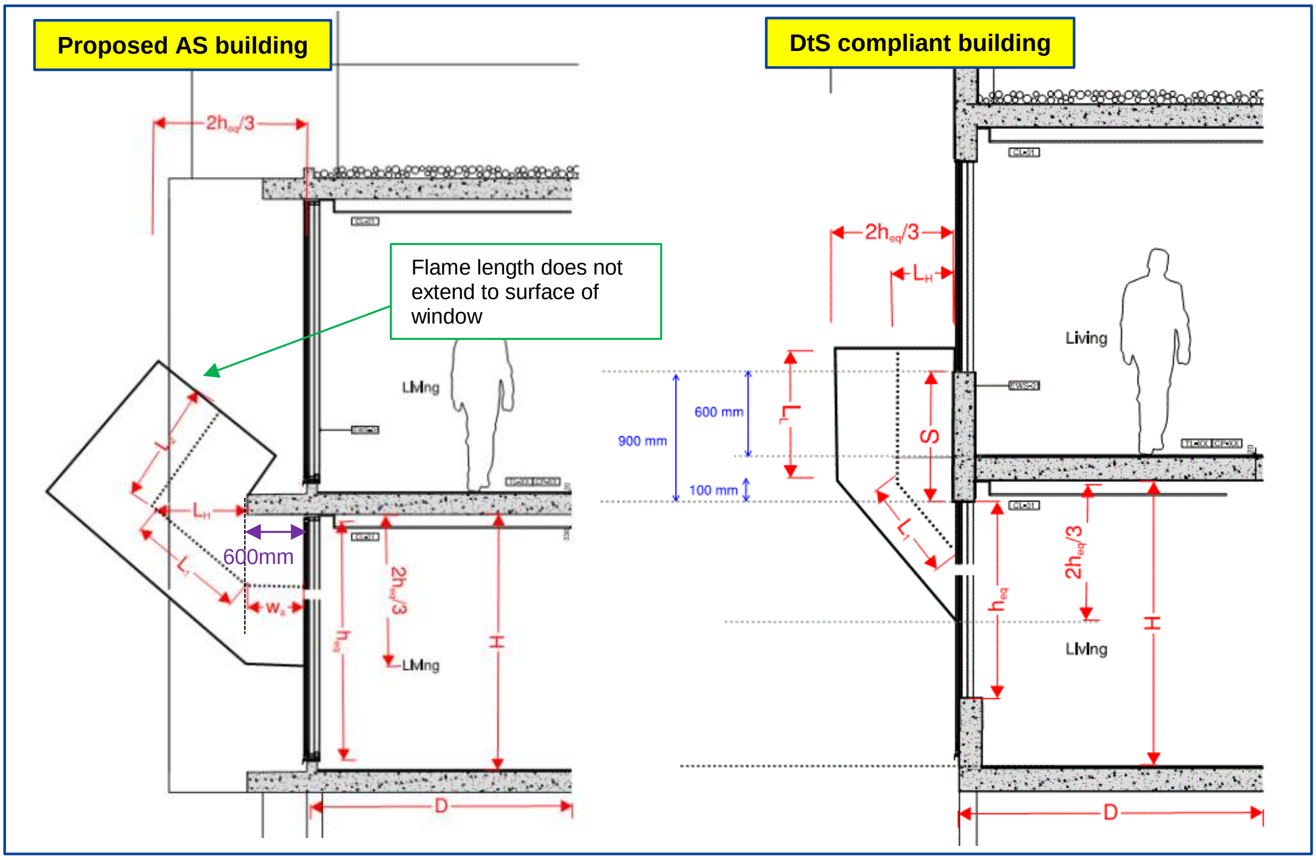


Figure 13: Flame projection parameters – Proposed Design versus a comparable DtS Design

It was found for the horizontal projection that the flame tip does not reach the surface of the upper window with the total flame length of 1.4 m. The temperature of the flame in this arrangement was found to be 634 °C.

For the DtS compliant spandrel beam (900 mm high), it was found that the flame tip extended well above the spandrel. The total length of the flame was 1.53 m which, unlike the proposed design, is in close contact with the facade and the opening above. The temperature of the projecting flame in this arrangement was found to be 590 °C. Refer to Table 13 for details on the calculations.

Inputs - Harbord Diggers Development (Buildings A to I	Proposed	DtS	
Room Dimensions			
Height (BCA Clause F3.1)	2.40	2.40	m
Width	4	4	m
Depth	12	12	m
Separating slab thickness	0.2	0.2	m
Fire load density	450	450	MJ/kg
Ambient temperature, T_0	20	20	°C
Effective absorptivity of soot	0.3	0.3	
Fire compartment openings			
Height, h_{eq}	2.40	1.90	m
Width, w	3.0	3.0	m
Distance between windows	0.0	0.0	m
Vertical fire spread separation elements			
Horizontal projection depth, w_a	0.6	0	m
Height of spandrel beam, S	0	0.9	m
Constants	**Proposed**	**DtS**	
Stefan-Boltzmann constant, σ	5.67E-11		kW/m^2K^4
Calculations	**Proposed**	**DtS**	
Window flame length			
Room floor area	48.0	48.0	m^2
Opening area, A_v	7.2	5.7	m^2
Overall heat release rate from burning rate (cellulosics)	8.40	7.64	MW
Flame thickness	1.60	1.27	m
Unadjusted flame height above soffit , L_L	1.37	1.64	m
Adjusted flame length to account for horizontal projection, L_L	-0.07	1.64	m
Distance to flame axis, L_H	0.80	0.63	m
Turning region flame length, L_1 unadjusted	0.80	0.63	m
Turning region flame length, L_1 adjusted	0.80	0.63	m
Turning region flame length, L_2	0.00	0.00	m
Total flame length, L_f	2.17	2.28	m
Compartment temperature			
Fire load (wood equivalent), L	1148.9	1148.9	kg
A_t	165.6	167.1	m^2
O	0.0674	0.0470	
Ω	626	700	
Compartment temperature	1023	1011	
Flame characterization			
Flame temperature at opening	841	920	
Flame length at bottom of upper window	1.40	1.53	m
Flame temperature at base of window above	634	651	°C

Figure 14: Proposed horizontal projection versus compliant spandrel – Flame projection & temperature

7.8 Conclusion

The performance of the proposed 600 mm horizontal projection was shown to be superior to that of a comparable DtS spandrel arrangement (vertical separation of 900 mm). Hence Performance Requirement CP2 of the BCA is therefore considered to be met.

8. AS 2 – Review of separation by Fire Walls

8.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 11: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit glazed wall & doors to form part of a required fire wall (separation of building classifications & different fire compartments within the building at basement levels only) and not be provided with the required FRL.	C2.7 & C3.5	CP2 and CP4	SS-B & SS-C	(b)(i)	(c)
To permit glazed elements at Lower Ground Floor Level to form part of a fire wall (separation of compartments) and be protected by a proprietary wall wetting system providing the required FRL.					
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

8.2 Description of non-compliance with DtS Provisions

It is proposed to permit glazed elements (wall & doors) to form part of a required fire wall (separation of building classification & different fire compartments at basement levels only) and not be provided with the required FRL under Clause C2.7 & C3.5. This is applicable to the following areas;

- The glazed elements of the leisure lobby area (which includes the leisure lift and feature stair connecting from Basement Levels 2 to Level 1) as identified in Table 14.
- The glazed elements which separate the alfresco gaming area, the Community Club, the Porte Cochere and the Gym / Aquatic Centre, as indicatively illustrated in Figure 16.

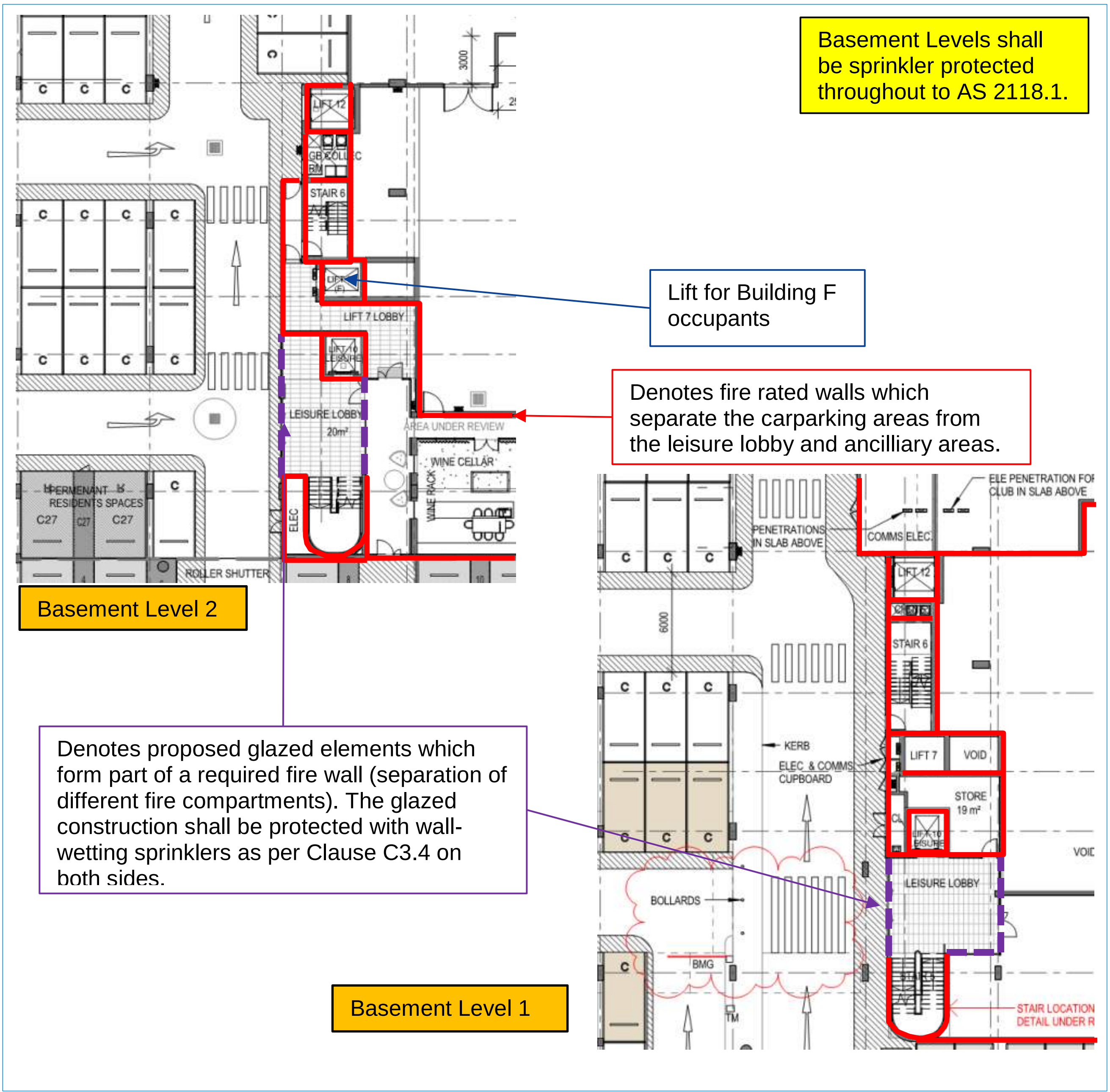


Figure 15: Leisure Lobby – proposed use of a glazed smoke rated wall in lieu of a required fire wall

It is proposed to also permit glazed elements at Lower Ground Floor Level to form part of a fire wall (separation of compartments) and be protected by a proprietary wall wetting system to provide the required FRL.

The required FRL is being provided by an active system rather than a passive system. This is applicable to the glazed elements which separate the Community Club, the Porte Cochere areas and the Gym / Aquatic Centre, as indicatively illustrated in Figure 16.

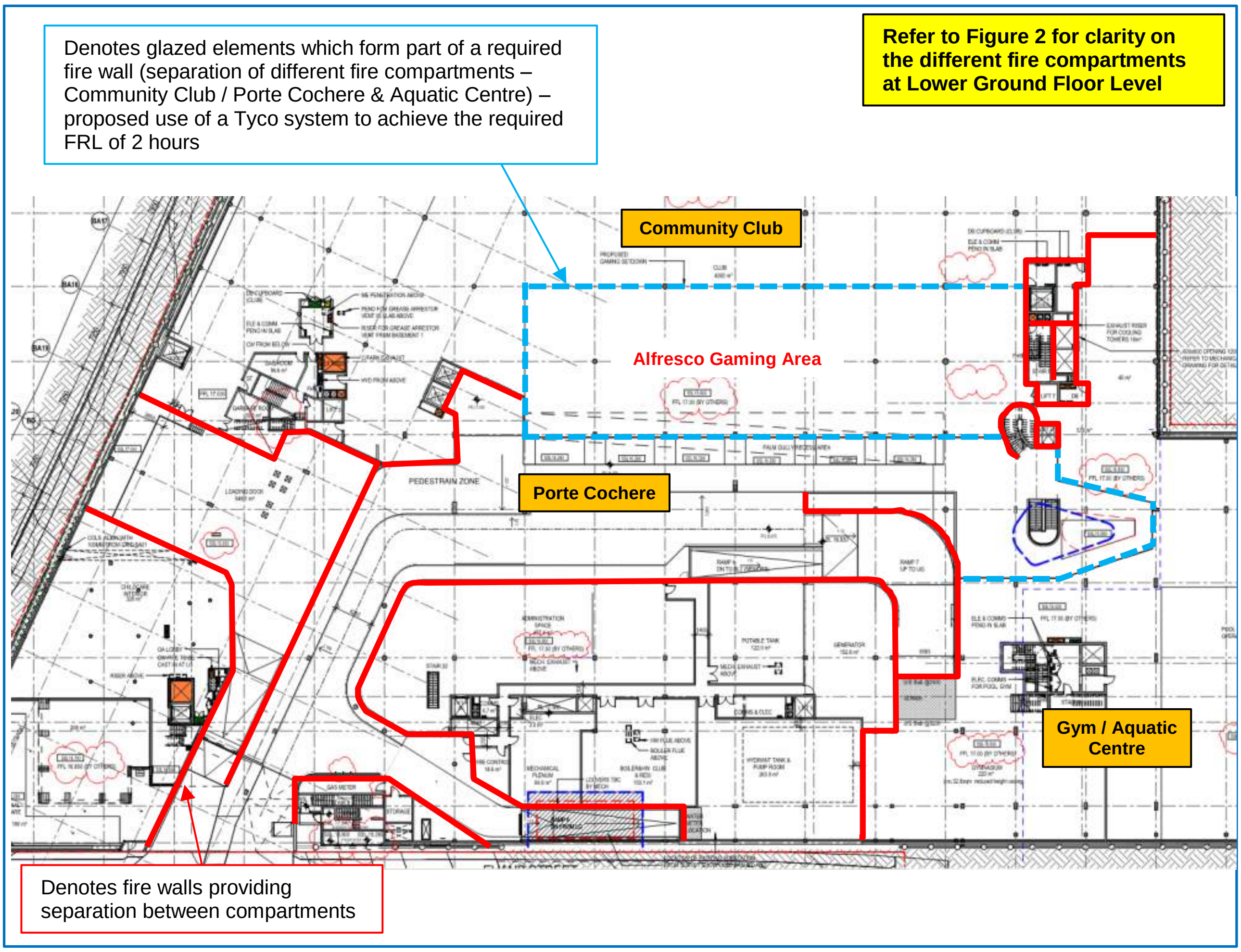


Figure 16: Lower Ground Floor Level – extent of compartmentation & glazed walls using Tyco system

8.3 Acceptance Criteria

The acceptance criterion is that the proposed solution presents a level of risk to life safety and separation by fire wall which shall include glazed elements will be at least equivalent to that afforded by a similar DtS compliant building design, by demonstrating that fire spread between the different fire compartments is unlikely to occur.

8.4 Hazards

The key hazard specific to the proposed building configuration & the use of glazed elements in a required fire wall is that there is an increased risk of fire spread between the different fire compartments as a result of the glazed elements, as they are not provided with the required FRL (passive fire barrier) specified under BCA Clauses C2.7 & C3.5.

8.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- The following areas shall be sprinkler protected throughout to AS 2118.1 which shall include the use of fast response sprinkler heads with an RTI of 50 $(m \cdot s)^{0.5}$ or less;
  - Throughout the basement levels, including the leisure lobby areas.
  - The Porte Cochere, Community Club areas and the Gym / Aquatic areas.

- The proposed glazed construction at Basement 1 and Basement 2 Levels (refer Figure 15), and at Lower Ground Floor Level (as identified in Figure 16) shall be protected with Tyco model WS specific application window sprinklers on both sides of the glazed elements and must be installed in accordance with the manufacturer's specifications. The specifications of the system are contained in Appendix E. However, note the following key items:
    - All combustible materials shall be kept at least 50.8 mm from the glazing. This shall be implemented via a pony wall (at least 0.9 m in height, where necessary).
    - There are restrictions on the type and size of glass panels.
    - There are restrictions on depths of mullions and transoms.
    - The glass shall be at least 6 mm thick and heat strengthened or tempered glass.
    - Any section of glazing above the door or adjoining the door must also be protected with the Tyco system.
    - Glazed doors within the glazed wall are required to automatically close so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door opening mechanisms, so as not to clash with the Tyco head.
    - The flow rates required to each Tyco WS head shall be as per the manufacturer's spec sheet.
    - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system.
- The proposed tyco WS drenching system is required to be separated from the sprinkler system water supply by valves.
- Isolation of both systems simultaneously for maintenance purposes shall not be allowable. This is to be included in the management in use plan.
- The number of heads required to activate simultaneously in each area must be reviewed, with calculations being carried out by the fire protection contractor to verify that the water supply available (both town main and tank supply) can achieve full flow of this system for no less than 2 hrs in the most disadvantaged area. These calculations must allow for the sprinkler system serving the occupied areas of the basement levels and the fire hydrant system to be in operation simultaneously.
- The proposed glazed construction at basement levels shall be smoke rated in accordance with Specification C2.5 – with self-closing doors fitted with smoke seals to AS 1530.7.
- The leisure lobby areas are required to be free of combustibles and ignition sources at all times. The following fire safety measures are to be adopted to the lobby areas at Basement Levels 1 & 2;
    - All furnishings contained within (if any, such as tables / seating) are to be of non-combustible materials as determined by AS 1530.1.
    - Shall have no combustible materials contained within and are to be designated sterile environments.
    - The leisure lobby areas and its bounding construction are to comprise of non-combustible construction.
- The lobby areas shall have no combustible materials contained within and are to be designated sterile environments. The following supporting signage is to be erected on their walls outlining this requirement. Signage to read as follows:

  "NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA"

  The words "NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA'" must be in letters not less than 50 mm in height. The lettering shall be in a colour contrasting with the background to which it is erected. The above requirements are be added to the Annual Fire Safety Statement for the building with the Building Management to inspect the leisure lobby areas on a monthly basis to ensure the required fire safety measure is being adhered to.

8.6 Method of Analysis

It is proposed to undertake a qualitative, deterministic and absolute analysis which shall demonstrate that the risk of fire spread between the identified fire compartments (refer Table 14 and Figure 16) in conjunction with the fire safety measures detailed in the section above shall contribute to limiting the likelihood of fire spread and as such satisfy the intent of BCA Performance Requirement CP2 and CP4.

It shall be demonstrated that the incorporation of a required sprinkler system to the Basement Levels, Community Club areas and Gym / Aquatic areas and a non-required sprinkler system to the Porte Cochere area results in the likelihood of fire spread between fire compartments being unlikely.

8.7 Assessment

8.7.1 Smoke separation of Leisure Lobby areas in basement levels

The leisure lift lobby at basement levels shall be separated from the carpark areas with smoke-proof construction incorporating glazing in accordance with Specification C2.5 which includes self-closing doors fitted with smoke seals to AS 1530.7.

It is submitted that the combustible content in the leisure lobby areas will be limited due to the nature of its use as it is a circulation space to be used on a daily basis for access to and from the lift which connects the car parking levels with the Community Club areas located at Lower Ground Floor Level. Hence, given the area's main use, ignition sources within will be minimal and the overall fire risk will be low and as such does not present a credible fire source. To ensure that the leisure lobby areas do not present a credible fire source, the following fire safety measures are also to be adopted;

- The leisure lobby areas and its bounding construction is to comprise of non-combustible construction.
- All ancillary furnishings (such as seating) are to be of non-combustible materials as determined by AS 1530.1.
- The leisure lobby areas are required to be free of combustibles and ignition sources at all times and to become a designated sterile environment;
- Additional supporting signage is to be erected in the leisure lobby area plus in entrance approach from outside on the wall outlining this requirement. Signage to read as follows:

  'NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA'

  The signage wording must be in capital letters not less than 50 mm in height. The lettering shall be in a colour contrasting with the background to which it is erected.

The above requirements are be added to the Annual Fire Safety Statement for the building with the Building Management to inspect the leisure lobby areas on a weekly basis to ensure the above required fire safety measures are being adhered to. The weekly inspection of the leisure lobby area to be also listed as an essential fire safety measure for the building.

The basement levels including the Lower Ground Floor Level, to which the leisure lobby connects, are to be provided with a sprinkler system to AS 2118.1. In the event of a fire, the sprinkler system is expected to control, if not suppress the fire. The sprinkler system acts to cool the upper smoke layer and wet adjacent combustibles and partitions helping to prevent the fire from spreading beyond the area of origin. Hence, the presence of a sprinkler system in this instance shall further contribute to eliminating fire spread between the identified areas / compartments of the building.

8.7.2 Fire separation via Tyco sprinkler heads

The Class 9b areas on the Lower Ground Floor shall be fire separated from the Porte Cochere area with construction having an FRL of at least -/120/120. The following areas are to be separated from the Porte Cochere area with fixed tempered glazing which is protected with Tyco WS type window drenchers on both sides of the glazing (as shown in Figure 16):

- The Aquatic Centre and Gym
- The Community Club including ancillary retail units (i.e. hairdresser / day spa tenancies)

The proprietary tested system incorporating fixed glazing in conjunction with Tyco sprinkler heads must be installed in accordance with the manufacturer's specifications detailed in Appendix E. This fire separation is considered sufficient due to the system having been subject to full scale fire tests in which the system was exposed to a standard heating scheme as per the ASTM E119 which is up to more than 1000 °C. This exposure condition is considered similar to that in an enclosure where flashover occurs.

The Lower Ground Floor including the subject areas is fully sprinklered. As a result, a fire occurring in these areas would be expected to be controlled by the operation of the sprinklers and contained within the area of origin. According to research conducted by [CIBSE] and [Warrington] the upper layer temperature is not likely to exceed 100°C in a sprinkler suppressed fire or 200°C in a sprinkler controlled fire (for example when a shielded fire continues to burn, but does not grow). Therefore, a flashover fire is unlikely to occur in these sprinkler protected areas and the caused exposure conditions would be much less severe than the standard fire test to which the glazing system is exposed in the fire test.

Section C.2 of Appendix C further supports the effect of sprinklers on temperatures as researched by [Taiwan] which concluded that the temperatures in the fire-affected room ranged between 200 °C and 400 °C which are too low to cause any structural fire damage.

The Australian guidelines [FCRC] provide recommendations based on the temperature differential ΔT between the two faces of the glass for the failure of glasses. Based on this criterion, ordinary glass breaks at ΔT= 80°C and tempered glass breaks at ΔT= 240°C. As discussed above, under a sprinkler controlled fire scenario, it is considered that a temperature differential of 240°C is unlikely to occur between the two faces of the tempered glass and thus failure of the glazing is unlikely to occur. In the case of a fire occurring immediately adjacent to the glazing, the Tyco specific application window sprinklers will activate and apply water to the entire surface of the glazing. As a result, a temperature differential of 240 °C is unlikely to be reached to cause the failure of the tempered glazing. Even if the temperature in these areas were to exceed this level, the Tyco drencher system would already have operated by that point, thereby mitigating the risk of glazing failure in this space.

8.7.3 Egress from building (CP4)

It is acknowledged that the leisure lobby area shall not form part of a designated egress route and is a circulation space only linking the car parking levels with the community club areas at Lower Ground Floor Level. The Class 9b areas on the Lower Ground Floor shall be fire separated from the Porte Cochere area with construction having an FRL of at least -/120/120 which is to be achieved by the Tyco system which is noted is a proprietary tested system. Given the provision of the fire safety measures discussed in Section 8.5, it is expected that the glazed construction shall remain intact and as such not compromise the safe evacuation from each area of the building and as such satisfies the intent of BCA Performance Requirement CP4.

8.8 Conclusion

This analysis demonstrates that the inclusion of the proposed the fire safety features detailed in Section 6 manages the variations from the relevant BCA Clauses. As such, BCA Performance Requirements CP2 and CP4 are met.

9. AS 3 – Openings within 3 m of the boundary

9.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 12: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit unprotected openings (in Building F) and a service riser (within Building E upper ground level roof) to be within 3 m of the side boundary that adjoins the public reserve by way of registering an easement or similar incumbent on the neighbouring land.	C3.2, C3.4	CP2	SS-C	(b)(i)	(b)(ii)
***Approach and assessment method used* -** The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

9.2 Description of non-compliance with DtS Provisions

Based on advice from the PCA, the extent of unprotected openings that are within 3 m of the boundary are limited to Building F on the residential areas at Levels 1 to 4 (within the south west boundary) and service riser openings within Building E Roof. These are indicatively illustrated in Figure 17 and Figure 18.

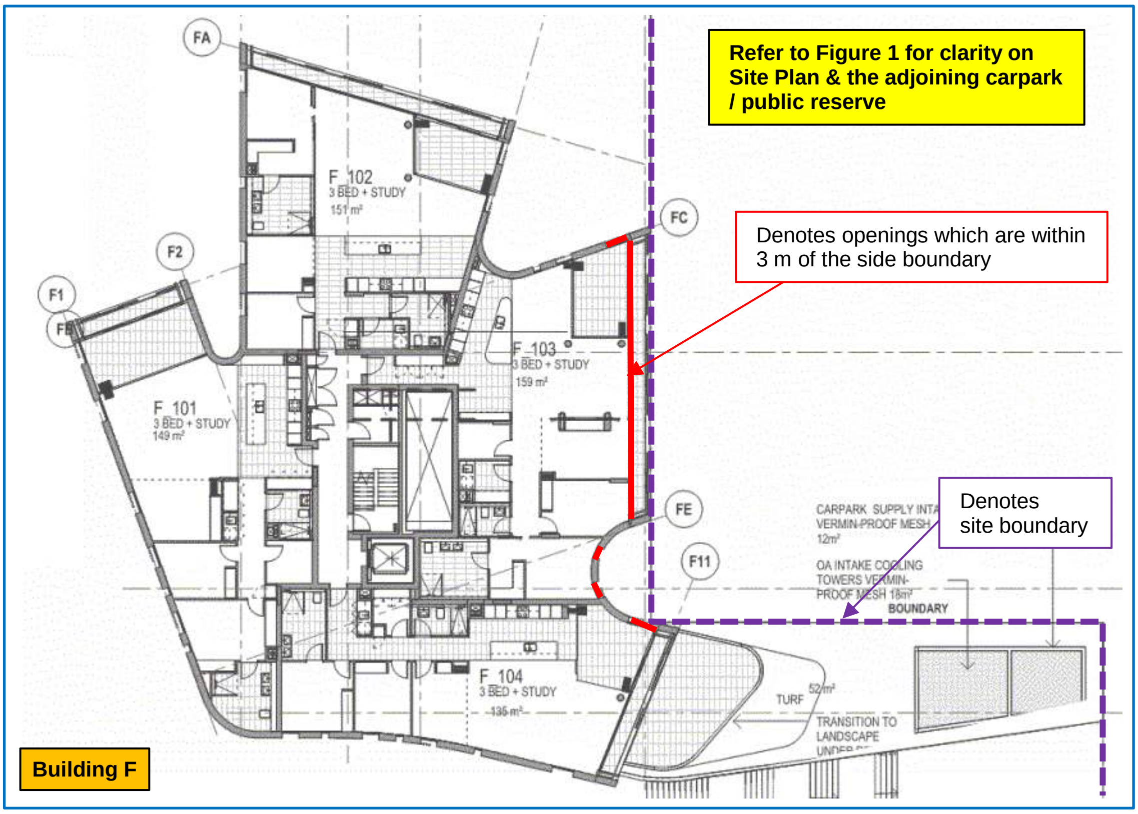


Figure 17: Building F (Level 1) – unprotected openings within 3 m of the side boundary

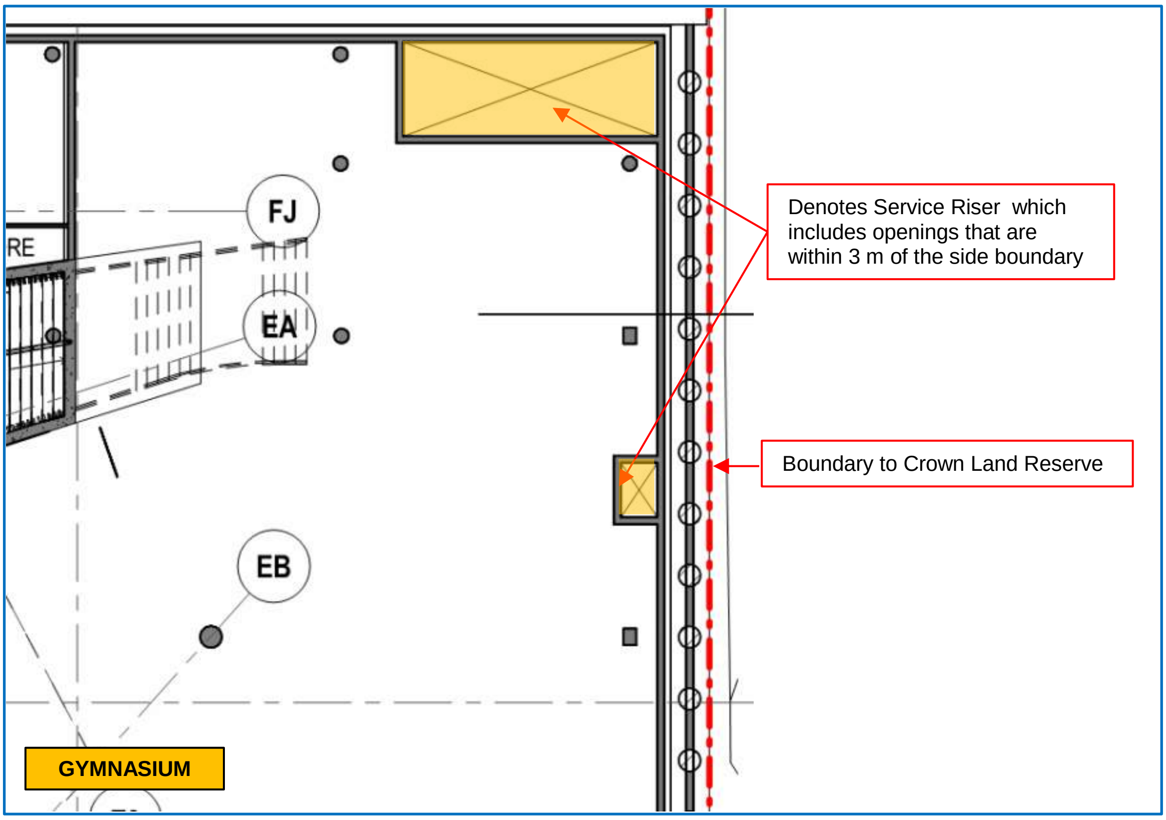


Figure 18: Building E (Rooftop) – service riser openings within 3 m of the adjoining boundary

9.3 Acceptance Criteria

An opening can either be a source of radiant heat (in the event that the fire compartment containing the opening is involved in fire), or it can be a receiver of radiant heat from an external source (for example a neighbouring building that is burning). When assessing fire spread between buildings, both aspects need to be considered.

To determine whether the Alternative Solution is considered to meet the BCA Performance Requirements, it needs to be demonstrated that the identified unprotected openings in the subject building which are within 3 m of the boundary do not pose an exposure hazard to the adjoining public reserve (or potential future development) and the adjoining reserve does not serve as an exposure hazard to the subject building and the proposed unprotected openings.

9.4 Hazards

The key hazard specific to the proposed building configuration & orientation to the adjoining boundary is that there is an increased risk of fire spread between buildings, as the identified unprotected openings are noted as being located closer than 3 m to the proposed boundary.

9.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development, incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- It is noted at present that the proposed building on the south west elevation currently overlooks the existing carpark and McKillop Park public reserve. However, if the adjoining carpark / public reserve is to become part of a future development (under a separate owner), this proposed Alternative Solution is to be reassessed to ascertain if the identified unprotected openings are required to be protected from thermal radiation emitted from a fire in the adjoining property. An agreement is to be created, where the Consent Authority is required to give written notice to the owner and/or occupier of the subject building.

The trigger for this written notice is the receipt of a Development Application for development of the adjacent allotments. On receipt of this written notice, the level of fire protection for the openings identified are to be re-assessed by a qualified fire engineer.

- Monitoring of the neighbouring carpark and McKillop Park public reserve as per the above requirement is to form a Critical Fire Safety Measure for the proposed development and is be added to the Annual Fire Safety Statement (AFSS) for the building.

9.6 Assessment

It is noted at present the Building F and Building E Gymnasium of the proposed Harbord Diggers development will overlook the existing carpark and McKillop Park which is a public reserve, as illustrated in Figure 19. It is unlikely that the zoning for this carpark / public reserve is to change due to development.

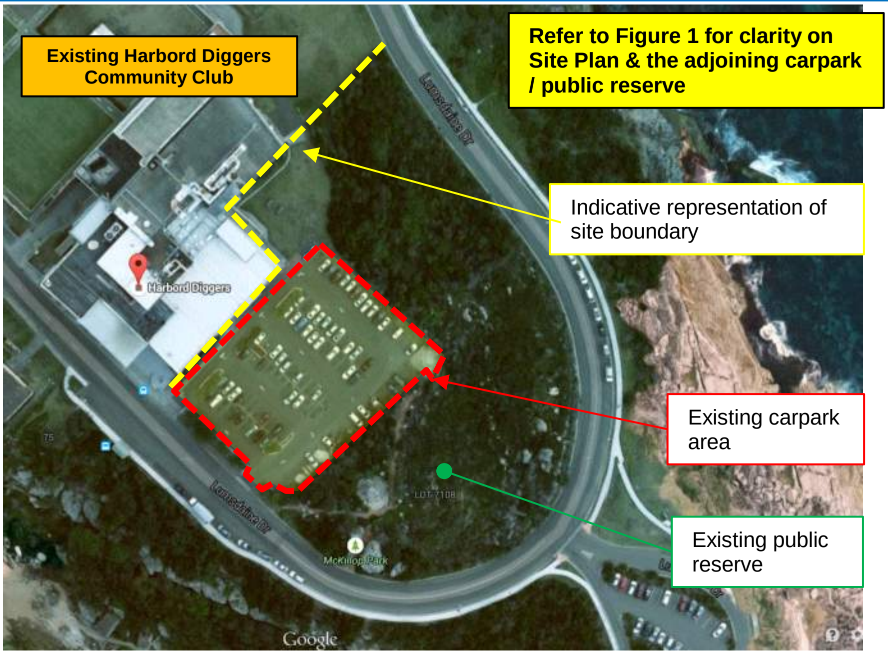


Figure 19: Existing aerial photo (Google©2015) – extent of adjoining carpark & public reserve

It is proposed to permit unprotected openings and service risers to be within 3 m of the side boundary that adjoins the public reserve by way of registering an easement or similar incumbent on the neighbouring land. This measure would prevent a future development to occur in the adjacent McKillop Park which may cause a fire source feature.

It is proposed that if the adjoining carpark / public reserve becomes part of a future development (under a separate owner), this proposed Alternative Solution is to be reassessed to ascertain if the identified unprotected openings are required to be protected from thermal radiation emitted from a fire in the adjoining property. An agreement is to be created, where the Consent Authority is required to give written notice to the owner and/or occupier of the subject building. The trigger for this written notice is the receipt of a Development Application for development of the adjacent allotments. On receipt of this written notice the level of fire protection for the openings identified are to be re-assessed by a qualified fire engineer.

The above requirement is to become a Critical Fire Safety Measure for the proposed development and is be added to the Annual Fire Safety Statement (AFSS) for the building.

9.7 Conclusion

It is submitted that the proposed solution in conjunction with the fire safety measures introduced demonstrate that BCA Performance Requirement CP2 has been met.

10. AS 4 – Review of egress from Class 2 SOUs

10.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 13: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit extended travel distances of up to 13 m to a single exit in lieu of the permissible 6 m in the Class 2 residential corridor areas of the development (in Buildings A, B, D, E & F).	D1.4	DP4 & EP2.2	SS-C, SS-D, SS-E & SS-F	(b)(ii)	(c)
To permit an extended travel distance of up to 30 m in lieu of the permissible 20 m to the single exit serving the storey at the level of egress (Upper Ground Floor Level).					
To permit Buildings A, B & D to be served by non-fire-isolated stairways that do not provide a continuous means of travel by way of its own flights and landings.	D1.9(a)				
Approach and assessment method used **-** The approach used in this solution will used qualitative, absolute and will use a comparative deterministic approach.					

10.2 Description of non-compliance with DtS Provisions

It is proposed to permit the entry doors of some of the SOUs within Buildings A, B, D, E & F to be located up to 11 m (in lieu of the permissible DtS distance of 6 m) from the single exit which is by way of a non-fire-isolated stair at Levels 2 & 1.

It is also proposed to permit an extended travel distance of up to 30 m (in lieu of the permissible 20 m under BCA Clause D1.4(a)(i)(B)) to the single exit serving the storey at the level of egress at Upper Ground Floor Level. A breakdown of the extended travel distances to each building has been detailed below;

- *Building A*

Upper Ground Floor Level – Up to 30 m from SOU A_003 in lieu of 20 m
Level 1 - Up to 10 m from SOU A_103 in lieu of 6 m
Level 2 - Up to 10 m from SOU A_203 in lieu of 6 m

- *Building B*

Level 1 - Up to 11 m from SOU B_104 in lieu of 6 m
Level 2 - Up to 11 m from SOU B_203 in lieu of 6 m
Level 2 - Up to 13 m from SOU B_234 in lieu of 6 m

- *Building D*

Level 1 - Up to 9 m from SOU D_104 & D_105 in lieu of 6 m
Level 2 - Up to 9 m from SOU D_204 & D_207 in lieu of 6 m

- *Building E*

Level 1 - Up to 8 m from SOU E_104 in lieu of 6 m
Level 2 - Up to 8 m from SOU E_204 in lieu of 6 m
Level 3 - Up to 8 m from SOU E_304 in lieu of 6 m

- *Building F*

Level 1 - Up to 9 m from SOU F_102 in lieu of 6 m
Level 2 - Up to 9 m from SOU F_202 in lieu of 6 m
Level 3 - Up to 9 m from SOU F_302 in lieu of 6 m
Level 4 - Up to 9 m from SOU F_402 in lieu of 6 m

A sample of the extended travel distances in the Class 2 areas has been indicatively illustrated in Figure 20 (Building B) and Figure 21 (which shows Building A). It is noted that Buildings A, B, C & D have similar egress arrangements.

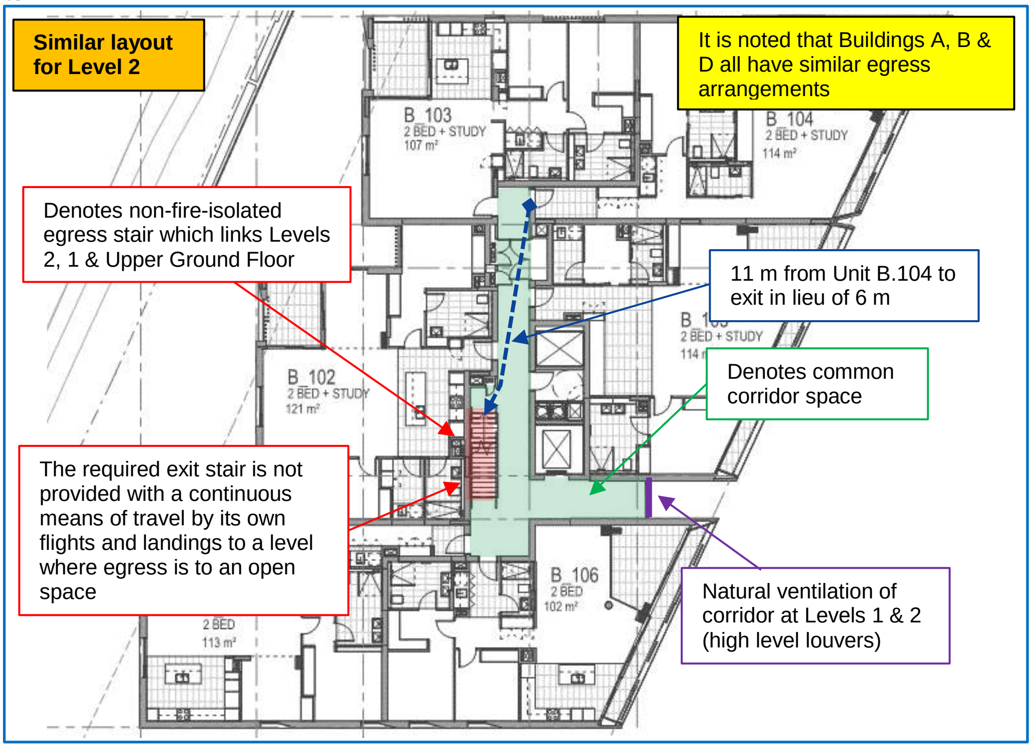


Figure 20: Building B Level 1 (sample layout) – extended travel distance to an exit greater than 6 m

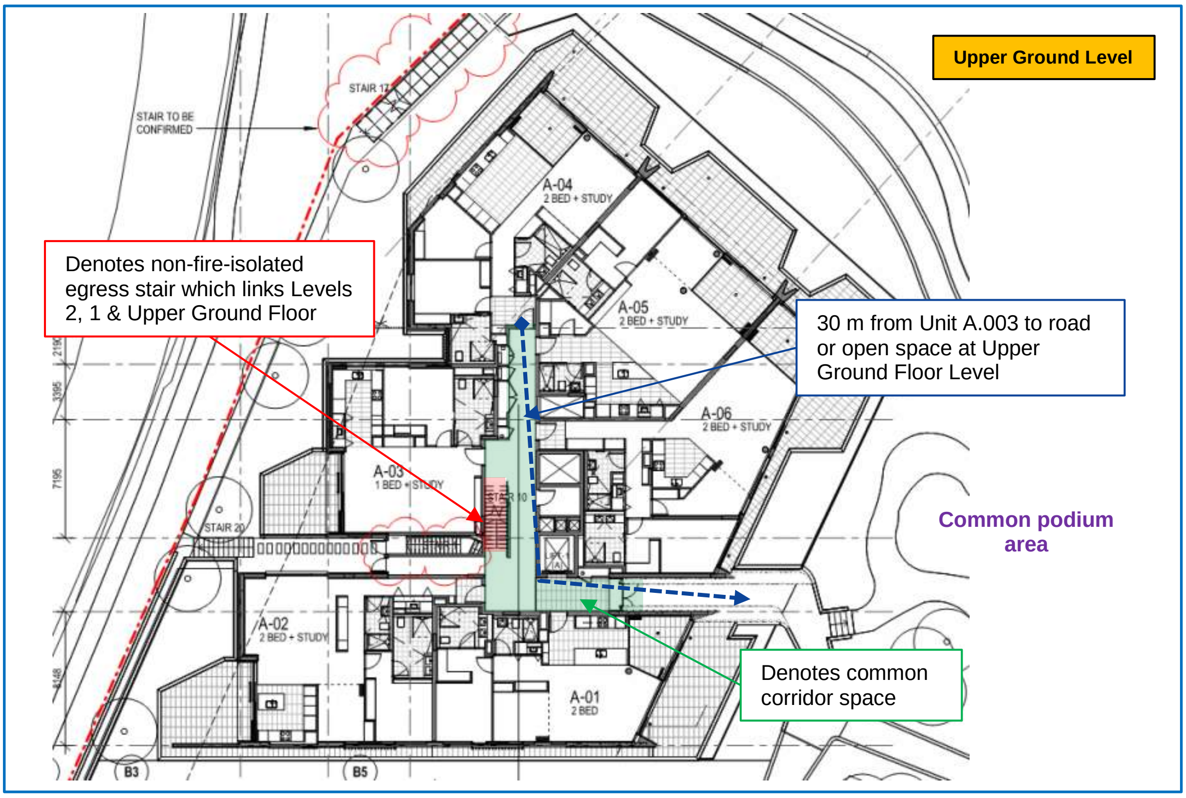


Figure 21: Building A Upper Ground Floor – egress by way of non-fire-isolated stairway (BCA D1.9(a))

It is proposed to permit Buildings A, B & D to be served by a non fire-isolated stair which does not have a continuous means of travel by way of its own flights and landings to a level at which egress is to the open space (in this instance the common podium area). This has been indicatively illustrated in Figure 22.

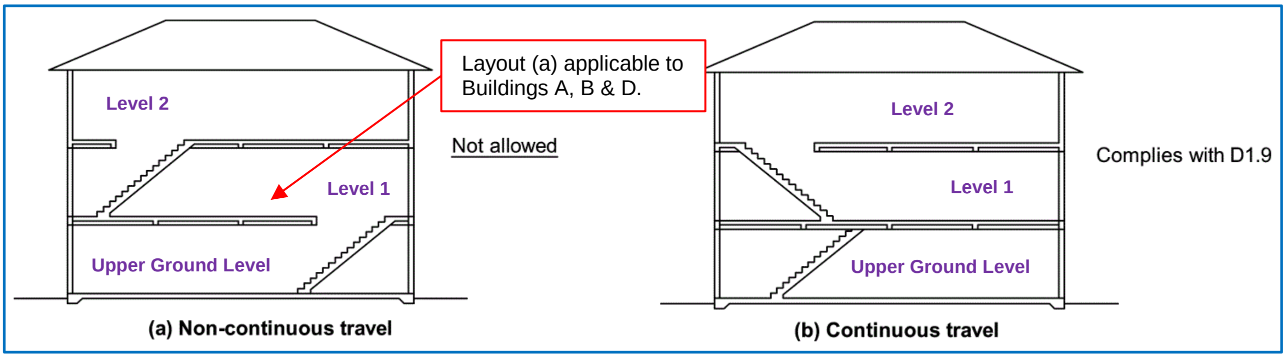


Figure 22: BCA Guide Figure D1.9(1) - sections showing compliance with BCA Clause D1.9(a)

10.3 Hazards

The hazard associated with the extended travel distance to an exit is that it results in an increased travel time in reaching an exit which in turn presents an increase in the likelihood that occupants may be exposed to untenable conditions in a fire scenario (smoke affected corridor).

The hazard associated with the required egress stair of Buildings A, B & D not being provided with a continuous means of travel comprising of flights of stairs and landings is that;

- Occupants upon reaching Level 1 have to move across a common corridor to reach the flight of stair which provides egress toward to the Upper Ground Floor Level which is the level of egress to open space and as such may be exposed to untenable conditions in the evacuation path.

The proposed stair configuration predominantly affects the occupants located at Level 2 as they have to descend to Level 1 and move across the corridor space.

10.4 Acceptance Criteria

The acceptance criterion for this Alternative Solution is that the proposed design incorporating additional safety measure can provide a level of life safety to occupants that is at least equivalent to or better than that afforded by a comparable building design that is compliant with BCA DtS provisions.

10.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- The residential levels of Buildings A, B, D, E & F are to be provided with an automatic fire detection and alarm system as follows;
  - AS 3786 smoke alarms installed within each residential unit (providing a local alarm within each unit only).
  - In addition to the DtS Provisions, heat detectors to be provided inside of each apartment (within 1.5 m of the entry door) of all residential buildings. Heat detectors to be Type A (AS 1603.1) combination fixed temperature and rate-of-rise and to be installed in accordance with AS 1670.1 and connected to the building smoke detection and occupant warning system discussed below. Activation of a heat detector to initiate a building wide fire evacuation alarm (limited to building of fire origin).
  - Smoke detectors located to AS 1670.1 within the common residential corridors and other internal public spaces. Detectors will be provided within 1.5 m of SOU doors within the common corridors.

The smoke detectors are to be connected to the building occupant warning system and to be arranged to initiate a building wide alarm.

- A Building Occupant Warning System (BOWS) shall be installed throughout the Buildings A, B, D, E & F in accordance with Clause 6 of BCA Specification E2.2a. The operation of this system shall be as per the OWS Fire Matrix in Appendix L and Evaucation Strategy presented in Appendix M of this report.
- Any required fire doors which are held open on electromagnetic locks (understood to be applicable to Building E only) are to disengage upon activation of a fire alarm condition anywhere on site to maintain separation between the different areas.
- The Class 2 residential corridors shall have the following FRL requirements as detailed in Table 3 of Specification C1.1;
  - FRL of 90/90/90 for loadbearing elements and
  - FRL of -/60/60 for non-loadbearing elements.
- All doors opening onto the residential corridors are required under the BCA DtS Provisions to be fire doors with an FRL of --/60/30 and fitted with self-closers. These doors shall be upgraded and be fitted with hot temperature smoke seals tested in accordance with AS 1530.7. This shall include the doors into the fire-isolated stairs of Buildings E & F.
- As per the request of FRNSW, the occupant warning system is to achieve an A-weighted sound pressure level of 75 dB at the bedhead as stipulated in Clause 3.22 of AS 1670.1 due to the presence of smoke seals to the SOU entry doors.
- Directional exit signs shall be provided in the common corridors of Buildings A, B & D to clearly identify the egress route in reaching a road or open space.

10.6 Method of Analysis

The Alternative Solution building will be qualitatively compared with a design that fully complies with the BCA DtS Provisions with particular reference to a Class 2 building and Provision D1.4 of the BCA in that there will be a travel distance of 6 m from an SOU door to the single exit and 20 m from an SOU located at the level of egress. The additional travel time associated with the extended travel distance of up to 5 m additional to the exit will be shown to be sufficiently compensated for by the proposed design measures when compared with a DtS compliant design. Correspondingly, it shall be demonstrated that the risk to evacuating occupants in the proposed design shall be at least equivalent to that of a DtS compliant egress arrangement.

As per the BCA Guide the intent of Clause D1.9(a) is to require that occupants in a required non-fire-isolated stairway are able to continue all the way via its own flights or landings down to the level from which egress to a road or open space is available. It would generally not be acceptable for an entire or substantial proportion of a storey to be called a “landing”. It is noted that the distance from between the most remote SOU entry doorway at Level 2 (in Buildings A, B & D) in reaching the open space is within the limits of BCA Clause D1.9(b)(ii) of 60 m. It will be shown that despite the proposed stair configuration to Buildings A, B & D not strictly meeting guidance given in BCA Clause D1.9(a) (as illustrated in Figure 22) that in conjunction with the proposed design measures when compared to a DtS compliant design that the risk to evacuating occupants in the proposed design shall be at least equivalent to that of a DtS compliant egress arrangement.

10.7 Assessment – Extended travel distance

In the event of fire, occupants in the apartment of fire origin are at the highest risk. A smoke alarm provided inside each apartment will provide a local alarm to alert occupants in the apartment of origin. When the occupants in the room of fire origin reach the corridor, they are in a place of relative safety and when the room entry door closes behind them, they will be able to make their way to the exit, usually in tenable conditions.

The extended travel distance from the entry door of the apartments to an exit would potentially affect the occupants served by the same corridor as the room of fire origin. It will make virtually no difference to occupants in different fire compartments and would have no effect on occupants inside the apartment of fire origin. The risk to occupants is that the stair may be unreachable in the event of a fire.

An increased travel time in reaching an exit which in turn presents an increase in the likelihood that occupants may be exposed to untenable conditions in a fire scenario (smoke affected corridor).In a DtS compliant design, BCA Clause D1.4(a) requires that in Class 2 to 3 buildings, the entrance doorway of any SOU must not be more than 6 m from an exit or a point from which travel in different directions to 2 exits is available or up to 20 m from a single exit serving the storey at the level of egress to road or open space.

Research by [Proulx], indicates a travel speed of 1.0 – 1.3 m/s for able-bodied people in moderately crowded situations, and 0.8 m/s for people with mobility disabilities. For robustness in the design, the unimpeded walking speed of a person has been taken as 0.8 m/s to assess travel time (to allow for all anticipated occupants of the development).

Hence the delay in evacuation due to the extended travel distance to an exit without any additional fire safety measure is an additional 8.25 s for a worst case scenario in the upper levels and 12.5 seconds at entry level compared with a DtS compliant design as demonstrated in Table 14.

Table 14: Travel Time comparison of residential SOUs to a DtS arrangement (non-Ground level)

Travel Distance description	DtS Design	Proposed Design (Upper Levels)	Time increase (Upper Levels)
Travel Distance to single exit / point of choice in direction of exits	6 m	13 m	-
Travel Time (0.8 m/s)	8 s	16.25 s	8.25 s

Table 15: Travel Time comparison of residential SOUs to a DtS arrangement (Ground level entry)

Travel Distance description	DtS Design	Proposed Design (Ground Level)	Time increase (Ground Level)
Travel Distance to single exit / point of choice in direction of exits	20 m	30 m	-
Travel Time (0.8 m/s)	25 s	37.5 s	12.5 s

It is proposed to modify the spacing of the smoke detectors to 2.1 m grid within the common corridor areas so they are positioned at 1.5 m from SOU doors.The grid spacing was calculated so as the furthest point to a fire from the smoke detectors within the corridor is no worse than 1.5 m as per the illustration below.

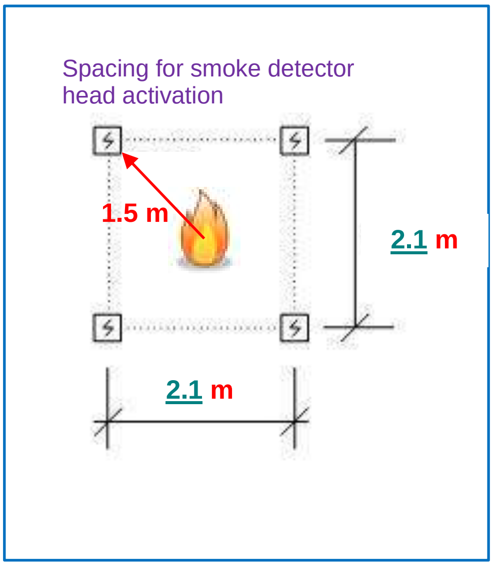


Figure 23: Smoke detector spacing

The decrease in detection time provided by additional smoke detection shall be utilised to account for the extended travel time. The detection for both cases on the activation time of smoke detectors and has been calculated using the equations presented in Appendix D of this report.

Table 16: Assessment of travel time reduction through proposed detection spacing

Input Parameters	Reference Design	Proposed Design
Ceiling height (m)	2.4 m	2.4 m
Height of fuel above floor (m)	0.5 m	0.5 m
Detector spacing (m)	10.2 m x 10.2 m grid	2.1 m x 2.1 m* grid
Ambient temperature (°C)	23 °C	23 °C
Actuation temperature (°C)	39 °C	39 °C
Fire growth time (s)	300 s	300 s
Output Parameters	**91 s**	**42 s**
Reduction in activation time	**-**	**49 s**
**Note; Grid determined by the requirement of having detectors at a 1.5 m distance from SOU doors*		

As can be seen from the results above, the proposed smoke detectors operate 49 seconds faster when compared with those of a DtS compliant design. As the improvement in the detection time is greater than the increase in time taken to travel the extended travel distances of 8.25 seconds in the upper levels and 12.5 seconds at entry level, the proposed configuration is considered to sufficiently mitigate the extended travel distances. This includes addressing the risk of an SOU door being chocked open on one of the floors, as occupants will be given over 49 seconds more time to overcome the distances identified. The provision of thermal detectors inside each SOU (over and above the DtS requirement for smoke alarms inside SOUs only), will also cover the risk posed by a fire inside an SOU when the door is closed and occupants are not at home.

Further to the above; at entry level, occupants can reach the final exit door at 22 m whilst the rest of the travel is externaly under the building overhang. The risk is therefore considered lower by the time they reach this point as any heat and/or smoke along the escape path under the overhang will vent to external. The additional 2 m internally will only add ~3 seconds to the overall travel time which is considered insignificant based on the detection provisions in place.

10.7.1 Passive fire protection to SOUs

Regardless of the fire intensity of a unit fire, occupants evacuating past a unit of fire origin shall be protected by bounding walls achieving an FRL of 90/90/90 complete with self-closing -/60/30 fire doors. If a fire occurs within any of the SOUs, the allocated FRL to each SOU could be expected to contain the fire within the unit of fire origin allowing adequate time for occupants to evacuate the building and for Fire Brigade intervention to the building.

The self-closing devices to the SOU doors shall ensure the fire separation of the SOU from the adjoining corridor / egress stair is maintained in that it forms a barrier for the passage of smoke from an SOU into the stair. In addition, to prevent smoke leakage around the SOU entry doors, it is proposed to upgrade the entry doors in all the residential buildings affected by an extended travel distance issue and fit them with hot temperature smoke seals (in accordance with AS 1530.7) as the Class 2 areas are unsprinklered. Smoke seals provide a barrier around the door limiting the spread of smoke into the corridor. In this way smoke spread into the corridor from an SOU door is reduced which should further facilitate egress from the floor of fire origin. This additional fire safety measure above and beyond the DtS provisions of the BCA and should compensate for the additional travel times stated above in terms of occupants having to travel in reaching an exit. The provision of smoke seals to SOU entry doors would ensure that the conditions within the corridor in the proposed design would be much better than a DtS compliant design in which smoke is likely to leak into the corridor through the clearance around the entry door.

10.7.2 Likelihood of a fire in the residential corridor

In residential buildings, the common corridors to the SOUs as discussed are fire separated from adjoining spaces by fire rated construction with all doors fire rated and fitted with self-closing devices. Lift landing doors and access doors / hatches into service shafts are also fire rated. Garbage shaft doors and doors to electrical distribution boards are of non-combustible construction.

Furthermore, the corridors are used for circulation and are to be kept free from obstructions and clear from combustibles. Floor and wall linings are to be compliant with BCA Spec. C1.10 and as such will have a low flame spread potential. Initiation of a fire within a residential corridor or fire spread from an adjoining space into the corridor is therefore highly unlikely. Hence given the common corridor’s main use, ignition sources within will be minimal and the overall fire risk will be low and as such does not present a credible fire source to prevent occupants from being able to access the storey exits which is by way of a non-fire-isolated stair.

Hence the blocking of an exit by fire is therefore unlikely in a residential corridor unless the bounding construction, fire stopping or a fire door fails (or does not close properly). In this instance visibility is likely to be lost in the corridor in any case and occupants would be more likely to remain in their apartments than to enter the corridor.

10.7.3 Fire Detection and Alarm System

The proposed residential buildings are to be provided with an automatic fire detection and alarm system in accordance with BCA Table E2.2a and Specification E2.2a as discussed in Section 10.5. The system is to incorporate AS 3786 smoke alarms installed within the residential units (so as to provide a local alarm within each unit) and smoke detectors in common corridors located as per AS 1670.1 at 1.5 m from SOU doors as described in Section 10.7. In addition, heat detectors are proposed to be installed in the SOUs located within 1.5 m of the entry door (Buildings A, B & D).

The building is to be provided with a Building Occupant Warning System(BOWS) in accordance with BCA Clause E4.9 and AS 1670.1. The smoke detectors in the common corridors and the heat detectors in the SOUs are to be connected to the BOWS and to initiate a building wide alarm. Hence the proposed system shall also contribute to providing occupants with early warning of the fire and prompt to evacuate from their SOU before the onset of untenable conditions.

10.8 Assessment – Travel via non-fire-isolated stairs

Buildings A, B & D are served by non-fire-isolated stairs. However, the stairs do not provide continuous means of travel by way of their own flights and landings. Figure 24 below illustrates the configuration of the non-fire-isolated stair, taking the one in Building B as an example. As shown in Figure 24, after travelling along the stairs down to a floor level, occupants from upper levels need to walk along the corridor adjacent to the non-fire-isolated stair to the next flight of stairs to continue egressing from the building. Appropriate directional exit signage to be provided in order to direct occupants evacuating to the final exit as per Clause E4.6 of the BCA.

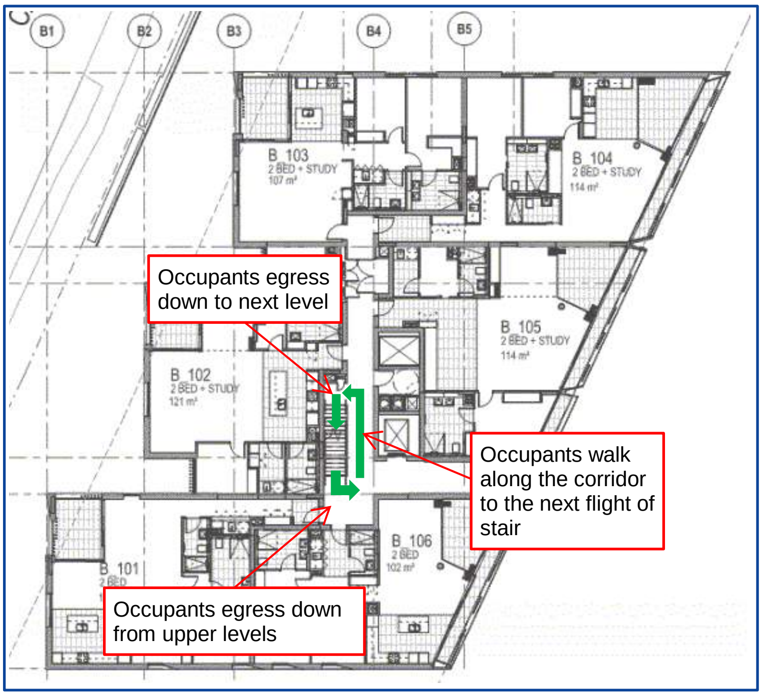


Figure 24: Travel via non-fire-isolated stair

The Guide to the BCA states that "*it would generally not be acceptable for an entire or substantial proportion of a storey to be called a landing*". An example is given in the first diagram in Figure 22 which shows that in the first configuration it is difficult for occupants to find the exit when they come down to the intermediate floor as the exit is not located in the vicinity.

In Buildings A, B & D, when travelling along the non-fire-isolated stairs for egress, occupants need to travel along a segment of corridor between two flights of stairs. As such, it is considered that the non-fire-isolated stairs do not provide a continuous means of travel by its own flights and landings. However, this arrangement is considered acceptable due to the following:

- Directional exit signs are required to be installed within the corridor on Level 1 of Buildings A, B & D. As a result, occupants egressing down from the non-fire-isolated stair can clearly see the exit signs and under the direction of these directional exit signs occupant would have no difficulties finding the next flight of stairs through which they can egress continuously down to the next level.
- Only occupants at Level 3 are not provided with continuous means of travel as per Clause D1.9 (a). Occupants on Level 1 only need to travel one flight of stairs to the Upper Ground floor from which egress to the outside is provided. Occupants on the Upper Ground floor have direct egress to outside without the need to use the non-fire-isolated stairs.
- It is noted that the worst case scenario in terms of the total travel distance along the non-fire-isolated stair is within Building B. The travel distance from the most remote entry door on Level 3 to the point of egress to a road or open space via the non-fire-isolated stair is approximately 40 m. This total travel is much less than a DtS compliant design which allows a total travel distance of 60 m via a non-fire-isolated stairs in reaching a road or open space.

10.9 Fire Brigade Intervention

As discussed in Section 5, when undertaking fire-fighting activities, the fire brigade would set up their fire hoses from the hydrants provided less than 4 m from the required stairs on their respective levels. Hence the extended travel distance to an exit is irrelevant to fire-fighting as they would be expected to deal with a fire in an SOU anywhere on the floor.

10.10 Conclusion

This analysis demonstrates that the inclusion of the proposed fire safety measures manages the variations from the relevant BCA Clause and as such BCA Performance Requirements DP4 and EP2.2 is considered to be met.

11. AS 5 – Extended TD's in carpark & loading dock

11.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 17: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the following extended travel distances to an exit in the Class 7a areas (Basement Levels 2 & 1); ▪ Up to 28 m in lieu of permissible 20 m in reaching a point where there is a choice of exits, ▪ Up to 70 m in lieu of permissible 40 m in reaching an alternative exit. ▪ Up to 95 m in lieu of the permissible 60 m between alternative exits.	D1.4(c) & D1.5	DP4 & EP2.2	SS-B, SS-D, SS-E & SS-F	(b)(ii)	(c)
To permit an extended travel distance of 38 m in lieu of the permissible 20 m to the single exit within the loading dock area at Lower Ground Floor Level.	D1.4(c)				
To permit an extended travel distance of 34 m in lieu of the permissible 20 m to a point of choice in the Cinema Room on Basement Level 2.					
Approach and assessment method used - The approach used in this solution will be qualitative and quantitative in nature and will use a deterministic comparative approach.					

11.2 Description of non-compliance with DtS Provisions

It is proposed to permit the following extended travel distances to an exit in the carparking areas (located at Basement Levels 2 & 1):

- Up to 28 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
- Up to 70 m in lieu of permissible 40 m in reaching an alternative exit,
- Up to 95 m in lieu of the permissible 60 m between alternative exits.

It is proposed to permit an extended travel distance of 38 m in lieu of the permissible 20 m to the single exit in the loading dock area at Lower Ground Floor Level. It is noted that the loading dock has been classified ancillary to the Class 9b Community Club areas and as such does not form a separate building classification.

It is proposed to permit an extended travel distance of 34 m in lieu of the permissible 20 m in reaching a point where there is a choice of exits, on the Basement Level 2 Cinema Room as shown in Figure 27.

At the time of preparing this FER, WSP | PB Fire has not been provided with a fit-out plan of the loading dock area showing the detailed layout and the exit / exit pathways within. The travel distances listed above are the maximum distances of travel accepted by the PCA for the project. Hence the Alternative Solution presented is based on the travel distance of 38 m.

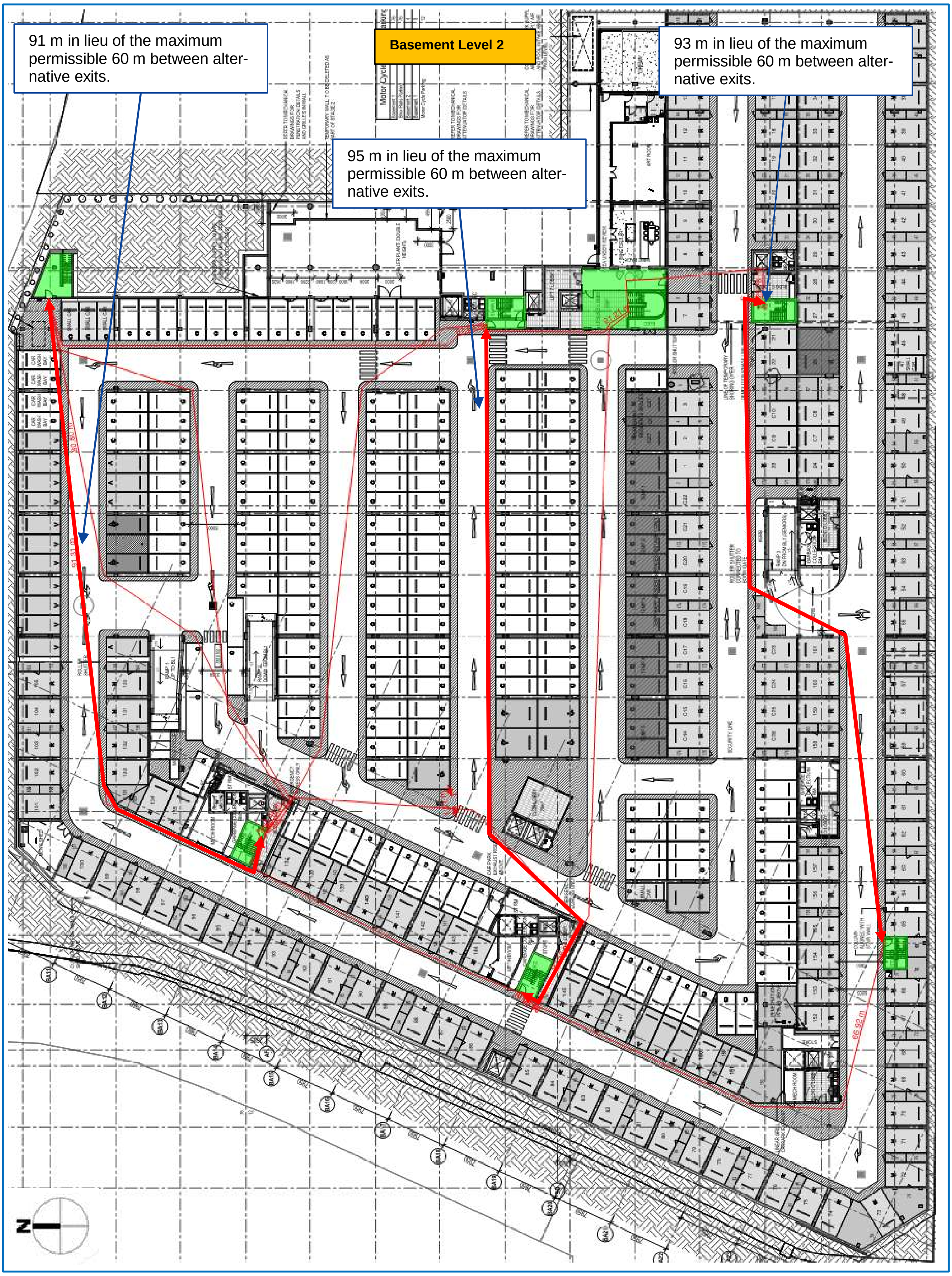


Figure 25: Basement Level 2 – extended travel distance between alternative exits.

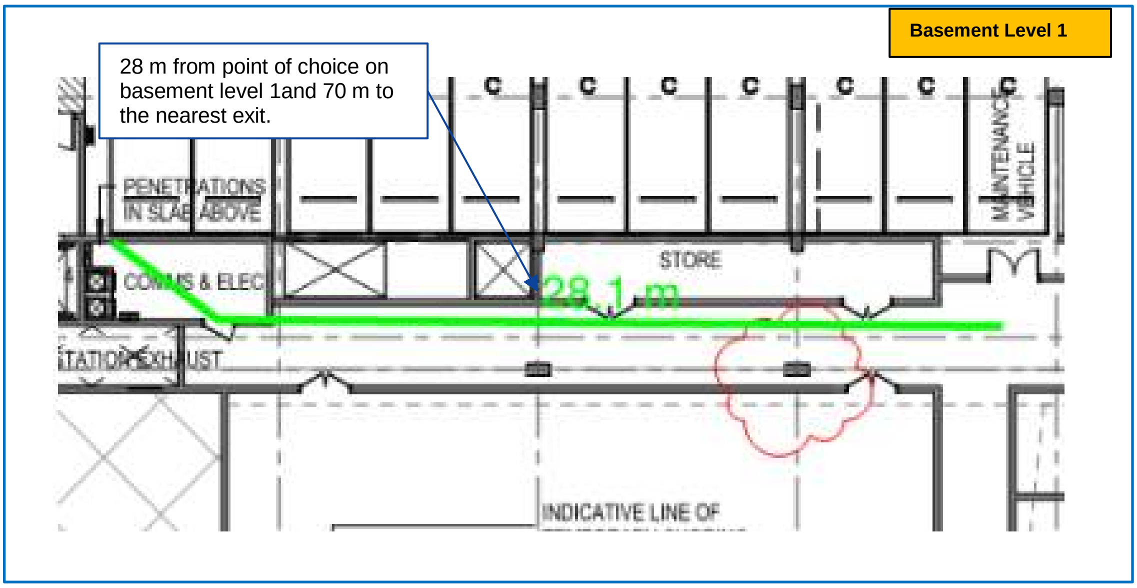


Figure 26: Basement Level 1 – extended travel distance to point of choice and nearest exit.

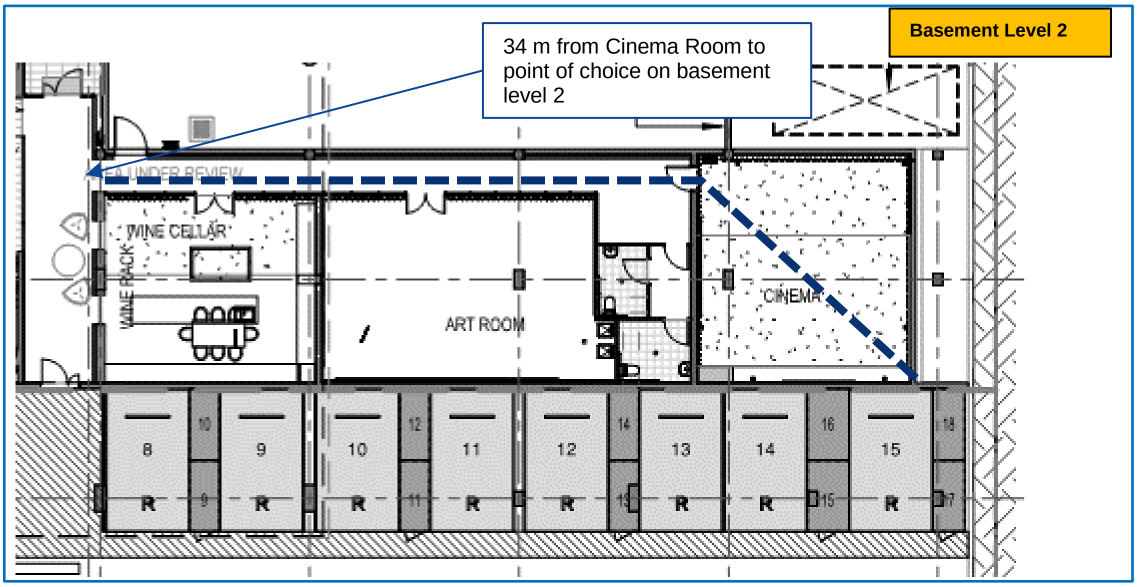


Figure 27: Basement Level 2 Cinema Room – extended travel distance to point of choice.

11.3 Acceptance Criteria

The acceptance criterion for this Alternative Solution is that the proposed design with increased travel distances can provide a level of life safety to occupants that is at least equivalent to or better than that afforded by a comparable building design that is compliant with BCA DtS provisions.

11.4 Hazards

The hazard specific to this Alternative Solution is that with an extended travel distance, it could take longer for the occupants to evacuate than in a compliant building, putting occupants at greater risk in the event of fire.

11.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution is as follows;

- Automatic sprinkler system to Basement Levels 1 & 2 as well as the loading dock area at Lower Ground Floor Level designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 modified as follows:
    - Provide fast response sprinkler heads (with an RTI of 50 $(m \cdot s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads.
    - Activation temperature of the sprinklers heads within the basement carparks are to be 68°C (subject to ambient conditions).
    - The sprinklers shall be installed at a spacing of 3 m x 4 m for an Ordinary Hazard system. Sprinklers within the basement levels are to be arranged so that no heads are in the direct path of airflow from the fan to prevent potential delays in activation. For further details please refer to Appendix H of this report.
    - The sprinkler system shall be connected to and activate the building occupant warning system.
    - Upon activation of the sprinkler system, an alarm signal shall be automatically transmitted to the fire brigade or to a fire alarm monitoring system connected to a fire station. The activation of sprinklers in the basement car parks shall also automatically turn off the impulse fans on the fire-affected floor and activate the building occupant warning system.
- The impulse fans shall be provided with duct smoke detectors. Upon activation of any of these smoke detectors or the sprinklers, all the impulse fans shall be shut down and the building occupant warning system shall be activated.
- The impulse fans should be located in driveways and access ways and not above car-parking spaces or other areas where there are stagnant fire loads.
- The activation of smoke detector heads provided in the circulation areas of the car-parks (in accordance with AS 1670.1-2015 Figure 7.5.2.2(c)) will automatically shut down the impulse fans on all levels and activate the building occupant warning system. It is proposed for these detectors to be provided on a 15 m grid spacing basis. Sensitivity of these heads to be reduced accordingly to avoid spurious alarms.

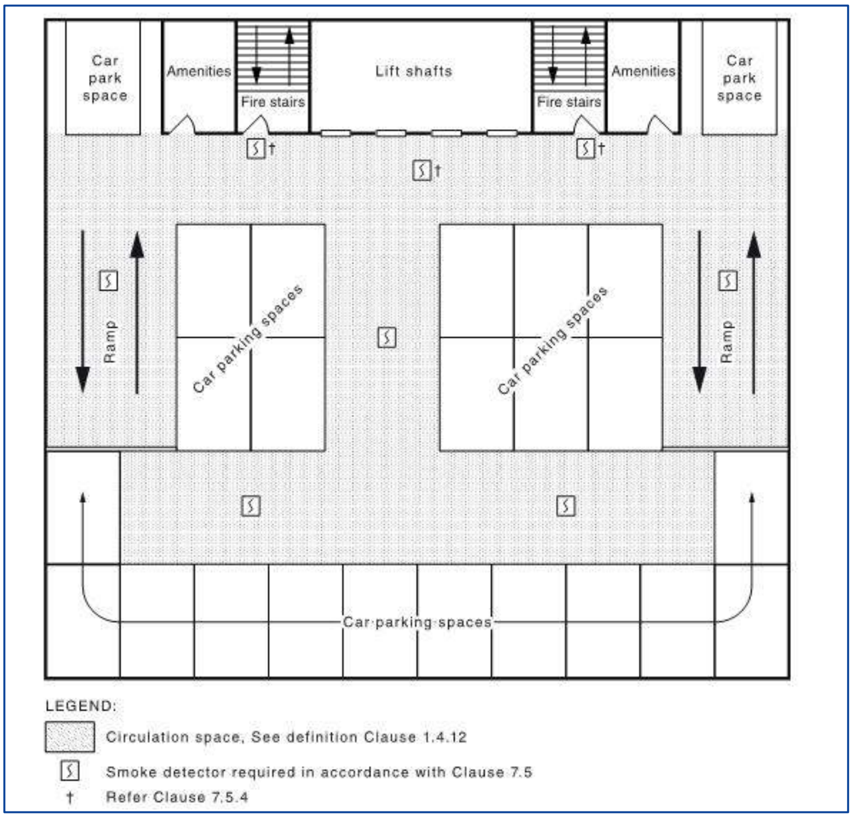


Figure 28: Figure 7.5.2.2(c) Indicative Detector Locations Example Car-Park

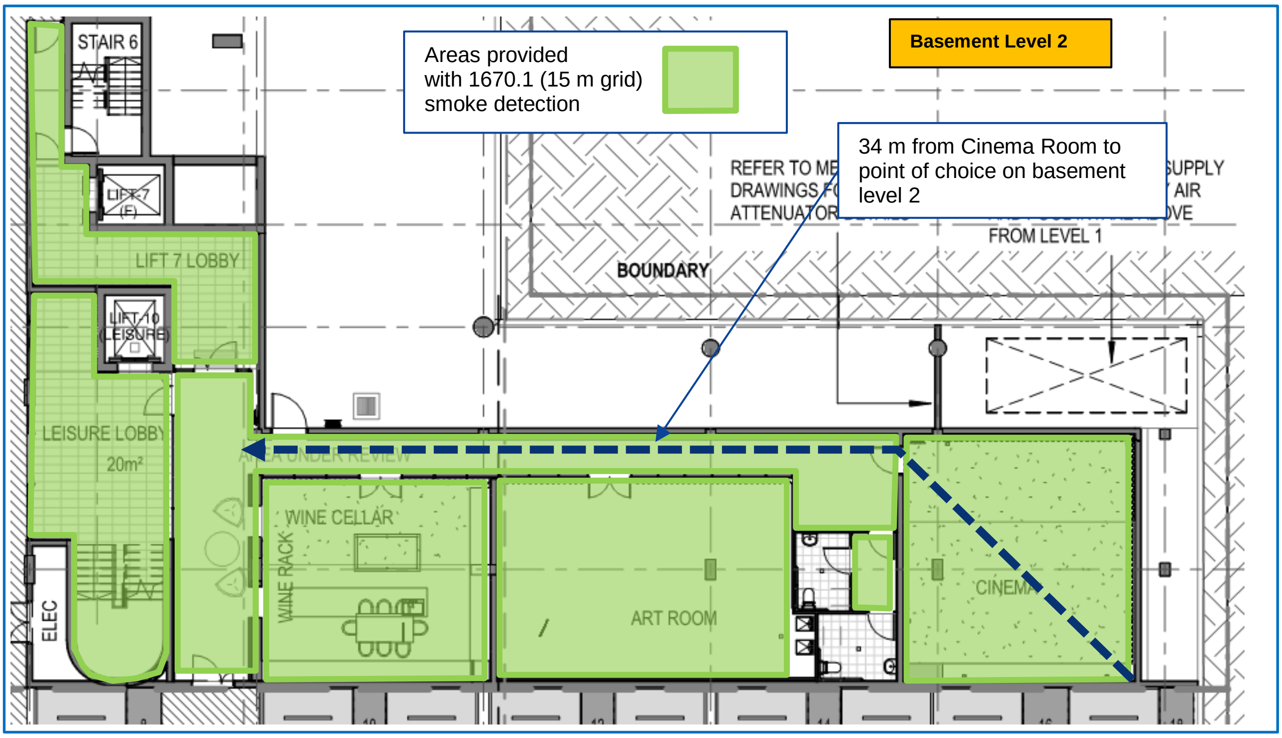
- Access doors along the security line (Basement Level 2) are required to failsafe open in fire mode.
- Automatic smoke detection is to be installed in accordance with AS 1670.1 on a 10.2 m grid spacing basis in Basement 2 areas shown in Figure 29.
- 

Figure 29: Basement Level 2 Cinema Room – Areas provided with AS1670.1 detection.

- As per recommendations from FRNSW, block plans to be provided beside hydrant valves within fire stair wherever additional hydrants are deemed necessary to achieve compliant coverage on site. The intent of this requirement is to pictorially and numerically illustrate the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a “YOU ARE HERE” note and be incorporated into the AFSS.

11.6 Method of Analysis

It is proposed to undertaken a comparative analysis whereby:

- DtS compliant travel distance to point of choice to exits (20 m) will be compared with the proposed design (up to 28 m)
- DtS compliant travel distance to an alternative exit (40 m) will be compared with the proposed design (up to 70 m).
- DtS compliant travel distance between alternative exits (60 m) will be compared with the proposed design (up to 95 m).
- DtS compliant travel distance to a single exit (20 m) will be compared with the proposed design of the loading dock area (up to 38 m)
- DtS compliant travel distance to point of choice to exits (20 m) will be compared with the proposed design (up to 34 m).

It is proposed to mitigate the identified extended travel distances with the provision of fast response sprinkler heads in lieu of the standard response sprinkler heads. The assessment will use a comparative RSET-RSET analysis. The decrease in the detection time afforded by the fast response heads in lieu of standard response heads will be shown to offset (compared) the increase in travel time resulting from the extended travel distances.

FDS modelling of fire scenarios in the basement carpark has been conducted as part of Alternative Solution AS 12 to assess the fire conditions within the basement carpark under the operation of the carpark ventilation systems. The results of the modelling shall further demonstrate that occupants have sufficient time to evacuate (despite having to undertake extended travel distances in reaching an exit) in a fire emergency in the carparking areas.

11.7 Assessment

11.7.1 Qualitative - Likelihood of fires in carparks

Statistical data obtained from the [NSWFB] during 2006/07 indicates that fires in carparking areas (noted to be associated with residential SOU buildings) account for approximately 2% of fires. Unfortunately, detailed statistics relating to number of fatalities and injuries in carparking areas is not readily decipherable from the statistics obtained from the NSWFB above. Given that it does not warrant categorisation, it could be assumed that the number of fatalities and injuries in carparking areas is low. A further review of international statistics, namely those obtained from New Zealand [NZFS], indicates that no fatalities occurred in any type of carparking occupancy in NZ between 1999 and 2004.

The incidence of car fires in carparks is extremely low. Based on further supporting data supplied by the Melbourne Fire and Emergency Services Board (MFESB) and data on the number of carparks in Melbourne (as researched by [Thomas]) the rate of fire starts in Melbourne CBD carparks is estimated to be 0.00007 fires reported to the fire brigade per car space per year. Also, data for New Zealand as researched by [Li] indicate that there were on average 12 fires per year in the estimated 200,000 parking spaces in New Zealand parking buildings, thereby putting the estimated fires reported to the fire brigade per car space per year at around 0.00006. This statistical data demonstrates that the probability of fires in carparks is very low. This aids in confirming the presumption that carparking occupancies do not typically result in a high risk to life due to fire.

11.7.2 Qualitative - Benefits of sprinklers on travel distances

The carparking levels, including the loading dock areas, are to be provided with an automatic sprinkler system to AS 2118.1. In the event of a fire, the sprinkler system is expected to control, if not suppress, the fire. The sprinkler system acts to cool the upper smoke layer and wet adjacent combustibles and partitions helping to prevent the fire from spreading beyond the area of origin.

Furthermore, by controlling the fire size, the amount of smoke produced is correspondingly also limited. Hence the provision of sprinklers in a building dramatically enhances life safety, property protection and fire brigade intervention. Where the sprinkler system operates successfully, occupant and fire fighter safety and the integrity of building elements reduces the threat to occupants, property damage and the attending fire brigade. The high reliability and efficiency of fire sprinklers is also supported by fire tests and statistics on structural building fires. These and associated benefits are discussed in detail in Appendix B.

The benefits of sprinklers are recognised by many international building codes by providing a range of concessions when sprinklers are provided. Many of these include an allowance to increase the travel distances when sprinklers are provided. A comparative study has been undertaken of the travel distance limitations contained within various building codes and standards as applicable to carparks as presented in Table 18 and Table 19 which is detailed below;

- A comparison of single exit travel distance provisions in a sample of international building codes demonstrating extended travel distance allowances when sprinklers are provided – refer to Table 18.
- A comparison of maximum travel distance to the nearest exit provisions in a sample of international building codes demonstrating extended travel distance allowances when sprinklers are provided - refer to Table 19.

Table 18: Comparison of single exit travel distance provisions & allowances for sprinkler inclusion

Building Code	Maximum allowable travel distance to a single exit or point of choice		Allowable increase for sprinklers (%)
	No sprinkler protection	Sprinkler protection	
Australia – BCA 2014	20	20	0
US – NFPA 101 (2009)	23	30	30
UK – Building Regulations 2000	18	18	0
BS 9999 (Risk profile B2)	20	24	20
New Zealand – C/AS7 (2013)	45	70	55

Table 19: Comparison of max travel distance to the nearest exit provisions & allowances for sprinkler inclusion

Building Code	Maximum allowable travel distance to the nearest exit of alternative exits		Allowable increase for sprinklers (%)
	No sprinkler protection	Sprinkler protection	
Australia – BCA	40	40	0
US – NFPA 101 (2009)	60	91	51
UK – Building Regulations 2000	45	45	0
BS 9999 (Risk profile B2)	50	60	20
New Zealand – C/AS7 (2013)	110	180	63

The tables demonstrate that up to 63 % travel distance increases are allowed by some building codes in recognition of the efficacy of sprinklers. It should, however, be noted that a direct comparison between the absolute travel distances are not appropriate as the overall fire safety measure provisions and the ways that travel distances are measured could vary between the codes. However, the principle of allowing an increase when sprinklers are provided is clearly demonstrated.

11.7.3 Travel time comparison to a DtS Compliant Building

In a DtS compliant design BCA Clause D1.4 stipulates that in Class 5 to 9 buildings, no point on a floor must be more than 20 m from an exit, or a point from which travel in different directions to 2 exits is available, in which case the maximum distance to one of those exits must not exceed 40 m. BCA Clause D1.5 requires the travel distance between alternative exits must not be greater than 60 m. In the proposed design the occupants in the carparking levels may be travelling;

- Up to 30 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
- Up to 70 m in lieu of permissible 40 m in reaching an alternative exit,
- Up to 95 m in lieu of the permissible 60 m between alternative exits.

and;

- Up to 38 m in lieu of permissible 20 m in reaching a single exit in the loading dock.
- Up to 34 m in lieu of permissible 20 m in reaching a point where there is a choice of exits in the basement level 2 Cinema Room.

As discussed in Alternative Solution AS 4, the unimpeded walking speed of a person has been taken as 0.8 m/s to assess travel time (to allow for all anticipated occupants of the development). Hence the delay in evacuation in the proposed building without any additional fire safety measures when compared to a DtS compliant design is detailed in Table 16. The delay in evacuation in the proposed building is up to a further 50 s when compared with a DtS compliant design.

Table 20: Travel Time comparison to a permissible DtS arrangement

Description of travel distance	Comparable DtS Design			Proposed Design			Additional time required due to extended travel distance (s)
	Distance (m)	Travel Speed (m/s)	Travel Time (s)	Distance (m)	Travel Time (m/s)	Travel Time (s)	
Basement Levels 1 & 2							
To POC in exits	20 m	0.8 m/s	25 s	30 m	0.8 m/s	38 s	13 s
To alternative exit	40 m	0.8 m/s	50 s	70 m	0.8 m/s	88 s	38 s
Between alternative exits	60 m	0.8 m/s	75 s	95 m	0.8 m/s	119 s	44 s
Loading Dock							
To single exits	20 m	0.8 m/s	25 s	38 m	0.8 m/s	48 s	23 s
Basement Levels 2 Cinema Room							
To POC in exits	20 m	0.8 m/s	25 s	34 m	0.8 m/s	43 s	18 s

In the sections that follow it has been demonstrated that the installation of enhanced fire detection provided by AS 1670.1 compliant extended coverage smoke detection in the carpark (15 m grid spacing) in lieu of relying purely on standard response sprinkler heads will facilitate total egress times being less than or equal to the comparative notional DtS case.

It is acknowledged that a cumulative travel distance of up to 190 m could be presented for the distance between alternative exits non-compliance. However, such a travel distance is not a realistic scenario in the subject carpark area. The carpark is noted to have a large floor area with each floor having an area of at least 13,666 m^2 and served by six (6) exits.

It is acknowledged that the distance between alternative exits under the BCA Guide is measured through a point of choice which is more applicable to a defined environment (i.e. a residential corridor or the like) which could have limitations / restictions in pathways to an exit. In a carpark, occupants will be able to move between and around cars and in this instance move to any of the numerous exits provided.

Notwithstanding the above, Appendix H of the FER has undertaken an ASET / RSET analysis for the carpark which has demonstrated that occupants in a fire scenario are expected to be able reach the exits prior to untenable conditions occuring – see Section 11.9 below.

11.7.4 Quantitative

It is proposed to mitigate the extended travel distances in the basement carpark with the provision of AS 1670.1-2015 in circulation spaces in accordance with Section 7.5.2.2. The DtS Provisions simply require sprinkler protection without specifying the Response Time Index (RTI) value of the heads, thereby permitting installations with standard response sprinkler heads as part of a DtS installation. The assessment will use a comparative RSET-RSET analysis. The increase in the detection time afforded by the provision of 15 m grid spaced smoke detection is compared to the increase in travel time resulting from the extended travel distances.

The RSET is determined by detection time, pre-movement time and the travel time as expressed in the following formula as found in [PD 7974-6];

The Required Safe Evacuation Time (RSET) is determined by the following formula [PD 7974-6]:

$$RSET = T_{det} + T_a + T_{pre} + T_{mov}$$

where

$T_{det} =$ Detection time – the time from ignition until a fire is detected (s)

$T_a =$ Alarm time – the time from detection to the alarm sounds (s)

$T_{pre} =$ Pre-movement time – consisting of alarm recognition and response times (s)

$T_{mov} =$ Movement time – the time occupants take to walk to the exit (s).

A medium t^2 fire will be assumed for the comparison assessment discussed in the section that follows. A medium t^2-growth rate is also noted to be proposed by [Ingason] for passenger cars in tunnel fire safety. This is also with consistent with guidance given in Table 6.2 of [CIBSE].

The sprinkler and smoke detectors activation time calculations have been undertaken using the equations presented in Appendix D. The inputs and results are presented in Table 21 below. Refer to Appendix D for details of the sprinkler activation times for the building.

Table 21: Fire Detector activation time calculation parameters

Description of input / output parameters	Basement Level 1		Basement Level 2		Loading Dock	
	Proposed Design (Smoke detectors AS 1670.1)	Reference Design (standard response sprinkler head DtS)	Proposed Design (Smoke detectors AS 1670.1)	Reference Design (standard response sprinkler head DtS)	Proposed Design (Smoke detectors AS 1670.1)	Reference Design (standard response sprinkler head DtS)
Input Parameters						
Ceiling height (m)	4.0 m	4.0 m	2.7 m	2.7 m	4.8 m	4.8 m
Height of fuel above floor (m)	0.8 m	0.8 m	0.8 m	0.8 m	0.8 m	0.8 m
Detector spacing (m)	15 m × 15 m	3 m × 4 m	15 m × 15 m	3 m × 4 m	15 m × 15 m	3 m × 4 m
Ambient temperature (°C)	23 °C	23 °C	23 °C	23 °C	23 °C	23 °C
Actuation temperature (°C)	39 °C	68 °C	39 °C	68 °C	39 °C	68 °C
Response Time Index, RTI $(m{\cdot}s^{0.5})$	N/A	135 $(m{\cdot}s)^{0.5}$	N/A	135 $(m{\cdot}s)^{0.5}$	N/A	135 $(m{\cdot}s)^{0.5}$
Conductance, C (m/s0.5)	N/A	0.85 $(m/s)^{0.5}$	N/A	0.85 $(m/s)^{0.5}$	N/A	0.85 $(m/s)^{0.5}$
Fire growth time (s)	300 s	300 s	300 s	300 s	300 s	300 s
Output Parameters						
Sprinkler activation time (s)	163 s	317 s	110 s	252 s	192 s	352 s
Reduction in time from proposed design	154 s		142 s		160 s	

As can be seen in Table 17, the proposed smoke detection system is expected to operate 142 - 160 seconds faster when compared with standard response sprinkler heads. As the improvement in the detection time is greater than the increase in time taken to travel the extended travel distances detailed in Table 18, the provision of AS 1670.1 Section 7.5.2.2 system, is considered to sufficiently mitigate the extended travel distance in the basement carparking levels. It should also be noted that an actuation temperature of 39 °C was used for the smoke detectors in this assessment to make allowance for the sensitivity being adjusted to suit their use in an area containing carpark exhaust fumes. Smoke detectors are commonly calculated as having an actuation temperature of ~15 °C above ambient [SFPE], [Heskestad], meaning this assumption provides redundancy in the results obtained, subject to the ambient air conditions at that time.

11.8 Cinema room enhanced smoke detection

Although the travel distance non-compliances identified have been sufficiently justified through the provision of 15 m extended spacing detection in the assessment above, we note that the 34 m travel distance from the cinema area on Basement Level 2 exceeds the DtS Provisions by over 50%. We therefore deem it appropriate to undertake additional analysis in relation to this area for the purposes of redundancy.

For this assessment, we will be comparing the fast response sprinklers being provided (which already reduce alarm activation times by 49 seconds in comparison to standard response type), with the response time of smoke detectors installed on 10 m grid basis throughout the rooms and corridor(s) leading to the exit from the cinema room.

A comparative RSET-RSET analysis will be carried out for this alternative solution. The differences in the detection are only considered in this assessment as the other variables are consistent in both the reference and proposed design.

Smoke Detector Activation Times

As can be seen in the results in the previous section (refer Table 20), there is an additional travel time of 18 seconds which is required to be allowed for within the Basement 2 cinema room.

In order to allow increases in travel time, it is proposed to provide smoke detectors on a 10.2 m grid in the tenancy area to reduce the activation time. The corresponding response time has been calculated (calculations are detailed in Appendix D of this report). This has been based on a medium growth rate fire [CIBSE Guide E]. The fire HRR is irrelevant in this instance, as the detectors will activate well before the fire reaches any significant size.

The following table is a summary of the results of the activation time calculations.

Table 22: Summary of activation time calculation results

Area	Comparable activation of DtS Standard response sprinkler system (s)	Comparable activation of fast response sprinkler system (s)	Proposed Design AS1670.1 with 10.2 m grid spacing detection (s)	Additional time allowed by the proposed design (s)
Basement level 2 Cinema room.	252	203	111	141

Therefore, the proposed reduced spacing of the smoke detectors allows a 141 s reduction in the detection time from the DtS design (standard response heads) and a reduction of 102 s from the fast response sprinkler heads being proposed for this development already.

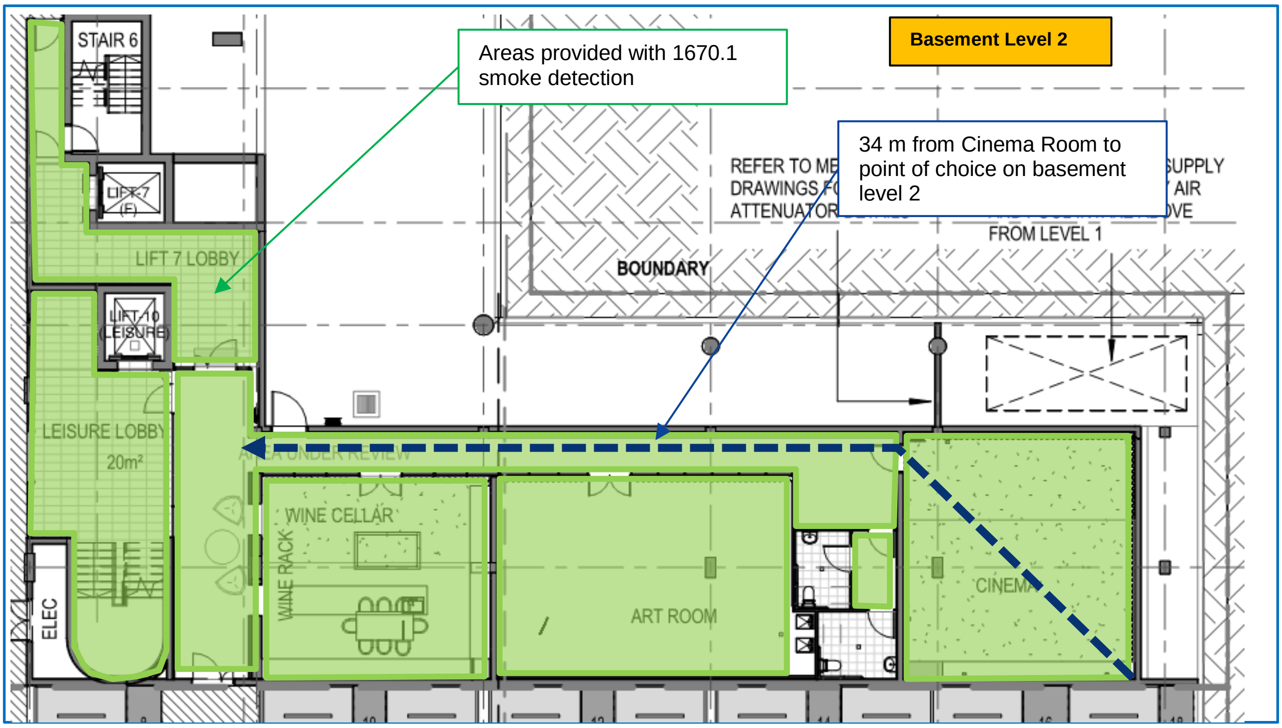


Figure 30: Basement Level 2 Cinema Room – Areas provided with AS1670.1 detection (10.2 m grid)

11.9 Basement level 1 & 2 – extended travel distance between alternate exits and exit redundancy

Where this alternative solution provides justification of the distance between alternative exits being up to 95 m in lieu of the BCA prescribed 60 m, it is to be noted that there are several alternative fire isolated stairs provided on each level. In a BCA compliant building which is provided with two exits, it is acceptable to have travel distances between exits of up to 60 m where the travel distance must be taken back through the point of choice.

Occupants may be required to travel up to 95 m when the measurement is taken back through the point of choice, although in the subject building there are seven exits provided in both of the basement levels 1 and 2. Due to the layout of the building there are additional exits available to an occupant where an exit is not accessible.

The guide to the BCA states that the intent of BCA Clause D1.5 is *'To require that if an exit is inaccessible, access to any required alternative exit must be accesible within a reasonable distance'.* As can be seen in Figure 25 there are multiple accessible exits available. Alternative exits are provided on both levels, where one of these exits is inaccessible the occupant may choose between different exits, these alternative exits are often less than the 95 m back through the point of choice that are justified in this alternative solution. Due to this reason the maximum of 95 m is considered conservative as there are exits which are closer which will be available to the occupant in an evacuation scenario meaning travel back through the point of choice to reach the alternative exit would be unlikely in such an area.

11.10 FDS Modelling of carpark

CFD modelling of fire scenarios in the basement carpark has been conducted as part of Alternative Solution AS 12 to assess the fire conditions within the basement carpark under the operation of the carpark ventilation systems. The results of the modelling have been presented in a separate report which is included in Appendix H of this report.

In order to assess the effects of the jet fans on tenability conditions within the carpark, a total of six fire scenarios have been considered utilising the proposed jet fan mechanical design for the carpark, three of the scenarios are applicable to this solution. Based on the results presented in Sections 7 and 8 of the CFD report, the required Margin of Safety of 1.5 between the Available Safe Egress Time (ASET) and the RSET analysis has been achieved.

The results of the CFD modelling confirm that the conditions in the carpark in a fire scenario are within the acceptance limits for both occupant egress and fire brigade intervention (as discussed in Sections 5.3 and 5.4 of the CFD report).

11.11 Conclusion

This analysis demonstrates that the proposed fire safety features manage the variations from the relevant BCA Clauses. As such, BCA Performance Requirements DP4 and EP2.2 are met.

12. AS 6 – Extended TD's in the Class 9b areas

12.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 23: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the following extended travel distances to an exit in the Class 9b areas (Lower & Upper Ground Floor Levels); ▪ Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice of exits; ▪ Up to 60 m in lieu of permissible 40 m in reaching an alternative exit; ▪ Up to 80 m in lieu of the permissible 60 m between alternative exits (Community Club only).	D1.4(c) & D1.5	DP4 & EP2.2	SS-B, SS-D & SS-E	(b)(ii)	(c)
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

12.2 Description of non-compliance with DtS Provisions

It is proposed to permit the following extended travel distances to an exit in the Class 9b areas as noted below;

- Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
- Up to 60 m in lieu of permissible 40 m in reaching an alternative exit,
- Up to 80 m in lieu of the permissible 60 m between alternative exits.

These Class 9b areas include the Community Club on the Lower Ground Floor and the Gym / Aquatic Centre on the Lower and Upper Ground Floor Levels.

At the time of preparing this FER, WSP | PB Fire has not been provided with a fit-out plan of the Community Club & Gym / Aquatic Centre showing the detailed layout and the exit / exit pathways within. The travel distances listed above are the maximum distances of travel accepted by the PCA for the project. Hence the Alternative Solution presented is based on the travel distances listed above.

12.3 Acceptance Criteria

The acceptance criterion for this Alternative Solution is that the proposed design with increased travel distances can provide a level of life safety to occupants that is at least equivalent to or better than that afforded by a comparable building design that is compliant with BCA DtS provisions.

12.4 Hazards

The hazard specific to this Alternative Solution is that with an extended travel distance, it could take longer for the occupants to evacuate than in a compliant building, putting occupants at greater risk in the event of fire.

12.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- The Lower Ground Floor (with the exception of the Day Care Centre) including the upper part of the Gym / Aquatic Centre on the Upper Ground Floor shall be provided with an automatic sprinkler system in accordance with BCA Specification E1.5 and AS 2118.1 except as modified below;

  - Fast response sprinkler heads (with an RTI of 50 $(m \cdot s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads shall be provided in the Gym / Aquatic Centre area to allow for earlier sprinkler actuation.

  - The Community Club and Gym is to be provided with a mechanical air handling system to AS/NZS 1668.1 which shall automatically shut down the air handling systems, except as modified below;

- It is proposed to modify the spacing of the smoke detectors from the required 20.4 m spacing (under Clause 4.10.5 of AS/NZS 1668.1) within the Community Club area to that of a 10.2 m grid, which resembles spacing of an AS 1670.1 system.

12.6 Method of Analysis

It is proposed to undertaken a comparative analysis whereby:

- DtS compliant travel distance to a point of choice in exits (20 m) will be compared with the proposed design (up to 25 m).
- DtS compliant travel distance to an alternative exit (40 m) will be compared with the proposed design (up to 60 m).
- DtS compliant travel distance between alternative exits (60 m) will be compared with the proposed design (up to 80 m).

It is proposed to mitigate the identified extended travel distance in the Community Club areas by reducing the detection spacing of the smoke heads of the AS/NZS 1668.1 system. It is proposed to mitigate the identified extended travel distances in the Gym / Aquatic Centre with the provision of fast response sprinkler heads in lieu of the standard response sprinkler heads. The assessments will also use a comparative RSET-RSET analysis.

The decrease in the detection time afforded by reducing the smoke detector spacing / incorporation of the fast response heads in lieu of standard response heads will be shown to offset (compared) the increase in travel time resulting from the extended travel distances.

It is noted that Alternative Solution AS 11 of this report addresses the proposed omission of sprinkler heads and smoke detectors from the pool area of the Aquatic Centre. The omission of smoke detectors and sprinklers from the pool area does not present a risk to life safety in this instance, given the low fire risk associated with the indoor pool area and given that the majority of the footprint of this area contains a wet space. It is noted that all remaining areas of the Aquatic Centre are being provided with enhanced fire detection provided by the earlier response of the sprinkler system (use of fast response sprinkler heads in lieu of the prescriptive standard response sprinkler heads) which will facilitate total egress times being less than or equal to the comparative notional DtS case. Refer to AS 11 for further discussions.

12.7 Assessment

12.7.1 Travel time comparison to a DtS Compliant Building

In a DtS compliant design, BCA Clause D1.4 stipulates that in Class 5 to 9 buildings, no point on a floor must be more than 20 m from an exit, or a point from which travel in different directions to 2 exits is available, in which case the maximum distance to one of those exits must not exceed 40 m. BCA Clause D1.5 requires that the travel distance between alternative exits must not be greater than 60 m. In the proposed design, the occupants in the carparking levels may be travelling;

- Up to 25 m in lieu of permissible 20 m in reaching a point where there is a choice of exits,
- Up to 60 m in lieu of permissible 40 m in reaching an alternative exit,
- Up to 80 m in lieu of the permissible 60 m between alternative exits.

As discussed in Section 11.7 of Alternative Solution AS 4, the unimpeded walking speed of a person has been taken as 0.8 m/s to assess travel time (to allow for all anticipated occupants of the development).

Hence the delay in evacuation in the proposed building without any additional fire safety measures when compared with a DtS compliant design is detailed in Table 22. The delay in evacuation in the proposed building is up to a further 25 s when compared with a DtS compliant design.

Table 24: Travel Time comparison to a permissible DtS arrangement

Description of travel distance	Comparable DtS Design			Proposed Design			Additional time required due to extended travel distance (s)
	Distance (m)	Travel Speed (m/s)	Travel Time (s)	Distance (m)	Travel Time (m/s)	Travel Time (s)	
To POC in exits	20 m	0.8 m/s	25	25 m	0.8 m/s	31	6 s
To alternative exit	40 m	0.8 m/s	50	60 m	0.8 m/s	75	25 s
Between alternative exits	60 m	0.8 m/s	75	80 m	0.8 m/s	100	25 s

In the sections that follow, it has been demonstrated that;

- ***(Community Club areas)*** - By reducing the smoke detector head spacing of the AS 1668.1 system (20.4 m grids) to that of an AS 1670.1 system (10.2 m grids) in the Community Club areas will allow for earlier warning of a fire within compared with a comparable DtS case and as such will compensate for the additional travel time as a result of the identified extended travel distances.
- ***(Gym / Aquatic areas)*** - The installation of enhanced fire detection provided by the earlier response of the sprinkler system (use of fast response sprinkler heads in lieu of standard response sprinkler heads) will facilitate total egress times being less than or equal to the comparative notional DtS case.

Fire Scenarios

Whilst the fit-out plan of the Club, Gym and the Aquatic centre is not available at the time of preparing this report, the likely fire scenarios expected in these areas would be as follows:

- Club: gaming machines and catering facility including kitchen and tables. A fire in the club may develop at a growth rate comparable to a shop fire, which is a fast growth fire as per Table 10.2 of [CIBSE].
- Gym and Aquatic Centre: The fuel load is considered mainly located in the staffed rooms / areas containing computers and paper works or the like and storage rooms, which are expected to be separated from the public areas. The areas around the pool and the activity areas in the Gym contain limited fire load, mainly being the bags brought in by customers. A worst case fire in the Gym and Aquatic Centre is considered to be in the staffed areas such as the reception and is similar to an office fire which grows at a medium growth rate as per Table 10.2 of [CIBSE].

For the purpose of this assessment, the following fire growth rates will be adopted:

- Club: a t^2 '*fast*' growth rate
- Gym and Aquatic Centre: a t^2 '*medium*' growth rate

Since the fire scenarios are used for determining the detection time only, the other quantitative fire characteristics were not determined, such as the maximum fire size.

12.7.2 Calculation of Evacuation Time

The Required Safe Evacuation Time (RSET) is determined by the following formula [PD 7974-6]:

$$RSET = T_{det} + T_a + T_{pre} + T_{mov}$$

where

$T_{det} =$ Detection time – the time from ignition until a fire is detected (s)

$T_a =$ Alarm time – the time from detection to the alarm sounds (s)

$T_{pre} =$ Pre-movement time – consisting of alarm recognition and response times (s)

$T_{mov} =$ Movement time – the time occupants take to walk to the exit (s).

The detection time for both designs will be based on the activation of smoke detectors / sprinkler heads depending on the area being assessed. The activation time of both smoke detectors as well as sprinkler heads will be calculated using the equations presented in Appendix D.

Since the smoke detector spacing for the proposed design is smaller than the reference design, it is expected that a quicker detection time would be achieved for the proposed design.

The inputs and results are presented in Table 23 and Table 24 below. Refer to Appendix D for details of the smoke head and sprinkler activation times for the Community Club and the Gym / Aquatic Centre.

Table 25: Community Club - Smoke Detector activation time calculation parameters

Input Parameters	Proposed Design	Reference Design
Ceiling height (m)	4.0 m	4.0 m
Height of fuel above floor (m)	0.5 m	0.5 m
Detector spacing (m)	10.2 m grid	20.4 m grid
Ambient temperature (°C)	23 °C	23 °C
Actuation temperature (°C)	39 °C	39 °C
Fire growth time (s)	150 s	150 s
Output Parameters	**72 s**	**102 s**

As can be seen in Table 23 the reduced smoke detector head spacing to 10.2 m grid is expected to operate 30 seconds faster when compared with standard spacing of 20.4 m grids under AS 1668.1. As the improvement in the detection time is greater than the increase in time taken to travel the extended travel distances detailed in Table 22, the provision of reducing spacing is considered to sufficiently mitigate the extended travel distance in the Community Club areas.

Table 26: Gym / Aquatic Centre - sprinkler activation time calculation parameters

Description of input / output parameters	Gym		Aquatic Centre	
	Proposed Design	Reference Design	Proposed Design	Reference Design
Input Parameters				
Ceiling height (m)	3.2 m	3.2 m	3.8 m	3.8 m
Height of fuel above floor (m)	0.8 m	0.8 m	0.8 m	0.8 m
Radial distance (m)	2.5 m	2.5 m	2.5 m	2.5 m
Detector spacing (m)	3 m × 4 m	3 m × 4 m	3 m × 4 m	3 m × 4 m
Ambient temperature (°C)	23 °C	23 °C	23 °C	23 °C
Actuation temperature (°C)	68 °C	68 °C	68 °C	68 °C
Response Time Index, RTI ($m{\cdot}s^{0.5}$)	50	135	50	135
Conductance, C ($m/s^{0.5}$)	0.65	0.85	0.65	0.85
Fire growth time (s)	300 s	300 s	300 s	300 s
Output Parameters				
Detector activation time (s)	228 s	279 s	256 s	308 s

As can be seen in Table 24, the fast response sprinkler heads are expected to operate 51-52 seconds faster when compared with standard response heads. As the improvement in the detection time is greater than the increase in time taken to travel the extended travel distances detailed in Table 24, the provision of fast response heads is considered to sufficiently mitigate the extended travel distance in the Gym / Aquatic Centre.

12.8 Conclusion

This analysis demonstrates that in conjunction with the proposed the fire safety features manage the variations from the relevant BCA Clauses. As such BCA Performance Requirements DP4 and EP2.2 are met.

13. AS 7 – Discharge of fire-isolated-stairs (Blocks E & F)

13.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 27: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the fire-isolated stairs serving Buildings E & F not to discharge to an open space.	D1.7(b)	DP4, DP5 & EP2.2	SS-C & SS-E	(b)(i)	(b)(ii)
To permit the path of travel from the discharge point of fire-isolated stair serving Building E to pass within 6 m of the glazed facade of the Gym on the upper ground floor.	D1.7(c)				
To permit path of travel from the discharge point of the fire-isolated stairs serving Building F to pass within 6 m of the glazed facade of the Café or the Seniors Lobby on the upper ground floor.					
To permit the fire-isolated passageway which provides access to the hydrant tank and pump room to have multiple doors opening onto the passageway without the exit being pressurised.	D1.7(d)				
To permit paths of travel on the Upper Ground Floor Level (applicable to Buildings D, E & F) to pass within 3 m of the openings associated with the Palm Gully and the Void space.	D2.12				
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

13.2 Description of non-compliance with DtS Provisions

13.2.1 Non-compliant discharge of fire stairs (Buildings E & F)

Both Buildings E and F are served by fire-isolated exits that discharge at the Upper Ground Floor Level as indicatively illustrated in Figure 31. Based on advice by the PCA, the stairs are not considered to discharge to an open space, as the upper parts of the building overhang above the stair discharge points. In addition, the path of travel from the discharge points of these fire-isolated stairs passes within 6 m of the openings in the external walls of Buildings E & F.

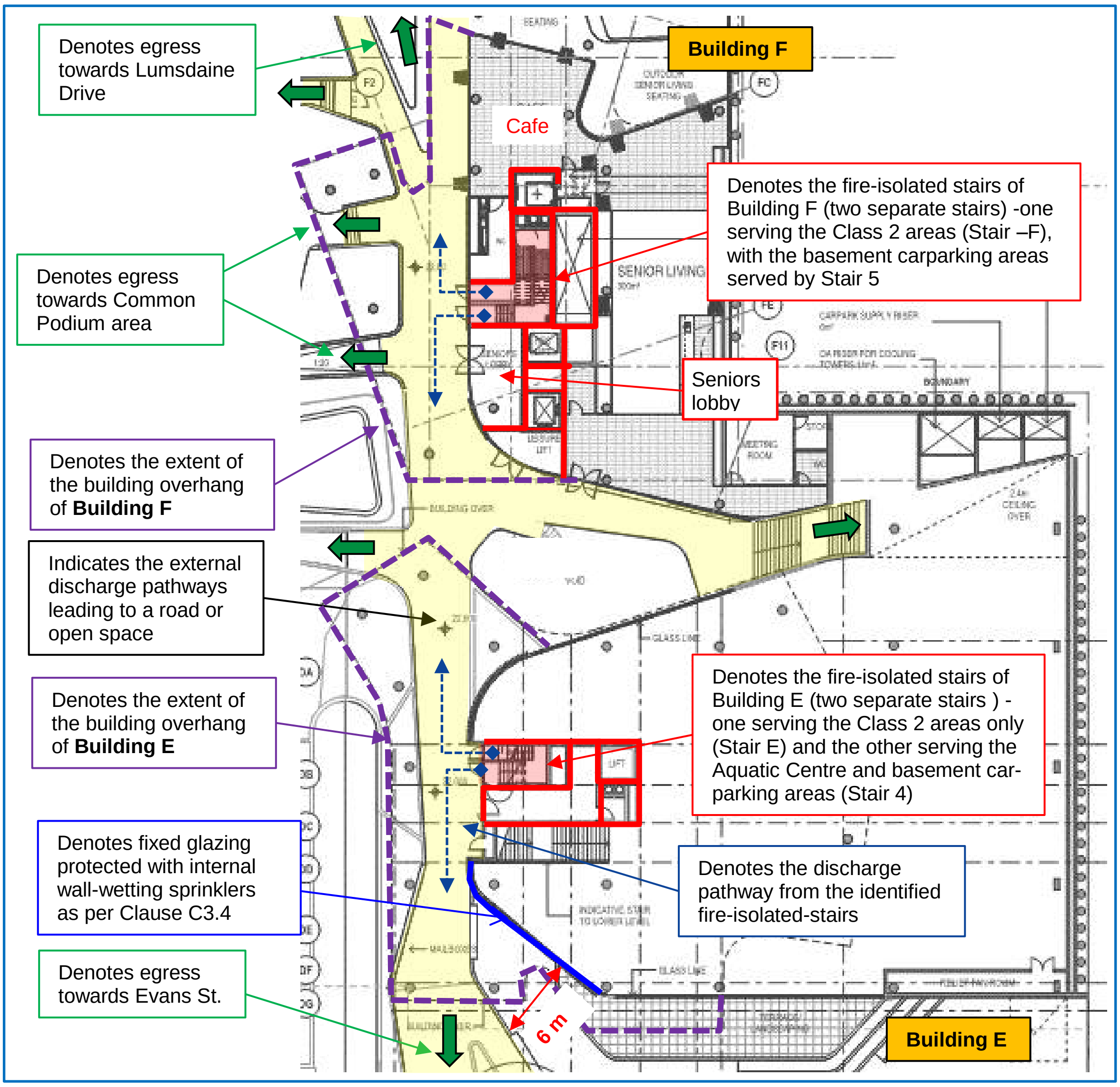


Figure 31: Building E & F (Upper Ground Floor Level) – discharge of fire-isolated stairs

13.2.2 Egress along the roof passing within 3 m of openings in external walls (Buildings D, E & F)

The exits serving Buildings D, E & F discharge towards the external landscaped podium area on the Upper Ground Floor Level, as indicatively illustrated in Figure 32. The paths of travel from the exits shall pass within 3 m of the openings associated with the Palm Gully and the Void space which connect to the Lower Ground Floor Level (Community Club / Port Cochere area). Based on direction from the PCA this constitutes a non-compliance with Clause D2.12 of the BCA.

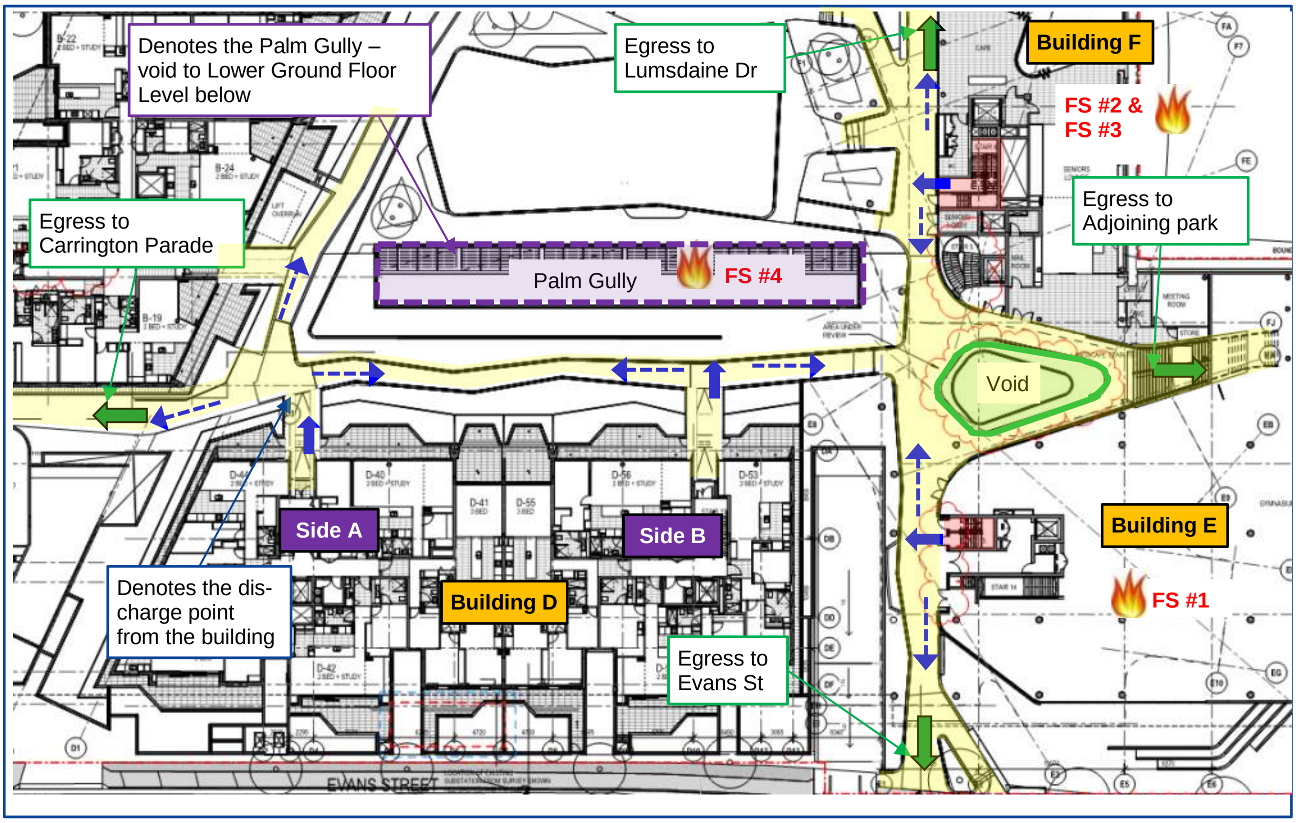


Figure 32: Buildings D, E & F – discharge pathway within 3 m of Palm Gully void openings

13.2.3 Multiple doors opening into fire-isolated passageway

A fire-isolated passageway is proposed to provide access to the hydrant tank and pump room. However, there are multipe doors opening onto the fire-isolated passageway as identified in Figure 33. It is proposed not to pressurise the passageway to AS/NZS 1668.1 which is required under BCA Clause D1.7(d).

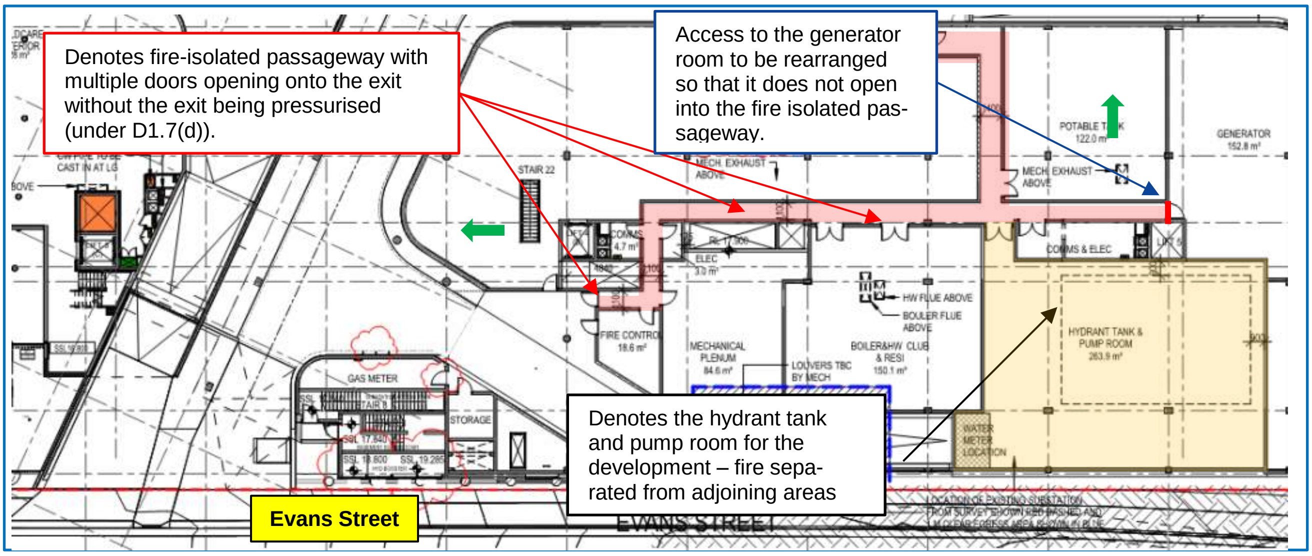


Figure 33: Fire-isolated passageway to pump room – multiple openings with no pressurisation

13.3 Acceptance Criteria

The acceptance criterion for the non-compliances regarding egress pathways from Buildings D, E & F is that occupants can safely evacuate to the streets without the need to be exposed to untenable fire conditions.

The acceptance criterion for the non-compliance regarding non-provision of pressurisation to fire-isolated passageways is that occupants and attending fire brigade can safely evacuate to the streets without the need to be exposed to untenable fire conditions.

13.4 Hazards

The hazards associated with the identified non-compliance lie in the following:

- In the event of a fire occurring in the Gym on the upper ground floor, occupants discharging from Building E need to pass the glazed external wall of the Gym when they try to egress to Evans Street or Lumsdaine Drive. The failure of the glazed walls would cause exposure conditions to the passing occupants. In the meantime, occupants may need to travel in a smoke contaminated environment due to the stair not discharging to an open space.
- In the event of a fire occurring in the Café on the upper ground floor, occupants discharging from Building F need to pass the glazed external wall of the Café when they try to egress to Lumsdaine Drive. The failure of the glazed walls would cause exposure conditions to the passing occupants. In the meantime, occupants may need to travel in a smoke contaminated environment due to the stair not discharging to an open space.
- In the event of a fire occurring in the Seniors Lobby on the upper ground floor, occupants discharging from Building F need to pass the glazed external wall of the Seniors Lobby when they try to egress to Evans St. The failure of the glazed walls would cause exposure conditions to the passing occupants. In the meantime, occupants may need to travel in a smoke contaminated environment due to the stair not discharging to an open space.
- In the event of a fire occurring on the Lower Ground Floor, exposure conditions may occur at the openings of the Palm Gully and the void space at Upper Ground Floor Level. This may affect the life safety of occupants from Buildings D, E & F who need to pass these openings in order to egress to the streets.

- The risk associated with multiple doors opening into the required fire-isolated passageway with no pressurisation to the exit is that a fire in an adjoining room could spill into the adjoining passageway making it impassable for evacuating occupants and attending fire brigade gaining access to the hydrant pump room.

13.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- An automatic sprinkler system designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 is to be provided to the Gym / Aquatic Centre where it is proposed to provide fast response sprinkler heads (with an RTI of 50 $(m \cdot s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads to allow for earlier sprinkler actuation.
- Alternative egress paths shall be provided and maintained from the discharge points of exits from Buildings D, E & F. The alternative egress paths are in opposite directions to different streets. Refer to Figure 32 and Figure 33 for clarity.
- The fire-isolated passageway shall have a minimum FRL of 90/90/90 with all doors opening into the passageway to be self-closing -/60/30 fire doorsets that shall also be upgraded and fitted with medium temperature smoke seals, capable of withstanding temperatures of 200°C for at least 30 minutes and tested in accordance with AS 1530.7.
- On the Upper Ground Floor, the leisure lift lobby of Building F shall be fire separated from the adjoining areas with construction having an FRL of not less than 60/60/60.
- Fire stairs 1 and 2 leading from the basement levels discharging at ground levels of Building A and B require that the openings within 6 m of the paths of travel are protected in accordance with C3.4. These windows shall be protected with Tyco model WS specific application window sprinklers on the SOU side of the window and must be installed in accordance with the manufacturer's specifications. The specifications of the system are contained in Appendix E. However, note the following key items:
  - Glazed doors or openable windows within the glazed wall are required to automatically close, so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door and window opening mechanisms, so as not to clash with the Tyco head.

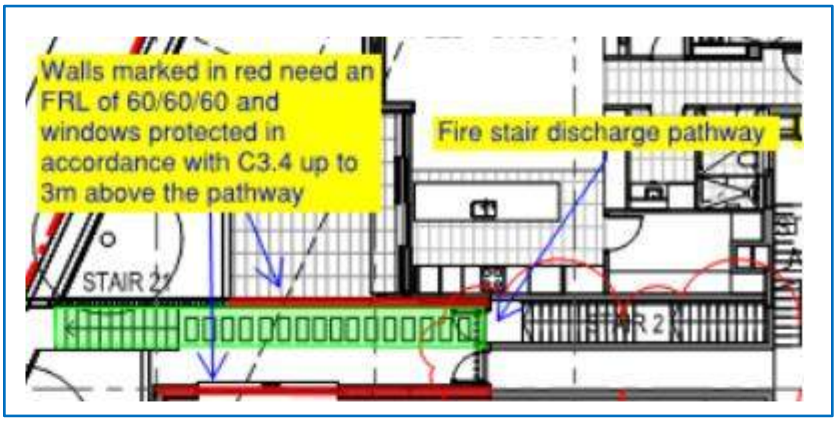


Figure 34: Openings in building A and B requiring C3.4 protection

13.6 Method of Analysis

The analysis to be conducted will be qualitative in nature and will use a deterministic absolute approach. The analysis is to demonstrate that occupants from Buildings D, E & F can safely evacuate to streets after they discharge onto the landscaped roof on the upper ground floor. Considering the hazards identified in Section 13.4, the following fire scenarios are to be assessed (which have been indicatively identified in Figure 32 and Figure 33):

- **Fire Scenario FS #1:** a fire occurs in the Gym on the upper ground floor.
- **Fire Scenario FS #2:** a fire occurs in the Café on the upper ground floor.
- **Fire Scenario FS #3:** a fire occurs in the Seniors Lobby on the upper ground floor.
- **Fire Scenario FS #4:** a fire occurs in the lower ground floor.
- **Fire Scenario FS #5:** a fire occurs in one of the rooms adjacent to the fire-isolated passageway providing access to fire pump room.

13.7 Assessment

13.7.1 Fire Scenario #1 (Building E)

Under this fire scenario, a fire occurs in the Gym on the upper ground floor. Occupants within the residential Building E would be directly affected due to the fire being located immediately beneath them. Since the Gym is fully sprinkler protected, a fire in the Gym would be expected to be controlled by the operation of sprinklers (if not suppressed) and be contained within the area of origin. Research conducted by CIBSE (1995) and England et al. (2000) indicated that the upper layer temperatures are not likely to exceed 100°C during a sprinkler suppressed fire and 200°C for a shielded fire, respectively. These temperatures may not cause the failure of the glazed walls in the Gym. Nonetheless, the glazing wall that is within 6 m of the egress path to Evans St shall be protected with internal wall-wetting sprinklers, as per Clause C3.4. As a result, occupants from Building E can evacuate towards Evans St without being exposed to untenable conditions from a fire within the building.

Strictly speaking, the fire stair does not discharge into an open space due to the building overhang. However, any smoke that spreads into this area through the failed glazing would be effectively vented to outside through the perimeter openings and would not affect the occupants egressing below.

Occupants in Buildings D and F can safely evacuate to either Carrington Parade or Lumsdaine Drive without need to pass the building on fire, as illustrated in Figure 32.

13.7.2 Fire Scenario #2 (Building F)

Under this fire scenario, a fire occurs in the Café on the upper ground floor. Occupants within the residential building F would be directly affected due to the fire being located immediately beneath them. Since the Senior Lobby is fire separated from the rest of the upper ground floor, the fire in the Café is unlikely to spread to the Senior Lobby. Therefore, occupants from Building F can safely evacuate towards the Evans St without passing the Café on fire.

Similarly, as discussed above, whilst the fire stair does not discharge into an open space due to the building overhang, any smoke that spreads into this area through the failed glazing would be effectively vented to outside through the perimeter openings and would not affect the occupants egressing below.

Occupants in Buildings D and E can safely evacuate to either Evans St or Carrington Parade without the need to pass the building on fire, as illustrated in Figure 32.

13.7.3 Fire Scenario #3 (Building F)

Under this fire scenario, a fire occurs in the Senior Lobby on the upper ground floor. Occupants within the residential Building F would be directly affected due to the fire being located immediately beneath them. Since the Senior Lobby is fire separated from the rest of upper ground floor, the fire is unlikely to spread to the Café. Therefore, occupants in Building F can safely evacuate towards Lumsdaine Drive without the need to egress towards Evans St and passing the fire within the Senior Lobby.

Similar to Fire Scenario #2, any smoke that spreads into this area through the failed glazing would be effectively vented to outside through the perimeter openings and would not affect the occupants egressing below.

Occupants in Buildings D and E can safely evacuate to either Evans St or Carrington Parade without the need to pass the building on fire, as illustrated in Figure 32.

13.7.4 Fire Scenario #4 (Community Club / Port Cochere area)

Under this fire scenario, a fire occurs in the lower ground floor. It is noted that the areas below the two voids are circulation areas, i.e. the club drop-off and the Porte Cochere. It is considered that there would be limited fire load within these areas. Therefore, the risk of a fire occurring in these areas is remote. In addition the lower ground floor is fully sprinkler protected. The fire would be expected to be controlled by the operation of sprinklers (if not suppressed) and be contained within the area of origin. If a fire occurs directly under one of the voids, the fire would be local to that void and is unlikely to spread to both voids.

In the case of a fire underneath the Palm Gully void, only part of the void may be affected by fire, considering that this void is approximately 40 m in length. In this situation, occupants from Side A (left part) of Building D can safely evacuate to Carrington Parade without the need to pass the Palm Gully void. Occupants from Side B (the right part) of Building D can safely evacuate away from any fire in the void, since two paths of travels are provided to both Carrington Parade and Evans St.

In the case of a fire underneath the smaller void, occupants from Buildings D, E and F can safely evacuate to Carrington Parade, Evans Street and Lumsdaine Drive, respectively, without the need to pass the smaller void.

13.7.5 Fire Scenario #5 (Fire-isolated passageway)

Under this fire scenario, a fire occurs in one of the rooms adjacent to the fire-isolated passageway, providing access to the fire pump room.

The fire-isolated passageway is to be separated from the adjacent rooms with construction having a FRL of at least 90/90/90, with all door openings to be protected with self-closing -/60/30 fire doorsets. In addition, all the doors shall be fitted with medium temperature smoke seals capable of withstanding temperatures of 200°C for at least 30 minutes and tested in accordance with AS 1530.7. Therefore, for this fire scenario, the fire would be contained within the room of origin and the quantity of smoke leaking into the passageway would be minimal, due to the provision of smoke seals to the doors.

The passageway is noted as serving plant rooms and the like, which shall have minimal occupant loading and that these are likely to be limited to maintenance staff and the like. Alternative exits are also provided at both ends of the passageway, either toward the carpark entry ramp or alternatively into the Port Cochere area.

Based on the above, it is considered that occupants or attending fire brigade can safely evacuate via the fire-isolated passageway.

13.8 Conclusion

This analysis has demonstrated that the proposed fire safety features detailed in Section 6 would ensure that occupants / fire brigade are able to safely evacuate the building. As such, BCA Performance Requirements DP4, DP5 and EP2.2 are met.

14. AS 8 – Discharge of exits into a covered space

14.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 28: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the discharge of exits to an under croft space that is not open to the sky. This is applicable to exits that discharge into the following areas; ■ Porte Cochere at Lower Ground Floor Level ■ Undercroft area to the north of the club ■ Building E overhang at Upper Ground Floor Level	D1.10	DP4 & EP2.2	SS-A, SS-B, SS-C, SS-E & SS-F	(b)(ii)	(b)(ii)
Approach and assessment method used - The approach in this solution will be qualitative and quantitative in nature and will use a deterministic absolute approach.					

14.2 Description of non-compliance with DtS Provisions

It is noted that WSP | PB Fire has not been provided with a fit-out plan of the Community Club area and the Gym / Aquatic Centre showing the detailed layout of the club and the exit paths within the club. The exits shown in Figure 35 are indicative only so should be reviewed against the fitout plans to ensure the two align prior to construction.

It is proposed to permit the discharge of exits to an under croft space that is not to a road or open space (open to the sky) and as such constitute a deviation from prescriptive guidance given in BCA Clause D1.10. This is applicable to exits that discharge into the following areas;

- Occupants of the Community Club and Gym / Aquatic Centre discharge into the Porte Cochere area at Lower Ground Floor Level (refer to Figure 37 & Figure 38 for clarity).
- Occupants of the Building E Gym area discharge in the overhang at Upper Ground Floor Level (refer to Figure 37 for clarity).
- Occupants of the Community Club discharge into an undercroft area to the north of the club (refer to Figure 38 for clarity). It is noted that the undercroft area to the north of the club extends up to 20 m from the club shopfront.

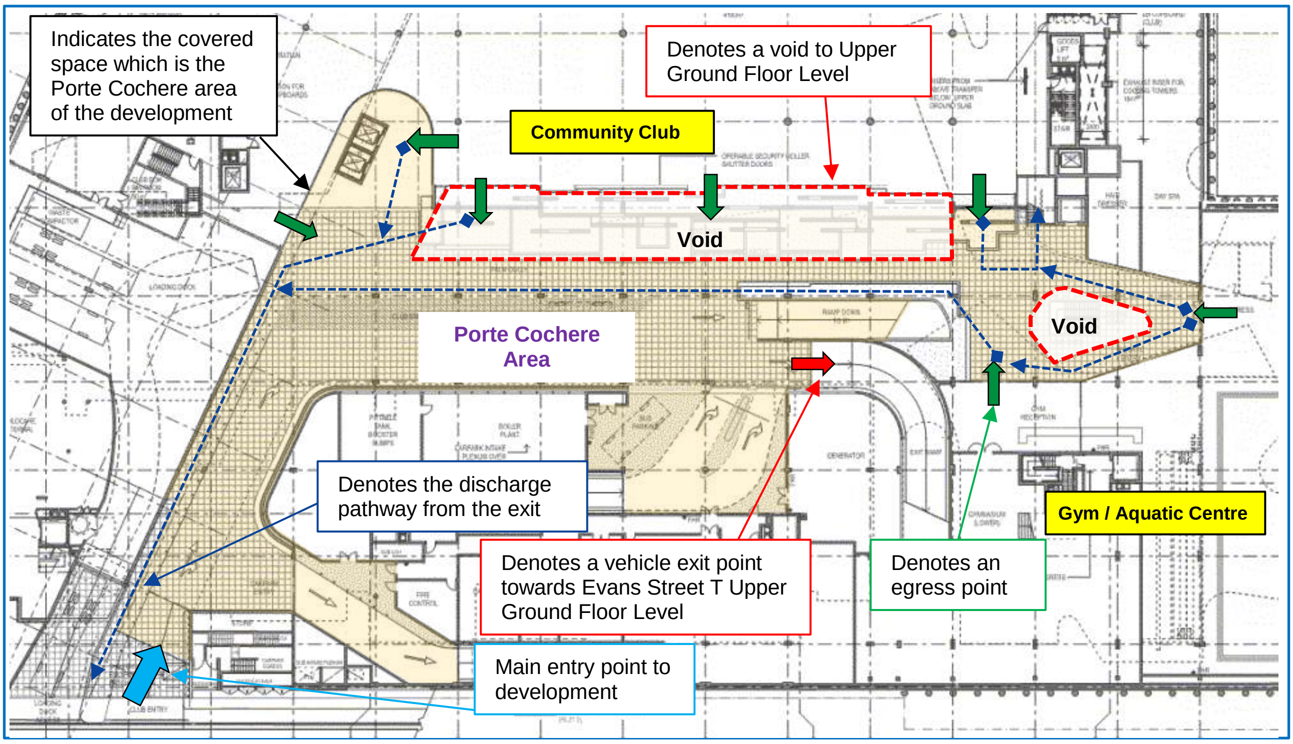


Figure 35: Lower Ground Floor Level – discharge of exits into the Porte Cochere area

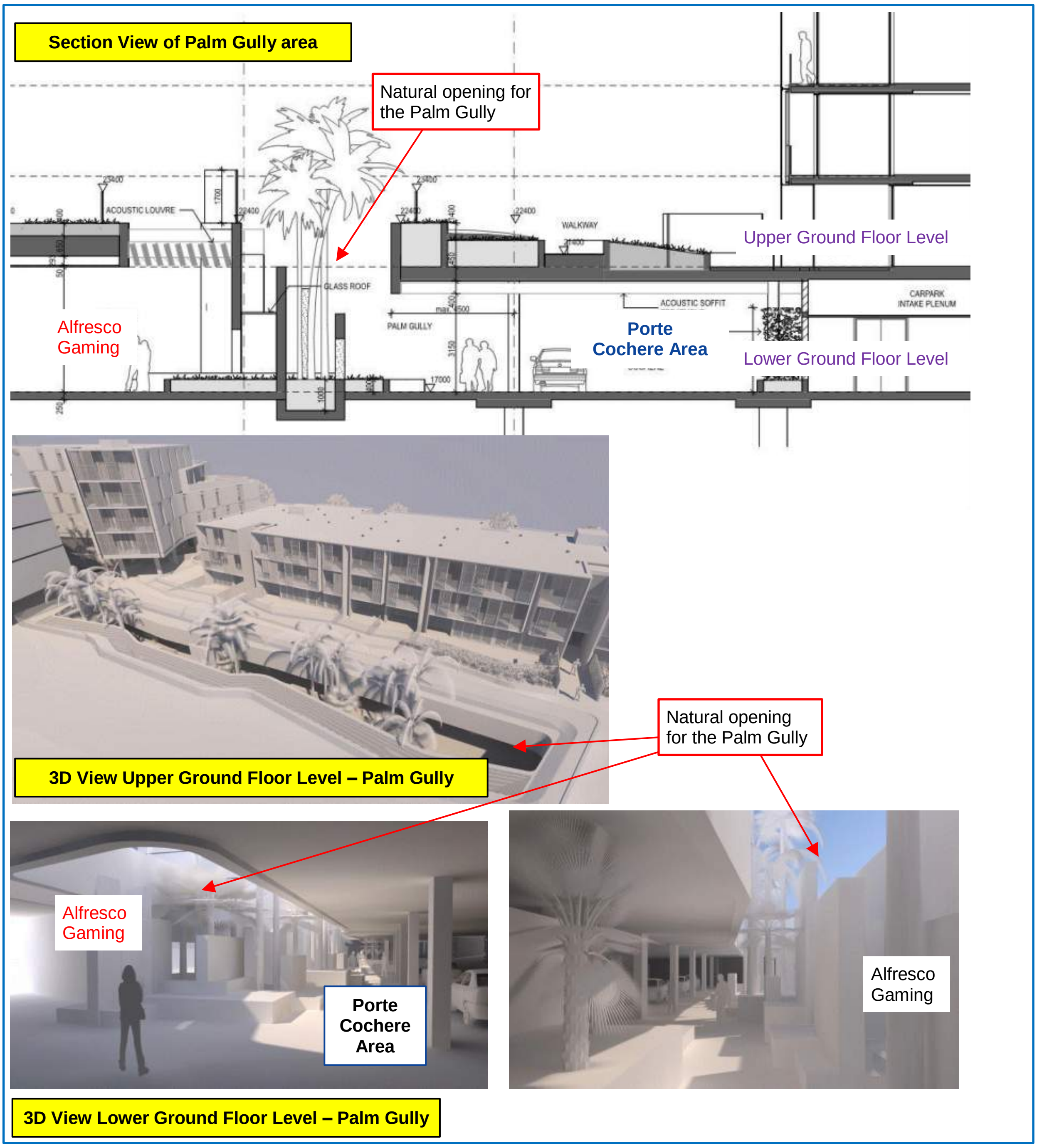


Figure 36: Natural opening within the Porte Cochere area / Palm Gully

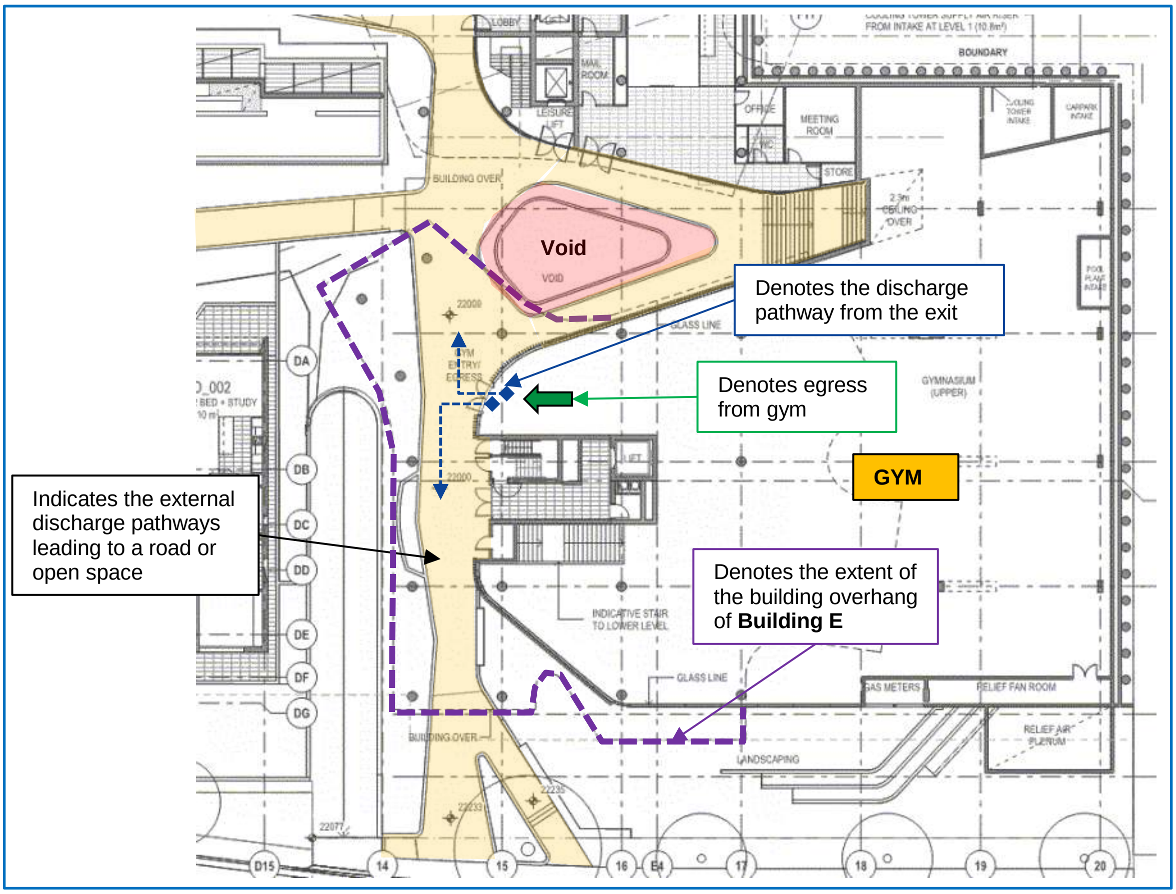


Figure 37: Building E (Upper Ground Floor) – discharge of exits from gym area into a covered space

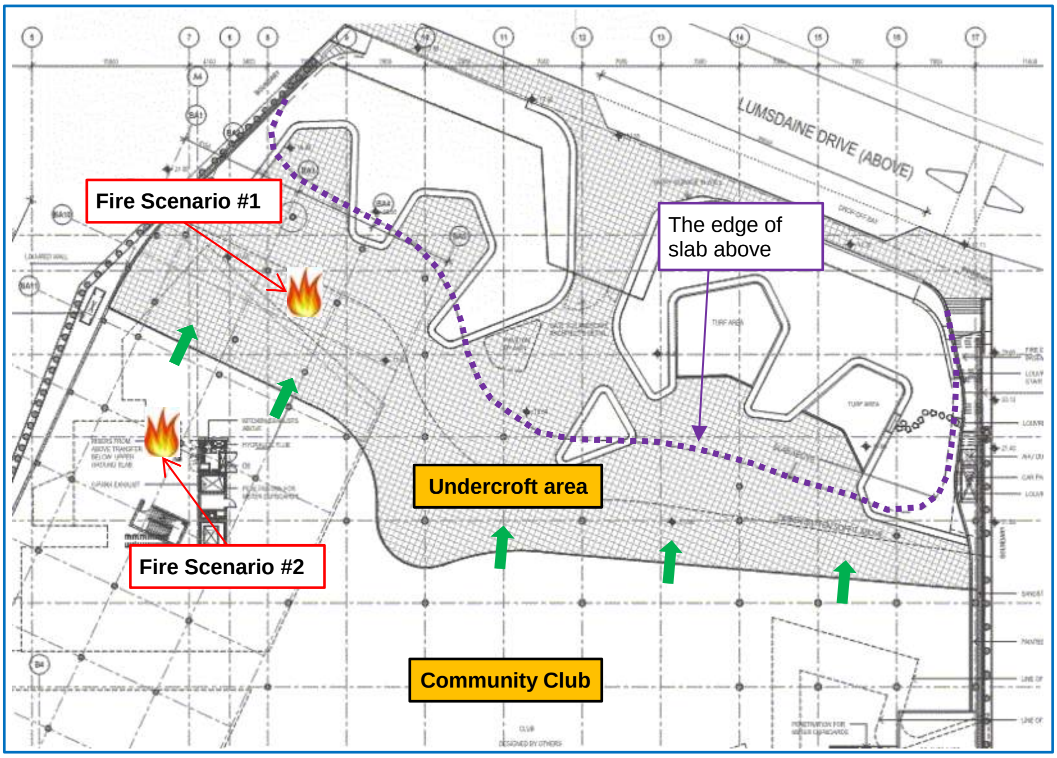


Figure 38: Club exits discharge into an undercroft area – Plan View

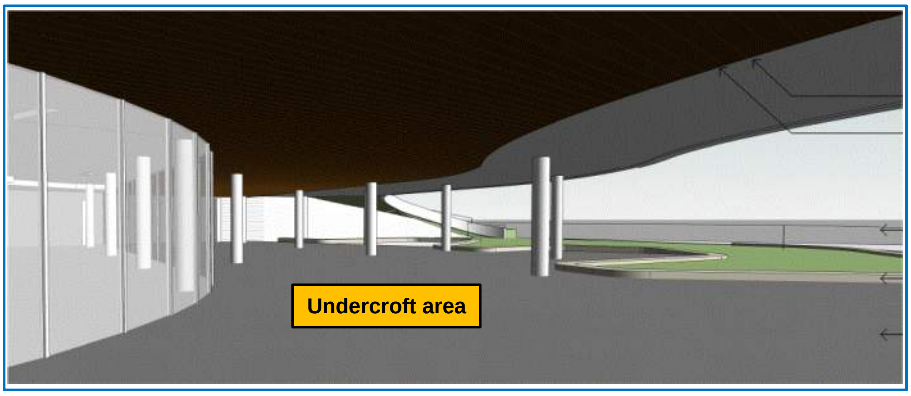


Figure 39: Exits from Club discharge to an undercroft area – Perspective View

14.3 Acceptance Criteria

The acceptance criterion is that in the event of a fire in the building, occupants would be able to safely walk through the covered area to a road or open space without being exposed to untenable conditions.

Where quantitative analysis is to be conducted, the following criteria summarized in Table 27 are to be adopted for assessing life safety:

Table 29: Occupant tenability criteria

Occupant Tenability Criteria		
Convective heat	Temperature < 60 °C at or below 2.0 m from the floor	Reference: [SOFS]- Practice Note for Tanebility Criteria in Building Fire
Radiant heat exposure	Radiant flux < 2.5 kW/m^2 at or below 2.0 m	
Visibility	When the smoke layer is below a height of 2.0 m: ▪ Reflective surface visibility > 10 m (for large spaces) ▪ Illuminated signage visibility > 5 m (queuing at exits)	

14.4 Hazards

When exits discharge to an undercroft area, occupants may be exposed to untenable conditions if a fire occurs in the undercroft area or in the areas adjacent to the undercroft area. As a result, occupants may not be able to evacuate safely through the undercroft area to the road or open space.

14.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development, incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- An automatic sprinkler system designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 is to be provided throughout the Lower Ground Floor including the undercroft area to the north of the club and the Gym on the Upper Ground Floor. Note that sprinklers are to be removed from the areas directly above the swimming pool – See AS 11 of this report.
- A designated egress pathway (with appropriate exit wayfinding signage) at least 1.5 m wide is to be provided in the Porte Cochere area, which leads directly to Evans Street and the stairs linking to Upper Ground Floor Level.
- The Porte Cochere area shall be naturally ventilated by the presence of the Palm Gully Void and stair void as well as the vehicle exit ramp linking to Upper Ground Floor Level.

- The Porte Cochere area and its circulation areas are not permitted to have any combustible materials, such as combustible seating and linings, materials and assemblies must be as per Table 1 of Specification C1.10.
- The undercroft area to the north of the club shall be fully open at the perimeter all the times.

14.6 Method of Analysis

14.6.1 Exit to the undercroft area to the north of club

The analysis undertaken has been qualitative, quantitative in nature and utilises a deterministic absolute approach. Fire modelling of certain fire scenarios using zone fire model [CFAST] developed by the National Institute of Standards and Technology of US is to be conducted such that the conditions within the undercroft area can be checked to determine whether occupants from the club can safely evacuate through this area to the open space.

The following fire scenarios are identified as the worst case fire scenarios for the assessment:

- **Fire Scenario #1**: A fire occurs in the undercroft area to the north of the community club at the location, as indicated in Figure 38. Tables, chairs and other furniture may be placed under the undercroft area for outdoor functions. A fire involving these items is likely to grow as a "*medium*" growth rate fire. Smoke is expected to be vented to the atmosphere through the perimeter openings. Since this area is sprinkler protected, the fire is considered to be controlled and contained within the area of origin. After the activation of the sprinklers, it is conservatively assumed that the fire would remain the size at the time of sprinkler activation. A sprinkler activation calculation has indicated that the fire is capped at a size of 1178 kW at the time of sprinkler activation. Refer to Appendix D for the output of the calculation.
- **Fire Scenario #2**: A fire occurs in the club area at the location as indicated in Figure 38. The club contains gaming machines and a catering facility, including a kitchen. A fire in the club may develop at a growth rate comparable to that of a shop fire, which is a fast growth rate fire, as per Table 10.2 of [CIBSE]. The fire is expected to break the glazing shopfront, resulting in smoke spread to the undercroft area. The fire is expected to be a sprinkler controlled fire, due to the club being fully sprinkler protected. After the activation of the sprinklers, it is conservatively assumed that the fire would remain the size at the time of sprinkler activation. A sprinkler activation calculation indicated that the fire would be capped at a size of 1570 kW at the time of sprinkler activation. Refer to Appendix F for the output of the calculation.

14.6.2 Discharge into the Port Cochere area / from Building E

The analysis undertaken has been qualitative and quantitative in nature and utilizes a deterministic absolute approach. The analysis is to demonstrate that the discharge into Port Cochere area (covered area) would not adversely affect the safe occupant evacuation in reaching a road or open space.

14.7 Assessment

14.7.1 Exit to the undercroft area to the north of the club

The two fire scenarios, as identified above, have been modelled using the zone fire model [CFAST]. The model setup and the results of the modelling are included in Appendix F. As can be seen from Appendix F, under these two fire scenarios, the hot smoke layer is expected to be maintained at a height above 3.5 m in the undercroft area and the temperatures of upper layer are expected to be slightly above 100 °C in the area of fire origin with the temperatures decreasing from around 70 °C to the ambient temperature in the most remote area from the fire. Therefore, it is considered that tenable conditions will be maintained in the undercroft areas for safe occupant evacuation.

14.7.2 Exit to the Porte Cochere area

The Porte Cochere area and its circulation areas are not permitted to have any combustible materials and as such it is unlikely that a fire would start within this area of the building. The inclusion of an automatic sprinkler system to the Porte Cochere area is to mitigate the fire risk to this area. It is further noted that the Porte

Cochere area shall be transient in nature in that its serves as a drop off point for cars to the Community Club areas where cars move on after the drop off point to either the carparking areas at basement levels or alternatively exiting the development at Evans Street.

As indicated in Figure 35 and Figure 36, there is a large void (referred to as the Palm Gully) providing natural ventilation to the Port Cochere area as well as a void containing an open stair adjacent to the Aquatic Centre. In an unlikely event of a fire occurring in the Porte Cochere area, smoke would be effectively vented out through these vent openings. In the event of a fire in the Alfresco Gaming area it is expected that the effects of heat and smoke would spread directly up into the open air, as the Alfresco Gaming area is immediately below the Palm Gully Void.

14.7.3 Robustness & uncertainty – zone modelling

For robustness in the design, a sensitivity case has been undertaken to demonstrate that conditions in the Port Cochere would not compromise occupant evacuation. The program [B-Risk] is a fire risk simulator (zone model) which has been utilised to demonstrate the conditions in the external covered pathway. The B-Risk model can be used for both single deterministic runs as well as multiple iterations of a scenario for the purpose of sensitivity analysis for producing probabilistic descriptors of fire risk under defined conditions. It is noted that B-Risk is used as further justification of the proposed configuration as a sensitivity assessment.

As discussed in Section 11.7.3, a medium t^2-growth rate is noted to be proposed by [Ingason] for passenger cars in tunnel fire safety which is also consistent with guidance given in Table 6.2 of [CIBSE]. In this instance, the fire size has been assumed to be a non-sprinkler-protected fire that grows to 4 MW. The general input parameters assumed for the zone modelling have been detailed in Table 30. An indicative 3D schematic view of the B-Risk fire model has been illustrated in Figure 40.

Table 30: B-Risk Fire Risk Simulator – Port Cochere

Parameter	Value	Unit		Comment
Port Cochere	Width	17 m		Indicative compartment size of the Port Cochere area with a floor area of ~ 1751 m^2.
	Length	103 m		
	Height	3.5 m		
Fire Location	-	-		Porte Cochere - Car Fire
Ventilation	Palm Gully Void	Area	339 m^2	See Figures 22 & 23 for indicative location of openings within the Palm Gully. Stair Voids have been omitted for further redundancy. This is an additional conservative assumption.
	Evans Street Entrance	Height	3.5 m	
		Width	6.4 m	
	Evans Street Exit	Height	3.5 m	
		Width	4.6 m	
Fire growth rate	0.0117 t^2 fire	kW		Non-sprinkler-protected Medium t^2 fire growth rate – capped at 4 MW. This is a conservative assumption, given that the Port Cochere area is sprinkler protected throughout to AS 2118.1.
Soot yield	0.07	g/g		This soot yield is conservative and is representative of that of a burning couch.
Time	600	seconds		Simulation Time

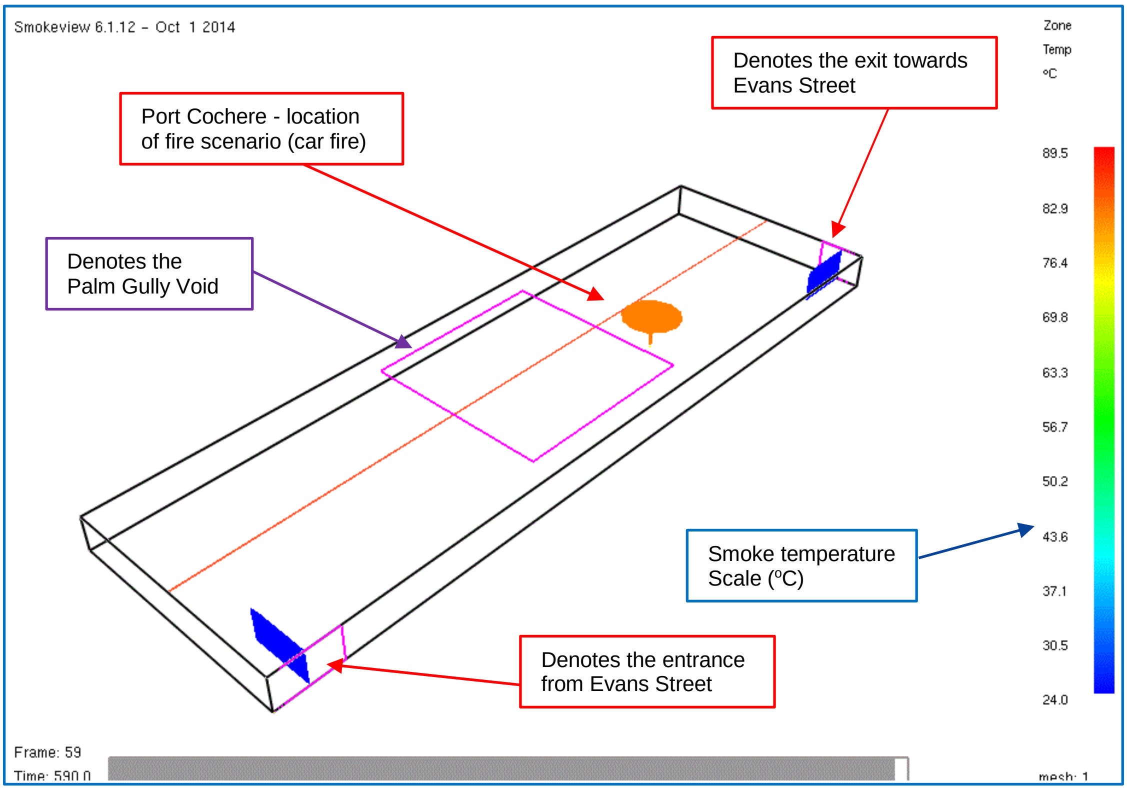


Figure 40: B-Risk zone model – 3D view of model for the Port Cochere area

The results of the B-Risk fire model has been illustrated in Figure 41, which illustrates the smoke layer height in metres in the Port Cochere area. The results show that whilst the smoke layer descends to circa 0.3 m in the underside of the 3.5 m high ceiling, the natural venting facilitates in dissipating the smoke out into the open air and tenable conditions are expected to be maintained within. Hence, in the proposed configuration, smoke is unlikely to descend to a point that would cause untenable conditions to be present in the Port Cochere area.

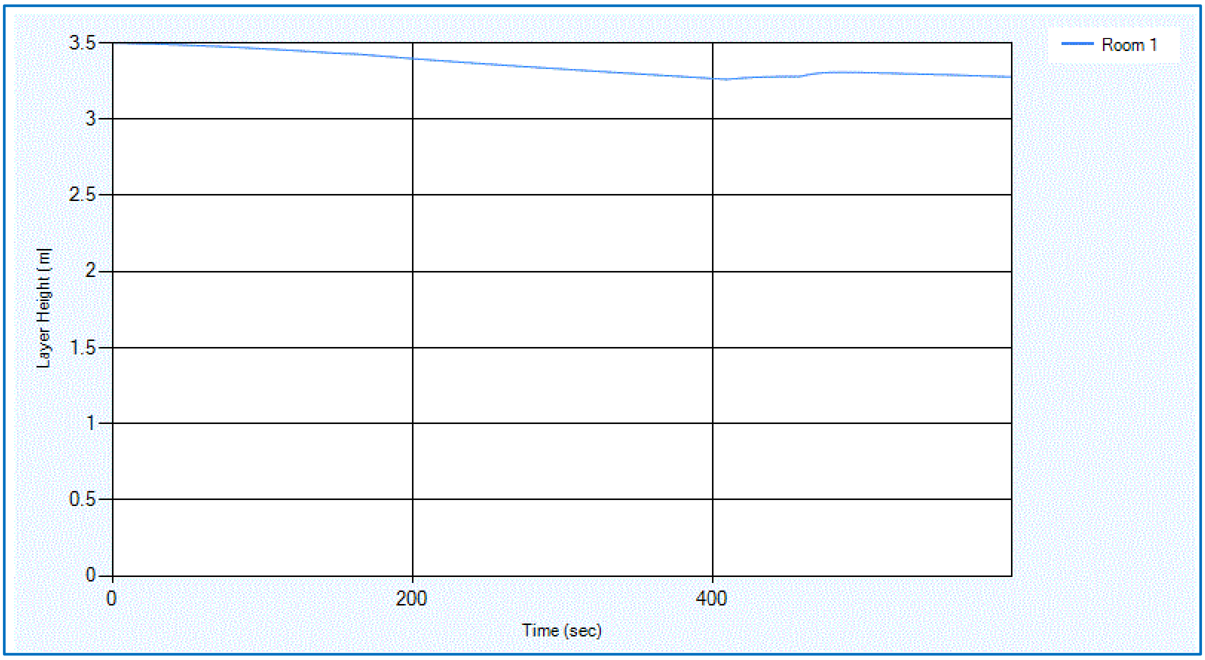


Figure 41: B-Risk results for Port Cochere - smoke layer height in meters

14.7.4 Exit to covered area from Upper Ground Floor Gym area

Occupants from the Gym on the Upper Ground Floor shall evacuate to a covered area (Building E overhang), as indicatively illustrated in Figure 38. The discharge pathway constitutes a circulation area providing access to and exit from the building and therefore it is considered unlikely that a fire would occur in this area, blocking the path of egress, due to no fire load being present in this area. In addition, part of the glazing shopfront of the Gym that is within 6 m of the path of egress is to be protected with internal wall-wetting sprinklers, as per Clause C3.4 and as indicated in Figure 31 of AS 7. The Gym is to be fully sprinkler protected and a fire within this area is likely to be controlled and contained within the area of origin. In the event of a fire in the Gym breaking the unprotected glazing facade, smoke would be vented out through the perimeter openings and it is unlikely to cause untenable smoke conditions.

This has been demonstrated in the CFAST modelling for the undercroft area to the north of the club, considering that the size of the overhang in this instance is considerably smaller. In the case of the fire causing excessive radiant heat flux to the passing occupants, as assessed in Alternative Solution AS 7, occupants will be able to safely evacuate to Evans Street, since the shopfront glazing at that side will be protected.

14.8 Conclusion

This qualitative and quantitative analysis shows that the proposed design involving the exit to the covered area will not adversely affect the safe occupant evacuation. As such, BCA Performance Requirements DP4 and EP2.2 are met.

It is noted that whilst two varying zone models has been utilised to assess the various identified fire scenarios identified in this solution, both types are approprioate tools used in the fire engineering industry to assess the conditions in a fire scenario. In both environments there is a larege natural ventilation present which facilitates in demonstrating tenable conditions ot the evacuating occupants.

15. AS 9 – Review of location of fire brigade facilities

15.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 31: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the fire hydrant pump room not to be accessed directly from a road or open space. The fire-isolated passageway that leads to the pump room shall be accessed directly from a covered space.	E1.3 & Cl.6.4.2 of AS 2419.1	EP1.3, EP1.6 & EP2.2	SS-F	(b)(i)	(b)(ii)
To permit the Fire Sprinkler Pump & Control Valve room be located in a room that is not directly accessed from a road or open space.	Cl.6 of Spec.E1.5				
To permit the FIP to be located in a room that is not directly accessed from a road or open space.	Cl.3 of Spec.E1.8				
To permit the fire hydrant booster not to be shielded with FRL 90/90/90 construction from openings within 2 m of the booster.	E1.3 & Cl. 7.3 of AS 2419.1.				
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

15.2 Description of non-compliance with DtS Provisions

The proposed Fire Hydrant Pump & Tank room is located at the end of a fire-isolated passageway at Lower Ground Floor Level. The proposed location is a departure from the requirements of Clause 6.4.2 of AS 2419.1, which states that a fire hydrant pumproom is to have *"a door opening to a road or open space, or a door opening to fire-isolated passage or stair which leads to a road or open space".* It is also noted that the Fire Sprinkler Pump & Control Valve room for the development is to be located within the same enclosure. As such, this is a deviation from the requirement of BCA Clause 6 of Specification E1.5.

In the proposed arrangement, the fire-isolated passageway that provides access to the Fire Hydrant Pump &Tank room / Fire Sprinkler Pump & Control Valve room is accessed from a covered space and not a road or open space as indicatively illustrated in Figure 42.

The Fire Indicator Panel (FIP) is located at Lower Ground Floor Level in a designated room to be referred to as a 'Fire Control Room' as identified in Figure 42. It is noted that Fire Control Room does not need to comply with the requirements of BCA Specification E1.8 as the proposed development is less than 50 m in effective height. Based on guidance from the PCA, the FIP for the building is being located in an area that is also not directly connected to a road or open space and as such is a departure from guidance given in BCA Clause 3 of Specification E1.8.

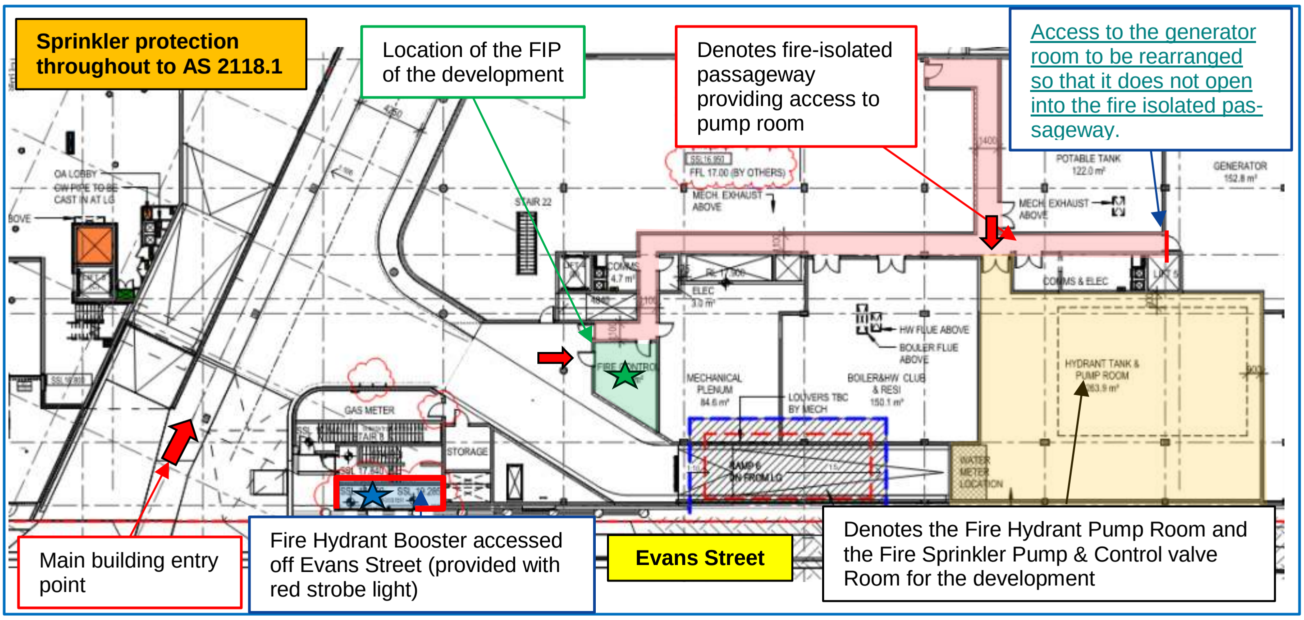


Figure 42: Location of booster, fire pump room & FIP

Clause 7.3 of AS 2419.1 provides guidance on the location of fire brigade booster assemblies. In the proposed arrangement, the building has the fire hydrant booster assembly located within the external wall of the building, but having unprotected openings within 2 m, these being the door openings from the fire stairs serving the basement levels as depicted in Figure 43. This does not meet the requirements of Clause 7.3(c) of AS 2419.1, and therefore does not comply with the BCA.

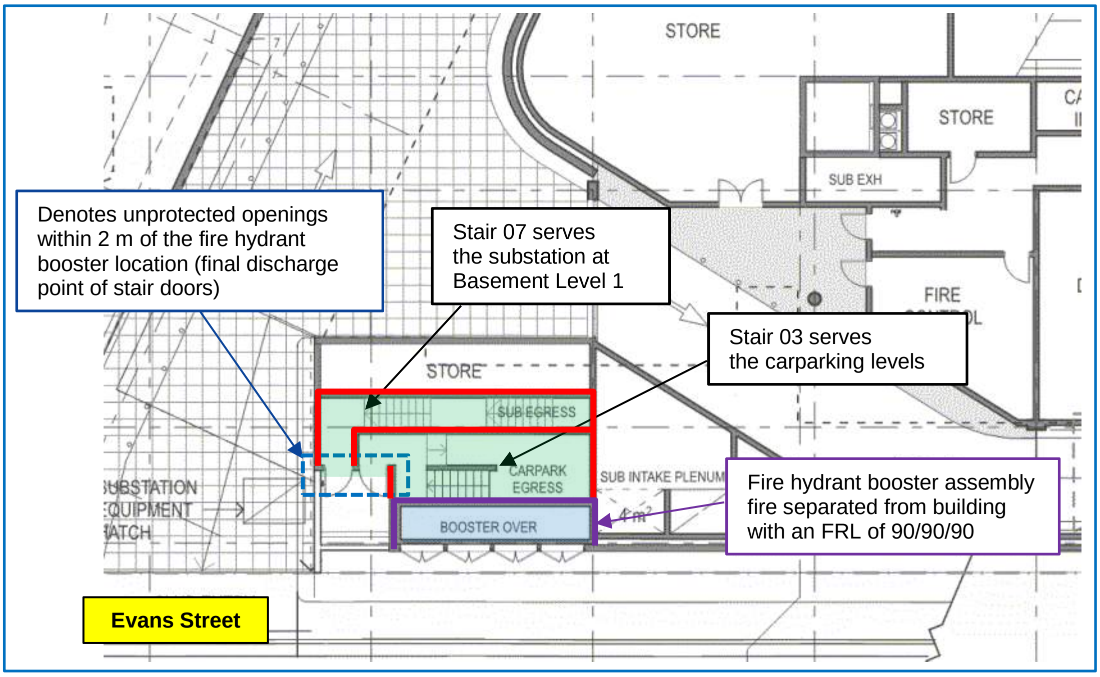


Figure 43: Fire Booster Assembly – located within 2 m of unprotected openings

15.3 Acceptance Criteria

To determine whether the Solution is considered to meet the BCA Performance Requirements, it needs to be demonstrated

- That the attending fire brigade can enter into the fire-isolated passageway without being overcome by the effects of fire within the building.

- That the location of the Fire Sprinkler Pump & Control Valve room is in an easy and accessible location for the attending fire brigade.
- That the location of the FIP does not compromise the safe evacuation of the attending fire brigade.
- That the fire hydrant booster assembly is located in a position from which firefighting personnel have access as required without being overcome by the effects of fire within the building.

It is noted that this Alternative Solution has also been submitted to FRNSW as part of the FEBQ submission (V01 as discussed in Section 1.4.1 of this report) for their review, comments and consideration.

FRNSW has reviewed the FEBQ V01 and issued feedback via email on the 29/09/2015 by means of updating the FEBQ form to V02 to include notes and commentary on the proposal put forward, which is noted to have been summarised in Table 1 of Appendix B. FRNSW has expressed no concerns regarding the subject Alternative Solution and as such the proposed configuration is considered acceptable, based on FRNSW feedback.

15.4 Hazards

Access to the Fire Hydrant Pump & Tank / Fire Sprinkler Pump & Control Valve room as well as the FIP is from a covered area (Porte Cochere on the Lower Ground Floor). In the event of a fire on the lower ground floor, there is an increased risk that firefighters could be exposed to fire conditions as they try to gain access / egress to the aforementioned fire-fighting facilities.

The hazard associated with the hydrant booster assembly being within 10 m of a fire source feature and not having the appropriately sized fire rated shield wall (required by AS 2419.1) is that a fire in the building could prevent the attending fire brigade from gaining access to the hydrant booster and safely operating the booster.

15.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development, incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows and identified in Figure 42;

- An automatic sprinkler system designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 is to be provided to the Porte Cochere areas, which shall include the service rooms adjacent to the area as noted in Figure 42.
- The fire-isolated passageway providing access to the Fire Hydrant Pump & Tank room / Fire Sprinkler Pump & Control Valve room (as identified in Figure 42) shall have a minimum FRL of 90/90/90 with all doors opening into the passageway to be self-closing -/60/30 fire doors, which shall also be upgraded and be fitted with medium temperature smoke seals capable of withstanding temperatures of 200°C for at least 30 minutes and tested in accordance with AS 1530.7.
- Entrance door to the fire-isolated passage way to be provided with signage indicating that this door provides access to the Fire Hydrant Pump & Tank room/ Fire Sprinkler Pump & Control Valve room. Signage to be in accordance with AS 2419.1.
- The Fire Hydrant Pump & Tank / Fire Sprinkler Pump & Control Valve room is to be fire separated from adjacent areas with fire rated walls achieving an FRL of 120/120/120, complete with self-closing -/120/30 fire doors. The doors are also to be upgraded and fitted with medium temperature smoke seals, as noted above.
- The ESB substation room at Basement Level 1 to be fire separated from adjacent areas with fire rated walls achieving an FRL of 120/120/120, complete with self-closing -/120/30 fire doors.
- The required non-fire-isolated stairs (Stair 03 and Stair 07) shall be fire separated from the adjoining areas at Basement Levels 1 & 2 with an FRL of 60/60/60 complete with self-closing -/60/30 fire doors.
- The fire hydrant booster shall be in an enclosure achieving an FRL of 90/90/90 as per Clause 7.3 of AS 2419.1, except that the door openings from fire stairs located within 2 m of the booster are not to be protected. Stair 07 doorway which discharges adjacent the Brigade booster assembly be fitted with a fire door despite this being to an external space.

- The fire hydrant block plan for the development (to the requirements of AS 2419.1) is to be located at the following areas;
  - At the fire brigade booster assembly at Evans St;
  - Within the allocated Fire Control Room for the development;
  - At the fire hydrant and pump room;
- Additional wayfinding signage is to be incorporated at the main entry point of the building so that it is visible from the street (as indicatively illustrated in Figure 44) to direct the attending fire brigade to the location of the Fire Control Room (including the FIP contained within) and Fire Hydrant & Pump Room for the development. The additional signage to be utilised must be fade resistant with wording in upper case letters not less than 100 mm in height in a colour contrasting with the background to which it is erected.
- Red strobe lights shall be provided at the following locations:
  - At the booster assembly;
  - At the entry point to the Fire Control Room & fire isolated passageway entrance providing access to the Fire Hydrant Pump &Tank / Fire Sprinkler Pump & Control Valve room.

  The red strobe lights noted above are to be activated by an alarm signal from the Fire Indicator Panel (FIP) that serves any on site automatic smoke detection and alarm system & sprinkler system.
- A red strobe light is also to be provided outside the entry point to the Fire Control Room & fire isolated passageway entrance providing access to the Fire Hydrant & Pump Room which is to operate upon a building fire alarm.

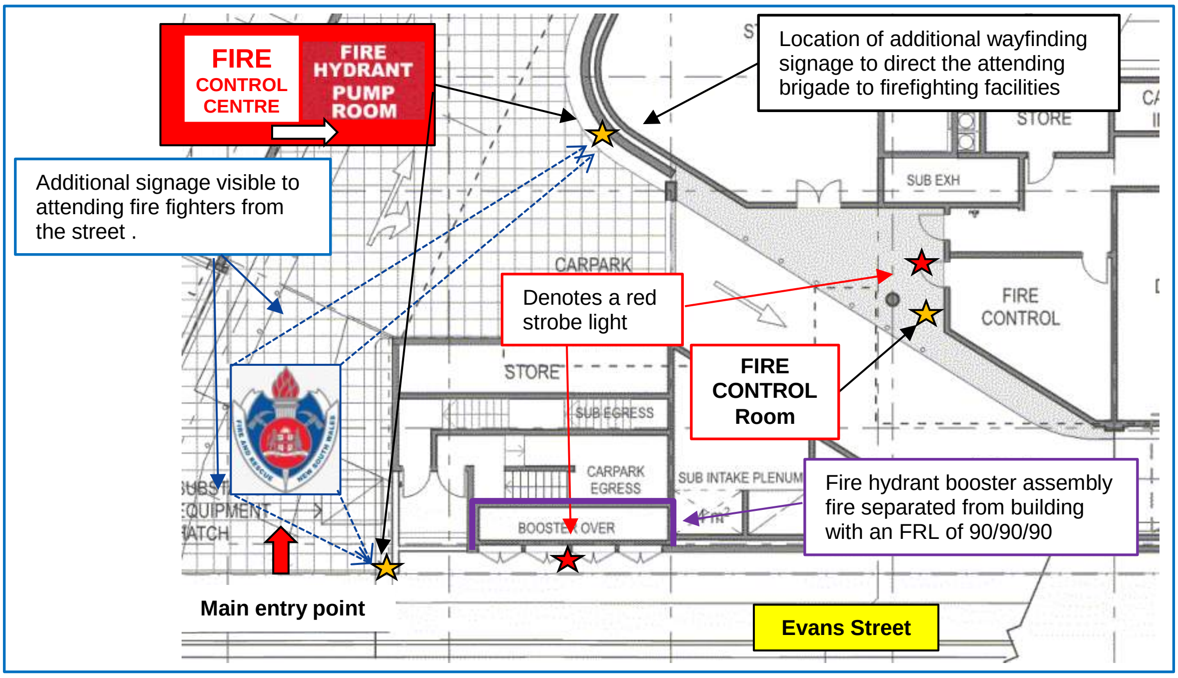


Figure 44: Proposed fire safety measures – signage & strobe lights for attending fire brigade

15.6 Method of Analysis

It shall be demonstrated that the location of the Fire Hydrant Pump &Tank room / Fire Sprinkler Pump & Control Valve room, the FIP for the development as well as the fire hydrant booster assembly in this instance shall not present a hazard to the attending fire brigade and as such, fire brigade intervention in the building should not be delayed.

15.7 Assessment

15.7.1 Fire Hydrant Booster Location

The hydrant booster assembly is located at Evans Street and contained in an enclosure achieving an FRL of 90/90/90, as shown in Figure 31. However, the booster is not shielded with construction having an FRL of 90/90/90, as per Clause 7.3 of AS 2419.1, as two door openings from the fire-isolated stairs are located within 2 m of the booster.

Since the fire stairs are required exits for egress during a fire emergency, the stairs would be free of any obstructions and combustibles. In addition, the stairs are to be fire separated from the adjoining areas at the served basement levels with construction having an FRL of 60/60/60, complete with self-closing -/60/30 fire doors. As a result, it is unlikely that a fire initiates in the stairs or a fire occurring in the basement levels spreads into the stairs and causes exposure conditions at the door openings. Therefore, whilst the two door openings from the fire stairs are not protected, fire fighters operating the booster within 2 m of the openings are unlikely to be exposed to any fire conditions from the openings.

The booster is located adjacent to the main building entry point and the provision of a red strobe light at the booster location will further facilitate the fire fighters to locate the booster assembly.

15.7.2 Access to Fire-fighting facilities

Access to the Fire Hydrant Pump & Tank room / Fire Sprinkler Pump & Control Valve room, and the FIP for the development necessitates the attending fire brigade to first enter the covered Porte Cochere area. From the Porte Cochere area, fire fighters can move towards the dedicated Fire Control Room (which houses the FIP for the development) or alternatively enter the fire-isolated passageway to gain access to the Fire Hydrant Pump & Tank room / Fire Sprinkler Pump & Control Valve room.

As discussed in Section 14.7.2, the Porte Cochere area serves as a circulation area providing the main access to the Community Club facilities on the Lower Ground Floor (pick up / drop off area) or alternatively the car parking areas of the development at basement levels. It shall contain a dedicated pedestrian walkway connecting the Community Club to Evans Street. The Porte Cochere area and its circulation areas are also not permitted to have any combustible materials, such as combustible seating and linings. Materials and assemblies must be as per Table 1 of Specification C1.10. Therefore, the risk of a fire occurring in this area and blocking the access to the fire service rooms is considered remote.

Regardless of the fire intensity of a room fire adjacent to the fire-isolated passageway, fire-fighters approaching the Hydrant & Sprinkler room shall be protected by bounding walls achieving an FRL of 90/90/90 complete with self-closing -/60/30 fire doors. The allocated FRL to each room could be expected to contain the fire within the room of fire origin, allowing adequate time for Fire Brigade intervention to the building. The self-closing devices to the doors shall ensure the fire separation of the room from the adjoining corridor is maintained in that it forms a barrier for the passage of smoke from an SOU into the stair. In addition, to prevent smoke leakage around the doors, it is proposed to upgrade the doors and fit them with medium temperature smoke seals (in accordance with AS 1530.7) capable of withstanding temperatures of 200 °C for at least 30 minutes. Smoke seals facilitate in providing a barrier around the door, limiting the spread of smoke into the corridor.

15.7.3 Additional Wayfinding Signage

The standard operating procedure for the fire brigade attending a building fire is to first go to the FIP upon arrival on site, in order to identify the location of a potential fire. Once this has been determined, they would go to the booster assembly to initiate fire intervention activities. In the proposed building configuration, the attending fire brigade will pass the fire hydrant booster assembly (and the flashing strobe light at the booster location) upon approach to the building FIP.

Additional wayfinding signage is to be incorporated at the main entry point of the building (as indicatively illustrated in Figure 44) to direct the attending fire brigade to the location of the Fire Control Room (including the FIP contained within) and Fire Hydrant Pump & Tank room / Fire Sprinkler Pump & Control Valve room for the development. The additional signage to be utilised must be fade resistant with wording in upper case letters not less than 100 mm in height and in a colour contrasting with the background to which it is erected. A red strobe light is also to be provided outside the entry point to the Fire Control Room & fire isolated passageway entrance providing access to the Fire Hydrant & Pump Room which is to operate upon a building fire alarm.

Hence, the additional signage and strobe light should inform and alert the brigade of the location of the fire-fighting facilities within the building.

15.7.4 Sprinkler protection

The Lower Ground Floor, including the Porte Cochere area, is fully sprinkler protected to AS 2118.1, which includes the use of fast response sprinkler heads which and allows for earlier sprinkler actuation. In the event of a fire the sprinkler system is expected to control, if not suppress the fire. A fire sprinkler system dramatically reduces the likelihood of a large fire developing in a building. Furthermore, by controlling the fire size, the amount of smoke produced is correspondingly also limited. In addition, the sprinkler water spray cools the smoke and acts to wet adjacent combustibles and partitions, helping to prevent the fire from spreading beyond the area of origin.

Hence, the provision of sprinklers in a building dramatically enhances life safety, property protection and fire brigade intervention. Where the sprinkler system operates successfully, occupant and fire fighter safety and the integrity of building elements reduces the threat to occupants, property damage and the attending fire brigade.

15.8 Conclusion

This analysis demonstrates that in conjunction with the proposed the fire safety features detailed in Section 6, manage the variations from the relevant BCA Clauses. As such, BCA Performance Requirements EP1.3, EP1.6 and EP2.2 are met.

16. AS 10 – Review of fire hydrant system

16.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG sub-systems.

Table 32: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit the fire hydrant system to be designed to have a minimum of 2 outlets (each with 10 l/s capacity) operating simultaneously in lieu of the required 3 outlets required for a fire compartment >10,000 m² (specific to the Class 7a areas).	E1.3 & Table 2.1of AS 2419.1	EP1.3	SS-F	(b)(i)	(b)(ii)
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

16.2 Description of non-compliance with DtS Provisions

According to AS 2419.1 & Table 2.1 (as illustrated in Figure 45), for any fire compartment >10,000 m² within a sprinkler protected building, the hydrant system should be designed to have a minimum of 3 outlets (each with 10 l/s capacity) operating simultaneously.

Building classification (see BCA)	Fire compartment floor area m²	No. of fire hydrant outlets required to flow simultaneously (Note 1)
2, 3, 5 and 9 (1 or 2 storeys contained)	≤1 000	1
2, 3, 5 and 9 (1 or 2 storeys contained)	>1 000 ≤5 000	2
2,3,5 and 9 (3 or more storeys contained)	≤500	1
2,3,5 and 9 (3 or more storeys contained)	>500 ≤5 000	2
6, 7 and 8 (Note 2)	≤500	1
6, 7 and 8	>500 ≤5 000	2
All classes sprinklered	>5 000 ≤10 000	2
All classes sprinklered	>10 000	3
All classes unsprinklered	>5 000 ≤10 000	3
All classes unsprinklered	>10 000	3 plus one additional fire hydrant for each additional 5 000 m² or part thereof

Figure 45: Table 2.1 of AS 2419.1 – Compartment > 10,000 m² (3 hydrant outlets simultaneously)

In the proposed development, the Basement Levels 1 & 2 form a single fire compartment with a floor area in excess of 10,000 m² (approximately 27,242 m²) and as such would require 30 l/s flow over 4 hours for the Fire Hydrant (FH) system which, with 10 l/s in-fill from street main, equates to a tank volume of 288,000 litres (20 x 60 x 60 x 4 hrs) for the FH system.

This is a substantial tank size requirement, which has implications on the proposed site which has constraints in the site footprint. The proposed development is situated on the headland, which separates Freshwater and Curl Curl beaches and has constraints in its design as part of the DA approval.

To facilitate the development design, it is proposed to introduce a reduced tank size for the development (with a volume of 144,000 litres), which is the fire hydrant system for the development being designed to have a minimum of 2 outlets (each with 10 l/s capacity) operating, simultaneously.

16.3 Acceptance Criteria

To determine whether the Solution is considered to meet the BCA Performance Requirements, it will be demonstrated that sufficient provision has been made for fire brigade intervention in the basement car parking levels in the proposed development.

It is noted that this Alternative Solution has also been submitted to FRNSW as part of the FEBQ submission (V01 as discussed in Section 1.4.1 of this report) for their review, comments and consideration.

FRNSW has reviewed the FEBQ V01 and issued feedback via email on the 29/09/2015 by means of updating the FEBQ form to V02 to include notes and commentary on the proposal put forward, which is noted to have been summarised in Table 1 of Appendix B. FRNSW has expressed no concerns regarding the subject Alternative Solution, and as such the proposed fire hydrant system for the development is considered acceptable, based on FRNSW feedback.

16.4 Hazards

The hazard specific to this Alternative Solution is that the carparking level, as a result of its excessive compartment floor area, is not being provided with the minimum number of fire hydrant outlets to operate simultaneously in a fire emergency. As such, this may hinder fire brigade intervention in the carparking levels of the development.

16.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development, incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- Basement Levels 1 & 2 are provided with a sprinkler system, throughout, in accordance with AS 2118.1.
- The design of the fire hydrant system is to be based on 2 fire hydrants flowing simultaneously at a flow rate of 10 L/s for a duration of at least 4 hours.

16.6 Method of Analysis

The proposed solution shall focus on the requirement of 3 outlets being based on a floor area greater than 10,000 m^2, when in reality, the risk is no greater to a car park less than 5,000 m^2, which requires the use of only two outlets operating, simultaneously.

16.7 Assessment

The number of fire hydrant outlets required to operate, simultaneously, is based on the floor area of the carpark and is not necessarily associated with the risk associated with the building classification. Carparks are noted to be a specific environment where a considerable amount of international research has been undertaken on the likes of a car fire size / the likelihood of fire spread between cars, both in a sprinkler-protected and non-sprinkler-protected environments, as well as the probability of a fire occurring within a carpark, which is discussed in the sections below.

16.7.1 Likelihood of fires in carparks

Statistical data obtained from the [NSWFB] during 2006/07 indicates that fires in carparking areas (noted to be associated with residential SOU buildings) account for approximately 2 % of fires. Unfortunately, detailed statistics relating to the number of fatalities and injuries in carparking areas is not readily decipherable from the statistics obtained from the NSWFB above. A further review of international statistics, namely those obtained from New Zealand [NZFS], indicates that no fatalities occurred in any type of carparking occupancy in NZ between 1999 and 2004.

The incidence of car fires in carparks is extremely low. Based on further supporting data supplied by the Melbourne Fire and Emergency Services Board (MFESB) and data on the number of carparks in Melbourne (as researched by [Thomas]) the rate of fire starts in Melbourne CBD carparks is estimated to be 0.00007 fires reported to the fire brigade per car space per year. Also, data for New Zealand, as researched by [Li], indicates that there were on average 12 fires per year in the estimated 200,000 parking spaces in New Zealand parking buildings, thereby putting the estimated fires reported to the fire brigade per car space per year at around 0.00006. This statistical data demonstrates that the probability of fires in carparks is very low. This aids in confirming the presumption that carparking occupancies do not typically result in a high risk to life due to fire.

16.7.2 Carpark fire size & the benefit of sprinkler protection

Building Research Establishment Ltd (BRE) had conducted research to study the fire risks associated with modern cars with an aim to provide guidance on the fire safety design of buildings housing cars. A series of large scale fire tests had been carried out in the burning hall [BRE]. The results of these tests are summarised in the report '*Design Fires for Use in Fire Safety Engineering*' providing guidance on design fires for cars [BRE Trust]. The heat release rate curves obtained from these tests are illustrated below. The fire tests also demonstrated that the presence of a sprinkler system in a car park would effectively contain the fire within the car of origin and prevent the spread of fire to adjacent cars. As shown in Figure 46, a sprinkler protected car park fire can reach up to 6 MW.

Where there are no sprinklers, a free-burn fire involving 3 cars is able to reach a maximum size of 16 MW. The peak value occurs when the fire spreads to the adjacent car.

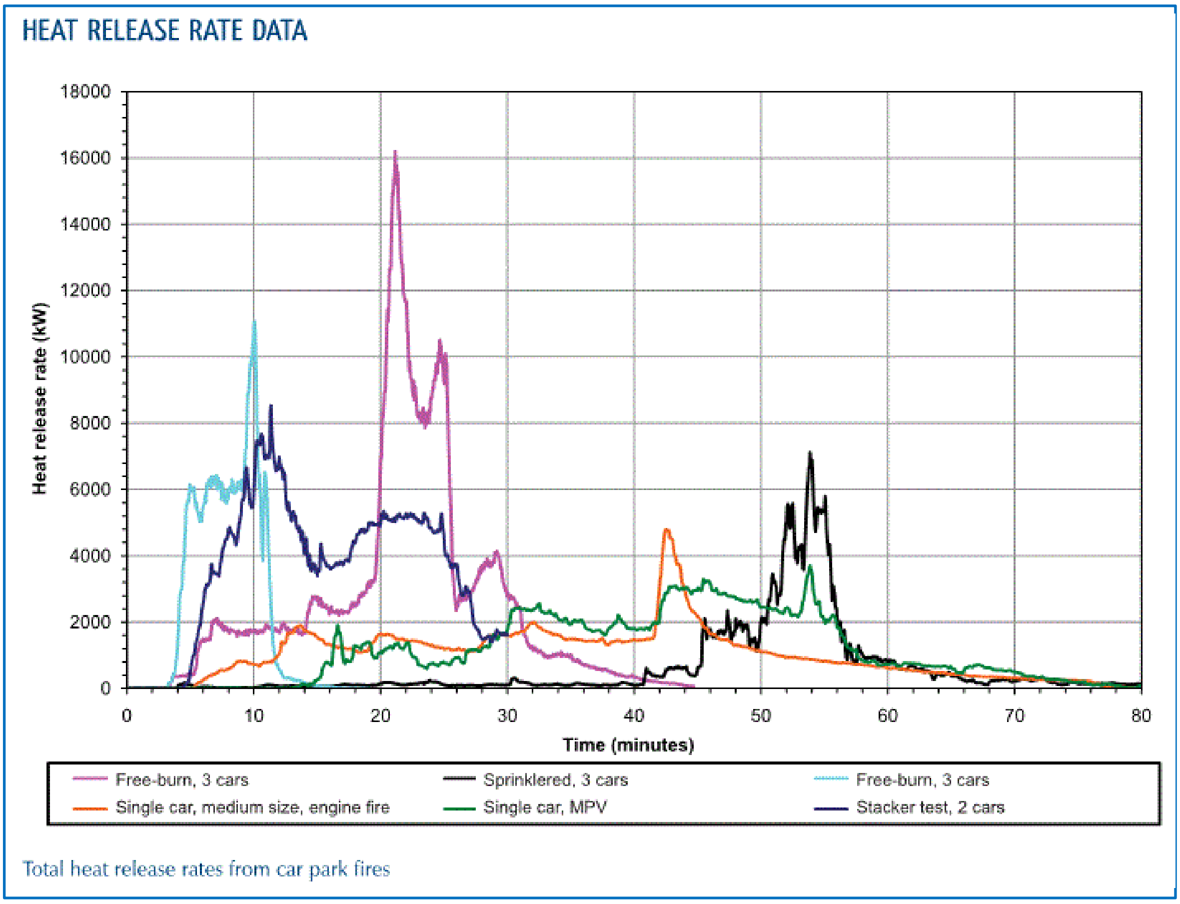


Figure 46: BRE Report Figure 6 – heat release rates from car perk fires (open-sided)

1.1.1.2 Effect of sprinklers on car fire

As discussed in Section 6 of this report, the proposed building is to be sprinkler protected to AS 2118.1 which includes the basement carparking levels. A sprinkler system dramatically reduces the likelihood of a large fire developing in a building. Furthermore, by controlling the fire size, the amount of smoke produced is correspondingly also limited. In addition, the sprinkler water spray cools the smoke and acts to wet adjacent combustibles and partitions, helping to prevent the fire from spreading beyond the area of origin.

Hence, due to the presence of a sprinkler system, a fire scenario in the subject carpark is likely to be limited to a single car fire. This is further supported by experimental studies detailed in [BD2552], which discusses fire spread between cars. Section 10 of BD2552 discusses the results of a three car fire test that was sprinkler protected. The results showed that the fire grew within Car 1 and the nearby sprinklers operated. The fire continued to burn and grow, eventually (after 55 minutes) breaking out and reaching a peak of around 7 MW. The first sprinkler actuated after 4 minutes and all six sprinklers eventually operated. However, the fire did not spread to Car 2 or Car 3 as can be seen in Figure 47.

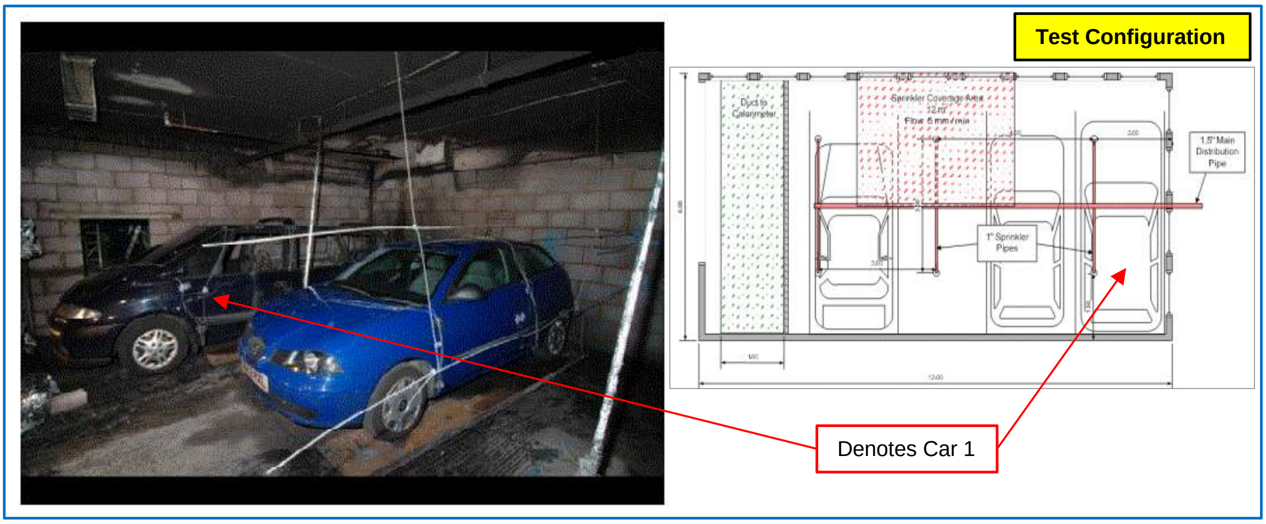


Figure 47: BD2552 Photograph 2.10.4: Test 2 after the test (no fire spread between cars)

After 1 hour from first sprinkler head actuation, the water supply was switched off. (This was to represent a tank supplied system holding the minimum recommended quantity of water.) By this time, the fire in Car 1 was dying down and, despite the cessation of sprinkler operation, continued to diminish.

16.7.3 Guidance in the FBIM Manual

It is further noted that the Fire Brigade Intervention Model (FBIM) manual by the Australasian Fire and Emergency Services Authorities Council August 2008 has a specific breakdown on fire sizes against hydrant flows. Section 15 and Chart 15 of the FBIM manual discusses the time taken to control and extinguish the fire and states the following;

> *'For practical purposes, the minimum flowrate necessary for application is 5 L/s for interior hose lines and 10 L/s for exterior hose lines. The firefighter tenability criteria (chart 12) determines whether or not hose lines are internal or external. The efficiency of water applied varies greatly with firefighting skill, equipment type, fire size, enclosure dimensions, water droplet size, etc. Research has shown the efficiency of water applied is in the order of 5% to 30%.....*
>
> *For firefighting in Australia, an efficiency of 15% is chosen for interior firefighting, and for firefighting external to the building, an efficiency of 5% is selected…..*
>
> *For the purposes of this model, interior firefighting hose streams delivering water at 5 L/s have an extinguishing capacity of 8 MW, comprising the theoretical absorption capacity and the smothering effect of the steam. For external firefighting, 10 L/s of applied water has an extinguishing capacity of 5.25 MW.'*

As noted in the section above, interior firefighting hose streams delivering water at 5 L/s have an extinguishing capacity of 8 MW. Hence, the proposed hydrant system design having a minimum of 2 outlets (each with 10 l/s capacity) operating simultaneously can potentially extinguish up to a 32 MW fire. Considering the likely fire size in the carpark (at most a 7MW fire) and likely to be confined to a single car, the proposed fire hydrant system is capable of coping with a fire occurring in the subject carpark even for a sprinkler failure scenario.

16.7.4 Fire Brigade intervention in the basement carparking areas

It is noted that all points on the Basement Levels shall be adequately covered by fire hoses attached to the hydrant at each storey exit (40 m coverage is afforded from each fire hose). When undertaking fire-fighting activities, the fire brigade would typically set up their fire hoses from the hydrants provided at the storey exit. Fire fighters would then move from the hydrants onto the floor plate under the protection of the hose stream issuing from the nozzle attached to the fire hose. Should they therefore need to retreat, they can follow the fire hose back to the exit.

It is noted that upon activation of a sprinkler head, the Brigade are automatically notified of a fire in the building via the Alarm Signalling Equipment (ASE) in the FIP. This contributes to the earliest possible arrival of the fire brigade to the building. Consequently, it is concluded that the fire brigade would be expected to start with fire suppression activities in the early stages of a fire emergency in the carparking levels.

16.8 Conclusion

This analysis demonstrates that the proposed tank reduction to the development which is the fire hydrant system being designed to have a minimum of 2 outlets (each with 10 L/s capacity) operating, simultaneously will not compromise fire brigade intervention in the carparking and as such satisfies the intent of Performance Requirement EP1.3.

17. AS 11 – Review of indoor pool area & fire measures

17.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 33: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit smoke detection for ventilation shutdown to be omitted from the high ceilinged indoor pool area (Aquatic Centre).	E2.2 & Spec E2.2a NSW Table E2.2b Specific Provisions – Class 9b Assembly Buildings	EP2.2	SS-A, SS-B & SS-E	(b)(i)	(b)(ii)
To permit the omission of fire hose reels to the indoor pool area with a view to providing additional hand held fire extinguishers.	E1.4	EP1.1			
To permit the omission of sprinkler coverage to the indoor pool area only	E1.5	EP1.4			
To permit the omission of a required fire wall which separates sprinklered and non-sprinklered areas	Clause 3 of Spec E1.5 inter alia AS 2118.1	CP2 & EP1.4			
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

17.2 Description of non-compliance with DtS Provisions

The proposed Aquatic Centre is required to be provided with a mechanical ventilation system to AS/NZS 1668.1. BCA NSW Table E2.2b states that a building used as an assembly building must be provided with automatic shutdown of any air-handling system that does not form part of the smoke hazard management system on activation of smoke detectors complying with Clause 5 of Specification E2.2a.

It is proposed to omit smoke detection from the high ceiling pool area only (to the areas indicatively illustrated in Figure 48) and to permit the air-handling systems serving the pool area to continue operation in a fire event in this space. Smoke detection for the shutdown of all other air-handling systems is to be provided in all other areas (mechanical ducting etc.) of the Aquatic Centre.

BCA Clause E1.4 indicates that hose reels must be installed if internal fire hydrants are installed. However, it is proposed to omit the hose reels from the indoor pool area (as identified in Figure 48) and to replace them with additional portable extinguishers.

The Aquatic Centre is to be provided with an automatic sprinkler system designed and installed in accordance with AS 2118.1. However, it is proposed to omit the sprinkler coverage to the indoor pool area (areas as identified in Figure 48).

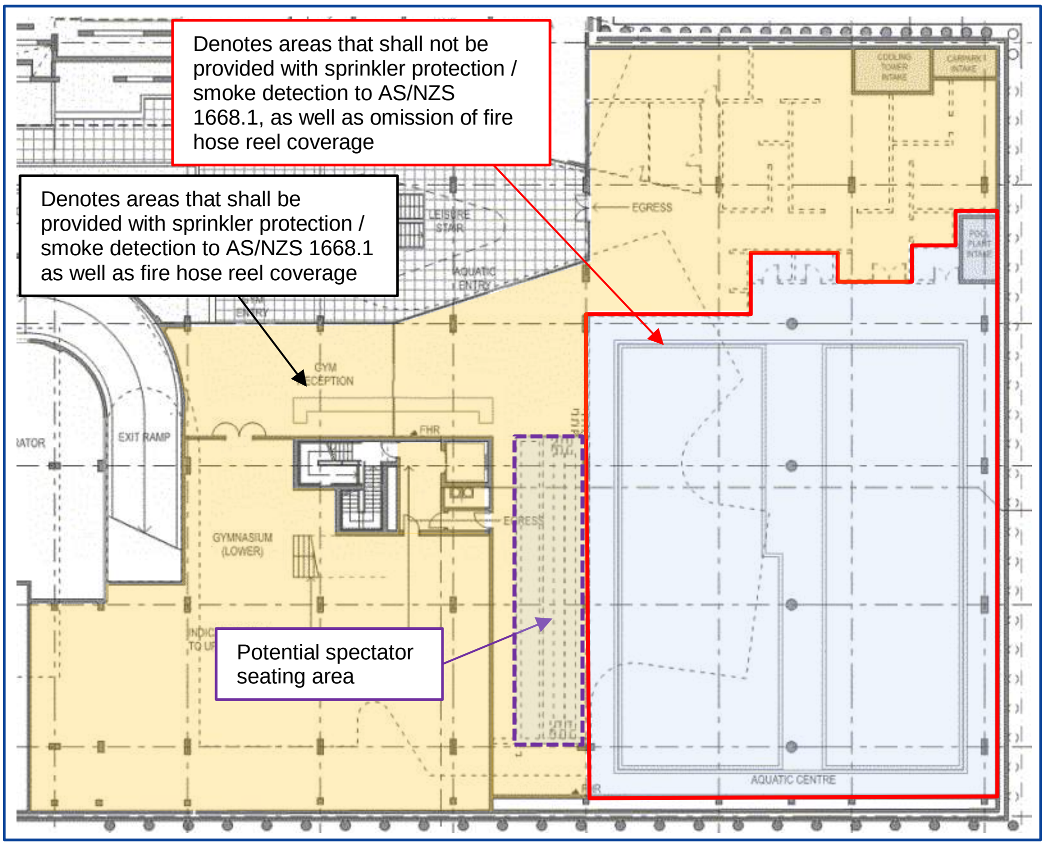


Figure 48: Extent of Gym / Aquatic Centre and the proposed indoor pool area

17.3 Acceptance Criteria

To determine whether the Solution is considered to meet the BCA Performance Requirements, it will be demonstrated that;

- The deletion of smoke detectors for ventilation shut-down in the high ceiling pool areas would not affect life safety.
- Sufficient provision has been made for first aid fire-fighting in the indoor pool area (proposed additional fire extinguishers to be provided as a substitute).
- The omission of the sprinkler heads to the pool area only would not compromise life safety in the building.

17.4 Hazards

The indoor pool area, by nature, is a wet area used exclusively for swimming activities that is essentially devoid of any significant combustible materials and as such, the risk of a fire within this space is very low. Hence, a fire scenario in the pool is considered an unlikely event. The hazard associated with the omission of smoke detection for automatic ventilation shutdown in the ceiling space is that in the event of a fire in the indoor pool area, smoke could spread to other areas of the Aquatic Centre / building.

The hazard specific to this solution is that if a fire was to occur in the non-sprinkler-protected indoor pool area and then spreads into the adjoining sprinkler protected area, then it could be too large and overwhelm the sprinklers in the sprinkler protected area, and as such puts life safety at risk.

17.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development, incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows, and as indicatively illustrated in Figure 48:

- An automatic sprinkler system designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 is to be provided to the Aquatic Centre with the exception of the indoor pool area.
- Fire hose reels shall be provided throughout the Aquatic Centre in accordance with BCA Clause E1.3 and AS 2441 except the indoor pool area.
- Portable fire extinguishers shall be provided throughout the building in accordance with BCA Clause E1.6 and AS 2444.
- Additional hazard specific portable hand held portable fire extinguishers (single 4.5 kg DCP multi-purpose extinguisher) are to be provided to the areas where fire hose reels were to be located.
- The Aquatic Centre is to be provided with a mechanical air handling system to AS/NZS 1668.1-1998 which shall automatically shutdown of the air handling system within.
- It is proposed to permit smoke detection for ventilation shutdown to be omitted from the high ceilinged indoor pool area only.

17.6 Method of Analysis

The analysis to be conducted will be qualitative in nature and will use a deterministic absolute approach. It is proposed to discuss the low fire risk associated with the indoor pool area (a swimming pool environment) given that the majority of the footprint of this area of the Aquatic Centre building contains a wet area.

The proposed solution shall demonstrate that the omission of smoke detection in the high ceiling areas, fire hose reel coverage, and sprinkler protection from the indoor pool area identified in Figure 48, would not affect the life safety of occupants within the Aquatic Centre for the following fire scenarios;

- **Fire Scenario #1:** a fire occurs in the pool area.
- **Fire Scenario #2:** a fire occurs in rooms surrounding the pool area.

Based on the assessment of the two fire scenario above it is also demonstrated that the requirement for a fire wall to separate the sprinkler protected and non-sprinkler protected areas does not pose a risk to fire spread.

17.7 Assessment

17.7.1 Fire scenario #1: Fire in indoor pool area

The indoor pool area is, by nature, a wet area used solely for swimming activities. The area is also likely to be enclosed with mainly a tiled surface (essentially a non-combustible lining). Consequently, the area is essentially devoid of any significant combustible material. There may be some minor combustible items present, such as a lifeguard chair / floatable foam device, etc. All materials used would be required to be water and corrosion resistant, and these items are likely to consist of plastic or hardwood to enable longevity of use in such an area. It is also noted that hazardous oxidising pool chemicals are not used or stored in the Aquatic Centre.

The materials detailed above would require a relatively large, sustained ignition source for them to set alight. Such ignition sources are not present in the vicinity of these fuel sources on site, given the use of the space, thereby negating the likelihood of combustion taking place. Hence, the fire risk within the identified indoor pool area is deemed to be very low.

The low fire risk associated with a swimming pool is indirectly recognised by Clause 903.3.1.1.1 of the [IBC], which provides guidance on exempt locations for automatic sprinklers and states the following;

“Automatic sprinklers shall not be required in the following rooms or areas where such rooms or areas are protected with an approved automatic fire detection system in accordance with Section 907.2 that will respond to visible or invisible particles of combustion. Sprinklers shall not be omitted from any room, merely because it is damp, of fire-resistance-rated construction or contains electrical equipment.

1. Any room where the application of water, or flame and water, constitutes a serious life or fire hazard.

2. Any room or space where sprinklers are considered undesirable because of the nature of the contents, when approved by the fire code official.

3. Generator and transformer rooms separated from the remainder of the building by walls and floor/ceiling or roof/ceiling assemblies having a fire-resistance rating of not less than 2 hours.

4. Rooms or areas that are of non-combustible construction with wholly non-combustible contents.

5. Fire service access elevator machine rooms and machinery spaces.

6. Machine rooms and machinery spaces associated with occupant evacuation elevators designed in accordance with Section 3008."

The low risk associated with a swimming pool area is also indirectly acknowledged in Section 12.3.5.3 of [NFPA 101]. Section 12.3.5.3 states that the requirements of Section 12.3.5.2 (which provides guidance on assembly occupancies and the requirement for automatic sprinkler system) shall not apply to the following;

'(1) Assembly occupancies consisting of a single multipurpose room of less than 12,000 ft2 (1115 m2) that are not used for exhibition or display and are not part of a mixed occupancy

(2) Gymnasiums, skating rinks, and swimming pools used exclusively for participant sports with no audience facilities for more than 300 persons.'

The exception exempts the participant sport area of such assembly occupancies from automatic sprinkler system requirements, because these areas are typically large open spaces with relatively low fuel loads. The exception includes only the participant sport area, such as an indoor swimming pool (without spectator seating) or the court area of an indoor tennis court.

Hence, based on the reference to the international guidance document, the risk associated with a swimming pool area is low. In the proposed Aquatic Centre, there may be some spectator seating provided. However, the seating, as identified in Figure 48, is to be located in areas provided with both an AS/NZS 1668.1 detection as well as sprinkler protection.

Given the limited combustible content of the indoor pool area and lack of ignition sources, the likelihood that a fire could be of a size to overwhelm the sprinklers in the sprinkler protected area is unlikely. Given that a fire scenario in the indoor pool is unlikely, the omission of smoke heads for automatic shutdown of the ventilation space in the high ceiling space is unlikely to have a negative impact on life safety in this part of the building. It is noted that the adjoining areas that present a credible fire scenario will be provided with both an AS/NZS 1668.1 detection as well as sprinkler protection. Hence given the fire risk in the pool area is low it is considered that life safety to the area is not compromised and occupants are occupants are not put in any undue risk in a fire emergency.

17.7.2 Fire scenario #2: Fire in areas surrounding the pool area

It is noted that the Aquatic Centre (with the exception of the indoor pool area ceiling space as identified in Figure 48), is to be provided with an automatic fire detection and alarm system to AS/NZS 1668.1 in accordance with BCA Table E2.2a and Specification E2.2a. In a fire situation, activation of a smoke head shall immediately cause automatic shutdown of the ventilation system and as such, not contribute to fire spread between the different areas of the Aquatic Centre.

An automatic sprinkler system designed and installed in accordance with BCA Specification E1.5 and AS 2118.1 is to be provided to the Aquatic Centre with the exception of the indoor pool area. A fire sprinkler system dramatically reduces the likelihood of a large fire developing in a building. Furthermore, by controlling the fire size, the amount of smoke produced is correspondingly also limited. In addition, the sprinkler water spray cools the smoke and acts to wet adjacent combustibles and partitions helping to prevent the fire from spreading beyond the area of origin which in this instance is the areas adjoining the indoor pool area. Given the limited combustible content of the indoor pool area and lack of ignition sources, the likelihood that a fire in the adjoining areas would spread into the indoor pool area is unlikely.

The Aquatic Centre is to also to be provided with a SSISEP in accordance with BCA Clause E4.9 and AS 1670.4. The AS/NZS 1668.1 smoke detectors and sprinkler system are to be connected to the SSISEP system and to initiate a building wide alarm. Hence the proposed SSISEP system shall contribute to providing occupants with early warning of the fire and prompt to evacuate from their SOU before the onset of untenable conditions.

17.7.3 Omission of required fire wall

As noted in the sections above, the fire risk associated with the pool area is unlikely given that is a wet environment with limited (if any) fuel load. The adjoining areas of the aquatic centre will be provided with an automatic sprinkler system which prevent the fire from spreading beyond the area of origin. Hence it is submitted that due to the lack of ignition sources within the pool area, a fire scenario within is unlikely overwhelm the sprinklers in the adjoining sprinkler protected areas. Hence the requirement for a fire rated wall in this instance is not required due to the low risk of fire to the pool space.

17.7.4 Omission of fire hose reels

As noted above, the indoor pool area is essentially devoid of any significant combustible materials and as such the risk of a fire within is very low. Hence, the chance of occupants having to undertake first aid fire-fighting in this space is unlikely.

It is noted that the intent of the hose reels, as discussed in the BCA Guide, is to provide a means of first aid fire-fighting, where it is appropriate for occupants to do so. However, building occupants (particularly those associated with an assembly building whom have no affiliation with the building like that of residential SOU which is a person's home) are generally expected to ensure that they are not put in undue risk where they should focus on evacuating themselves and their friends rather than remaining in the building during a fire emergency to try and fight a fire with a fire hose reel. The use of fire hose reels could, therefore, increase the likelihood of injury or death in the case of a fire, due to the occupants remaining in the building and fighting the fire (when they have not been suitably trained to do so) instead of evacuating.

To mitigate the shortfall in fire hose reel coverage to the indoor pool area, it is proposed to provide portable hand held fire extinguishers. Fire extinguishers are a much more appropriate method of initial attack on a fire, as they have a limited capacity of approximately 30 s of continuous use, at which point occupants should still have time to evacuate if they have not been able to extinguish a fire. This means that it is less likely for a person to continue attempting to fight a fire, which may become too large and then overwhelms them. Fire extinguishers also do not prevent fire doors from closing properly or create trip hazards to the same extent as a fire hose reel unwound across a corridor / circulation egress space.

Fire hose reels are also quite heavy (particularly when charged with water) and require an amount of strength which many occupants may not possess, particularly elderly, young, or unwell occupants. Extinguishers are much lighter and easier to move and wield and therefore are more useful to a wider number of the buildings occupants.

17.8 Conclusion

This analysis demonstrates that in conjunction with the fire safety features detailed in Section 6 manage the variations from the relevant BCA Clauses. As such, BCA Performance Requirement CP2, EP1.1, EP1.4 and EP2.2 is considered to be met.

18. AS 12 – Impulse Fans in Basement Carparks

18.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause which is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 34: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit an impulse fan ventilation system in the basement car parks in lieu of a traditional ducted ventilation system.	E1.5, E2.2 and F4.11	EP1.4; EP2.2 and FP4.4	SS-A, SS-B, SS-D, SS-E & SS-F	(b)(i)	(b)(ii)
Approach and assessment method used - The approach in this solution will be quantitative, qualitative in nature and will use a deterministic absolute approach.					

18.2 Description of non-compliance with DtS Provisions

It is proposed to install a mechanical ventilation system incorporating impulse fans in the basement carparks in lieu of a traditional ducted ventilation system. Note that the terms 'impulse fan' and 'jet fan' are used interchangeably in the following sections.

The latest AS 1668.2 – 2012 permits the use of impulse fans for normal ventilation in carparks. However, it is understood that the impulse fans are allowed to be used as an alternative to provide ventilation to dead end spaces when the space is difficult to be covered by the ducted system. In this sense, a ventilation system using impulse fans throughout a carpark is not considered compliant with AS 1668.2. In the proposed development, impulse fans are proposed to be used throughout the basement carparks as the normal ventilation system in lieu of a traditional ducted ventilation system during normal day to day operation. This should be addressed as an Alternative Solution to ensure compliance with Performance Requirement FP4.4 regarding the air quality.

BCA Clause E2.2 requires an AS 1668.2 mechanical ventilation system in a carpark building to comply with Clause 5.5 of AS/NZS 1668.1 with certain concessions. Clause 5.5 of AS/NZS 1668.1 requires the exhaust system to continue to operate in fire mode and shall operate at its full capacity where the system incorporates variable flow rates. However, it is considered that these requirements were meant to apply to the traditional ducted ventilation systems and the BCA does not give consideration to impulse fans and does not provide any requirements or guidance for the operation of impulse fans in fire mode. For this reason, the mechanical design utilising impulse fans should be addressed as an Alternative Solution to demonstrate compliance with Performance Requirement EP2.2.

Concerns have been raised on the use of jet fans in sprinkler protected carparks by fire brigades in Australia. They are questioning whether the high velocity air jets created by impulse fans could significantly delay the sprinkler activation and could cause activation of sprinklers further from the seat of fire. For this reason, an Alternative Solution is required to demonstrate compliance with Performance Requirement EP1.4.

This Alternative Solution will verify that although the jet fans will be used for day to day operation to maintain safe carpark emissions within the space (alongside the standard carpark exhaust risers serving this space), sufficient provision has been made to prevent their continued operation in the event of a fire. This is for the purposes of preventing the efficacy of the sprinkler system being affected by airflow through the space, nor creating turbulent smoke flows through the space which could affect occupant evacuation.

18.3 Acceptance Criteria

The acceptance criteria for the proposed impulse fan ventilation system are as follows:

- The system shall achieve a satisfactory performance, as required by AS 1668.2 in maintaining an acceptable emissions concentration level in the basement car parks in normal mode.
- The system shall not adversely affect the ability of occupants to evacuate safely from the car parks in fire situations.

- The system shall not adversely affect the operation of the sprinkler system in preventing fire spread to adjacent vehicles in fire situations.

Conditions are considered tenable for occupants if the following tenability criteria detailed in Table 33 are not exceeded.

Table 35: Occupant tenability criteria

Occupant Tenability Criteria	
Convective heat	Temperature < 60 °C at or below 2.0 m from the floor
Radiant heat exposure	Radiant flux < 2.5 kW/m^2 at or below 2.0 m
Visibility	When the smoke layer is below a height of 2.0 m: ▪ Reflective surface visibility > 10 m (for large spaces) ▪ Illuminated signage visibility > 5 m (queuing at exits)

The acceptance criteria for life safety of occupants are as follows:

- For primary design fire scenarios: **ASET ≥ 1.5×RSET**
- For sensitivity fire scenarios: **ASET ≥ 1.0×RSET**

Where **ASET** is the 'Available Safe Egress Time' and **RSET** is the 'Required Safe Egress Time'.

18.4 Hazards

The latest AS 1668.2 – 2012 permits the use of impulse fans for normal ventilation in carparks. However, it is understood that the impulse fans are allowed to be used as an alternative to provide ventilation to dead end spaces when the space is difficult to be covered by the ducted system. In this sense, a ventilation system using jet fans throughout a carpark is not considered compliant with AS 1668.2. In the proposed development, jet fans are proposed to be used throughout the basement carparks as the normal ventilation system in lieu of a traditional ducted ventilation system and as such needs to be investigated in respect to the dilution and removal of carbon monoxide from the car park.

The hazards associated with jet fans as part of a mechanical ventilation system has been discussed in detail in Section 4.1 of the CFD report contained in Appendix H.

18.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution is as follows:

- The carpark is to be provided with an automatic sprinkler system to AS 2118.1-1999, which is to include the use of fast response sprinkler heads with an RTI of $50(m\cdot s)^{0.5}$ or less.
- Sprinklers within the basement levels are to be arranged so that no heads are in the direct path of airflow from the fan to prevent potential delays in activation. For further details please refer to Appendix H of this report (CFD report).
- Automatic smoke detector heads to be provided at circulation spaces within the car-park levels at 15 m grid as per AS 1670.1:20015. Sensitivity of these heads to be reduced accordingly to avoid spurious alarms.

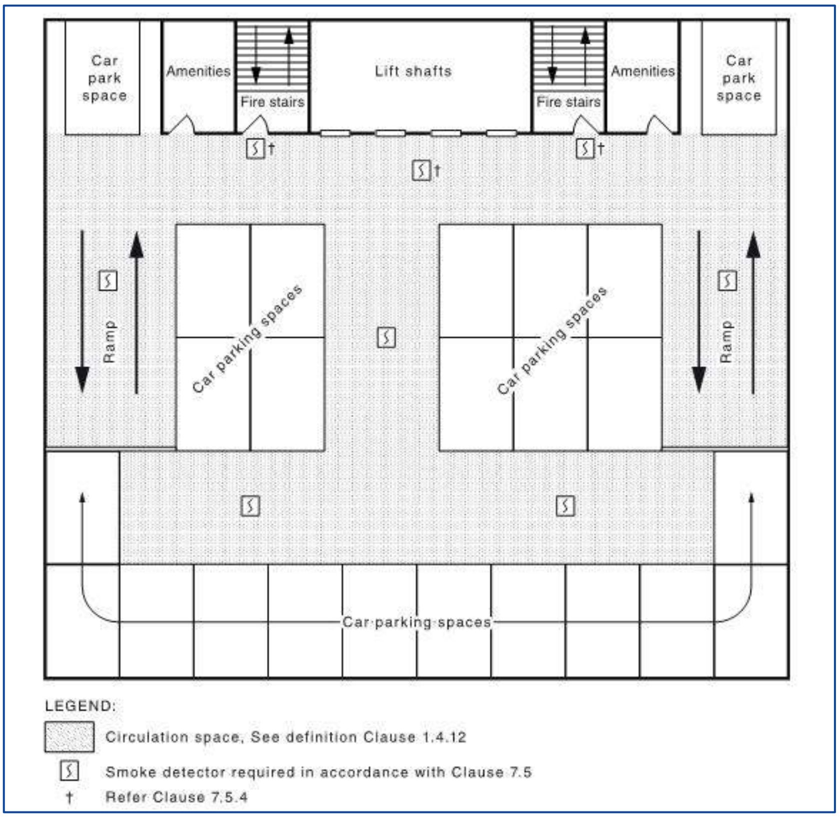


Figure 49: Figure 7.5.2.2(c) Indicative Detector Locations Example Car-Park

- The mechanical ventilation system serving the basement car parks shall be designed in accordance with AS/NZS 1668.1 - 1998 and AS 1668.2 – 2012, as well as the FRNSW Fire Safety Guideline document for impulse fans in car-parks. The mechanical ventilation systems have exhaust and supply arrangements as follows:
  - On Basement 1: exhaust rate: 72 m^3/s; supply rate: 65 m^3/s and three natural supply air inlets via the vehicle ramp.
  - On Basement 2: exhaust rate: 51 m^3/s; supply rate: 45 m^3/s and four natural supply air inlets via the vehicle ramp.
  - The supply fans and exhaust fans are kept running and ramp to full speed if on variable speed drive (VSD) in the event of a fire being detected within the building (in relation to the supply/exhaust riser fans serving the basement levels – not the jet fan system).
  - Supply systems to be fitted with duct smoke detectors to switch off the supply fans if smoke is detected in the supply ducts.
- Impulse fans in conjunction with CO sensors and associated controls are proposed to be installed in the basement car parks to achieve a performance of diluting pollutants, as required by AS 1668.2 – 2012. Fantech model JIU-CPCEC-SD jet fan or other products that can produce equivalent jet flow pattern shall be installed in the basement car parks.
- The impulse fans should be located in driveways and access ways and not above car-parking spaces or ither areas where there are stagnant fire loads.
- The impulse fans shall be provided with duct smoke detectors. Upon activation of any of these smoke detectors or the sprinklers, all the impulse fans shall be shut down and the building occupant warning system shall be activated.
- The activation of sprinklers in the basement car parks shall also automatically turn off the impulse fans on the fire-affected floor, activate the building occupant warning system and call FRNSW via the ASE.

- A control switch shall be provided for each of the basement carpark levels to enable manual control of the impulse fans by attending fire brigade personnel. The control switches shall be incorporated in the FIP as a Fire Fan Control Panel (FFCP).
- An indicative layout of the impulse fans units for both Basement Levels 1 & 2 has been illustrated in Appendix B of the CFD report attached in Appendix H of this report which have been designed by Fantech.
- Mechanical layout plans for the basement levels are to be provided at the FIP indicating impulse fans location with numbers, as designed on the FIP. Operational instructions for the impulse fans (Auto and Manual) shall be provided at the FIP.
- Testing of the mechanical system serving the carpark level shall consist of verifying that upon activation of a fire initiating device (detector, flow switch, etc.) all jet fans shall cease operation on both carpark floors simultaneously. The carpark supply and exhaust system shall then ramp up to full speed operation, as per AS 1668.1.

18.6 Method of Analysis

CFD modelling has been undertaken to demonstrate that the proposed mechanical ventilation system (use of jet fans) serving the basement carpark levels of the development meets the Performance Requirements EP1.4 and EP2.2 of the BCA.

A CFD analysis has also been undertaken to demonstrate that the jet fans maintain a constant air movement across the domain and prevent air stagnation to effectively dilute products and, as such, shall demonstrate compliance with BCA Performance Requirement FP4.4.

FRNSW is noted to have a Fire Safety Guideline for impulse fans in sprinkler protected car parks as follows; *'Guideline for impulse fans in car parks Version 01 issued on the 09/10/2014'*.

The assessments undertaken via CFD modelling (including the design fire locations) are in line with the type of analysis required by Fire & Rescue NSW for the incorporation of jet fans in a sprinkler protected carpark, as discussed in detail in Section 4.2.1 of the CFD Report contained in Appendix H.

A total of 9 fire scenarios have been considered as part of the CFD analysis, to assess whether the Alternative Solution is considered to meet the BCA Performance Requirements EP1.4 & EP2.2. The fire scenarios have been discussed in detail in Section 6.3.3 and 6.3.4 of the attached CFD report in Appendix H.

18.7 Assessment

18.7.1 CFD Report (Appendix H)

This report presents the design assumptions and the results of the CFD modelling study of the mechanical ventilation system and discusses its impact on sprinkler activation, the tenability conditions of the carparking areas during egress of people from the floor of fire origin, as well as fire fighters entering the fire floor. A summary of the results has been presented below;

- ***Sprinkler Analysis Summary***

In order to assess the effects of the jet fans on sprinkler activation, some small scale CFD modelling has been conducted. A total of three scenarios (referred to as FS #1 to FS #3) were undertaken.

Based on the results it has been demonstrated that when the fire is located in the immediate airflow of the jet fans, the sprinkler activates later when the jet fans are running compared with when they are not. The time to sprinkler activation will depend on the location of the fire, but the results show that the difference between the fire scenarios is small. The results of the simulations undertaken are consistent with the findings undertaken by [Enright]. Enright concluded in his analyses (16 CFD simulations) that delays of ≤ 30 s to sprinkler activation occurred where the sprinkler and jet fans layout was coordinated so the sprinklers are in plane with the jet fan nozzle.

- ***Slice File of Basement Vehicle Fire***

In order to show the temperature of the fire across the vehicle fire in the basement a slice file of the vehicle is shown at maximum HRR.

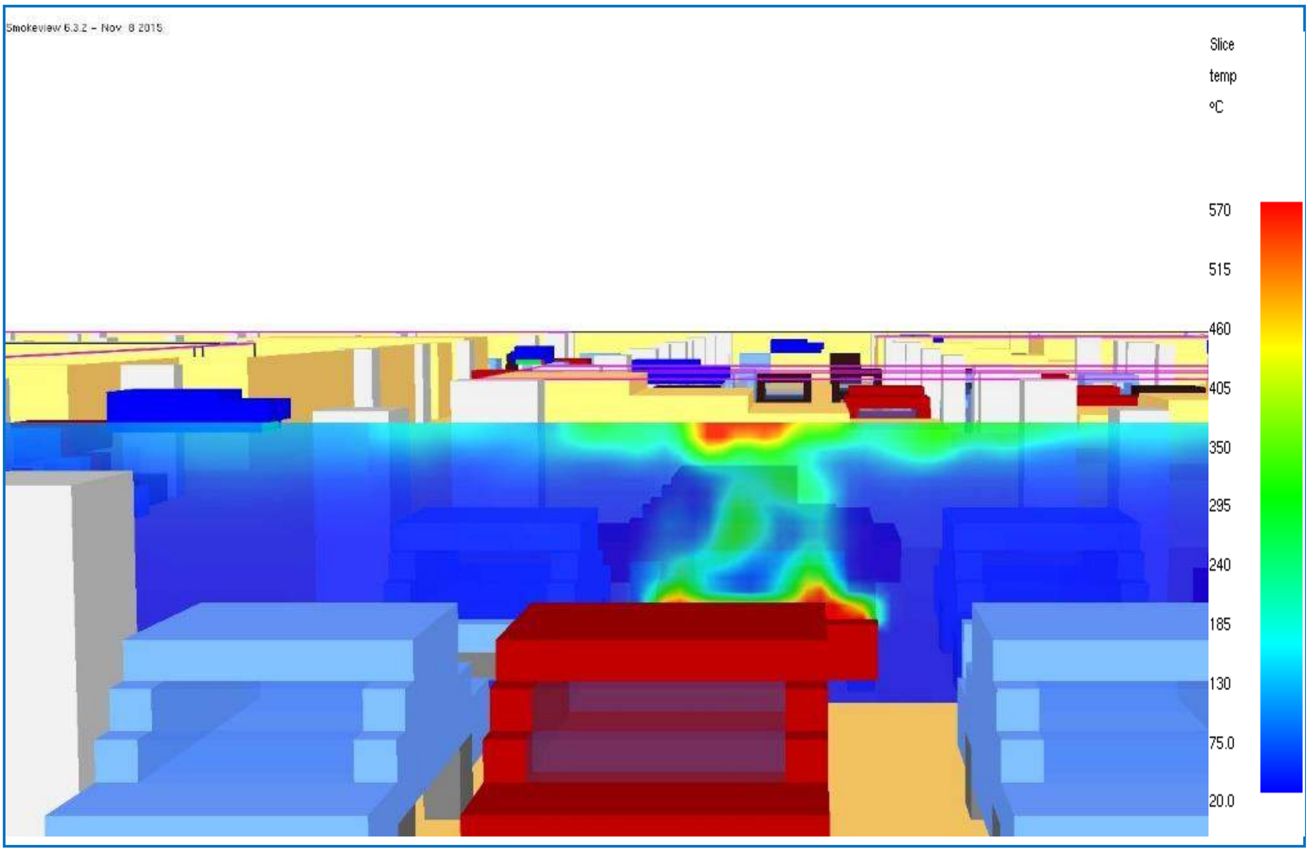


Figure 50: Slice File of Basement Vehicle Fire

The above slice file is taken 1,056 seconds into the simulation. As can be seen by the above slice file there are temperatures surrounding the fire in excess of 550 °C.

➢ ***Tenability Analysis Summary***

In order to assess the effects of the jet fans on tenability conditions within the carpark, a total of six fire scenarios (referred to as FS #4 to FS #9) were undertaken, utilising the proposed jet fan mechanical design. Based on the results presented, it is submitted that the required Margin of Safety of 1.5 between the Available Safe Egress Time (ASET) and the Required Safe Egress Time (RSET) analysis has been achieved as summarised in Table 34. The "margin of safety" presented is the difference between the RSET x 1.5 and the ASET. I.e. Margin of safety = ASET – (RSET x 1.5). The "margin of safety" demonstrates that the ASET is well in excess of the RSET, even after a "factor of safety" of 1.5 is applied.

The results of the CFD modelling confirm that the conditions in the carpark in a fire scenarios are within the acceptance limits for both occupant egress and fire brigade intervention, as discussed in Section 18.3.

Table 36: ASET / RSET Comparison Analysis

Fire Scenarios	RSET Time (s)	RSET x 1.5 (s)	ASET Time (s)	Margin of Safety	
FS #4	327 seconds	491 seconds	>500 seconds	> 9 seconds	**Satisfied**
FS #5	276 seconds	414 seconds	>500 seconds	> 86 seconds	**Satisfied**
FS #6	288 seconds	432 seconds	>450 seconds	> 18 seconds	**Satisfied**

Although the ASET comes close to the RSET on two of the scenarios modelled when the 1.5 safety factor is applied, it should also be noted that at least one exit is maintained throughout the entire model run on each of the above scenarios (1000 second model run per scenario). The assessment is therefore considered conservative as a result as an exit would always be available to occupants even after the ASET cut-off time nominated in the table above.

18.7.2 CO Report (Appendix I)

The CO results of the FDS model at Basement Levels 1 & 2 have been presented in Appendix G of this report. The results shows that the CO rate does not reach 100 ppm anywhere in the basement. The steady state condition demonstrates that the polluted air is effectively diluted in all parts of the basement and carbon monoxide levels are maintained lower than those in the defined exposure limits, outlined in AS 1668.2.

18.8 Conclusion

Based on the quantitative assessment undertaken, it has been demonstrated that the impulse fan ventilation system serving the basement car parks can achieve the following:

- The system will achieve a satisfactory performance, as required by AS 1668.2 in maintaining an acceptable emissions concentration level in the basement car parks.
- Safe occupant evacuation from the basement car parks can be undertaken.
- The system will not adversely affect the operation of the sprinkler system and spread of fire to adjacent cars is avoided.

Therefore, Performance Requirements EP1.4, EP2.2 and FP4.4 of the BCA are considered to be met.

19. AS 13 – Location of Fire Control Centre

19.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Table 37: Summary of Alternative Solution

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system
Allow the Fire Control Centre to be >300 mm above Ground Level	E1.8 and Spec E1.8	EP1.6	SS-F
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.			

1.1 Details of Departures from DtS Provisions

The proposed design for the subject building includes the provision of a Fire Control Centre (FCC) on Lower Ground Level, as required by BCA Clause E1.8. It has been identified that the FCC on Lower Ground Level is >300 mm below street level, which constitutes a non-compliance with BCA Spec. E1.8.

The location of the FCC and the applicable Finished Floor Levels (FFLs), both at street level (hydrant booster SSL) and at the FCC have been assessed. Details on these two locations can be found in Figure 51.

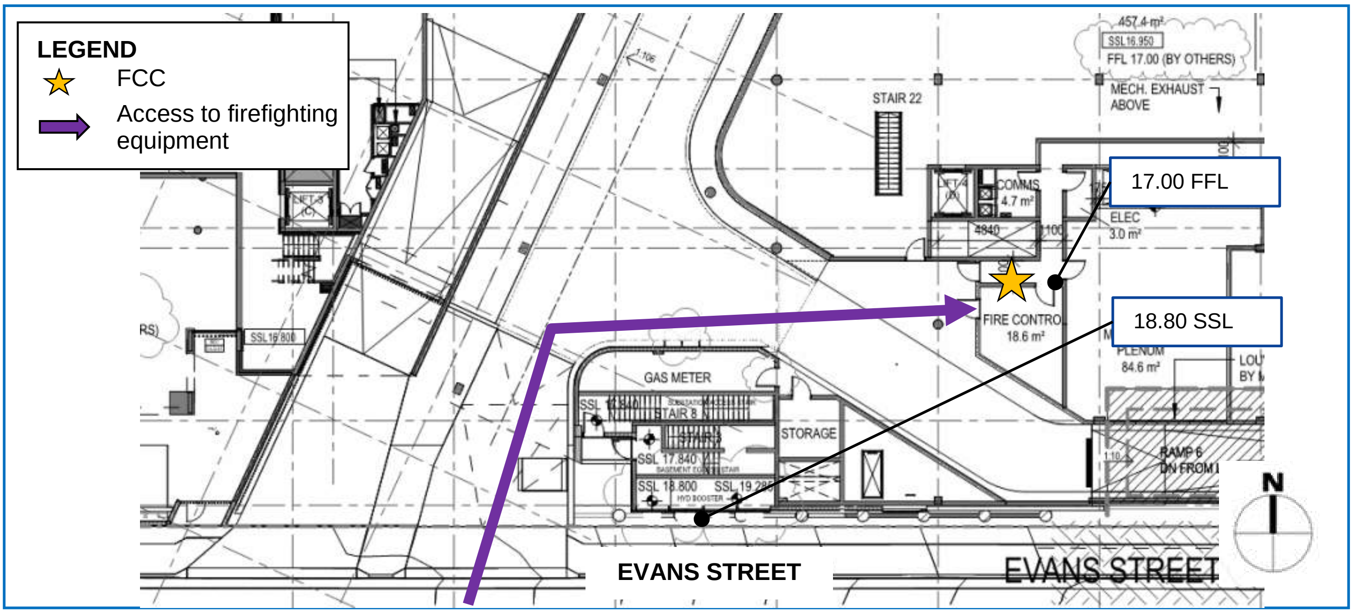


Figure 51: Brigade access to Fire Control Centre

1.2 Discussion and intent of the BCA

1.2.1 DtS Provision E1.8 and Spec. E1.8

The limitation on the difference in level between the FCC and a road or open space is to help fire fighters carry their equipment and make entry easier.

1.3 Approach and assessment method used

The approach in this solution will be qualitative in nature and will use a deterministic absolute approach using the assessment methods as shown in Table 38.

Table 38: Approach and Assessment Methods Used

Clause A0.5	Clause A0.9
Compliance with the Performance Requirements can only be achieved by— (a) complying with the Deemed-to-Satisfy Provisions **(b) formulating an Alternative Solution which—** **(i) complies with the Performance Requirements**; or (ii) is shown to be at least as equivalent to the Deemed-to-Satisfy Provisions; or (c) a combination of (a) and (b)	**The following Assessment Methods, or any combination of them, can be used to determine that a Building Solution complies with the Performance Requirements:** (a) Evidence to support that the use of a material, form of construction or design meets a Performance Requirement or a Deemed-to-Satisfy Provision as described in A2.2 of the BCA. **(b) Verification methods such as—** (i) the Verification Methods in the BCA; or **(ii) such other verification methods as the appropriate authority accepts for determining compliance with the Performance Requirements** (c) Comparison with the Deemed-to-Satisfy Provisions (d) Expert Judgement

1.4 Acceptance Criteria

The acceptance criteria for this assessment will be based on ease of access for the attending fire brigade to reach the Fire Control Centre without causing a significant delay.

19.2 Hazards

The hazard associated with this Alternative Solution is that the Brigade may be delayed in reaching the required equipment upon attendance on site.

19.3 Proposed fire safety measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the building incorporating measures specific to the consideration of the Alternative Solutions.

No additional fire safety measures specific to this Alternative Solution are deemed necessary.

1.5 Assessment

It is considered that the proposed means of access to the Fire Control Centre are sufficient for Brigade use, due to the following:

- The steps/ramp up to the level via which the FCC equipment is accessed will be BCA compliant, meaning that the size of each step, the nosing / slip resistance of these, the gradient and handrails will be designed and implemented appropriately. All of these items will assist Brigade members with walking down them while carrying their equipment.
- The Brigade booster is located remote from the FCC (at street level), meaning that any hoses associated with connecting to the booster will not be required to be carried down this flight of steps/ramp.
- Should a fire occur on the uppermost residential level of this building (Level 4), Brigade members would be expected to walk up no fewer than six flights of stairs, having a rise of nearly 18 m between the FCC and the fire affected floor. The approximately 1.8 m descent between street level and the FCC should therefore not pose any significant problem as a result of this fact.

1.6 Conclusion

The assessment has demonstrated that adequate facilities are provided and that BCA Performance Requirement EP1.6 is achieved.

20. AS 14 – Connection of four storeys with an open stair

20.1 Introduction

The following table provides a summary of the Alternative Solution, the relevant BCA DtS Clause that is affected and the relevant BCA Performance Requirements and IFEG subsystems.

Description of Alternative Solution	DtS Clause	Performance Requirements	IFEG Sub-system	BCA (A0.5)	BCA (A0.9)
To permit stair 5 to indirectly connect more than four storeys	D1.12	CP2 & EP 2.2	SS-A, SS-B, SS-C, SS-D, SS-E & SS-F	(b)(ii)	(c)
Approach and assessment method used - The approach in this solution will be qualitative in nature and will use a deterministic absolute approach.					

20.2 Description of non-compliance with DtS Provisions

20.2.1 Non-compliant Stair 5

Stair 5 indirectly connects four storeys including the two basement parking levels and the upper and lower ground levels. The two basement parking levels are sprinkler protected and fire separated through drenched glazing. The upper ground level is open to atmosphere via a large void opening. Based on direction from the PCA, this constitutes a non-compliance with Clause D1.12 of the BCA.

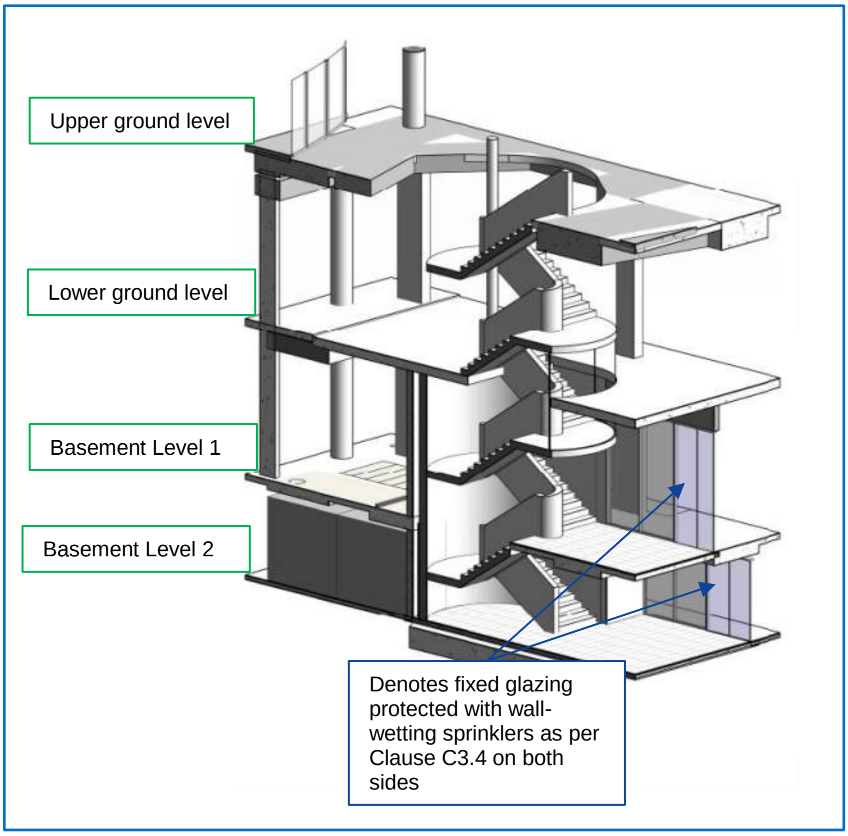


Figure 52: Stair 5 - Orthogonal Projection

20.3 Acceptance Criteria

The acceptance criterion for the non-compliance relating to Stair 5 is that the proposed design requirements can provide a level of life safety to occupants that is at least equivalent to or better than that afforded by a comparable building design that is compliant with BCA DtS provisions.

20.4 Hazards

The hazards associated with the identified non-compliance with Stair 5 connecting four storeys is that fire and smoke from any one of the four storeys could spread to all four storeys, as opposed to only two storeys in a DtS compliant scenario. This could potentially impede occupants in their egress from the lower storeys.

As per the BCA Guide, the intent of BCA Clause D1.12 is to limit the spread of fire and smoke through unprotected openings for stairways, ramps, escalators and moving walkways. BCA Clause D1.12 restricts the number of storeys that can be interconnected by a non-required non-fire-isolated stairway and recognises that an unprotected opening for a stairway can lead to the spread of fire or smoke from one floor to another.

BCA DtS Clause D1.12(d) permits a non-required non-fire isolated stair to connect no more than two storeys.

BCA Specification D1.12 stipulates (simplified) an enclosing shaft should be of either 2 hour fire resisting construction or glazed -/60/30 construction protected by wall wetting sprinklers.

Conversely, up to three sprinkler protected floors can be interconnected by an open stair without a fire resisting shaft if one of the floors has direct egress to a road or open space.

20.5 Proposed Fire Safety Measures

The fire safety measures listed in Section 6 form the holistic fire safety design for the development incorporating measures specific to the consideration of the Alternative Solutions.

Fire safety measures specific to this Alternative Solution are as follows;

- The proposed glazed construction around Stair 5 (as identified in Figure 52) shall be provided with Tyco Model WS specific application window sprinklers on both sides of the glazed elements and must be installed in accordance with the manufacturer's specifications which are included in Appendix E. However, note the following key items:
  - All combustible materials shall be kept at least 50.8 mm from the glazing. This shall be implemented via a pony wall (at least 0.9 m in height, where necessary).
  - There are restrictions on the type and size of glass panels.
  - There are restrictions on depths of mullions and transoms.
  - The glass shall be at least 6 mm thick and heat strengthened or tempered glass.
  - Any section of glazing above the door or adjoining the door must also be protected with the Tyco system.
  - Glazed doors within the glazed wall are required to automatically close so as to allow the Tyco heads to attenuate the glass. Consideration must be given regarding the door opening mechanisms, so as not to clash with the Tyco head.
- The proposed tyco WS drenching system is required to be separated from the sprinkler system water supply by valves.
- Isolation of both systems simultaneously (drencher system and occupied space sprinkler system) for maintenance purposes shall not be allowable. This is to be included in the management in use plan.
- The number of heads required to activate simultaneously in each area must be reviewed, with calculations being carried out by the fire protection contractor to verify that the water supply available (both town main and tank supply) can achieve full flow of this system for no less than 2 hrs in the most disadvantaged area. These calculations must allow for the sprinkler system serving the occupied areas of the basement levels and the fire hydrant system to be in operation simultaneously.

- The automatic sprinkler system to Basement Levels 1 & 2 as well as the loading dock area at Lower Ground Floor Level will be designed and installed in accordance with BCA Specification E1.5 and AS2118.1, modified as follows:
  - Provide fast response sprinkler heads (with an RTI of 50 $(m \cdot s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads.
  - The sprinklers shall be installed at a spacing of 3 m x 4 m for an Ordinary Hazard system.
  - The sprinkler system shall be connected to and activate the building occupant warning system.
- The leisure lobby areas are required to be free of combustibles and ignition sources at all times. The following fire safety measures are to be adopted to the lobby areas at Basement Levels 1 & 2;
- The leisure lobby areas and its bounding construction are to comprise of non-combustible construction.
- All furnishings contained within (if any i.e.; such as tables / seating) are to be of non-combustible materials, as determined by AS 1530.1.
- The lobby areas shall have no combustible materials contained within and are to be designated sterile environments. The following supporting signage is to be erected on their walls outlining this requirement. Signage to read as follows:

  "NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA"

  The words "NO COMBUSTIBLE MATERIALS TO BE PLACED IN THIS AREA'" must be in letters not less than 50 mm in height. The lettering shall be in a colour contrasting with the background to which it is erected.

  The above requirements are be added to the Annual Fire Safety Statement for the building with the Building Management to inspect the leisure lobby areas on a monthly basis to ensure the required fire safety measures are being adhered to.

20.6 Method of Analysis

The proposed solution, with the additional protective measure, will be compared to a BCA DtS compliant stair which connects two levels. The assessment will show that the risk is no greater to occupants that the DtS as the two basement levels at the base of this stair are both fully sprinkler protected. The risk of a significant fire occurring on these two floors is considered negligible as a result.

20.7 Assessment

20.7.1 Sprinkler Protection

Automatic sprinkler system to Basement Levels 1 & 2 as well as the loading dock area at Lower Ground Floor Level designed and installed in accordance with BCA Specification E1.5 and AS 2118.1. These areas are provided with fast response sprinkler heads (with an RTI of 50 $(m \cdot s)^{0.5}$ or less) in lieu of the required standard response sprinkler heads.

In the event of a fire, it is expected that the sprinkler system will control, if not suppress the fire. The sprinkler system will act to wet adjacent combustible materials and partitions and is expected to prevent fire spread beyond the area of fire origin. By controlling the size of a fire the sprinkler system minimises the amount of smoke produced and is expected, therefore, to ensure the safety of occupants outside the immediate vicinity of the fire start. The reliability and efficacy of sprinkler protection is well known. This is recognised by regulatory authorities, fire engineers and fire brigades across the globe, and discussed in detail in Appendix C.

20.7.2 ***Fire separation of basement parking levels***

The lower two storeys of the connecting open stairs are class 7a carparking levels. Basement levels are separated from the staircases with a glazed construction, which is protected with Tyco model WS specific application window sprinklers on both sides of the glazed elements. The glazed doors are within the glazed wall are required to automatically close so as to allow the Tyco heads to attenuate the glass.

The proprietary tested system incorporating fixed glazing in conjunction with Tyco sprinkler heads must be installed in accordance with the manufacturer's specifications detailed in Appendix E. This fire separation is considered sufficient due to the system having been subject to full scale fire tests in which the system was exposed to a standard heating scheme as per the ASTM E119 which is up to more than 1000 °C. This exposure condition is considered similar to that in an enclosure where a flashover occurs.

The Basement Levels 1 & 2 are fully sprinklered. As a result, a fire occurring in these areas would be expected to be controlled by the operation of the sprinklers and contained within the area of origin. According to research conducted by [CIBSE] and [Warrington] the upper layer temperature is not likely to exceed 100°C in a sprinkler suppressed fire or 200°C in a sprinkler controlled fire (for example when a shielded fire continues to burn, but does not grow). Therefore, a flashover fire is unlikely to occur in these sprinkler protected areas and the resulting exposure conditions are likely to be much less severe than the standard fire test to which the glazing system is exposed in the fire test.

Section C.2 of Appendix C further supports the effect of sprinklers on temperatures as researched by [Taiwan], which concluded that the temperatures in the fire-affected room ranged between 200 °C and 400 °C, which are too low to cause any structural fire damage.

The Australian guidelines [FCRC] provide recommendations based on the temperature differential ΔT between the two faces of the glass for the failure of glasses. Based on this criterion, ordinary glass breaks at ΔT= 80°C and tempered glass breaks at ΔT= 240°C. As discussed above, under a sprinkler controlled fire scenario, it is considered that a temperature differential of 240°C is unlikely to occur between the two faces of the tempered glass and thus failure of the glazing is unlikely to occur. In the case of a fire occurring immediately adjacent to the glazing, the Tyco specific application window sprinklers will activate and apply water to the entire surface of the glazing. As a result, a temperature differential of 240 °C is unlikely to be reached to cause the failure of the tempered glazing.

This system provides a sufficient level of fire separation on the lower two levels and results in only the upper two floors being connected. Due to the unlikely event of smoke on the Lower and Upper Ground Levels flowing down into the stair, which is open on those levels, the stair is comparable to the BCA DtS compliant stair connecting no more than two consecutive storeys (BCA Clause D1.12(d)).

20.7.3 ***Sterile nature of stair area***

With the measures in place to provide fire separation of the stairs from the remainder Basement Level 1 & 2, a fire within the stair itself could still pose a risk to occupants of the stair. This area within the stair is required to be clear and free of combustible materials, as it will be used as a circulation space and path of access between the levels. All furnishings contained within (if any i.e.; such as tables / seating) are to be of non-combustible materials, as determined by AS 1530.1.

The lobby areas shall have no combustible materials contained within and are to be designated sterile environments. This is supported by signage in the area. These requirements are to be added to the Annual Fire Safety Statement for the building where building management are required to inspect the lobby area on a monthly basis.

Due to the sterile nature of the space around the stairs, this area will be devoid of combustible materials and owing to this lack of fuel and relatively few ignition sources in these areas, a fire starting in these areas is deemed unlikely. Even if a fire were to occur, it would likely be a smouldering fire that would burn out relatively quickly owing to the limited fuel load available. This does not pose a significant risk to the spread of fire between the levels.

20.7.4 ***Open nature of upper stair***

In the BCA DtS (Clause D1.12(d)) equivalent stair, the stair may be fully enclosed on the upper level, which could become smoke logged due to smoke from a lower level fire as demonstrated in the figure below.

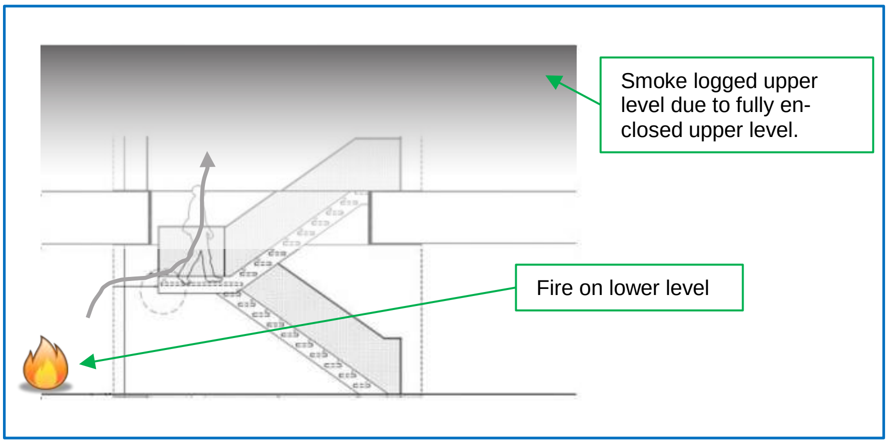


Figure 53: DtS example showing enclosed stair.

The proposed design is open to atmosphere in the upper level, allowing the smoke to readily dissipate and maintaining a higher level of occupant safety than that of the DtS equivalent stair shown in Figure 53. Additionally, the hot gas layer that would be located at the ceiling will be able to escape to atmosphere. It is likely that this hot gas layer will escape to atmosphere through these openings and will not reach the temperature required for flashover.

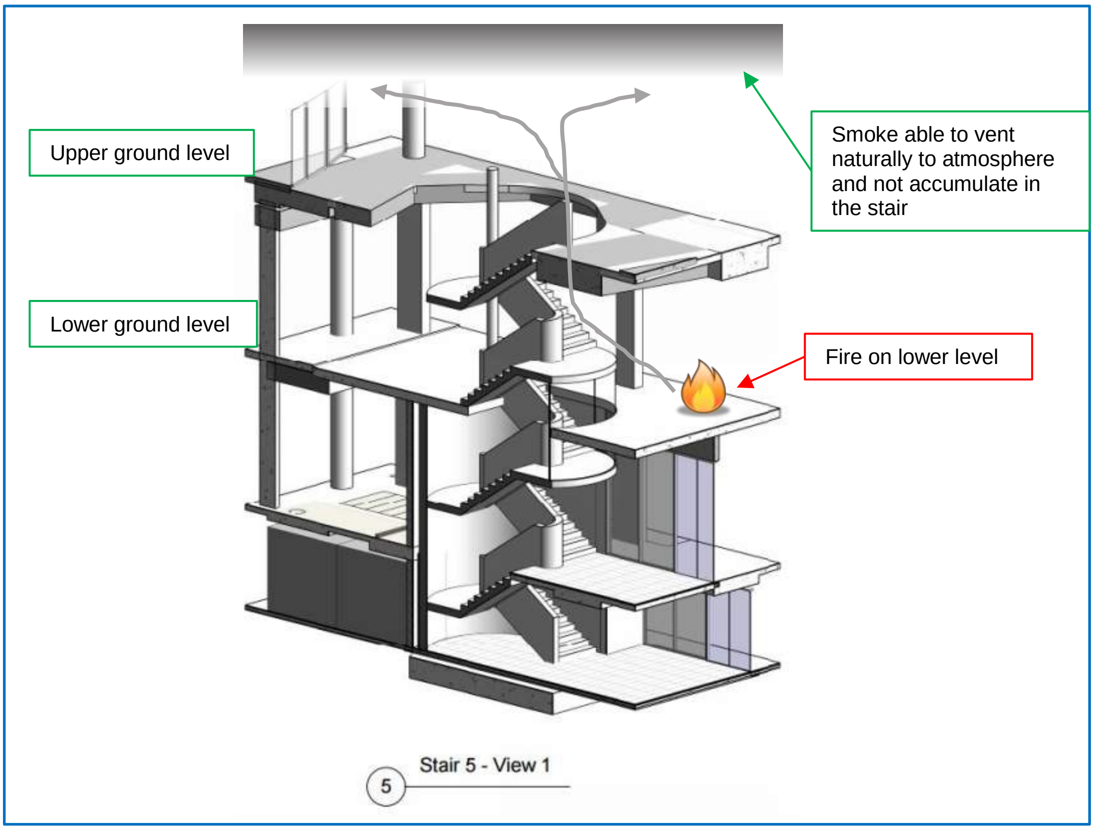


Figure 54: Proposed design with open to atmosphere upper level

1.7 Conclusion

The assessment has demonstrated that adequate additional safety measures have been provided and that compliance with BCA Performance Requirement CP2 and EP2.2 are achieved.

21. References in this FER

[Alpert] Alpert R.L., Ceiling Jet Flows, The SFPE Handbook of Fire Protection Engineering, 4th Edition, National Fire Protection Association, Quincy.

[AFAC] AFAC, Fire Brigade Intervention Model. Version 2.2, Australasian Fire Authorities Council, October 2004.

[AS/NZS 1668.1] AS 1668.1 – 2012. The use of ventilation and air-conditioning in buildings; Fire and smoke control in multi-compartment buildings, Standard Australia Limited, Sydney.

[AS 1668.2] AS 1668.2 – 2012. The use of ventilation and air-conditioning in buildings; Mechanical Ventilation in buildings, Standard Australia Limited, Sydney.

[BCA] ABCB 2014, *National Construction Code Series, Volume 1, Building Code of Australia 2014, Class 2 to Class 9 Buildings,* Australian Building Codes Board, Canberra.

[BCA Guide] *Guide to the Building Code of Australia*, Australian Building Codes Board.

[Bennetts] Bennetts, I.D., and Thomas, I.R., Performance Design of Low-rise Sprinklered Shopping Centers for Fire Safety, Journal of Fire Protection Engineering, 2002.

[BD2552] BRE 'Fire spread in car parks' December 210 Department for Communities and Local Government.

[BRE Trust] Design Fires for use in Fire Safety Engineering by Christopher Mayfield and Danny Hopkin

[CIBSE TM19] *Relationships for Smoke Control Calculations, CIBSE Technical Memoranda TM19, London, CIBSE 1995*.

[CFAST] Richard D. Peacock., CFAST – Consolidated Model of Fire Growth and Smoke Transport (Version 6) User's Guide, NIST Special Publication 1041r1.

[Enright] Enright, P.A., Impact of Jet fan Ventilation Systems on Sprinkler Activation, IFE 2013 Paper.

[FCRC] Australian Fire Engineering Guidelines (1996), First Edition, Fire Code Reform Centre Ltd., Sydney, Australia.

[Geiman] Geiman, J.A., Gottuk, G.T.,and Milke, J.A., Evaluation of Smoke Detector Response Estimation Methods: Optical Density, Temperature Rise, and Velocity at Alarm, Journal of Fire Protection Engineering, pp. 251-266, Vol.16, November 2006.

[IFEG] ABCB 2005, International Fire Engineering Guidelines, 2005 Edition, Australian Building Codes Board, Canberra.

[Hall] Hall, J, U.S Experience with Sprinklers, National Fire Protection Association, Quincy, 2012

[Heskestad] Heskestad, G. and Bill, R., Quantification of Thermal Responsiveness of Automatic Sprinklers Including Conduction Effects, Fire Safety Journal 14:113–125, 1988.

[Ingason] Ingason, Haukur, Design Fires in Tunnels, 2006.

[Li] Li, Y., Assessment of Vehicle Fires in New Zealand Parking Structures, Master's Thesis in fire Engineering, Department of Civil Engineering, University of Canterbury, Christchurch, New Zealand, 2004.

[Lougheed] Lougheed, G.G., McCartney, C., Taber, B.B., Sprinklered Mercantile Fires, NRCC-44234, National Research Council of Canada.

[Marryatt] Marryatt, HW Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand 1886–1988, Craftsman Press Pty Ltd, Melbourne, 1988.

[Madrzykowski] Madrzykowski, D., The Reduction in Fire Hazard in Corridors and Areas Adjoining Corridor Provided with Sprinklers, Report NISTR 4631, NIST, US Department of Commerce.

[Nystedt] Nystedt, F., Verifying Fire Safety Design in Sprinklered Buildings, Report 3150, Department of Fire Safety Engineering and Systems Safety Lund University, Sweden, 2011.

[NSWFB] New South Wales Fire Brigade, Statistical Data of Fire Events for 2006-2007.

[NZFS] New Zealand Fire Services, Statistical Data of Fire Events for 1999-2004.

[Proulx] Proulx, G., Evacuation Time, 4th Edition, Chapter 3-12, SFPE Handbook of Fire Safety Engineering National Fire Protection Association, and Society of Fire Protection Engineers, 2008.

[PD 7974-6] PD7974-6 - 2004. *“The application of fire safety engineering principles to fire safety design of buildings – Part 6: Human factors: Life safety strategies – Occupant evacuation, behaviour and condition (Sub-system 6)”, BSI British Standards.*

[SOFS] *‘Practice Note for Tenabiliity Criteria in Building Fires’*, Version 2.0, dated 03.04.2014 prepared by the Society of Fire Safety NSW Chapter Engineers Australia.

[Thomas] Thomas, I.R., Fires in Carparks, Fire Australia February 2004, Eastside Printing.

[Warrington] Building Control Commission and Warrington Fire Research 2000, Fire Resistant Barriers and Structure

Tel: 02 8907 0900
Level 1, 41 McLaren Street, North Sydney NSW 2060.

UNITED
BY OUR
DIFFERENCE

Appendix A BCA Perofrmance Requirements & IFEG Sub-systems

A.1 IFEG Sub-systems

The sub-systems as described in Section 1.1.1 of the IFEG are detailed in the table below. To assist in the analysis of the fire safety system, it is convenient to consider it as comprising six sub-systems, each of which is has been detailed for ease of reference.

Sub-systems A to F	Description of the Sub-system as per IFEG
SS-A *Fire Initiation & Development & Control*	Sub-system A (SS-A) is used to define design fires in the enclosure of fire origin as well as enclosures to which the fire has subsequently spread and how fire initiation and development might be controlled.
SS-B *Smoke Development & Spread & Control*	Sub-system B (SS-B) is used to analyze the development of smoke, its spread within the building, the properties of the smoke at locations of interest and how the development and spread might be controlled.
SS-C *Fire Spread & Impact & Control*	Sub-system C (SS-C) is used to analyze the spread of fire beyond an enclosure, the impact a fire might have on the structure and how the spread and impact might be controlled.
SS-D *Fire Detection, Warning & Suppression*	Sub-system D (SS-D) is used to analyze detection, warning and suppression for fires. This process enables estimates to be made of the effectiveness of suppression.
SS-E *Occupant Evacuation & Control*	Sub-system E (SS-E) is used to analyze the evacuation of the occupants of a building. This process enables estimates to be made of the times required for occupants to reach a place of safety.
SS-F *Fire Services Intervention*	Sub-system F (SS-F) is used to analyze the effects of the intervention activities of fire services on a fire including the effectiveness of suppression activities.

A.2 Relevant BCA Performance Requirements applicable to the identified Alternative Solutions

A.2.1 Section C of the BCA - Fire resistance

BCA Performance Requirement CP2

"(a) A building must have elements which will, to the degree necessary, avoid the spread of fire—
(i) to exits; and
(ii) to sole-occupancy units and public corridors; and
(iii) between buildings; and
(iv) in a building.
(b) Avoidance of the spread of fire referred to in (a) must be appropriate to—
(i) the function or use of the building; and
(ii) the fire load; and
(iii) the potential fire intensity; and
(iv) the fire hazard; and
(v) the number of storeys in the building; and
(vi) its proximity to other property; and
(vii) any active fire safety systems installed in the building; and
(viii) the size of any fire compartment; and
(ix) fire brigade intervention; and
(x) other elements they support; and
(xi) the evacuation time."

As per the BCA Guide the intent of Performance Requirement CP2 is to deal with the spread of fire both within the building and between buildings, and which does not only result from the structural failure of a building element. CP2 does not make any reference to a fire-resistance level (FRL). FRLs are only included as part of the Deemed-to-Satisfy Provisions. However, proponents of an Alternative Solution should note, if they so wish.

BCA Performance Requirement CP4

> *"To maintain tenable conditions during occupant evacuation, a material and an assembly must, to the degree necessary, resist the spread of fire and limit the generation of smoke and heat, and any toxic gases likely to be produced, appropriate to —*
> *(a) the evacuation time; and*
> *(b) the number, mobility and other characteristics of occupants; and*
> *(c) the function or use of the building; and*
> *(d) any active fire safety systems installed in the building"*

A.2.2 Section D of the BCA – Access and Egress

BCA Performance Requirement DP4

> *"Exits must be provided from a building to allow occupants to evacuate safely, with their number, location and dimensions being appropriate to—*
>
> *(a) the travel distance; and*
> *(b) the number, mobility and other characteristics of occupants; and*
> *(c) the function or use of the building; and*
> *(d) the height of the building; and*
> *(e) whether the exit is from above or below ground level.*

As per the BCA Guide the intent of Performance Requirement DP4 is to provide guidance for the number, dimensions and distribution of exits.

BCA Performance Requirement DP5

> *"To protect evacuating occupants from a fire in the building exits must be fire-isolated, to the degree necessary, appropriate to—*
>
> *(a) the number of storeys connected by the exits; and*
> *(b) the fire safety system installed in the building; and*
> *(c) the function or use of the building; and*
> *(d) the number of storeys passed through by the exits; and*
> *(e) fire brigade intervention.*

As per the BCA Guide the intent of Performance Requirement DP5 is to provide guidance for determining when fire-isolated exits are necessary to provide protection for evacuating occupants.

A.2.3 Part E1 of the BCA – Services and Equipment

BCA Performance Requirement EP1.1

> *"A fire hose reel system must be installed to the degree necessary to allow occupants to safely undertake initial attack on a fire appropriate to—*
>
> *(a) the size of the fire compartment; and*
> *(b) the function or use of the building; and*
> *(c) any other fire safety systems installed in the building; and*
> *(d) the fire hazard."*

As per the BCA Guide, fire hose reels in buildings allow occupants to fight a fire. The fire may be in its infancy, and early control or extinguishment may reduce the hazard, allow more time for evacuation and prevent structural damage.

BCA Performance Requirement EP1.3

> *"A fire hydrant system must be provided to the degree necessary to facilitate the needs of the fire brigade appropriate to—*
>
> *(a) fire-fighting operations; and*
> *(b) the floor area of the building; and*
> *(c) the fire hazard."*

As per the BCA Guide the intent of BCA performance Requirement EP1.3 is to provide guidance on a fire hydrant system so as to provide adequate water, under sufficient pressure and flow, to allow the fire brigade to fight fires. The use of the expression *"to the degree necessary"* in EP1.3 indicates that the BCA recognises that not all buildings need fire hydrants. Any decision made in this context can extend to not requiring an item to be installed or a particular level of performance to be achieved, if that is the appropriate action to be taken.

If an Alternative Solution is used, it may be appropriate to assess it using E1.3 for guidance purposes. However it is stressed that compliance with E1.3 is not compulsory if alternative means can be found to satisfy the appropriate authority that the Performance Requirements will be achieved.

BCA Performance Requirement EP1.4

> *"An automatic fire suppression system must be installed to the degree necessary to control the development and spread of fire appropriate to—*
>
> *(a) the size of the fire compartment; and*
> *(b) the function or use of the building; and*
> *(c) the fire hazard; and*
> *(d) the height of the building."*

As per the BCA Guide BCA performance Requirement EP1.4 is not limited to sprinkler systems. A sprinkler system is only one type of automatic fire suppression system. EP1.4 is not limited to sprinkler systems. If it can be demonstrated that another automatic fire system can control the development and spread of a fire, it may comply with EP1.4. Its activation must be "automatic" and must not depend on human intervention.

The BCA Guide sets out the criteria for automatic fire suppression systems as follows:

> *"As set out in EP1.4, an automatic fire suppression system, such as a sprinkler system, must be installed when necessary, and be appropriate to a number of factors. When implementing, the likely size and intensity of a fire should be taken into consideration. This can be measured by:*
>
> - *the size of the fire compartment which is a measure of the size of any potential fire;*
> - *the function or use of the building will affect the fire load in the building;*
> - *the fire hazard which means the danger in terms of potential harm and degree of exposure arising from the start and spread of fire, and the smoke and gases generated by a fire; and*
> - *the height of the building, because once a building gets above a certain height it becomes extremely difficult (and eventually impossible) for the fire brigade to undertake external rescue or firefighting from ladders and the like. The height also affects evacuation time."*

A.3 Part E2 of the BCA – Smoke Hazard Management

BCA Performance Requirement EP2.2

> *"(a) In the event of a fire in a building the conditions in any evacuation route must be maintained for the period of time occupants take to evacuate the part of the building so that—*
> *(i) the temperature will not endanger human life; and*
> *(ii) the level of visibility will enable the evacuation route to be determined; and*
> *(iii) the level of toxicity will not endanger human life.*
> *(b) The period of time occupants take to evacuate referred to in (a) must be appropriate to—*
> *(i) the number, mobility and other characteristics of the occupants; and*
> *(ii) the function or use of the building; and*
> *(iii) the travel distance and other characteristics of the building; and*
> *(iv) the fire load; and*
> *(v) the potential fire intensity; and*
> *(vi) the fire hazard; and*
> *(vii) any active fire safety systems installed in the building; and*
> *(viii) fire brigade intervention."*

As per the BCA Guide, Performance Requirement EP2.2 states that occupants must be given time to evacuate before the onset of untenable conditions. EP2.2(a) specifies these conditions as dangerous temperatures, low visibility and dangerous levels of toxicity.

A.4 Part E4 of the BCA – Emergency Lighting, Exit Signs and Warning Systems

BCA Performance Requirement FP4.4

BCA Performance Requirement FP4.4 states that:

> *"A mechanical air-handling system installed in a building must control -*
>
> *(a) the circulation of objectionable odours; and*
> *(b) the accumulation of harmful contamination by micro-organisms, pathogens and toxins."*

Appendix B FRNSW IFSR feedback and responses

B.1 Initial IFSR feedback received on 24th August 2016

The table below details the feedback and comments from FRNSW detailed in the IFSR dated 24/08/2016. The below table discusses the items raised by FRNSW and WSP I Parsons Brinckerhoff’s commentary and actions undertaken with regards to the FRNSW feedback.

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
Issue #1 **Review of Spandrel Separation**	**Satisfied**	**Noted**	**Satisfied**	Noted
Issue #2 **Separation by Fire Walls**	**Conditionally satisfied** a. The water supply to the wall-wetting drencher system should be separately valved and independent to the sprinkler system serving the fire compartments concerned. Suitable management provisions should be included to ensure that both the sprinkler system and wall-wetting drencher system are not isolated at the same time. b. The proposed glazing is to be appropriately protected from mechanical damage (i.e. bollards are to be provided to all glazing where any chance of mechanical damage may occur).	**Additional design requirements added to the FER as follows:** - The proposed tyco WS drenching system is required to be separated from the sprinkler system water supply by valves. (section 6.3) - Isolation of both systems simultaneously for maintenance purposes shall not be allowable. This is to be included in the management in use plan (section 6.6). - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system that is suitable . (section 6.3)	a.The hydraulic requirements for the proposed wall-wetting protection, such as required water flow rates, number of heads required to activate simultaneously / area of operation, required duration of water supply, etc is to be detailed. This should consider and address simultaneous activation with the sprinkler and hydrant systems to ensure an adequate water supply is provided. This should also be demonstrated as adequate to provide an equivalent amount of protection to that of a fire-rated wall achieving an FRL as required by the DtS Provisions of the BCA. All items should be justified in the analysis. b.The water supply to the wall-wetting drencher system should be separately valved and independent to the sprinkler system serving the fire compartments concerned. Suitable management provisions should be included to ensure that both the sprinkler system and wall-wetting drencher system are not isolated at the same time. c. The proposed glazing is to be appropriately protected from mechanical damage (i.e. bollards are to be provided to all glazing where any chance of mechanical damage may occur). d. The specification in Figure 13 of the FER for the leisure lobby on Basement Levels 1 and 2 is not consistent with the proposal for Issue Number 14 which requires wall wetting drenchers to be provided on both sides. Refer to FRNSW comments on Issue Number 14. FRNSW consider that these wall-drenchers are required in order to achieve a level of fire separation from the adjacent spaces on basement levels 1 and 2. e. Figure 2 has not been updated to reflect the compartmentation shown in Figure 14.	a. Text now added stating the following: 'The number of heads required to activate simultaneously in each area must be reviewed, with calculations being carried out by the fire protection contractor to verify that the water supply available (both town main and tank supply) can achieve full flow of this system for no less than 2 hrs in the most disadvantaged area. These calculations must allow for the sprinkler system serving the occupied areas of the basement levels and the fire hydrant system to be in operation simultaneously'. A review is to take place by the construction team to verify compliance is achieved also as WSP have not been provided with all the details of the system to verify this is already achieved. b. Isolation of both systems simultaneously for maintenance purposes shall not be allowable. This has now been included in the management in use plan (Section 6.6), and is also listed within AS2 of the report as required. c. This requirement was already included. No action required - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system that is suitable . (Section 6.3). Requirement now included in AS2 as well for clarity. d. Tyco WS are required to be included on both sides of glazing on Basement Levels 1 and 2. These are specified and have been updated within the relevant sections of the report. e. Noted, however Figure 2 is indicative only to illustrate the general layout of the various building classifications on site. An updated drawing showing this information was not available so the original diagram has been left in place.
Issue #3 **Openings within 3 m of the boundary**	**Conditionally satisfied** a. Evidence of the agreement that is to be created with the Consent Authority should be provided to the Certifying Authority prior to issue of an Occupation Certificate. The final agreement should demonstrate, to the satisfaction of the Certifying Authority, that the owner and occupier of the subject building are both made aware (not either or) of any future changes to the adjacent public reserve / open carpark that would require reassessment of the alternative solution.	**Noted and agreed. Please refer to the following:** - This is a requirement of the AFSS for the building, the level of fire protection for the openings identified are to be re-assessed by a qualified fire engineer where there are any changes to the adjacent public reserve / open car park. (section 9.5)	a. Evidence of the agreement that is to be created with the Consent Authority should be provided to the Certifying Authority prior to issue of an Occupation Certificate. The final agreement should demonstrate, to the satisfaction of the Certifying Authority, that the owner and occupier of the subject building are both (not either or) made aware of any future changes to the adjacent public reserve / open carpark that would require reassessment of the alternative solution.	a. This requirement was already included. Please refer to text taken directly from the FER noting how the monitoring of the adjacent allotment will form part of the AFSS process for the site: 'Monitoring of the neighbouring carpark and McKillop Park public reserve as per the above requirement is to form a Critical Fire Safety Measure for the proposed development and is be added to the Annual Fire Safety Statement (AFSS)

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
				for the building.' (taken from section 9.5).
Issue #4 **Egress from Class 2 SOUs**	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) The provision of hot smoke seals will delay the activation of a building wide fire evacuation alarm. The heat detectors are only provided for Building A, B and D only, and the assessment needs to address the delay in other buildings where the extended travel distances occur, especially for Building E where the release of the electromagnetic locks to form the required fire isolated stair is relay activation of a local smoke alarm. b) The requirements for smoke seals should be applied to all doors that open onto the coridors where extended travel distances occur. c) The analysis has not addressed the increased risk of a fire blocking the path of travel in the event an SOU door is chocked open or fails, due to the potential greater number of SOU's along the corridors with extended distances of travel.	**Noted and agreed. Additional design requirements added to the FER as follows:** - a) Thermal detectors now to be provided within 1.5 m of SOU entry doors in all buildings containing Class 2 areas with non-compliant travel ditances (not just Building A, B and D). It should be noted that the door release in place in Building E will operate upon a general fire trip in any portion of the site, so this will not cause any delays on this item. - b) All doors opening onto residential corridors are now noted as requiring smoke seals as noted. - c) Additional text now added in Section 10.7.2 regarding this point to address FRNSW concerns around fire doors potentially failing or being chocked open.	a) The analysis has not adequately addressed the increased risk of a fire blocking the path of travel in the event an SOU door is chocked open or fails, due to the potential greater number of SOU's along the corridors with extended distances of travel. b) Section 10.5 – The requirement "Any required fire doors which are held open on electromagnetic locks (understood to be only applicable to Building E only) are to disengage upon activation of a local fire alarm to maintain separation between the different areas." has not been included in the design requirements in Section 6. Further justification is required as to why this activation only occurs on local fire alarm, and not detection of any fire in the building. FRNSW recommend that these doors close upon any fire trip. c) The FER in Section 10.8 on page 53 refers to occupants on Level 3 – it is assumed that this is Level 2 (being the topmost floor of Buildings A, B and D. It is also recommended that directional exit signage be provided on the Upper Ground Level to direct occupants to the final exit. d) Additional issue in Rev 2 - Level 2 - Up to 13 m from SOU B_234 in lieu of 6 m – This distance has not been updated in the Executive Summary or in Section 6 design requirements. The assessment also refers to 12.25m in Table 14, whereas the distance nominated is 13m. e) To permit an extended travel distance of up to 30 m in lieu of the permissible 20 m to the single exit serving the storey at the level of egress (Upper Ground Floor Level) – this item has been increased from the previous value of 22m. This distance has not been addressed in the analysis. f) The OWS Fire Matrix in Appendix L and the Evacuation Strategy in Appendix M need further explanation and justification for appropriateness with the Alternative Solutions. Insufficient information has been provided in order to understand the proposal.	a) A quantitative assessment has been presented in the report with additional smoke detector heads provided within the common corridor spaces to adequately address the travel distances presented in the Class 2 areas. Detectors will be within 1.5 m of SOU doors to justify this shortfall. b) Section has been modified with the electromagnetic locks releasing upon activation of a fire alarm initiating device anywhere within the building. Text provided as follows: 'Any required fire doors which are held open on electromagnetic locks (understood to be only applicable to Building E only) are to disengage upon activation of a fire alarm condition anywhere on site to maintain separation between the different areas.' c) Noted, directional exit signage is required as per the BCA E4.6 as noted in the design requirements of AS4 d) PCA identified distance of 12.25 m for Building B Level 2 Unit B-34. Noted and updated in the revised FER document. e) Noted. A quantitative assessment has been added to show that the inclusion of smoke detectors within the corridors will adequately address the travel distances required in the Class 2 area in upper ground level, over and above DtS. f) A statement has been added in Section 6 referencing Appendix L for the detection and alarm system design requirements
Issue #5 **Extended travel distances in car-parking & loading dock**	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case. b) The offset achieved by the earlier activation of the fast response sprinkler heads does not appear to be greater than the additional travel time in all cases. c) Refer to comments on issue number 12 regarding the impact of jet fans on sprinkler activation which renders the current	**Noted, however we do not concur with all of the commentary provided. Please refer to the following responses in relation to each point made:** a) The DtS distance between alternative exits of 60 m is made up of the following; 20 m to a point of choice and then upon realising that the nearest exit is blocked, enabling the occupant to reach the next nearest exit within 40 m. This is the same as how we have carried out this assessment but with longer travel distances; 30 m to a point of choice, and then up to 70 m to the nearest exit from that point. The distance should not need to allow for the occupant to walk all the way to the exit door, realise it cannot be opened and then have to walk the full 100 m back to the next available exit. That is not the intent of how the BCA is written. Text has been added to the report in Section 11.7.3 to reflect this fact. It should also be noted that this non-compliance occurs on the basement carparking levels which contain six (6) exits in total each.	a) The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case. FRNSW does not agree with the interpretation in the FER of how DtS travel distances are measured. Please see the figure below taken from the Guide to the BCA 2015. b) Refer to comments on issue number 12 regarding the impact of jet fans on sprinkler activation which renders the current analysis invalid. c) As per FRNSW FEB comments, if additional hydrants in	a) This has previously been addressed and discussed. - The DtS distance between alternative exits of 60 m is made up of the following; 20 m to a point of choice and then upon realising that the nearest exit is blocked, enabling the occupant to reach the next nearest exit within 40 m. This is the same as how we have carried out this assessment but with longer travel distances; 30 m to a point of choice, and then up to 70 m to the nearest exit from that point. The distance should not need to allow for the occupant to walk all the way to the exit door, realise it cannot be opened and then have to walk the full 100 m back to the next available exit. That is not the intent of how the BCA is written. Text has been added to the report in Section 11.7.3 to reflect this fact. It should

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
	analysis invalid. d) As per FRNSW FEB comments, if additional hydrants in accordance with Clause 3.2.3.3 of AS2419.1-2005 are necessary to achieve hose coverage - FRNSW recommends that a floor specific block plan be installed adjacent to the internal fire hydrants located within the fire isolated stairwells. The sole purpose of the block plans is to locate the additional internal hydrants on that level by pictorially and numerically illustrating the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the fire safety schedule.	Even if one of the exits were blocked, occupants would be likely to head towards whichever were the nearest exit they could see in the open plan space, rather than going all the way back to the point of choice before making this decision. b) Basement 2 travel distance between alternative exits were incorrectly nominated as being 100 m. This has been addressed in the revised document. All time offsets provided through the provision of fast response sprinklers now more than justify the increased travel distances which have been identified. c) Refer Item #12 below. d) Text added to solution as follows: *'As per recommendations from FFRNSW, block plans to be provided beside hydrant valves within fire stair wherever additional hydrants are deemed necessary to achieve compliant coverage on site. The intent of this requirement is to pictorially and numerically illustrate the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the fire safety schedule.*	accordance with Clause 3.2.3.3 of AS2419.1-2005 are necessary to achieve hose coverage - FRNSW recommends that a floor specific block plan be installed adjacent to the internal fire hydrants located within the fire isolated stairwells. The sole purpose of the block plans is to locate the additional internal hydrants on that level by pictorially and numerically illustrating the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the fire safety schedule. d) The travel distances listed in this analysis are not consistent with those in Section 6.5, and not all travel distances assessed are listed in Section 6.5. Slightly different distances are nominated throughout the analysis also. The distances should be consistent throughout the report.	also be noted that this non-compliance occurs on the basement carparking levels which contain six (6) exits in total each. Even if one of the exits were blocked, occupants would be likely to head towards whichever were the nearest exit they could see in the open plan space, rather than going all the way back to the point of choice before making this decision. b) Jet Fans to be addressed through improved detection spacing in accordance with AS1670.1-2015. Immediate Jet Fan shutdown will be included. The provision of this detection on the basement levels will expedite the alarm times considerably on these floors, over and above the fast response vs. standard response sprinkler activation assessment currently within the FER. c) This requirement was already included. No action required -Text added to solution as follows: *'As per recommendations from FFRNSW, block plans to be provided beside hydrant valves within fire stair wherever additional hydrants are deemed necessary to achieve compliant coverage on site. The intent of this requirement is to pictorially and numerically illustrate the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the fire safety schedule.* d) Noted – Travel Distances have been corrected where needed in the report for consistency.
Issue #6 **Extended travel distances in the Class 9b areas**	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case.	**WSP do not agree with the commentary put forward here. Please refer to the following:** a) The DtS distance between alternative exits of 60 m is made up of the following; 20 m to a point of choice and then upon realising that the nearest exit is blocked, enabling the occupant to reach the next nearest exit within 40 m. Although we have extended these distances as part of the Alt Sol, the total distance when discussing the distance between alterantive exits should not need to allow for the occupant to walk all the way to the exit door, realise it cannot be opened and then have to walk the full 80 m back to the next available exit. That is not the intent of how the BCA is written. It should also be noted that the largest time increase which comes as a result of extended travel distances identified in this Alt Sol is 25 seconds, whereas we have reduced alarm activation times by 30 – 52 seconds, depending on which area is being studied. No further assessment is deemed necessary as a result.	The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case. FRNSW does not agree with the interpretation in the FER of how DtS travel distances are measured. Please see the figure below taken from the Guide to the BCA 2015.	a) This has previously been addressed and discussed. - The DtS distance between alternative exits of 60 m is made up of the following; 20 m to a point of choice and then upon realising that the nearest exit is blocked, enabling the occupant to reach the next nearest exit within 40 m. Although we have extended these distances as part of the Alt Sol, the total distance when discussing the distance between alternative exits should not need to allow for the occupant to walk all the way to the exit door, realise it cannot be opened and then have to walk the full 80 m back to the next available exit. That is not the intent of how the BCA is written. It should also be noted that the largest time increase which comes as a result of extended travel distances identified in this Alt Sol is 25 seconds, whereas we have reduced alarm activation times by 30 – 52 seconds, depending on which area is being studied. No further assessment is deemed necessary

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
				as a result.
Issue #7 **Discharge of fire-isolated stairs (Blocks E & F)**	**Satisfied**	**Noted**	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) The revised layout of this area has changed access and egress from the pump room. This includes an increased distance of travel to exit from the pump room, and the inclusion of access to the generator room from the same corridor, which introduces additional hazards. These changes do not facilitate safe access and egress for fire fighters to and from the pump room and may pose a risk to occupants evacuating via this corridor.	a) Access to the hydrant pump room has not changed since issue of revision 1 FER. This has been addressed and approved by FRNSW previously in section 15.7.2 in both revision 1 and 2 of the report. Although the FER requires bounding walls achieving an FRL of 90/90/90 complete with self-closing -/60/30 fire doors. WSP recommend the doors to generator room be relocated to a location other than into this corridor.
Issue #8 **Discharge of exits into a covered space**	**Satisfied**	**Noted**	**Satisfied**	N/A
Issue #9 **Location of fire brigade facilities**	**Conditionally satisfied** a. All signage associated with equipment used by attending fire fighters, such as indicating access to the FIP and access to pump and valves rooms should be readily viewable from the street. b. The red strobes identifying the location of the FIP and the booster assembly should be clearly visible from the street.	**Additional design requirements added to the FER** - Signage design requirements to be modified to be visible from Evans Street (section 6.4) - Red strobe light for booster is visible from Evans Street - FIP red strobe light is located at the FIP which is not visible from the street, the strobe will be visible on approach to the main entry of the building and signage directing the attending brigade personnel will be visible from the street.	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) The revised layout of this area has changed access and egress from the pump room. This includes an increased distance of travel to exit from the pump room, and the inclusion of access to the generator room from the same corridor, which introduces additional hazards. These changes do not facilitate safe access and egress for fire fighters to and from the pump room. b) All signage associated with equipment used by attending fire fighters, such as indicating access to the FIP and access to pump and valves rooms should be readily viewable from the street. c) The red strobes identifying the location of the FIP and the booster assembly should be clearly visible from the street. d) The requirement "The above requirement is be added to the Annual Fire Safety Statement for the building with the Building Management to inspect the leisure lobby areas on a monthly basis to ensure that the required fire safety measure is being adhered too." In Section 6.4 of the FER has been moved out of location and now refers to a different requirement. e) Figure 37 hasn't been updated and is not consistent with Figure 28. f) The door providing access to the fire isolated passageway entrance providing access to the Fire Hydrant & Pump Room should be provided with signage to indicate that this door provides access to the Fire Hydrant & Pump Room. This should be provided in accordance with AS2419.1-2005 and any other relevant NCC clauses and Australian Standards.	a) Access to the hydrant pump room has not changed since issue of revision 1 FER. This has been addressed and approved by FRNSW previously in section 15.7.2 in both revision 1 and 2 of the report. Although the FER requires bounding walls achieving an FRL of 90/90/90 complete with self-closing -/60/30 fire doors. WSP recommend the doors to generator room be relocated to a location other than into this corridor. b, c) This requirement was already included, as per the following. - Signage design requirements to be modified to be visible from Evans Street (section 6.4) - Red strobe light for booster is visible from Evans Street - FIP red strobe light is located at the FIP which is not visible from the street, the strobe will be visible on approach to the main entry of the building and signage directing the attending brigade personnel will be visible from the street. d) Noted. Bullet point transferred in correct position. e) Noted and updated as per Figure 28 of the report. f) Noted. Requirements has been added in the Alternative Solution and in Section 6.4 of the updated FER.
Issue #10 **Fire hydrant system**	**Satisfied**	**Noted**	**Satisfied**	**Noted**

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
Issue #11 **Indoor pool area & fire measures**	**Satisfied**	**Noted**	**Satisfied**	**Noted**
Issue #12 **Impulse fans in basement carparks**	**FRNSW is not satisfied that the alternative solution will meet the performance requirements it is intended to meet.** a) Issue number 5 relies on the use of fast response heads to offset the extended travel distances, whereas the analysis in issue number 1o shows that this sprinkler activation is delayed by the jet fans. This therefore renders the analysis of extended travel distances invalid. b) The extended travel distances from issue number 5 need to be considered in the RSET, including FRNSW comments on addressing the distance of travel between alternative exits. Refer to FRNSW comments on issue number 5. c) The evaluation of queuing time does not consider the progressive blocking of exits as the areas become untenable. This will increase travel distances for some occupants and also increase queuing time at exits that are available, and needs to be addressed in the evaluation of RSET. d) Not all requirements / recommendations from FRNSW Guideline (Refer to FRNSW Guideline at http://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/impulse_fans_in_carparks.pdf) have been incorporated, for example the requirement to locate jet fans between rows of sprinkler heads and in driveways only.	**Noted, however we do not concur with all of the commentary provided. Please refer to the following responses in relation to each point made:** a) Text included in Alt Sol stating the following: *The impulse fans shall have in-built duct smoke detectors. These smoke detectors are required to be connected to FIP. On activation of any of these smoke detectors, all the impulse fans on the fire-affected floor shall be switched off automatically and remain switched off unless manually reset at FIP and the building occupant warning system shall be activated.* Given smoke detectors operate much earlier in the timeline of a fire scenario than a sprinkler head would, the effect these jet fans could have on sprinkler operation times is therefore deemed to have been addressed. b) As per Section 6.2.6 of the CFD report (Appendix H) the ceiling height used on the two basement levels was considerably lower than is being constructed on site to both simplify the geometry of the model, and to enable the boundaries of the model to align with the mesh size used. Basement 2 was modelled with a uniform 2.5 m ceiling height (in lieuof the actual height of 2.7 m) and Basement 1 was modelled with a 3 m ceiling height (in lieu of a ceiling which ranged between 3 and 4.4 m across the floorplate). It should also be noted that two exits are stil available at 500 seconds which is where we place the cutoff of tenable conditions in each scenario, with one exit (ST03) still then being available 1000 seconds into the analysis. No reference is made to these points in the CFD appendix at present. Occupants would move towards the available exits as smoke migrated across the floor. The fact that two exits are still available at the 500 second cut off time we show in the report more than covers the travel distance issues noted by FRNSW. c) Refer item b) above for commentary relating to this issue. d) Noted. Text added to solution noting the following *'Sprinklers within the basement levels are to be arranged so that no heads are in the direct path of airflow from the fan to prevent potential delays in activation. For further details please refer to Figure 14 of Appendix H of this report'*. This was also noted in Appendix H Table 6 Item 2 for clarity.	a) FRNSW have reviewed the responses provided in Appendix B of the FER to the previous IFSR issued by FRNSW. FRNSW do not agree with the comment that the provision of smoke detectors addresses the impact on sprinklers as this has not been verified. Whilst it is acknowledged smoke detectors will operate earlier than sprinklers, there is still the potential for different air movements to exist at sprinkler heads which may delay sprinkler activation. The CFD Report in Appendix H of the FER demonstrates that there is a delay in activation of the sprinklers (up to 35 seconds). This therefore needs to be considered in the analysis of Issue Number 5 as it reduces the earlier activation time of the fast response sprinklers. Also, the actual impact of delaying sprinkler operation by 35 seconds has not been discussed and addressed. b) Refer also to FRNSW comments on issue number 5. c) FRNSW reiterate other comments from the previous IFSR that need to be considered. These include: i) The extended travel distances from issue number 5 need to be considered in the RSET, including FRNSW comments on addressing the distance of travel between alternative exits. ii) The evaluation of queuing time does not consider the progressive blocking of exits as the areas become untenable. This will increase travel distances for some occupants and also increase queuing time at exits that are available, and needs to be addressed in the evaluation of RSET. d) The travel speed of 1.2 m/s in the calculation of RSET in the CFD Report in Appendix H of the FER has not been revised to 0.8 m/s as used in Issue Number 5. e) Not all requirements / recommendations from FRNSW Guideline (Refer to FRNSW Guideline at http://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/impulse_fans_in_carparks.pdf) have been incorporated in the design requirements of Section 6 of the FER, for example the requirement to locate jet fans in driveways only and testing requirements. f) FRNSW Guideline recommends that "The detection system should only shut down the impulse fan system and not activate the occupant warning system or fire brigade notification unless it is appropriate to use within a car park environment and would not cause spurious alarms." It is acknowledged that the current proposal is to have the occupant warning system activated from the activation of detectors within the impulse fans, however it has not been demonstrated whether these are appropriate for a car parkenvironment to mitigate the issue of spurious alarms. Should the detectors be considered inappropriate for such operation, the impact on the alternative solution, including a delayed activation of the occupant warning system to that currently assumed, would need to be addressed. g) Item 5 from Table 6 of the CFD Report in Appendix H of the FER has not been adequately addressed. Reference to	WSP believe there may be a misinterpretation by FRNSW that the jet fan system is proposed to continue operation in fire mode based on the considerable comments provided here. a) Jet Fans issue noted has been addressed through improved detection spacing in accordance with AS1670.1-2015 figure 7.5.2.2 (c) within the basement areas. Immediate Jet Fan shutdown will occur upon activation of one of these heads on this floor, in addition to these detectors operating the BOWS on this floor (as per AS5 of the report) We also have a sensitivity assessment in the CFD report where a 4 MW fire was allowed for. This more than covers the 35 second delay which the jet fan operation may provide. b) Comments regarding issue 5 have been addressed in AS5 as noted. c) i) Refer updated AS5 as noted above. ii) Based on population numbers expected at any time within a car-park, queuing times do not have any significant effect on evacuation times, given quantity of exits available. d) CFD modelling report has now been updated to reflect revised travel speed. e) Noted. Documentation has been reviewed and missing items were added in revised FER (namely the provision of jet fans should only occur in driveway areas). f) Noted. Additional smoke detector heads with lower sensitivity will be provided at 15 m spacing as per AS 1670.1:2015. Upon activation of any detector within the space, the fans will be shut down automatically and the alarm will sound to initiate evacuation of the fire affected level. It is noted at this point that Fire Brigade will not receive a signal upon activation of those detector heads but when a sprinkler head activates within the car-park areas they will. It is noted that this will improve the required egress time for occupants present within the car-park levels over and above the reduction in alarm times offered from a fast response vs. standard response sprinkler activation assessment as was provided previously. g) Noted. Text now added to the design requirements of AS12 stating the following:

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
			AS1668.1 is not sufficient, as the proposal is dealing with a system that does not comply with the standard, and additional testing requirements should be specified to adequately test the system. h) FRNSW do not agree with the tenability criteria in the CFD report. Convective temperature should be measured at head height irrespective of the height of the hot layer, as the air may be heated by the hotlayer or fire itself. Also, FRNSW consider that visibility should be measured to non-illuminated objects for all aspects of visibility, even when queuing at exits. Toxicity has not been addressed in the analysis. i) The CFD Report in Appendix H of the FER requires further CFD results to demonstrate realistic fire temperatures are being achieved. j) No description is provided as to how the shut down time of jet fans is determined for fire scenarios 4 to 9 in the CFD Report in Appendix H of the FER. Similarly, no details are provided on how the detection times in Table 16 of the CFD Report have been determined. k) Section 6.2.1 of the FER notes that “The supply fans and exhaust fans are kept running and ramp to full speed if on variable speed drive (VSD)”, however it does not state when this is to occur. l) FRNSW do not consider the fire growth rate and peak fire sizes to be appropriate to resemble a car fire in a sprinklered carpark. Based on the results of other testing, it is considered a more conservative value should be used for the fire growth rate and peak fire size (a minimum of 2.5 MW is considered applicable for a single car fire). This is also demonstrated in the figure from the BRE report referenced in the CFD Report which shows peak heat release rates above 1.5MW. (b) FRNSW is not satisfied that the fire hydrants in the proposed fire hydrant system will be accessible for use by FRNSW. (c) FRNSW is conditionally satisfied that the couplings in the system will be compatible with those of the fire appliances and equipment used by FRNSW.	‘Testing of the mechanical system serving the carpark level shall consist of verifying that upon activation of a fire initiating device (detector, flow switch, etc.) all jet fans shall cease operation on both carpark floors simultaneously. The carpark supply and exhaust system shall then ramp up to full speed operation, as per AS 1668.1. h) Please note that the tenability criteria set in the CFD report have been derived from IFEG, CIBSE Guide E and are referenced in other relevant fire safety codes / publications. Please also note that the CFD report as well as the FER document have been peer reviewed by another fire engineering consultancy with an accredited C10 fire engineer who are in agreement with WSP’s proposal. The temperature and visibility levels have been measured at head height and the results are presented in Section 7 of the CFD report. No further action is required in regards to this item. i) The results presented are well within the tenability criteria set in Table 6 of the CFD report at the end of the simulation (1000 seconds) following a significant amount of time that the fire was at steady state phase – giving enough time for temperatures to buit up. The results presented for each scenario are showing the highest temperatures achieved and given that the tenability limits are not exceeded no further assessment needs to be presented. An additional slice file has been added to the FER section 12 (Figure 50) which shows the section of the design fire in the basement is over 550 ºC. j) Please refer to Table 11 of the CFD report. As described in the table, depending on the fire location the models are looking at when the smoke detectors within the jet fans will activate which in turn will automatically turn off the fans. k) Please note this is in relation to the car-park exhaust system rather than the impulse fans. The subject statement is applicable to the supply and exhaust fans of the fire affected floor. Revised text now states the following: ‘The supply fans and exhaust fans are kept running and ramp to full speed if on variable speed drive (VSD) in the event of a fire being detected within the building (in relation to the supply/exhaust riser fans serving the basement levels – not the jet fan system).

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
				l) Agreed, however, please note that the test results presented by BRE and Branz show fire decay phase whilst the CFD scenarios presented remain at steady state phase for the duration of the simulations. As shown in the graphs presented in the CFD report from the studies referenced, fire sizes don't peak until well after the 15 minutes time limit set in the modelling assessment. At that stage occupants would have evacuated the premises with RSET values not greater than approximately 9 minutes. Further to the above, sensitivity scenario FS#6 modelling a 4MW fire size demonstrates that occupants have evacuated the premises within 8 minutes (1.5 safety factor included), whilst at the end of the simulation ST03 is still available with the south side of the fire affected floor being unaffected from smoke. b) Fire Hydrants are accessed via the fire-siolated stairs. This in accordance with AS 2419.1. c) Noted.
Issue #13 **Location of fire control centre**	**N/A**	**N/A**	**Satisfied**	**N/A**
Issue #14 **Connection of four storeys with an open stair**	**N/A**	**N/A**	**Conditionally satisfied** a. The water supply to the wall-wetting drencher system should be separately valved and independent to the sprinkler system serving the fire compartments concerned. Suitable management provisions should be included to ensure that both the sprinkler system and wall-wetting drencher system are not isolated at the same time. b. The proposed glazing is to be appropriately protected from mechanical damage (i.e.bollards are to be provided to all glazing where any chance of mechanical damage may occur). c. The hydraulic requirements for the proposed wall-wetting protection, such as required water flow rates, number of heads required to activate simultaneously / area of operation, required	a. This requirement was already included. No action required - Isolation of both systems simultaneously for maintenance purposes shall not be allowable. This is to be included in the management in use plan (Section 6.6). b. This requirement was already included. No action required - The proposed glazed construction shall be provided with protection from mechanical damage, this is to be in the form of vehicle protecting permanent bollard system that is suitable . (Section 6.3) c. This level of detail will be required for the fire protection designers. Details will be

FEBQ Ver 01 reference	IFSR 1 FRNSW comment	WSP Response	IFSR 2 FRNSW comment	WSP Response
			duration of water supply, etc is to be detailed. This should consider and address simultaneous activation with the sprinkler and hydrant systems to ensure an adequate water supply is provided. This should also be demonstrated as adequate to provide an equivalent amount of protection to that of a fire-rated wall achieving an FRL as required by the DtS Provisions of the BCA. All items should be justified in the analysis. d. Not all requirements of the glazing and wall-wetting system proposed have been included in the design requirements in Section 6. These should be included to ensure that the requirements are included in the design and installation and maintained throughout the life of the building. e. The reference to Figure 32 in Section 20.5 is incorrect. f. Figure 45 indicates that the fixed glazing is protected with internal wall-wetting sprinklers as per Clause C3.4 whereas the text in the assessment states the glazing be protected on both sides. FRNSW consider that the Tyco window sprinkler system proposed, or equivalent, be used with protection provided on both sides.	included where possible in the revised FER document. d. Noted. Section has been updated with all relevant requirements now being listed. e. Noted f. Both sides will be protected as noted.

Appendix C Sprinkler Reliability Research

C.1 Introduction

In the event of a fire the sprinkler system is expected to control, if not suppress the fire. A fire sprinkler system dramatically reduces the likelihood of a large fire developing in a building. Furthermore, by controlling the fire size, the amount of smoke produced is correspondingly also limited. In addition, the sprinkler water spray cools the smoke and acts to wet adjacent combustibles and partitions helping to prevent the fire from spreading beyond the area of origin. When the sprinkler system operates successfully the fire resistance of building elements is largely irrelevant as the fire is not expected to grow large enough to compromise the structural integrity of the building.

Hence the provision of sprinklers in a building dramatically enhances life safety, property protection and fire brigade intervention. Where the sprinkler system operates successfully, occupant and fire fighter safety and the integrity of building elements is maintained which reduces the threat to occupants, property damage and the attending fire brigade.

C.2 Reliability and efficiency of fire sprinklers

Statistics from the National Fire Protection Association (NFPA) by [Hall] provides recorded statistics on buildings fitted with automatic fire sprinkler systems between the years 2003-2007 in United States. Based on the NFPA's data, when sprinklers operate, they are effective 97 % of the time, resulting in a combined performance of operating effectively in 91 % of all reported fires where sprinklers were present in the fire area and the fire was large enough to activate them. The reliability of sprinkler system in Australia and New Zealand as researched by [Marryatt] is generally significantly higher than in the US. Sprinkler reliability in the UK has been estimated to be up to 95 % whilst in Australia it has been estimated to be up to 99 % as researched by [Bukowski]. Therefore, the likelihood of sprinklers not activating is considered to be low.

C.3 Impact of sprinklers on fire spread

Fire statistics and full scale experiments conducted by [Bennetts] have demonstrated that sprinklers are effective in extinguishing or confining fire spread to the room of origin, or within a large compartment to the sprinkler design area. The reason for this lies in the fact that sprinkler design standards are regularly updated to reflect the latest fire experiences, developments in sprinkler technology and evolving fire hazards resulting from new materials / storage arrangements.

The National Fire Protection Association (NFPA) as researched by [Hall] provides statistics on building fires in the United States from 2006 to 2010, with an automatic fire sprinkler system installed. The report determined that when sprinklers operate, they are effective 97 % of the time, resulting in a combined performance of effective operation in 89 % of all reported fires where sprinklers were present in the fire area and the fire was large enough to activate them. The results from this study are shown in Figure 1 below for various occupancies.

B. Wet Pipe Sprinklers Only

Property Use	Number of fires per year where sprinklers were present	Non-confined fires too small to activate equipment	Fires coded as confined fires	Number of qualifying fires per year	Percent where equipment operated (A)	Percent effective of those that operated (B)	Percent where equipment operated effectively (A x B)
All public assembly	2,820	490	1,780	550	92%	95%	87%
Eating or drinking establishment	1,260	250	680	330	94%	94%	88%
Educational property	1,810	410	1,220	180	85%	97%	82%
Health care property*	2,970	640	2,030	300	89%	98%	87%
All residential	25,250	2,300	19,420	3,540	95%	98%	92%
Home (including apartment)	19,840	1,250	16,240	2,350	95%	97%	93%
Hotel or motel	1,680	350	1,060	270	91%	98%	89%
Store or office	3,650	1,040	1,630	980	91%	97%	88%
Grocery or convenience store	730	230	330	160	90%	97%	88%
Department store	410	170	130	120	90%	97%	87%
Office	930	230	540	160	89%	99%	88%
Manufacturing facility	2,290	630	700	960	91%	95%	86%
All storage	600	130	210	260	86%	98%	84%
Warehouse excluding cold storage	340	80	90	170	87%	97%	85%
All structures**	41,680	5,960	28,660	7,050	92%	97%	89%

* Nursing home, hospital, clinic, doctor's office, or development disability facility.
** Includes some properties not listed separately above.

Figure 1: Wet pipe sprinkler effectiveness by property use 2006-2010 Structure Fires.

Although these statistics relate to sprinkler systems in the U.S., it is expected that the performance and reliability of sprinkler systems in Australia will be equivalent or better as [Marryatt] reports a sprinkler efficiency value of 99.5 % for sprinkler systems in Australia, and [Bennetts] a value of 98.5 % for low rise shopping centres in Australia.

C.4 Impact of sprinklers on fire intensity

The effectiveness of sprinkler systems to control fire intensity is also demonstrated by the NFPA study undertaken by [Hall] which reports that flame damage is reduced on average by 34 % when sprinklers are installed. Furthermore, it was found that more than 85 % of light /ordinary hazard occupancies building fires are controlled by 2 sprinklers, and more than 93 % by 4 sprinklers or less.

This is supported by research conducted in Taiwan by [Lai], which demonstrated that one operating sprinkler was able to prevent flashover in a full scale fire office experiment. Temperatures in the fire-affected room ranged between 200 °C and 400 °C which are too low to cause any structural fire damage. Outside the immediate vicinity of the fire and beyond the fire room, gas temperatures will decrease until the gas temperature is below the sprinkler activation temperature as more sprinklers will activate. Also, the National Research Council of Canada (NRC) based on studies conducted by [Lougheed], estimates that four operating sprinklers are likely to control a shielded fire in a typical retail shop to 2.5 MW when four or less sprinklers operate.

C.5 Impact of sprinklers on life safety

The NFPA study conducted by [Hall] also indicates that an automatic sprinkler system has a significant impact on life safety by reducing the number of fatalities in fires. As demonstrated by the figure below (repeated from the referenced document), sprinklers significantly reduce the number of fatalities in a fire when the system operates as intended.

Property Use	Without automatic extinguishing equipment	With wet pipe sprinklers	Percent reduction
All public assembly	0.5	0.0	100%
Residential	7.3	1.1	85%
Home (including apartment)	7.3	1.3	83%
Boarding or rooming house	9.2	1.7	81%
Hotel or motel	7.2	0.0	100%
Residential board and care home	8.3	2.1	75%
Dormitory or barracks	1.1	0.0	100%
Store or office	1.5	0.4	72%
Manufacturing facility	1.8	0.5	69%
Warehouse excluding cold storage	3.0	3.2	No reduction
All structures	6.2	0.9	86%

Figure 2: Estimated reduction in civilian deaths per thousand fires associated with wet pipe sprinklers, by property use 2006-2010 Structure Fires.

The above statistics is supported by evidence provided by [Nystedt] from several full scale experiments that showed that fire effluents from a sprinklered fire is generally not a threat to life. Although visibility was found to be reduced at sprinkler actuation, it was concluded that sprinklers are able to fully protect people outside the room of origin and the system also provide protection to those inside the room of origin who are not intimately involved with the fire.

This is further supported by a study conducted [Madrzykowski] (by NIST in the USA) to investigate and quantify sprinklered fire exposure on an exit corridor and spaces adjacent to that corridor. The aim was to collect data to support the appraisal of conditions in building corridors and to assess exposures for occupants who may be unable to evacuate the fire floor and have to take refuge in their apartments or other spaces on the fire floor. The study compared the conditions in a test facility due to a 1 MW crib fire with those of a fire under control by a sprinkler. The test facility consisted of a burn room, a target room and a corridor connecting the two rooms. A 0.46 m wide by 1.52 m high opening was provided between the corridor and the burn room. The target room was protected using a simulated "standard door" (6 mm top cut, 6 mm side cut and a 13 mm undercut). Gas temperatures and concentrations of oxygen, carbon dioxide, and carbon monoxide were measured at selected points' in the three rooms. Tenability was assessed using both temperature and gas toxicity criteria. This assessment showed that sprinklers maintained tenable conditions outside the room of fire origin, both within the corridor and within the target room. Results from that study are presented in Figure 3 below.

SPRINKLER IN BURN ROOM				
TEST No.	6	7	8	9
BURN ROOM	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	12.9 %	13.3 %	*	15.5 %
CO_2 (MAX)	7.2 %	6.7 %	*	4.1 %
CO (MAX)	0.6 %	0.5 %	*	*
Temp @ 1.5m (MAX)	202°C	140°C	95°C	48°C
CORRIDOR	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	17.8 %	17.7 %	18.6 %	18.2 %
CO_2 (MAX)	2.4 %	2.5 %	1.8 %	2.3 %
CO (MAX)	*	*	*	*
Temp @ 1.5m (MAX)	40°C	28°C	23°C	22°C
TARGET ROOM	SHIELDED FIRE		UNSHIELDED FIRE	
	S.S.	Q.R.S.	S.S.	Q.R.S.
O_2 (MIN)	20.7 %	20.8 %	20.9 %	20.8 %
CO_2 (MAX)	0.4 %	0.3 %	0.2 %	0.2 %
CO (MAX)	< 0.1 %	< 0.1 %	< 0.1 %	< 0.1 %
Temp @ 1.5m (MAX)	25°C	25°C	25°C	24°C

Figure 3: Results from tests conducted by [Madrzykowski] (NIST in the USA)

Appendix D Detector Activation Models

D.1 Sprinkler Activation Model

The change in temperature of a sprinkler sensing element in a ceiling jet is determined from the two-parameter sprinkler activation model developed by [Heskestad] is defined by:

$$\frac{dT_s}{dt} = \frac{\sqrt{U}}{RTI}\left[(T - T_0) - \left(1 + \frac{C}{\sqrt{U}}\right)(T_s - T_0)\right]$$

Equation 1

Alpert's ceiling jet correlations (developed by [Alpert]) are used to estimate the maximum ceiling jet excess temperature and velocity:

$$T - T_o = 16.9\frac{\dot{Q}^{2/3}}{H^{5/3}} \qquad for\ \frac{r}{H} \leq 0.15$$

$$T - T_o = 5.38\frac{\dot{Q}^{2/3}/H^{5/3}}{(r/H)^{2/3}} \qquad for\ \frac{r}{H} > 0.18$$

$$U = 0.95\left(\frac{\dot{Q}}{H}\right)^{1/3} \qquad for\ \frac{r}{H} \leq 0.15$$

$$U = 0.20\frac{(\dot{Q}/H)^{1/3}}{(r/H)^{5/6}} \qquad for\ \frac{r}{H} > 0.15$$

Equation 2

where

$\frac{dT_s}{dt}$	change in sensor temperature over time (°C/s)
U	gas speed at the sensing element (m/s)
RTI	Response Time Index of the element ($(m \cdot s)^{1/2}$)
T	gas temperature (°C)
T_0	ambient temperature (°C)
C	conduction factor ($(m/s)^{1/2}$)
$\dot{Q}$	heat release rate (kW)
H	ceiling height (m)
r	radial distance of sensor from fire (m)

The conduction factor C and the RTI can be estimated for the various sprinkler response types from Figure 1 below (taken from AS 4118.1).

The slowest response for a listed fast response sprinkler is obtained for an RTI of 50 $(m/s)^{1/2}$ and a C-factor of 0.8 $(m/s)^{1/2}$.

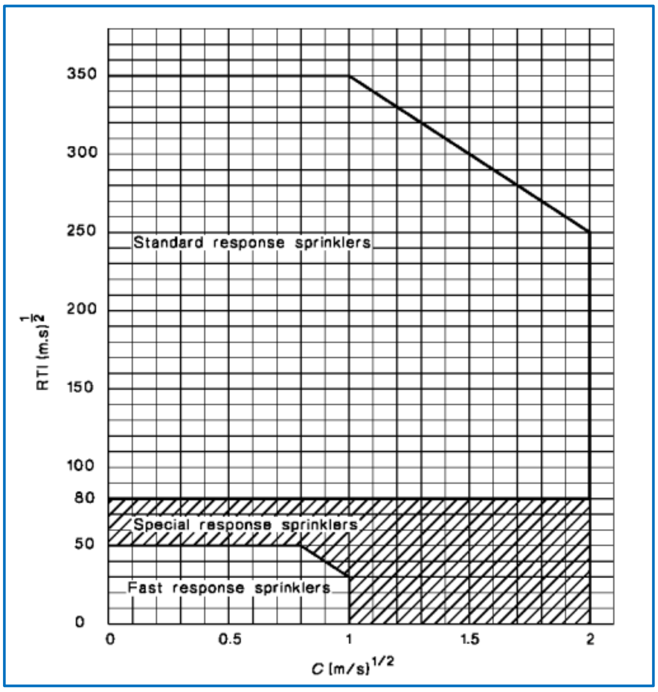


Figure 1: Standard orientation sprinkler RTI and C limits.

D.2 Smoke Detector Activation

The activation time of smoke detectors is difficult to predict as there are a large range of variables that play a role; smoke detectors differ in operating principle, design, are sensitive to the mode of combustion, ventilation and the like. In addition, detection technology is also continuously advancing. Despite these difficulties, various generic methods are in use for the estimation of detector activation time. In this analysis, the constant temperature rise method will be used. This method assumes that the detector will activate when the temperature of the smoke at the location of the detector has increased by a certain value. For smouldering fires this value has been found be in the range between 1 °C – 3 °C as researched by [Geiman]. For flaming fires, it was found that 90 % of smoke detectors activated before the temperature at the detector rose by more than ~16 ºC.

The activation of a smoke detector is therefore predicted from Equation 2; with detector activation assumed to occur at a gas temperature of 16 ºC above ambient.

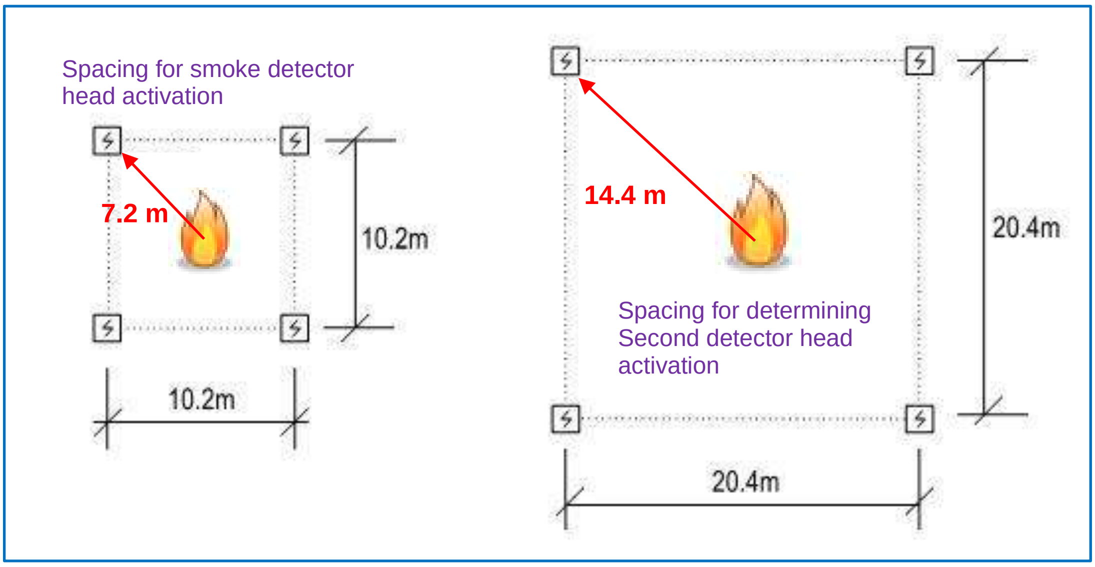


Figure 2: Standard smoke detector spacing under AS1670.1

D.3 Smoke Detector Calculation Results

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 4: Extended TDs in Residential Common Corridors - Reference Design
Date: 27/03/2017

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	2.4	m
Fuel height	0.5	m
Detector spacing	2.1 x 2.1	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	42	s
Fire size at detector activation	21	kW

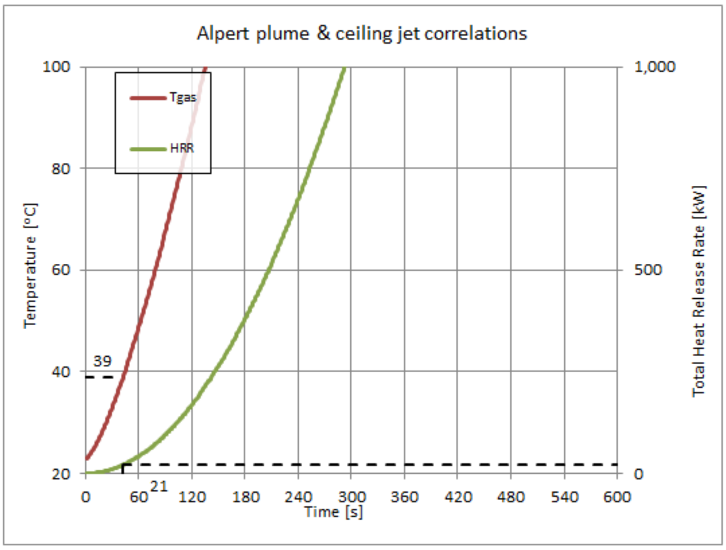


Figure 3: Calculation of Smoke Detector Activation Time – Proposed Design (Common Corridor)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 4: Extended TDs in Residential Common Corridors - Reference Design
Date: 27/03/2017

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	2.4	m
Fuel height	0.5	m
Detector spacing	10.2 x 10.2	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	91	s
Fire size at detector activation	97	kW

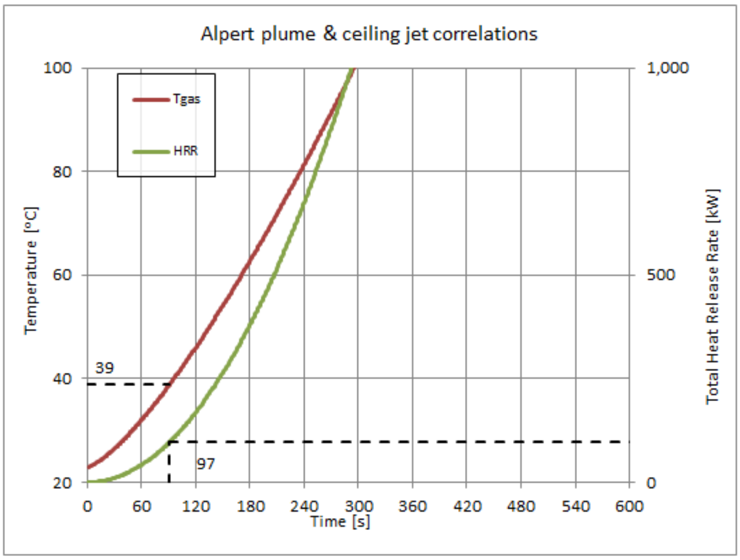


Figure 4: Calculation of Smoke Detector Activation Time – Reference Design (Common Corridor)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Community Club - Proposed Design
Date: 4/09/2015

INPUT

Design fire	
Growth time*	150 s
Convective fraction	0.70
Geometry	
Ceiling height	4.0 m
Fuel height	0.5 m
Detector spacing	10.2 x 10.2 m
Use 2nd row Detector?	☐
Smoke Detector	
Room temperature	23 °C
Activation temperature	39 °C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at detector activation	72 s
Fire size at detector activation	243 kW

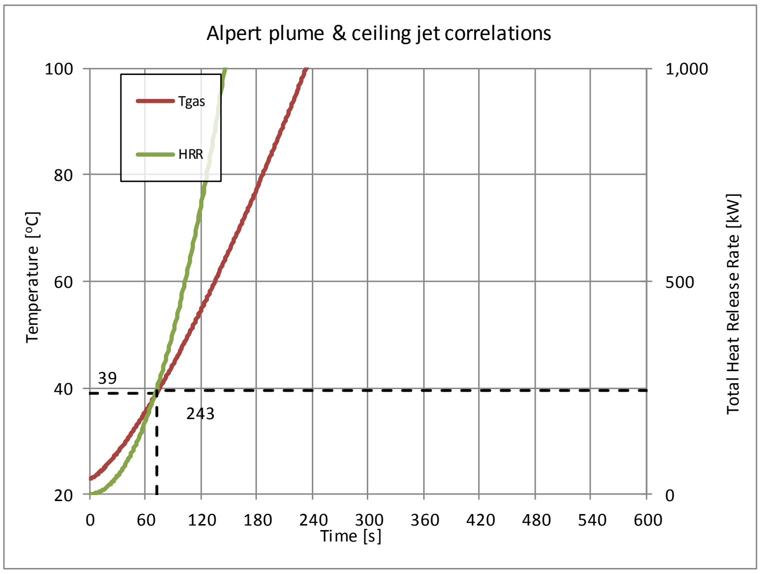


Figure 5: Calculation of Smoke Detector Activation Time – Proposed Design (Community Club)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Community Club - Reference Design
Date: 4/09/2015

INPUT

Design fire	
Growth time*	150 s
Convective fraction	0.70
Geometry	
Ceiling height	4.0 m
Fuel height	0.5 m
Detector spacing	20.4 x 20.4 m
Use 2nd row Detector?	☐
Smoke Detector	
Room temperature	23 °C
Activation temperature	39 °C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at detector activation	102 s
Fire size at detector activation	488 kW

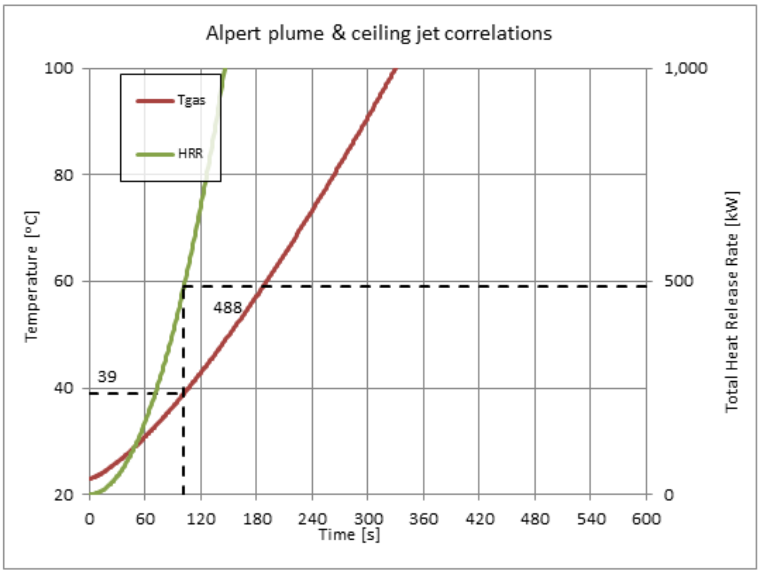


Figure 6: Calculation of Smoke Detector Activation Time – Reference Design (Community Club)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Gym - Proposed Design
Date: 4/09/2015

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	3.2	m
Fuel height	0.5	m
Detector spacing	10.2 x 10.2	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	118	s
Fire size at detector activation	163	kW

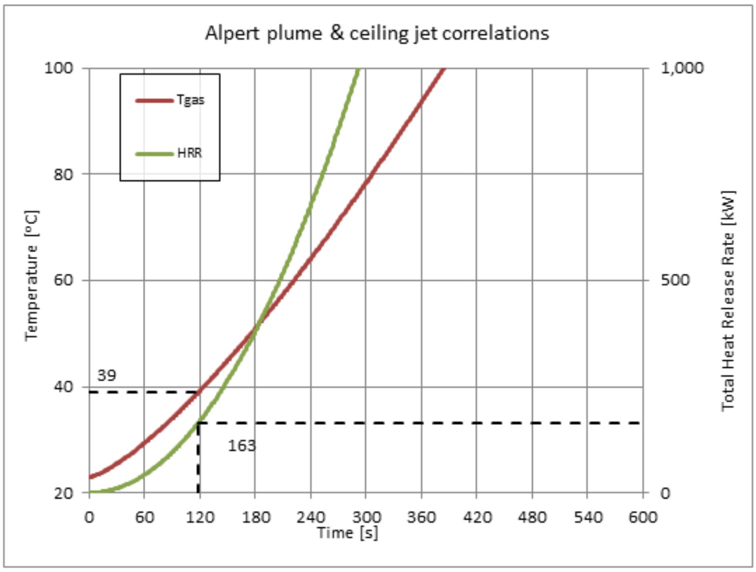


Figure 7: Calculation of Smoke Detector Activation Time – Proposed Design (Gym)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Gym - Reference Design
Date: 4/09/2015

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	3.2	m
Fuel height	0.5	m
Detector spacing	20.4 x 20.4	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	167	s
Fire size at detector activation	327	kW

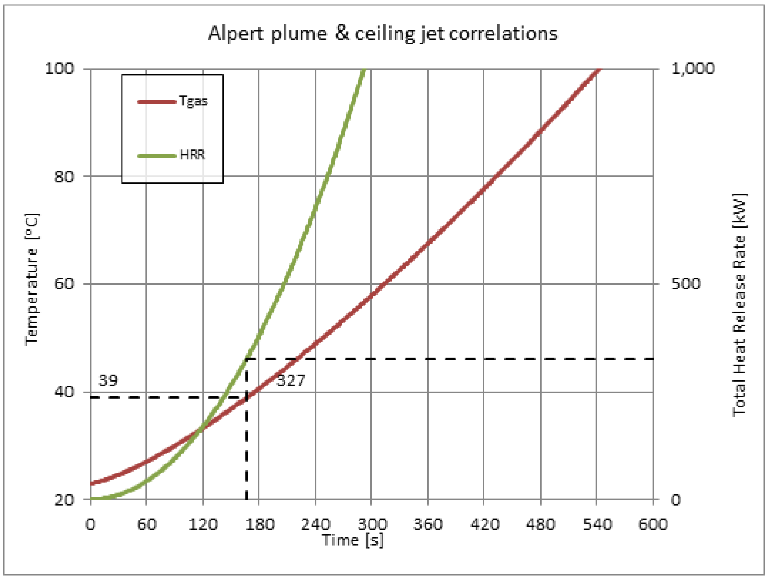


Figure 8: Calculation of Smoke Detector Activation Time – Reference Design (Gym)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Aquatic Centre - Proposed Design
Date: 4/09/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.8 m
Fuel height	0.5 m
Detector spacing	10.2 x 10.2 m
Use 2nd row Detector?	☐
Smoke Detector	
Room temperature	23 °C
Activation temperature	39 °C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at detector activation	138 s
Fire size at detector activation	223 kW

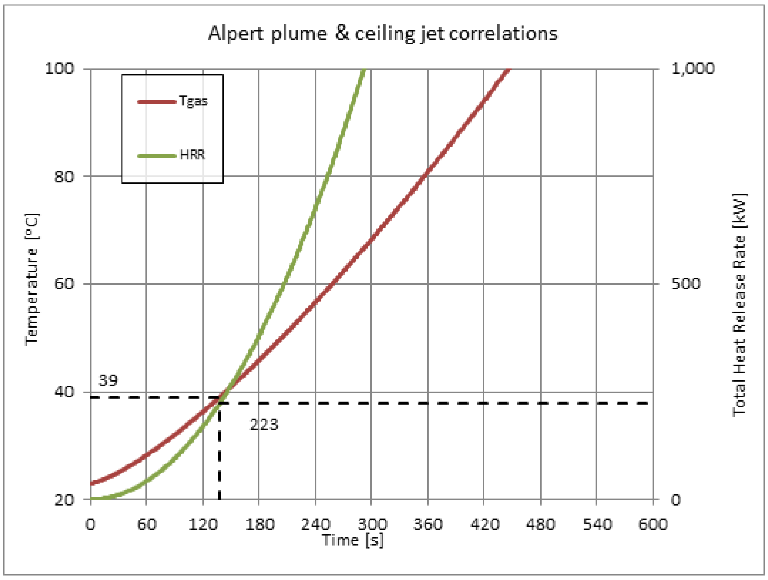


Figure 9: Calculation of Smoke Detector Activation Time – Proposed Design (Aquatic Centre)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 6: Extended TDs in Aquatic Centre - Reference Design
Date: 4/09/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.8 m
Fuel height	0.5 m
Detector spacing	20.4 x 20.4 m
Use 2nd row Detector?	☐
Smoke Detector	
Room temperature	23 °C
Activation temperature	39 °C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at detector activation	194 s
Fire size at detector activation	441 kW

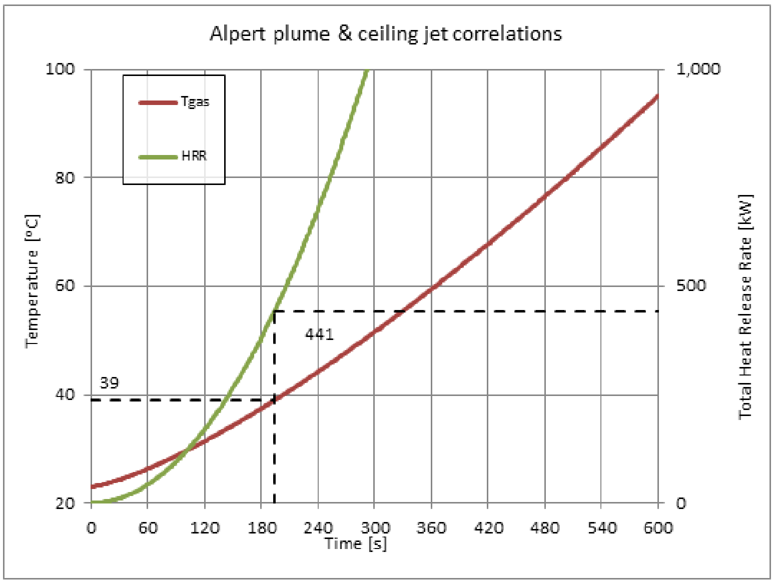


Figure 10: Calculation of Smoke Detector Activation Time – Reference Design (Aquatic Centre)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended TDs in Basement 1 - Proposed Design
Date: 31/03/2017

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	4.0	m
Fuel height	0.8	m
Detector spacing	15.0 x 15.0	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	163	s
Fire size at detector activation	311	kW

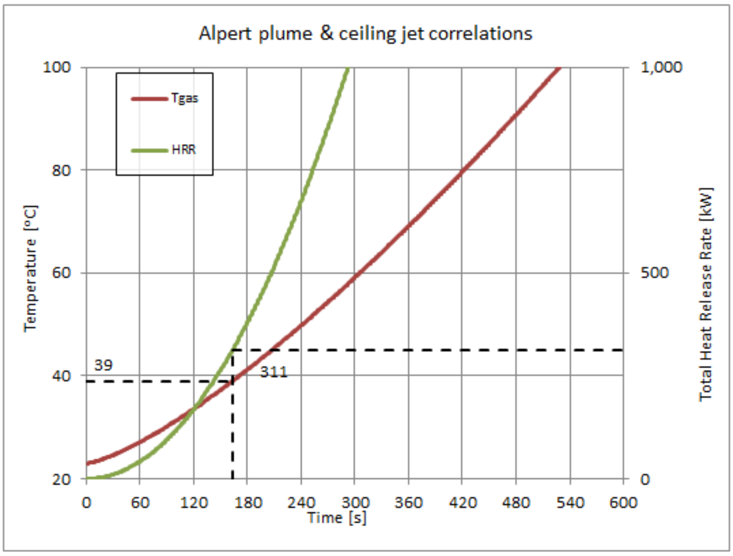


Figure 11: Calculation of Smoke Detector Activation Time – Basement Level 01 – Proposed Design

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended TDs in Basement 2 - Proposed Design
Date: 31/03/2017

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	2.7	m
Fuel height	0.8	m
Detector spacing	15.0 x 15.0	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	110	s
Fire size at detector activation	142	kW

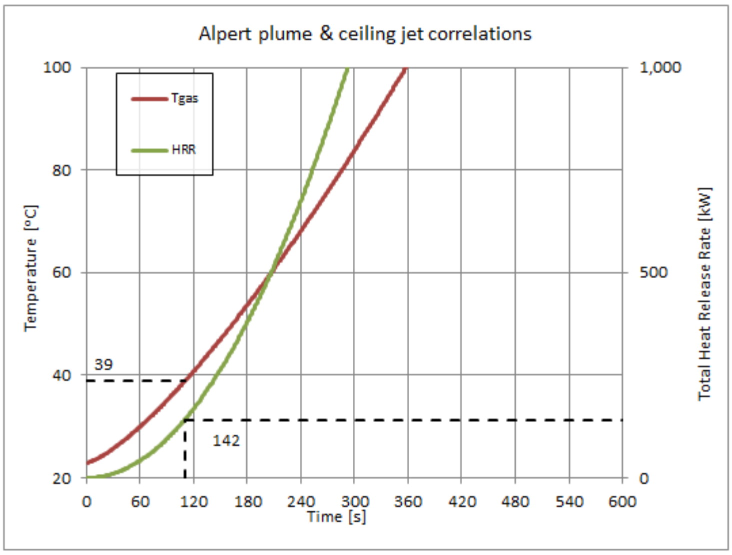


Figure 12: Calculation of Smoke Detector Activation Time – Basement Level 02 – Proposed Design

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended TDs in Loading Dock - Proposed Design
Date: 31/03/2017

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	4.8	m
Fuel height	0.8	m
Detector spacing	15.0 x 15.0	m
Use 2nd row Detector?	☐	
Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	192	s
Fire size at detector activation	432	kW

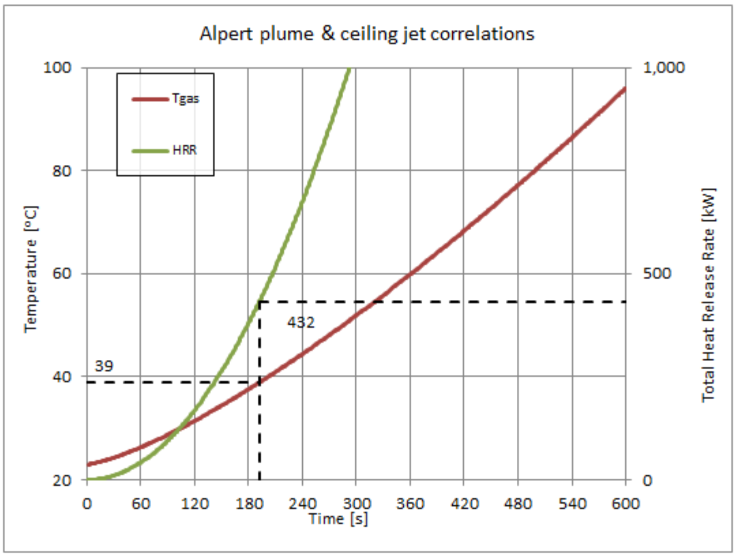


Figure 13: Calculation of Smoke Detector Activation Time – Loading Dock – Proposed Design

D.4 Sprinkler Activation Calculation Results

SPRINKLER ACTIVATION MODEL - t-squared 'medium' growth fire

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended travel in basement carparks - Reference Design
Date:25/08/2015

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	4.0	m
Fuel height	0.8	m
Sprinkler spacing	3.0 x 4.0	m
Use 2nd row sprinkler?	☐	
Sprinkler		
Room temperature	23	°C
Activation temperature	68	°C
Response time index, RTI	135	$(m.s)^{0.5}$
Conductance, C	0.9	$(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at sprinkler activation	317	s
Fire size at sprinkler activation	1178	kW

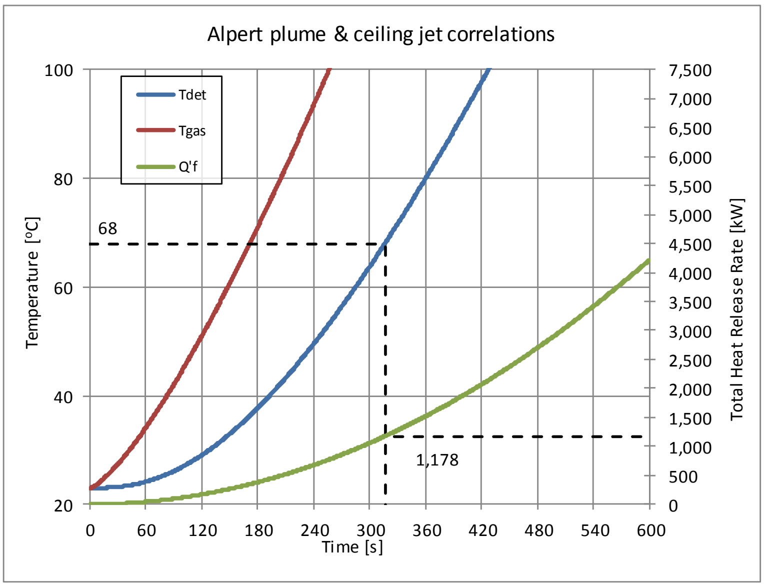


Figure 14: Sprinkler activation time calculation – Basement Level 01 – Reference Design

SPRINKLER ACTIVATION MODEL - t-squared 'medium' growth fire

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended travel in basement carparks - Reference Design
Date:25/08/2015

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	2.7	m
Fuel height	0.8	m
Sprinkler spacing	3.0 x 4.0	m
Use 2nd row sprinkler?	☐	
Sprinkler		
Room temperature	23	°C
Activation temperature	68	°C
Response time index, RTI	135	$(m.s)^{0.5}$
Conductance, C	0.9	$(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at sprinkler activation	252.5	s
Fire size at sprinkler activation	747	kW

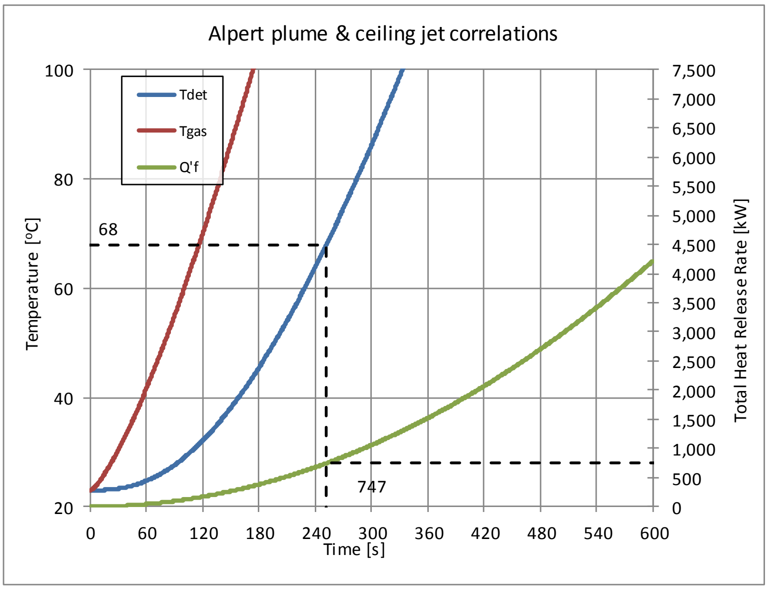


Figure 15: Sprinkler activation time calculation – Basement Level 02 – Reference Design

SPRINKLER ACTIVATION MODEL - t-squared 'medium' growth fire

Project : FEG1444000 Harbord Diggers
Alternative solution 5: Extended travel in Loading Dock - Reference Design
Date:07/09/2015

INPUT

Design fire		
Growth time*	300	s
Convective fraction	0.70	
Geometry		
Ceiling height	4.8	m
Fuel height	0.8	m
Sprinkler spacing	3.0 x 4.0	m
Use 2nd row sprinkler?	☐	
Sprinkler		
Room temperature	23	°C
Activation temperature	68	°C
Response time index, RTI	135	$(m.s)^{0.5}$
Conductance, C	0.85	$(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at sprinkler activation	351.5	s
Fire size at sprinkler activation	1448	kW

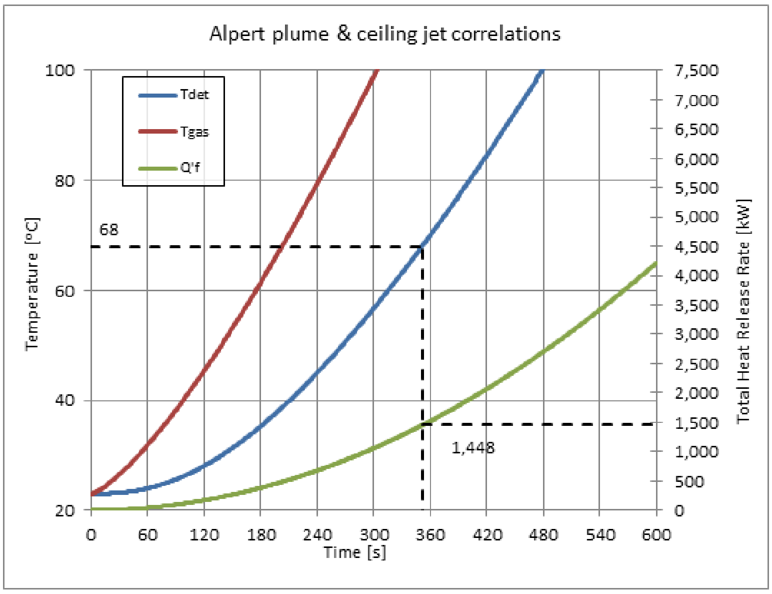


Figure 16: Sprinkler activation time calculation – Loading Dock – Reference Design

SPRINKLER ACTIVATION MODEL - t-squared 'medium' growth fire

Project : FEG1444000 Harbord Diggers
Alternative solution 8: Exits discharge into undercroft areas
Date:08/09/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	4.0 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	135 $(m.s)^{0.5}$
Conductance, C	0.85 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	317 s
Fire size at sprinkler activation	1178 kW

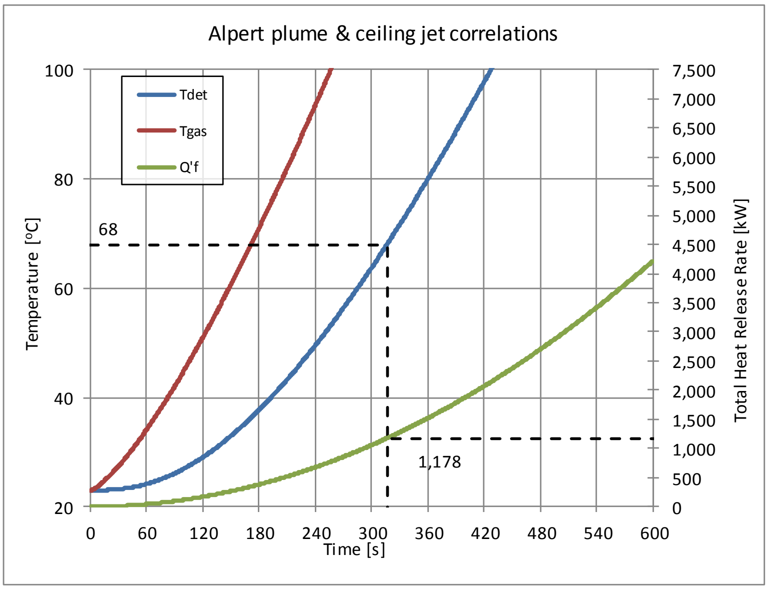


Figure 17: Sprinkler activation time calculation – Undercroft area to north of club

SPRINKLER ACTIVATION MODEL - t-squared 'medium' growth fire

Project : FEG1444000 Harbord Diggers
Alternative solution 8: Exits discharge into undercroft areas
Date:08/09/2015

INPUT

Design fire	
Growth time*	150 s
Convective fraction	0.70
Geometry	
Ceiling height	4.0 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	135 $(m.s)^{0.5}$
Conductance, C	0.85 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	183 s
Fire size at sprinkler activation	1570 kW

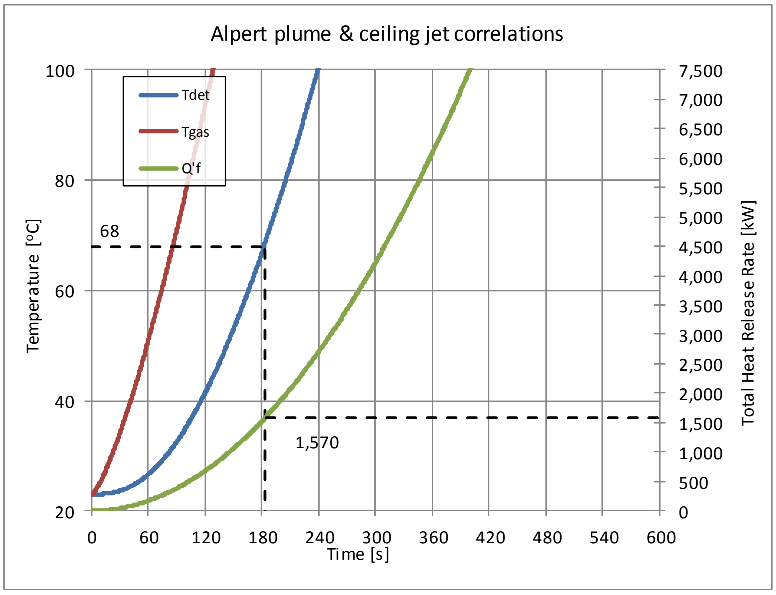


Figure 18: Sprinkler activation time calculation – Club

SPRINKLER ACTIVATION MODEL - t-squared fire

Project : FEG1444000
Alternative solution: AS 6
Date: 23/10/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.2 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	50 $(m.s)^{0.5}$
Conductance, C	0.7 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	228 s
Fire size at sprinkler activation	609 kW

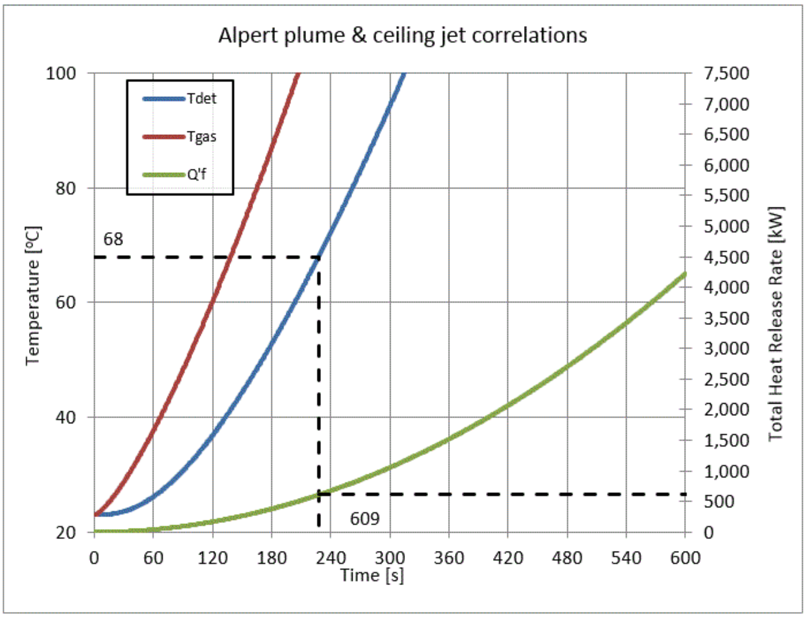


Figure 19: Sprinkler activation time calcualtion - Gym (RTI 50)

SPRINKLER ACTIVATION MODEL - t-squared fire

Project : FEG1444000
Alternative solution: AS 6
Date: 23/10/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.2 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	135 $(m.s)^{0.5}$
Conductance, C	0.9 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	278.5 s
Fire size at sprinkler activation	909 kW

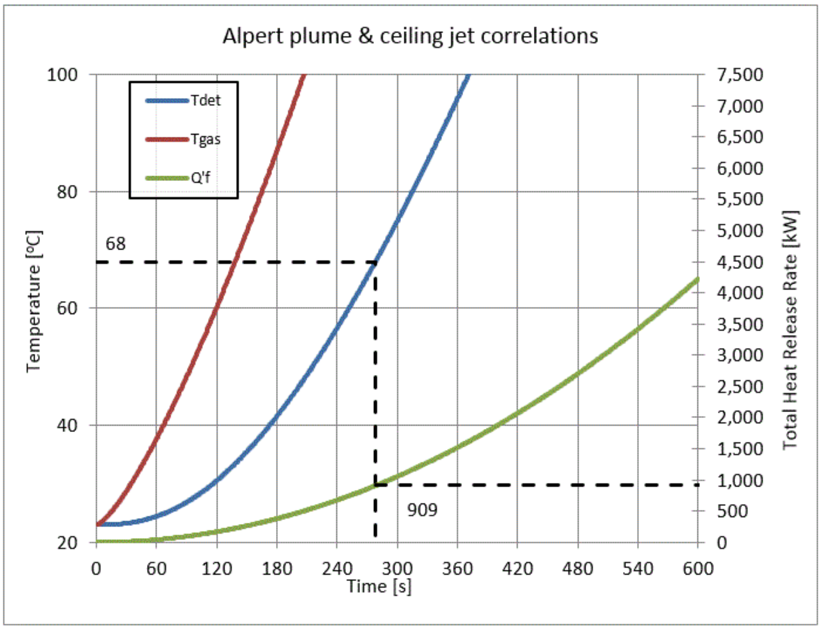


Figure 20: Sprinkler activation time calcualtion - Gym (RTI 135)

SPRINKLER ACTIVATION MODEL - t-squared fire

Project : FEG1444000
Alternative solution: AS 6
Date: 23/10/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.8 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	50 $(m.s)^{0.5}$
Conductance, C	0.7 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	256 s
Fire size at sprinkler activation	768 kW

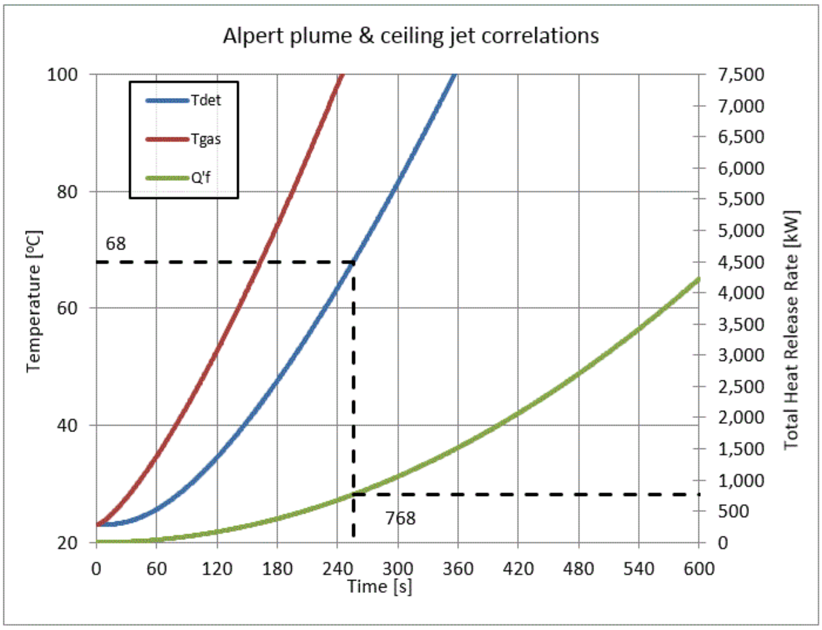


Figure 21: Sprinkler activation time calculation - Aquatic centre (RTI 50)

SPRINKLER ACTIVATION MODEL - t-squared fire

Project : FEG1444000
Alternative solution: AS 6
Date: 23/10/2015

INPUT

Design fire	
Growth time*	300 s
Convective fraction	0.70
Geometry	
Ceiling height	3.8 m
Fuel height	0.8 m
Sprinkler spacing	3.0 x 4.0 m
Use 2nd row sprinkler?	☐
Sprinkler	
Room temperature	23 °C
Activation temperature	68 °C
Response time index, RTI	135 $(m.s)^{0.5}$
Conductance, C	0.9 $(m.s)^{0.5}$

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS	
Time at sprinkler activation	307.5 s
Fire size at sprinkler activation	1108 kW

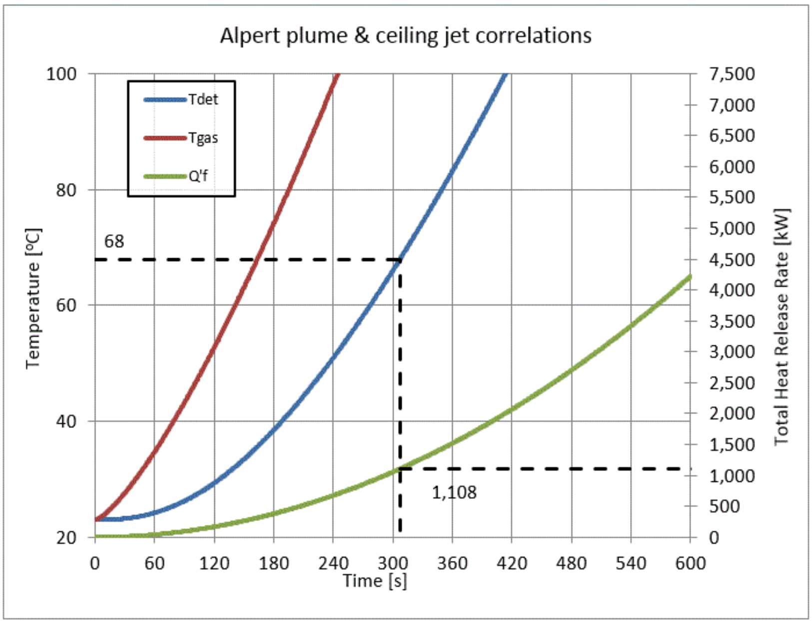


Figure 22: Sprinkler activation time calculation - Aquatic centre (RTI 135)

SMOKE DETECTOR ACTIVATION MODEL - t-squared fire with Alpert's Ceiling Jet Correlation

Project : FEG1444000
Alternative solution: AS 6
Date: 23/10/2015

Design fire		
Growth time*	300	s
Convective fraction	0.70	

Geometry		
Ceiling height	3.0	m
Fuel height	0.5	m
Detector spacing	10.0 x 10.0	m
Use 2nd row Detector?		

Smoke Detector		
Room temperature	23	°C
Activation temperature	39	°C

* time for fire to grow to 1055 kW
slow - 600 s ; medium - 300 s; fast - 150 s; ultra-fast - 75 s

RESULTS		
Time at detector activation	111	s
Fire size at detector activation	144	kW

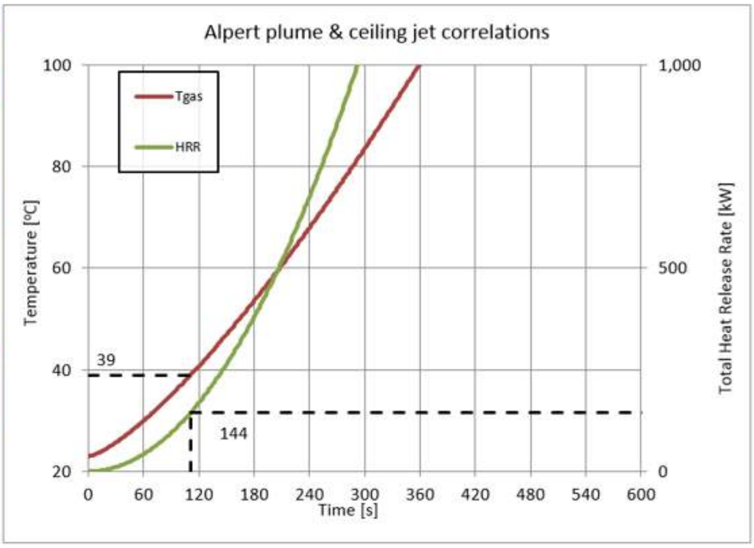


Figure 23: Smoke detector time calculation – Basement Level 2 Cinema Room

Appendix E Tyco Specification Sheet

Model WS Specific Application Window Sprinklers Horizontal and Pendent Vertical Sidewall 5.6 K-factor

General Description

The TYCO Model WS Specific Application Window Sprinklers are fast response, glass bulb-type spray sprinklers available in Horizontal Sidewall and Pendent Vertical Sidewall models.

These sprinklers are the first to be specifically Listed to provide complete wetting and coverage for heat strengthened, tempered, or ceramic glass windows using closed sprinklers. As part of the testing, the gas flow required to achieve the time/temperature relationship specified in ASTM E119 was established in a test furnace without sprinkler protection. A window assembly protected with the TYCO Model WS Window Sprinklers was then installed in the test furnace, and the same gas flow conditions were maintained for a two-hour test period. No cracking or visible damage to the window was permitted during the test period, even when a hose stream was directed at the window.

The success of the Model WS Window Sprinklers is based on their fast response thermal sensitivity and on their specially designed deflectors that ensure that the spray pattern wets the entire surface of the window.

Based on successful testing, the Model WS Window Sprinklers can be used as interior protection of windows or glazing in a sprinklered building or non-sprinklered building in accordance with Section 104 of the IBC ("Alternate Materials, Design and Methods of Construction and Equipment"). Also, the Model WS Window Sprinklers can be used as an open sprinkler for "Outside Sprinkler Protection against Exposure Fire", using the design requirements of NFPA.

As with any specific application sprinkler, the installation instructions included in this data sheet must be precisely followed. If there are additional local or jurisdictional installation standards/codes for window sprinklers on glazed window systems, this document does not relieve the designer/installer from these requirements. Consult your local jurisdiction to verify if or when these additional guidelines must be followed.

IMPORTANT

Always refer to Technical Data Sheet TFP700 for the "INSTALLER WARNING" that provides cautions with respect to handling and installation of sprinkler systems and components. Improper handling and installation can permanently damage a sprinkler system or its components and cause the sprinkler to fail to operate in a fire situation or cause it to operate prematurely.

NOTICE

TYCO Model WS Specific Application Window Sprinklers described herein must be installed and maintained in compliance with this document, as well as with the applicable standards recognized by the approval agency, in addition to the standards of any authorities having jurisdiction. Failure to do so may impair the performance of these devices.

The owner is responsible for maintaining their fire protection system and devices in proper operating condition. The installing contractor or manufacturer should be contacted with any questions.

Sprinkler Identification Number (SIN)

TY3388 - Horizontal Sidewall
TY3488 - Pendent Vertical Sidewall

TY3388 is a re-designation for C3388
TY3488 is a re-designation for C3488

Technical Data

Approvals
UL and C-UL Listed

NYC under MEA 289-04-E

Approvals only apply to the service conditions indicated in the Design Criteria section.

Additional Recognition
ICC Evaluation Service (ESR-2397)
Ontario Building Code

Pipe Thread Connection
1/2 inch NPT

Discharge Coefficient
K=5.6 GPM/psi$^{1/2}$ (80,6 LPM/bar$^{1/2}$)

Temperature Ratings
155°F (68°C)
200°F (93°C)

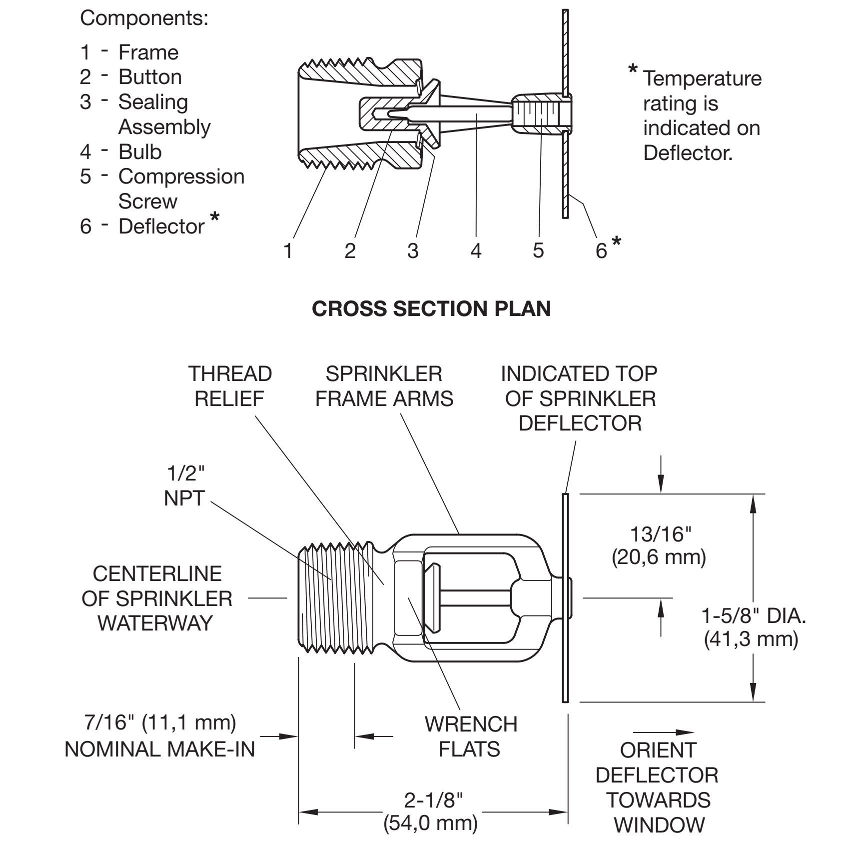
Finish
Natural Brass, Signal White (RAL9003) Polyester, and Chrome Plated

Physical Characteristics

Frame	Brass
Button	Bronze/Copper
Sealing Assembly	Beryllium Nickel w/TEFLON
Bulb	Glass (3 mm dia.)
Compression Screw	Brass
Deflector	Brass/Bronze

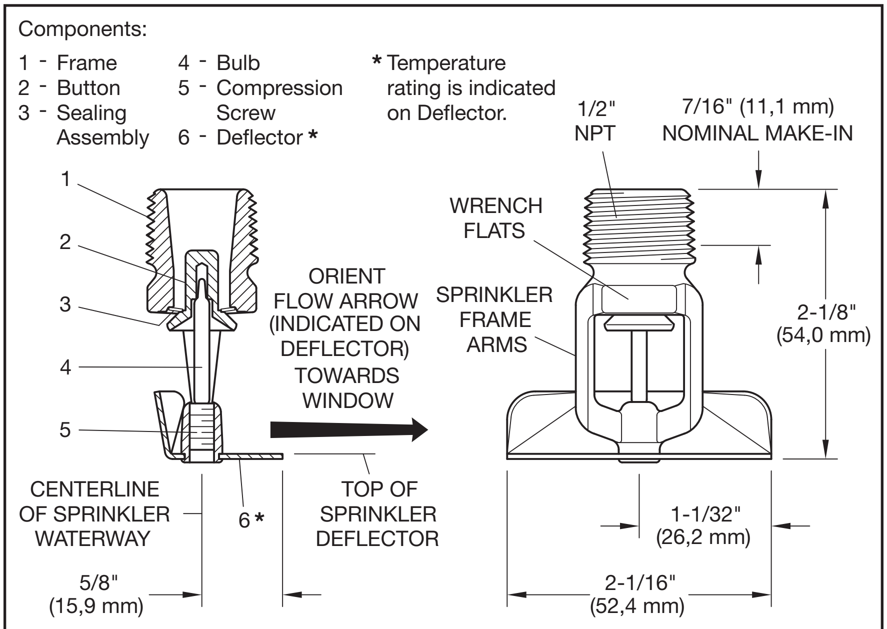
Operation

The glass bulb contains a fluid that expands when exposed to heat. When the rated temperature is reached, the fluid expands sufficiently to shatter the glass bulb, allowing the sprinkler to activate and water to flow.



SIDE ELEVATION

FIGURE 1
MODEL WS WINDOW SPRINKLER
HORIZONTAL SIDEWALL



CROSS SECTION **TOWARDS WINDOW ELEVATION**

FIGURE 2
MODEL WS WINDOW SPRINKLER
PENDENT VERTICAL SIDEWALL

Design Criteria

The TYCO Model WS Specific Application Window Sprinklers are UL and C-UL Listed and NYC Approved (MEA 335-01-E) for use as "Specific Application Window Sprinkler" and as open sprinklers for "Outside" use.

These sprinklers are also recognized by Underwriters Laboratories of Canada (ULC), and the Ontario Building Code for use in the Province of Ontario, Canada as providing a two-hour equivalency for a fire separation assembly when installed in accordance with this code.

Area of Use
When acceptable to the Authority Having Jurisdiction and unless modified by a local jurisdictional standard or code mentioned previously, the TYCO Model WS Window Sprinklers may be used in either a sprinklered or unsprinklered building to protect non-operable window openings that are part of a fire separation provided:

- in an interior fire separation, the window sprinklers are installed on both sides of the window in the fire separation (Figure 3A-1),
- in jurisdictions where exterior spatial separation (that is, separation from adjacent space) is defined as protecting an adjacent building from a fire in your building, window sprinklers are installed on the interior side of the building (Figure 3A-2), or
- in jurisdictions where exterior spatial separation is defined as protecting your building from a fire in an adjacent building (that is, exposure protection), open window sprinklers are installed on the exterior side of the building (Figure 3A-3).

System Protection Type
- Interior: Wet Systems
- Outside Exposure: Deluge

Glass Type
The following types and thicknesses of glass are recognized for use with TYCO Model WS Window Sprinklers:

- Non-operable, heat-strengthened, tempered, single-glazed (single pane), not less than 1/4 in. (6 mm) thick;
- Non-operable, heat-strengthened, tempered, double-glazed (double pane or insulated), not less than 1/4 in. (6 mm) thick;
- Non-operable, UL Classified and labeled FireLite Plus WS ceramic glass by Technical Glass Products (TGP), not less than 5/16 in. (8 mm) thick; or,

***NOTE:** Refer to FireLite Plus WS ceramic glass technical data sheet for other classification limitations at www.fireglass.com.*

- Non-operable, stronger glass window assemblies, not less than 1/4 in. (6 mm) thick.

Type of Window Frame/Mullion
Non-combustible Frame with a standard EPDM rubber gasket seal

Vertical joints of glass panes must be connected by butt-joints using a silicone sealant between the individual panes or by Noncombustible Mullions.

(Refer to Figures 3B-1 and 3B-2)

Maximum Length of Window Assembly
Unlimited

Maximum Height of Window Assembly
13 ft. (3,96 m)

(Refer to Figures 3C and 3D)

Maximum Distance Between Window Sprinklers
8 ft. (2,44 m)

(Refer to Figures 3B-1 and 3B-2)

Minimum Distance Between Window Sprinklers
6 ft. (1,83 m) unless separated by a baffle or mullion of sufficient depth to act as a baffle.

A mullion will act as a baffle, when in the case of the Pendent Vertical Sidewall, the mullion extends to the back of the sprinkler deflector, and in the case of the Horizontal Sidewall, the mullion extends to the sprinkler wrench flat.

(Refer to Figures 3B-1 and 3B-2)

Minimum Distance from Standard Sprinklers
6 ft. (1,83 m) unless separated by a baffle

Sprinkler Location
- Mullioned Glazing Assemblies: Locate window sprinklers within each mullioned glazing segment. Refer to Figure 3B-1.
- Butt-Jointed Glazing Assemblies: Locate window sprinklers on maximum 8 ft. (2,44 m) centers. Refer to Figure 3B-2.

Maximum Distance from Vertical Mullion
4 ft. (1,22 m)

(Refer to Figure 3B-1)

Minimum Distance from Vertical Mullions
4 in. (101,6 mm)

(Refer to Figure 3B-1)

Intermediate Horizontal Mullions
Intermediate Horizontal Mullions were not tested with the Model WS Window Sprinklers. Their use is outside the scope of the "Specific Application" Listing for the window sprinklers. Refer to Figure 3B-3.

Deflector Location
Sprinkler Deflectors must be located as described below in order to ensure that the entire surface of the glass window is covered. Sprinkler Deflectors are positioned with respect to the window frame, not the ceiling.

- Horizontal Sidewall: Locate within the outside edge of the window frame from 1/2 to 4 in. (12,7 mm to 101,6 mm) away from the glass and 2 ± 1 in. (50,8 mm ± 25,4 mm) down from the top of the exposed glass. Refer to Figure 3C.
- Pendent Vertical Sidewall: Locate 4 to 12 in. (101,6 mm to 304,8 mm) from the face of the glass and 3 ± 1 in. (76,2 mm ± 25,4 mm) down from the top of exposed glass. Refer to Figure 3D.

Minimum Clearance from Face of Glass to Combustible Materials
For glass types other than FireLite Plus WS ceramic glass by TGP, all combustible materials shall be kept 2 in. (50,8 mm) from the front face of the glass. This can be accomplished by a minimum 36 in. (914,4 mm) pony wall or other method acceptable to the authority having jurisdiction.

Escutcheon Assemblies
The Model WS Window Sprinklers can be used with any metallic flush or extended escutcheons, provided the dimensions from the sprinkler deflector to the window frame and glass surface as specified in this data sheet are maintained. These sprinklers are not listed for recessed applications.

Recommended Hydraulic Requirements
The authority having jurisdiction should be consulted to determine the hydraulic requirements for each installation.

Interior Protection Sprinklered Building
Identify which compartmented area has the most hydraulically demanding window sprinklers. Calculate up to the most demanding 46.5 linear feet of Model WS Window Sprinklers on one side of the glazing. The 46.5 linear feet (14,2 linear meters) is based upon 1.2 x the square root of the system area of operation, when the system area of operation is 1500 sq.-ft. in accordance with NFPA 13 Light/Ordinary Hazard density curves.

Where the area of Glazing is less than 14.2 linear meters, all window sprinklers on one side shall be calculated.

If an area reduction for quick response sprinklers is utilized, the linear length of the calculated window sprinklers may be reduced, but in no case shall be less than 36 linear feet (1.2 x $\sqrt{900}$).

If a single fire can be expected to operate Model WS Window Sprinklers and sprinklers within the design area of a hydraulically calculated system, the water demand of the window sprinklers shall be added to the water demand of the hydraulic calculations and shall be balanced to the calculated area demand.

If the window sprinklers are located in an area other than the hydraulic design area, the demand of the window sprinklers is not required to be added to the demand of the remote hydraulic design area. However, it is necessary to prove hydraulically the simultaneous operation of the Model WS Window Sprinklers and the ceiling sprinklers adjacent to the window sprinklers.

Interior Protection Non-Sprinklered Building
Calculate all sprinklers on the most demanding side of the glazing assembly within the enclosure.

Exterior Exposure Protection
Calculate all sprinklers controlled by the deluge valve using the design requirements of NFPA.

Duration of Water Supply
Duration of water supply must comply with requirements of NFPA. If window sprinklers are used to provide the equivalency of a fire rating, the water supply must be capable of supplying water for the required rating period.

Minimum Flow per Sprinkler
20 GPM (75,7 LPM) for sprinkler spacing of 6 to 8 ft. (1,83 to 2,44 m) or 15 GPM (56,8 LPM) for sprinkler spacing less than 6 ft. (1,83 m).

Maximum Pressure per Sprinkler
- Horizontal Sidewall: 70 psi (4,83 bar)*

* The 70 psi is only for cold solder purposes. If there is a baffle or a mullion of sufficient depth to act as a baffle, separating the sprinklers, the maximum pressure is 175 psi (12,07 bar).

- Vertical Sidewall: 175 psi (12,07 bar)

When acceptable to the Authority Having Jurisdiction the Model WS Specific Application Window Sprinklers may be used in either a sprinklered or unsprinklered building to protect nonoperable window openings that are in an interior fire separation, the window sprinklers are installed on both sides of the window in the fire separation.

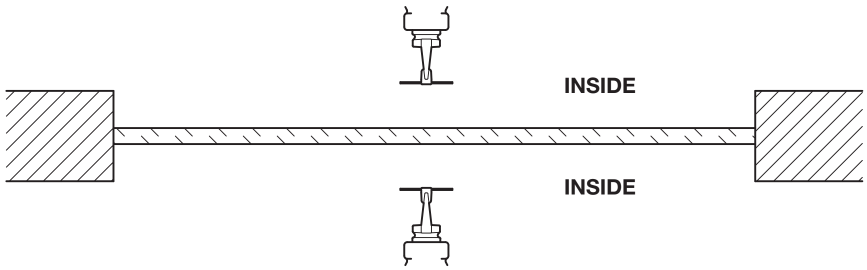


FIGURE 3A-1 - INTERIOR FIRE SEPARATION

When acceptable to the Authority Having Jurisdiction the Model WS Specific Application Window Sprinklers may be used in either a sprinklered or unsprinklered building to protect nonoperable window openings that are part of a fire separation provided in jurisdictions where exterior spatial separation is defined as protecting an adjacent building from a fire in your building, window sprinklers are installed on the interior side of the glass.

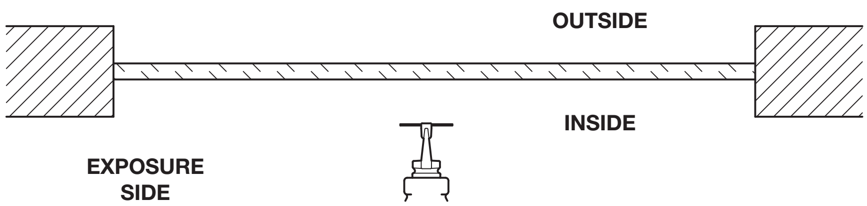


FIGURE 3A-2 - EXTERIOR FIRE SEPARATION - SPRINKLERS INSIDE

When acceptable to the Authority Having Jurisdiction the Model WS Specific Application Window Sprinklers may be used in either a sprinklered or unsprinklered building to protect nonoperable window openings that are part of a fire separation provided in jurisdictions where exterior spatial separation is defined as protecting your building from a fire in an adjacent building, open window sprinklers are installed on the exterior side of the glass.

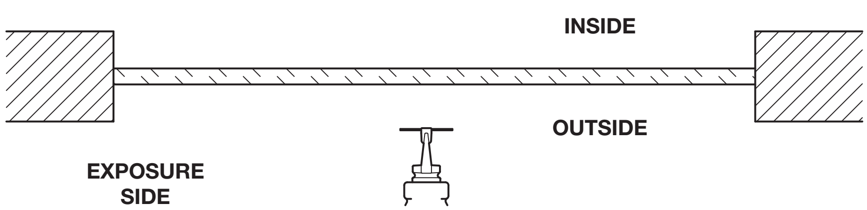


FIGURE 3A-3 - EXTERIOR FIRE SEPARATION - SPRINKLERS OUTSIDE

FIGURE 3A (A-1 TO A-3)
TYPICAL NON-OPERABLE WINDOW OPENINGS

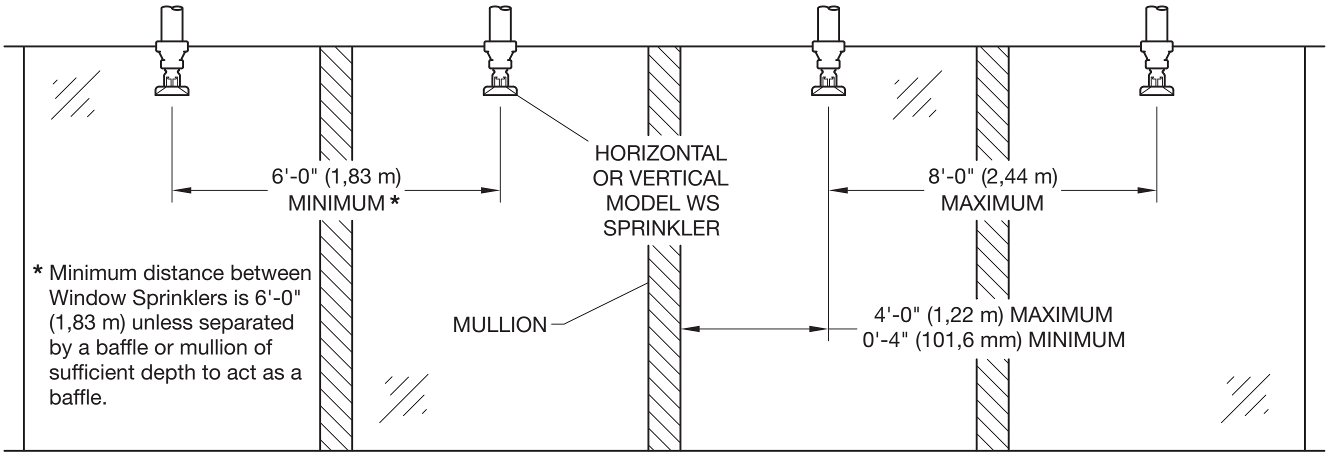


FIGURE 3B-1 - MULTIPLE WINDOWS SEPARATED BY MULLIONS

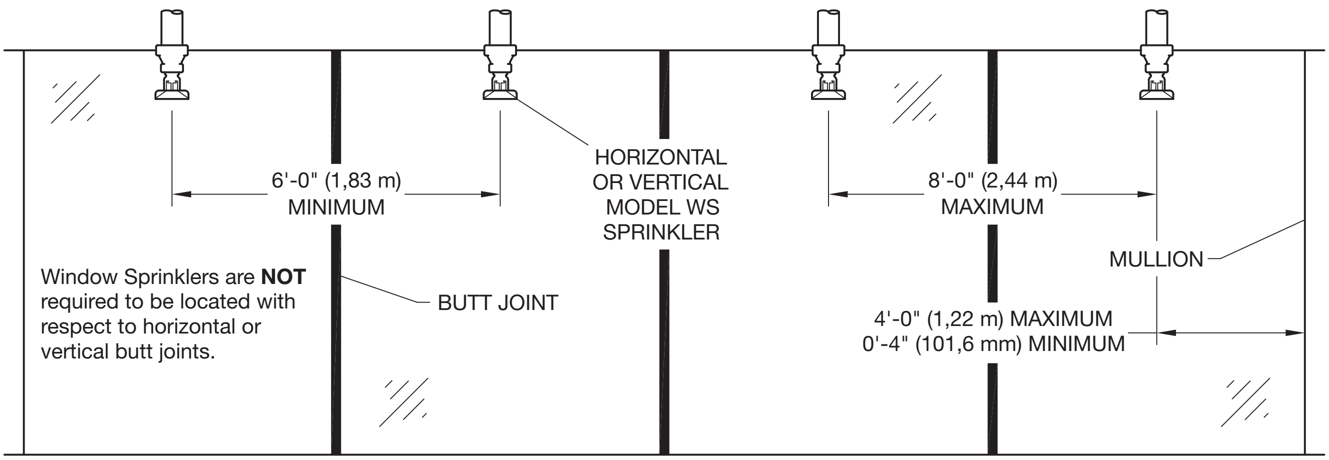


FIGURE 3B-2 - MULTIPLE WINDOWS SEPARATED BY BUTT JOINTS

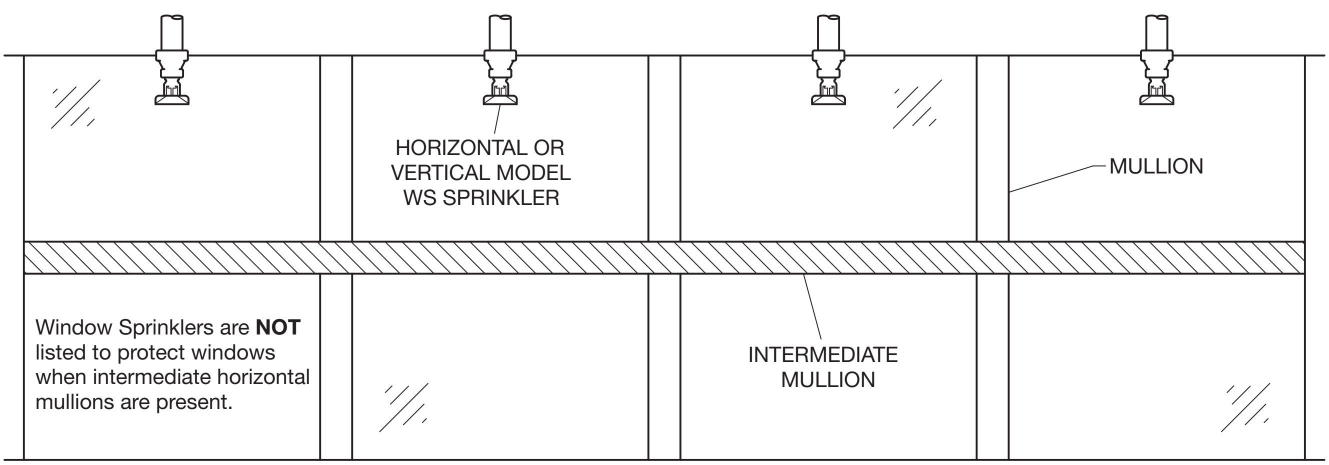


FIGURE 3B-3 - WINDOWS WITH HORIZONTAL MULLIONS

FIGURE 3B (B-1 TO B-3)
WINDOW MULLIONS AND BUTT JOINTS

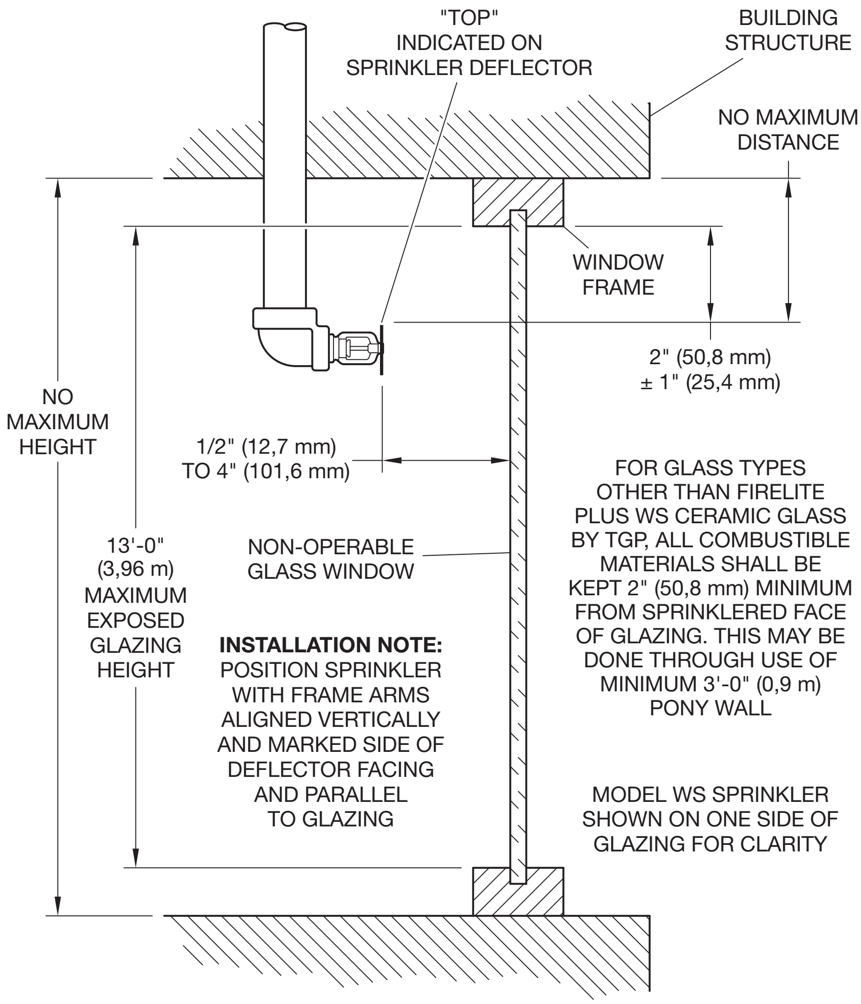


FIGURE 3C
MODEL WS HORIZONTAL SIDEWALL SPRINKLER
TYPICAL INSTALLATION

Installation

The TYCO Model WS Specific Application Window Sprinklers must be installed in accordance with this section.

General Instructions
Do not install any bulb-type sprinkler if the bulb is cracked or there is a loss of liquid from the bulb. With the sprinkler held horizontally, a small air bubble should be present. The diameter of the air bubble is approximately 1/16 in. (1,6 mm).

A leak-tight 1/2 inch NPT sprinkler joint should be obtained by applying a minimum-to-maximum torque of 7 to 14 ft.-lbs. (9,5 to 19,0 Nm). Higher levels of torque may distort the sprinkler inlet with consequent leakage or impairment of the sprinkler.

Step 1. Install the pendent vertical sidewall sprinkler only in the pendent position with the center-line of the sprinkler parallel to the glass surface. Orient the sprinkler so that the direction of flow indicated on the sprinkler deflector is facing the window.

Step 2. Install the horizontal sidewall sprinkler only in the horizontal position with the center-line of the sprinkler perpendicular to the glass surface. Orient the sprinkler so that the word “Top” indicated on the sprinkler deflector is facing the top of window frame.

Step 3. With pipe-thread sealant applied to the pipe threads, hand-tighten the sprinkler into the sprinkler fitting.

Step 4. With reference to Figures 1 or 2, apply End A of W-Type 20 Sprinkler Wrench only (Figure 4) to the sprinkler wrench flats and tighten the sprinkler into the sprinkler fitting.

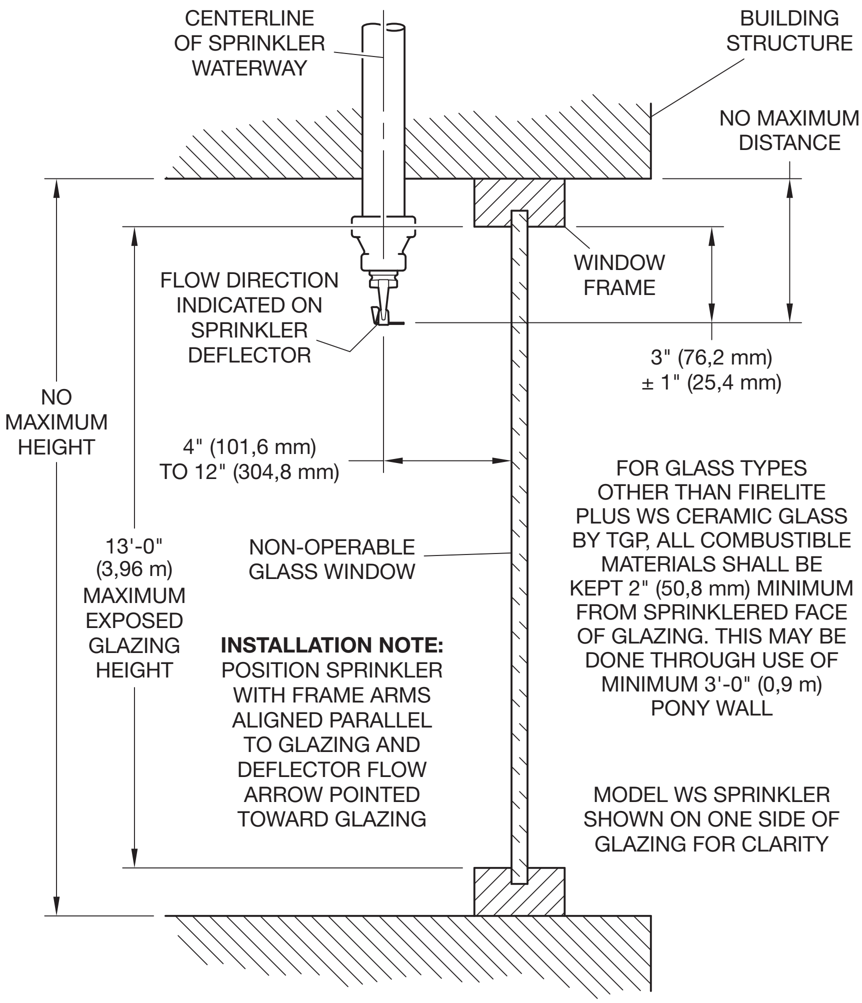


FIGURE 3D
MODEL WS PENDENT VERTICAL SIDEWALL SPRINKLER
TYPICAL INSTALLATION

Care and Maintenance

The TYCO Model WS Specific Application Window Sprinklers must be maintained and serviced in accordance with this section.

Before closing a fire protection system main control valve for maintenance work on the fire protection system that it controls, obtain permission to shut down the affected fire protection systems from the proper authorities and notify all personnel who may be affected by this action.

Sprinklers which are found to be leaking or exhibiting visible signs of corrosion must be replaced.

Automatic sprinklers must never be painted, plated, coated, or otherwise altered after leaving the factory. Modified sprinklers must be replaced. Sprinklers that have been exposed to corrosive products of combustion, but have not operated, should be replaced if they cannot be completely cleaned by wiping the sprinkler with a cloth or by brushing it with a soft bristle brush.

Care must be exercised to avoid damage to the sprinklers - before, during, and after installation. Sprinklers damaged by dropping, striking, wrench twist/slippage, or the like, must be replaced. Also, replace any sprinkler that has a cracked bulb or that has lost liquid from its bulb. (Ref. Installation Section.)

The owner is responsible for the inspection, testing, and maintenance of their fire protection system and devices in compliance with this document, as well as with the applicable standards recognized by the Approval agency (e.g., NFPA 25), in addition to the standards of any authorities having jurisdiction. Contact the installing contractor or sprinkler manufacturer regarding any questions.

Automatic sprinkler systems are recommended to be inspected, tested, and maintained by a qualified Inspection Service in accordance with local requirements and/or national codes.

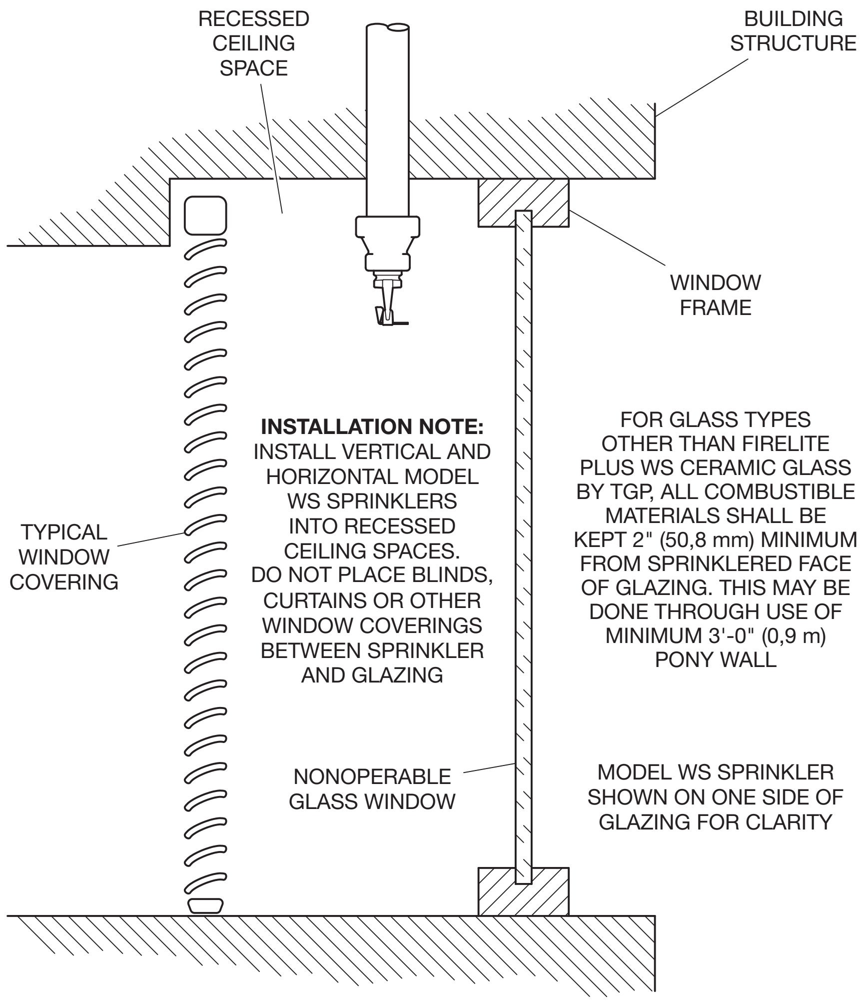


FIGURE 3E
MODEL WS PENDENT VERTICAL SIDEWALL SPRINKLER
RECESSED CEILING TYPICAL INSTALLATION

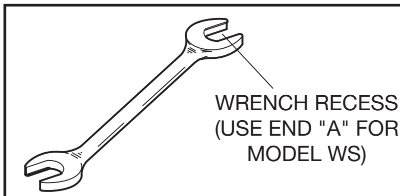


FIGURE 4
W-TYPE 20 SPRINKLER
WRENCH

Limited Warranty

For warranty terms and conditions, visit www.tyco-fire.com.

Ordering Procedure

Contact your local distributor for availability. When placing an order, indicate the full product name and Part Number (P/N).

Model WS HSW Window Sprinkler with NPT Thread
Specify: Model WS Specific Application Window Sprinkler TY3388, Horizontal Sidewall, with (specify) temperature rating, (specify) finish, and P/N (specify)

155°F (68°C)
Natural Brass . . . . P/N 50-305-1-155
Signal White (RAL9003)
Polyester . . . . P/N 50-305-4-155
Chrome Plated . . . . P/N 50-305-9-155

200°F (93°C)
Natural Brass . . . . P/N 50-305-1-200
Signal White (RAL9003)
Polyester . . . . P/N 50-305-4-200
Chrome Plated . . . . P/N 50-305-9-200

Model WS Pendent Vertical Sidewall Window Sprinkler with NPT Thread
Specify: Model WS Specific Application Window Sprinkler TY3488, Pendent Vertical Sidewall, with (specify) temperature rating, (specify) finish, and P/N (specify)

155°F (68°C)
Natural Brass . . . . P/N 50-304-1-155
Signal White (RAL9003)
Polyester . . . . P/N 50-304-4-155
Chrome Plated . . . . P/N 50-304-9-155

200°F (93°C)
Natural Brass . . . . P/N 50-304-1-200
Signal White (RAL9003)
Polyester . . . . P/N 50-304-4-200
Chrome Plated . . . . P/N 50-304-9-200

Sprinkler Wrench
Specify: W-Type 20 Sprinkler Wrench, P/N 56-000-1-106

GLOBAL HEADQUARTERS | 1400 Pennbrook Parkway, Lansdale, PA 19446 | Telephone +1-215-362-0700

Appendix F Zone Fire Modelling

F.1 Introduction of CFAST

CFAST is a two-zone fire model used to calculate the evolving distribution of smoke, fire gases and temperature throughout compartments of a building during a fire. These can range from very small containment vessels, on the order of 1 m^3 to large spaces on the order of 1000 m^3.

The modelling equations used in CFAST take the mathematical form of an initial value problem for a system of ordinary differential equations (ODEs). These equations are derived using the conservation of mass, the conservation of energy (equivalently the first law of thermodynamics), the ideal gas law and relations for density and internal energy. These equations predict as functions of time quantities such as pressure, layer height and temperatures given the accumulation of mass and enthalpy in the two layers. The CFAST model then consists of a set of ODEs to compute the environment in each compartment and a collection of algorithms to compute the mass and enthalpy source terms required by the ODEs.

F.2 CFAST model setup

The undercroft area to the north of the club has a variant depth between the shopfront and its outer edge. To model the smoke movement in this area more precisely, the CFAST model is constructed to have five compartments for this area with different widths. The interface between compartments is fully height opening. Full height vent openings are also set at the perimeter of the area in the model. Refer to Figure 1 below for an illustration of the CFAST model. An additional compartment is added where a fire is modelled in the club adjacent to the undercroft area. A fully height opening with a width of 10 m is created between the fire compartment and the undercroft area to represent the opening caused by failed shopfront glass. Refer to Figure 2 below for this scenario.

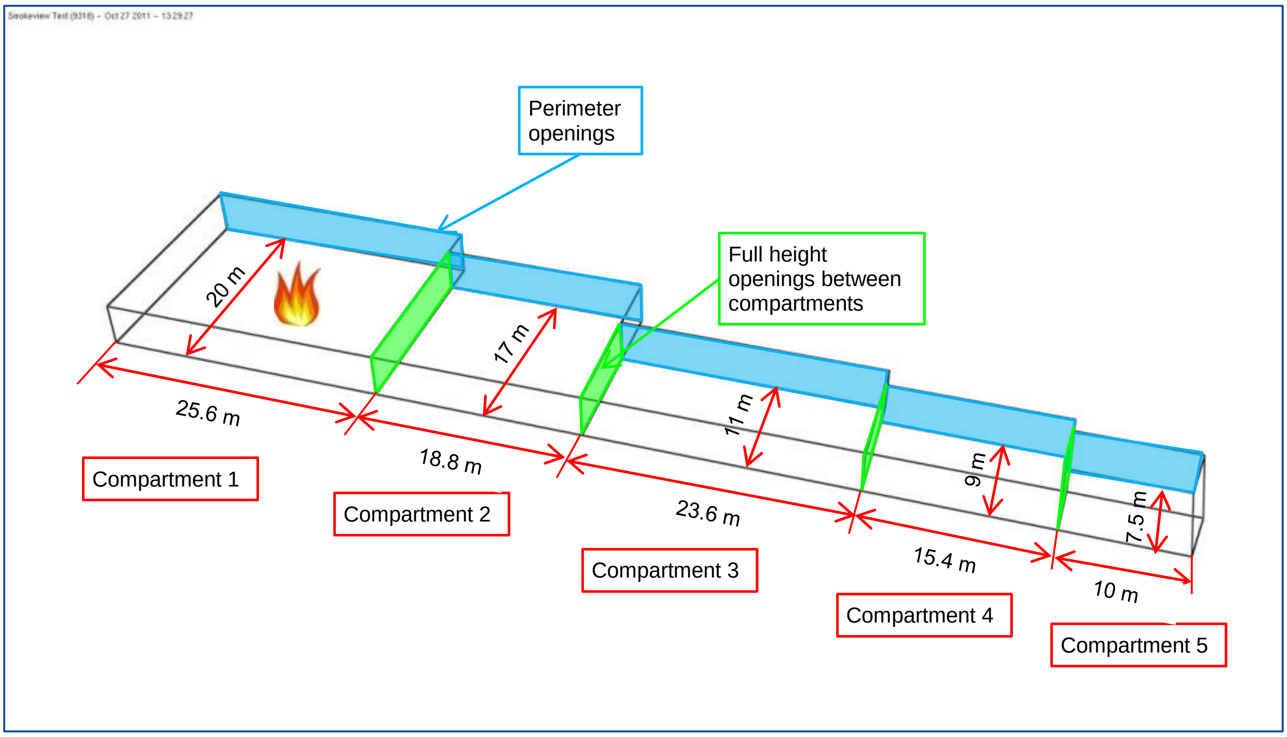


Figure 1: Setup of CFAST model – Fire in Community Club Undercroft area (refer to Figure 25 of AS 8)

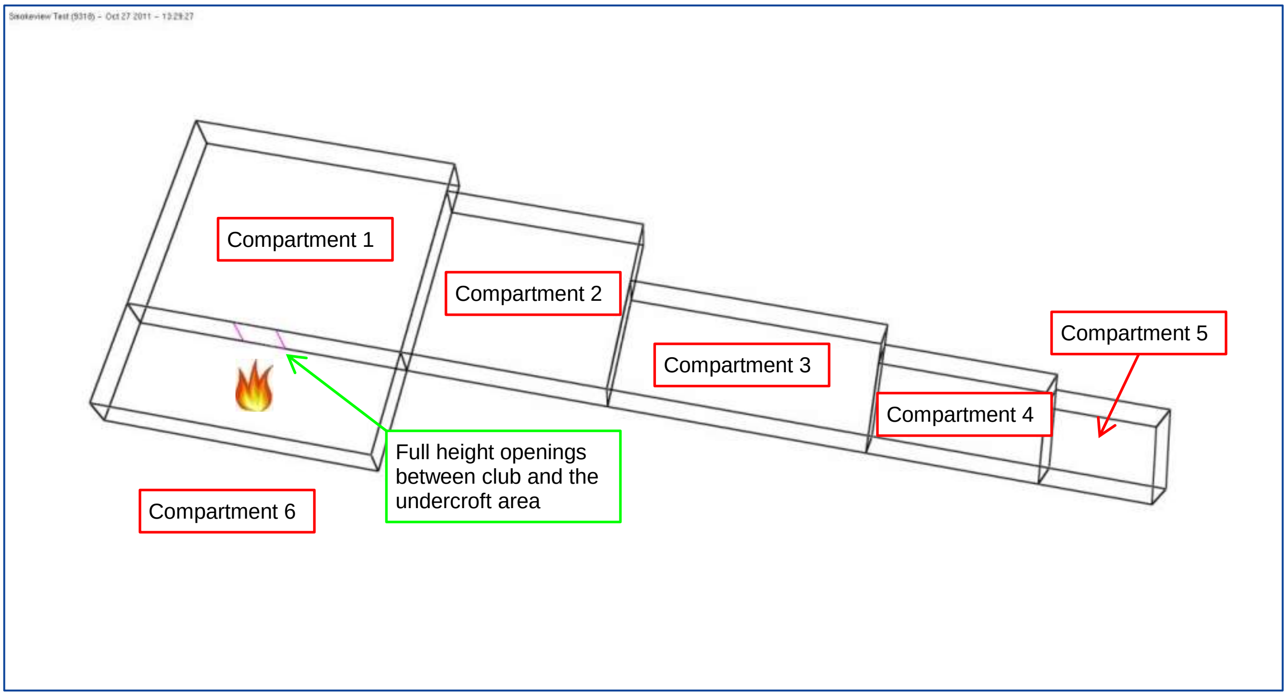


Figure 2: Setup of CFAST model – Fire in Community Club (refer to Figure 25 of AS 8)

F.3 CFAST Results

F.3.1 Fire in the Community Club Undercroft Area

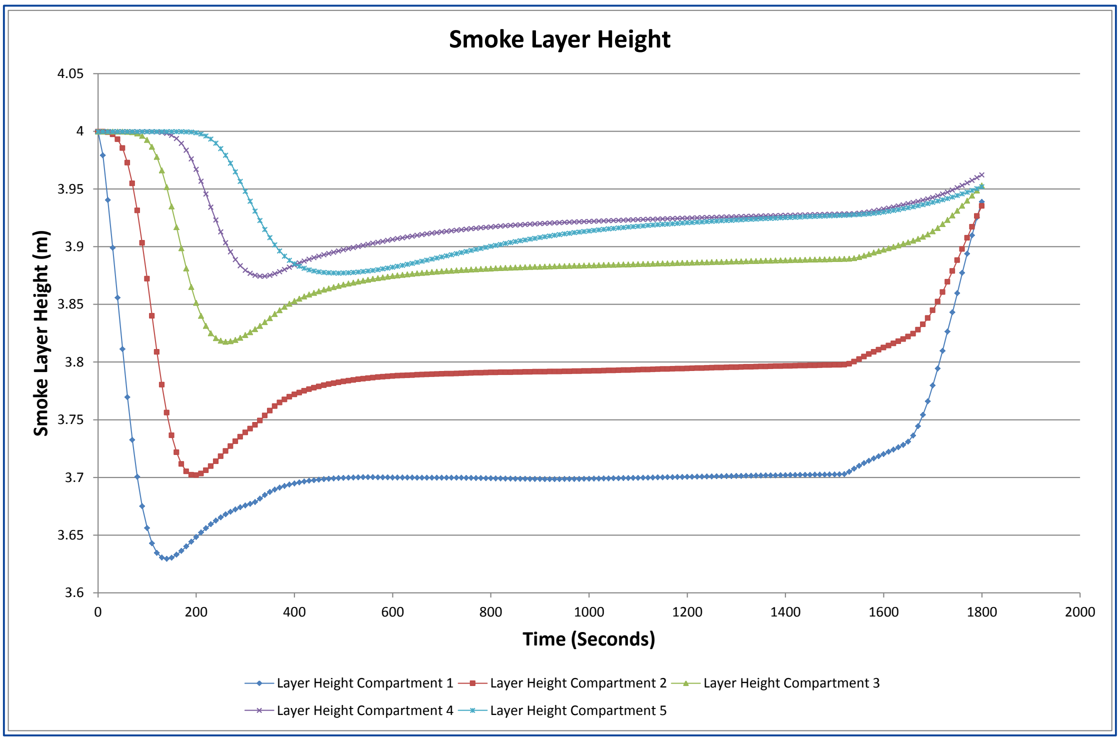


Figure 3: Smoke Layer Height in Different Areas

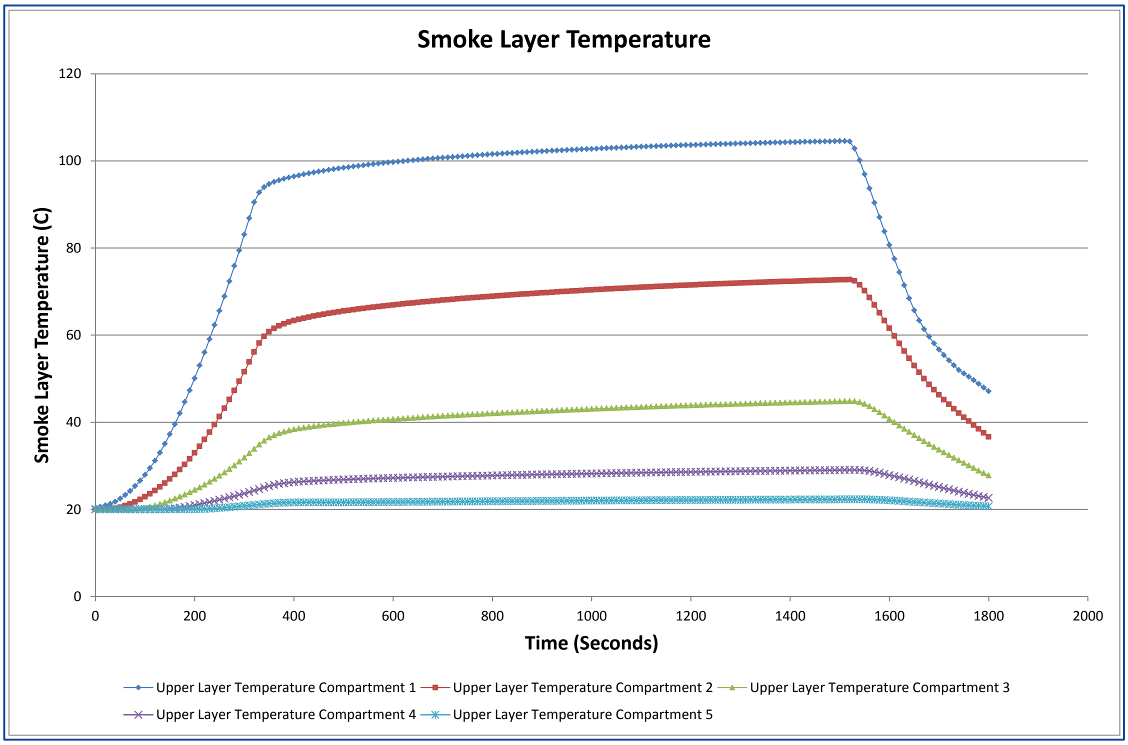


Figure 4: Smoke Layer Temperature in Different Areas

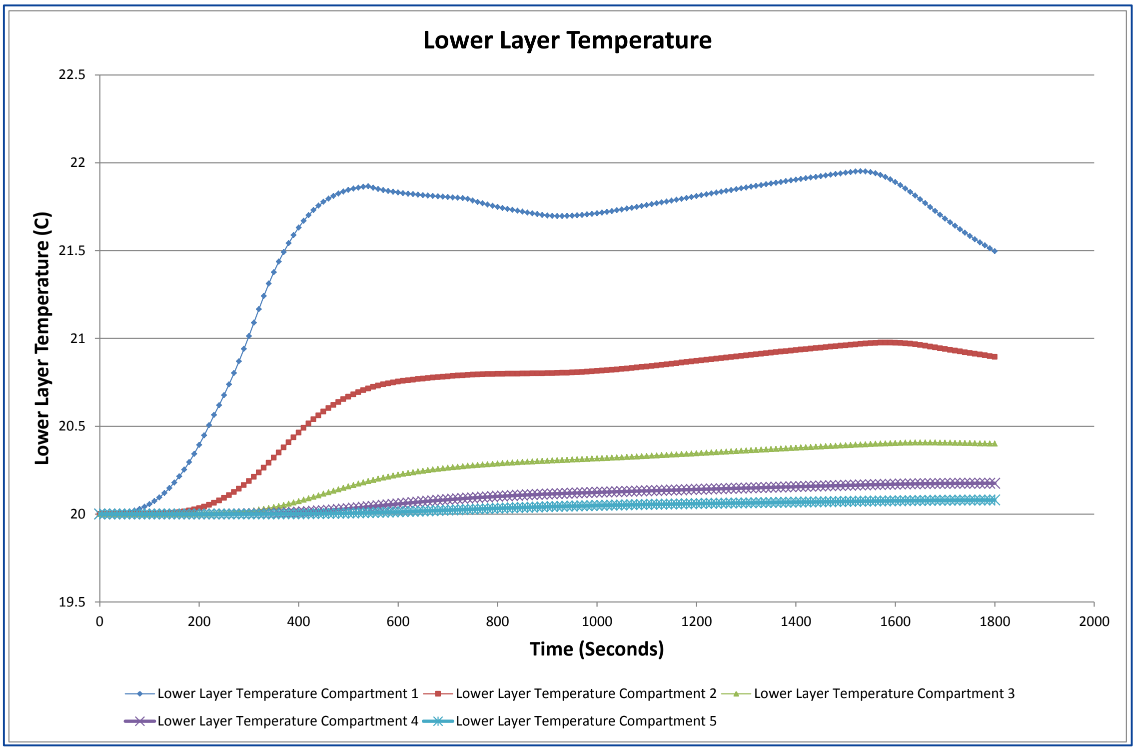


Figure 5: Lower Layer Temperature in Different Areas

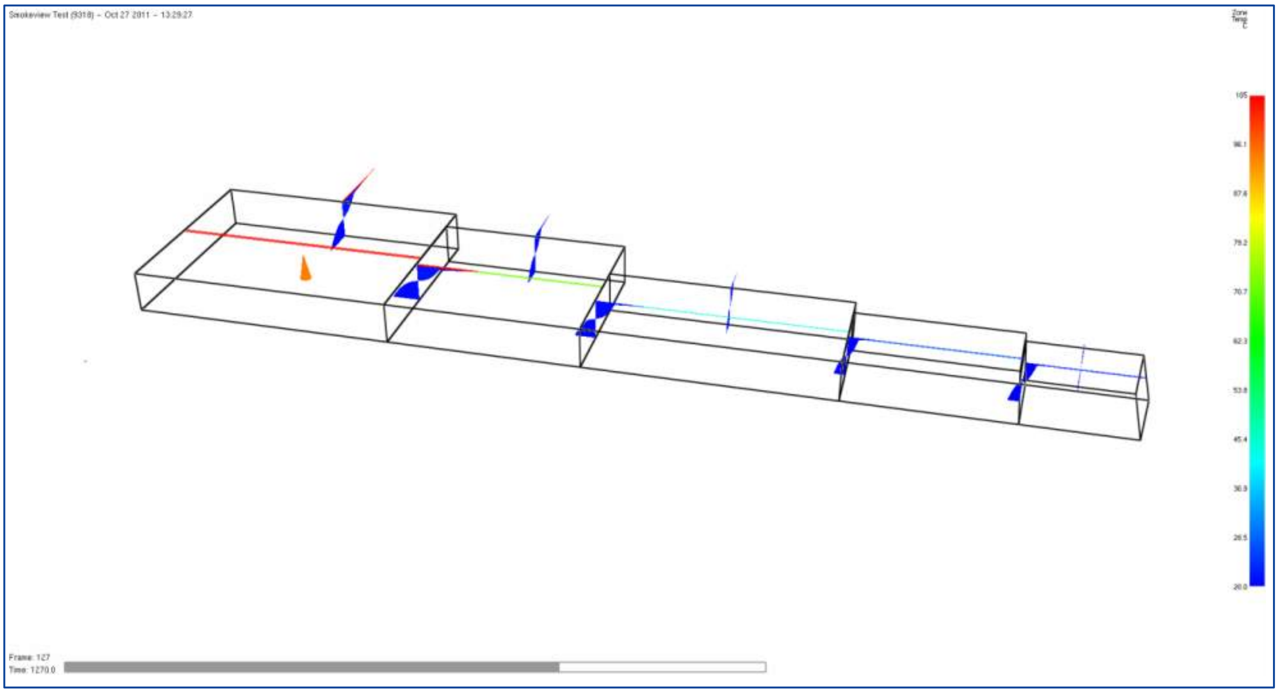


Figure 6: Smokeview output of the CFAST modelling

F.3.2 Fire in Community Club

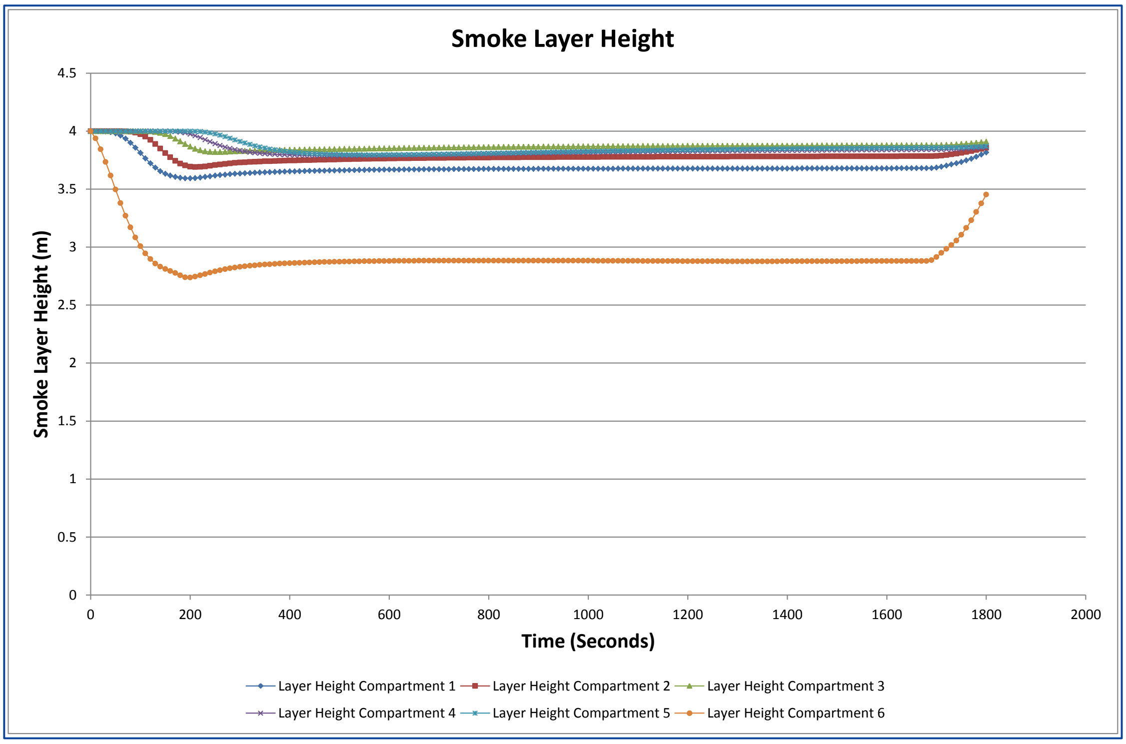


Figure 7: Smoke Layer Height in Different Areas

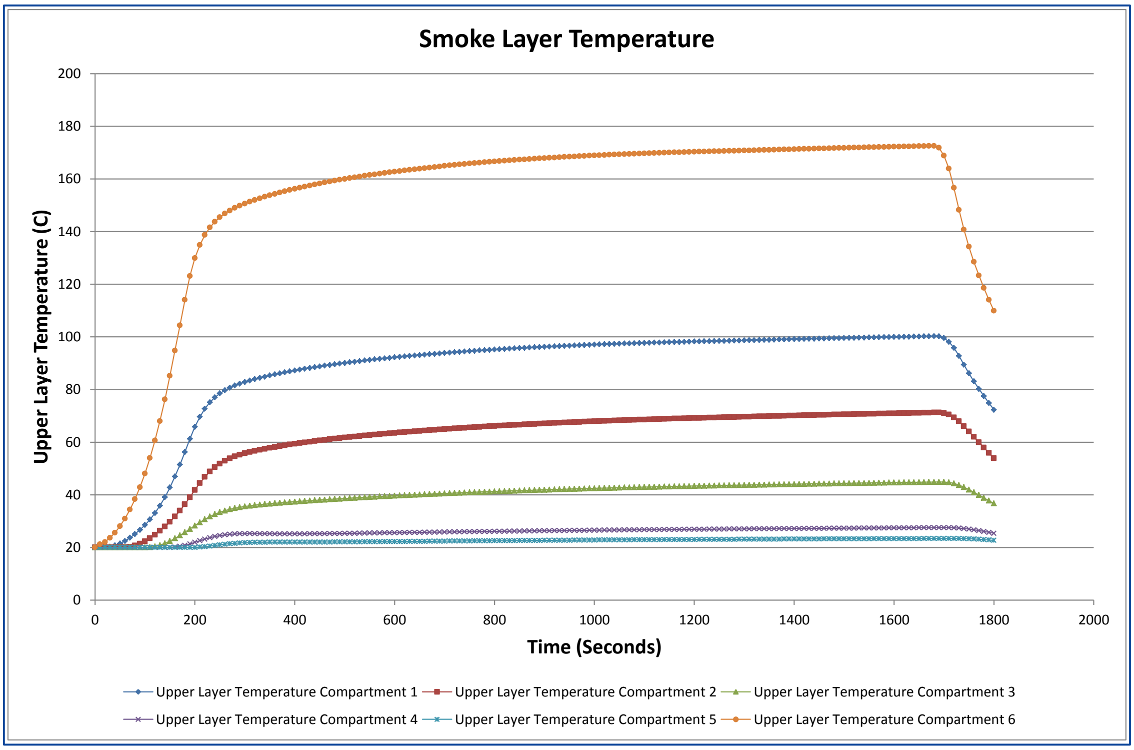


Figure 8: Smoke Layer Temperature in Different Areas

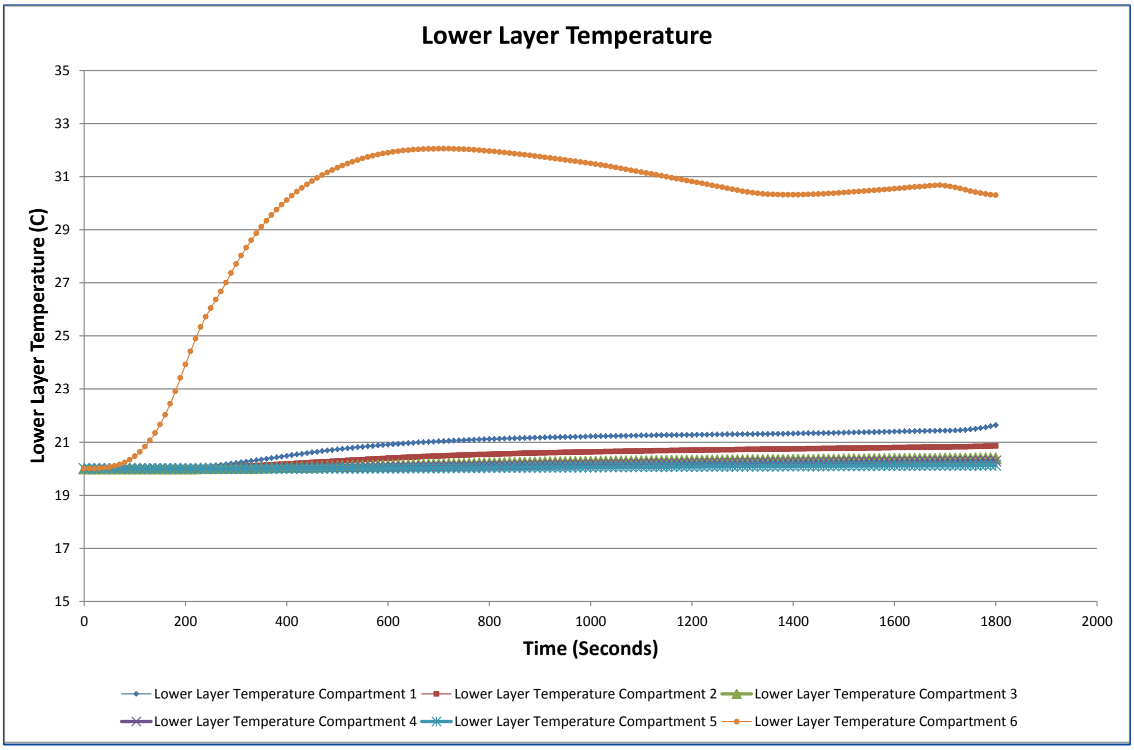


Figure 9: Lower Layer Temperature in Different Areas

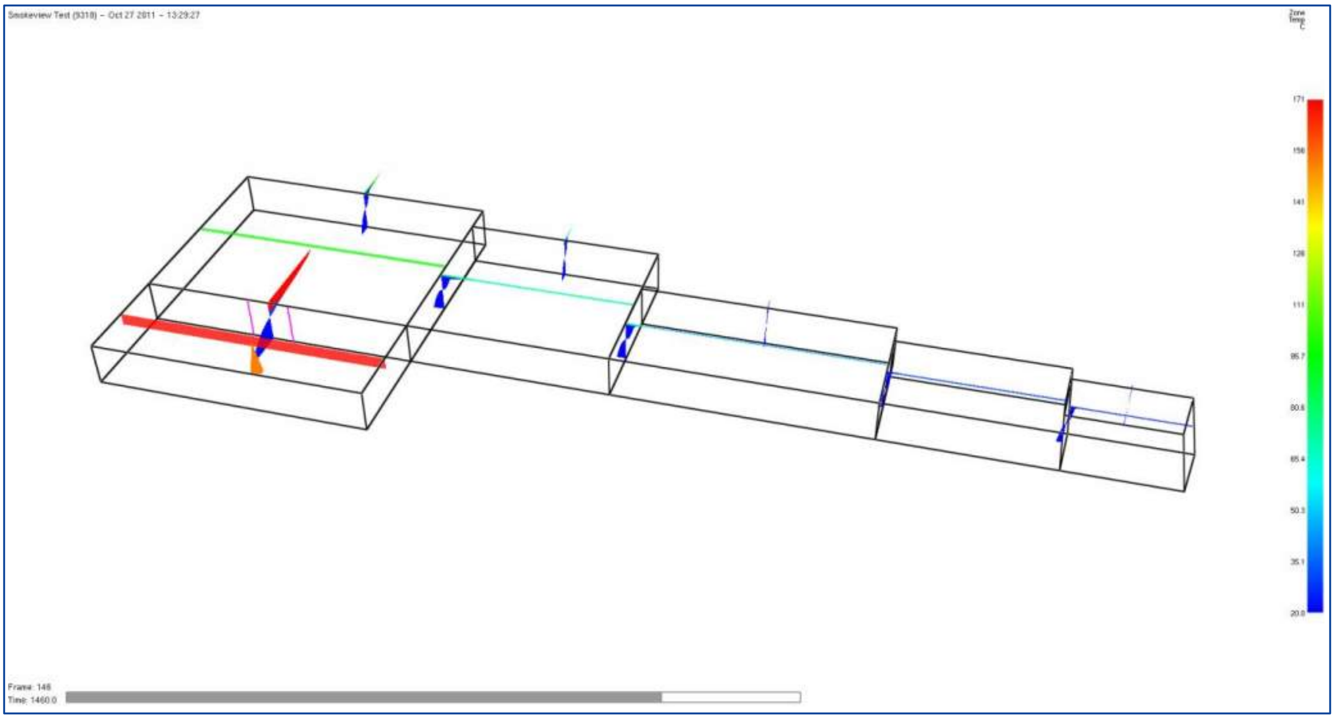


Figure 10: Smokeview output of the CFAST modelling

Appendix G Radiation From Flames

G.1 Introduction (radiation from flames extending from compartment windows)

The purpose of this appendix is to present the theory and calculation methods used for vertical flame spread resulting from radiation from flames extending from windows.

Flames generally extend through windows under post-flashover conditions when all the combustibles in the room are involved in fire and the fire is ventilation controlled. This means that the amount of burning inside the fire room is limited by the amount of air that can enter via the openings in the compartment. If the burning is intense enough, more fuel will be volatised inside the compartment that can be burned. Gaseous fuel will then exit with the smoke and will combust on the outside as soon as oxygen is encountered. This external burning manifests as flames that could extend for several meters up the façade of the building.

In order to assess the propensity of vertical flame spread, it is necessary to estimate the flame temperature, flame length, flame thickness and radiation from the flame to the building façade above window of origin. This involves calculating the compartment temperature under post-flashover conditions; characterising the flame dimensions, calculating the variation in flame temperature with flame length and finally calculating the radiation from the flame to the façade.

The Law equations are often used for calculating the flame characteristics and radiation from external flames and are given below as abstracted from [Eurocode 1].

[Eurocode 1] BS EN 1991-1-2:2002, *Eurocode 1 – Actions on Structures – Part 1-2: General Actions – Actions on structures exposed to fire*, BSI, 2009.

G.2 Compartment fire temperature

The rate of burning from is given by:

$$\dot{Q} = min\left(\left(A_f \dot{q}_{f,d}\right)/\tau_f\,;3.15\left(1-e^{-0.036/O}\right)A_v\left(\frac{h_{eq}}{D/W}\right)^{0.5}\right)$$

And the fire compartment temperature

$$T_g = 6000\left(1-e^{-0.1/O}\right)O^{0.5}\left(1-e^{-0.00286\Omega}\right)+T_o$$

where

$$\Omega = \frac{A_f \dot{q}_{f,d}}{(A_v A_t)^{0.5}} \quad and \quad O = \frac{A_v\sqrt{h_{eq}}}{A_t}$$

and

A_f the floor area of the fire compartment, (m^2)

A_t the internal surface area of the fire compartment, (m^2)

A_v the area of the vent, (m^2)

D the depth of the fire compartment, (m)

h_{eq} the effective height of the vents, (m^2)

$\dot{Q}$ heat release rate of fire, (MW)

$\dot{q}_{f,d}$ fire load density, (MJ/m^2)

T_g the temperature in the fire compartment, (^{o}C)

T_o the ambient temperature, (^{o}C)

W the width of the fire compartment, (m)

τ_f burn time for typical furniture room fire, 1200 s

G.3 Flame characterization

The characteristics of flames issuing from openings under fully developed post-flashover conditions can be estimated from the equations presented in Figure 1.

The equations are for conditions where there is no forced draught. Since only a comparative analysis is performed, this should not affect the subsequent conclusion.

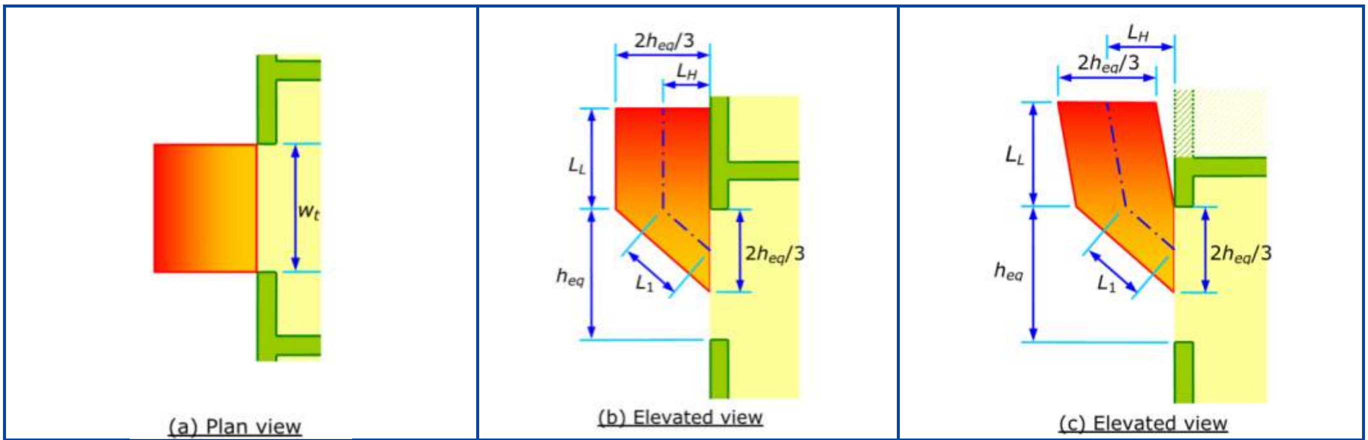
The equations in Figure 1 cover both instances where the opening is below the top of the façade and there is a façade wall above, as well as when the opening is at the top of the façade and does not have a wall above. If there is a horizontal projection above the opening, the equations need to be modified so that the overall flame length is preserved. The equations are then modified as follows:

For a horizontal projection with depth w_a above the opening – spanning the full width – and for a wall above the opening and $h_{eq} \leq 1.25w_t$

- Flame length L_L is decreased by $w_a(1+\sqrt{2})$
- Horizontal projection of flame L_H is increased by w_a

For a horizontal projection with depth w_a above the opening – spanning the full width – and for no wall above the opening or $h_{eq} \leq 1.25w_t$

- Flame length L_L is decreased by w_a
- Horizontal projection of flame L_H is increased by w_a



Flame width and depth [m]	Flame width = window width $\boldsymbol{w_t}$; flame depth = $\boldsymbol{2\,h_{eq}/3}$	
Flame length $\boldsymbol{L_L}$ [m]	$L_L = 1.9\left(\frac{\dot{Q}}{w_t}\right)^{2/3} - h_{eq}$	
Flame horizontal projection $\boldsymbol{L_H}$, [m]		$\boldsymbol{L_H = 0.6(L_L/h_{eq})^{1/3}}$
a) $h_{eq} \leq 1.25w_t$	$\boldsymbol{L_H = h_{eq}/3}$	
b) $h_{eq} > 1.25w_t$ and distance to other window $>4w_t$	$\boldsymbol{L_H = 0.3h_{eq}(h_{eq}/2w_t)^{0.54}}$	
c) in other cases	$\boldsymbol{L_H = 0.454h_{eq}(h_{eq}/2w_t)^{0.54}}$	
Flame axis length $\boldsymbol{L_1}$ [m]	$\boldsymbol{L_1 = h_{eq}/2}$	
Flame length along axis $\boldsymbol{L_f}$, [m]		
a) $\boldsymbol{L_L > 0}$	$\boldsymbol{L_f = L_L + L_1}$	$\boldsymbol{L_f = \sqrt{L_L^2 + (L_H - h_{eq}/3)^2} + L_1}$
b) $\boldsymbol{L_L = 0}$	$\boldsymbol{L_f = 0}$	$\boldsymbol{L_f = 0}$
Flame temperature $\boldsymbol{T_w}$ [K] at window with emissivity = 1.0	$\boldsymbol{T_w = \frac{520}{1 - 0.475(L_f w_t/\dot{Q})} + T_o \quad and \quad \frac{L_f w_t}{\dot{Q}} < 1}$	
Flame temperature $\boldsymbol{T_z}$ along axis and emissivity $\boldsymbol{\varepsilon_f}$ where $\boldsymbol{d_f}$ is the flame thickness [m]	$\boldsymbol{T_z = \left(T_w - T_o\left[1 - 0.4725\left(\frac{L_x w_t}{\dot{Q}}\right)\right]\right) + T_o \quad and \quad \frac{L_f w_t}{\dot{Q}} < 1}$ $\varepsilon_f = 1 - e^{-0.3d_f}$	
Where a member is immersed in flame, the convective heat transfer coefficient is [W/m²K]	$\boldsymbol{\alpha_c = 4.67(1/d_{eq})^{0.4}(\dot{Q}/A_v)^{0.6}}$	

where

$\boldsymbol{\rho_g}$ is the internal gas density, kg/m³
A_v is the total area of vertical openings on all walls $\sum_i A_{vi}$, m²
d_{eq} is the geometric characteristic of external member (diameter or side) , m
d_f is the flame thickness, m
g is the gravitational acceleration, m/s²
h_{eq} is the weighted average of window heights on all walls $\sum_i A_{vi}h_{vi}/A_v$, m
L_x is the axis length from the window to the point where calculation is made, m
$\dot{Q}$ is the rate of heat release, MW

Figure 1: Window flame properties under no forced draught conditions

G.4 Radiation from the flame

For calculating the radiative flux from the window flame to a point on the façade above, the configuration factor is required. However, as the flame temperature varies along the length of the flame, the radiative flux cannot be calculated in a straightforward manner. [Carlsson] describes a procedure where the flame is broken up into discrete increments; and for each increment the configuration factor and radiative flux is then calculated; and the contribution from each increment is then finally summed to arrive at the total heat flux.

[Carlsson] *Carlsson, E., External Fire Spread to Adjoining buildings – A review of fire safety design guidance and related research, Lund University, 1991.*

The radiative flux from each discrete element, *i*, is calculated from

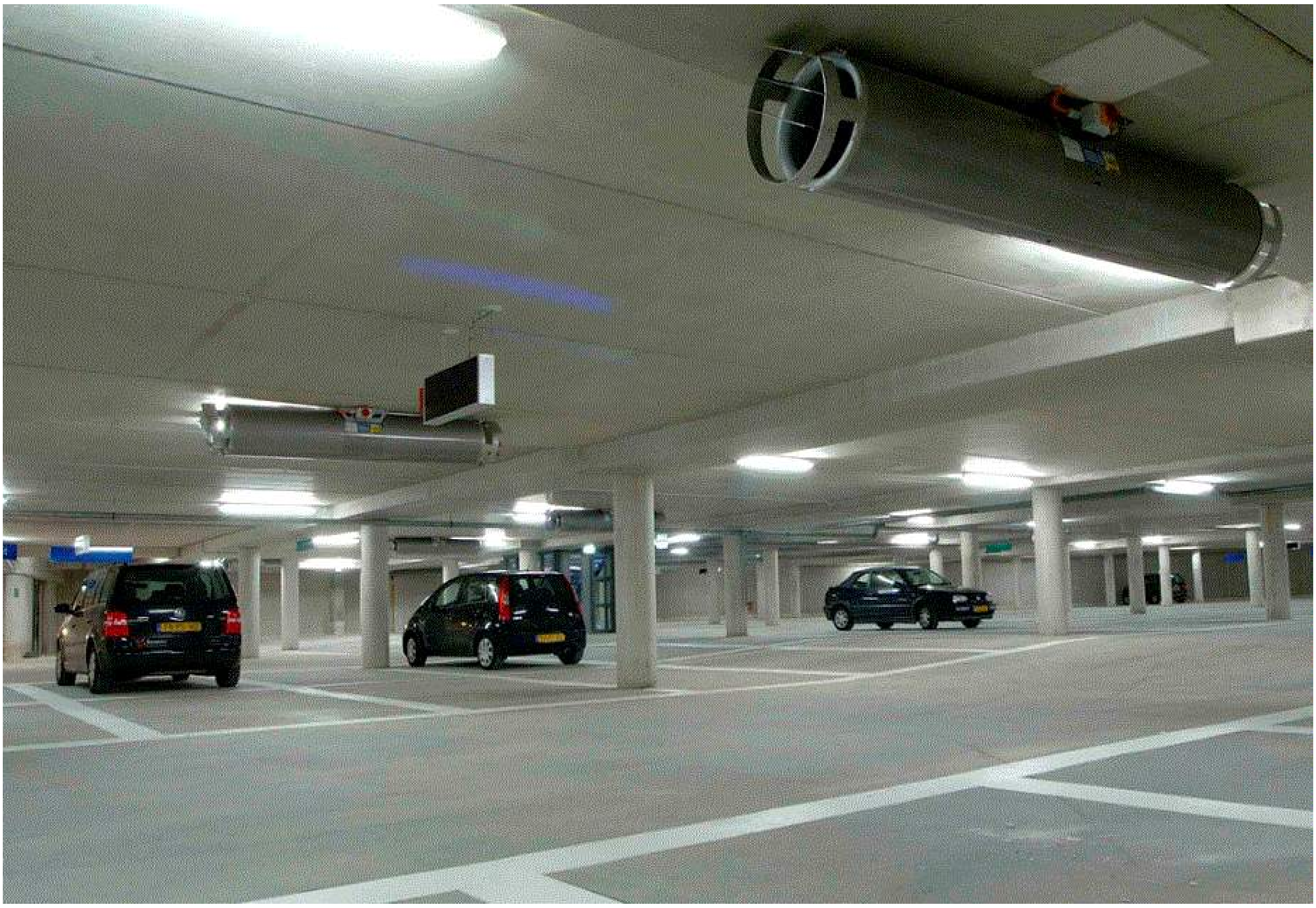
$$\dot{q}_i'' = F_{ij}\varepsilon\sigma\left(273 + T_{fi}\right)^4$$

where T_{fi} is the temperature of the flame at point *i*, and F_i is the configuration from point *i* to the point *j* on the façade where the heat flux is calculated.

The total heat flux at point *j* is then is then

$$\dot{q}_j'' = \sum_i \dot{q}_i$$

Appendix H Carpark CFD Modelling Report



HARBORD DIGGERS REDEVELOPMENT, 80 EVANS STREET FRESHWATER

CFD Modelling Report

Rev 2

4/04/2017

FEG1444000 CFD Modelling

Quality Management

Issue History

Revision	Remarks
Rev 0	Final Issue of report issued for stakeholder information.
Rev 1	Final Report for inclusion as part of the Fire Engineering Report.
Rev 2	Modifications on travel speed following comments from FRNSW
Rev 3	

QA History

Revision	Rev 1	Rev 2
Date	29/10/2015	04/04/2017
Prepared by	Emil Persson	
Checked by	Michael Lawless	
Authorised by	Lloyd Wilkinson	

HARBORD DIGGERS REDEVELOPMENT, 80 EVANS STREET FRESHWATER

CFD Modelling Report

Rev 2

4/04/2017

Client

(Mounties Group)
Mount Pritchard Distict Community Club Pty Ltd
Suite 8.01, Level 8 28-34 O'Connell Street
Sydney, NSW 2000
ABN: 98 000 458 622

Registered Company

WSP Buildings (Pty) Ltd
ABN: 47 005 113 468

Level 1, 41 McLaren Street
PO Box 6245
North Sydney NSW 2060
Australia

Tel: 02 8907 0900
www.wspgroup.com.au

WSP Contacts

Wayne Bretherton
Principal, Director of Specialist Disciplines
Mob: 0408 517 535
Wayne.Bretherton@wspgroup.com

Reference used in this CFD Modelling Report

Please note that the abbreviated text enclosed in [ ] refers to a referenced document which is described in full in the Reference Section of this report (Section 8) which is noted to be presented in alphabetical order.

Executive Summary

WSP Buildings Pty Ltd has been appointed by the Mounties Group to undertake fire engineering services associated with the proposed Harbord Diggers development located at 80 Evans Street, Freshwater NSW 2096.

The purpose of this report is to demonstrate, using CFD modelling, that the proposed the mechanical ventilation system (use of jet fans) serving the basement carpark levels of the development meets the Performance Requirements EP1.4 and EP2.2 of the BCA.

This report presents the design assumptions and the results of the CFD modelling study of the mechanical ventilation system and discusses its impact on sprinkler activation, the tenability conditions of the carparking areas during egress of people from the floor of fire origin, as well as fire fighters entering the fire floor.

The assessments undertaken in this report are in line with the type of analysis required by Fire & Rescue NSW as discussed in Section 4.2.1.

Sprinkler Analysis Summary

In order to assess the effects of the jet fans on sprinkler activation, some small scale CFD modelling has been conducted. A total of three scenarios (referred to as FS #1 to FS #3) have been selected for assessment as detailed in Table 10. The fire activation of sprinklers for fire scenarios FS #1 to FS #3 are detailed in Table 14 of this report and discussed in Section 7.1.1.

Based on the results it has been demonstrated that when the fire is located in the immediate airflow of the jet fans, the sprinkler activates later when the jet fans are running compared to when they are not. The time to sprinkler activation will depend on the location of the fire but the results show that the difference between the fire scenarios is small. The results of the simulations undertaken are consistent with the findings undertaken by [Enright]. Enright concluded in his analyses (16 CFD simulations) that delays of ≤ 30 s to sprinkler activation where the sprinkler and jet fans layout was coordinated so the sprinklers are inplane with the jet fan nozzle.

Tenability Analysis Summary

In order to assess the effects of the jet fans on tenability conditions within the carpark, a total of six fire scenarios (referred to as FS #4 to FS #9) as detailed in

Table 11 have been considered utilising the proposed jet fan mechanical design. Based on the results presented in Sections 7 and 8, it is submitted that the required Margin of Safety of 1.5 between the Available Safe Egress Time (ASET) and the Required Safe Egress Time (RSET) analysis has been achieved as summarised in Table 1.

The results of the CFD modelling confirm that the conditions in the carpark in a fire scenario are within the acceptance limits for both occupant egress and fire brigade intervention as discussed in Sections 5.3 and 5.4 of this report.

Table 1: ASET / RSET Comparison Analysis

Fire Scenarios	RSET Time (s)	RSET x 1.5 (s)	ASET Time (s)	Safety factor	
FS #4	352 seconds	528 seconds	>528 seconds	> 1.5	**Satisfied***
FS #5	301 seconds	452 seconds	>500 seconds	> 1.5	**Satisfied**
FS #6	313 seconds	470 seconds	>470 seconds	> 1.5	**Satisfied***

Table of Contents

1.1.1 Abbreviations used in this report

The following abbreviations are used in this report.

Abbreviation	Description
FRNSW	Fire & Rescue New South Wales
BCA	Building Code of Australia
CFD	Computational Fluid Dynamics
CO	Carbon monoxide
DtS	Deemed-to-Satisfy
FER	Fire Engineering Report
FEBQ	Fire Engineering Brief Questionnaire
FFL	Finished floor level

2 Introduction

2.1 Background & Introduction

It is proposed to install an impulse fan ventilation system in the basement car parking levels of the proposed development in lieu of a ducted ventilation system.

2.1.1 Complying with BCA Performance Requirements EP1.4 & EP2.2

BCA Clause E2.2 requires an [AS 1668.2] mechanical ventilation system in a carpark building to comply with Clause 5.5 of [AS/NZS 1668.1] with certain concessions. Clause 5.5 of AS/NZS 1668.1 requires the exhaust system to continue to operate in fire mode and shall operate at its full capacity where the system incorporates variable flow rates. However, it is considered that these requirements were meant to apply to the traditional ducted ventilation systems and the BCA does not give consideration to impulse fans and does not provide any requirements or guidance for the operation of impulse fans in fire mode. For this reason, a mechanical design utilising impulse fans should be addressed as an Alternative Solution to demonstrate compliance with Performance Requirement EP2.2.

Concerns have been raised on the use of jet fans in sprinklered carparks by fire brigade (notably FRNSW as noted in the Section 2.1.2) in Australia. They are questioning whether the high velocity air jets created by impulse fans could significantly delay the sprinkler activation and could cause activation of sprinklers further from the seat of fire. For this reason, an Alternative Solution is required to demonstrate compliance with Performance Requirement EP1.4.

2.1.2 Fire & Rescue NSW

FRNSW is noted to have a Fire Safety Guideline for impulse fans in sprinkler protected car parks (as listed in Table 2). As discussed in Section 5 of the guideline, FRNSW is of the view that the installation of impulse fans is not a Deemed-to-Satisfy solution in the current AS 1668.2 unless the design consists of a single impulse fan serving a dead end spot in the carpark. Where the installation exceeds this, such as a series of impulse fans (like the current proposal), the system is no longer considered DtS and an Alternative Solution is required to ensure that BCA Performance Requirements EP1.4 and EP2.2 are satisfied.

It is noted that FRNSW is a referral authority for this project and a FEBQ has been submitted to FRNSW for their review, comment & consideration. An FEBQ application (Issue V01) was lodged to the FRNSW on 31st of July 2015 under Clause 144 of EP&A Regulation 2000 which has included the input parameters utilised as part of the CFD Modelling.

2.1.3 Complying with BCA Performance Requirements FP4.4

The latest AS 1668.2 permits the use of impulse fans for ventilation in carparks. However, it is understood that the impulse fans are allowed to be used as an alternative to provide ventilation to dead end spaces when the space is difficult to be covered by the ducted system. In this sense, a ventilation system using impulse fans throughout a carpark is not considered compliant with AS 1668.2. In the proposed development, jet fans are proposed to be used throughout the basement carparks as the normal ventilation system in lieu of a traditional ducted ventilation system. This should be addressed as an Alternative Solution to ensure compliance with Performance Requirement FP4.4 regarding the air quality.

A separate CO modelling report has been undertaken by WSP Fire to demonstrate compliance with the Performance Requirement FP4.4.

Both the CO & the subject CFD modelling reports shall be incorporated in the Final FER for the Harbord Diggers Development (attached as an appendix) as a justification in demonstrating compliance with BCA Performance Requirements EP1.4, EP2.2 & FP4.4 for the carparking levels.

2.2 Scope & Objectives

The purpose of this report is to demonstrate, using CFD modelling, that the proposed mechanical smoke exhaust strategy to the carparking areas of the development meets the Performance Requirements EP1.4 and EP2.2 of the BCA.

In addition, the report will also show the tenability conditions of the carparking areas during egress of people from the floor of fire origin, as well as fire fighters entering the fire floor.

This report runs through the process of determining a realistic timeline of events, the assumptions made for the model input parameters and the assumed tenability criteria. These assumptions form the basis for determining whether the system satisfies the performance requirements of the BCA.

This report focuses solely on the technical aspects of the CFD modelling and the methodology used in the CFD modelling process. All other aspects of the Fire Engineering Strategy for the Harbord Diggers development are presented in the FER for the project.

2.3 Sources of information

The relevant drawings and documentation which have been assessed as part of this CFD Modelling report are listed in Table 2.

Table 2: Relevant Drawings & Documentation

DWG No.	Drawing Name	Organisation	Date	Rev
A1000	Overall Basement Level 2 Plan	Architectus+Chrofi	13/06/2015	Q
A1001	Overall Basement Level 1 Plan	Architectus+Chrofi	13/06/2015	Q
A1002	Overall Lower Ground Floor Plan	Architectus+Chrofi	15/06/2015	Q
WSP-ME-0-B02-100	Basement 2 – Air conditioning and ventilation overall layout	WSP	27/02/2015	2
WSP-ME-0-B01-100	Basement 1 – Air conditioning and ventilation overall layout	WSP	27/02/2015	3
Report 2013/1528	Harbord Diggers Redevelopment 80 Evans Street, Freshwater BCA Compliance Report	Steve Watson & Partners	07/07/2015	2.1
Fire Safety Guideline	Fire Safety Guideline: Guideline for impulse fans in car parks	Fire & Rescue NSW	09/10/2014	01

2.3.1 Figures used in this report

It is noted that the figures presented in this report provide an indicative illustration of the carparking areas, the CFD modelling (discussed in Section 6) and it associated findings. The CFD model has been based on the architectural drawings prepared by Architectus+Chrofi detailed in Table 2.

3 Description of Carpark & Proposed Mechanical System

3.1 Description of car parking levels

The carparking area of the proposed development comprises of two floor levels which have been referred to as Basement Levels 2 & 1. A breakdown of each level has been detailed in Table 3 which has been based on detail contained within Section 11.2 of the BCA Report.

Table 3: Floor areas and volumes

Floor Level	Approx. Area (m^2)	Approx. Volume (m^3)	Ceiling Height
Basement Level 2	13,728	41,184	2.7 m
Basement Level 1	13,666	40,998	Ranges 3 m (in part) to 4.4 m

3.2 Carpark Population

The population to the carparking levels has been detailed in Table 4 which is based on detail from Section 11.4 of the BCA Report prepared by Steve Watsons & Partners which utilises an occupant floor loading of 30 m^2 per person (as prescribed in BCA Table D1.13) for a carpark.

Table 4: Distribution of occupants in carparking areas

Floor Level	Area (m^2)	Occupant density (m^2/person)	Number of occupants
Basement Level 2	13,728	30	458
Basement Level 1	13,666	30	456

3.3 Carpark Layout & means of escape

The extent of the carparking areas at Basement Levels 2 & 1 have been indicatively illustrated in Figure 1 and Figure 2. The means of escape for the carparking levels is by way of Stairs ST01 to ST06. Please note that the layouts indicated are indicative sketches only and should be read in conjunction with the Architectus+Chrofi drawings listed in Table 2.

Vehicle entry to the proposed development shall be by way of Evans Street which has been indicatively illustrated in Figure 3. The carparking entry and exit points shall be by way of the Port Cochere area which is located at Lower Ground Floor Level.

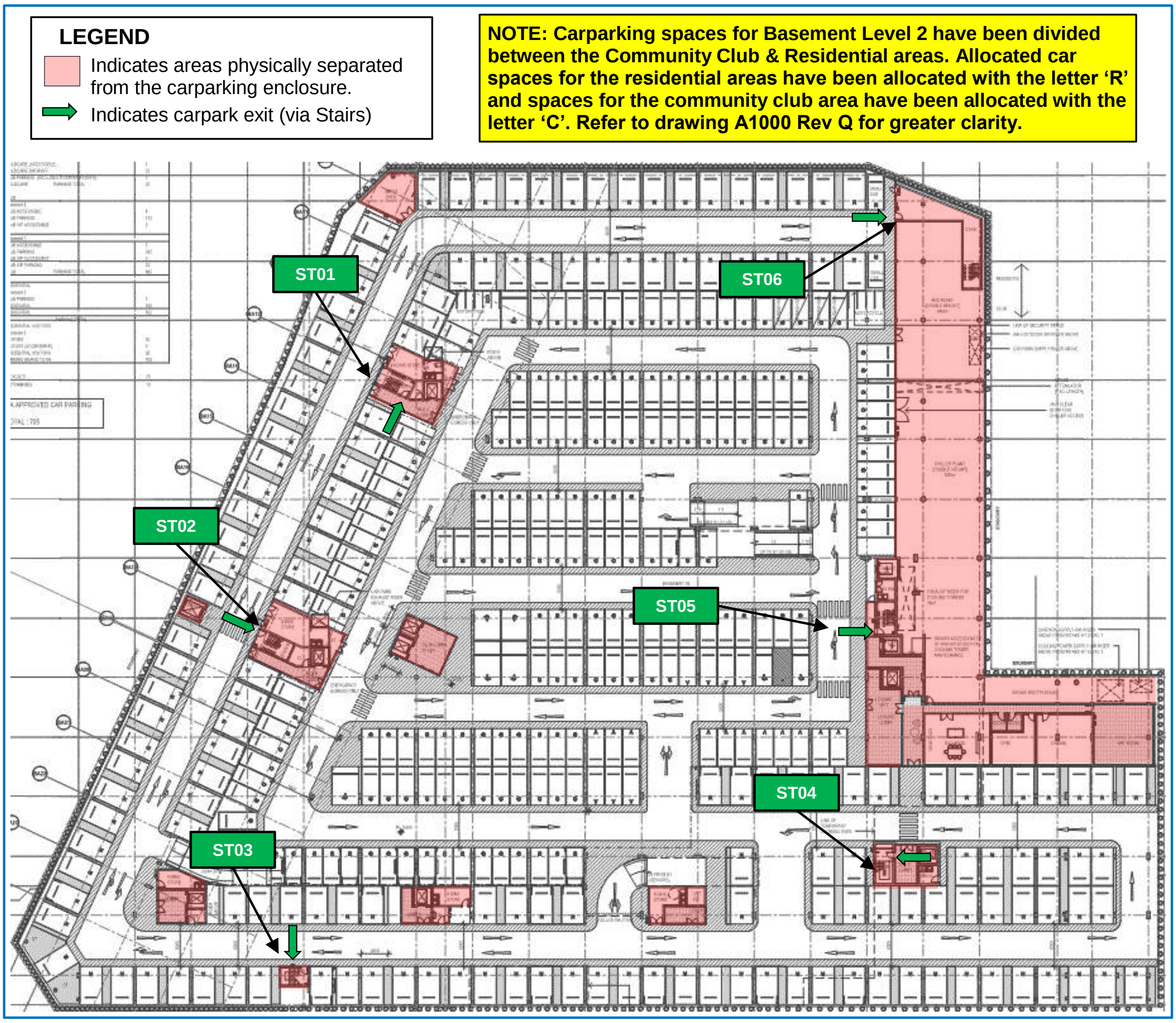


Figure 1: Overall Basement Level 2 Plan – extent of carparking areas and exits within

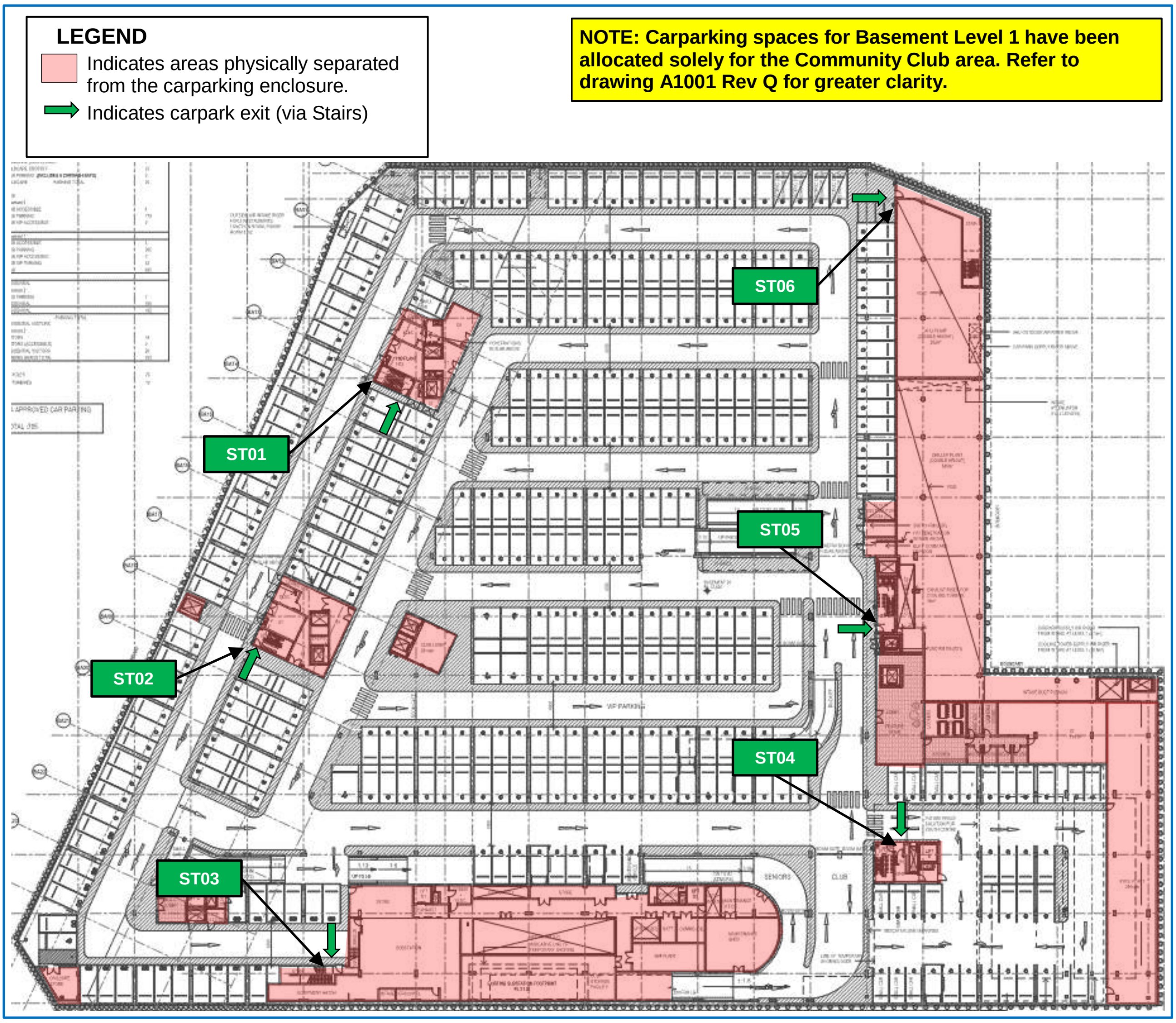


Figure 2: Overall Basement Level 1 Plan – extent of carparking areas and exits within

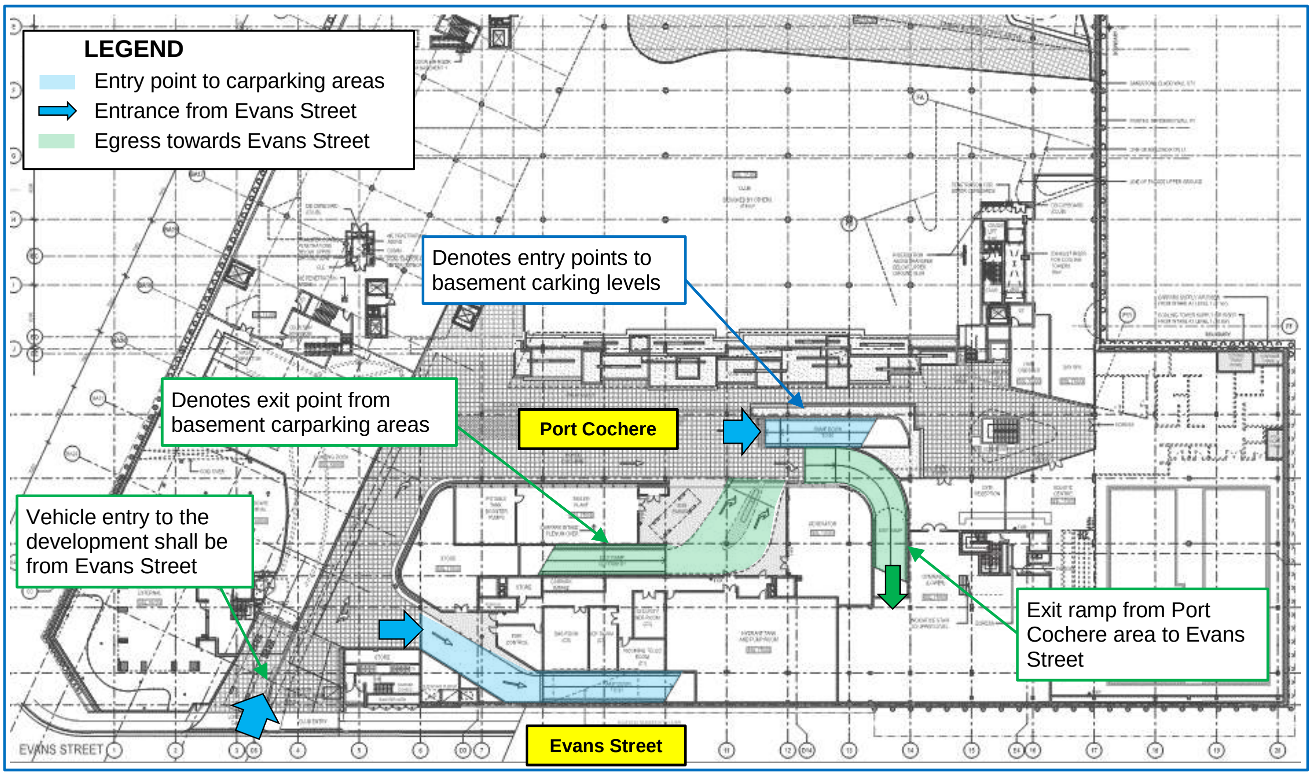


Figure 3: Lower Ground Floor Level – vehicle approach & entry / exit points of the car parking areas

3.4 Car park Ventilation System

As discussed in Section 2.1 of this report, it is proposed to install a jet fan ventilation system in the basement carparks of the Harbord Diggers Development in lieu of a ducted ventilation system. A jet ventilation system is based on a number of small, strategically located high velocity jet fans mounted directly beneath the ceiling, in place of the distribution ductwork traditionally used in car parks. The system provides constant flow and air movement around a car park ensuring harmful pollutants do not gather and accumulate in dead areas.

Induction fans producing a high velocity jet which thrusts against the air in front of the fan imparting momentum to all the surrounding air through entrainment as it diffuses. The volume of entrained air is significantly greater than that passing through the fan. The induction fans are carefully positioned to mix the air in the car park and direct it towards the main extract fan intake points which has been indicatively illustrated in Figure 4. The main extract fans are sized to provide the required airflow rates however, given the reduced need for, or complete elimination of ducting, the resulting reduction in system resistance means they are typically smaller and consume less energy than fans for fully ducted systems.

Figure 4: Principle of operation - workings of an Impulse Fan (Image © Fantech)

The car park ventilation system for the development has been summarised in Table 5 which has been based on the mechanical drawings prepared by WSP as well as the impulse fan layouts for the proposed basement provided by Fantech. The proposed design shall utilise the Fantech JIU-CPCEC-SD Impulse Fan unit throughout with the technical specification sheet for this unit attached in Appendix A for ease of reference. Each jet fan shall have a 1.2 m^3/s air velocity at the nozzle. To decrease simulation times, each jet fan in FS#1-9 shall have a 2.0 m^3/s air volumetric flow at the nozzle. A 1.2 m^3/s flow rate is used in CO simulations to give more onerous results, as less air movement in the car park will increase the amount of CO compared to higher velocities. It is noted that a different velocity of 2.0 m^3/s has been used in fire scenarios. This is seen as a more conservative approach for the fire scenarios as higher velocities and volumetric flow rate will give later sprinkler activation time(because of higher velocity will increase the smoke movement) and more smoke movement. Difference in velocities from jet fans for the CO and fire scenarios is also made to decrease required simulation time).

An indicative layout of the impulse fans units for both Basement Levels 2 & 1 have been illustrated in Figure 34 and Figure 35 of Appendix B which have been designed by Fantech. Table 5 provides a breakdown of mechanical supply and exhaust points at each level as well as the number of impulse fans at each level. The following detail should be read in conjunction with the drawings presented in Table 2. Refer to the WSP mechanical drawings for clarity on the location of the supply air point inlet points and exhaust points at each level of the carpark.

Table 5: Mechanical Supply and Exhaust rates of carpark ventilation system

Floor Level	Mechanical Supply		Mechanical Exhaust		No. of natural supply air inlet	No. of Jet fans
	Supply Rate (m^3/s)	No. of Vents	Exhaust Rate (m^3/s)	No. of Vents		
Basement Level 2	15 (Area 2)	1	17 (Area 1)	1	4	20
	10 (Area 8)	1	17 (Area 3)	1		
	20 (Area 7)	1	17 (Area 6)	1		
Total	**45 m^3/s**	**3**	**51 m^3/s**	**3**		
Basement Level 1	15 (Area 2)	1	24 (Area 1)	2	3	18
	20 (Area 8)	1	24 (Area 3)	2		
	30 (Area 7)	1	24 (Area 6)	2		
Total	**65 m^3/s**	**3**	**72 m^3/s**	**6**		

4 Review of FRNSW guidance

4.1 Hazards associated with Jet Fans in a fire scenario

The jet fans can create high velocity air jets and are likely to cause turbulence in the atmosphere. Therefore, in the event of a fire in a car park, there are concerns about the use of jet fans as follows:

- The activation of sprinklers could potentially be delayed and sprinkler heads downstream of the fire seat may unnecessarily be activated. As a result, the fire may grow to a larger size due to the delayed sprinkler activation and may cause fire spread to adjacent vehicles depending on how long the delay is. The occupant warning may also be delayed where the sprinkler system is the sole means to detect a fire. Activation of sprinklers downstream of the fire seat may increase the water demand of the sprinkler system above the design allowance.
- The turbulence caused by the operation of jet fans will promote mix of smoke and air that could destroy the smoke stratification therefore may cause reduced visibility and tenability for occupants. To this end, it is customary to shut the jet fan system down upon detection of a fire. The impact of smoke spread and tenability in the carpark during egress period need to be demonstrated.

4.2 Fire & Rescue NSW Guideline – Design requirements

Sections 5.1 of the FRNSW guideline discussed in Section 2.1.2, provides a breakdown of the design requirements for the impulse system which is issued for stakeholder review (including FRNSW) as part of the Fire Engineering Brief process under the [IFEG]. The design requirements has been listed in Table 6 which discusses the proposed design of the impulse system against FRNSW requirements.

Table 6: Design requirements as per FRNSW Guideline

Design requirements as per Section 5.1 of FRNSW Guideline		Proposed Design
Item 1	The impulse fans should be located in driveways and access ways, and not above carparking spaces or other areas where there are stagnant fire loads.	The design provided by Fantech for the carparking levels which is detailed in Figure 34 and Figure 35 of Appendix B – has the impulse fans located in the driveways and access ways.
Item 2	The impulse fans should be located between rows of sprinklers and it should be demonstrated that the air jet from the impulse fans does not impinge upon any sprinkler heads.	The impulse fans will be located between rows of sprinklers as indicatively illustrated in Figure 13 and Figure 14 of Section 7.1 of this report. The CFD assessment in this report shall demonstrate that the air jet from the impulse fans does not impinge upon any sprinkler heads within.
Item 3	The impulse fans are to shut down upon detection of fire within the carpark, including activation of any sprinkler system or smoke detector head within the circulation car-park areas. However, in addition, an appropriate means of shutting down the impulse fan system via the provision of a suitable detection system is also to be provided. The detection system should only shut down the impulse fan system and activate the occupant warning system but will not activate fire brigade notification unless it is appropriate to use within a car park environment and would not cause spurious alarms.	The activation of smoke detector heads provided in the circulation areas of the car-parks will automatically shut down the impulse fans on the fire affected floor and activate the building occupant warning system. The activation of sprinklers in the basement car parks shall also automatically turn off the impulse fans on the fire-affected floor and activate the building occupant warning system. The impulse fans shall have in-built duct probe smoke detectors. These smoke detectors are required to be connected to the FIP. On activation of any of these smoke detectors, all the impulse fans on the fire-affected floor shall be switched off automatically and remain switched off unless manually reset at the FIP and the building occupant warning system shall be activated.
Item 4	Manual control of the impulse fans should also be provided for fire-fighters at the Fire Fan Control Panel (FFCP) so that the impulse fans can be used during fire brigade intervention if	Manual control of the impulse fans will be provided for fire-fighters at the FFCP or FIP. This shall include individual ON-AUTO-OFF switches for each of the impulse fans and exhaust and supply fans on the FFCP or FIP. Mechanical layout plan for basement

Design requirements as per Section 5.1 of FRNSW Guideline		Proposed Design
	required.	levels to be provided at FIP indicating impulse fans location with numbers as designed on FIP.
Item 5	The shutdown operation of the proposed detection system should be tested during the commissioning tests prior to occupancy. The test procedures should be in accordance with the relevant Australian Standards for the applicable detection system.	The testing of the system shall be in accordance with AS 1670.1 and AS 1668.1. Commissioning testing will verify the jet fans cease operation in the event of smoke being detected in the carpark, or a flow switch being triggers on one of these floors.
Item 6	Sprinklers, where required, must be installed as per the BCA and AS 2118.1: 1999.	Sprinklers are being installed throughout the car-parking areas in accordance with AS 2118.1 which includes fast response sprinklers (RTI ≤ 50) spaced on a 3 m by 4 m grid to Ordinary Hazard 2 system.

4.2.1 Analysis required

Section 5.2 of the FRNSW guideline provides a breakdown on the type of analysis required for ascertaining both the impact on sprinkler performance as well as the impact on conditions for occuapants and firefighters. The analysis is to be undertaken for two scenarios, a fire located within the immediate airflow directly in front of an impulse fan and a fire located outside the immediate airflow as illustarted in Figure 5.

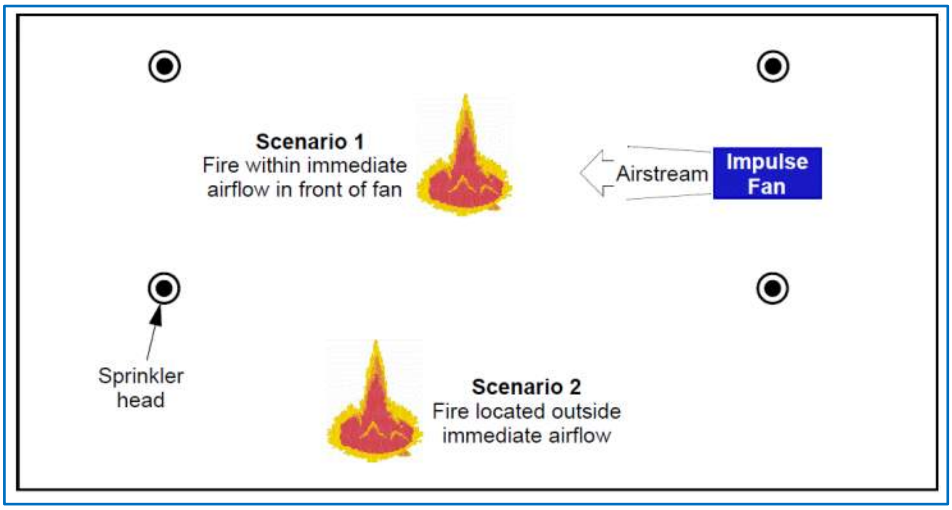


Figure 5: Fire Scenario locations for analysis of sprinkler performance (Figure 1 of FRNSW Guideline)

5 Acceptance Criteria

5.1 Introduction

This section of the report runs through the acceptance criteria with regards to tenability conditions of the carparking areas during egress of people from the floor of fire origin, as well as fire fighters entering the fire floor.

To determine whether the Alternative Solution is considered to meet the BCA Performance Requirements EP1.4 & EP2.2, it needs to be demonstrated that the intent of the BCA is met in that;

- The jet fan system shall not adversely affect the operation of the sprinkler system in preventing fire spread to adjacent vehicles.
- There is sufficient time for the occupants of the carpark to evacuate via the exits provided. It needs to be demonstrated that tenable conditions are maintained during evacuation, and that occupants can escape to a safe place. In addition, conditions for fire service intervention will also be reviewed.

5.2 Approach & Method of Analysis

It is proposed to provide a quantitative analysis, which will determine the evacuation time for persons in the carpark to evacuate against tenability conditions within this area which will be supported by the use of CFD modelling.

It is proposed to undertake an Available Safe Egress Time (ASET) versus Required Safe Egress Time (RSET) analysis for the carpark with reduced exit capacity. By evaluating the likely warning afforded to occupants evacuating the carpark, it is possible to carry out a time based comparison of the time available for occupants to escape (if necessary) or to reach a place of safety (ASET) against the actual time taken for occupants to escape (RSET).

CFD modelling is being used to determine the ASET for the carparking areas. The ASET is required to exceed the RSET by a sufficient margin of safety. Typically a factor of safety of 1.5 or a period 5 minutes (whichever is the lesser) is required under the [IFEG].

This may be expressed as:

$$SF = \frac{ASET}{RSET} \qquad or\ alternatively \qquad SF = ASET - RSET$$

Equation 1

Where:

ASET = available safe egress time (min) as determined by CFD smoke modelling

RSET = required safe egress time (min) based on known life safety systems and research on evacuation

SF = safety factor

The ASET and RSET concepts are illustrated in Figure 6 below. The intent of the ASET / RSET comparison analysis is to assess whether occupants can safely evacuate from the basement car park in order to assess compliance with Performance Requirement EP2.2.

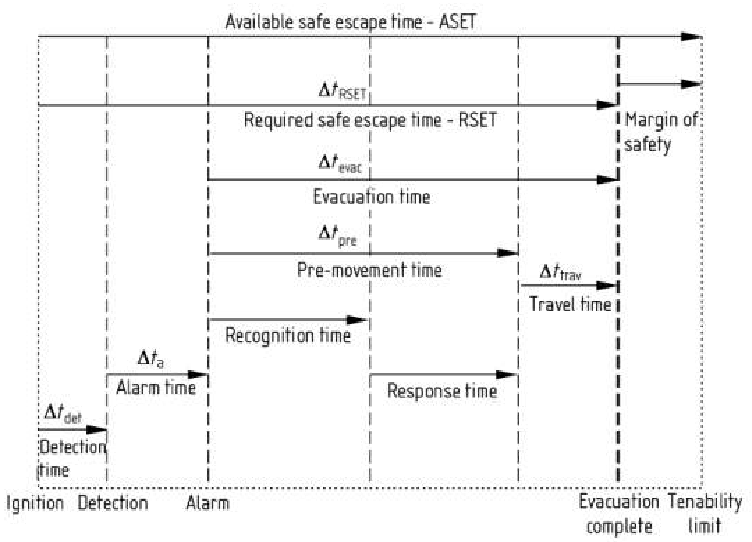


Figure 6: ASET – RSET timeline

5.3 Occupant Tenability Criteria

Where CFD modelling is undertaken the acceptance criteria with regard to enclosure tenability for occupant evacuation shall be in accordance with the IFEG and [CIBSE] and other relevant fire safety codes / publications which have been detailed in Table 7.

Table 7: Occupant tenability criteria

Occupant Tenability Criteria	
Convective heat	Temperature < 60 °C when smoke layer is below 2.0 m
Radiant heat exposure	Radiant flux < 2.5 kW/m^2 at 2.0 m, or smoke layer temperature < 200 ºC when smoke layer is at or above 2.0 m
Visibility	When the smoke layer is below a height of 2.0 m: ▪ Reflective surface visibility > 10 m (for large spaces) ▪ Illuminated signage visibility > 5 m (queuing at exits)

5.4 Fire Brigade Tenability Criteria

For the purpose of assessing the safety of the fire brigade personnel, the criteria set out by Australasian Fire Authorities Council [AFAC] may be used which has been summarised in Figure 7.

	Routine Condition	Hazardous Condition	Extreme Condition	Critical Condition
Maximum Time	25 minutes	10 minutes	1 minute	< 1 minute
Maximum Air Temperature	100°C	120°C	160°C	> 235°C
Maximum Radiation	1kW/m^2	3kW/m^2	4 - 4.5kW/m^2	> 10kW/m^2

Figure 7: Exposure limits for fire fighters under various condition (abstract from [ASFS])

6 Design Criteria & Assumptions

6.1 Computational Fluid Dynamics

The CFD model used in this assessment was Fire Dynamics Simulator 6 (FDS 6.1.2), produced by the National Institute of Science and Technology (NIST). The simulator has been extensively validated against both real and laboratory fires and is considered to be an industry standard.

The assumptions and limitations of the simulator are not reviewed here and full reference should be made to NIST Special Publication 1018 '*Fire Dynamics Simulator (Sixth Edition) Technical Reference Guide'*. All models have been both undertaken and checked by experienced users in line with the recommendations of NIST.

6.1.1 Simulation Approach

This section of the report runs through the assumptions made for the CFD modelling input parameters. The simulation approach is to demonstrate that the proposed mechanical smoke exhaust strategy to the carparking areas of the development meets the Performance Requirements EP1.4 and EP2.2 of the BCA.

6.2 Simulation Parameters

6.2.1 Model Design & Geometry Construction

The CFD model has been constructed as per the architectural drawings provided as per Table 2. While some elements of the geometry have been simplified in order to provide a stable model platform, care has been taken to retain all elements which have influence over the flow field within the model. Elements such as beams, columns and ramps have been included.

An overview of the carpark model built using FDS is shown in Figure 8 which is a 3D image of the carparking areas. A further floor by floor breakdown of the carparking areas has been illustrated in Figure 9.

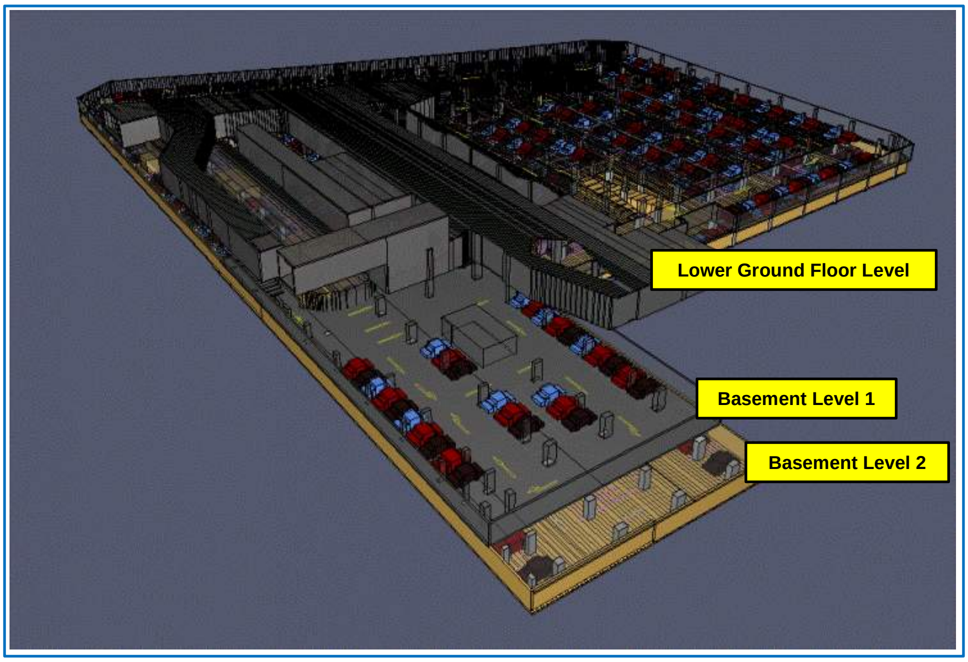


Figure 8: 3D image of the FDS Model for carparking levels used for CFD Modelling

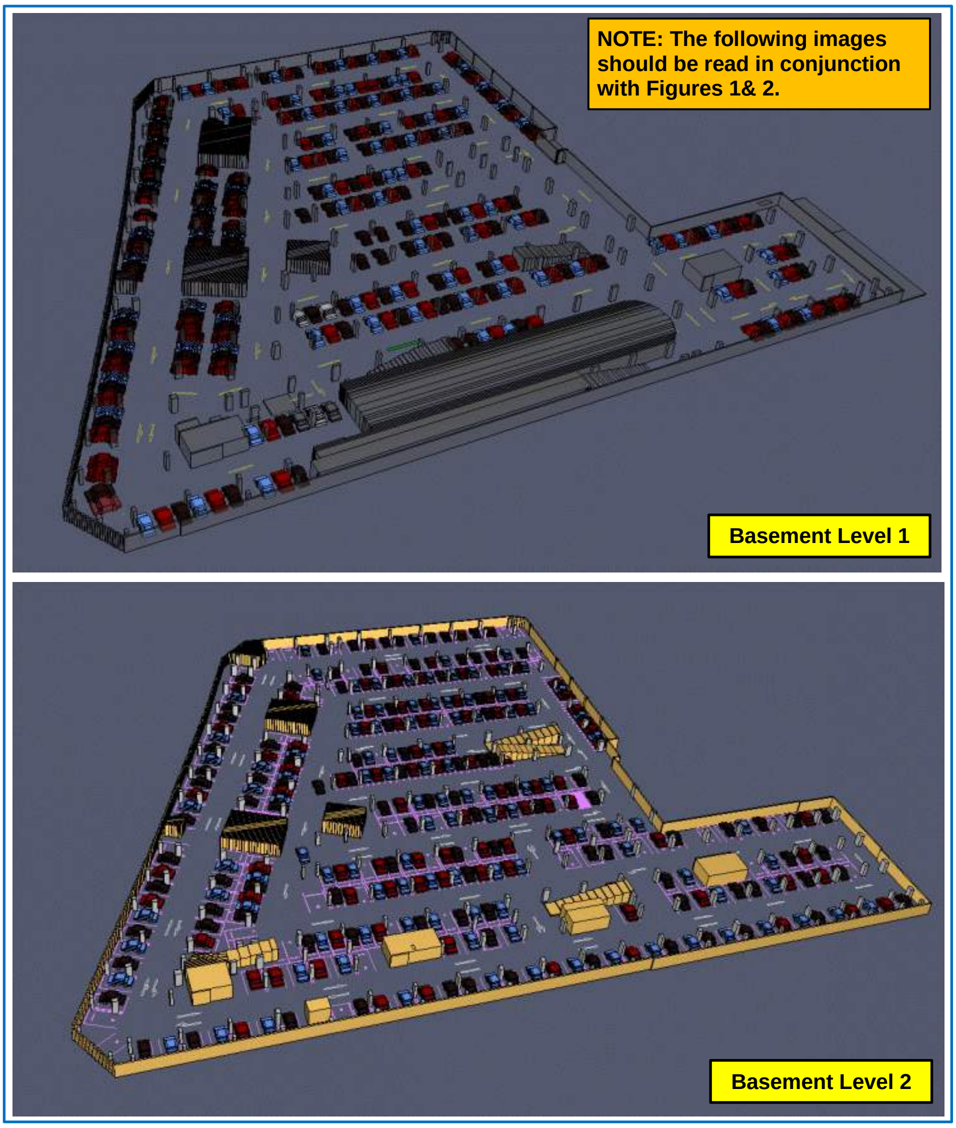


Figure 9: FDS Model (floor by floor) of the carpark including entry points to carpark

6.2.2 Model accuracy

The models have been created to replicate the proposed architectural design to a level of detail and accuracy which is considered to be acceptable in order to provide realistic results.

All obstructions, walls and floors have been modelled as inert surfaces.

6.2.3 Mesh sizing

The accuracy of the CFD modelling is affected by the number of grid cells used in the CFD calculations. For the critical areas, such as around Jet Fans and around the fire, the provided meshes have grid cells which measure 0.125 m x 0.125 m x 0.125 m or 0.0625 m x 0.0625 m x 0.0625 m. For the rest of the model, the meshes have grid cells of 0.250 m x 0.250 m x 0.250 m and for less important areas are meshes having grid size 0.5 m x 0.5 m x 0.5 m. Based on experience, this grid size is considered to be suitable for this model.

6.2.4 Slice files

A number of slice files have been place throughout the model to allow for the visualisation of the gas phase flow patterns and quantities. The CFD model assesses visibility, temperature and velocity slice files. The conditions at these slice files can be seen in the results.

6.2.5 Species, soot yield and CO yield

A reaction has been added to the model to simulate the production of certain smoke particle:

Table 8: Species, soot yield and CO yield

Parameter	Carbon atoms	Hydrogen atoms	Oxygen atoms	Nitrogen atoms	Other atoms	Co yield	Soot yield	Hydrogen factor
Value	1.0	1.7	0.3	0.008	0	0.04	0.198	0.1

6.2.6 Different measures

The different ceiling heights have been assessed as part of this report are listed in Table 9.

Table 9: Basement Level ceiling heights

Floor	Actual Ceiling height (m)	Ceiling Height used
Basement Level 2	2.7 m	2.5 m (for CFD simulation)
Basement Level 1	Ranges 3 m (in part) to 4.4 m	3 m (for CFD simulation)

It is noted that the ceiling heights in the CFD model are actually lower than the ceiling heights of the proposed carpark. The lower value was utilised to fit within the rectangular grid utilised in the CFD model. The lower dimensions utilised presents a more conservative analysis as it essentially presents a smaller built environment.

6.3 Design fires

In FDS the combustion/reaction process is a conversion of fuel to products of combustion, such that the production rate of each product species is proportional to the fuel consumption rate. This means that for each fuel molecule, fixed amounts of CO2, H2O, CO, and soot are formed and these products persist in the plume indefinitely with no further reaction.

FDS does well in the smoke transport and the prediction of O_2 levels. It does not automatically predict the CO concentration. An additional combustion reaction needs to be added to the simulation to run in parallel to the fire in order to predict the CO levels. Therefore the fire size, soot yield, species, and CO yield are the main parameters that will have to be specified.

6.3.1 Fire size and growth rates associated with carparks

The Heat Release Rate (HRR) reference curve proposed by Schleich [SR255] for a single car fire, as illustrated in Figure 10, is proposed to be used as design fire. The fire curve is based on five individual car fire tests under a calorimeter hood and is based on European cars from the 1980s up to 1995 models. The HRR for the later cars are greater and has been used to derive the reference fire curve shown in Figure 10.

The tests conducted by Schleich showed that it took 12 minutes for fire to spread to an adjacent car and that a third car would ignite after 24 minutes when the first car fire would be entering the decay phase.

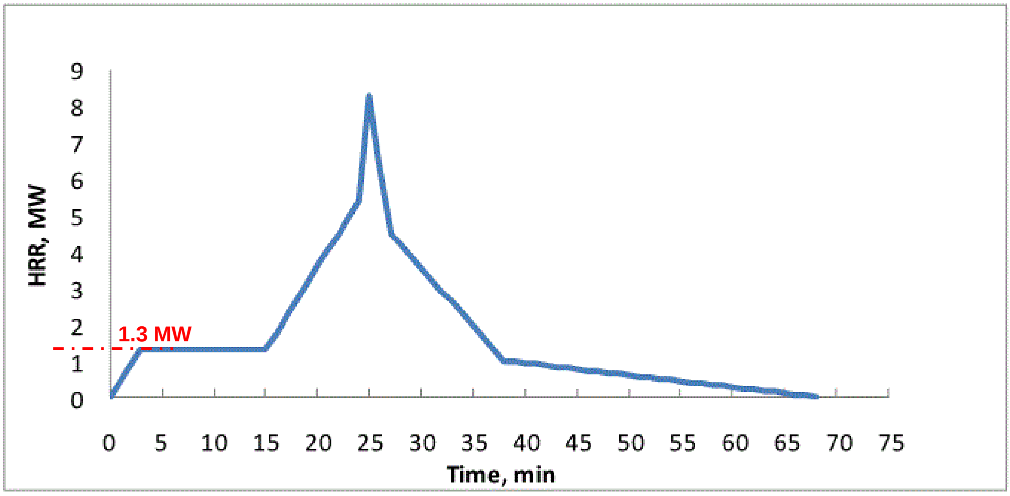
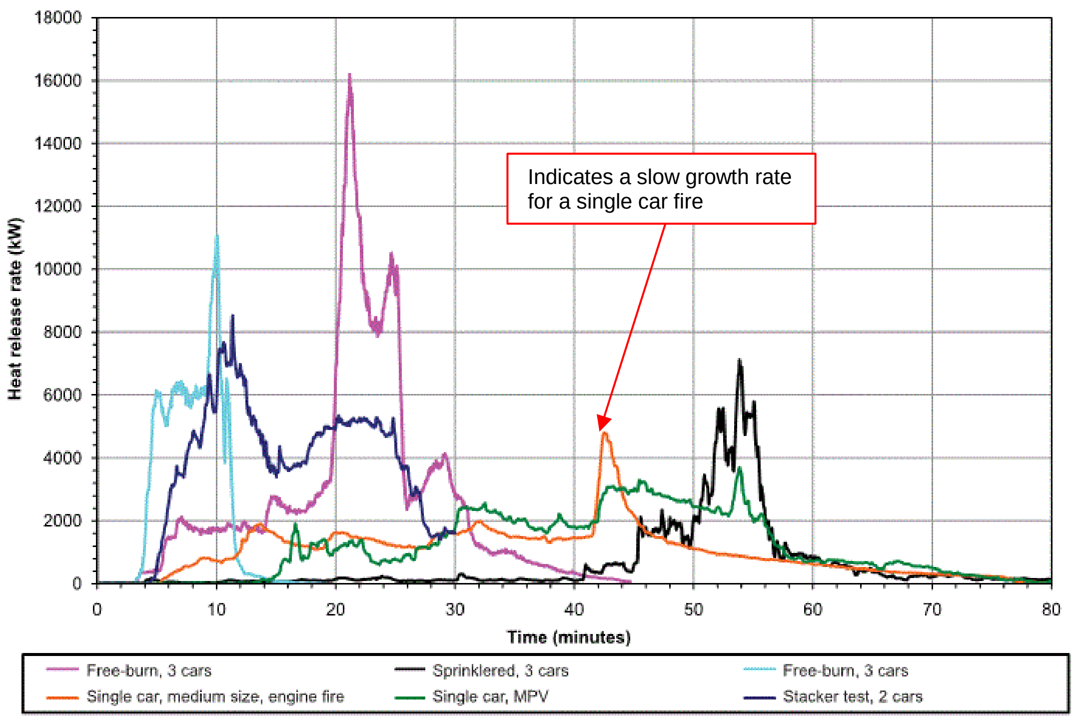


Figure 6: HRR reference curve for single car fire

Figure 10: Branz Report (Figure 6) – fire growth rate for a single car fire

It is further noted that the [BRE] report '*Design Fires for Use in Fire Safety Engineering*' provides guidance on design fires for cars. The heat release results for three experiments simulating an open-sided carpark (with and without sprinklers) and one experiment simulating a car stacker are reported and are pictorially illustrated in Figure 11. The HRR for a single car fire test undertaken by BRE is considerably slower than the proposed reference design fire curve. The long incipient fire phase associated with car fires has also conservatively been ignored.

HEAT RELEASE RATE DATA



Total heat release rates from car park fires

Figure 11: BRE Report Figure 6 – heat release rates from car perk fires (open-sided)

6.3.2 Proposed Fire Scenarios

The car park in the subject development is fully sprinklered. In the event of a fire in the car park, the fire is expected to be controlled by the operation of sprinklers and contained within the car of origin. It is assumed that the fire grows at a slow growth rate to a maximum size of 1.5 MW and remains that size till the end of the simulation. As discussed before, the [BRE] report recommends a fire growth coefficient for a sprinklered car park fire which is much slower than t^2 slow growth rate.

For the sensitivity analysis, a fire scenario growing at a medium growth rate was also assessed and this fire grows to a maximum fire size of 4 MW and remains that size till the end of the simulation. This fire scenario may be representative of a sprinkler failure scenario.

6.3.3 Fire Scenarios (sprinkler analysis)

As discussed in Section 2.1.1, fire authorities are concerned that the operation of the jet fans may delay the activation of sprinklers. In order to assess the effects of the jet fans on sprinkler activation, some small scale CFD modelling has been conducted. A total of three scenarios have been selected for assessment as detailed in Table 10 which has been based on the type of analysis required by FRNSW discussed in Section 4.2.1.

For fire scenario FS #1 to FS #3, the fire is located 1.2 m above floor level on top of the roof of a car. The growth rate for the sprinkler fire scenarios has been specified as t^2 medium, which is considered to be conservative based on slow t^2 growth rates for car fires discussed in Section 6.3.1.

Table 10: Fire Scenarios – for Sprinkler Activation Analysis

Fire Scenarios	Growth Rate & Size	Location relative to jet fans	Description of fire scenario
FS #1	t^2 medium growth rate	Jet Fan Off	This is a base case scenario representing a car park without jet fans. Sprinklers will activate as they are designed to. Note that in a DtS design, the sprinkler system may comprise standard response sprinklers. Therefore, the use of fast response sprinkler in the modelling would provide a conservative analysis.
FS #2	t^2 medium growth rate	Fire within immediate airflow in front of jet fan	The high velocity jet stream from the jet fan will directly blow the fire plume which effects the smoke movement patterns within the car park. As a result, the activation of sprinklers may be affected.
FS #3	t^2 medium growth rate	Fire outside immediate airflow of jet fan	This scenario may cause less disturbance to smoke movement than FS #2 but may still affect sprinkler activation.

6.3.4 Fire Scenario (tenability analysis)

In order to assess the effects of the jet fans on tenability conditions within the carpark, a total of six scenarios have been selected for the carpark levels as detailed in

Table 11. The fire scenarios proposed are noted to have been based on the type of analysis required by FRNSW discussed in Section 4.2.1.

For fire scenarios FS #4, FS # 5, FS #7 and FS #8, the fire is located at 0.75 m above floor level with a slow fire growth rate reaching a maximum fire size of 1.5 MW.

For a sensitivity analysis, a fire scenario (FS # 6 & FS #9) growing at a medium growth rate is assessed with the fire reaching a maximum fire size of 4 MW. These fire scenarios may be representative for a sprinkler failure scenario.

Table 11: Fire Scenarios – for Tenability Analysis

Fire Scenarios	Growth Rate (t^2 fire)	Fire Size (MW)	Floor Location	Location relative to jet fans	Description of fire scenario
FS #4	Slow	1.5 MW	Basement Level 2	In front of Jet Fans	Fire is in the front of car (area ~ 1.5 m^2) and 0.75 m above FFL. The fire scenario has been chosen as it is considered to show how long it takes for a detector in a jet fan to activate when a fire is located away from the centreline of the jet fans.
FS #5	Slow	1.5 MW	Basement Level 2	Away from the centreline of jet fans	Fire is in the front of car (area ~ 1.5 m^2) and 0.75 m above FFL. The fire scenario has been chosen as it is considered to show how long it takes for a detector in a jet fan to activate when a fire is located away from the centreline of the jet fans.
FS #6	Medium	4 MW	Basement Level 2	Sensitivity Analysis - In front of Jet Fans. This fire scenario may be representative of a sprinkler failure scenario.	Fire on roof of car (area ~ 3 m^2) and 1.5 m above FFL. The fire is assumed to start at the roof of a car. The fire scenario has been chosen as it is considered to show how long it takes for a detector in a jet fan to activate when a fire is located in front of the jet fans. This scenario is part of a sensitivity analysis and may be representative for a sprinkler failure scenario.
FS #7	Slow	1.5 MW	Basement Level 1	As per FS # 4	As per FS # 4
FS #8	Slow	1.5 MW	Basement Level 1	As per FS # 5	As per FS # 5
FS #9	Medium	4 MW	Basement Level 1	As per FS # 6	As per FS # 6

The input parameters for the fire scenarios modelled in CFD have been detailed in Table 12. An indicative mark-up of the fire locations for Basement Level 2 have been illustrated in Figure 12. Each fire size shall remain that size to the end of each CFD simulation.

Table 12: Input Parameters for Fire Scenarios for FS #4 to FS #9

Fire Scenarios	Area of Fire (m^2)	Growth Rate (kW/s^2)	HRRPUA (kW/m^2)	Ramp up time (s)	Maximum fire size (MW)
FS #4	1.5	t^2 slow (0.003)	1000	707	1.5
FS #5	1.5	t^2 slow (0.003)	1000	707	1.5
FS #6	3.0	t^2 medium (0.012)	1333	577	4.0

It is noted that both carparking levels have a similar floor layouts as can be illustrated in Figure 1 & Figure 2 of this report. Basement Level 2 has a lower floor to ceiling height when compared to Basement Level 1 as noted in Table 3. The lower ceiling height means that in a fire scenario the effects of a heat and smoke would spread at a faster rate due to the smaller compartment dimensions.

A fire at Basement Level 2 presents the worst case fire scenario in the carparking areas of the development as smoke will spread towards Basement Level 1 due to the vehicle ramps connecting the levels. Hence both levels are affected by a fire scenario as in the event of a fire scenario at Basement Level 1 the effects of heat and smoke would vent out through the vehicle entry and exit points of the carpark at Lower Ground Floor Level identified in Figure 3, and as such Basement Level 2 should remain unaffected.

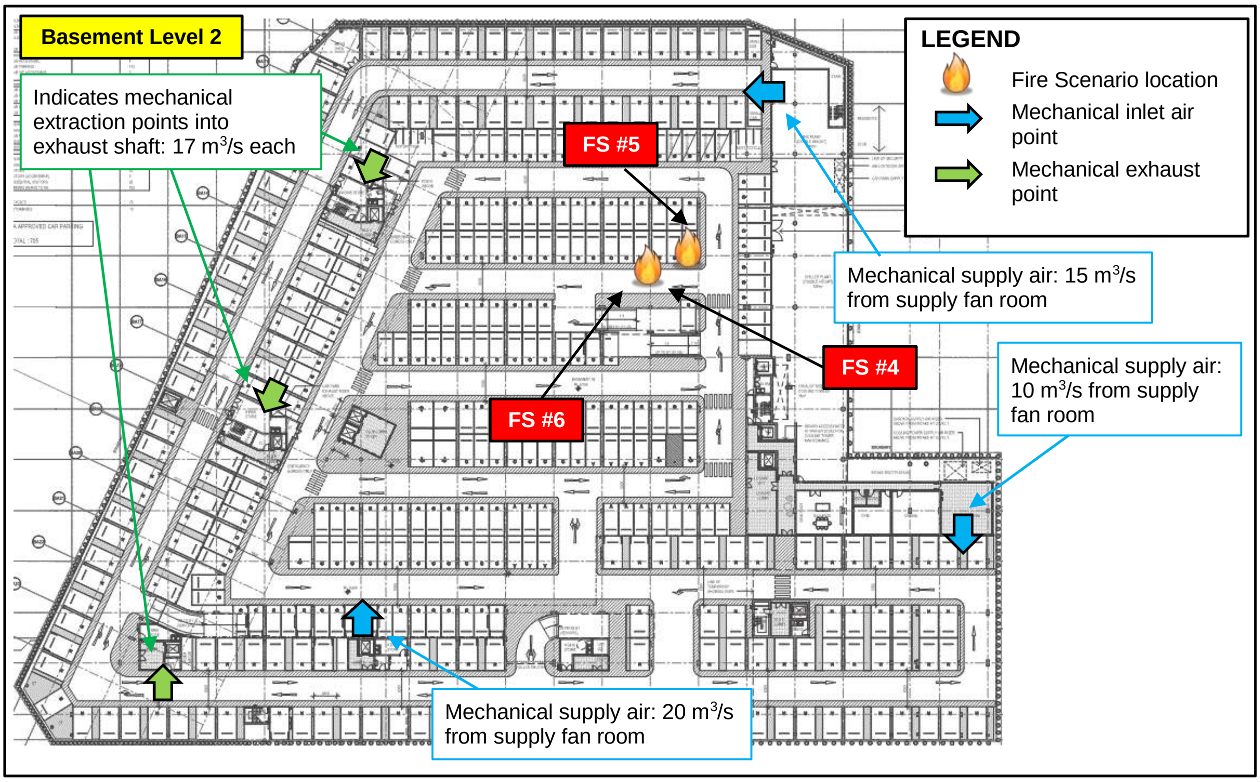


Figure 12: Location of Fire Scenarios FS #4, FS #5 & FS #6 for Basement Level 2

6.3.5 Simulation time

It is noted that the simulation times for Fire Scenario FS #1 to FS #3 have been simulated until sprinkler activation.

The simulation times for Fire Scenario FS #4 to FD #6 have been simulated until it is possible to calculate ASET and RSET. The models have been set up to run for a total of 1000 seconds based on the calculated RSET for the carparking areas discussed in Section 8 of this report.

7 CFD Modelling Results

7.1 Fire Scenario Sprinkler Results

As discussed in Section 6.3.3, FS #1 is a base scenario in which the jet fan is turned off such that the results of the other scenarios can be compared to assess the delay effect of jet fans on the sprinkler activation. For the fire scenarios FS #2 and FS #3, the jet fans keep running during the simulation with scenario FS #2 having the fire located in the immediate air flow from the jet fans and scenario FS #3 having the fire outside the immediate airflow of the jet fan.

The fire scenarios for the sprinkler assessment has been modelled in FDS using 'Sprinkler Link'. Sprinkler link is a device defined in the FDS model to simulate the sprinkler activation without producing water spray in the model. The parameters of sprinkler links that are used in the FDS model have been detailed in Table 13. The sprinklers are located such that the jet fan is centrally located between two rows of sprinklers. This follows the recommendations by [Enright] who conducted a similar CFD investigation to investigate the impact of jet fan ventilation systems on sprinkler activation. This design requirement has been incorporated in the sprinkler design for the basement car park in the subject development. Refer to for Figure 13 and Figure 14 for locations of fire in the FDS models.

Table 13: Sprinkler activation time comparison

Description of parameters	Inputs
Ceiling height (m)	2.5 m (refer to table 10)
Height of fuel above floor (m)	1.2 m
Sprinkler Spacing (m) Ordinary Hazard Category 2 system	3 m x 4 m
Ambient temperature (°C)	20
Actuation temperature (°C)	68
Fire growth rate (s)	613
Response time index ($m^{1/2}/s^{1/2}$)	50 (Fast response heads)
Conduction factor ($m^{1/2}/s^{1/2}$)	0.65

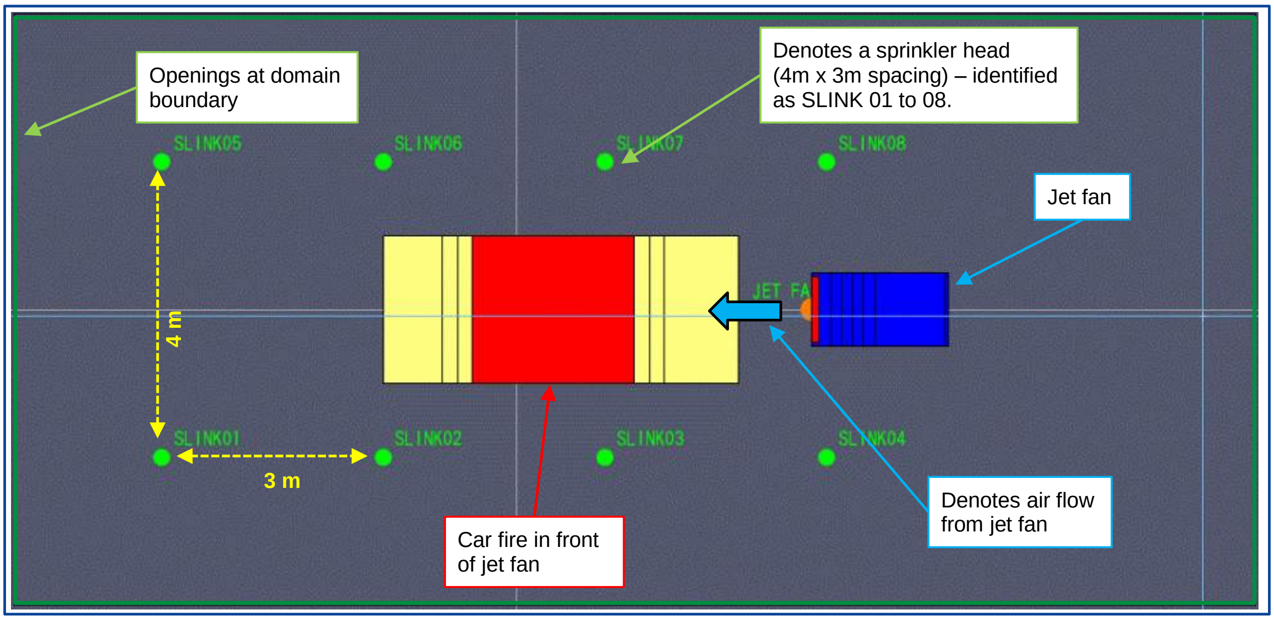


Figure 13: Fire Located within Immediate Airflow in front of Jet Fan (FS #1 & FS #2)

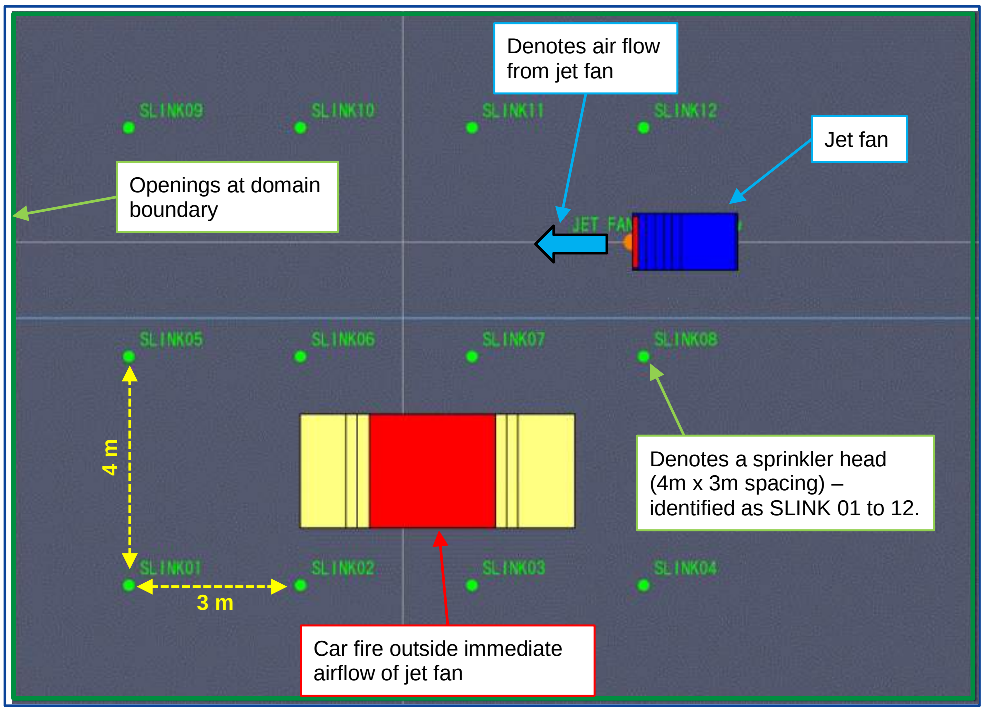


Figure 14: Fire Located outside Immediate Airflow of Jet Fan (FS #3)

7.1.1 Results of FDS modelling for Scenario FS #1 to FS #3

The activation of sprinklers for fire scenarios FS #1 to FS #3 are detailed in Table 14.

Table 14: Sprinkler Activation Time

Fire Scenarios	Growth Rate & Size	Location relative to jet fan	Operating of jet fan	Sprinkler activation time (s)
FS #1	t^2 medium growth rate	Fire within immediate airflow in front of jet fan	Jet fan turned off throughout simulation	215 seconds (SLINK 03 - refer to Figure 13)

Fire Scenarios	Growth Rate & Size	Location relative to jet fan	Operating of jet fan	Sprinkler activation time (s)
FS #2	t^2 medium growth rate	Fire within immediate airflow in front of jet fan	Jet fan running throughout simulation	250 seconds (SLINK 02 - refer to Figure 13)
FS #3	t^2 medium growth rate	Fire outside immediate airflow of jet fan	Jet fan running throughout simulation	218 seconds (SLINK 03 - refer to Figure 14)

The results of the simulations undertaken are consistent with the findings undertaken by [Enright]. Enright concluded in his analyses (16 CFD simulations) that delays of ≤ 30 s to sprinkler activation where the sprinkler and jet fans layout was coordinated so the sprinklers are inplane with the jet fan nozzle.

Based on the results in Table 14 it has been demonstrated that when the fire is located in the immediate airflow of the jet fans, the sprinkler activates later when the jet fans are running compared to when they are not. The difference between the sprinkler activation for when the jet fan is off and when the jet fan is running is small (35 seconds).

In FS #1 it is (SLINK 03) that activates first but in FS #2 it is a sprinkler situated further away from the jet fan (SLINK 02) that activates first.

This does not significantly increase the hazard to occupants with the safety margin in the egress design being many times greater than this. Furthermore, the jet fans do not adversely affect the visibility in means of escape.

It is noted that the time to sprinkler activation will depend on the location of the fire but the results show that the difference between the fire scenarios is small.

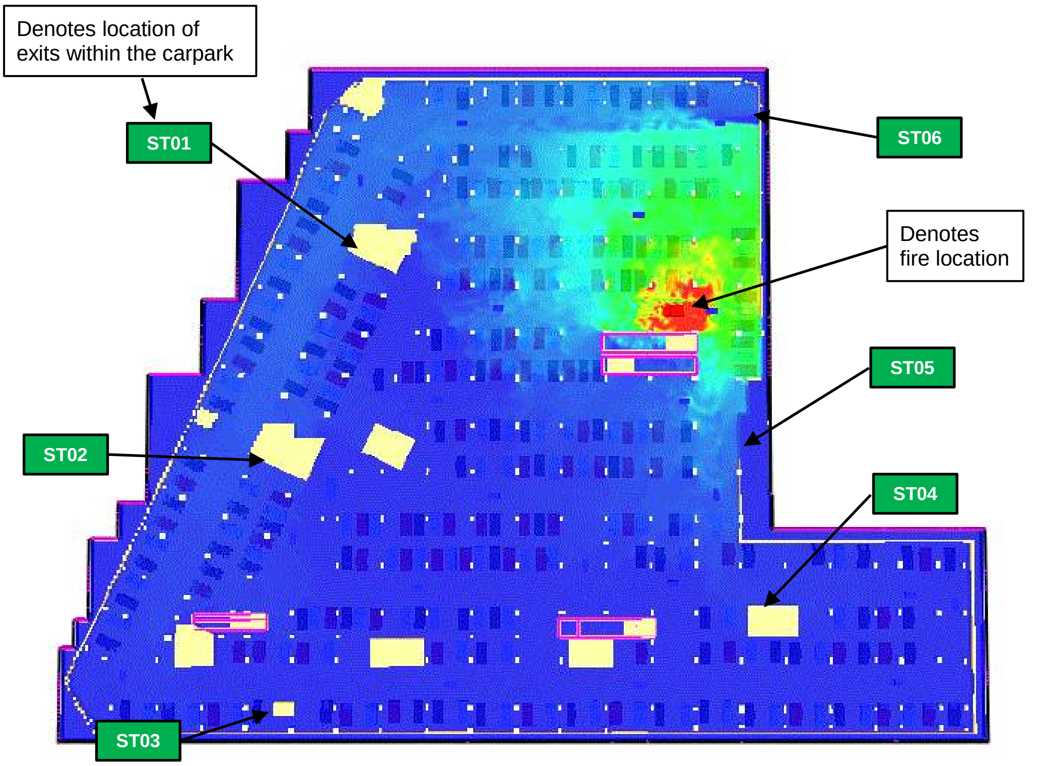
7.2 Results of FDS modelling for Fire Scenario FS #4

Figure 15 show some typical slice files for temperature (°C) at certain times in the simulation for Fire Scenario FS #4. The temperature at the end of the simulation is less than 60 °C which is less than occupant tenability failure criteria for convective heat criteria listed in Table 7. The temperature is also within the routine condition temperature of 100 °C set in Figure 7 for fire-fighter intervention.

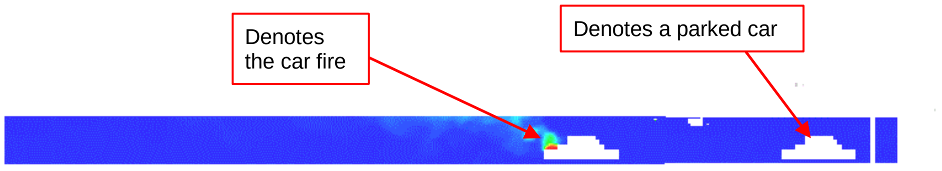
Figure 16 and Figure 17 show some typical slice files for air velocity (m/s) at certain times in the simulation. Figure 16 depict the mechanical inlet air flow to the carpark as well as the jet fans operating and moving air across the carpark domain. Figure 17 shows that the jet fans are still operational at 150 seconds and the point at which the jet fan ventilation system shuts down at 157 seconds.

Figure 18 shows the smoke visibility (in meters) slice files in the carpark. The visibility slice files at 500 seconds show that the exits via stairs ST03 and ST04 are still available. At the end of the simulation almost 25 % of the carpark is still free from smoke and as such occupants still have an exit available (ST03). Figure 19 shows smoke visibility at 100 seconds which shows the smoke plume from the car fire being blown down stream. A slice file at 200 seconds (after the jet fans are mechanically shut down at 157 seconds) shows that the fire plume is no longer affected by the jet fans and the smoke is rising vertically from the fire source.

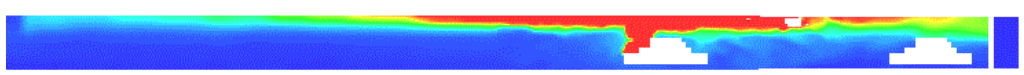
Based on the results of Fire Scenario FS #4, the ASET is considered to be greater than 500 seconds as there are still two exits available as noted above (stair ST03 and ST04) for the potential occupants within.



1000 Seconds: Slice file at 2 m above FFL.



100 Seconds: Slice file through fire. Fire has not reached maximum heat release rate.



1000 Seconds: Slice file through fire. Fire has reached maximum heat release rate and stopped growing.

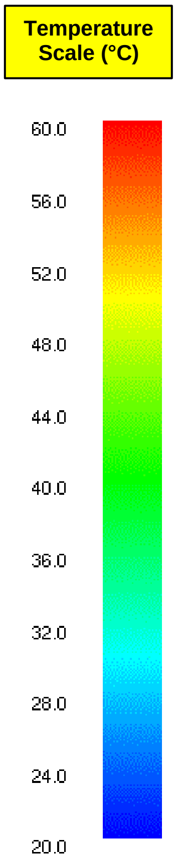
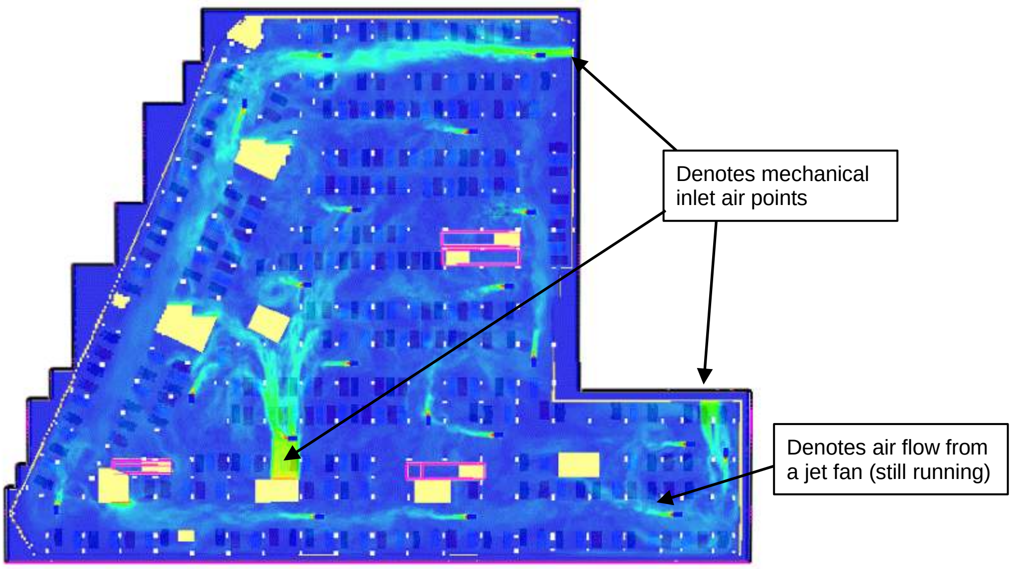
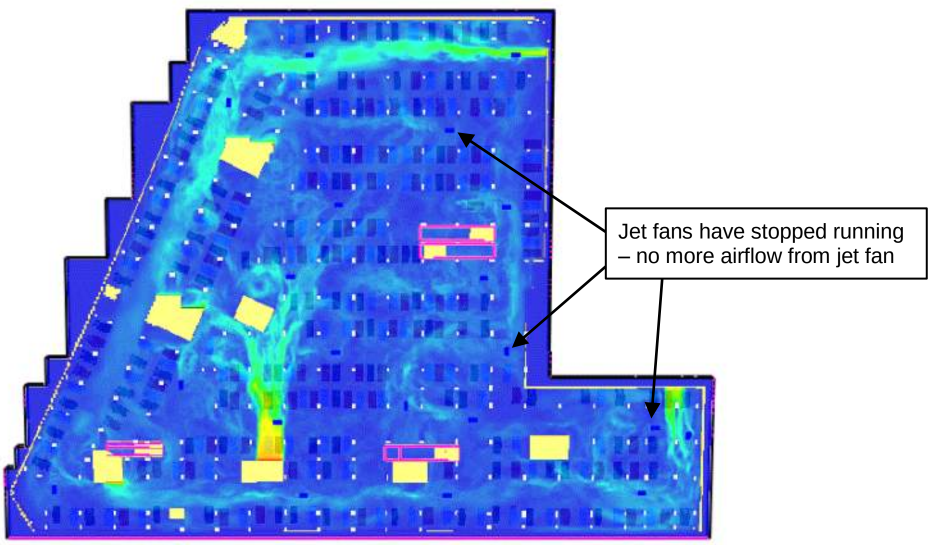


Figure 15: Temperature Contour (°C) at 2 m above FFL for Fire Scenario FS #4.



150 seconds: Jet fans are still running, no smoke has been detected.



157 seconds: Jet fans have stopped running, smoke has been detected.

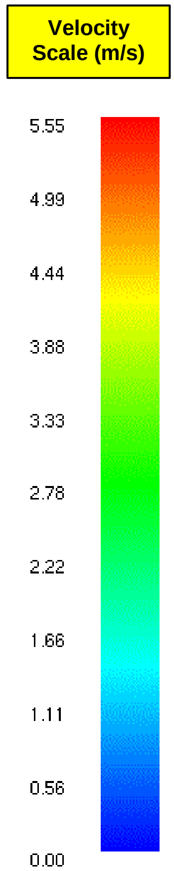


Figure 16: Plan view of Basement Level 2 - Velocity Contour at 2 m above FFL for Fire Scenario FS #4.

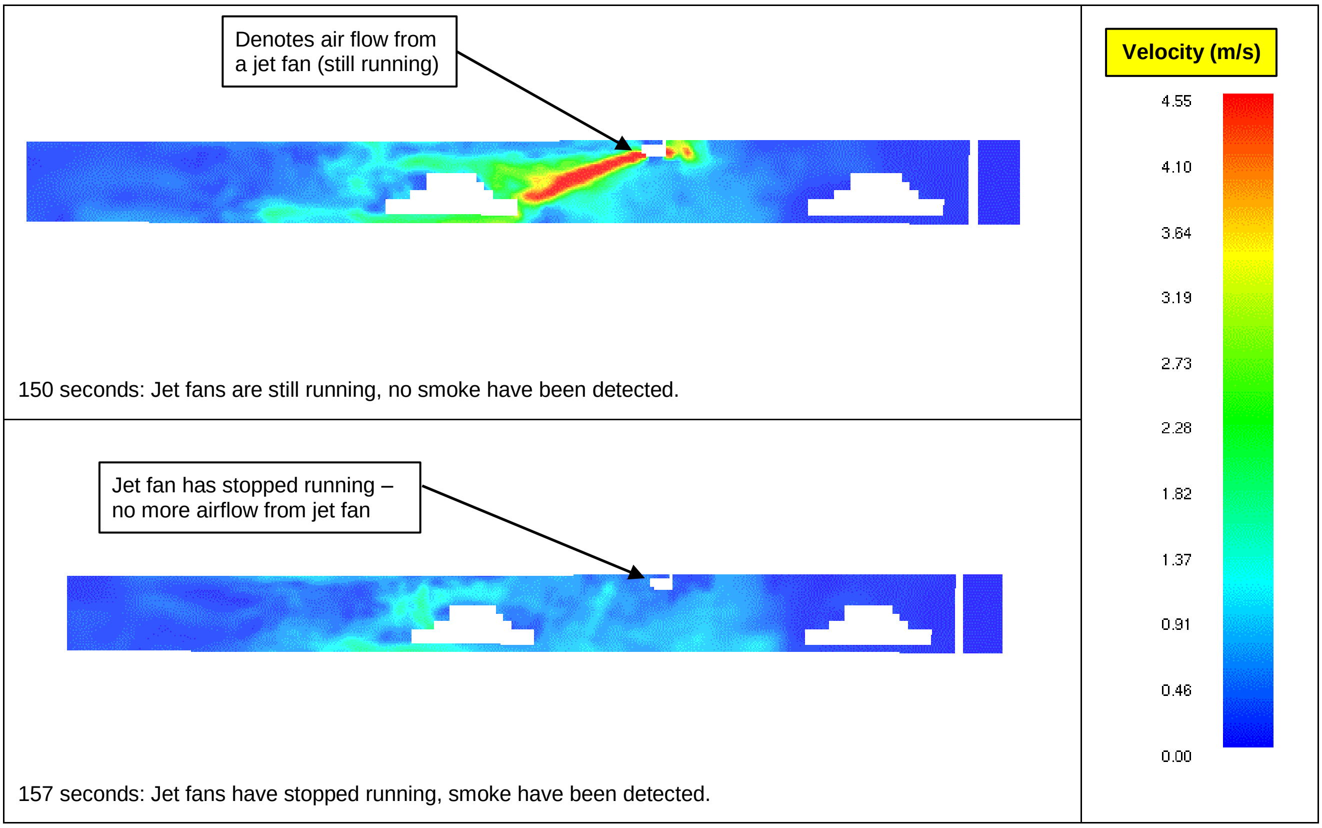


Figure 17: Section view - Velocity Contour through Jet Fans for Fire Scenario FS #4

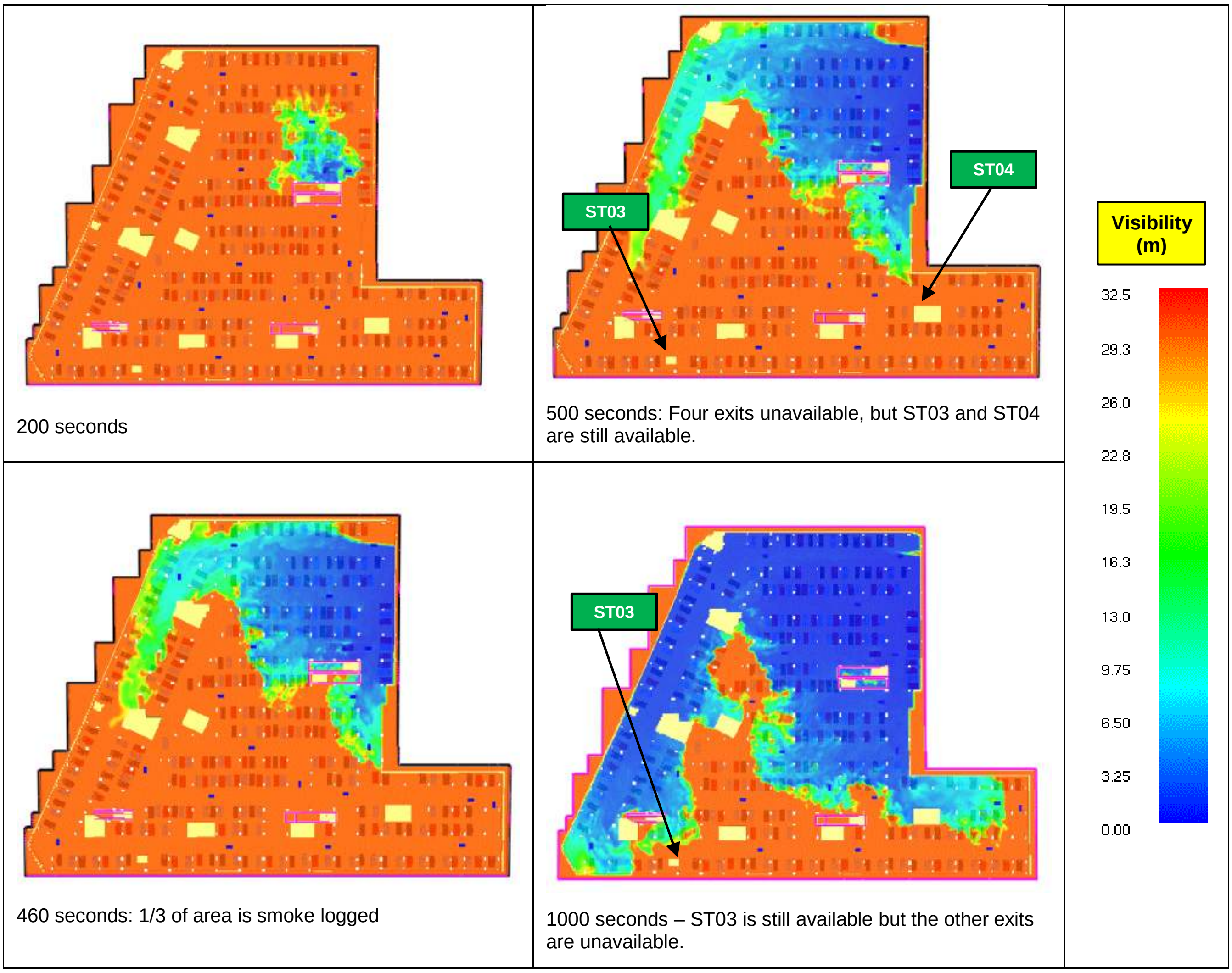
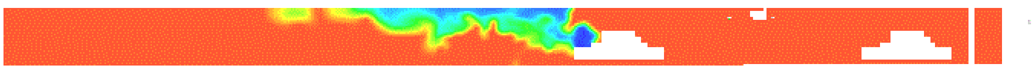
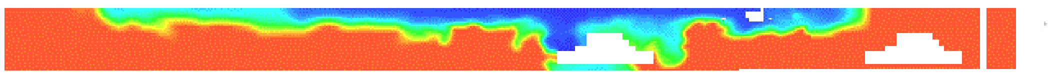


Figure 18: Plan view Basement Level 2 - Visibility Contour at 2 m above FFL for Fire Scenario FS #4.



100 seconds: Jet fans are still running and the fire plume was blown towards the downstream



200 seconds: Jet fans are turned off. A vertically rising fire plume was assumed with well-established smoke layer below the ceiling.

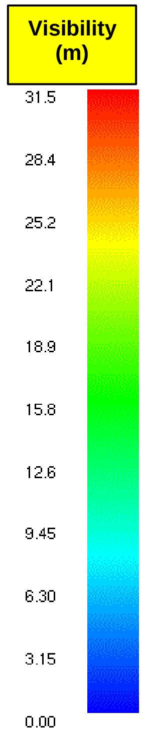


Figure 19: Section view - Visibility Contour through fire for Fire Scenario FS #4.

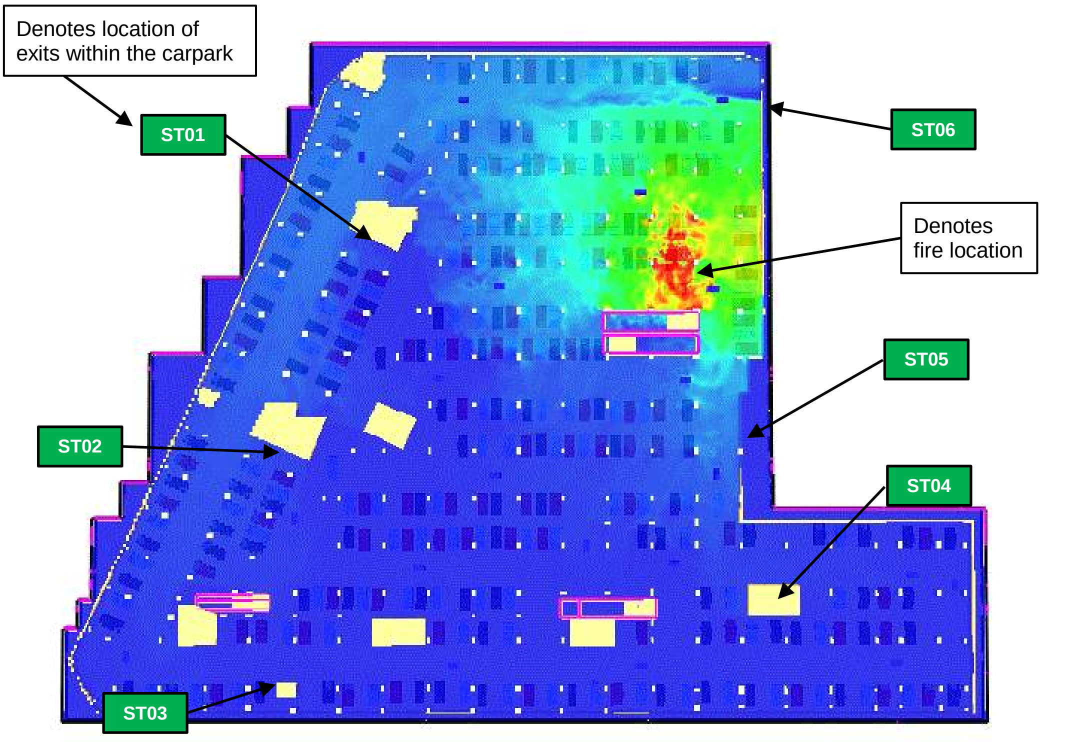
7.3 Results of FDS modelling for Fire Scenario FS #5

Figure 20 shows some typical slice files for temperature (°C) at certain times in the simulation for Fire Scenario FS #5. The temperature at the end of the simulation is less than 60 °C which is less than occupant tenability criteria for convective heat criteria listed in Table 7. The temperature is also within the routine condition temperature of 100 °C set in Figure 7 for fire-fighter intervention.

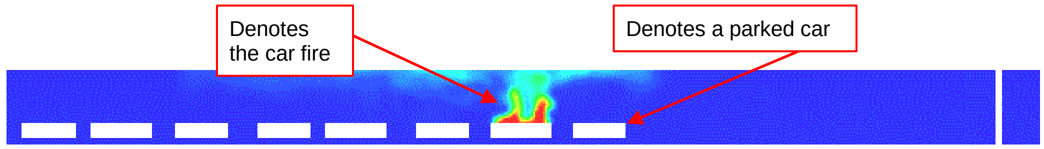
Figure 21 and Figure 22 show some typical slice files for air velocity (m/s) at certain times in the simulation. Figure 21 depict the mechanical inlet air flow to the carpark as well as the jet fans operating and moving air across the carpark domain. Figure 22 shows that the jet fans are still operational at 100 seconds and the point at which the jet fan ventilation system shuts down at 106 seconds.

Figure 23 shows the smoke visibility (in meters) slice files in the carpark. The visibility slice files at 500 seconds show that the exits via stairs ST03 and ST04 is still available. At the end of the simulation almost 25 % of the carpark is still free from smoke and as such occupants still has an exit available (ST03). Figure 24 shows smoke visibility at 100 seconds which shows the smoke plume form the car fire being blown down stream. A slice file at 200 seconds (after the jet fans are mechanically shut down at 110 seconds) shows that the fire plume is no longer affected by the jet fans and the smoke is rising vertically from the fire source.

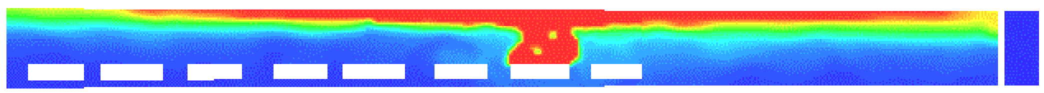
Based on the results of Fire Scenario FS #5, the ASET is considered to be greater than 500 seconds as there are still two exits available as noted above (stair ST03 and ST04) for the potential occupants within.



1000 Seconds: Slice file at 2 m above FFL.



100 Seconds: Slice file through fire. Fire has not reached maximum heat release rate.



1000 Seconds: Slice file through fire. Fire has reached maximum heat release rate and stopped growing.

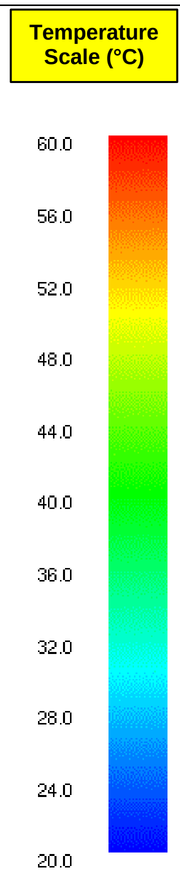
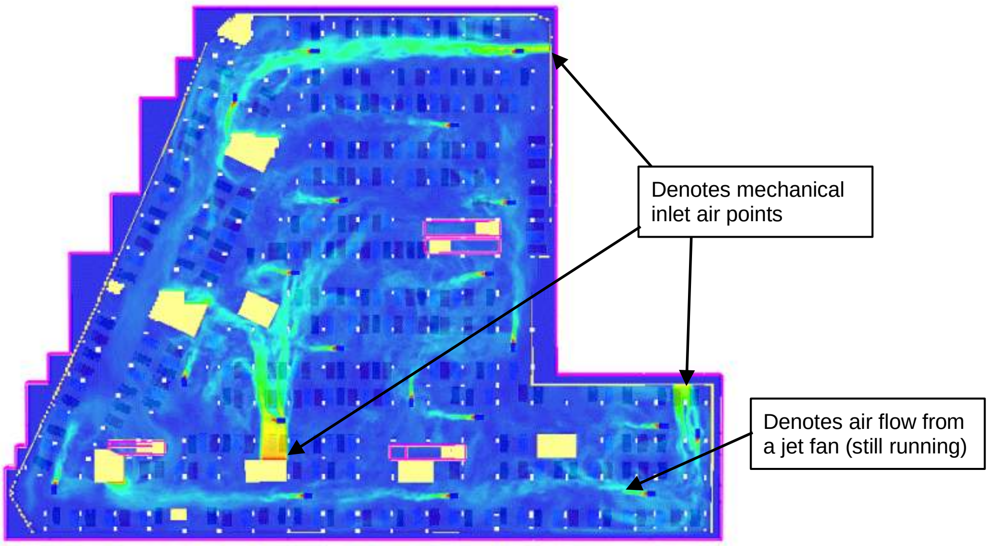
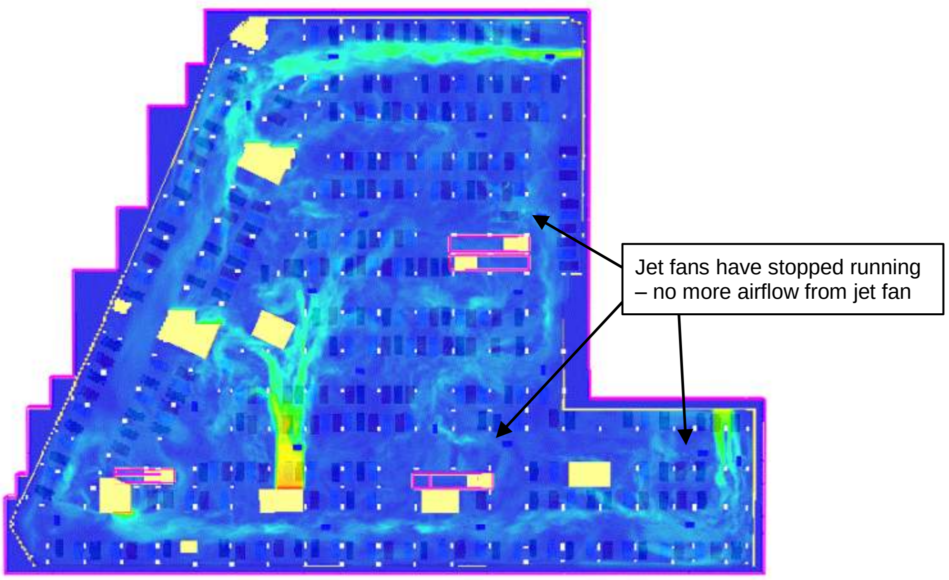


Figure 20: Temperature Contour at 2 m above FFL and velocity contour through fire for Scenario #5.



100 seconds: Jet fans are still running, no smoke hasbeen detected.



106 seconds: Jet fans have stopped running, smoke has been detected.

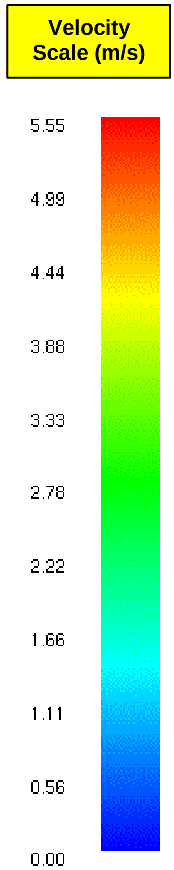
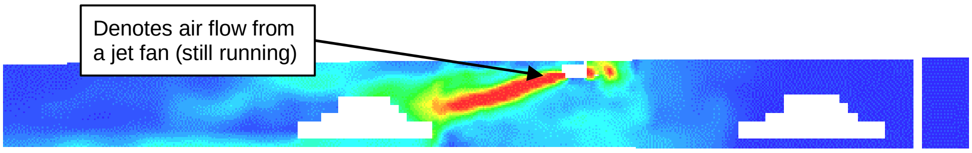
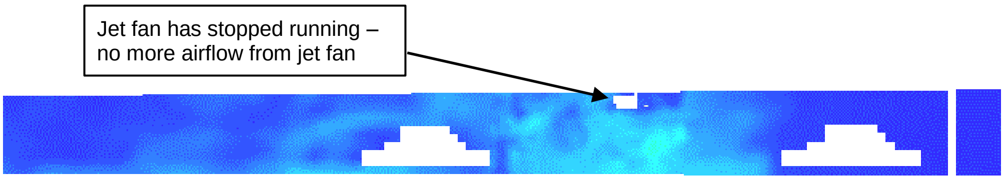


Figure 21: Plan view Basement 2 - Velocity Contour at 2 m above FFL for Fire Scenario FS #5.



100 seconds: Jet fans are still running, no smoke has been detected.



106 seconds: Jet fans have stopped running, smoke has been detected.

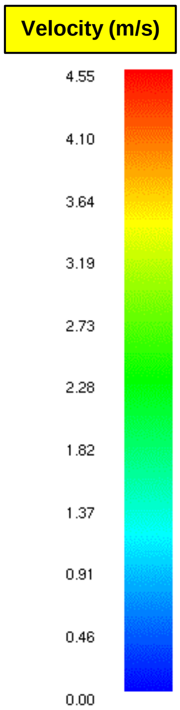
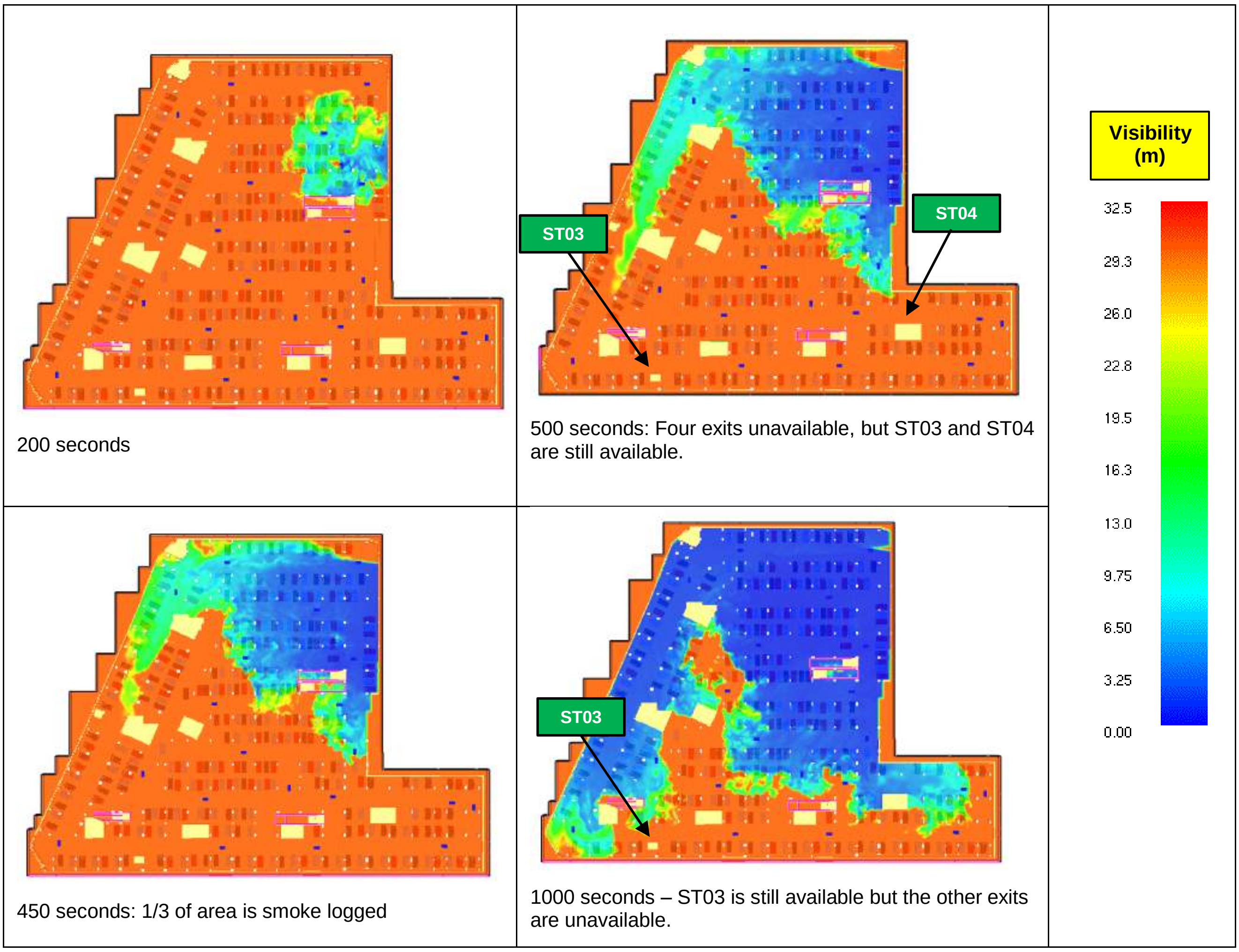


Figure 22: Section view - Velocity Contour through Jet Fans for Fire Scenario FS #5.



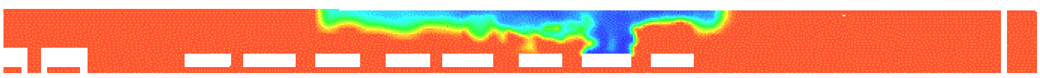
200 seconds

500 seconds: Four exits unavailable, but ST03 and ST04 are still available.

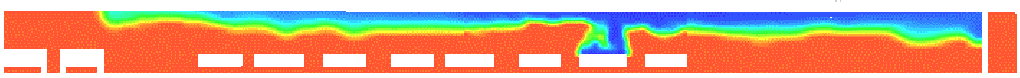
450 seconds: 1/3 of area is smoke logged

1000 seconds – ST03 is still available but the other exits are unavailable.

Figure 23: Plan view Basement 2 - Visibility Contour at 2.0m above FFL for Fire Scenario FS #5.



100 seconds: Jet fans are still running and the fire plume was blown towards the downstream



200 seconds: Jet fans are turned off. A vertically rising fire plume was assumed with well-established smoke layer below the ceiling.

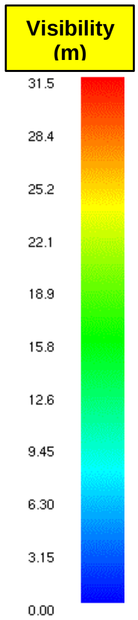


Figure 24: Section view - Visibility Contour through fire for scenario #5.

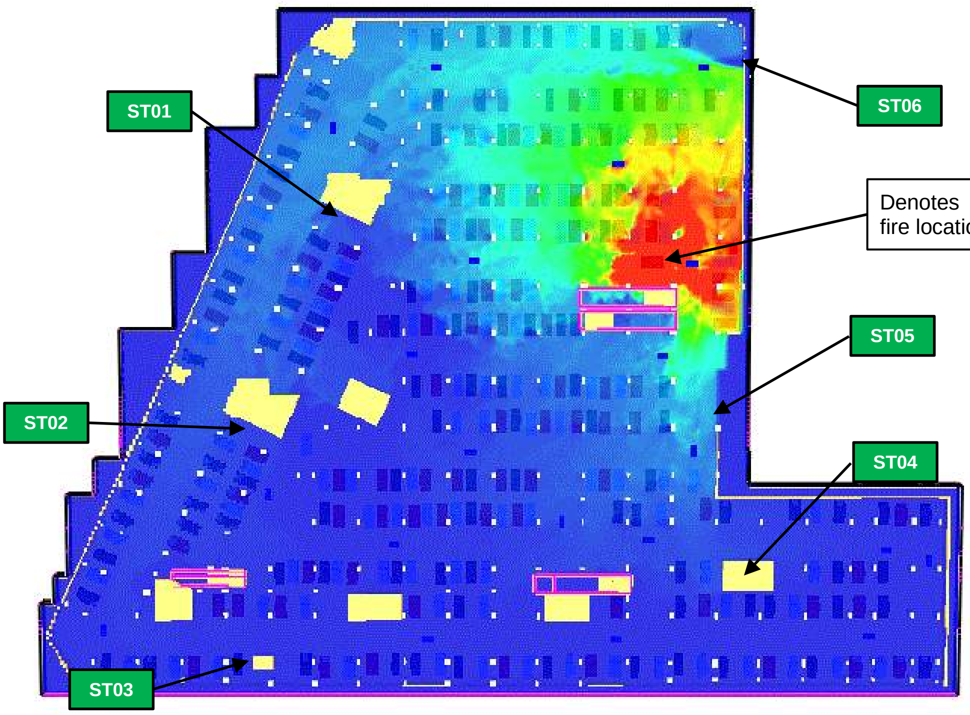
7.4 Results for Fire Scenario FS #6 (4 MW fire)

Figure 25 show some typical slice files for temperature (°C) at certain times in the simulation for Fire Scenario FS #6. The temperature at the end of the simulation is less than 60 °C which is less than occupant tenability criteria for convective heat criteria listed in Table 7. The temperature is also within the routine condition temperature of 100 °C set in Figure 7 for fire-fighter intervention.

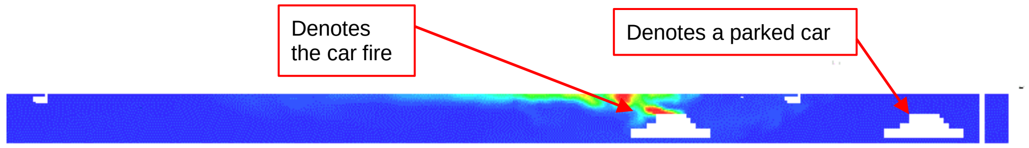
Figure 26 and Figure 27 show some typical slice files for air velocity (m/s) at certain times in the simulation. Figure 26 depict the mechanical inlet air flow to the carpark as well as the jet fans operating and moving air across the carpark domain. Figure 27 shows that the jet fans are still operational at 110 seconds and the point at which the jet fan ventilation system shuts down at 118 seconds.

Figure 28 shows the smoke visibility (in meters) slice files in the carpark. The visibility slice files at 450 seconds show that the exits via stairs ST03 and ST04 are still available. At the end of the simulation almost 25 % of the carpark is still free from smoke and as such occupants still has an exit available (ST03). Figure 29 shows smoke visibility at 100 seconds which shows the smoke plume form the car fire being blown down stream. A slice file at 200 seconds (after the jet fans are mechanically shut down at 118 seconds) shows that the fire plume is no longer affected by the jet fans and the smoke is rising vertically from the fire source.

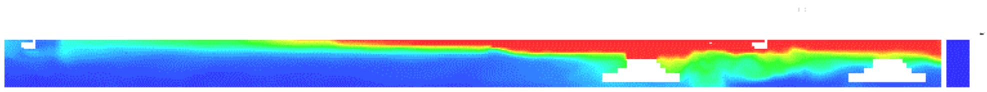
Based on the results of Fire Scenario FS #6, the ASET is considered to be greater than 450 seconds as there are still two exits available as noted above (stair ST03 and ST04) for the potential occupants within.



1000 Seconds: Slice file at 2 m above FFL.



100 Seconds: Slice file through fire. Fire has not reached maximum heat release rate.



1000 Seconds: Slice file through fire. Fire has reached maximum heat release rate and stopped growing.

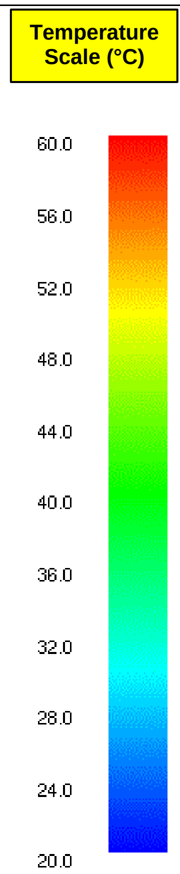
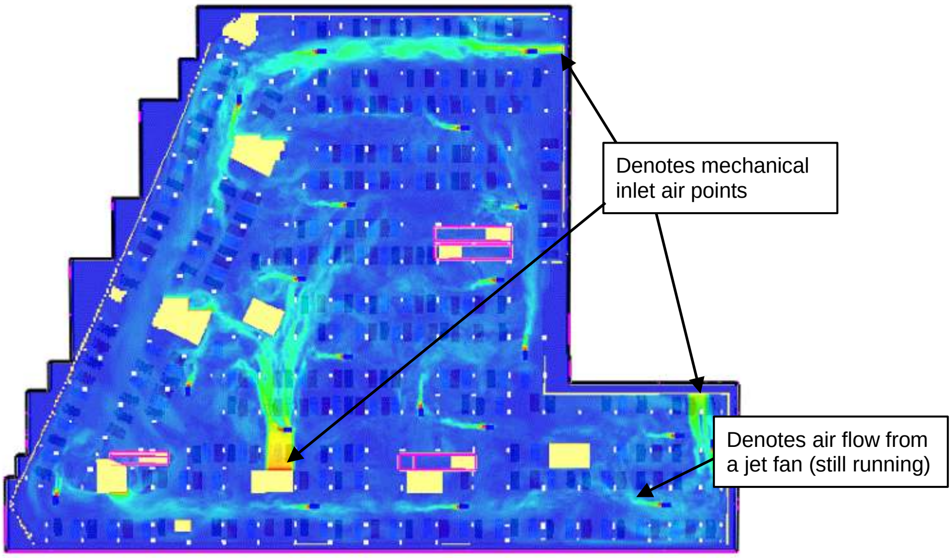
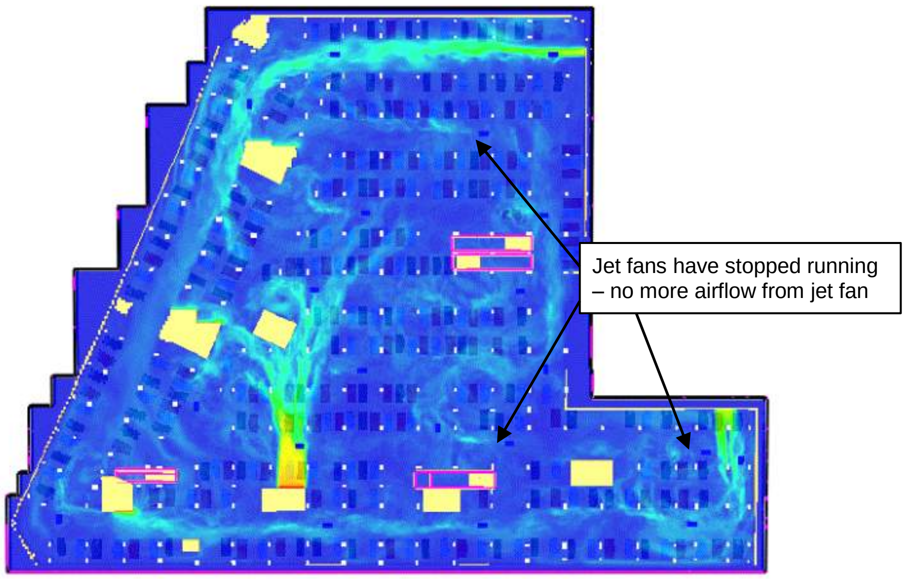


Figure 25: Temperature Contour at 2 m above FFL and temperature contour for Fire Scenario #6.



110 seconds: Jet fans are still running, no smoke have been detected.



120 seconds: Jet fans have stopped running, smoke have been detected.

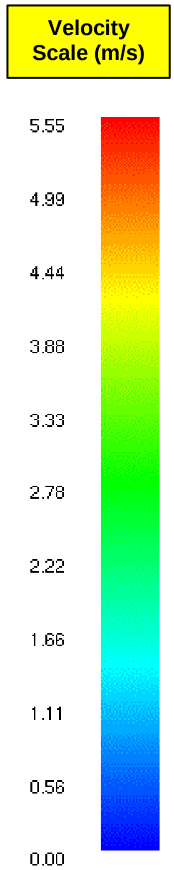


Figure 26: Plan view Basement 2 - Velocity Contour at 2 m above FFL for Fire Scenario FS #6.

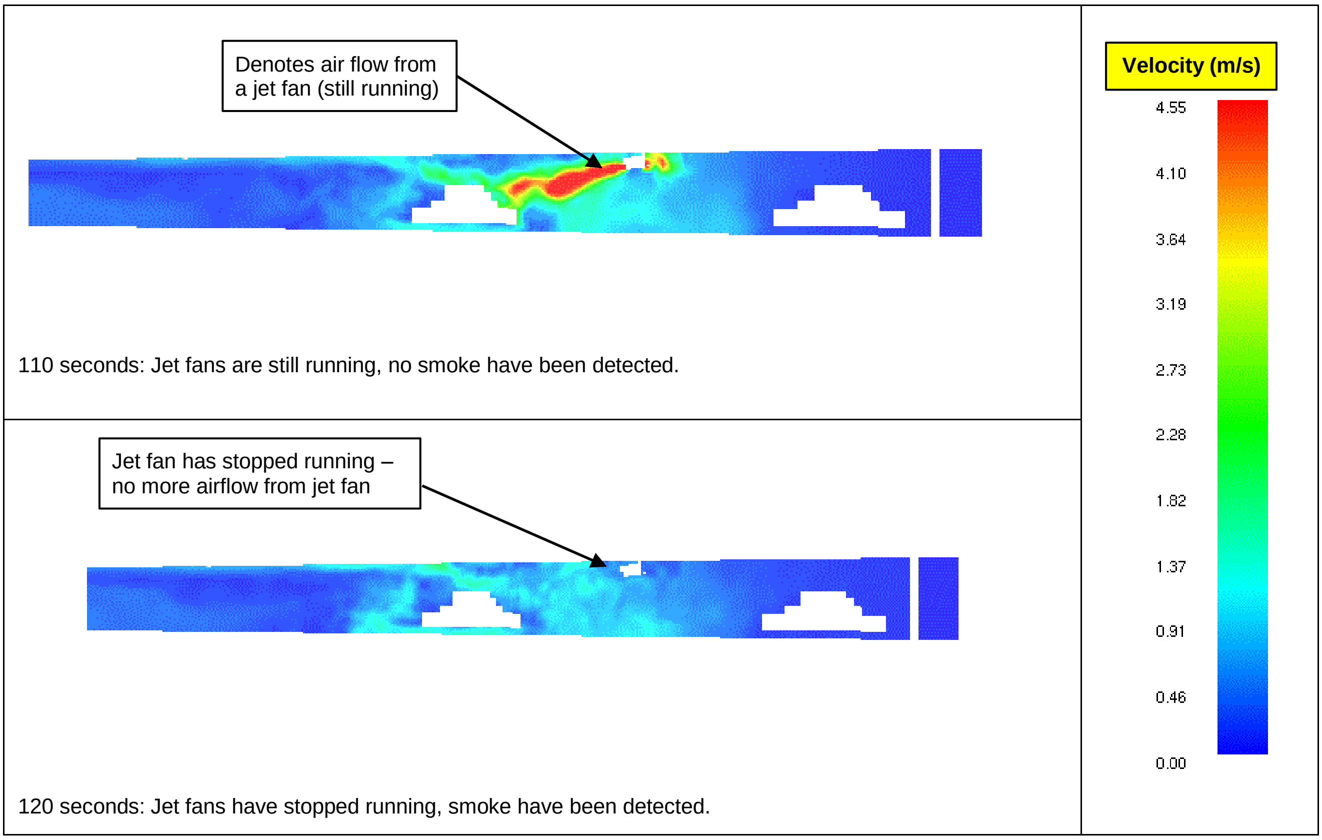
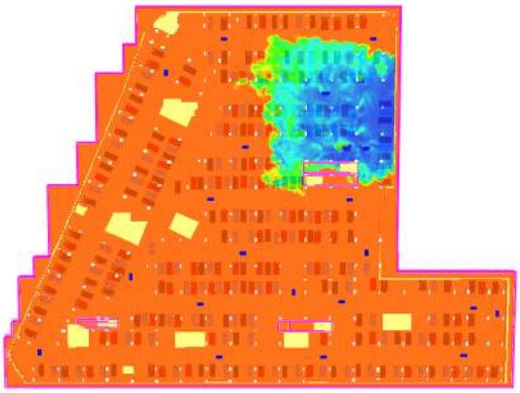
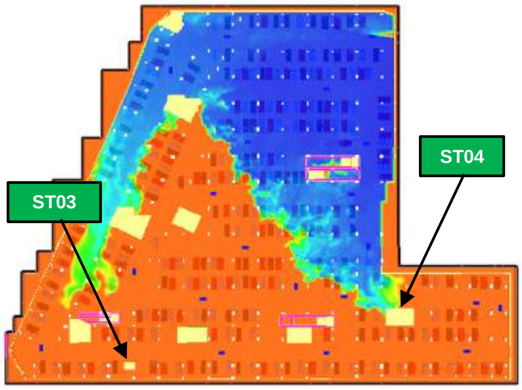


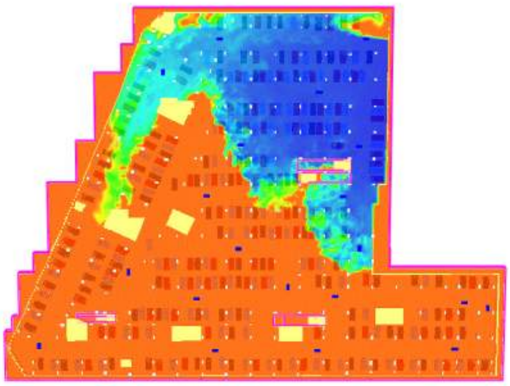
Figure 27: Section view - Velocity Contour through Jet Fans for Fire Scenario FS #6.



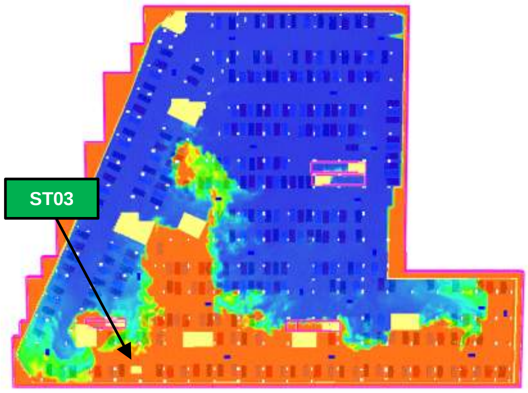
200 seconds



450 seconds: Four exits unavailable, but ST03 and ST04 are still available.



350 seconds: 1/3 of area is smoke logged



1000 seconds – Exit G is still available but the other exits are unavailable.

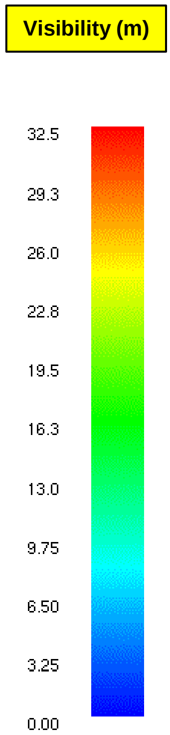
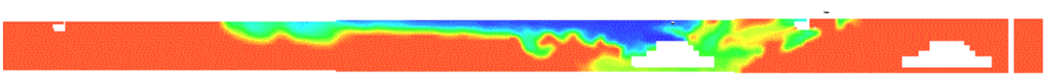
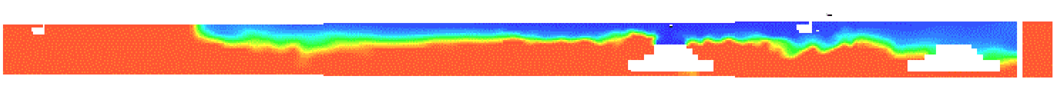


Figure 28: Plan view Basement 2 - Visibility Contour at 2 m above FFL for Fire Scenario FS #6.



100 seconds: Jet fans are still running and the fire plume was blown towards the downstream



200 seconds: Jet fans are turned off. A vertically rising fire plume was assumed with well-established smoke layer below the ceiling.

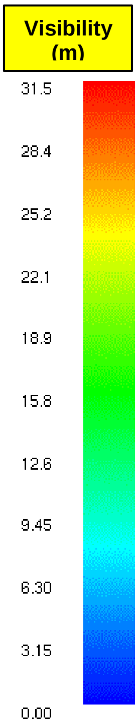


Figure 29: Section view - Visibility Contour through fire for Fire Scenario FS #6.

7.5 ASET summary

The ASET for Fire Scenarios FS #4 to FS#6 have been summarised in Table 15 below.

Table 15: ASET summary

Fire Scenarios	ASET Time (s)
FS #4	>500 seconds
FS #5	>500 seconds
FS #6	>450 seconds

8 Egress Assessment (RSET)

8.1 Required Safe Egress Time (RSET)

The egress analysis requires that the RSET be determined for the nominated reasonable worst case fire scenarios in the basement carpark. The RSET is determined from the time it takes from fire initiation until occupants reach a place of safety. The RSET comprises of three distinct phases:

Cue Time – time from fire initiation until occupants become aware of a potential fire threat. It can be broken down in detection time and alarm time.

Response Time – this consist of the time taken by occupants to process the information and is the time from becoming aware of a potential fire threat until actually starting to move towards an exit. The response time considers the time it takes for the first as well as the last occupant to move towards an exit.

Movement Time – this includes the time it takes for occupants to walk towards the nearest exit (travel time), as well as the time occupants spent queuing at exits before entering a place of safety (queue time).

The cue and response times are a function of occupant characteristics, type of warning system and location of occupants with respect to the location of the fire, whilst the movement time is a function of occupant numbers, distribution of occupants relative to the exits and total aggregated effective exit width available for use.

The RSET is broken down into four distinct phases as follows:

$$RSET = \Delta T_{det} + \Delta T_a + \Delta T_{pre,1st} + \max[(\Delta T_{pre,dist} + \Delta T_{travel}), \Delta T_{queue}]$$

Equation 2
where

ΔT_{det} = detection time, the time until a fire is detected (s)

ΔT_a = alarm time, the time until the alarm sounds (s)

$\Delta T_{pre,1st}$ = pre-movement time of first few occupants (1st percentile) (s)

$\Delta T_{pre,dist}$ = difference in pre-movement time between last few (99th percentile) and first few (1st percentile) occupants, (s)

ΔT_{queue} = queue time at exits (s)

ΔT_{travel} = travel time, the time occupants take to walk to a place of safety (s)

Assuming an even distribution of occupants through the space, it is reasonable to assume that a queue forms immediately at the exits when the first few occupants started to move. If the queuing time at exits is longer than the time elapsed between when the last and the first few occupants started to move to the exits, plus the time required by the last few occupants to walk to the exits, there will still be a queue at the exits when the last few occupants arrive at an exit. Correspondingly, occupant movement is then flow controlled as illustrated in Figure 30 below. Otherwise occupant movement is unrestricted and dependent on the pre-movement time of the last few occupants and the distance they need to walk to the exits.

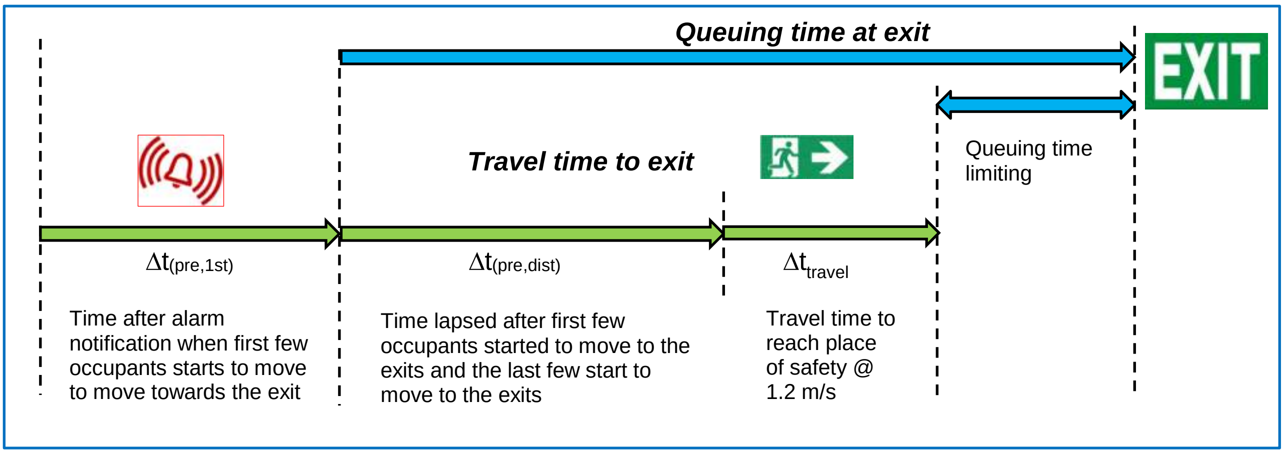


Figure 30: Illustrating queue time limiting evacuation

8.1.1 Cue Time (Detection time & alarm time)

The alarm time is the time from when the detector activates until the alarm sounds. In modern detection systems this is almost instantaneous; and on this basis the alarm time is ignored. The detection time represents the moment at which the potential existence of a fire is perceived. In the zone of fire origin, the flames and smoke plume may be seen very early in the development of the fire. At the periphery of the zone of fire origin, the smoke layer may be seen or smelt. Communication of the existence of the fire would also be expected to occur between occupants in the zone of fire origin.

The detection time in the subject carpark can be taken as the shortest time of any of the following;

- Activation of a sprinkler head;
- Activation of the in-built duct probe smoke detector in the jet fan (as noted in Table 6). These smoke detectors are required to be connected to FIP. On activation of any of these smoke detectors, all the impulse fans on the fire-affected floor shall be switched off automatically and remain switched off unless manually reset at FIP and the building occupant warning system shall be activated.

The sprinkler activation times for fire scenarios FS #1 to FS #3 has been discussed in Section 7.1 with the activation times for the fire scenario presented in Table 14. However it is noted that in a fire situation, smoke would likely spill into the adjoining areas in the early stages of the fire and activate the smoke detector head in the jet fan before a sprinkler head would activate.

The following detection times for the jet fans have been detailed in Table 16 which has been based on the CFD modelling results for fire scenarios FS #4 to FS #6 as discussed in Section 7.

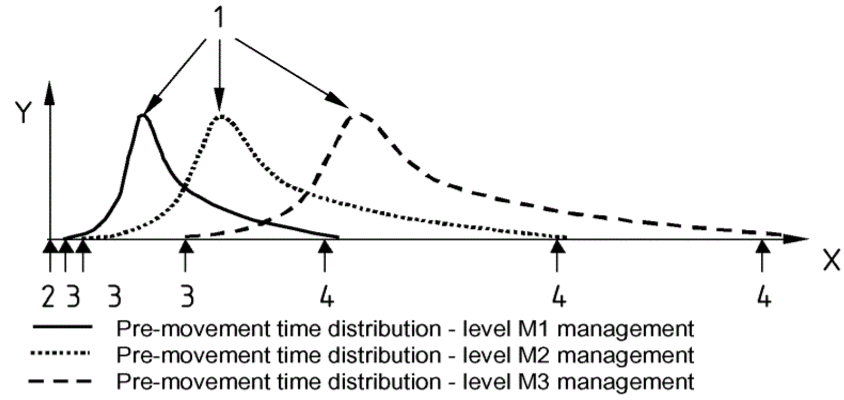
Table 16: Detection times of smoke detectors for Fire Scenarios FS #4 to FS #6

Fire Scenarios	Type of detection	Cue Time
FS #4	Activation of built in duct probe smoke detectors	157 seconds
FS #5		106 seconds
FS #6		118 seconds

8.1.2 Response times (pre-movement times)

This consists of the time it takes for occupants to register that the cue (visual or aural) is an indication of a potential fire and the time to decide to evacuate.

This pre-movement behaviour is recognised by Figure C.1 of Annex C of [PD 7974-6], which mentions that once the first few occupants begin to move, the pre-movement distributions tend to follow approximately log-normal distributions, with a rapid increase in the number of occupants starting to move soon after the beginning of the distribution and a long tail until the last few occupants move as shown in Figure 31.



Key
X Time
Y Persons/s
1 $\Delta t_{pre\ (occupant\ distribution)}$
2 Alarm
3 $\Delta t_{pre\ (first\ occupants)}$
4 99th percentile

NOTE Pre-movement of first occupants to move and subsequent pre-movement time distribution is lengthened by progressively lower levels of fire safety management.

Figure C.1 — Representation of pre-movement time distributions and effects of different levels of fire safety management

Figure 31: Figure C.1 of PD 7974.6 - Representation of pre-movement time distribution

The occupants of the subject carpark are expected to be awake, aware and mostly unfamiliar with the building. They generally could also be expected to be stationary for short periods of time only as they will be moving between their parked car and the lifts / exits and vice versa. As such, as the carpark have good lines of sight, they could be expected to readily see, hear or smell a developing fire and to react quickly and move to the nearest available exit if in danger.

Guidance in Table C1 of PD 7974-6 suggests a design pre-movement time of 30 s for the first few occupants (1st percentile) to respond with the last few occupants (99th percentile) responding 120 s later. This conforms to a building use where occupants are awake but unfamiliar with the building. It is noted that the subject carpark shall also be equipped with a voice alarm system. On this basis it is considered reasonable to assume the aforementioned response times (as illustrated in Table 17).

Table 17: Response times for carparking levels (as per Table C.1 of PD 7974-6)

Behavioural Scenario Category	Type of occupants	Pre-travel activity times
Awake & Unfamiliar	$\Delta T_{pre,1st}$ - First occupants (1st percentile)	30 seconds
	$\Delta T_{pre,dist}$ - Last occupants (99th percentile)	120 seconds

8.1.3 Movement time (travel time)

Based on guidance from the BCA Report for the development it is understood that the following travel distances has been identified in the carparking areas;

- Up to 25 m in lieu of permissible 20 m in reaching where there is a point of choice in exits,
- Up to 60 m in lieu of permissible 40 m in reaching an alternative exit.

Hence the worst case travel distance for an evacuating occupant in the carpark is travelling up to 60 m in reaching an alternative exit.

Research by [Proulx], indicates a travel speed of 1.0 – 1.3 m/s for able-bodied people in moderately crowded situations, and 0.8 m/s for people with mobility disabilities. For robustness in the design, the unimpeded walking speed of a person has been taken as 0.8 m/s to assess travel time (to allow for all anticipated occupants of the development).

The occupant travel time in reaching an exit in the carpark has been detailed in Table 18.

Table 18: Occupant travel time in the carpark

Description of travel distance	Proposed Design – Carparking levels		
	Distance (m)	Travel Time (m/s)	Travel Time (s)
To the nearest alternative exit	60 m	0.8 m/s	75 s

8.1.4 Queuing Time at Exits

It is noted that the carparking level will be intermittently occupied whereby persons park their car and move towards other areas of the building. The subject carpark is a large open area (approximate total floor area of ~27,394 m^2) which would mean that the occupant movement to the exits available at any of the levels would likely be staggered, thereby lessening the number of persons present at an exit. It is further noted that the available exits at sited at various locations at this level as illustrated in Figure 1 and Figure 2. The anticipated low population of the carparking level would spread amongst the exits available at each level. Therefore, it is unlikely that a high crowd loading would be present at any of the exits available. The occupant loading for the carpark has been detailed in Table 4.

The queue time at the available exit doors can be estimated from the SFPE hydraulic model undertaken by [Gwynne]. This model accounts for lateral body sway and requires that a 150 mm boundary layer be applied to each side of the door so that the effective door width is 900 mm – 300 mm = 600 mm. It is noted that the doors have conservatively been taken as 900 mm wide according to the drawings listed in Table 2. This adds further redundancy to the egress assessment.

Values for occupant density, constant horizontal travel, a-value are taken from [Mowrer]. Values for door width, number of doors and total number of people are taken from the relevant drawings in Table 2. As shown by the exit queue time calculation above, the queue time is 98 seconds for the carpark.

Table 19: Queueing Time into exits of the carpark

Input Description	Input parameters
Fc- Calculated flow (person/m)	9.4
D – occupant density (persons/m^2)	1.9
K (constant)	1.4
a (constant)	0.266
Total door width	10.8 m
Number of doors (2 levels – 6 per level)	12
Boundary layer (m)	0.15 m
We – effective width	7.2 m
Total number of people	914
Total queueing time (s)	**98 s**

8.1.5 RSET Calculation for the carpark

The calculated RSET for each of Fire Scenarios FS #4 to FS #6 in the carpark is shown in Table 19.

.

Table 20: Carpark – Estimated RSET calculation for Scenario FS #4 – FS#6

Description	Fire Scenario No.		
	FS #4	**FS #5**	**FS #6**
T_{det} (Detection time) – Time to the first detector activates (as per Table 16)	157	106	118
$\Delta T_{pre,1st}$ - First occupants (1st percentile) Time (30 seconds as per Table 17) from the detection time to the first occupants begin to move towards an exit.	- (a)	- (a)	- (a)
$\Delta T_{pre,dist}$ - Last occupants (99th percentile) Time (120 seconds as per Table 17) from the detection time to the last occupants begin to move towards an exit.	120	120	120
Δt_{travel} (Travel time (m/s)) to an exit based on worst case travel distance of up to 50 m for all the occupants.	75	75	75
Δt_{queue} – Based on the queueing time into the stairs (98 seconds as per Table 19)	NA(b)	NA(b)	NA(b)
Required Safe Egress Time (RSET)	352 s	301 s	313 s

NOTE:

As noted in Section 8.1, the time for the first occupant to move to the exit is negated by the fact that the last occupant begins to move 120 seconds after the detection time and therefore is not accumulative.

It is noted that if the queuing time is less than the difference in time between the last and first few occupants starting to move the exits plus the time required to walk to and exit , then there will be no queue at the exits when the last few occupants arrive. Egress is then not flow restricted. The converse will result in a flow restricted situation, i.e. queue time dependent.

9 Conclusions

9.1 ASET / RSET Comparison Analysis

The following table shows the comparison between the ASET and RSET times for the different fire scenarios assessed in the carpark.

Table 21: ASET/RSET Comparison Analysis

Fire Scenarios	RSET Time (s)	RSET x 1.5 (s)	ASET Time (s)	Safety factor	
FS #4	352 seconds	528 seconds	>528 seconds	> 1.5	**Satisfied***
FS #5	301 seconds	452 seconds	>500 seconds	> 1.5	**Satisfied**
FS #6	313 seconds	470 seconds	>470 seconds	> 1.5	**Satisfied***

Based on the proposed design requirements and the assessment undertaken, it has been demonstrated that occupants of the basement carpark could be expected to evacuate the carpark safely before conditions in the carpark could become threatening.

*Even though Scenarios FS#4 and FS#6 seem to exceed the ASET limit set in this report, it is still considered acceptable as ST03 is available throughout the simulation in both cases offering a safe means of escape to any potential occupants still present at the time in the car-park.

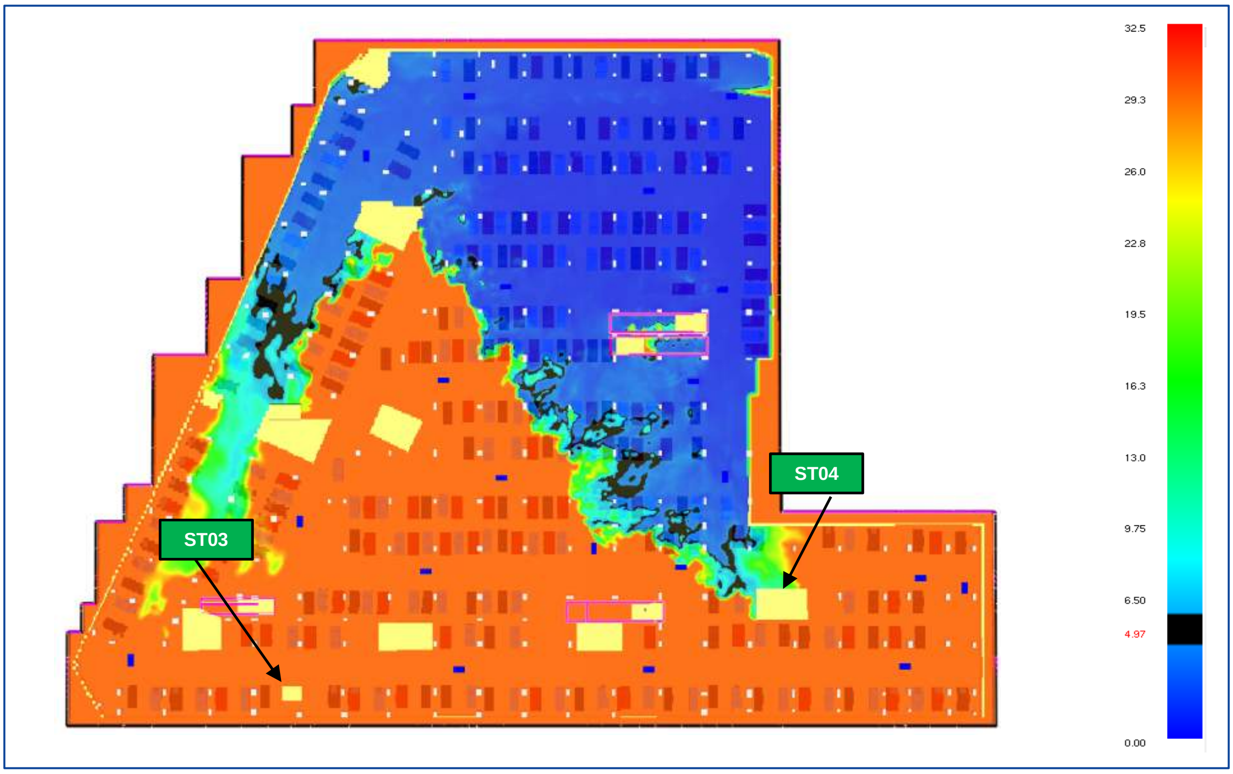


Figure 32: Visibility slice file from FS#6 at 470 seconds at 2 m height from FFL

As can be seen in the figure above from FS#6, at 470 seconds the majority of the car-park floor area is unaffected by smoke whilst tenable conditions around the fire-isolated stairs are well above the limits set in Table 7.

The figure below is a snapshot at 540 seconds of simulation time from FS#4 with both fire-isolated stairs being unaffected by untenable conditions. At that time all occupants are expected to have already evacuated the premises and therefore RSET is considered to be significantly less than ASET.

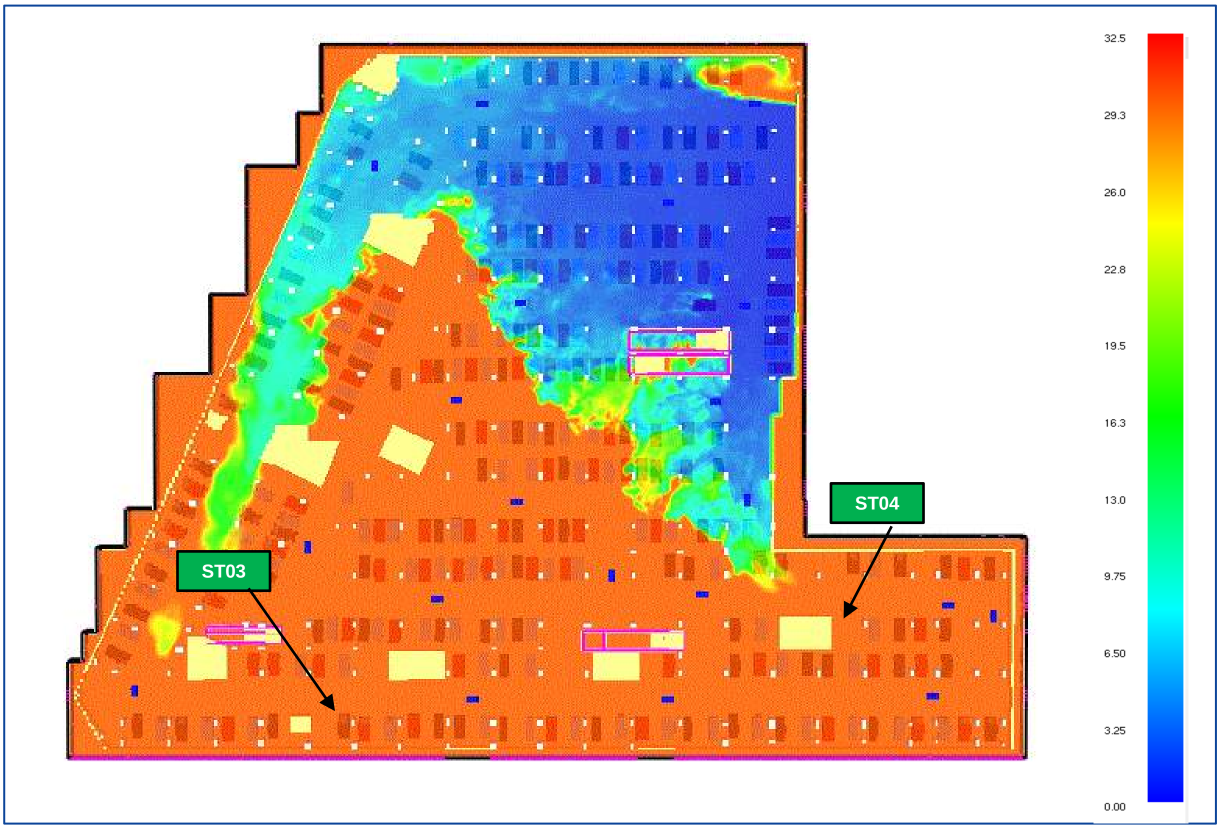


Figure 33: Visibility slice file from FS#4 at 540 seconds at 2 m height from FFL

Correspondingly, Performance Requirements EP1.4 and EP2.2 of the BCA are considered to be met.

9.1.1 Recommendations;

The impulse fans must be installed as per the manufacturer's recommendations with careful consideration of the following;

- Ceiling features (i.e. ceiling beams).
- Vertical clearance (so as to ensure maximum flexibility in the design).
- Obstructions and clashes with other services (i.e. sprinkler piping / signage etc).
- Guidance from FRNSW regarding the installation and operation of jet fans.

10 References

[AFAC] AFAC, *Fire Brigade Intervention Model. Version 2.*2, Australasian Fire Authorities Council, October 2004.

[AS/NZS 1668.1] *AS 1668.1 – 2012. The use of ventilation and air-conditioning in buildings; Fire and smoke control in multi-compartment buildings, Standard Australia Limited, Sydney.*

[AS 1668.2] *AS 1668.2 – 2012. The use of ventilation and air-conditioning in buildings; Mechanical Ventilation in buildings, Standard Australia Limited, Sydney.*

[BCA] ABCB 2014, National Construction Code Series, Volume 1, *Building Code of Australia 2014, Class 2 to Class 9 Buildings*, Australian Building Codes Board, Canberra.

[BRE] Mayfield, C. and Hopkin D., *Design Fires for Use in Fire Safety Engineering*, BRE Trust, Garston, Watford WD25 9XX, ISBN 978-1-84806-152-1, 2011.

[CIBSE] CIBSE Guide E: *Fire Safety Engineering*, CIBSE, 2010.

[IFEG] ABCB 2005, *International Fire Engineering Guidelines*, 2005 Edition, Australian Building Codes Board, Canberra

[Proulx] Proulx, G., *Evacuation Time*, 4th Edition, Chapter 3-12, SFPE Handbook of Fire Safety Engineering National Fire Protection Association, and Society of Fire Protection Engineers, 2008.

[Gwynne] Gwynne, S. M. V.,and Rosenbaum, E. R., Employing the Hydraulic Model in Assessing Emergency Movement, Chapter 13-3, SFPE Handbook of Fire Safety Engineering (4th Ed.), National Fire Protection Association, and Society of Fire Protection Engineers, 2008.

[PD 7974-6] PD7974-6 - 2004. "*The application of fire safety engineering principles to fire safety design of buildings – Part 6: Human factors: Life safety strategies – Occupant evacuation, behaviour and condition (Sub-system 6)",* BSI British Standards.

[FRNSW] Fire Safety Guideline: *Guideline for impulse fans in car parks - Version 01* Issued 09th October 2014 by Fire & Rescue NSW.

[PD7974-6] PD7974-6, Application of Fire Safety Engineering Principles to the Design of Buildings – Part 6: *Human factors – Life safety strategies: Occupant evacuation, behaviour and condition*, BSI, 2004.

[SR255] Branz Study Report SR 255 (2011) for carparks involving modern and stacking systems

[Enright] Enright, P.A., *Impact of Jet fan Ventilation Systems on Sprinkler Activation*, IFE 2013 Paper.

[Mowrer] Section 3 Chapter 14 of the SFPE Handbook 4th Edition, 2008. Emergency Movement by Harold E. "Bud" Nelson and Frederick W. Mowrer.

Appendix A Impulse Fan JIU-CPCEC-LH/SD Unit (Spec)

Appendix B Impulse Fan Layout (provided by Fantech)

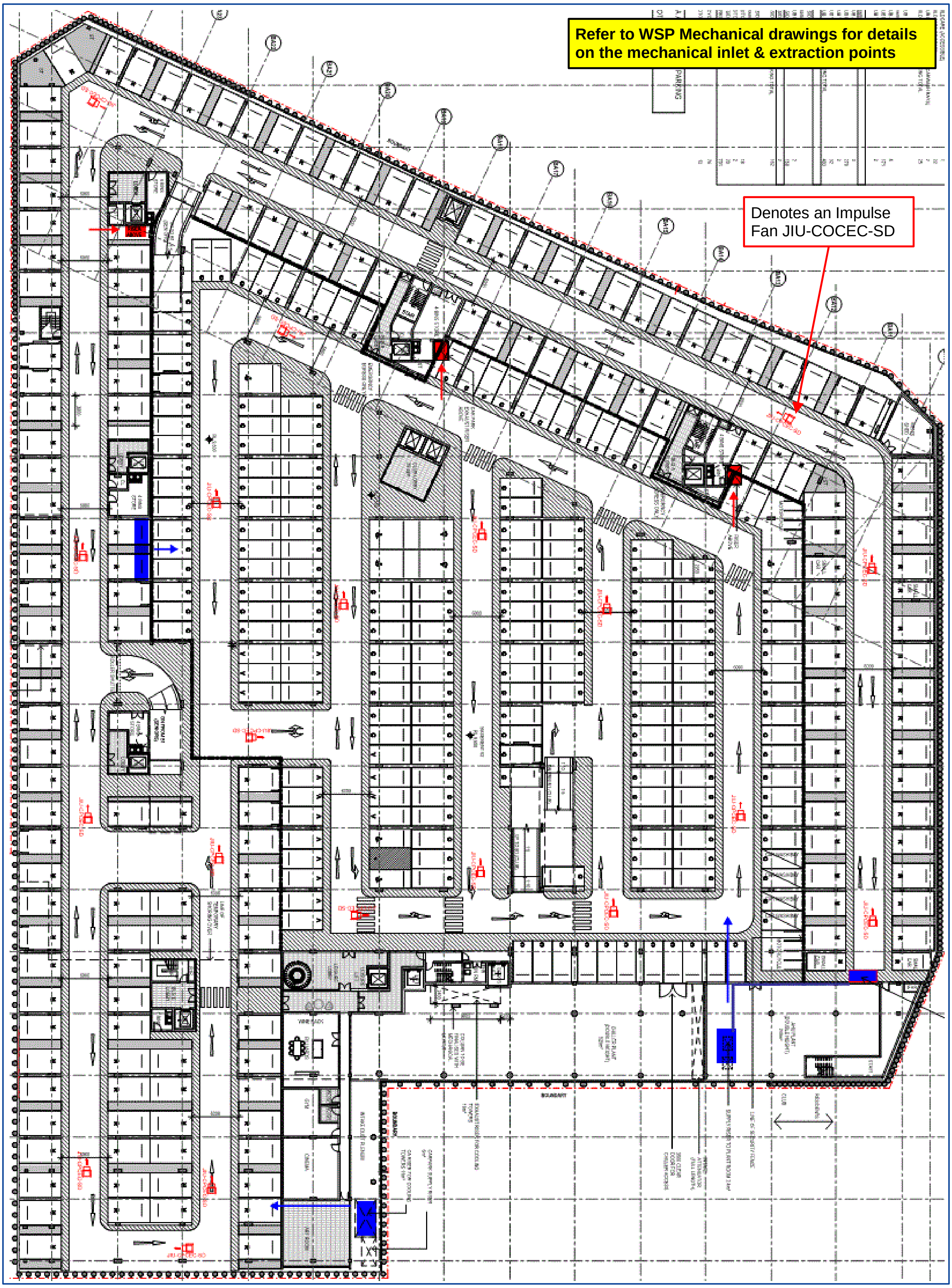


Figure 34: Basement Level 2 – Impulse fan layout as provided by Fantech

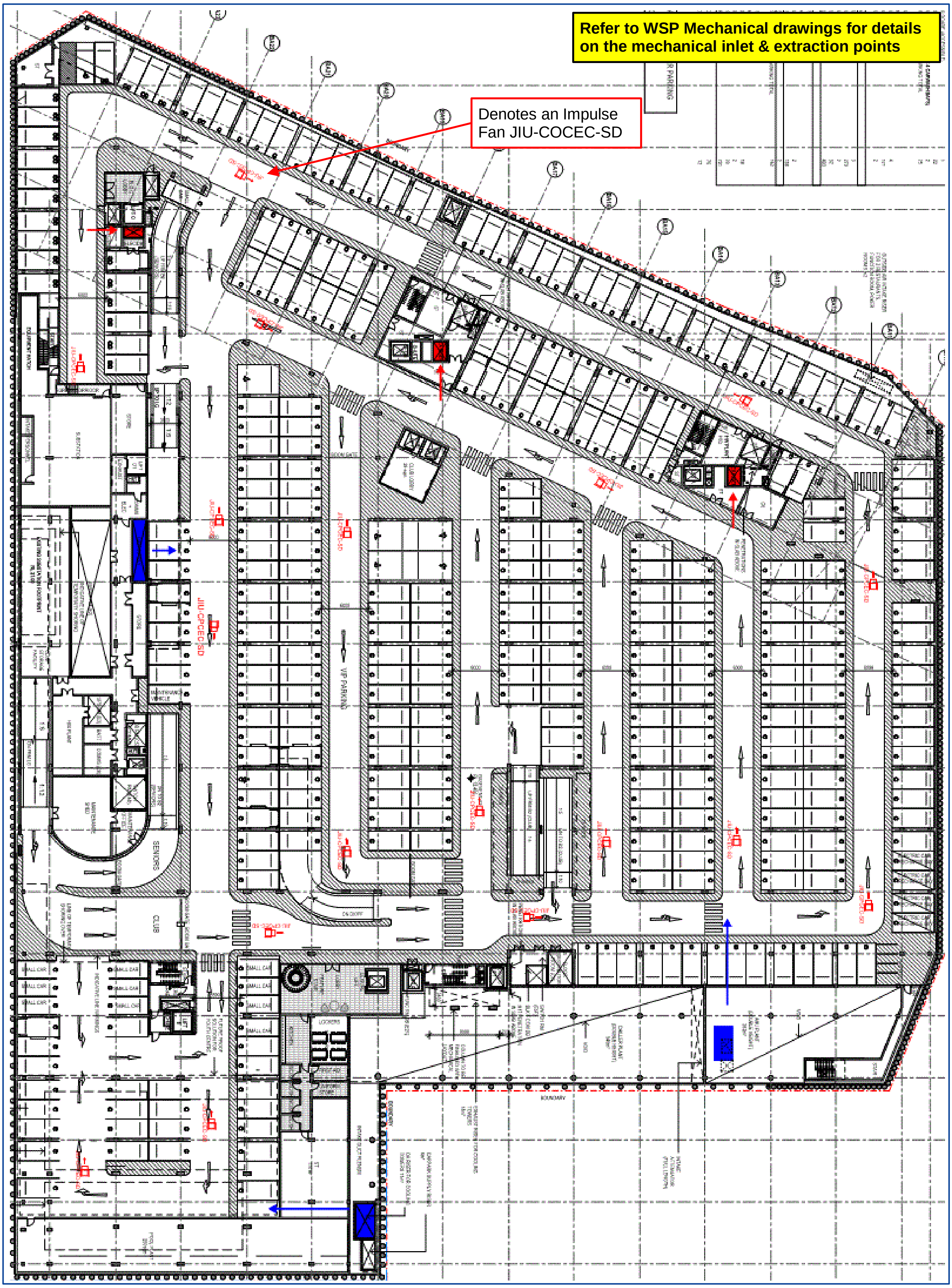


Figure 35: Basement Level 1 – Impulse fan layout as provided by Fantech

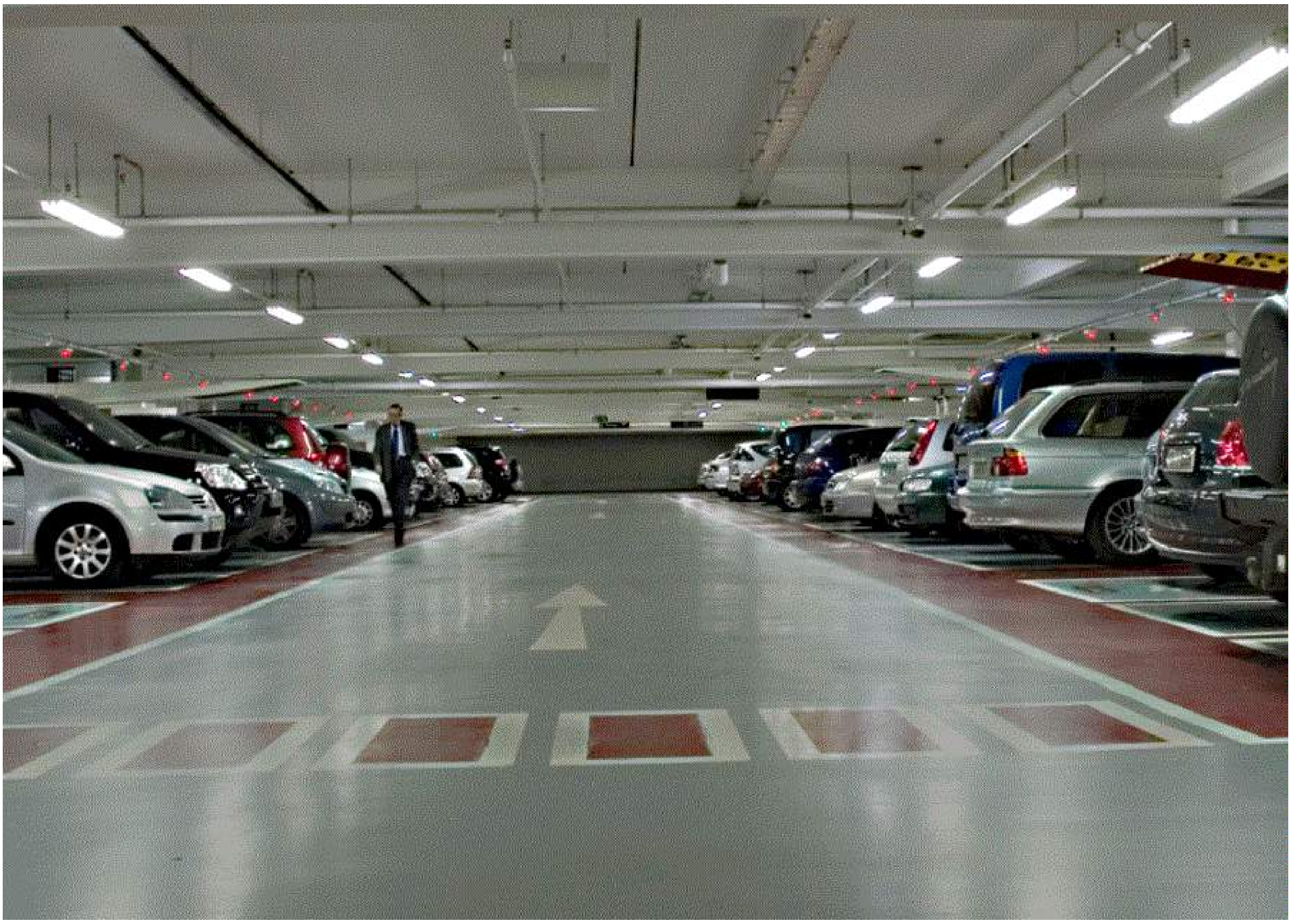
WSP

Level 1, 41 McLaren Street
PO Box 6245
North Sydney NSW 2060
Australia

Tel: 02 8907 0900
www.wspgroup.com

UNITED
BY OUR
DIFFERENCE

Appendix I Carpark CO Modelling Report



HARBORD DIGGERS REDEVELOPMENT, 80 EVANS STREET FRESHWATER

CO Modelling Report

Rev 0

25/08/2015

FEG1444000 CO Modelling

Quality Management

Issue History

Revision	Remarks
Rev 0	Final Issue of report issued for stakeholder information.
Rev 1	
Rev 2	
Rev 3	

QA History

Revision	Rev 0	Rev 1
Date	25/08/2015	
Prepared by	Emil Persson	
Checked by	Michael Lawless	
Authorised by	Lloyd Wilkinson	

HARBORD DIGGERS REDEVELOPMENT, 80 EVANS STREET FRESHWATER

CO Modelling Report

Rev 0

25/08/2015

Client

(Mounties Group)
Mount Pritchard Distict Community Club Pty Ltd
Suite 8.01, Level 8 28-34 O'Connell Street
Sydney, NSW 2000
ABN: 98 000 458 622

Registered Company

WSP Buildings (Pty) Ltd
ABN: 47 005 113 468

Level 1, 41 McLaren Street
PO Box 6245
North Sydney NSW 2060
Australia

Tel: 02 8907 0900
www.wspgroup.com.au

WSP Contacts

Emil Persson
Fire Engineering Intern
emil.persson@wspgroup.com

Michael Lawless
Senior Fire Safety Engineer
Mob: 0474 323 289
michael.lawless@wspgroup.com

Lloyd Wilkinson
Associate | NSW Fire Engineering Manager
Mob: 0451 824 877
lloyd.wilkinson@wspgroup.com

Wayne Bretherton
Principal, Director of Specialist Disciplines
Mob: 0408 517 535
Wayne.Bretherton@wspgroup.com

Reference used in this CO Modelling Report

Please note that the abbreviated text enclosed in [ ] refers to a referenced document which is described in full in the Reference Section of this report (Section 8) which is noted to be presented in alphabetical order.

Executive Summary

WSP Buildings Pty Ltd has been appointed by the Mounties Group to undertake fire engineering services associated with the proposed Harbord Diggers development located at 80 Evans Street, Freshwater NSW 2096.

This report summarises the modelling assessment of the mechanical ventilation system serving the basement carpark levels of the Harbord Diggers development and presents the design assumptions and results of the CFD modelling study of the mechanical ventilation system. The design uses an Alternative Solution with the installation of impulse fans (also known as jet fans) in conjunction with CO sensors and associated controls being a performance based solution as described in [AS 1668.2].

This report specifically investigates the performance of the ventilation system in respect to the dilution and removal of carbon monoxide from the car park. The CO Modelling detailed in this report confirms that the proposed air distribution system achieves dilution of contaminants in the enclosure and maintains contaminant concentration below the recommended exposure standards.

In order to undertake the assessment a Computational Fluid Dynamics (CFD) model was built of the proposed car park, including its proposed ventilation system. The modelling has been undertaken based on the design documentation (listed in Table 2) and the following vehicle movements and emissions as discussed in Section 4 which have been summarised below:

- 701 cars in total, where 342 cars in Basement Level 1 and 359 cars in Basement Level 2. According to, Section 96 Traffic Report Section 3.5.1, 50 % of the car park capacity is seen as a worse case assessment. With this given, 351 cars has been modelled in the CFD-calculations.
- Assumed peak afternoon exit as a worst-case scenario, this due to vehicle emissions being higher on a cold start.
- Fleet average emissions as per AS 1668.2, decreasing from 25 g/min in the first minute of operation to 3.2 g/min when hot in the 6^{th} minute.
- 6 km/h driving speed within the car park.
- 0.5 minute de-parking time
- Background CO concentration of 9 ppm.
- No wind affects (carpark is underground)

The modelled CO concentrations results for the cark have been summarised in Table 1:

Table 1: Average CO concentrations for Basement Level 1 & 2

Parking Usage Factor	Floor Level	Height (mm)	Average CO concentration (ppm)	Meets Standard
100 % Parking Usage Factor, Afternoon Peak Exiting Vehicles	Basement Level 2	1800	10.0	**Pass**
	Basement Level 1	1800	10.0	**Pass**

Table of Contents

- ***Abbreviations used in this report***

The following abbreviations are used in this report.

Abbreviation	Description
FRNSW	Fire & Rescue New South Wales
BCA	Building Code of Australia
CFD	Computational Fluid Dynamics
CO	Carbon monoxide
DtS	Deemed-to-Satisfy
FER	Fire Engineering Report
FEBQ	Fire Engineering Brief Questionnaire

1 Introduction

1.1 Background & Introduction

The latest AS 1668.2 permits the use of jet fans for ventilation in carparks. However, it is understood that the jet fans are allowed to be used as an alternative to provide ventilation to dead end spaces when the space is difficult to be covered by the ducted system. In this sense, a ventilation system using jet fans throughout a carpark is not considered compliant with AS 1668.2. In the proposed Harbord Diggers development, jet fans are proposed to be used throughout the basement carparks as the normal ventilation system in lieu of a traditional ducted ventilation system.

This is required to be addressed as an Alternative Solution to ensure compliance with Performance Requirement FP4.4 regarding the air quality.

1.1.1 Complying with BCA Performance Requirements EP1.4 & EP2.2

BCA Clause E2.2 requires an AS 1668.2 mechanical ventilation system in a carpark building to comply with Clause 5.5 of [AS/NZS 1668.1] with certain concessions. Clause 5.5 requires the exhaust system to continue to operate in fire mode and shall operate at its full capacity where the system incorporates variable flow rates. However, it is considered that these requirements were meant to apply to the traditional ducted ventilation systems and the BCA does not give consideration to jet fans and does not provide any requirements or guidance for the operation of jet fans in fire mode. For this reason, the mechanical design utilising jet fans should be addressed as an Alternative Solution to demonstrate compliance with Performance Requirement EP2.2.

1.2 Scope & Objectives

The intent of this report is to specifically investigate the performance of the ventilation system in respect to the dilution and removal of carbon monoxide (CO) from the basement carparking levels.

The CO Modelling detailed in this report is used to demonstrate that the proposed air distribution system achieves dilution of contaminants in the carpark enclosure and maintains contaminant concentration below the recommended exposure standards and as such shall demonstrate compliance with BCA Performance Requirement FP4.4. The design uses an Alternative Solution with the installation of jet fans in conjunction with CO sensors and associated controls being a performance based solution as described in AS 1668.2.

1.3 Assumption and Limitations

This report documents the predicted time-weighted CO concentrations, based on the documented input criteria.

Actual car park CO concentrations can be affected by a large number of variables including: car density, actual vehicle emissions, number of car movements, weather, facilities management, and car park user behaviour.

As such, the results in this report are valid only under the modelling conditions stated in this document. Significant variations to the design and use of the car park will render the conclusions of this report invalid.

1.4 Sources of information

The relevant drawings and documentation which have been assessed as part of this CO Modelling report are listed in Table 2.

Table 2: Relevant Drawings & Documentation

DWG No.	Drawing Name	Organisation	Date	Rev
A1000	Overall Basement Level 2 Plan	Architectus+Chrofi	13/06/2015	Q
A1001	Overall Basement Level 1 Plan	Architectus+Chrofi	13/06/2015	Q
A1002	Overall Lower Ground Floor Plan	Architectus+Chrofi	15/06/2015	Q
WSP-ME-0-B02-100	Basement 2 – Air conditioning and ventilation overall layout	WSP	27/02/2015	2

DWG No.	Drawing Name	Organisation	Date	Rev
WSP-ME-0-B01-100	Basement 1 – Air conditioning and ventilation overall layout	WSP	27/02/2015	3
Issue S96 Traffic Report 20150615.docx	Section 96 Traffic Report	Arup	15/06/2015	-
Report 2013/1528	Harbord Diggers Redevelopment 80 Evans Street, Freshwater BCA Compliance Report	Steve Watson & Partners	07/07/2015	2.1

1.4.1 Figures used in this report

It is noted that the figures presented in this report provide an indicative illustration of the carparking areas, the CFD modelling (discussed in Section 5) and it associated findings. The CFD model has been based on the architectural drawings prepared by Architectus + Chrofi detailed in Table 2.

2 System Compliance to AS 1668.2

2.1 Approach

For car park ventilation, the Deemed-to-Satisfy requirements as outlined in the BCA 2015 would require a ducted ventilation system complying with AS 1668.2.

Air flow rates have been calculated by the performance based dilution method in accordance with Clause 4.2 of AS 1668.2 as an Alternative Solution. It is noted that AS 1668.2 allows the Regulatory Authority to approve performance based alternatives that achieve dilution of contaminants in the enclosure and maintain contaminant concentrations below the recommended exposure standard.

The Dilution Method considers CO emissions for various vehicle types and traffic flow conditions. It is a time based model that calculates the CO generation rate and subsequently the ventilation required to reduce contaminant concentrations to acceptable levels.

2.2 Derivation of performance based solution formulae

Removal of contamination within a space to maintain acceptable concentration levels is defined through the following relationship:

$$Q = \frac{E}{C} \qquad \text{Equation (1)}$$

where: Q = air flow rate

E = contaminant CO generation rise, and

C = rise in contaminant concentration level

For car park applications, a generalised expression of equation (1) is:

$$Q = E_C . n . \frac{t}{C} \qquad \text{Equation (1a)}$$

where: E_C = CO emission rate per operating car engine

n = number of cars with engine operating; and

t = time (s)

The CO generation rise maybe expressed as:

$$\begin{aligned} E_{CO} = \; & [(n_1 \times P_{ex1}) \times (t_{11} \times E_1 + t_{12} \times E_2 + \cdots t_{1n} \times E_n)] + \\ & [(n_2 \times P_{ex2}) \times (t_{21} \times E_1 + t_{22} \times E_2 + \cdots t_{2n} \times E_n)] + [\ldots \end{aligned} \qquad \text{Equation (2)}$$

where: E_{CO} = CO generated (g/h);

n_1 = total number of cars in car park level under consideration (eg. level 1);

n_2 = total number of cars in other car park levels which pass through the level under consideration (n/a in this instance);

P_{ex1} = per cent of cars exiting from level 1 in one hour;

P_{ex2} = per cent of exiting cars passing through level 1 from other levels in 1 hour (n/a in this instance);

t_{11} = duration of engine operation with CO emission rate of E_1 (min), level 1;

t_{12} = duration of engine operation with CO emission rate of E_2 (min), level 1;

t_{1n} = duration of engine operation with CO emission rate of E_n (min), level 1;

t_{21} = duration of engine operation with CO emission rate of E_1 (min), level 2 (n/a in this instance);

t_{22} = duration of engine operation with CO emission rate of E_2 (min), level 2 (n/a in this instance);

t_{2n} = duration of engine operation with CO emission rate of E_n (min), level 2 (n/a in this instance);

E_1, E_2, E_n = CO emission rate (g/min) of first, second, n^{th} minute of engine operation from cold-start according to data in "Survey of Australia and Overseas standards"

The required ventilation flow rate (Q) can be expressed as:

$$Q = 0.242.\frac{E_{CO}}{C_{ppm}} \quad \text{Equation (1b)}$$

where: Q = air flow rate (m^3/s)

C_{ppm} = rise in CO Concentration level (ppm)

0.242 = is a constant derived from the conversion of the units from seconds to hours divided by the molar volume of CO – ie $=\frac{\left(\frac{1}{3.6}\right)}{1.148} = 0.242$

2.3 Alternative Solution – Jet ventilation fans

An Alternative Solution using jet fans in conjunction with CO sensors and associated controls, based on the performance approach detailed in AS 1668.2 is proposed.

A Computational Fluid Dynamics (CFD) Analysis to justify the proposal is presented in this document and will demonstrate that the jet fans maintain a constant air movement across the domain and prevent air stagnation to effectively dilute products.

3 Description of Carpark & Proposed Mechanical System

3.1 Description of car parking levels

The carparking area of the proposed development comprises of two floor levels which have been referred to as Basement Levels 2 & 1. A breakdown of each level has been detailed in Table 3 which has been based on detail contained within Section 11.2 of the BCA Report.

Table 3: Floor areas and volumes

Floor Level	Approx. Area (m^2)	Approx. Volume (m^3)	Ceiling Height
Basement Level 2	13,728	41,184	2.7 m
Basement Level 1	13,666	40,998	Ranges 3 m (in part) to 4.4 m

It is noted that the carparking spaces for Basement Levels 2 & 1 have been divided between the Community Club & Residential areas of the development. Allocated car spaces for the residential areas have been allocated with the letter '*R*' and spaces for the community club area have been allocated with the letter '*C*'. Basement Level 1 is to be allocated solely for the Community Club areas with Basement Level 2 divided between both the Community Club and the Residential areas of the building.

Vehicle entry to the proposed development shall be by way of Evans Street which has been indicatively illustrated in Figure 1. The carparking entry and exit points shall be by way of the Port Cochere area which is located at Lower Ground Floor Level.

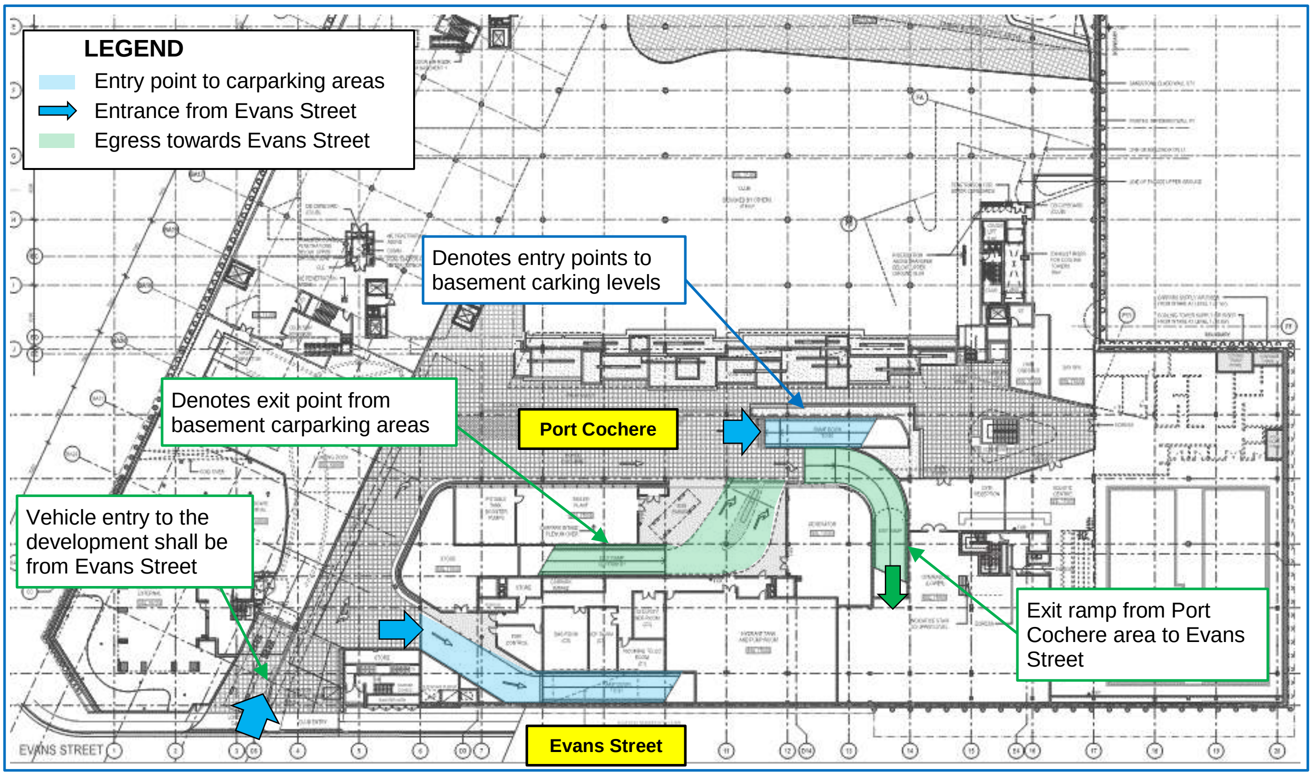


Figure 1: Lower Ground Floor Level – vehicle approach & entry / exit points of the car parking areas

The extent of the carparking areas at Basement Levels 2 & 1 have been further illustrated in Figure 2 and Figure 3. The main exit points of the carpark has been referred to as Exits A, B & C. Exits A & B are located at Basement Level 2 with Exit C located at Basement Level 1. Exit C is the final exit from the carpark and discharges at Lower Ground Floor Level as illustrated in Figure 3.

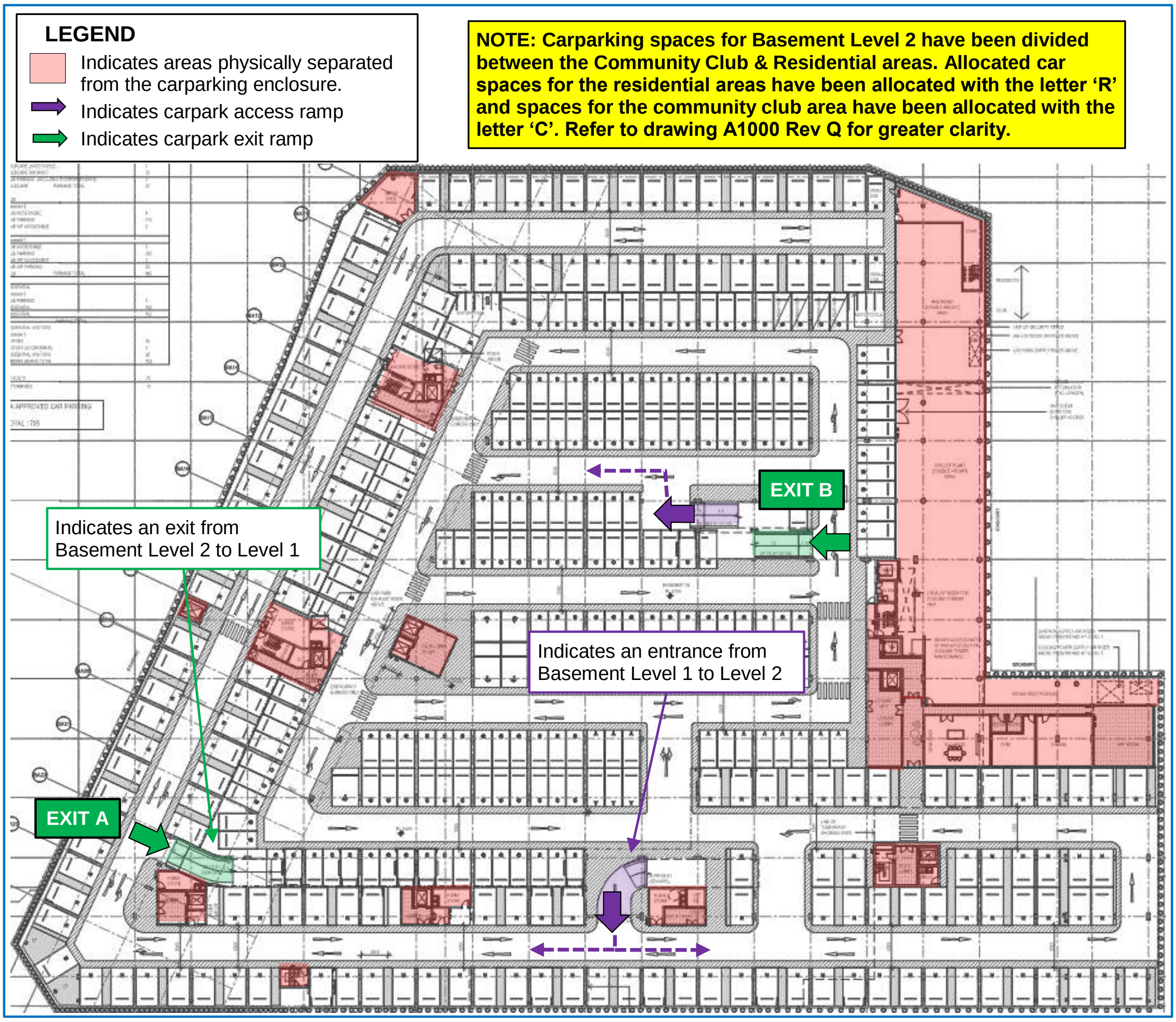


Figure 2: Overall Basement Level 2 Plan – extent of carparking areas

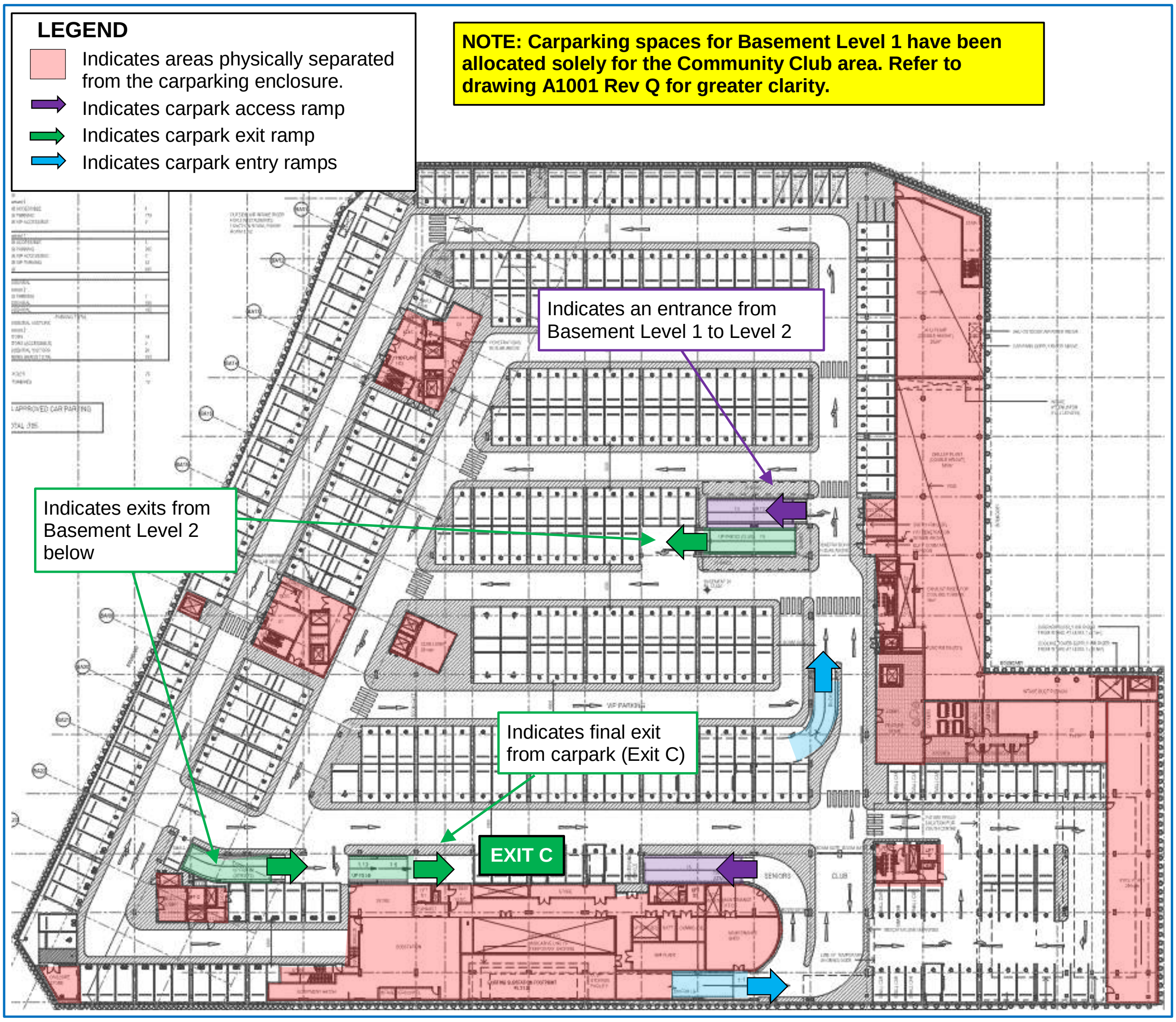


Figure 3: Overall Basement Level 1 Plan – extent of carparking areas

3.2 Jet fan ventilation system

A jet fan ventilation system is based on a number of small, strategically located high velocity jet fans mounted directly beneath the ceiling, in place of the distribution ductwork traditionally used in car parks. The system provides constant flow and air movement around a car park ensuring harmful pollutants do not gather and accumulate in dead areas.

Jet fans producing a high velocity jet which thrusts against the air in front of the fan imparting momentum to all the surrounding air through entrainment as it diffuses. The volume of entrained air is significantly greater than that passing through the fan. The induction fans are carefully positioned to mix the air in the car park and direct it towards the main extract fan intake points which has been indicatively illustrated in Figure 4. The main extract fans are sized to provide the required airflow rates however, given the reduced need for, or complete elimination of ducting, the resulting reduction in system resistance means they are typically smaller and consume less energy than fans for fully ducted systems.

Figure 4: Principle of operation - workings of an Jet Fan (Image © Fantech)

The car park ventilation system for the development has been summarised in Table 4 which has been based on the mechanical drawings prepared by WSP as well as the jet fans layouts for the proposed basement provided by Fantech. The proposed design shall utilise the Fantech JIU-CPCEC-SD Impulse Fan unit throughout with the technical specification sheet for this unit attached in Appendix A for ease of reference. Each jet fan shall have a 1.2 m^3/s air velocity at the nozzle.

An indicative layout of the jet fans units for both Basement Levels 2 & 1 have been illustrated in Figure 20 and Figure 21 of Appendix B which have been designed by Fantech. Table 4 provides a breakdown of mechanical supply and exhaust points at each level as well as the number of jet fans at each level. The following detail should be read in conjunction with the drawings presented in Table 2. Refer to the WSP mechanical drawings for clarity on the location of the supply air point inlet points and exhaust points at each level of the carpark.

Table 4: Mechanical Supply and Exhaust rates of carpark ventilation system

Floor Level	Mechanical Supply		Mechanical Exhaust		No. of natural supply air inlet	No. of Jet fans
	Supply Rate (m^3/s)	No. of Vents	Exhaust Rate (m^3/s)	No. of Vents		
Basement Level 2	15 (Area 2)	1	17 (Area 1)	1	4	20
	10 (Area 8)	1	17 (Area 3)	1		
	20 (Area 7)	1	17 (Area 6)	1		
Total	**45 m^3/s**	**3**	**51 m^3/s**	**3**		
Basement Level 1	15 (Area 2)	1	24 (Area 1)	2	3	18
	20 (Area 8)	1	24 (Area 3)	2		
	30 (Area 7)	1	24 (Area 6)	2		
Total	**65 m^3/s**	**3**	**72 m^3/s**	**6**		

4 Design Criteria & Assumptions

4.1 Introduction

It is noted that the proposed mechanical ventilation system to serve the basement carpark levels of the Harbord Diggers development must be designed in accordance with AS 1668.2.

4.2 Number of cars

A total of 701 car parking spaces are to be provided at Basement Levels 1 and 2 (based on car spaces identified on the architectural drawings detailed in Table 2), with the number of spaces to each level as follows;

- Basement Level 1 - 342 cars parking spaces
- Basement Level 2 - 359 car parking spaces

4.2.1 Traffic Report

According to, Section 3.5.1 of the Section 96 Traffic Report prepared by ARUP for the proposed development, 50 % of the car park capacity is seen as a worse case assessment. Hence based on the guidance presented in the traffic report, 351 cars have been utilised for the modelling with the number of spaces to each level as follows;

- Basement Level 1 – 171 cars parking spaces
- Basement Level 2 – 180 car parking spaces

4.3 Basis of Airflow Formulae for Carparks (Appendix J of AS 1668.2)

4.3.1 Emission Assumptions

Performance calculations and emission rates for the CFD modelling are as per Appendix J1 of [AS 1668.2 which provides guidance on the *'Basis of Airflow rates Formulae for Carparks'*. Table 5 below presents the CO Emission rates on a cold engine start.

Table 5: Fleet average CO emission rates on cold engine start (Appendix J1 of AS 1668.2)

Time (of operation)	CO Emission Rates
First minute	25 g/min
Second minute	16 g/min
Third minute	10 g/min
Fourth minute	7 g/min
Fifth minute	5 g/min
Hot	3.2 g/min
NOTE: It has been assumed that emission controls do not start functioning effectively until several minutes after the engine has been in operation. Accordingly, the above figures are independent of advancement in engine and emission control designs.	

For the purposes of this report, CO emissions have been calculated for cars exiting the car park in the afternoon peak periods. This equates to 351 cars leaving the car park in a one-hour period. As CO emission rates are higher when an engine is cold, this is assumed to be a worst-case approach.

4.3.2 Average car speed

Appendix J2 of AS 1668.2 provides guidance on the average car speed for a car park which prescribes an average vehicular speed of 6 km/h (0.01 min/m).

Based on the proposed carpark configuration and the distance from the most remote points of the carpark to reach Exits A, B & C (identified in Figure 2 & Figure 3) and utilising a travel speed of 6 km/h, the total exiting time per level will be within a minute. For the purposes of the CO modelling, the total exiting time per level shall be capped at 1 minute. Hence this equates to a total time of 2 minutes when travelling from Basement Level 2 (lowest level) in reaching the final exit from the carparking levels.

4.3.3 Ambient CO Concentration

Appendix J3 of AS 1668.2 provides guidance on ambient CO concentrations and states a peak 9 ppm concentration which is based on standard and goals set by the National Environment Protection Council (NEPC and the National Health and Medical Research Council (NHMRC).

4.3.4 Parking times

Appendix J4 of AS 1668.2 provides guidance on the car park parking times and states;

> *"The following times are used:*
> *(a) Parking—car drives at 6 km/h to space, and takes 1 min to park.*
> *(b) De-parking—car takes 0.5 min to leave space, and then takes 0.5 to 1.5 min to leave zone.*
> *(c) Cars exiting from other areas are in the second minute of operation."*

A 0.5 m de-parking is to be utilised for cars to leave their respective zones. Based on the total exiting times of the carparking levels discussed in Section 4.3.2, the following assumptions has been made with regards the Fleet Average CO Emission rates which has been based on guidance given in Table 5;

- First minute - 25 g/min
- Second minute - 16 g/min

4.3.5 Environmental conditions

It is assumed that the worst case for CO clearance is a still day, so wind affects have been ignored in the model. An external air temperature of 20°C has been assumed.

4.4 Emission Calculations

In order to effectively calculate the likely CO concentrations in the carparking areas, each level of the carpark has been broken up into zones of roughly equal size. There are 15 zones in Basement Level 2 (as represented by B2 annotation) and 11 zones in Basement Level 1 (as represented by B1 annotation) which have been indicatively illustrated in Figure 5. The exiting path for the different zones has also been illustrated.

These zones allow the calculation to take into account the likely variances in CO concentration due to the travel distances and driving times for an individual car to an exit.

Table 6 describes the number of car parking spaces in every zone (identified in Figure 5) and the number of cars passing through each zone on their way out and which exit the cars in the particular zone exits through (Exits A, B & C). It has been assumed that the CO emission rates as discussed in Table 5 has been evenly distributed among the cars contained within each zone.

Table 6: Number of Cars in zone in Basement Levels 2 & 1

Basement Level 2				Basement Level 1			
Zone	No. of Car Spaces in zone	No. of cars exiting through zone	Exit	Zone	No. of Car Spaces in zone	No. of cars exiting through zone	Exit
B2R1	25	137	A	B1C1	34	0	C
B2R2	13	65	A	B1C2	15	34	C
B2R3	13	52	A	B1C3	18	0	C
B2R4	18	34	A	B1C4	36	80	C
B2R5	34	0	A	B1C5	11 + 162 (From B2)	335	C
B2R6	17	42	A	B1C6	33 + 199 (From B2)	67	C
B2R7	24	18	A	B1C7	40	179	C
B2R8	18	0	A	B1C8	36	44	C
B2C1	33	29	B	B1C9	39	0	C
B2C2	29	0	B	B1C10	44	0	C
B2C3	20	62	B	B1C11	40	106	C
B2C4	24	82	B				
B2C5	25	174	B				
B2C6	33	0	B				
B2C7	35	33	B				

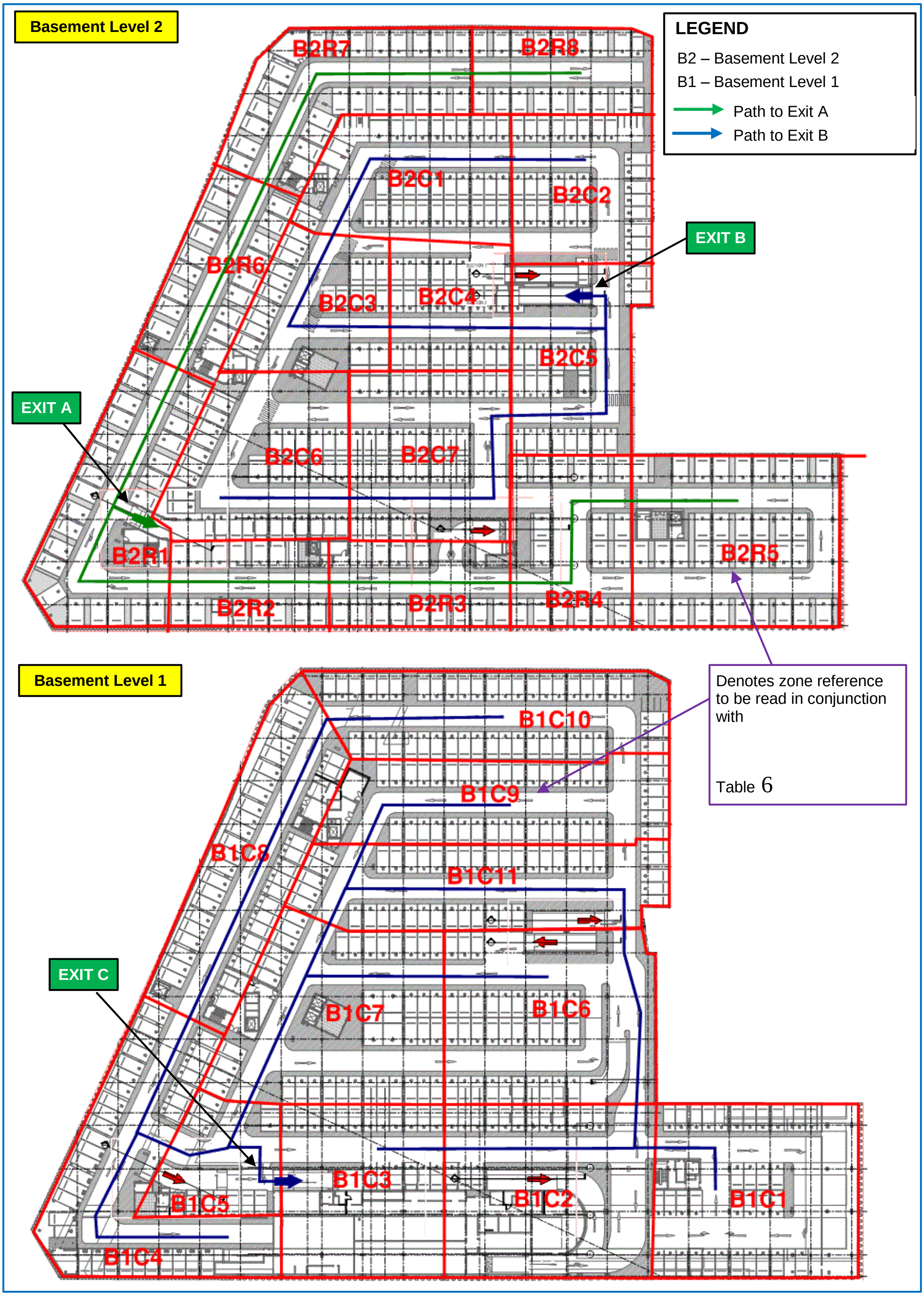


Figure 5: Car park emissions zone layout for Basement level 2

4.5 CO Calculations for carpark

For each zone in the Basement Levels 1 and 2 illustrated in Figure 5, an average driving distance to the nearest exit has been calculated. From this, a time has been derived representing the average time taken for a car parked in a particular zone to exit the car park. This time has been assumed to be a maximum of 2 minutes for cars leaving Basement Level 2 and a maximum of 1 minute for cars leaving Basement level 1 which has been discussed in Section 4.3.2. This have been assumed from the fact that AS 1668.2 prescribes an average vehicular speed within the car park of 6 km/h. From this time, an average CO emission per zone has been calculated which has been based on the equations discussed in Section 2.

The calculated CO emission rates detailed in Table 7 have been used in the CFD-modelling.

Table 7: CO Emission rates for Basement Level 2 & 1

Basement Level 2		Basement Level 1	
Zone	**CO Emission Rates (g/min)**	**Zone**	**CO Emission Rates (g/min)**
B2R1	4050	B1C1	850
B2R2	1950	B1C2	1225
B2R3	1625	B1C3	450
B2R4	1300	B1C4	2900
B2R5	850	B1C5	14426
B2R6	1475	B1C6	5684
B2R7	1050	B1C7	8659
B2R8	450	B1C8	2000
B2C1	1550	B1C9	975
B2C2	725	B1C10	1100
B2C3	2050	B1C11	3650
B2C4	2650		
B2C5	4975		
B2C6	825		
B2C7	1700		

4.5.1 Different measures

The different ceiling heights have been assessed as part of this report are listed in Table 8.

Table 8: Basement Level ceiling heights

Floor	Actual Ceiling height (m)	Ceiling Height used
Basement Level 2	2.7 m	2.5 (for CFD simulation)
Basement Level 1	Ranges 3 m (in part) to 4.4 m	3 (for CFD simulation)

It is noted that the ceiling heights in the CFD model are actually lower than the ceiling heights of the proposed carpark. The lower value was utilised to fit within the rectangular grid utilised in the CFD model. The lower dimensions utilised presents a more conservative analysis as it essentially presents a smaller built environment.

5 Modelling Methodology

5.1 Computational Fluid Dynamics

The CFD model used in this assessment was Fire Dynamics Simulator 6 (FDS 6.1.2), produced by the National Institute of Science and Technology (NIST). The simulator has been extensively validated against both real and laboratory fires and is considered to be an industry standard.

The assumptions and limitations of the simulator are not reviewed here and full reference should be made to NIST Special Publication 1018 '*Fire Dynamics Simulator (Sixth Edition) Technical Reference Guide'*. All models have been both undertaken and checked by experienced users in line with the recommendations of NIST.

5.1.1 Computational Domain

The accuracy of a Computational Fluid Dynamics calculation is highly dependent on a suitable mesh topology. Autodesk SimCFD allows the user to perform comprehensive topological interrogation to ensure an appropriate mesh size and distribution on every edge, surface and volume within the model. Geometric curvature gradients, and proximity to neighbouring geometry are all considered when assigning a mesh.

In this case, the mesh topology has been customised to ensure the most efficient mesh distribution has been specified. This ensures a fine mesh located close to the jet fans, as well as a larger mesh size within the open fluid areas throughout the car park.

The FDS modelling also works in a similar way and final model has just over 12.6 million cells.

The different basement levels have been simulated separate because of the large number of cells in every floor. A fewer number of cells decreases the required simulation time.

5.1.2 Simulation Approach

A study of the CO concentration levels due to normal car movements within the car park has been undertaken to determine the efficiency of the mechanical ventilation system, with design parameters from Australian Standard AS 1668.2 as discussed in Section 4 of the report.

The simulation methodology is to demonstrate a time-independent, steady state condition within the car park and demonstrate conditions are maintained within the allowed acceptance criteria for occupant exposure to CO.

A steady state analysis will demonstrate a 'time-averaged' result and highlight the performance of the proposed mechanical solution to manage the calculated CO load.

The model will therefore not demonstrate the proposed systems reaction to initially elevated CO levels, the subsequent clearance period and system response time. Rather the model demonstrates the stable 'post-response' phase with the main ventilation system fully engaged to remove the required mass of air.

5.2 Simulation Parameters

5.2.1 Atmospheric Contaminant

Section 4.12.1 of AS 1668.2 specifies the requirements for monitoring of atmospheric contaminants in a car park. It also states that the atmospheric contaminant to be monitored shall be CO. Refer also to comment C4.12.1 below:

> '***C4.12.1*** *Advice from health authorities indicate that monitoring of CO is optimum for contaminant monitoring systems for enclosures used by vehicles with combustion engines. Although NO_2 is produced by some combustion engines monitoring results have indicated that CO levels exceed the exposure standard (ES) before NO_2 levels.'*

The CFD model and analysis therefore solely relates to CO development and as such NO_x emissions have not been modelled.

5.2.2 Vehicle Definition

Actual car movement within the car park is not explicitly modelled; the movements of individual vehicles have been simplified by distributing the full emissions load evenly across a number of zones which has been discussed and outlined in Section 4.4 and

Table 6.

5.2.3 *Vehicle Contaminant*

Refer to Table 5 above for details of the fleet average emission rates per minute of operation from Appendix J1 of AS 1668.2. Vehicle emission rates are calculated from the number of vehicles moving per hour, the maximum travel distance and the average vehicle speed. All exhaust gases are emitted at 200°C.

5.2.4 *Geometry Construction*

The model has been constructed as per the architectural drawings provided as per Table 2. All boundary geometry has been created with Autodesk Inventor and then imported into Autodesk SimCFD in order to carry out the CFD. In Autodesk SimCFD, a single fluid region is input in order to calculate the fluid dynamics within the car park.

While some elements of the geometry have been simplified in order to provide a stable model platform, care has been taken to retain all elements which have influence over the flow field within the model. Elements such as beams, columns and ramps have been included.

An overview of the carpark model built using FDS is shown in Figure 6 which is a 3D image of the carparking areas. A further floor by floor breakdown of the carparking areas has been illustrated in Figure 7.

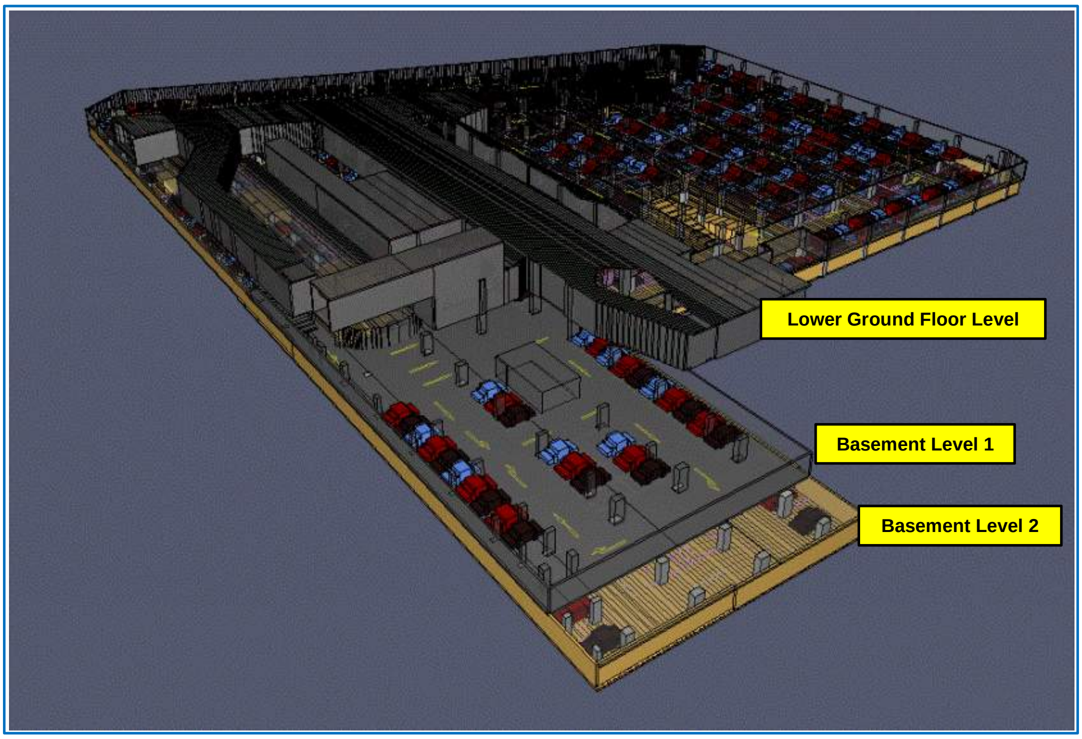


Figure 6: 3D image of the FDS Model for carparking levels used for CO Modelling

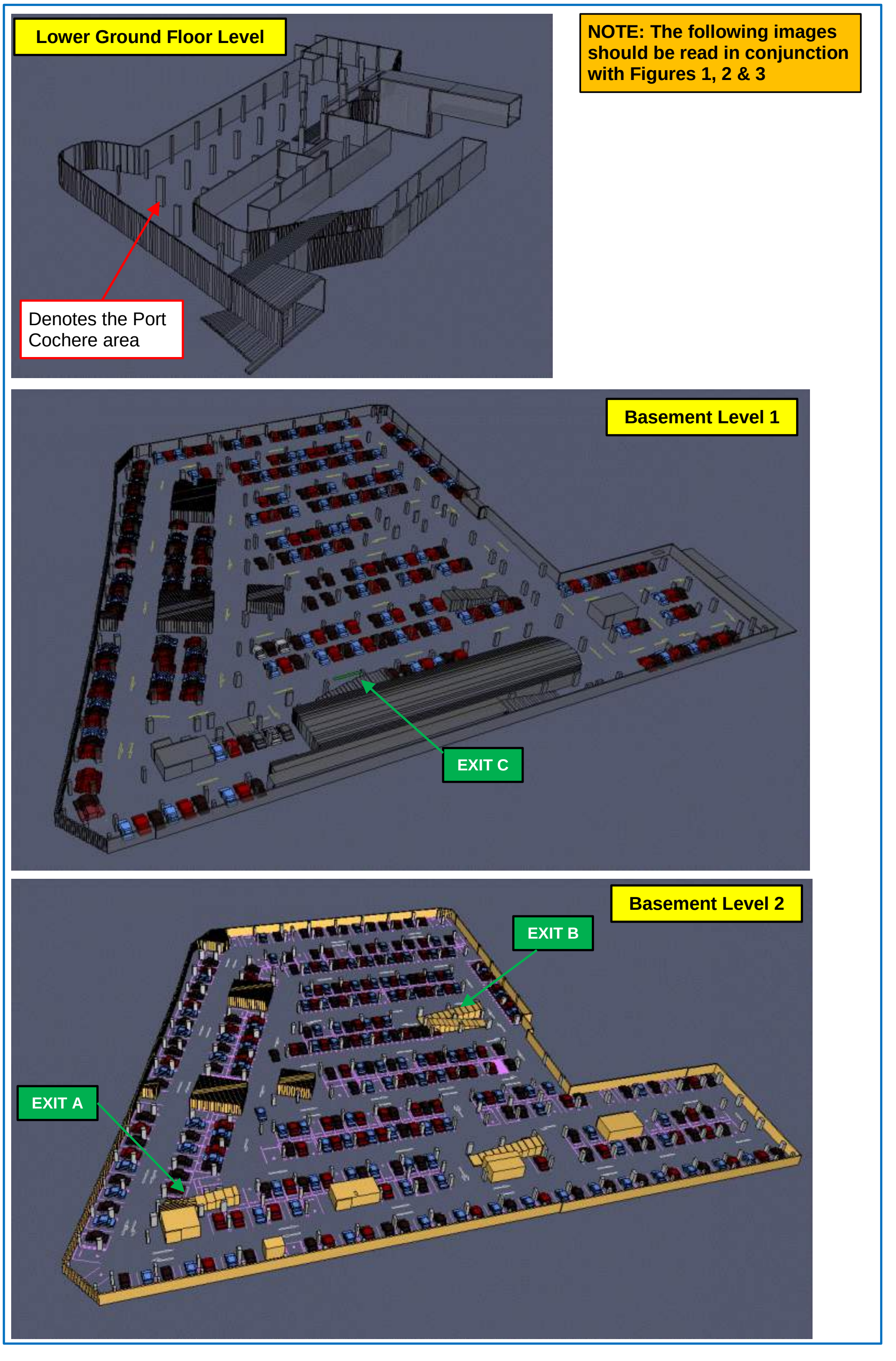


Figure 7: FDS Model (floor by floor) of the carpark including entry points to carpark

5.2.5 Boundary Conditions and Assumptions

Outdoor air is drawn from the external openings and supply air ducts. The outdoor air enters with a fixed temperature of 20°C.

A modified Petrov-Galerkin advection scheme has been used as the numerical transportation mechanism through the solution domain. The Petrov-Galerkin scheme provides a stable advection solution suitable for scalar-type transport equations.

5.3 Acceptance Criteria

Appendix J5 of AS 1668.2 provides guidance on CO Criteria and states;

> *"The formula aims for a 1 h average of 60 ppm (51 ppm rise) on the basis that it is intended—*
> *(a) to ensure that peak concentrations for short periods do not exceed 100 ppm rise;*
> *(b) if CO monitoring devices are set to reduce ventilation when CO concentration drops below 40 ppm to ensure that the 8 h average does not exceed 50 ppm;*
> *(c) to ensure that the eight-hour average does not exceed 50 ppm; and*
> *(d) to limit percentage blood COHb to 5% for car park users."*

Appendix N of AS 1668.2 provides guidance on 'Performance Application to car park ventilation' with Section N4 providing guidance on other arrangements and states;

> *"Any other arrangement may be used, provided it is demonstrated to limit the CO concentration, between 750 mm and 1800 mm above the floor, generally to—*
> *(a) 60 ppm 1 h maximum average;*
> *(b) 100 ppm peak value; and*
> *(c) 30 ppm (TWA) 8 h."*

The methodology is to demonstrate a steady state 'hourly average' condition based on the active main exhaust fans and proposed jet fans locations for the design CO loading. The steady state conditions demonstrate that the polluted air is effectively diluted in all parts of the carpark and contaminant levels are maintained lower than the defined exposure limits. For modelling validation purposes it must be demonstrated that the design meets the CO criteria of 60 ppm (51 ppm rise) per hour at a height of 1.8 m above finished floor level which is the maximum allowable concentration.

5.4 Results Interpretation

The modelling methodology is based on a time independent, steady state flow. Therefore the model will not record the response of the system and hence the dilution of CO by the action of the fans. This is considered to be a conservative approach as changes in the fan speed would be expected to introduce additional dilution of the CO contaminant.

The results demonstrate the average condition in the car park with the ventilation system fully engaged, and will discuss results in terms of the 60 ppm and 100 ppm peak values as noted in Section 5.3. The analysis determines the general airflow profile to demonstrate that there are no significant stagnation regions, and identify any areas of limited airflow and potential improvement.

6 Results of CO Modelling

6.1 Steady State CO Profiles for Basement Level 1

The CO results of the FDS model at Basement Level 1 has been illustrated in Figure 8 to Figure 10. The results shows that the CO rate does not reach 100 ppm anywhere in the basement. The steady state condition demonstrates that the polluted air is effectively diluted in all parts of the basement and carbon monoxide levels are maintained lower than those in the defined exposure limits outlined in AS 1668.2.

The red spots in the slice files illustrates the most critical points. The black spots in the slice files illustrates the points with a CO rate over 60 ppm. While the average CO concentration for the Basement 1 is 10.0 ppm at 1.8 m above floor level, some zones have slightly higher average CO emissions. The scale to the right shows the CO rate, where 0.00 means 0 ppm and 1.00 means 100 ppm.

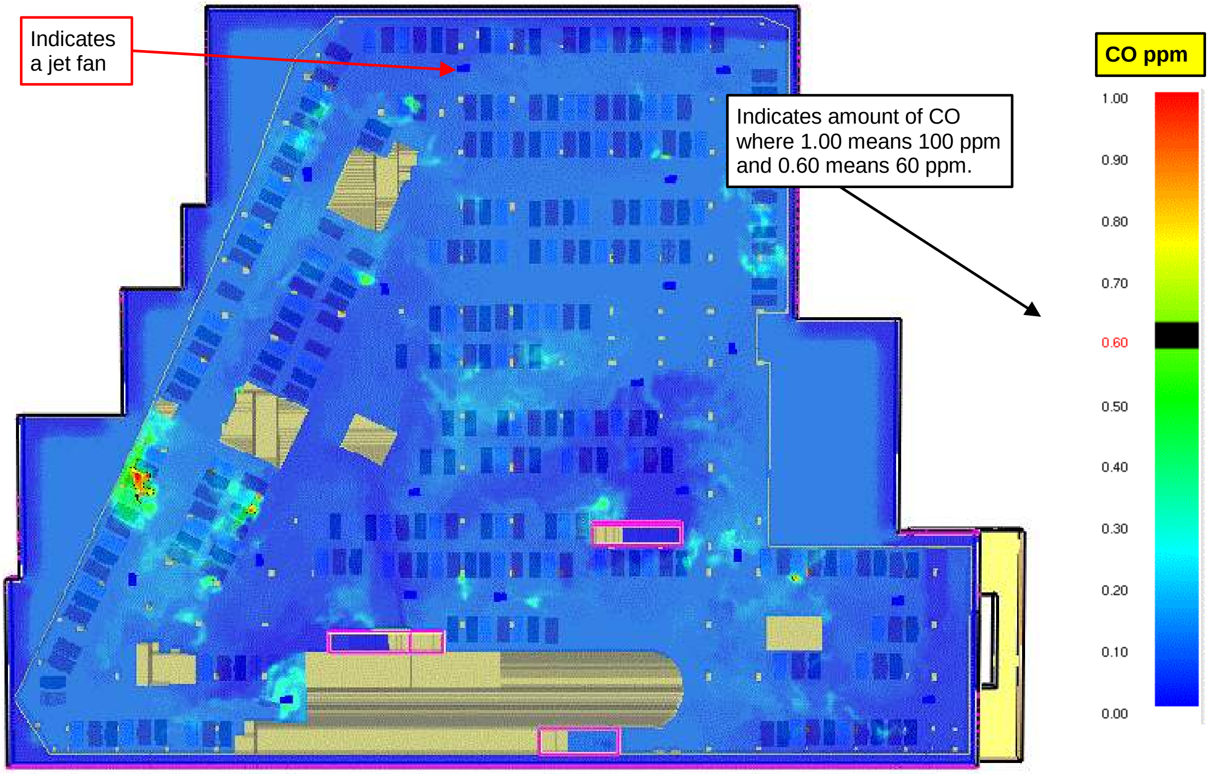


Figure 8: Plan view Basement 1 - CO Contour at 1.8 m above floor level, at 100 Seconds

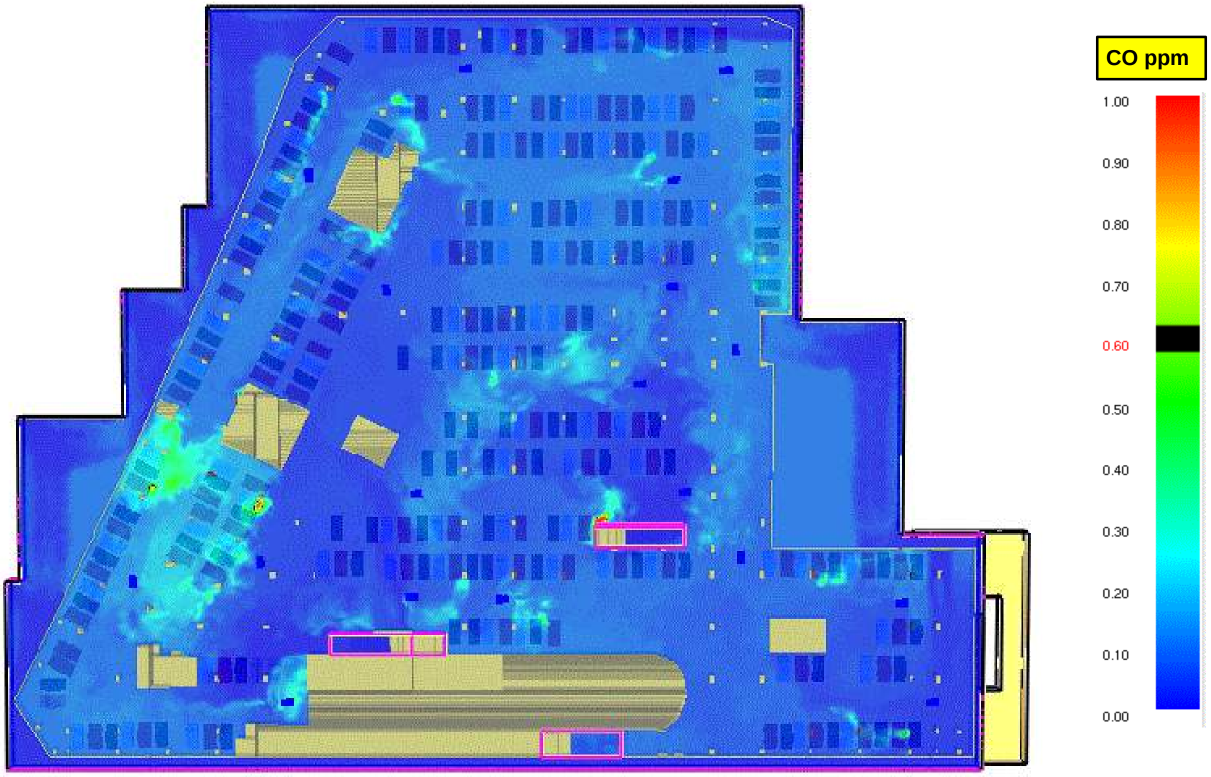


Figure 9: Plan view Basement 1 – CO Contour at 1.8 m above floor level, at 200 Seconds

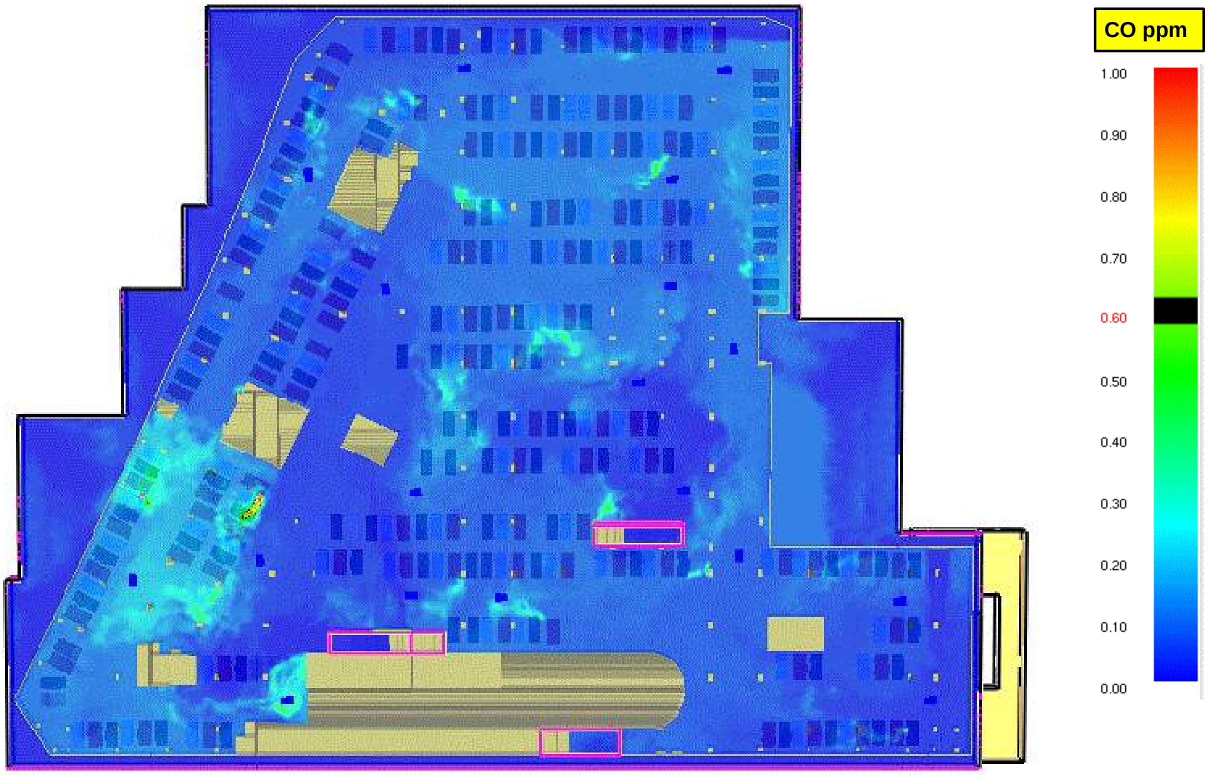


Figure 10: Plan view Basement 1 - CO Contour at 1.8 m above floor level, at 300 Seconds

6.2 Steady State Velocity Profiles for Basement Level 1

The air velocity results of the FDS model for Basement Level 1 has been illustrated in Figure 11 to Figure 13. The figures show that there are no significant change in velocity in specific areas after 100 seconds. The results display the air velocity at 100 second intervals which show that air flow by way of the jet fans achieves the dilution of contaminants in the enclosure and maintains contaminant concentration below the recommended exposure standards. Air flow has been demonstrated across the carpark domain.

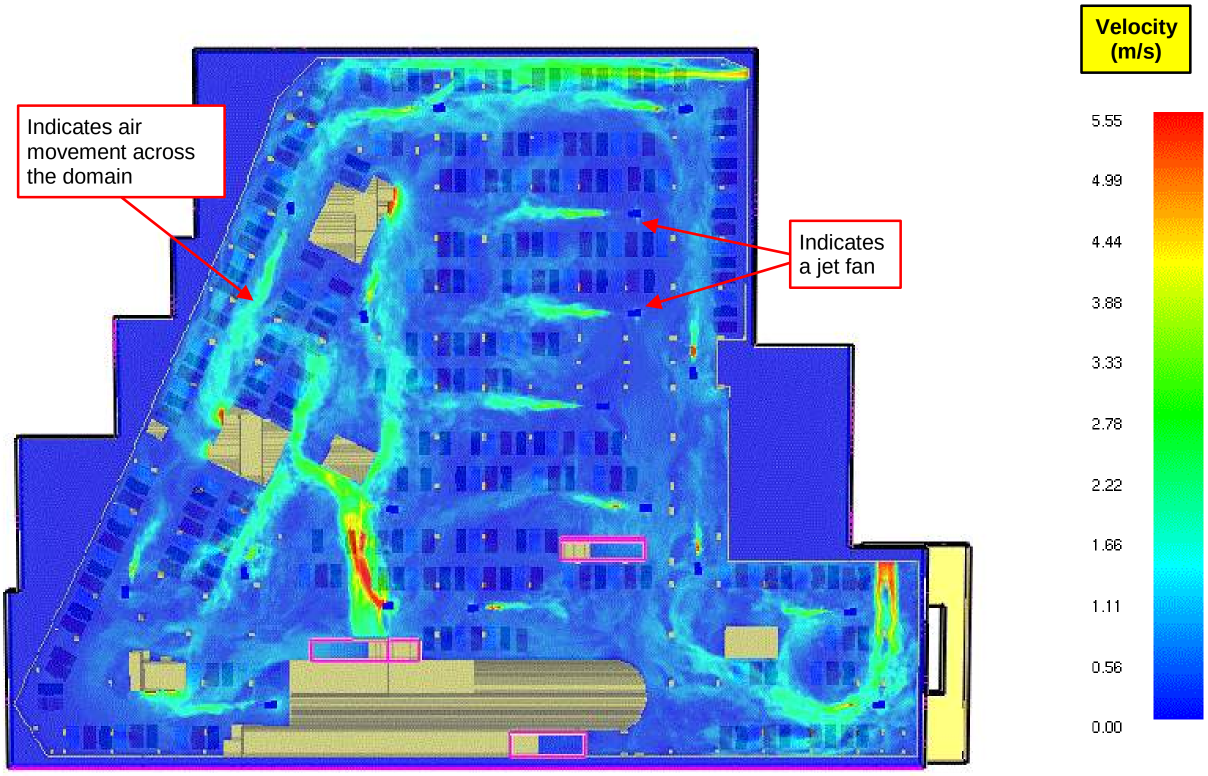


Figure 11: Plan view Basement 1 - Velocity Contour at 1.8 m above floor level, at 100 Seconds

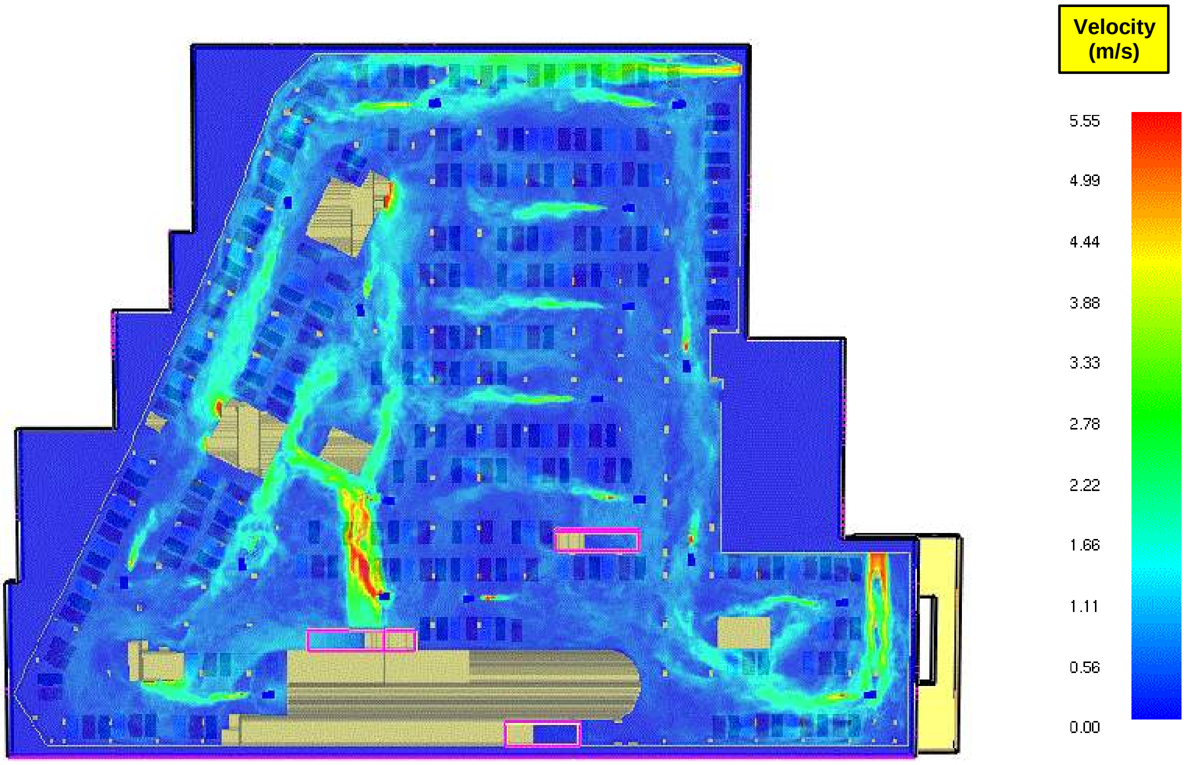


Figure 12: Plan view Basement 1 - Velocity Contour at 1.8 m above floor level, at 200 Seconds

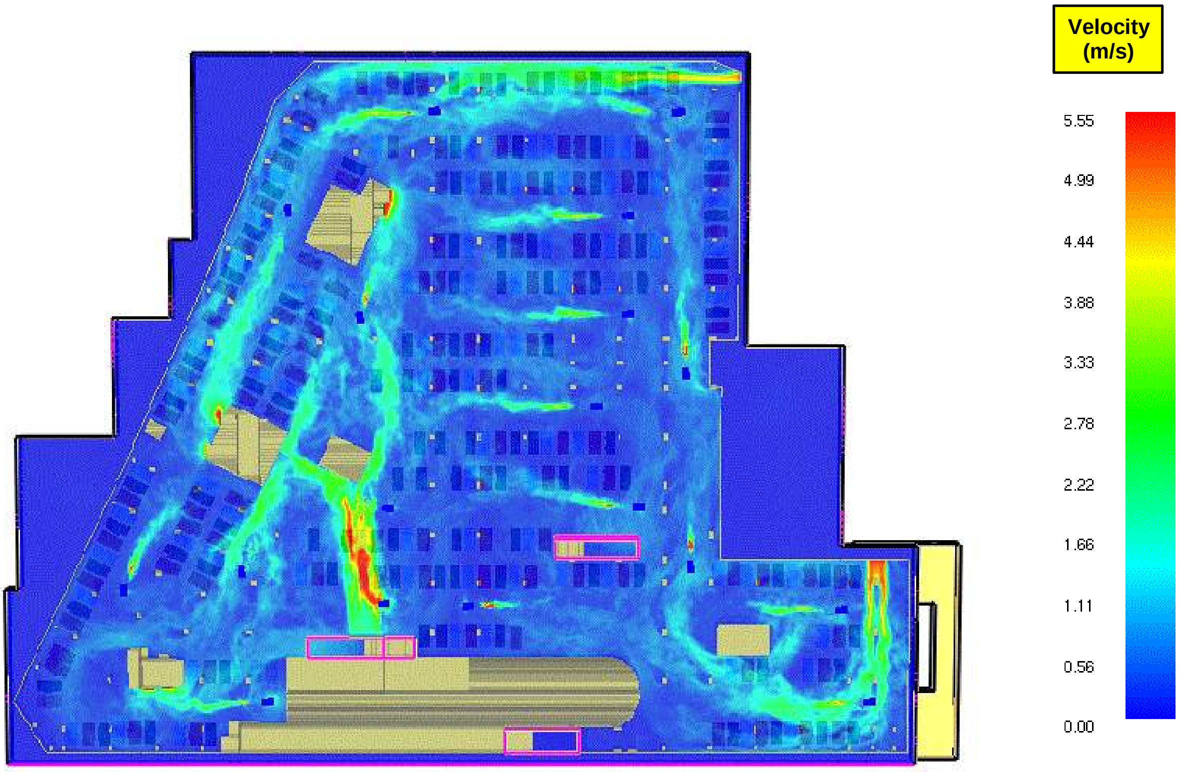


Figure 13: Plan view Basement 1 - Velocity Contour at 1.8m above floor level, at 300 Seconds

6.3 Steady State CO Profiles for Basement Level 2

The CO results of the FDS model for Basement Level 2 has been illustrated in Figure 14 to Figure 16. The figures shows that the CO rate does not reach 100 ppm anywhere in the basement. The steady state condition demonstrates that the polluted air is effectively diluted in all parts of the basement and carbon monoxide levels are maintained lower than those in the defined exposure limits outlined in AS 1668.2.

The red spots in the slice files illustrates the most critical points. The black spots in the slice files illustrates the points with a CO rate over 60 ppm. While the average CO concentration for the Basement 2 is 10.0 ppm at 1.8 m above floor level, some zones have slightly higher average CO emissions. The scale to the right shows the CO rate, where 0.00 means 0 ppm and 1.00 means 100 ppm.

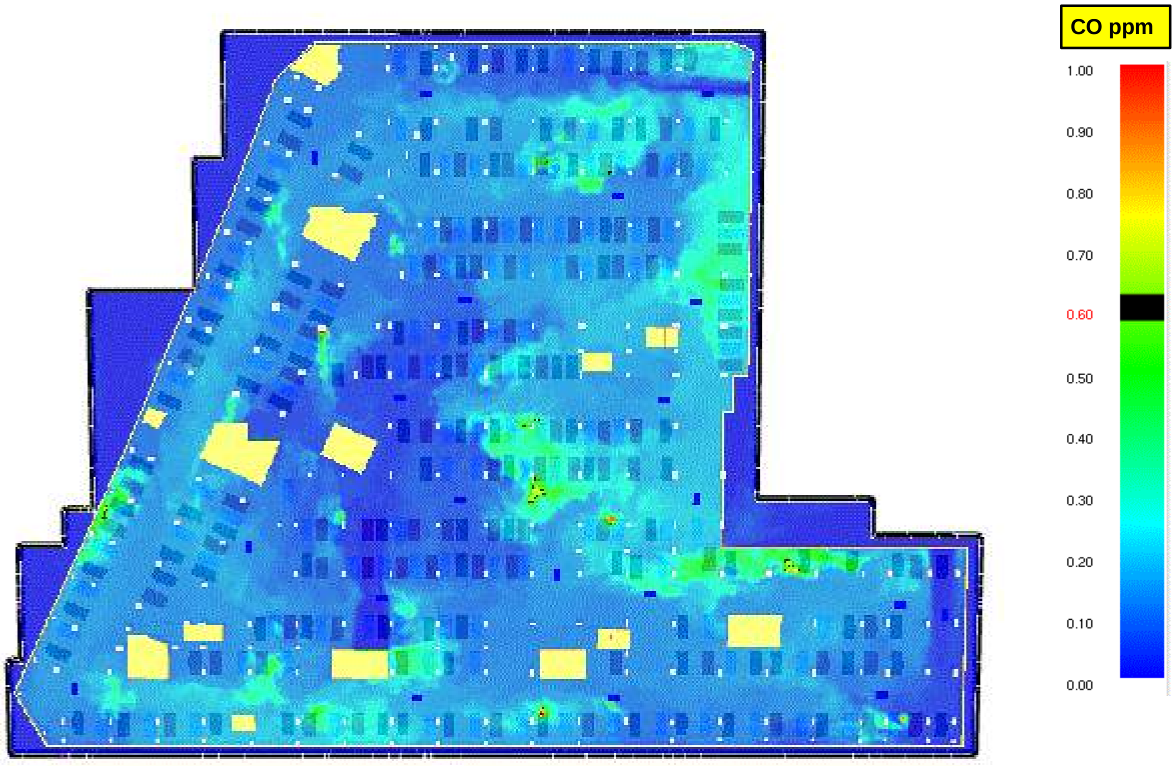


Figure 14: Plan view Basement 2 - CO Contour at 1.8 m above floor level, at 100 Seconds

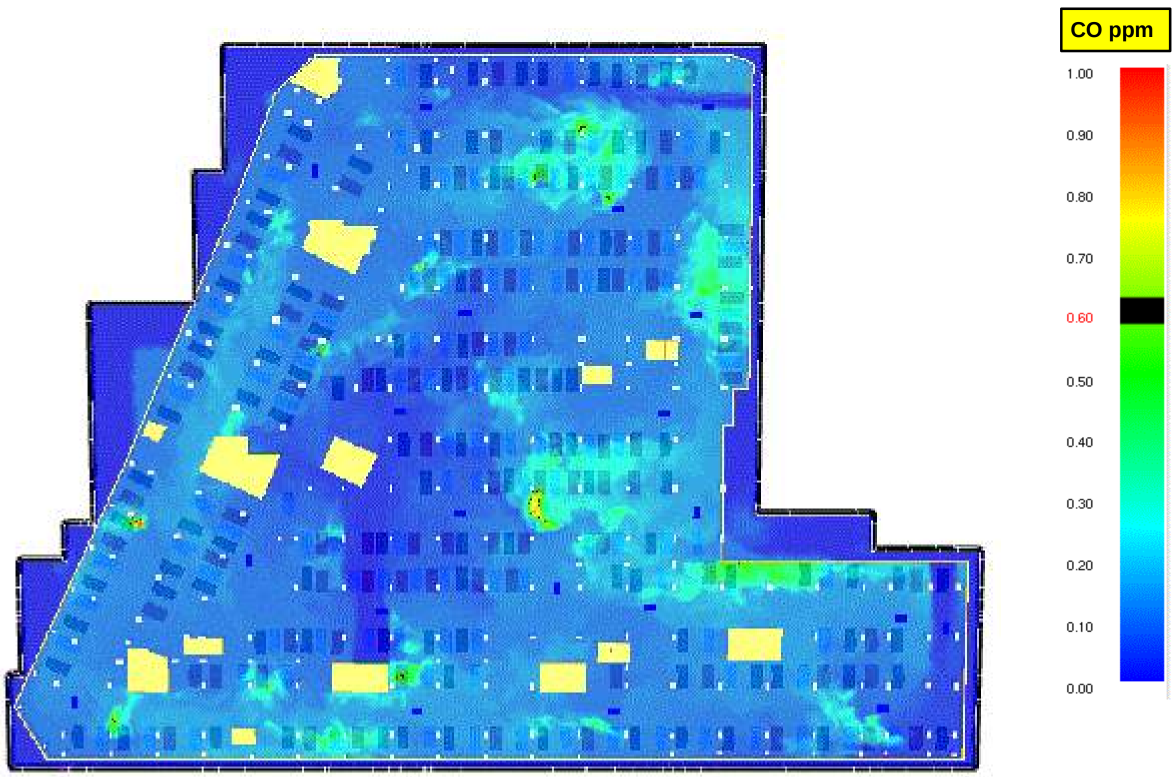


Figure 15: Plan view Basement 2 - CO Contour at 1.8 m above floor level, at 200 Seconds

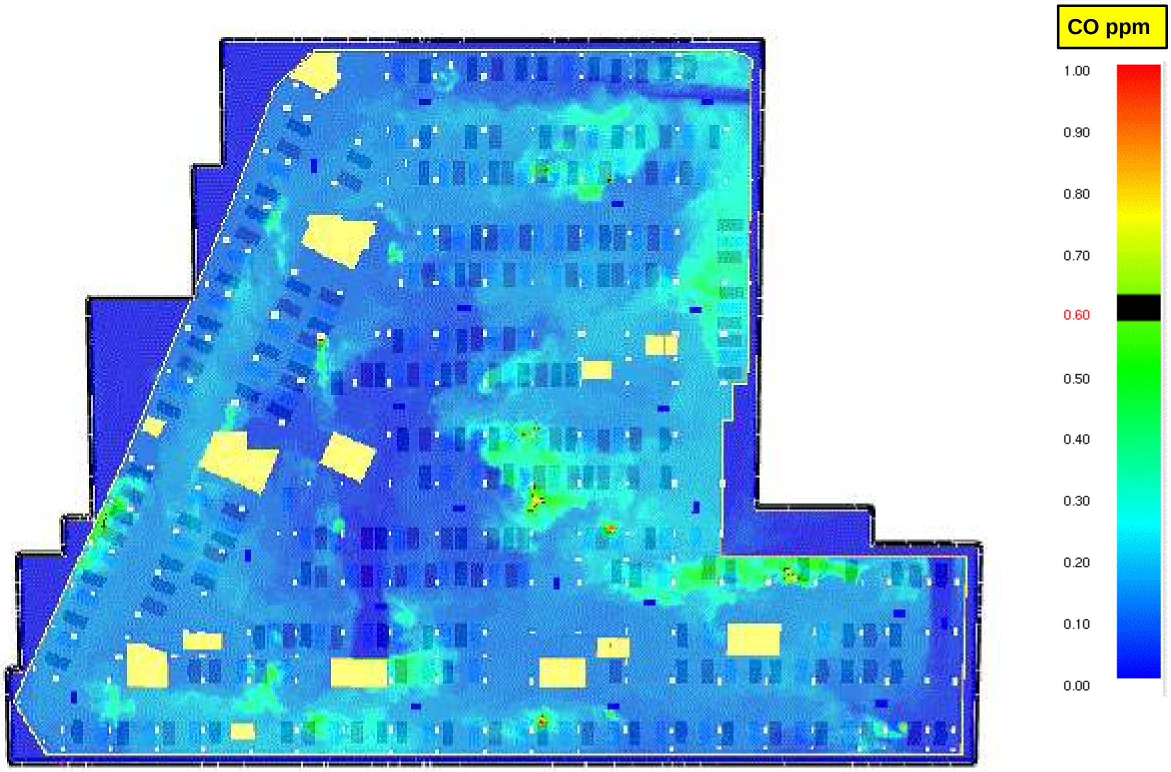


Figure 16: Plan view Basement 2 - CO Contour at 1.8 m above floor level, at 300 Seconds

6.4 Steady State Velocity Profiles for Basement 2

The air velocity results of the FDS model for Basement Level 2 has been illustrated in Figure 17 to Figure 19. The figures show that there are no significant change in velocity in specific areas after 100 seconds. The results display the air velocity at 100 second intervals which show that air flow by way of the jet fans achieves the dilution of contaminants in the enclosure and maintains contaminant concentration below the recommended exposure standards. Air flow has been demonstrated across the carpark domain.

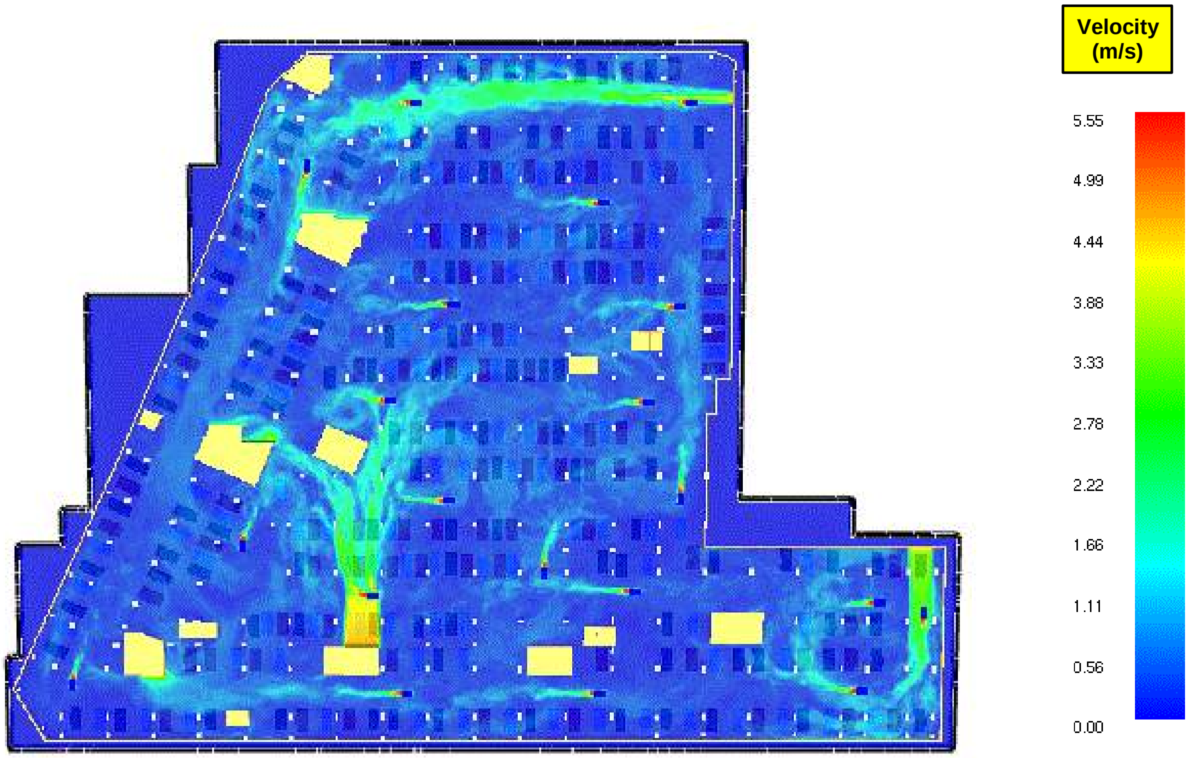


Figure 17: Plan view Basement 2 - Velocity Contour at 1.8 m above floor level, at 100 Seconds

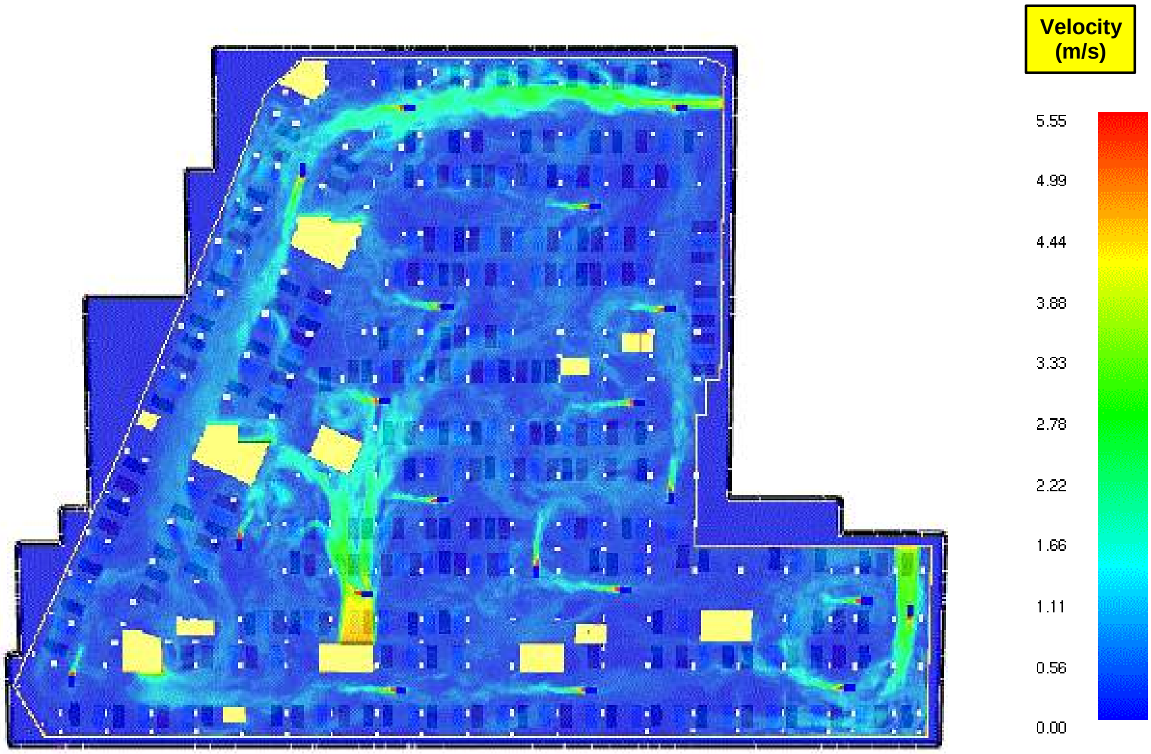


Figure 18: Plan view Basement 2 – Velocity Contour at 1.8 m above floor level, at 200 Seconds

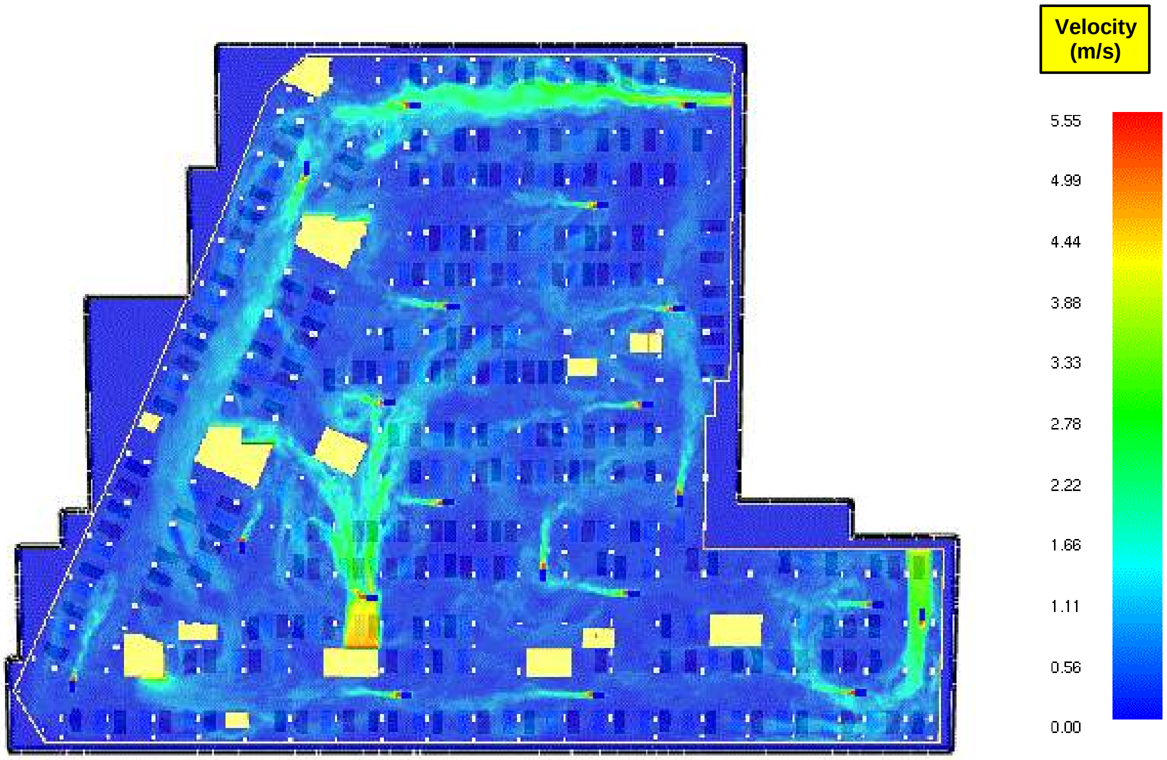


Figure 19: Plan view Basement 2 - Velocity Contour at 1.8 m above floor level, at 300 Seconds

6.5 CO Modelling Summary

The CO concentrations determined are compared with the acceptable limits of 60 ppm average and 100 ppm peak level. The average CO concentrations for each basement level is shown in the Table 9.

Table 9: Average CO concentrations - Initial Assessments

Parking Usage Factor	Floor Level	Height (mm)	Average CO concentration (ppm)	Meets Standard
100 % Parking Usage Factor, Afternoon Peak Exiting Vehicles	Basement Level 2	1800	10.0	**Pass**
	Basement Level 1	1800	10.0	**Pass**

7 Conclusions of CO Modelling

7.1 Summary

- The proposed car park ventilation system maintains and achieves CO concentration levels within the allowance called for in AS 1668.2 as summarised in Table 9.
- While the average CO concentration for the both Basement Levels are much lower than 60 ppm, some zones have slightly higher average CO emissions. However these zones still fall well within the allowable 60 ppm time-weighted average limit.
- The only areas in the car park with concentrations higher than allowable 60 ppm are in the immediate vicinity of the car exhausts. Beyond this emission region, the CO levels rapidly decrease.
- Based on the design parameters and assumptions outlined in this report, the proposed design solution meets the criteria put forward in AS 1668.2, specifically in ensuring that *'the concentrations of atmospheric contaminants within the enclosure do not exceed occupational or community exposure limits'.*

7.1.1 Recommendations;

The jet fans must be installed as per the manufacturer's recommendations with careful consideration of the following;

- Ceiling features (i.e. ceiling beams)
- Vertical clearance (so as to ensure maximum flexibility in the design)
- Obstructions and clashes with other services (i.e. sprinkler piping / signage etc)

8 References

[BCA] ABCB 2014, *National Construction Code Series, Volume 1, Building Code of Australia 2014, Class 2 to Class 9 Buildings, Australian Building Codes Board, Canberra.*

[AS/NZS 1668.1] *AS 1668.1 – 2012. The use of ventilation and air-conditioning in buildings; Fire and smoke control in multi-compartment buildings, Standard Australia Limited, Sydney.*

[AS 1668.2] *AS 1668.2 – 2012. The use of ventilation and air-conditioning in buildings; Mechanical Ventilation in buildings, Standard Australia Limited, Sydney.*

[FRNSW] *Fire Safety Guideline: Guideline for impulse fans in car parks - Version 01 Issued 09th October 2014 by Fire & Rescue NSW.*

Appendix A Impulse Fan JIU-CPCEC-LH/SD Unit (Spec)

Digital EC

JIU-CPCEC Series JetVent Fans

The JIU-CPCEC series of JetVent fans represents a new step forward in car park ventilation systems. These energy efficient fans feature advanced digital EC motor technology with integrated speed control, doing away with VSDs, current overloads and motor phase protection. It even simplifies electrical connections between fans in the car park.

However, the truly revolutionary feature of this system is ComLink, the digital communication between JetVent fans, sensors and the pre-configured Digital EcoVent Zone Controller. The result is a very simple control wiring scheme that is easy to install and easy to commission while providing the ultimate in energy efficiency and system monitoring. The JetVent Digital EC system will vary the operating speed of the impulse fan units and therefore the ventilation rate, according to the CO or NO_x pollutant levels in the car park.

Integrated smoke detection

The Digital EC JetVent fans now come with a factory fitted and fully integrated smoke detection kit that ensures a simplified installation and reliable operation. This innovative feature allows the Fantech EcoVent intelligent car park controller or BMS to monitor for smoke and respond accordingly.

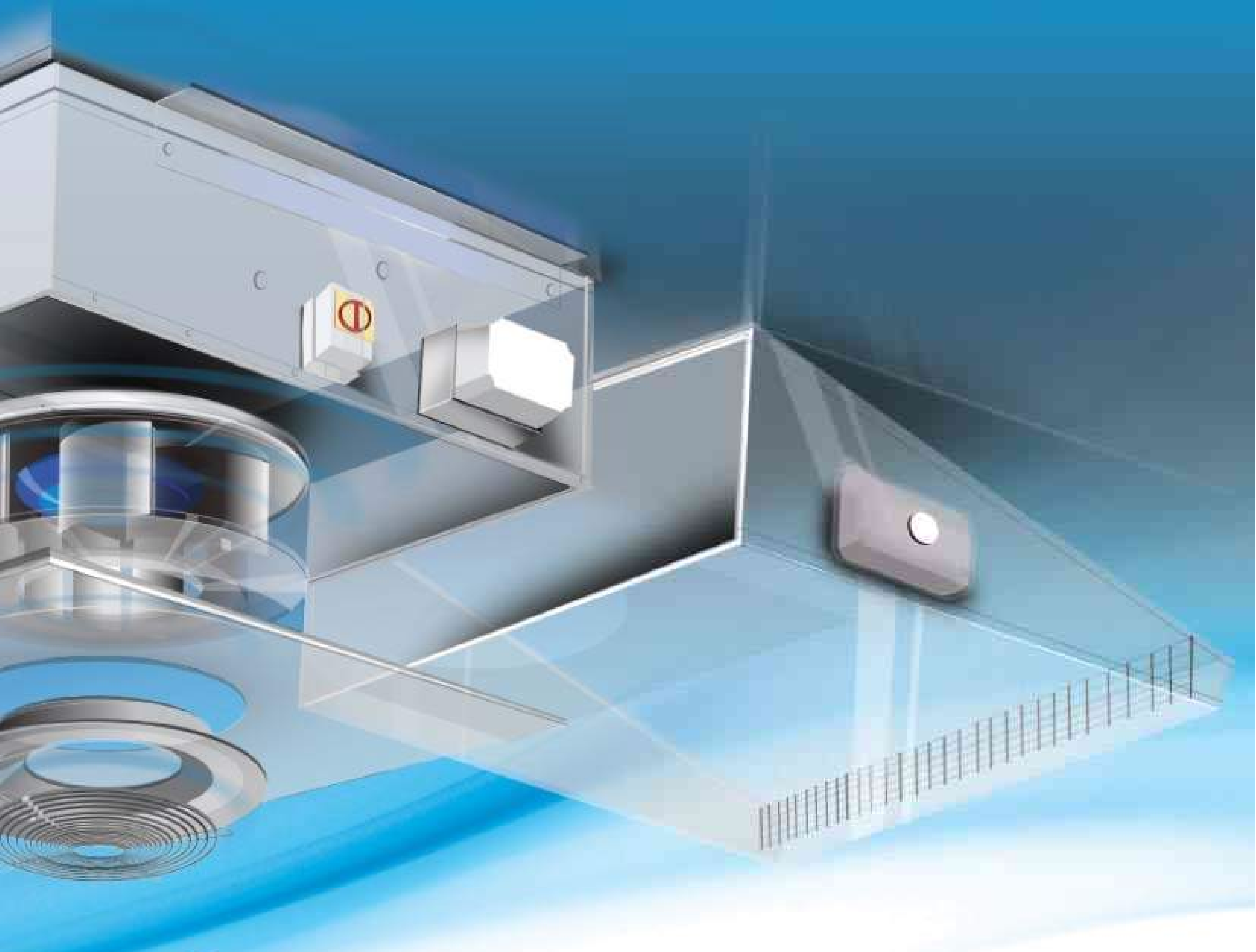
Product Code	Fan Speed		Thrust Rating		Car park Installed Noise Levels		Free-field Noise Rating		Power Consumption		Current	
	rpm		N		dB(A) @ 8m#		dB(A) @ 3m#		kW		A	
	High speed	Pre-set speed*	High speed	Pre-set speed*	High speed	Pre-set speed*	High speed	Pre-set speed*	High speed	Pre-set speed*	High speed	Pre-set speed*
JIU-CPCEC-HP	1230	858	91.8	48.2	75.2	65.0	65.8	56.5	2.9	1.0~	4.2	1.6
JIU-CPCEC-SD	1770	1296	52.2	28.4	72.4	65.0	64.4	56.7	1.7	0.7~	2.5	1.1
JIU-CPCEC-LH	1770	1120	46.8	18.9	76.4	65.0	68.7	56.7	1.7	0.4~	2.6	0.8

Car park installed noise levels apply 8m/3m away from the fan with multiple fans operating. Contact your nearest Fantech office to confirm if this is applicable to your installation.

~ Estimated power consumption.

* Pre-set speed so fan does not operate above the AS2107:2000 recommended noise level of 65dB(A) @ 8m.

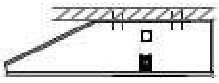
Table 4. JetVent JIU-CPCEC series technical data



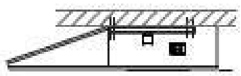
How to Order

Step 1

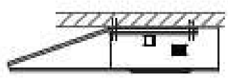
Select the digital EC JetVent fan model



JIU-CPCEC-HP



JIU-CPCEC-SD

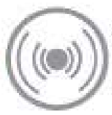


JIU-CPCEC-LH

Step 2

Select Isolator or Smoke Detection Kit

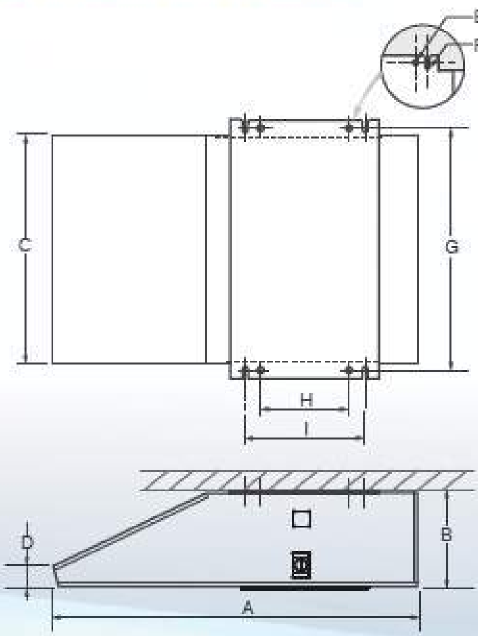
Isolator Kit
(Code: JIU-ISOLATORKIT)



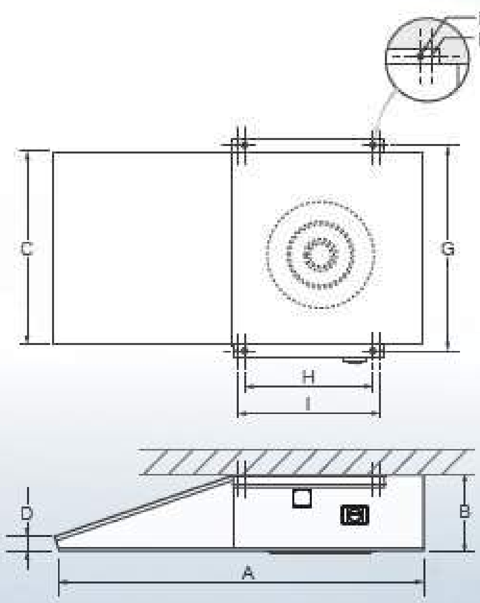
Smoke Detector Kit
(Code: JIU-SMOKEKIT)

Digital EC
JIU-CPCEC Series JetVent Fans

Dimensional Drawings



JIU-CPCEC-HP



JIU-CPCEC-LH/SD

Product Code	A	Vertical Height B	C	D	E	F	G	H	I	Approx. Weight kg
JIU-CPCEC-HP	1833	492	1151	110	30	16	1240	450	600	160
JIU-CPCEC-SD	1745	370	906	68	25	13	973	605	675	89
JIU-CPCEC-LH	1745	322	906	68	25	13	973	605	675	89

Dimensions in mm

Note:
- Lower noise levels achievable with further speed reduction.
- Electrical supply - 415V, three-phase, 50Hz.

Appendix B Impulse Fan Layout (provided by Fantech)

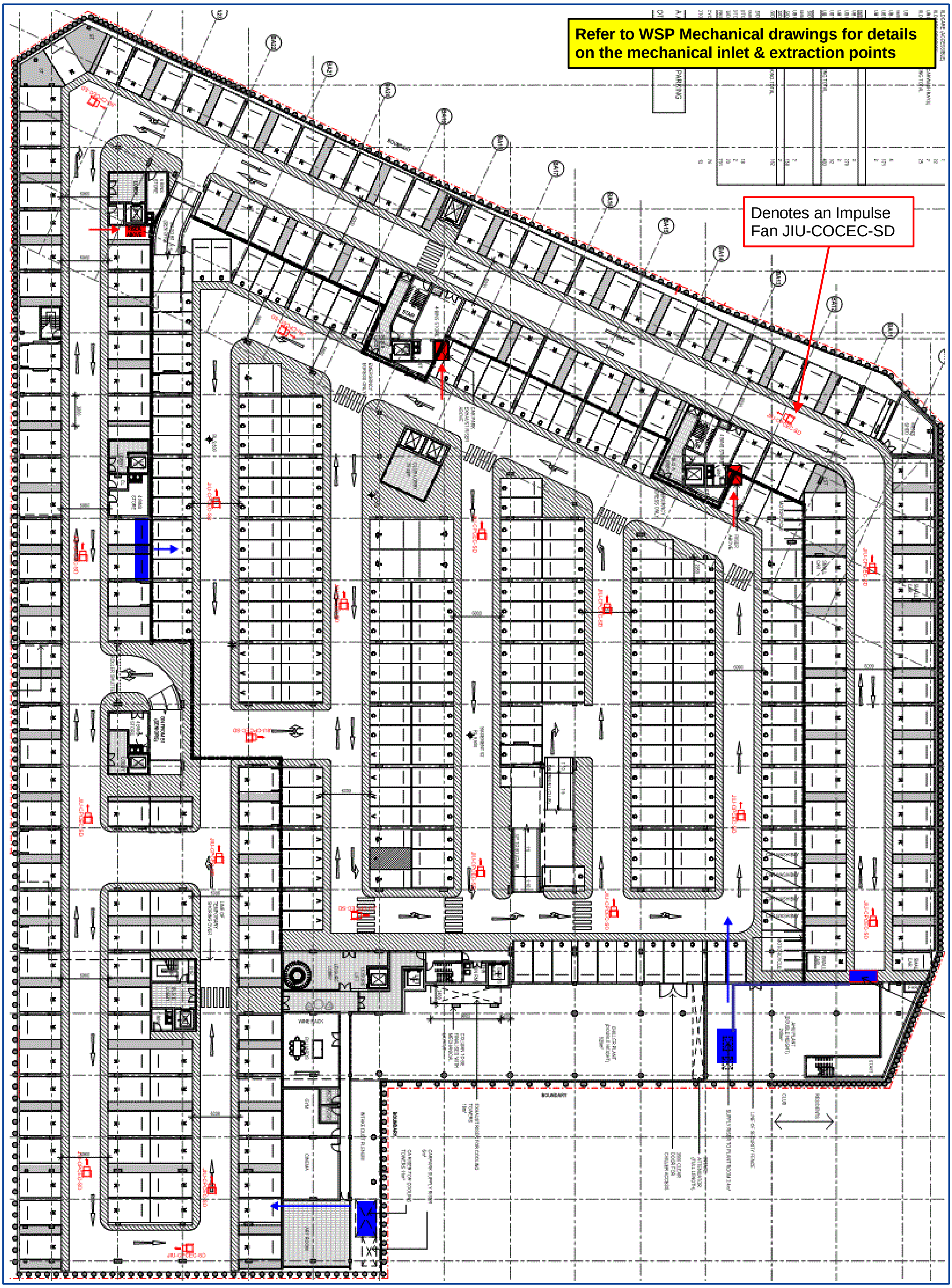


Figure 20: Basement Level 2 – Impulse fan layout as provided by Fantech

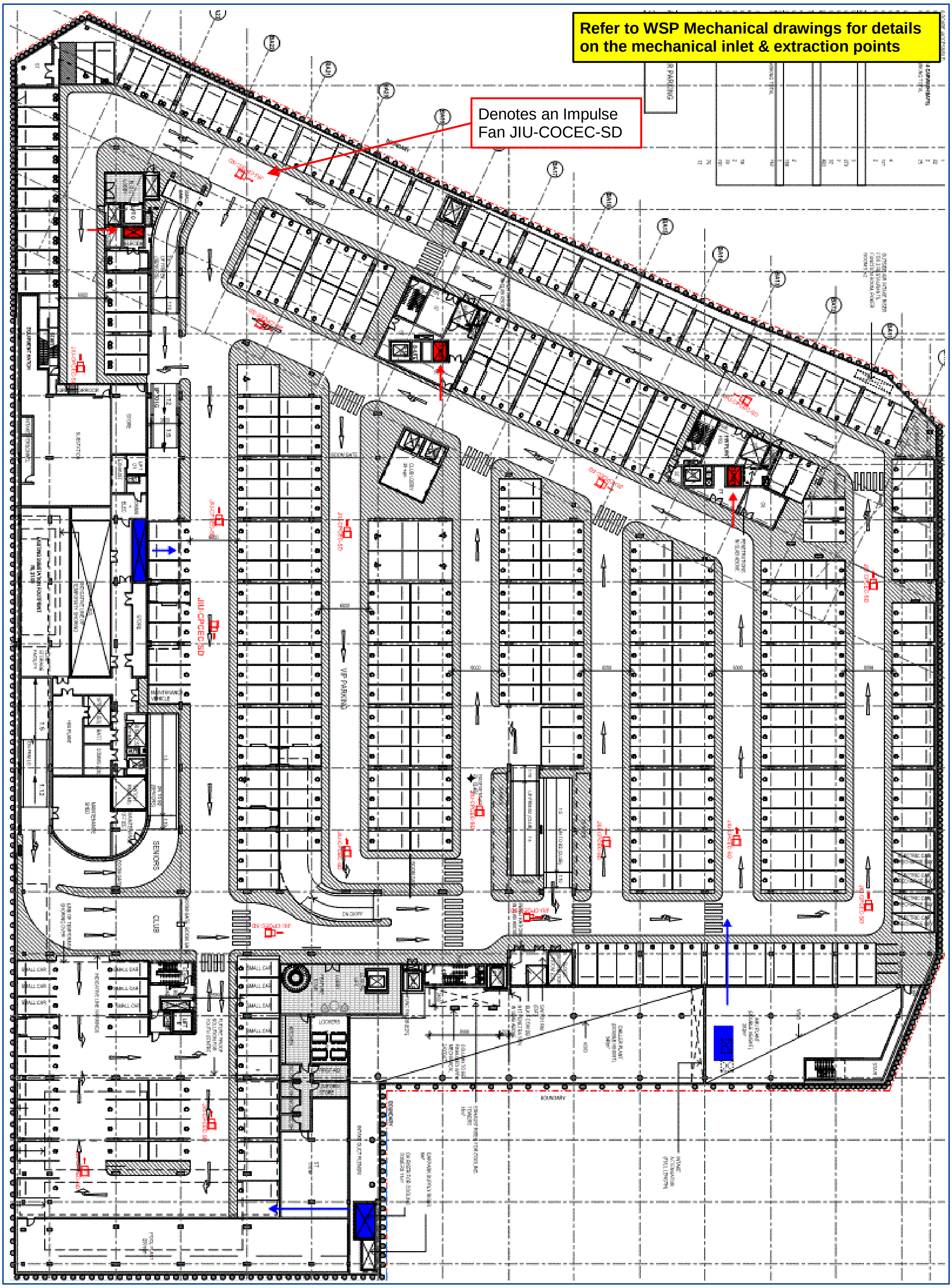


Figure 21: Basement Level 1 – Impulse fan layout as provided by Fantech

Appendix J Third Party Peer Review by Olsson Fire & Risk (OFR)

J.1 Introduction

It is noted Olsson Fire & Risk has undertook the following Third Party Fire Engineering Peer Review report (based on the FER Rev 0 for the project prepared by WSP | PB) as summarised below;

- OFR Fire Engineering Peer Review Report S16007 Revision PR1.0 issued on the 29/02/2016.

Table 1 provides a breakdown of WSP | Parsons Brinckerhoff 's response & commentary to the items raised in the above OFR report which was issued to OFR on the 23/05/2016. It also details OFR's final comments to the feedback provided which was issued formerly on an email via Aconex on the 27/06/2016.

- OFR Fire Engineering Peer Review Report S16007 Revision PR1.0 issued on the 10/04/2017.

Table 2 provides a breakdown of FRNSW IFSR Comments along with response & commentary from OFR. The final column is response and commentary from WSP | PB on how the comments from OFR have been addressed within the Fire Engineering Report.

Table 1: Peer Review Comments by OFR (on FER Rev 0) & WSP | Parsons brinckerhoff Actions undertaken

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
1	General	The framework of the report is in line with that suggested by the International Fire Engineering Guidelines (IFEG) which provide guidance on the structure of a Fire Engineering Report. The report includes the relevant content suggested by the IFEG to adequately document a performance-based fire engineering assessment. The general presentation of the report and the level of detail provided in the analysis is considered appropriate and sufficient to enable the reader to understand the subject issue and the method of resolution in most instances. It was observed that the acceptance criteria commonly applied to the Alternative Building Solution makes reference to 'intent' of the Building Code of Australia or Australian Standard as the case requires. Intent of both the Building Code of Australia and Australian Standards is a subject descriptor and it is recommended that the acceptance criteria be modified to ensure that it is absolute.	Noted. It is noted that only Alternative Solutions AS 9, AS 10 & AS 11 (under the acceptance criteria heading contained within) makes reference to the 'intent' of the BCA. The acceptance criteria of AS 9 to AS 11 can be modified in an updated FER report to ensure that terminology is 'absolute' and that the text associated with the intent of the BCA has been omitted.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
2	Page 2 – Quality Management	The details of accreditation of the Fire Safety Engineer should be included in the final version of the Fire Engineering Report.	Noted and agreed. This shall be captured in an updated FER report.	Noted. Please undertake agreed changes.
3	Page 4-6 – Table 1	The travel distances detailed in the Fire Engineering Report do not align with the detail contained in the Building Code of Australia Report prepared by SWP (dated 07/07/2015) for the distance between alternative exits. The Building Code of Australia Consultant should confirm travel distances prior to finalisation of the Fire Engineering Report.	Noted – It is acknowledged that the BCA report for the development does not reflect the detail contained within the FER. The travel distances specified in the FER have been based on guidance & direction provided by Steve Watson & Partners.	Noted. We would recommended that any assumptions relied upon outside the BCA report be included in the report appendices.
4	Page 10 – Table 3	The Principal Certifying Authority detailed in the Stakeholder table should be confirmed.	Noted and agreed. This shall be captured in an updated FER report.	Noted. Please undertake agreed changes.
5	Page 22 – section 5.4	The first and second paragraphs are contradictory in relation to the extent of sprinkler coverage. The first paragraph confirms that only part of the building is sprinkler protected, whilst the second states that sprinklers are throughout the building. The latter is assumed to be incorrect and it is recommended for clarity that the text be suitably adjusted.	Noted and agreed. This section of the FER shall be reviewed to make it clearer to the reader. The first paragraph is correct with the building being sprinkler protected in part only.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
6	Page 23-24 – section 6	The terms fire control centre and fire control room are used interchangeably. Recognising that a fire control room is not required in the building it is recommended that Section 6 exclusively use one defined term or the other so as to avoid confusion for the reader and future readers of the report.	Noted. Under the prescriptive requirements of the BCA, the proposed building is only required to be provided with a Fire Control Centre in accordance with Clause 2 of Specification E1.8. The terminology used in the report is in line with the architectural labelling of the room as introduced in Section 5.2 of the FER. Please note that Section 1.7.1 of the FER states that the figures used in the report should be read in conjunction with the architectural drawings detailed in Table 4. The Fire Control Room is discussed in Section 6 (notably Page 24 under Section 6.1) with regards to the provision of a red strobe light to identify the location of the Fire Control Centre (Fire Inspection Panel) for the attending brigade. Clarity can be added to Section 6 in an updated FER with regards to the required provision of a Fire Control Centre in accordance with Clause 2 of Specirfication E1.8.	Noted. Please undertake agreed changes.
7	Page 26 (WSP | PB note: Page 23) – Section 6.1	It is recommended, to avoid confusion, that the requirements for portable fire extinguishers in the areas where fire hose reels have been removed are clarified. The BCA DtS provisions for portable fire extinguishers are significantly less than what AS 2444 would require, therefore there is likely to be confusion as to which requirement takes precedent.	Noted and agreed. Definitive clarity shall be given in an updated FER (notably Alternative Solutuon AS 11) with regards to the provision of fire extinguishers.	Noted. Please undertake agreed changes.
8	Page 24 – Section 6.2	It is recommended that the minimum level of performance required of the in duct smoke detectors for the car parks impulse fans be detailed in the fire engineering requirements.	The performance specified in the FER is in line with the guidance required by the FRNSW Guideline: Guideline for impulse fans in car parks (V01 issued on the 09/10/2014).	Noted. It is recommended that the design team (i.e. fire services contractor) to ensure that design requirements are specific enough.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
9	Page 24 (WSP | PB note: Page 25) – section 6.3	The requirements for support of another part are recommended to be included in the first bullet point to avoid confusion with regard to the fire ratings that may need to be applied to basement carpark columns and beams.	The performance specified in the FER is in line with the guidance required by the FRNSW Guideline: Guideline for impulse fans in car parks (V01 issued on the 09/10/2014).	Noted. Just to clarify, the current reading of the wording would suggest that the columns and beams of the entire carpark are to be 120/--/-- and the concessions of Table 3.9 of Spec C1.1 are not to be applied. This should be confirmed with the design team.
10	Page 27 – section 6.4	It is noted that the warning signage is nominated at 50 mm. Whilst it is not the purpose of the peer review to nominate design requirements it is suggested that the sizing of the text be confirmed with the project stakeholders to assess it compatibility with the design aspiration for the lobby.	Please note that as part of the design process, WSP | Parsons Brinckerhoff has interacted with the design team and put the design forward for their review, comments & consideration. The sizing of the text needs to be legible to outline the required fire safety measure of the leisure lobby.	Noted.
11	Page 29 – section 6.6	AS 3 relies on administration controls by a third party to notify building owners of the development of the adjoining site. This is at odds with the description in table 1 which refers to a registered easement or the like that can be applied into perpetuity. Refer to AS 3 for additional comments.	This level of detail has been agreed with Steve Watson & Partners as well as the client. The text utilised in both AS 3 and Section 6.6 of the FER has been based on guidance received from Fire & Rescue NSW on similiar issues. It is noted that the Harbord Diggers site is unique in so far that the redevelopment works have undergone a strict DA process which had limitations posed on the client with regards to the development of the headland area in Freshwater. The area in question being developed is currently under the contol of the Mounties Group. The adjolining areas form part of McKillop Park, which is noted to be a Public Reserve that cannot be built upon, as advised by the client.	Noted. It is suggested that the description in Table 1 be updated to reflect the design approach (i.e. there will not be a registered easement).

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
12	Page 30-33 – AS 1	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being CP2. The approach and assessment method nominated applies a comparative approach whilst nominating A0.5(b)(i) (refer to Table 1 and Table 9). The assessment utilises international practice, namely the Euocode methodology to demonstrate that the separation afforded in the subject design is equivalent to that of a Deemed-to-Satisfy case. This is considered an appropriate methodology. We would however recommend, given the nature of the assessment applied, that A0.5(b)(ii) may be more appropriate. The acceptance criteria selected for the Alternative Building Solution contains two parts. The first states that the criteria is the prevention of fire spread to the same extent as the DTS provisions of the BCA. Given the results demonstrate flame spread of between 1.40 m – 1.53 m in each case the use of the term 'prevents appears counter-intuitive. Whilst we understand the intent of the terminology we would recommend rewording of this element.	Noted and agreed. The assessment methodology shall be amended to be A0.5(b)(ii) which shall be captured in an updated FER. The assessment text shall also be amended to state that the proposed spandrel configuration shall provide a level of resistance to vertical fire spread which is at least equivalent to that of a permissible DtS Design.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
13	Page 35 – AS 2	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being CP2 and CP4. The approach and assessment method nominated applies an absolute approach whilst nominating A0.5(b)(ii) (refer to Table 1 and Table 12) (WSP | PB note: Table 11). The assessment utilises a literature review and international practice (including fire test data), to demonstrate that the separation afforded in the subject design meets the Performance Requirements. Whilst the assessment at the basement Level 1 carpark lobby would be strengthened through the application of quantitative analysis of fire spread, this is considered an appropriate methodology. We would however recommend, given the nature of the assessment applied, that A0.5(b)(i) may be more appropriate.	Noted and agreed, the assessment methodology shall be amended to be A0.5(b)(i) which shall be captured in an updated FER.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
14	Page 41 – AS 3	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being CP2. The approach and assessment method nominated applies an absolute approach. The assessment relies upon the current use of the adjoining land to demonstrate that the separation afforded in the subject design meets the Performance Requirements. This is considered an appropriate methodology. The trial design offered in Section 9.5 differs from the description offered in Table 1 and Table 9 (WSP | PB note: Table 12). The trial design relies upon the consent authority (i.e. Council) via agreement, as opposed to via the imposition of a restrictive covenant on the adjoining land to notify the building owners in the event of development of the adjoining land. Without evidence of such agreement from Council the alternative solution is likely to be difficult to enforce and apply. If an easement or restriction of use cannot be applied on the adjoining allotment it is recommended that proof of the agreement be included in the final Fire Engineering Report.	See WSP | PB commentary to Item 11 above. Please note that Tables 1 & 12 provide a description of the Alternative Solution. Section 9.5 discusses the proposed fire safety measures for Alternative Solution AS 3 which is also reflected in Section 6 of the FER. It is agreed that it would be beneficial to the client and the upkeep of the subject Alternative Solution, that proof of an agreement be obtained with regards to the potential development of the adjoining public reserve (from the council). This could then be included in the Final FER for the development.	Refer to item 11.
15	Page 44 – AS 4	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being DP4 and EP2.2. The approach and assessment method nominated applies a comparative approach whilst stating an absolute approach (refer to Table 14) (WSP | PB note: Table 13). The assessment utilises a comparative approach to demonstrate that the extended travel distances afforded in the subject design are suitably mitigated so as to be equivalent to that of a Deemed-to-Satisfy case. This is considered to be a suitable methodology.	Noted and agreed. The Class 2 corridors shall have the following FRL requirements as detailed in Table 3 of Specification C1.1 and shall be made clear in an updated FER; • FRL of 90/90/90 for loadbearing elements and • FRL of -/60/60 for non-loadbearing elements. It is acknowledged that the SOUs are not sprinkler protected and that temperatures in the compartment could be in excess of 200 °C in a fire situation. Therefore, the updated FER report shall be amended to clearly specify hot smoke	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		We would recommend, given the nature of the assessment applied, that Table 14 be updated to reflect the comparative approach as it may be more appropriate. It was noted that in Section 10.7.1 reference is made to bounding walls achieving an FRL of 90/90/90. It is recommended that it be clarified as to whether the alternative building solution is more onerous than the provisions of Table 3 Specification C1.1 which would permit reduced FRL's to non-load bearing bounding walls. This section also quantifies the use of medium temperature fire seals to offset the additional travel distance. We understand that the sole occupancy units are not sprinkler protected and therefore temperatures in excess of 200°C are likely to be exceeded within the apartment. It is recommended that the analysis consider the benefit associated with the required smoke seals given the likely conditions in the apartment of fire origin.	seals in accordance with AS 1530.7 to areas which are not sprinkler protected (notably the Class 2 areas) and medium smoke seals to areas which are sprinkler protected.	
16	Page 48 (WSP | PB note: Page 52) – AS 5	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision have been correctly identified as being DP4 and EP2.2. The approach and assessment method nominated applies a comparative approach. The assessment relies upon the fast response sprinkler heads to demonstrate that the response time of the detection system is better than that of a Deemed to Satisfy design. Section 11.8 also includes a cross reference to details relating to an ASET/RSET analysis undertaken in the carpark. The assessment also reviews literature relating to international building codes to demonstrate the suitability of the trial design. This is considered an appropriate methodology. Where specific temperatures are required of the sprinklers heads for acceptance of the Alternative Building Solution it is recommended that the temperature rating of those sprinklers be documented in the trial design.	Noted and agreed – the temperature rating of the sprinklers shall be included in an updated FER. It is acknowledged that a cumulative travel distance of up to 190 m could be presented. However, such a travel distance is not a realistic scenario in the subject carpark area. The carpark is noted to have a large floor area with each floor having an area of at least 13,666 m^2 and served by 6 exits. It is acknowledged that the distance between alternative exits under the BCA Guide is measured through a point of choice which is more applicable to a defined environment (i.e. a residential corridor or the like) which could have limitations / restictions in pathways to an exit. In a carpark, occupants will be able to move between and around cars and in	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		The analysis undertaken in Section 11.7.3 considers movement of each phase of the evacuation path (i.e. movement to a point of choice; movement to the nearest exit; and movement to an alternative exit) in isolation. It is not considered that these events are mutually exclusive, and it is recommended that the analysis consider the cumulative impact of extended travel distances. It is considered that the extended travel to a point of choice assessment would be strengthened by the inclusion of a discussion relating to the risk of entrapment and likelihood of blockage on the final 18 m of the travel path to the point of choice. Within the discussion of the CFD analysis of Section 11.8 references to the term of margin of safety are included. However, a factor of safety has been applied and a margin of safety has then been adopted in addition to this. It is recommended that this be clarified.	this instance move to the 6 exits provided. Notwithstanding the above, Appendix H of the FER has undertaken an ASET / RSET analysis for the carpark which has demonstrated that occupants in a fire scenario are expected to be able reach the exits prior to untenable conditions occuring. The above detail shall be included in an updated FER for the development.	

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
17	Page 58 – AS 6	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision have been correctly identified as being DP4 and EP2.2. The approach and assessment method nominated applies a comparative approach whilst stating an absolute approach (refer to Table 23). The assessment utilises a comparative approach to demonstrate that the extended travel distances afforded in the subject design are suitably mitigated, so as to be equivalent to that of a Deemed-to-Satisfy case. We would recommend, given the nature of the assessment applied, that Table 23 be updated to reflect the comparative approach as it may be more appropriate. Subject to clarification of the following point this is considered to be a suitable methodology. The comparative assessment utilises the difference in spacing between an AS 1670 detector spacing (ABS case) and an AS 1668 detector spacing (DtS case) and the use of fast response sprinklers (ABS case) and standard response sprinklers (DtS case). It is noted that AS 11 provides for the omission of smoke detectors and sprinklers from the pool area of the aquatic centre. Subsequently Table 26 appears to incorrectly benchmark the DtS and ABS case by referencing systems that are either not required, or not provided in the pool area.	Noted and agreed. Table 23 shall be updated to reflect the comparative approach utilised in the alternative solution. It is acknowledged that AS 11 discusses the omission of smoke detectors and sprinklers from the pool area of the Aquatic Centre and this needs to be discussed in Alternative Solution AS 6 which shall be undertaken in an updated FER. The omission of smoke detectors and sprinklers from the pool area does not present a risk to life safety in this instance, given the low fire risk associated with the indoor pool area and given that the majority of the footprint of this area contains a wet space. It is further noted that all remaining areas of the Aquatic Centre are being provided with enhanced fire detection provided by the earlier response of the sprinkler system (use of fast response sprinkler heads in lieu of the prescriptive standard response sprinkler heads) which will facilitate total egress times being less than or equal to the comparative notional DtS case.	Noted .Please undertake agreed changes. The discussion relating to omission of detectors from the pool area is recommended to be included within the body of the report.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
18	Page 65 – AS 7	Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision have been correctly identified as being DP4, DP5 & EP2.2. Two different acceptance criterion are listed for the non-conformances however it is noted that the terms for both parts are the same. It is suggested that this could be consolidated. The approach and assessment method nominated applies an absolute approach. This is considered an appropriate methodology. It is noted that the selected fire scenarios have not been specifically quantified and are located in a number of locations adjacent to the discharge points so as to test the fire safety systems within the building. Based on the approach adopted in the assessment, this is considered acceptable. In Section 13.7.5 the discussion uses relative directions 'left' and 'right' to describe the various parts of the building. It is recommended that cardinal directions be used to avoid confusion.	Noted and agreed – Section 13.7.5 shall be updated to provide clarity on the directions upon discharge of the fire-isolated passageway (i.e. Into the Port Cochere and towards Evans Street or up to the Common Podium Area).	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
19	Page 69 – AS 8	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being DP4 and EP2.2. The approach and assessment method nominated applies an absolute quantitative and qualitative approach whilst stating that a qualitative approach will be applied (refer to Table 28). The assessment methodology in parts relies upon quantitative analysis through the use of zone modelling. We would recommend, given the nature of the assessment applied, that Table 28 be updated to reflect the quantitative approach as it may be more appropriate. The assessment utilises zone modelling for determination of the under croft (CFAST) and Porte Cochere (B-Risk) available safe egress time (ASET). The description of the assessment methodology (Section 14.6) is silent on the use of the selection of the different models and it is recommended that suitable reasoning be provided. Section 14.6.1 incorrectly references Appendix D for the output files. It is further recommended that the input files for the modelling be included within the document for future reference. Subject to clarification of the following point above this is considered to be a suitable methodology. It is recommended that authorative references for the acceptance criteria detailed in Table 29 should be included.	Additional supporting text with regards to the application of both CFAST and B-Risk shall be included in Section 14.6 of an updated FER. Section 14.6.1 is noted to have contained a typographical error (reference to Appendix D and not the intended Appendix F) and this shall be corrected in an updated FER. An appropriate reference shall also be included in Table 29 as part of an updated FER.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
20	Page 78 – AS 9	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being EP1.3, EP1.6 and EP2.2. The approach and assessment method nominated applies a qualitative approach. This is considered an appropriate methodology. Review of the floor plate and elevation also indicates that a ventilation opening (Sub intake plenum) is located within the setback of the booster. It is recommended that comment should be made in both the hazard assessment and the analysis relating to this element. It is noted that the wayfinding signage is nominated at 100 mm. Whilst it is not the purpose of the peer review to nominate design requirements it is suggested that the sizing of the text be confirmed with the project stakeholders to assess whether it can physically fit upon the door in the spacing nominated.	It is noted that the ventilation opening (Sub intake plenum) located within the setback of the booster has not been identifed to WSP | Parsons Brinckerhoff Fire as an unprotected opening. This shall be reviewed and discussed with the PCA and shall be referenced & assessed in an updated FER document if needs be. In regards to the recommendations associated with wayfinding signage size of 100 mm, the assessment put forward has been agreed in principle by the FRNSW who would be attending a fire scenario in the subject building.	Noted.
21	Page 84 – AS 10	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being EP1.3. The approach and assessment method nominated applies a qualitative approach with review of fire incident statistics, empirical data and AFAC guidance. This is considered an appropriate methodology. It is considered that Section 16.7.1 could be strengthened by including a discussion on the maximum number of vehicles involved in carpark fires in order to reverse engineer the area of hydrant coverage that could reasonably be expected.	Noted. However, the assessment put forward has been agreed in principle by FRNSW who would be attending a fire scenario in the subject building and therefore further discussion is not required.	Noted.
22	Page 89 – AS 11	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision have been identified as being EP1.1, EP1.4 and EP2.2.	Additional detail is to be added to Section 17.7.1 in an updated FER to specifically address how life safety is not compromised to the pool area by not providing a sprinkler system.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		AS 2118.1 requires sprinkler and non-sprinkler protected parts to be separated by fire rated construction. It is considered that CP2 subsequently be considered to be included. The approach and assessment method nominated applies a qualitative approach with consideration of two separate fire scenarios. It is noted that the selected fire scenarios have not been quantified and are located in two separate points so as to test the fire safety systems and trail design within the building. Based on the approach adopted in the assessment, this is considered acceptable. Within the assessment it is recommended that the analysis of the fire scenarios (x 2) and the omission of fire hose reels be presented sequentially. The acceptance criteria nominated for the assessment is in part: The deletion of smoke detectors for ventilation shut-down in the high ceiling pool areas would not affect life safety. Section 17.7.1 does not directly consider whether life safety is affected but rather considers the risk level in that part of the building .It is recommended that the assessment be expanded or the acceptance criteria and assessment methodology be modified to reflect the analysis presented. The assessment is recommended to include consideration of the risk associated with the omission of fire rated separation between the pool and remainder of the aquatic centre.	It is acknowledged, that by default, in not provding sprinkler protection (in part of the pool area, only, as identified in Figure 35) this introduces the additional non-compliance with BCA Clause 3 of Specification E1.5. Alternative Solution AS 11 shall also be updated to account for the identified additional non-complaince of not providing a required fire wall to separate the sprinkler protected areas from the non-sprinkler protected areas	
23	Page 94 – AS 12	The Performance Requirement(s) related to the identified non-conformance of the BCA Deemed-to-Satisfy provision has been correctly identified as being EP1.4, EP2.2and FP4.4. It is noted that FP4.4, and conformance with Performance Requirement (being related to health and amenity) should be addressed by an appropriately qualified mechanical engineer.	Noted and agreed. The CO modelling has been reviewed internally by the WSP | PB Mechanical team and this will be acknowledged in an updated Appendix I. Table 34 of AS 12 shall also be updated to reflect the quantitative analysis undertaken.	Noted. Please undertake agreed changes.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		The approach and assessment method nominated applies an absolute qualitative approach whilst stating that a qualitative approach will be applied (refer to Table 34). The assessment methodology in parts relies upon quantitative analysis through the use of CFD modelling. We would recommend, given the nature of the assessment applied, that Table 34 be updated to reflect the quantitative approach as it may be more appropriate. Within the discussion of the CFD analysis of Section 18.7.1 references to the term of margin of safety are applied. However, a factor of safety has been applied and a margin of safety has then been adopted in addition to this. It is recommended that this be clarified.	Section 18.3 of the FER is to be also updated to clearly detail the CFD acceptance criteria which in this instance is a factor of safety of 1.5 (RSET x 1.5). The ”margin of safety” presented is the difference between the RSET x 1.5 and the ASET. I.e. Margin of safety = ASET – (RSET x 1.5). The ”margin of safety” demonstrates that the ASET is well in excess of the RSET, even after a ”factor of safety” of 1.5 is applied.	
24	Appendix H – CFD Modelling Report	CFD modelling using FDS has been undertaken to assess the impact of the impulse fans on sprinkler activation and occupant evacuation within the basement carpark. The following clarifications are recommended: ▪ Input files should be included for completeness and to allow verification of the assessment undertaken. ▪ Within the discussion of the CFD acceptance criteria references to the term of margin of safety are applied. However, a factor of safety has been applied (i.e. 1.5) and a margin of safety has then been adopted (i.e. ASET – RSET) in addition to this. It is recommended that this be clarified. ▪ The results appear highly dependant on the location of the fire. It is recommended that further location sensitivities be undertaken to test the robustness of the design. ▪ Mesh and domain parameters should be included in the documentation. ▪ The images from the modelling undertaken indicate that the velocity from the impulse fans is in the order of 5.55 m/s. It is our understanding that the peak velocity from impulse fans is in the order of 18 m/s.	WSP | Parsons Brinckerhoff has the following commentary response to the 8 bullet points raised for Appendix H. For ease of reference we have labelled our responses 1 to 8; 1. The inclusion of input files for the CFD modelling presents a conflict with regards to handing over of our Intellectual Property. Notwithstanding this, if OFR has any further specific questions (other than those identified below), we are happy to provide further clarity in relation to the CFD modelling inputs, on receipt of explicit requests. 2. The CFD acceptance criteria in this instance is a ”factor of safety” of 1.5 (RSET x 1.5) as detailed in Table 21 of Appendix H. This shall be made clear in an updated FER and Appendix H. The ”margin of safety” presented is the difference between	Noted. Please undertake agreed changes. To clarify in relation to item 3) and 8) of the WSP response. o We would recommend that as the design fire locations have been selected to mimic the FRNSW guidance that some additional commentary relating to this be included in the report, particularly given the nature of the absolute assessment undertaken. o It is our understanding that the movement time has been calculated using hydraulic flow calculations. As a result it is likely that as exits become untenable that travel distances may vary. We agree that this is unlikely to impact on the overall result but consider that this assumption should be included within the report.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		Should reduced velocities be applied in the modelling suitable validation need be included in the documentation. ■ It is recommended that authoritative references for the determination of fuel sources for the mixture fraction reaction be included. ■ The travel speed adopted in the CFD modelling (1.2 m/s) contradicts that applied in AS 5 (0.8 m/s). The evacuation modelling is understood to rely upon the equal distribution of occupants at the exits. It is recommended, given that exits progressively become unavailable throughout the model that additional discussion on the gradual loss of tenability at exits be provided in the analysis.	the RSET x 1.5 and the ASET. I.e. Margin of safety = ASET – (RSET x 1.5). The ”margin of safety” demonstrates that the ASET is well in excess of the RSET, even after a ”factor of safety” of 1.5 is applied. 3. The assessments undertaken are in line with the requirements and guidance required by FRNSW, as discussed in Section 4.2 of Appendix H. The intent of the Alternative Solution is not essentially to validate the carpark layout, but more so to validate the use of jet fans as part of a mechanical design and to demonstrate that any impact on sprinkler activation should not jeopardise firefighting operations. 4. Mesh and domain parameters shall be included in an updated FER report - notably Appendix H. 5. This shall be corrected in the next revision of the FER report – notably in Appendix H. It is agreed that the peak velocity should have read in the order of 18 m/s. 6. Authoritative references for the determination of fuel sources for the mixture fraction reaction shall be included in the next revision of the FER report & Appendix H. 7. The travel speed is to be revised to be consistent with the detail throughout the FER report, notably in Alternative Solution AS 5 (0.8 m/s). 8. The evacuation calculation assumes that the car park is fully occupied, which would be the worst case situation. If, as suggested, an	

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
			unequal distribution of occupants exists, the resulting assumption is that fewer occupants would be present in the car park. In this situation, the queuing time would reduce, due to there being fewer occupants required to leave the space. In any case, and as already noted in the report, the queuing time does not impact on the RSET, due to accummulation of pre-movement time and travel time having precedence. If fewer occupants were present in the car park, both premovement time and travel time would be unaffected. Pre-movement time is based on the Management Level, which would be unchanged. Travel time for a reduced occupant number would remain the same. Given the number of exits available to occupants and the results of the calculation presented, it is deemed that the ASET vs. RSET assessment method remains valid.	
25	Appendix I – CO Modelling Report	Olsson Fire & Risk are not mechanical engineers and would recommend that the CO modelling be peer reviewed by an appropriately qualified mechanical engineer. However the following clarifications are recommended: ■ The results presented in Table 1 contradict AS 1668.2 and the discussion provided in Section 4 in relation to parking usage rates (AS 1668 requires 30 %, the traffic report is understood to state 50 % and the engineering applies 100 %) ■ The modelling results are indicated at 300 seconds only. AS 1668 requires conditions to be monitored at up to 60 minutes.	The CO modelling has been reviewed internally by the WSP | PB Mechanical team and this will be acknowledged in a revised Appendix I. A WSP | PB mechanical engineer shall be added to the QA History in the Quality management Section of the report. WSP | PB has the following commentary response to the 7 bullet points raised for Appendix I; 1. Table 1 of the CO report contains a typographical error and should read as being 50 %, which is in line with	Noted. Please undertake agreed changes. We maintain that the CO modelling assumptions and results should be verified by a mechanical engineer.

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
		■ The average CO levels identified in the modelling are shown to be 10 ppm from the results. Average background levels of CO are 9 ppm indicating that the impact of the vehicles in the carpark contributes only 1 ppm to a background CO level. The results are recommended to be tested and validated. ■ Results are measured at a height of 1.8 m. AS 1668 requires results to be measured between 0.75 m and 1.8 m and subsequently additional supporting information is recommended to be included. ■ Mesh and domain parameters should be included in the documentation. ■ The images from the modelling undertaken indicate that the velocity from the impulse fans is in the order of 5.55 m/s. It is our understanding that the peak velocity from impulse fans is in the order of 18 m/s. Should reduced velocities be applied in the modelling suitable validation need be included. Authorative references for the suitability of FDS as a CO modelling tool are recommended to be included.	the first bullet point of the Executive Summary of the FER. 2. 300 seconds has been adopted, as essentially, this is the time that the proposed jet fan system is required to undertake an air change through the carpark and, as such, remove toxins from the air. 3. The analysis demonstrates that sufficient air movement is realised over the domain, not to cause significant build-up of CO in concentrated pockets. The extract and supply quantities are based on AS1668.2 as well as detail contained within the traffic report for the development. 4. The weight of CO is less than air and, as such, the height of 1.8 m was assessed, given that it would present the highest concentrations of carbon monoxide. Therefore, this was considered to be the worst case scenario. 5. Mesh and domain parameters shall be included in an updated FER report & Appendix I. 6. It is noted that a velocity of 5.55 m3/s has been utilised, as it presents a more conservative velocity in the model as it essentially shows less air movement in the carpark. It is noted that the inclusion of higher velocities would present better results in terms of removing toxins from the air. 7. References as to why FDS used as a CO Modelling tool shall be	

Item	Location in Report	Peer Review Comment	WSP | PB Comments	OFR Final Comment
			included in an updated FER report & Appendix I (notably Section 5).	

Table 2: Peer Review Comments by FRNSW IFSR, OFR & WSP | Parsons brinckerhoff Actions undertaken

Item	FRNSW Comments	OFR Second Peer Review Comments	WSP | PB Comments & Response
AS 4	a) The analysis has not adequately addressed the increased risk of a fire blocking the path of travel in the event an SOU door is chocked open or fails, due to the potential greater number of SOU's along the corridors with extended distances of travel. b) … c) … d) … e) … f) …	It is considered that the quantitative assessment included in Rev 3 of the Fire Engineering Report suitably demonstrates that the improvement in detection time compensates for the additional travel distance. A corollary to the assessment, whilst not specifically documented within the assessment, is that the risk level, or inversely the level of safety therefore likely to equivalent to that of a Deemed-to-Satisfy design. Similarly, the provision of sprinklers with a risk reducing factor in excess of 30%, as well as the additional safety measures within the design is considered to suitably offset the marginal increase in travel time.	As per the OFR comments, the risk has been adequately addressed in the current FER (Rev 03). No further action required.

Item	FRNSW Comments	OFR Second Peer Review Comments	WSP | PB Comments & Response
AS 5	a) The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case. FRNSW does not agree with the interpretation in the FER of how DtS travel distances are measured. Please see the figure below taken from the Guide to the BCA 2015. b) Refer to comments on issue number 12 regarding the impact of jet fans on sprinkler activation which renders the current analysis invalid. c) … d) …	a) It is considered that the response provided by WSP Parsons Brinckerhoff in the Fire Engineering Report has not addressed the comments of Fire & Rescue New South Wales. We also refer to our comments from our Peer Review: *The analysis undertaken in Section 11.7.3 considers movement of each phase of the evacuation path (i.e. movement to a point of choice; movement to the nearest exit; and movement to an alternative exit) in isolation. It is not considered that these events are mutually exclusive, and it is recommended that the analysis consider the cumulative impact of extended travel distances*. This is not to say that we disagree with the principle applied in the methodology, as is demonstrated through the comparison to internationally recognised building codes. It is logical to assume that an occupant will travel to a point and if an exit is obstructed choose another exit. Indeed the Fire & Rescue New South Wales comments similarly state that where such a position is taken it *"should be demonstrated for all areas of the building subject to the analysis".* Rather the assessment currently does not demonstrate that a logical path would include travel as assessed in the Fire Engineering Report. To resolve this issue we would suggest the inclusion of a number of wayfinding paths demonstrating the logic applied and the redundancy within the design be included. b) Refer to Issue 12 comments.	a) Noted and Agreed. An additional mark up of Basement Level 2, showing the extended distances between alternative exits has been provided in Alternative Solution 5 (Figure 25) along with additional discussion regarding the intent of the BCA Section D1.5 and the provision of additional exits to satisfy this intent (Section 11.9 of FER rev 3).

Item	FRNSW Comments	OFR Second Peer Review Comments	WSP | PB Comments & Response
AS 6	a) The travel time in the RSET analysis should reflect the total travel distance required to be travelled by an occupant when travelling between alternative exits, i.e. travel to the nearest exit plus travel to the alternative exit. If occupants are unlikely to travel back via the point of choice, this should be demonstrated for all areas of the building subject to the analysis. However, it should be noted that the exit may be inaccessible for reasons other than untenable conditions in a fire event, e.g. blocked or locked doors, and therefore it should be assumed occupants travel up to the nearest exit in this case. FRNSW does not agree with the interpretation in the FER of how DtS travel distances are measured. Please see the figure below taken from the Guide to the BCA 2015.	a) Refer to comments included in Issue Number 5 (a) above.	a) Noted and Agreed. An additional mark up of Basement Level 2, showing the extended distances between alternative exits has been provided in Alternative Solution 5 (Figure 25) along with additional discussion regarding the intent of the BCA Section D1.5 and the provision of additional exits to satisfy this intent (Section 11.9 of FER rev 3).
AS 7	a) The revised layout of this area has changed access and egress from the pump room. This includes an increased distance of travel to exit from the pump room, and the inclusion of access to the generator room from the same corridor, which introduces additional hazards. These changes do not facilitate safe access and egress for fire fighters to and from the pump room and may pose a risk to occupants evacuating via this corridor.	a) It is understood from the commentary of WSP Parsons Brinckerhoff that the additional hazard identified by Fire & Rescue New South Wales, being access to the generator room ,and extended travel distances have been addressed as follows: a. The travel distance is identical to that previously not objected to by Fire & Rescue New South Wales; and b. Access to the generator room is to be rearranged. In addition, should concerns still be raised with this matter it is recommended that remote pump control could be provided at the booster to minimise access requirements for FRNSW.	a) Noted and agreed. Access to the generator room will be required to be re-arranged so that the generator room does not open into the fire isolated passageway to the hydrant tank and pump room. As shown in Fig 42 of FER rev 3.

Item	FRNSW Comments	OFR Second Peer Review Comments	WSP | PB Comments & Response
AS 9	a) The revised layout of this area has changed access and egress from the pump room. This includes an increased distance of travel to exit from the pump room, and the inclusion of access to the generator room from the same corridor, which introduces additional hazards. These changes do not facilitate safe access and egress for fire fighters to and from the pump room. b) … c) ... d) … e) … f) ...	a) Refer to comments included in Issue Number 7 (a) above.	a) Noted and agreed. Access to the generator room will be required to be re-arranged so that the generator room does not open into the fire isolated passageway to the hydrant tank and pump room. As shown in Fig 42 of FER rev 3.

AS 12	a) FRNSW have reviewed the responses provided in Appendix B of the FER to the previous IFSR issued by FRNSW. FRNSW do not agree with the comment that the provision of smoke detectors addresses the impact on sprinklers as this has not been verified. Whilst it is acknowledged smoke detectors will operate earlier than sprinklers, there is still the potential for different air movements to exist at sprinkler heads which may delay sprinkler activation. The CFD Report in Appendix H of the FER demonstrates that there is a delay in activation of the sprinklers (up to 35 seconds). This therefore needs to be considered in the analysis of Issue Number 5 as it reduces the earlier activation time of the fast response sprinklers. Also, the actual impact of delaying sprinkler operation by 35 seconds has not been discussed and addressed. b) Refer also to FRNSW comments on issue number 5. c) FRNSW reiterate other comments from the previous IFSR that need to be considered. These include: i. The extended travel distances from issue number 5 need to be considered in the RSET, including FRNSW comments on addressing the distance of travel between alternative exits. ii. The evaluation of queuing time does not consider the progressive blocking of exits as the areas become untenable. This will increase travel distances for some occupants and also increase queuing time at exits that are available, and needs to be addressed in the evaluation of RSET. d) The travel speed of 1.2 m/s in the calculation of RSET in the CFD Report in Appendix H of the FER has not been revised to 0.8 m/s as used in Issue Number 5. e) Not all requirements / recommendations from FRNSW uideline (Refer to FRNSW Guideline at	a) We agree with Fire & Rescue New South Wales response in relation to verification of this item i.e that smoke detectors do not address the impact on sprinklers. The impact of this is, however, considered to be related to the technical accuracy of the statement as opposed to the literal impact on the assessment, which is deemed to be relatively insignificant. The inclusion of the smoke detectors does suitably offset the delay as a result of increased air movement around sprinkler heads, which being fast response type respond more favourably than those of a Deemed-to-Satisfy design. It is considered that this response is reasonable given that a Deemed-to-Satisfy design permits impulse fans, albeit not in series alignment. b) As commented upon above in Issue Number 5 and herein. c) i. Refer to comments under Issue Number 5 ii. We agree with the comments of WSP Parsons Brinckerhoff whereby congestion within the car park is considered to be unlikely, even under progressive loss of tenability. d) … e) We recommend Appendix B be updated to nominate the items that are now included but that were omitted from earlier versions of the Fire Engineering Report. f) … g) We agree with the WSP Parsons Brinckerhoff approach. Reference to AS 1670.1 and AS 1668.1 is appropriate given the lack of a specific Australian Standard for Impulse Fans. h) Whilst arguments can be made for higher (or lower) levels of safety we support WSP Parsons Brinckerhoffs use of internationally recognised	a) Noted, no further action required. b, c) Noted and Agreed. An additional mark up of Basement Level 2, showing the extended distances between alternative exits has been provided in Alternative Solution 5 (Figure 25) along with additional discussion regarding the intent of the BCA Section D1.5 and the provision of additional exits to satisfy this intent (Section 11.9 of FER rev 3). d) N/A e) Appendix B has been updated to reflect these changes. g) Noted, no action required. h) Noter, no action required. i) An additional slice file has been added to the FER section 12 (Figure 50) which shows the section of the design fire in the basement is over 550 ºC. j) N/A k) N/A l) Noted, no action required.

	http://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/impulse_fans_in_carparks.pdf) have been incorporated in the design requirements of Section 6 of the FER, for example the requirement to locate jet fans in driveways only and testing requirements. f) FRNSW Guideline recommends that "The detection system should only shut down the impulse fan system and not activate the occupant warning system or fire brigade notification unless it is appropriate to use within a car park environment and would not cause spurious alarms." It is acknowledged that the current proposal is to have the occupant warning system activated from the activation of detectors within the impulse fans, however it has not been demonstrated whether these are appropriate for a car park environment to mitigate the issue of spurious alarms. Should the detectors be considered inappropriate for such operation, the impact on the alternative solution, including a delayed activation of the occupant warning system to that currently assumed, would need to be addressed. g) Item 5 from Table 6 of the CFD Report in Appendix H of the FER has not been adequately addressed. Reference to AS1668.1 is not sufficient, as the proposal is dealing with a system that does not comply with the standard, and additional testing requirements should be specified to adequately test the system. h) FRNSW do not agree with the tenability criteria in the CFD report. Convective temperature should be measured at head height irrespective of the height of the hot layer, as the air may be heated by the hotlayer or fire itself. Also, FRNSW consider that visibility should be measured to nonilluminatedobjects for all aspects of visibility, even when queuing at exits. Toxicity has not been addressed in the analysis.	texts and guidance material for the measurement of acceptance criteria. i) We recommend slice files through the fire plume be included in the Computational Fluid Dynamics report to validate the model and demonstrate realistic plume temperatures have been achieved e.g. the current slice files indicate temperatures of 60ºC only. j) … k) … l) We do not object to the design fire sizes nominated by WSP Parson Brinckerhoff for the purpose of demonstrating the influence on sprinkler activation – being the primary purpose of the Fire & Rescue New South Wales guideline document. .	

Item	FRNSW Comments	OFR Second Peer Review Comments	WSP | PB Comments & Response
	i) The CFD Report in Appendix H of the FER requires further CFD results to demonstrate realistic fire temperatures are being achieved. j) No description is provided as to how the shut down time of jet fans is determined for fire scenarios 4 to 9 in the CFD Report in Appendix H of the FER. Similarly, no details are provided on how the detection times in Table 16 of the CFD Report have been determined. k) Section 6.2.1 of the FER notes that "The supply fans and exhaust fans are kept running and ramp to full speed if on variablespeed drive (VSD)", however it does not state when this is to occur. l) FRNSW do not consider the fire growth rate and peak fire sizes to be appropriate to resemble a car fire in a sprinklered carpark. Based on the results of other testing, it is considered a more conservative value should be used for the fire growth rate and peak fire size (a minimum of 2.5 MW is considered applicable for a single car fire). This is also demonstrated in the figure from the BRE report referenced in the CFD Report which shows peak heat release rates above 1.5MW.		

Appendix K Fire & Rescue NSW Feedback (on FEBQ V02)

K.1 FRNSW Feedback on FEBQ V02

Table 1 details the feedback and comments from FRNSW received by email on the 30/09/2015 on FEBQ V01 (submitted to FRNSW on the 31/07/2015). The below table discusses the items raised by FRNSW on their review of the FEBQ and WSP's commentary and actions undertaken with regards the FRNSW feedback.

- FRNSW File Number – FRN15/1742 (#8544)

Table 1: FRNSW feedback via FEBQ V02 on FEBQ V01 and WSP's commentary & action undertaken

Location in FEBQ Issue 1	FRNSW Comments	WSP Comments & Action Undertaken
Page 13 of 67 – *Principal Building Characteristics*	FRNSW: The above information has not indicated the location of the Sprinkler Valve Room.	Section 5 of the FER and notably Figure 7 has been updated to provide clarity on the location of the fire brigade equipment for the proposed development.
Page 17 of 67 – *Grade of water supply (sprinklers)*	FRNSW: The presented architectural plans have not detailed the location of the Sprinkler Valve Room (SVR). FRNSW assumes that the SVR will be located in a code compliant location. If at the time of the 152 inspection the Fire Brigade assessing Officer considers this not to be the case, then FRNSW recommendation to move the SVR may result. FRNSW recommends that this information be provided in the FER (or version 03 of this FEBQ if applicable) for FRNSW assessment and input.	Noted. As per comments above. Section 5 of the FER and notably Figure 7 has been updated to provide clarity on the locvation of the fire brigade equipment for the proposed development.
Pages 26 & 28 of 67 – *AS 1*	Absolute *& Comparative* (as specified above). FRNSW: FRNSW conditionally supports the proposed trial design, subject to the following: ▪ Appropriate and clearly detailed comparison is established with regards to flame projections from both the base case design and the alternative solution design. i.e., a comparison with a DTS design complying with Clause C2.6(a)(iv) should be considered, as this would be considered appropriate; ▪ Inputs used for the calculation of the flame projections from both the base case design and the alternative solution design; and ▪ The outcomes from analysing both the proposed design and the DtS design.	Noted and agreed. Alternative Solution AS 1 & Appendix G of this FER provides clarity on the calculation & methodologies used as part of the assessment. The assessment undertaken has compared the subject design with a permissible BCA compliant spandrel design – see Figure 9 and notably Figure 10 for clarity on the results of the comparable assessment undertaken.

Location in FEBQ Issue 1	**FRNSW Comments**	**WSP Comments & Action Undertaken**
Pages 31 & 32 of 67 – *AS 2*	FRNSW: Given that CP4 is nominated, tenability of occupant evacuation should also ne included in the Acceptance Criteria. FRNSW: FRNSW recommend that occupant evacuation be also considered in the analysis given the nomination of Performance Requirement CP4. FRNSW: FRNSW provide conditional support for the presented strategy, subject to FRNSW recommendations above being presented in the next version of the FEBQ for review. Additionally, doors located within the glazed elements of the fire wall would be required to be automatically closed. FRNSW recommend that the relevant Essential Fire Safety Measures be nominated to support this requirement.	Noted and agreed. CP4 has been discussed in Section 8.7.3 of the FER. All of the relevant items listed in Section 6 of this FER are to be included in the essential service schedule and listed in the Annual Fire Safety Statement. All Alternative Solutions to be listed in the Essential Services Schedule and Annual Fire Safety Statement.
Page 35 of 67 – *AS 3*	FRNSW: FRNSW is in agreement with regards to the easement being included in the AFSS and the proposal to include it as a Critical Fire Safety Measure, however the proposed trial design needs to be justified with a quantitative analysis.	Noted. However the adjoining area is a public reservce and not likely to be built upon. The agreement requires the development to be reassessed by a Fire Engineer to ascertain the likelihood of fire spread between allotments. This would involve a quantitiative analysis. The proximity to the boundary of the openings would require protection to the identified openings of Building F.
Pages 36, 39 & 40 of 67 – *AS 4*	(assumed to be "in lieu of 6 m"?) *All furnishings contained within (if any i.e.; such as tables / seating) are to be of non-combustible materials as determined by AS 1530.1.* FRNSW: FRNSW recommend that this be included as an Essential Fire Safety Fire Safety Measure to be included in the Fire Safety Schedule and AFSS. FRNSW: In order to satisfy the Performance Requirement EP2.2, considering the provision of smoke seals to the SOU doors and the extended travel distances, FRNSW recommend the occupant warning system achieve an A-weighted sound pressure level of 75dB at the bedhead (as stipulated in AS1670.1-2004 Clause 3.22) in lieu of the requirements of Spec E2.2a Clause 6 of the BCA.	This was a typographical error issued as part of the FEBQ submission and has been amended in this FER. The occupant warning system is to achieve an A-weighted sound pressure level of 75dB at the bedhead (as stipulated in AS1670.1-2004 Clause 3.22) in lieu of the requirements of Spec E2.2a Clause 6 of the BCA. All of the relevant items listed in Section 6 of this FER are to be included in the essential service schedule and listed in the Annual Fire Safety Statement. All Alternative Solutions to be listed in the Essential Services Schedule and Annual Fire Safety Statement.

Location in FEBQ Issue 1	FRNSW Comments	WSP Comments & Action Undertaken
Pages 41& 42 of 67 – *AS 5*	FRNSW: FRNSW recommend that pictorial representations be provided for the above listed departures FRNSW: In principle support provided by FRNSW for the presented strategy and subject to the following: If additional hydrants in accordance with Clause 3.2.3.3 of AS2419.1-2005 are necessary to achieve hose coverage - FRNSW recommends that a floor specific block plan be installed adjacent to the internal fire hydrants located within the fire isolated stairwells. The sole purpose of the block plans is to locate the additional internal hydrants on that level by pictorially and numerically illustrating the location of the next available additional hydrant. The plans should be a minimum of A3 in size and be orientated to reflect the floor plate as being viewed facing the door with a "YOU ARE HERE" note and be incorporated into the fire safety schedule.	Noted and agreed. A floor specific block plan be installed adjacent to the internal fire hydrants located within the fire isolated stairwells. The intent of the block plans is to locate the additional internal hydrants on that level by pictorially and numerically illustrating the location of the next available additional hydrant.
Pages 43 & 44 of 67 – AS 6	*(b) (ii) or (c)?* FRNSW: FRNSW provide in principle support for the presented strategy	Under BCA Clause A0.9 - The assessment methods used to determine that a Building Solution complies with the Performance Requirements has been updated to (c).
Page 48 of 67 – *AS 7* Page 51 of 67 – *AS 8*	FRNSW: FRNSW provide in principle support for the presented strategy	Noted.
Page 55 of 67 – *AS 9*	FRNSW: FRNSW provide in principle support for the presented strategy. However it is unclear what the deviation from 300mm is in respect to Clause 3 of Specification E1.8. Additionally, given the obvious location of the booster assembly when entering the premises, FRNSW do not consider the red strobe at the booster assembly necessary and would prefer to ensure that the red strobe indicating the location of the FIP is clearly visible from the entrance.	The non-compliance associated with Clause 3 of Specification C1.1 is that the the 'Fire Control Room' is noted linked specifically to a road or open space. There is no issue with a change in level of 300 mm. Red strobe lights shall be provided at the following locations: ▪ At the booster assembly; ▪ At the entry point to the Fire Control Room & fire isolated passageway entrance providing access to the Fire Hydrant Pump &Tank / Fire Sprinkler Pump & Control Valve room.

Location in FEBQ Issue 1	FRNSW Comments	WSP Comments & Action Undertaken
Pages 56,27 & 58 of 67 – *AS 10*	*(b) (ii)* or (c)? When comparison to the Deemed to Satisfy provisions is used as an assessment method, the Acceptance Criteria should include that the analysis will demonstrate at least equivalence with a comparable DtS design building. Subjective or opinion based terms such as 'not likely to', 'sufficient', 'should not', etc. are inappropriate for inclusion in Acceptance Criteria. Consultation with FRNSW is not appropriate. FRNSW is not the authority having jurisdiction, accordingly direct reference to FRNSW should not be included as part of the Acceptance Criteria. FRNSW: FRNSW provide in principle support for the presented strategy.	Under BCA Clause A0.9 - The assessment methods used to determine that a Building Solution complies with the Performance Requirements has been updated to btoh (b)(ii) & (c).
Page 61 of 67 – *AS 11*	FRNSW: FRNSW provide in principle support for the presented strategy	Noted.
Pages 61, 64 of 67 – *AS 12*	*(b) (ii)* or (c)? FRNSW: The CFD form was not presented with the FEBQ. FRNSW: In principle support, subject to details not included in this Alternative Solution and compliance with the Fire & Rescue Guideline: http://www.fire.nsw.gov.au/gallery/files/pdf/guidelines/impulse_fans_in_carparks.pdf	The CFD form was issued to FRNSW on Friday 31/07/2015 at 5:22 PM in PDF format. The CFD form was issued to FRNSW again on Monday 17/08/2015 at 2:16 PM in word format. Alternative Solution AS 12 of this FER has been based on the guidance given in the subject FRNSW guideline.

Appendix L OWS Fire Matrix

FlameSafe Fire Protection Pty. Limited

Unit 2, 8-10 Mary Parade
Rydalmere, NSW, 2116

Fire Protection Contractors
Email: info@flamesafe.com.au

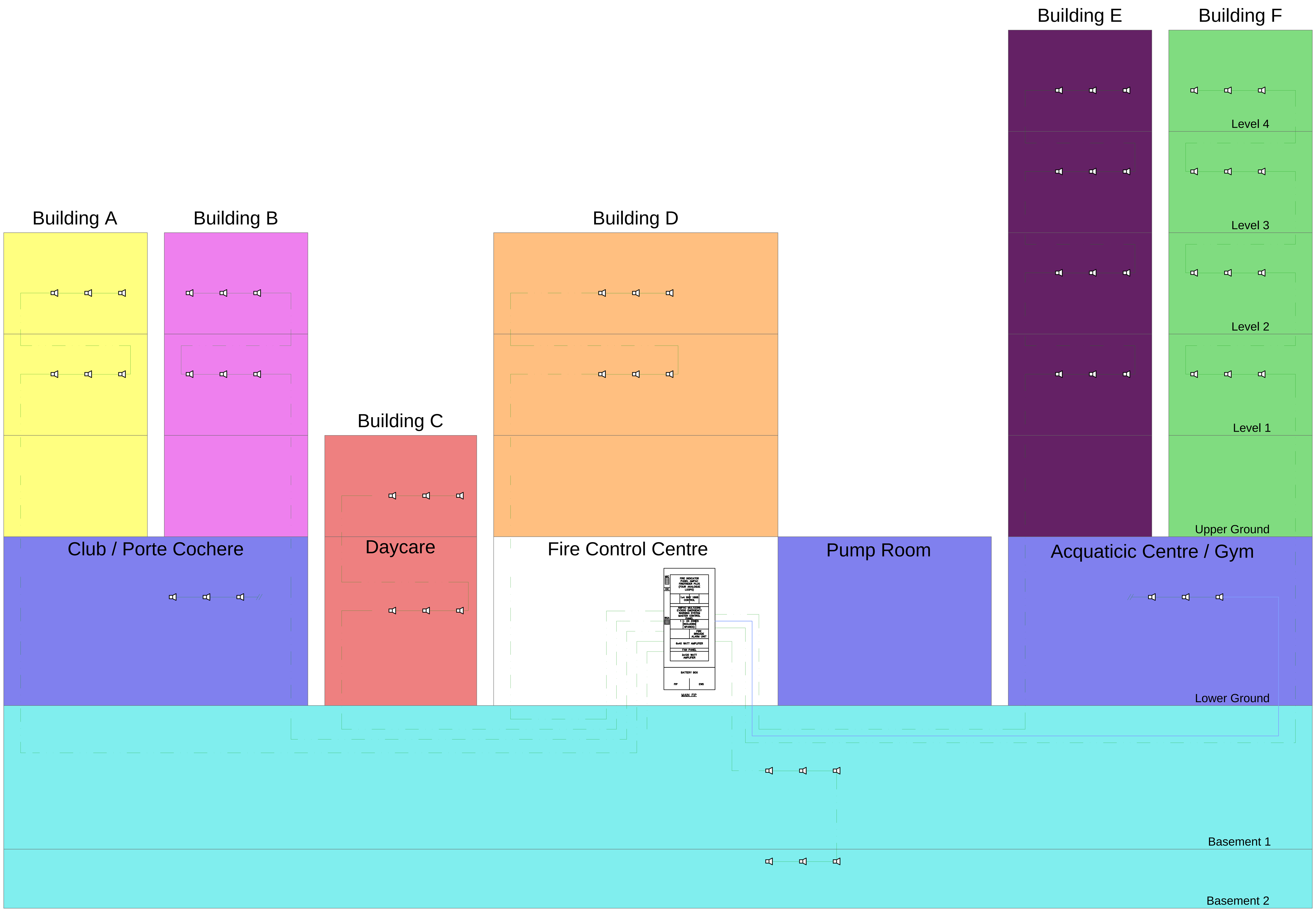
Phone: 9638 1662
Fax: 9638 3665

OWS Fire Matrix

Site: Harbord Diggers
Date: 11/11/2016
Designed by: Mark Anderson
Stage changeover time: 3min

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8
	Basement 1/2	Lower Ground	Building A	Building B	Building C	Building D	Building E	Building F
BASEMENT Alarm								
Stage 1	Alert							
Stage 2	Evac	Alert			Alert			
Stage 3	Evac	Evac	Alert	Alert	Evac	Alert	Alert	Alert
Stage 4	Evac	Evac	Evac	Evac	Evac	Evac	Evac	Evac
Lower Ground Alarm								
Stage 1		Alert			Alert			
Stage 2	Alert	Evac	Alert	Alert	Evac	Alert	Alert	Alert
Stage 3	Evac	Evac	Evac	Evac	Evac	Evac	Evac	Evac
Building A Alarm								
Stage 1			Alert					
Stage 2		Alert	Evac		Alert			
Stage 3	Alert	Evac	Evac		Evac			
Stage 4	Evac	Evac	Evac	Alert	Evac			
Stage 5	Evac	Evac	Evac	Evac	Evac			
Building B Alarm								
Stage 1				Alert				
Stage 2		Alert		Evac	Alert			
Stage 3	Alert	Evac		Evac	Evac			
Stage 4	Evac	Evac	Alert	Evac	Evac			
Stage 5	Evac	Evac	Evac	Evac	Evac			
Building C Alarm								
Stage 1		Alert			Alert			
Stage 2	Alert	Evac			Evac			
Stage 3	Evac	Evac		Alert	Evac	Alert		
Stage 4	Evac	Evac		Evac	Evac	Evac		
Building D Alarm								
Stage 1						Alert		
Stage 2		Alert			Alert	Evac		
Stage 3	Alert	Evac			Evac	Evac		
Stage 4	Evac	Evac			Evac	Evac	Alert	
Stage 5	Evac	Evac			Evac	Evac	Evac	
Building E Alarm								
Stage 1							Alert	
Stage 2		Alert			Alert		Evac	
Stage 3	Alert	Evac			Evac		Evac	
Stage 4	Evac	Evac			Evac	Alert	Evac	Alert
Stage 5	Evac	Evac			Evac	Evac	Evac	Evac
Building F Alarm								
Stage 1								Alert
Stage 2		Alert			Alert			Evac
Stage 3	Alert	Evac			Evac			Evac
Stage 4	Evac	Evac			Evac		Alert	Evac
Stage 5	Evac	Evac			Evac		Evac	Evac

Appendix M Evacuation Strategy



FlameSafe Fire Protection Pty. Limited

Incorporated In NSW (ABN 62 071 993 292)

UNIT 2, 8-10 MARY PARADE
RYDALMERE N.S.W. 2116

Phone: 02 9638 1662
Fax No: 02 9638 3665

EMAIL: info@flamesafe.com.au

LEGEND

- Zone 8
- Zone 7
- Zone 6
- Zone 5
- Zone 4
- Zone 3
- Zone 2
- Zone 1

NOTES

1) THE OCCUPANT WARNING SYSTEMS FOR EMERGENCY PURPOSES (OWS) DESIGNED & INSTALLED ACCORDING TO BCA & AS 1670.4 2004.
2) LOCATE HORN SPEAKERS MINIMUM 600mm FROM ANY SPRINKLER HEAD.
3) SPEAKERS ARE NOT TO BE INSTALLED IN CEILING TILES REQUIRED FOR ACCESS TO A/C UNIT FILTERS, CONTROLS, ETC
4) SPEAKERS SHOULD BE ARRANGED GENERALLY AS SHOWN BUT MAY BE ADJUSTED TO CO-ORDINATE WITH THE REQUIREMENTS OF OTHER SERVICES.
5) CABLE RUNS INDICATIVE ONLY

CABLE TYPES

DATE	REV.	DESCRIPTION	INITIAL
11.11.16	A	ISSUED FOR INFORMATION	M.A.

PROJECT

HARBORD DIGGERS

NORTH

DRAWING TITLE

FIRE SPEAKER ZONING

AUTOMATIC FIRE ELECTRICAL SYSTEM

DESIGN	DATE	JAN 2015	
M.A.	JOB No.	32271	
DRAWN	DRAWING NUMBER		
M.A.	FSC-FE-00-02		
CHECKED			
-.-.			
SCALE			
NA	Rev.	A	
A1			

WSP

Level 1, 41 McLaren Street
PO Box 6245
North Sydney NSW 2060
Australia

Tel: 02 8907 0900
www.wspgroup.com