Fire Safety Study

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Appendix X

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Cockle Bay Wharf Land Bridge over the Western Distributor

Fire Safety Study

DPT and DPPT Operator Pty Ltd

25 October 2016

Revision: 2

Reference: 253427

Bringing ideas to life

Document control record

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1 Introduction

A new land bridge structure over the Western Distributor has been proposed as part of an office tower and retail complex development at Cockle Bay Wharf. This land bridge would create a partial enclosure to the elevated northbound Western Distributor and southbound Market St towards Anzac Bridge, and the on grade northbound and southbound Western Distributor and northbound Wheat Rd.

DPT and DPPT Operator Pty Ltd have requested that Aurecon undertake a study of the fire safety condition of the existing roadways as a result of the land bridge and thus provide guidance on whether the tenability condition suggests that the enclosure be classified as an underpass rather than a tunnel – noting that the roadways are not prohibited dangerous goods routes.

This study is to be undertaken in two ways as follows:

1. Computational Fluid Dynamics (CFD) modelling will provide a comparison of the tenability conditions beneath the land bridge and within a hypothetical tunnel as defined in the Australian Standard for Tunnel Fire Safety.

   Under the definition of a tunnel, AS4825 provides the following guidance:

   > A substantially enclosed roadway or track-way greater than 80m in length.
   >
   > NOTE: What constitutes a tunnel depends on the likelihood of development of untenable conditions. If the degree of cover is less than 75%, the accumulation of smoke is unlikely.

2. A comparison will be undertaken with the fire safety conditions and design outcomes of the adjacent underpass associated with the Four Points by Sheraton at 161 Sussex St with the intention of continuing the same design philosophy where the conditions are similar. The Four Points by Sheraton underpass is approximately 45m to the north of the land bridge and the two have a number of roadways in common.

The length of the land bridge is approximately 140m and the cross sections, which are indicative only, are shown in the figures below.

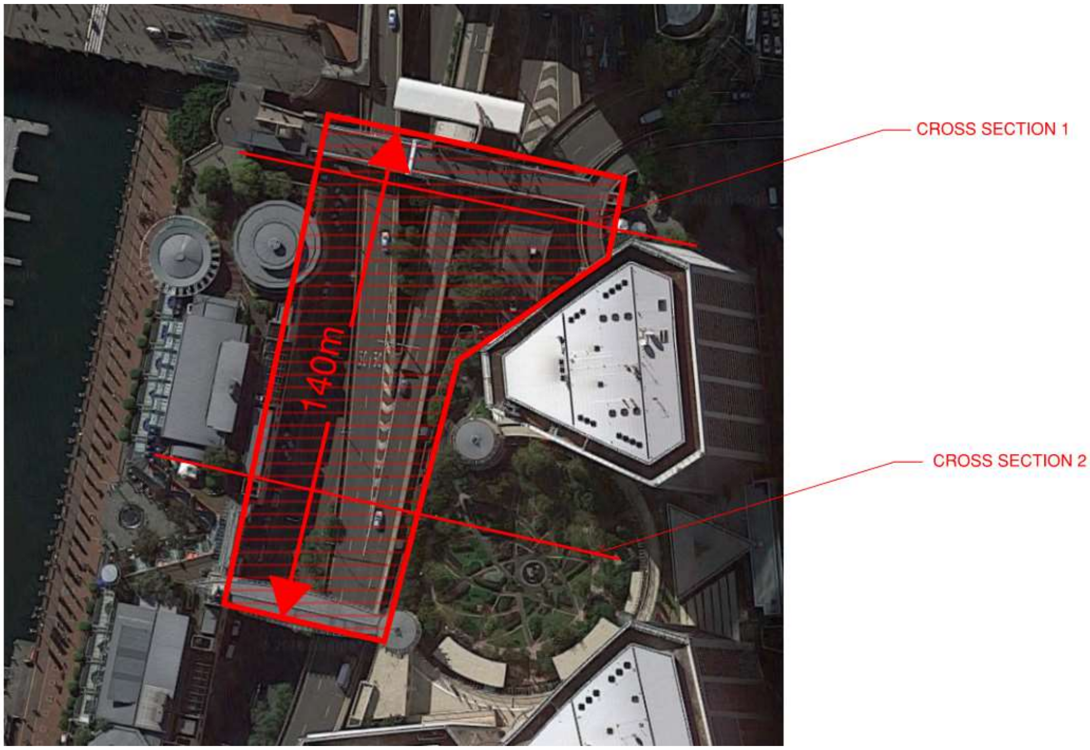


Figure 1: Extent of proposed land bridge - plan

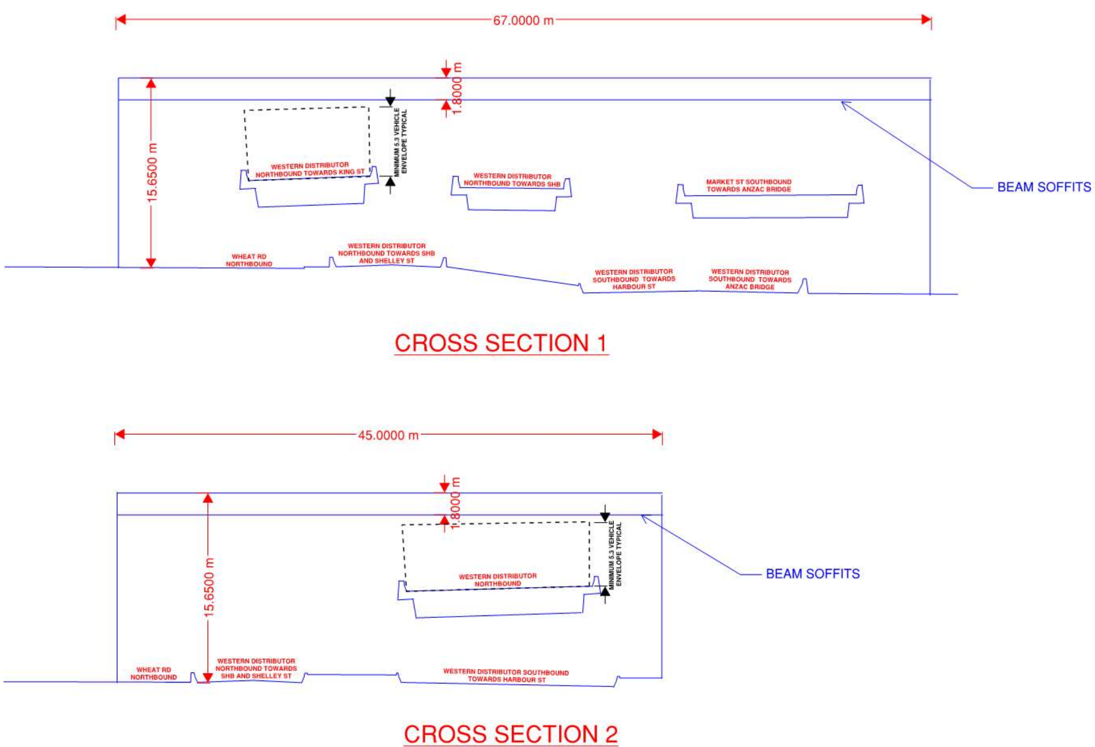


Figure 2: Indicative cross sections of roadways beneath the proposed land bridge (dimensions are approximate only)

In general the envelope of a road tunnel is not significantly greater than the envelope of the road itself. The envelope of the enclosure created by the proposed land bridge at Cockle Bay is significantly larger, providing improved means of smoke and heat dissipation in the event of a fire. As the ratio of the width of the fire source and the width of the tunnel decreases, the peak fire size also decreases.

In addition to the improved tenability resulting from the large enclosure, the likelihood of a fire is reduced due to all of the roadways being uni-directional.

2 Computational Fluid Dynamics (CFD) Modelling

In order to demonstrate the tenability of fire safety beneath the land bridge, a series of CFD simulations have been conducted. The simulations are able to demonstrate the conditions during a fire event and this enables assessments of the egress conditions to be made. The modelling was undertaken with the Fire Dynamics Simulator (FDS) CFD package.

3 The Fire

For a fire generated by a typical heavy goods vehicle (HGV), test results presented in NFPA 502 provide a peak heat release rate (HRR) between 20MW and 200MW. The fire scenario analysed is shown in Figure 3. It has a peak HRR of 157MW which is consistent with the representative HRR suggested by NFPA 502 as a typical design fire size for tunnels without dangerous goods vehicles/flammable goods (refer to paragraph below) and without fixed water based firefighting systems. It is based on findings of the large scale fire test in Runehamar tunnel in 2003 by Technical Research Institute of Sweden (SP). The fire reached peak value within 14 minutes and contained Wood pallets (82%) and Polyurethane plastic (18%).

In line with the work undertaken on the neighbouring Four Points by Sheraton Underpass to determine the design fire events, a dangerous goods vehicle (DGV) fire has not been assessed. Refer to section 9 of this memorandum for further information.

The fire is located in the centre of the enclosure as this is considered critical for smoke spread and infilling. A fire towards the end of the enclosure would result in smoke and heat escaping the covered area sooner. Although the egress time will be greater with the fire towards the end of the enclosure, the results from the fire at the centre indicate that the increase to egress time would not be of concern – particularly given the less severe conditions produced by the fire at the ends.

Wind influence has not been considered in the modelling as it is expected the wind will cool the smoke and push it out of the covered section and make the analysis less conservative. Having said this, we provide the following comment. In line with the assessment detailed in “Fire engineering report R1.2, 161 Sussex Street - Western Distributor Underpass” dated 15 April 2015, at the neighbouring underpass the predominant wind directions are from the south and the west.

A wind from the south is likely to improve the tenability of the northbound roadways during a fire as the smoke is ventilated in the direction of vehicle flow and is therefore pushed away from the upstream vehicles. At the lower southbound roadways, the smoke is likely to be ventilated over the vehicles behind the incident given the height of the space.

A wind from the west is unlikely to improve or worsen the conditions beneath the land bridge as the western face is closed by the building development.

No consideration has been given to the use of fire sprinkler systems or mechanical ventilation which would give a significant benefit to the tenability of the fire event.

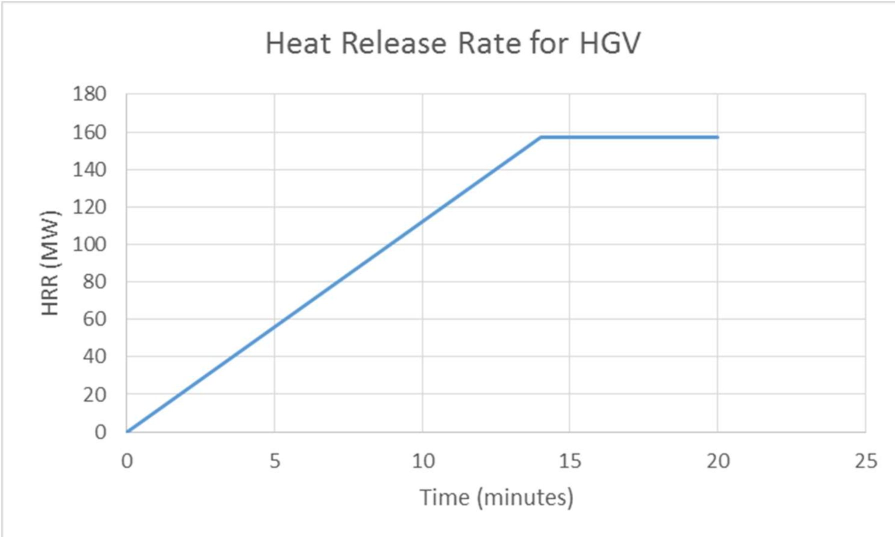


Figure 3: Heat release rate for a heavy goods vehicle

4 Assessment

Three scenarios have been considered for the purposes of this study and these are described below.

> **Scenario 1:** A fire at mid-length of an 80m long hypothetical assumed standard tunnel with internal dimensions as shown in Figure 4. This scenario is used as a datum of tenability conditions based on the general definition of a tunnel in AS4825 (as described above).

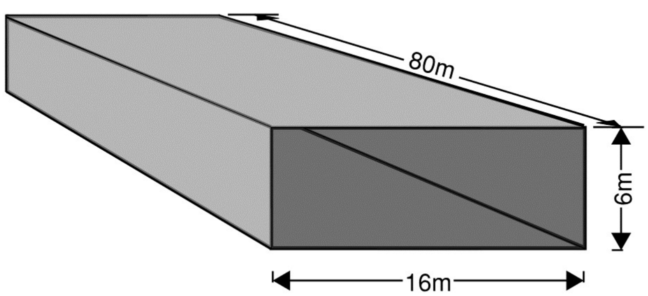


Figure 4: Scenario 1 hypothetical datum tunnel

> **Scenario 2:** A fire at mid-length of the enclosure on the elevated northbound Western Distributor.
>
> **Scenario 3:** A fire at mid-length of the enclosure on Harbour St.

These scenarios are shown below in Figure 5 to Figure 7.

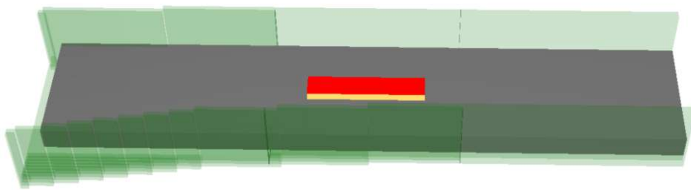


Figure 5: Scenario 1: Fire in a hypothetical 80m long datum tunnel

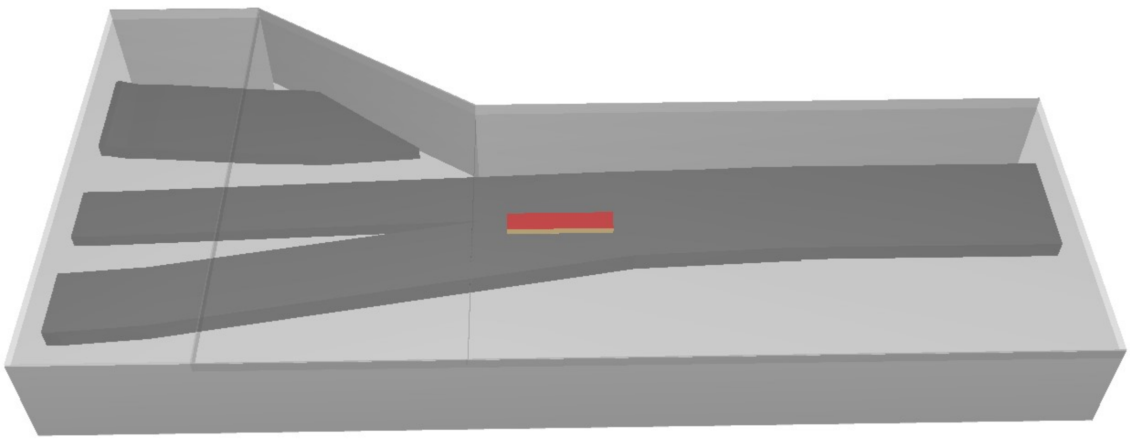


Figure 6: Scenario 2: Fire on the elevated Western Distributor

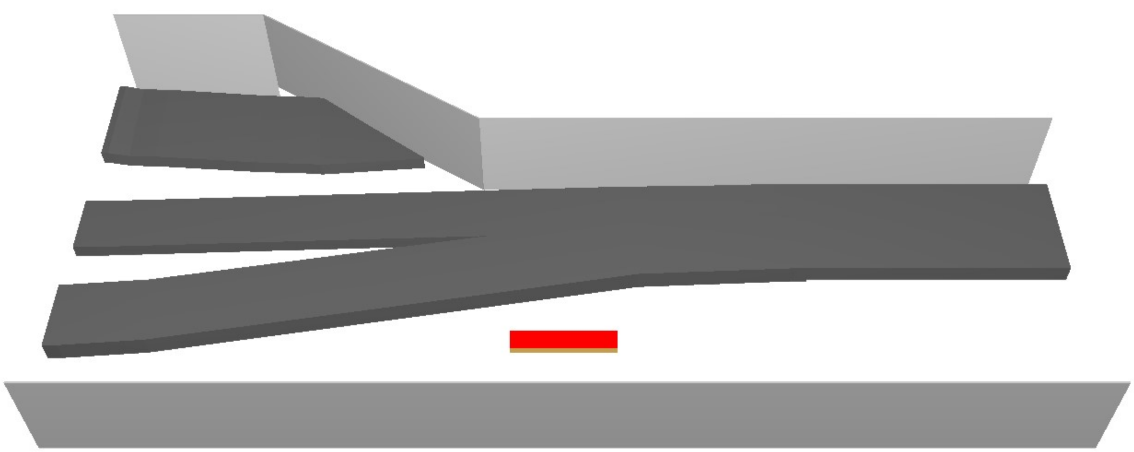


Figure 7: Scenario 3: Fire on Harbour St

Tenability conditions are measured 2m above the surface where people need to evacuate i.e. 2m above the road level. The acceptance criteria for tenability is taken from NFPA 502 as follows:

- Visibility: > 10 m
- Temperature: < 60^{0}C

5 Summary of Findings

The CFD assessment found the following:

Scenario 1:

- The concentration of smoke within the smaller cross-sectional area causes reduced visibility and increased temperature conditions in the tunnel when compared with the larger more open space in scenarios 2 and 3 which are specific to the proposed development.
- Given the length of the tunnel the Required Safe Egress Time (RSET) could be expected to be within the allowable limits. However the conditions associated with fighting the fire as time progresses are worsened.
- The simulations clearly indicate reduced tenability in this hypothetical tunnel when compared with the proposed development.

Scenario 2:

- The tenability of scenario 2 is well above the acceptance criteria defined for this assessment. Given the steadiness of the visibility and temperature beyond 15 minutes, indefinite tenability can be assumed provided that the fire does not spread.
- Temperatures in excess of 60^0C are confined to the area around the fire source.
- The conditions associated with fighting the fire are much improved from scenario 1 – particularly as there is a 'safe' zone on the lower level of the enclosure from which firefighting efforts could be based which is unaffected by the fire on the elevated roadway.

Scenario 3:

- Tenability on the elevated roadway is slightly improved but comparable with scenario 1 in the short term. In contrast to the hypothetical datum tunnel, the smoke and temperature conditions become steady after approximately 15 minutes leading to much improved tenability conditions beyond this time when compared with scenario 1. In addition, there is the benefit that the fire itself is not on the elevated roadway. Tenability is achieved throughout a 20 minute period with the steady smoke and temperature conditions beyond approximately 15 minutes indicating continuing tenability.
- Localised patches of reduced visibility and increased temperature occur on the elevated roadway but these fluctuate and are not expected to be limiting to egress – particularly as there is no fire on the elevated roadway.
- Tenability is achieved at the lower road levels and could be considered to be indefinite with the large height of the enclosure allowing the smoke and heat to rise well above the roadway.
- Firefighting conditions are much improved from scenario 1 at both road levels – particularly at the lower level which could be used to fight a fire on the elevated level also.

Refer to sections 7 and 8 below for the comparative outputs of the scenarios described above. For the temperature plots, 60^0C indicates 60^0C and above as this is the temperature which has been taken as the acceptance criteria for the purpose of this exercise.

6 Occupant Egress

The egress and human movement simulator, Pathfinder, has been used to estimate the occupant movement and evacuation times. The following parameters have been considered:

- An average of 1.5 occupants per vehicle;
- Cars are estimated to be approximately 4.9-5.2m in length and queuing at 6.7m centres;
- Each lane has been assessed to have 22 vehicles. It has been conservatively assumed that there are four full lanes of traffic along the entire length of the land bridge even though there are only three lanes at the entry;

- One passenger bus containing 50 passengers has also been included without reducing the number of cars;
- Thus a total of 182 occupants;
- The fire is assumed to be located at the northern end of the land bridge and to be conservatively blocking exit via both of the Western Distributor streams towards the Sydney Harbour Bridge and towards King St;
- Population distribution and travel speed;
    - Adults (90%): 1.2m/s
    - Child (5%): 0.5m/s
    - Disabled (5%): 0.5m/s
- Egress is via the road ways only; and
- Combined cue time and pre-movement time is taken as 1-4 minutes uniformly distributed over the occupants.

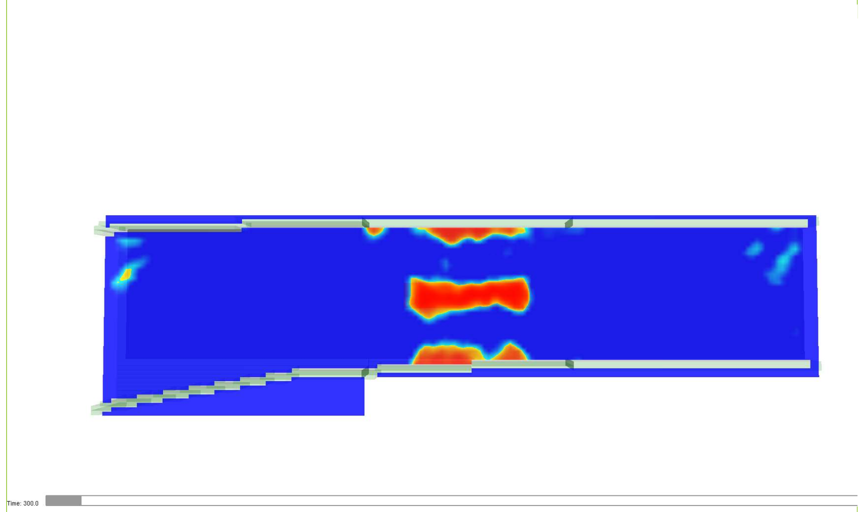
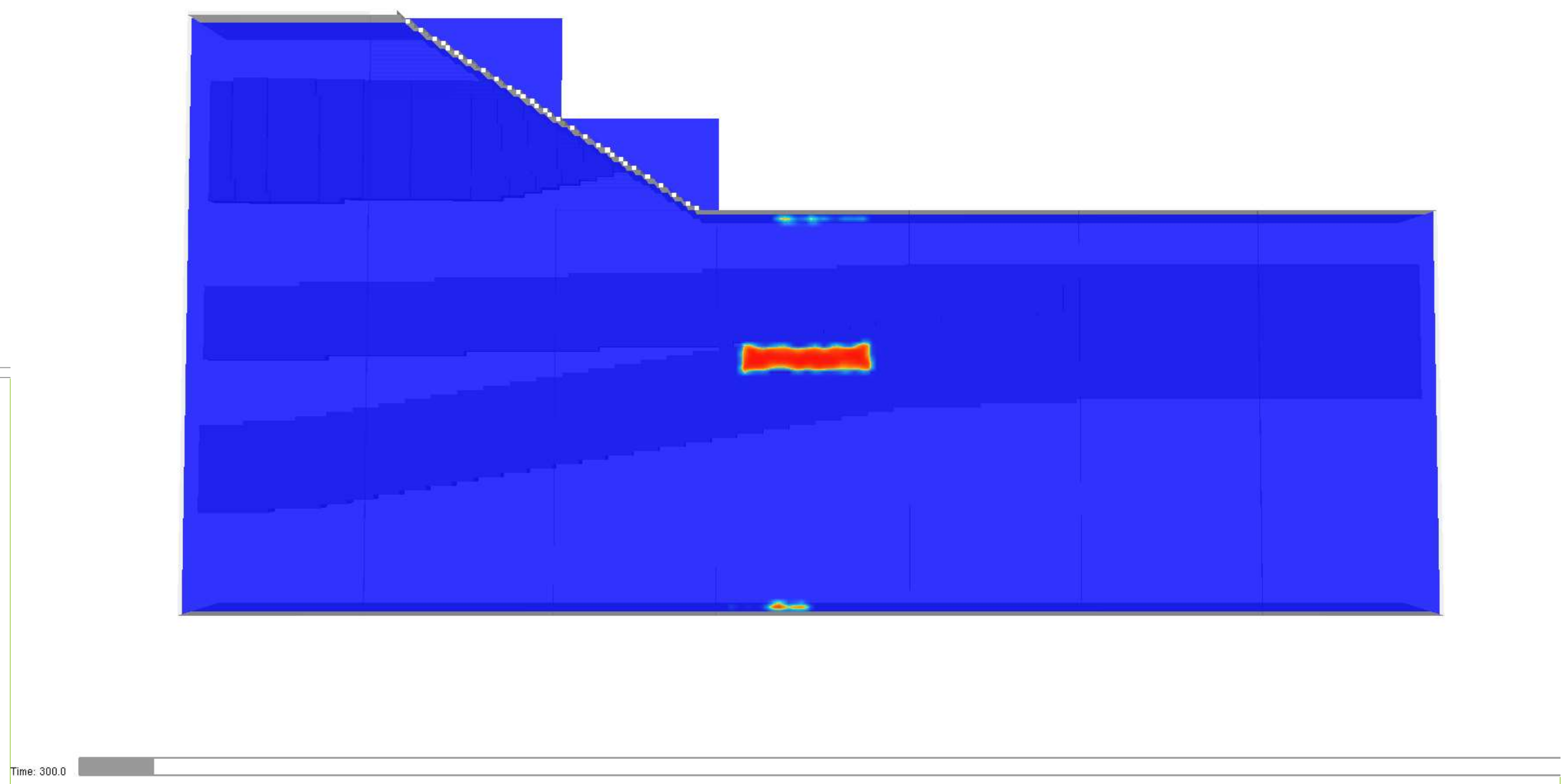
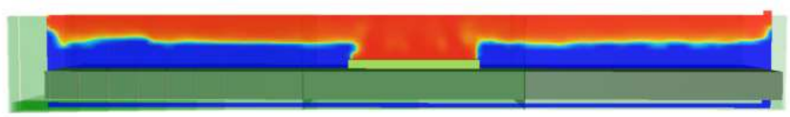
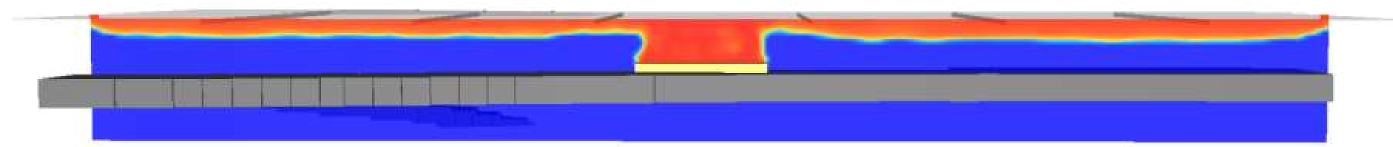
Our analysis indicates that the required egress time for upstream users to safely evacuate in the above scenario is 8 minutes.

Were only one of the northern exits to be blocked the egress time would reduce to 7 minutes.

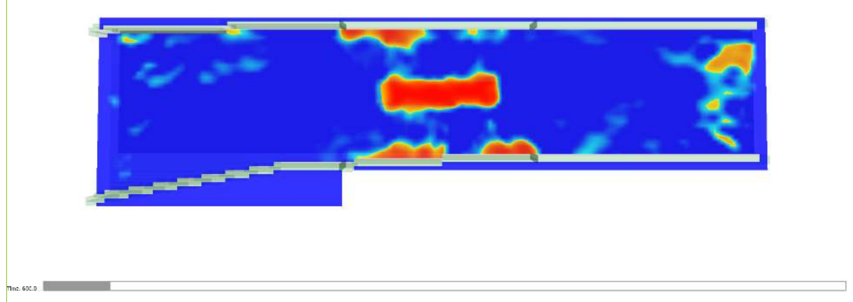
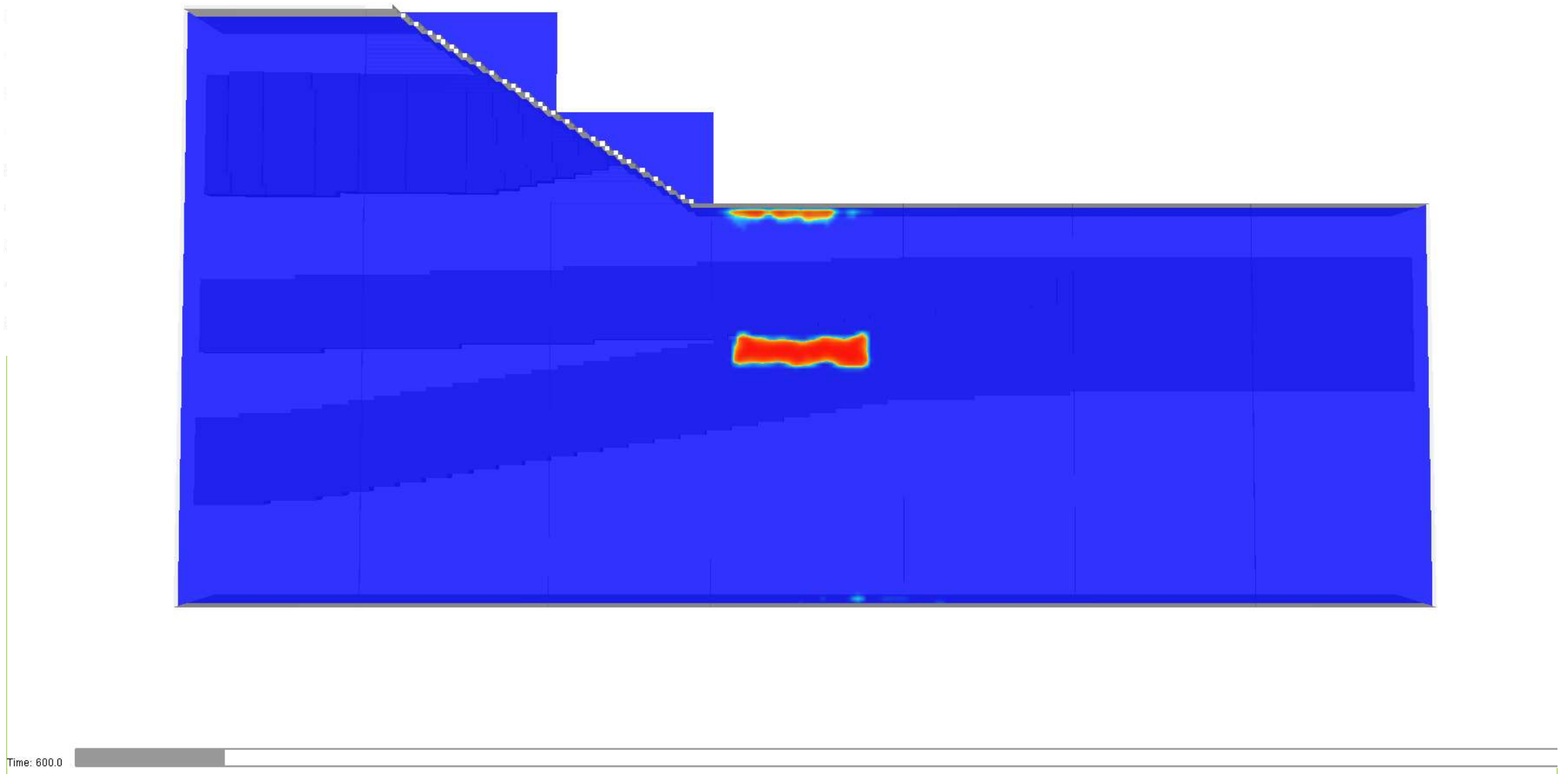
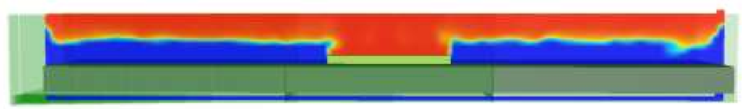
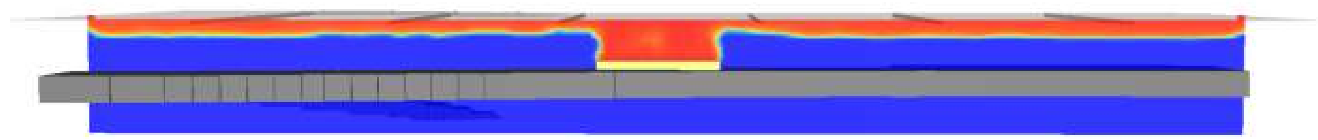
In the case where the fire is located in the centre of the elevated roadway beneath the land bridge (as assessed as being the most critical case for the fire simulations), and exits were available at either end, the egress time has been determined as 5 minutes. Users downstream would continue to drive and exit the underpass as normal and are not expected to be affected by the fire.

7 Comparison of Fire on the Elevated Western Distributor and 80m Long Datum Tunnel

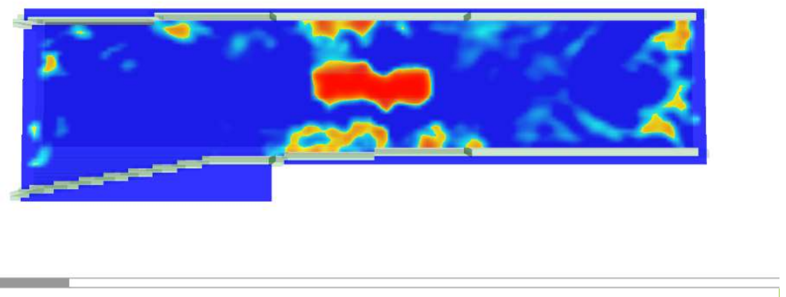
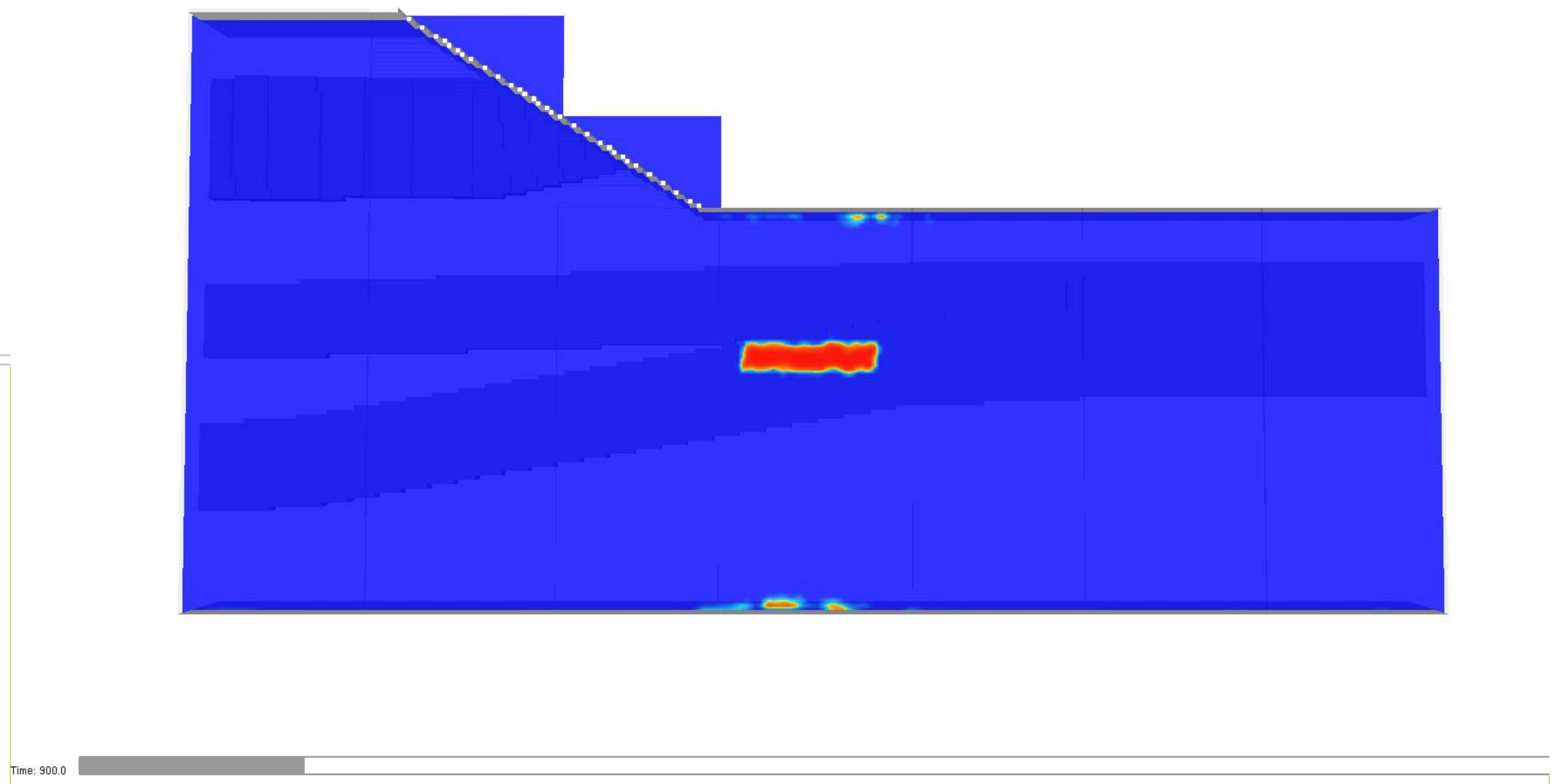
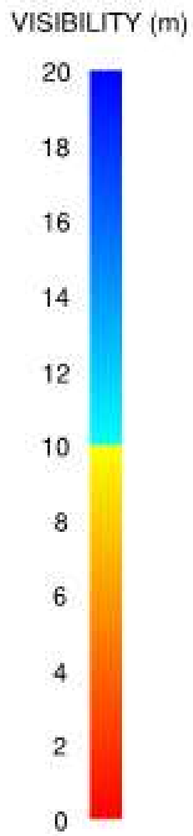
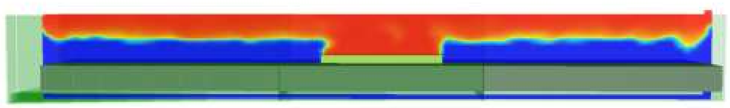
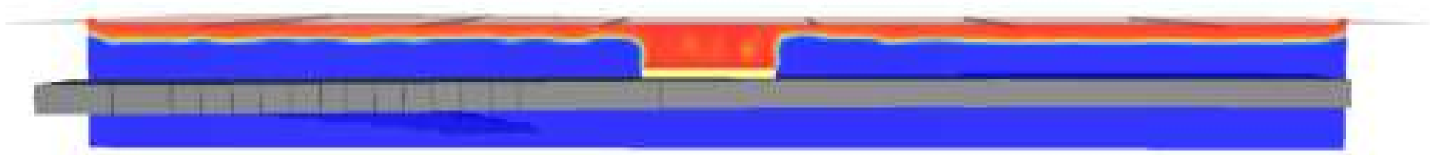
7.1 Visibility – after 5 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	**Scenario 2 – Fire on the elevated Western Distributor**	
Plan – 2m above road			
Long Section			

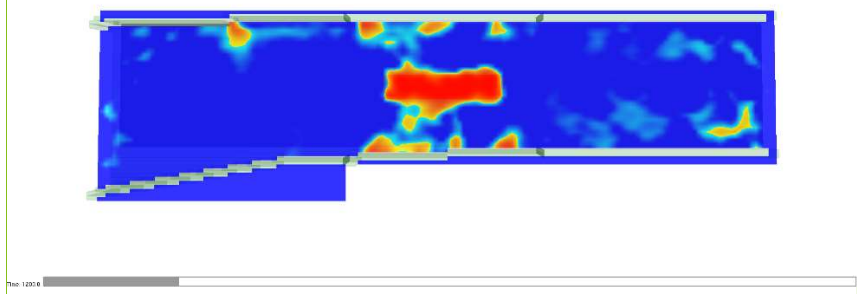
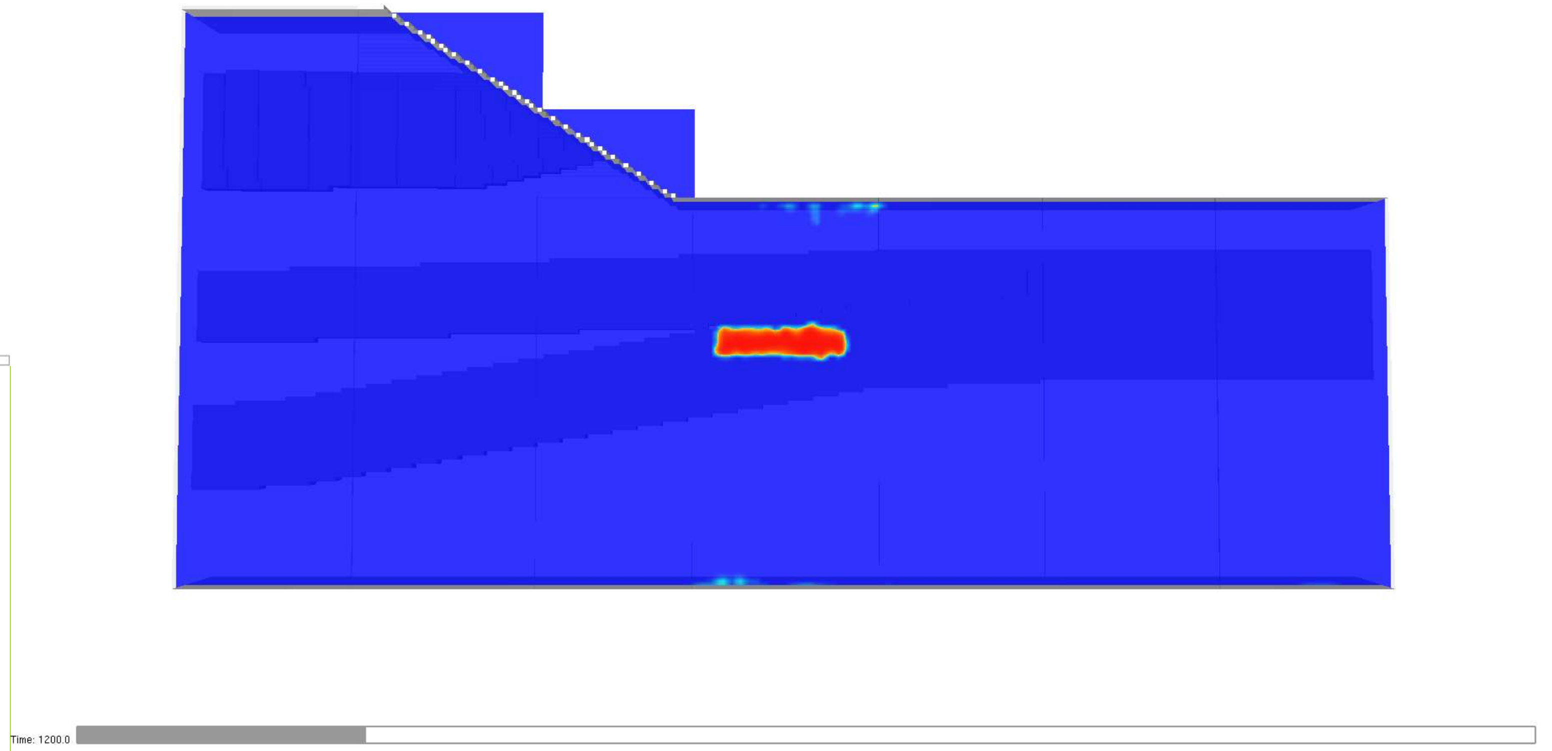
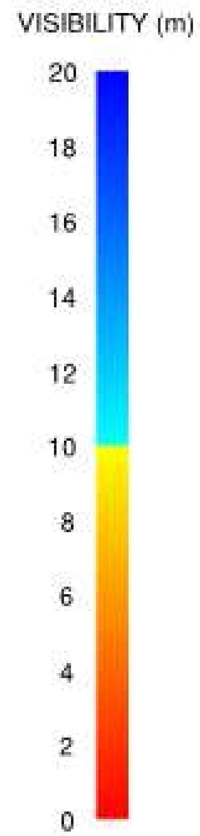
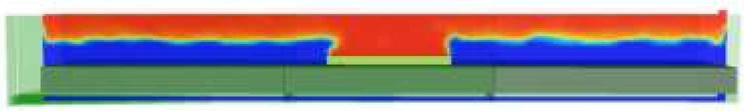
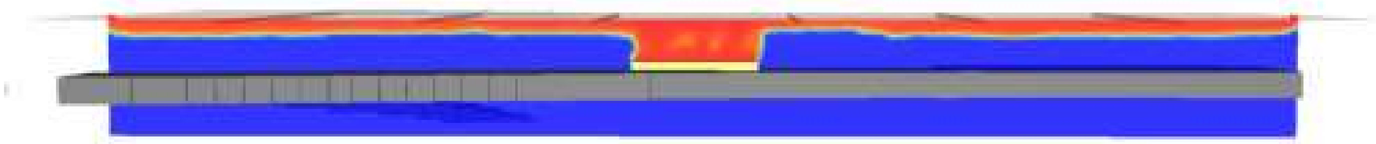
7.2 Visibility – after 10 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

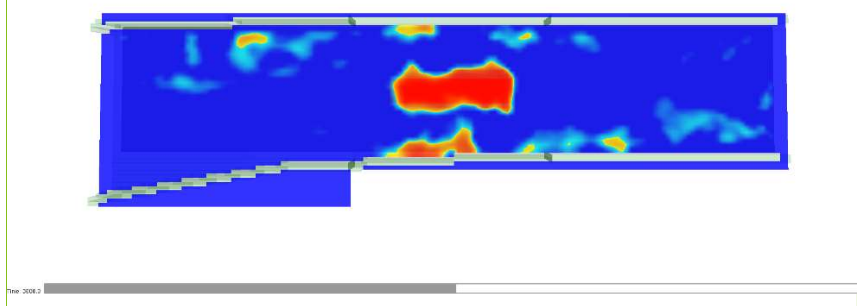
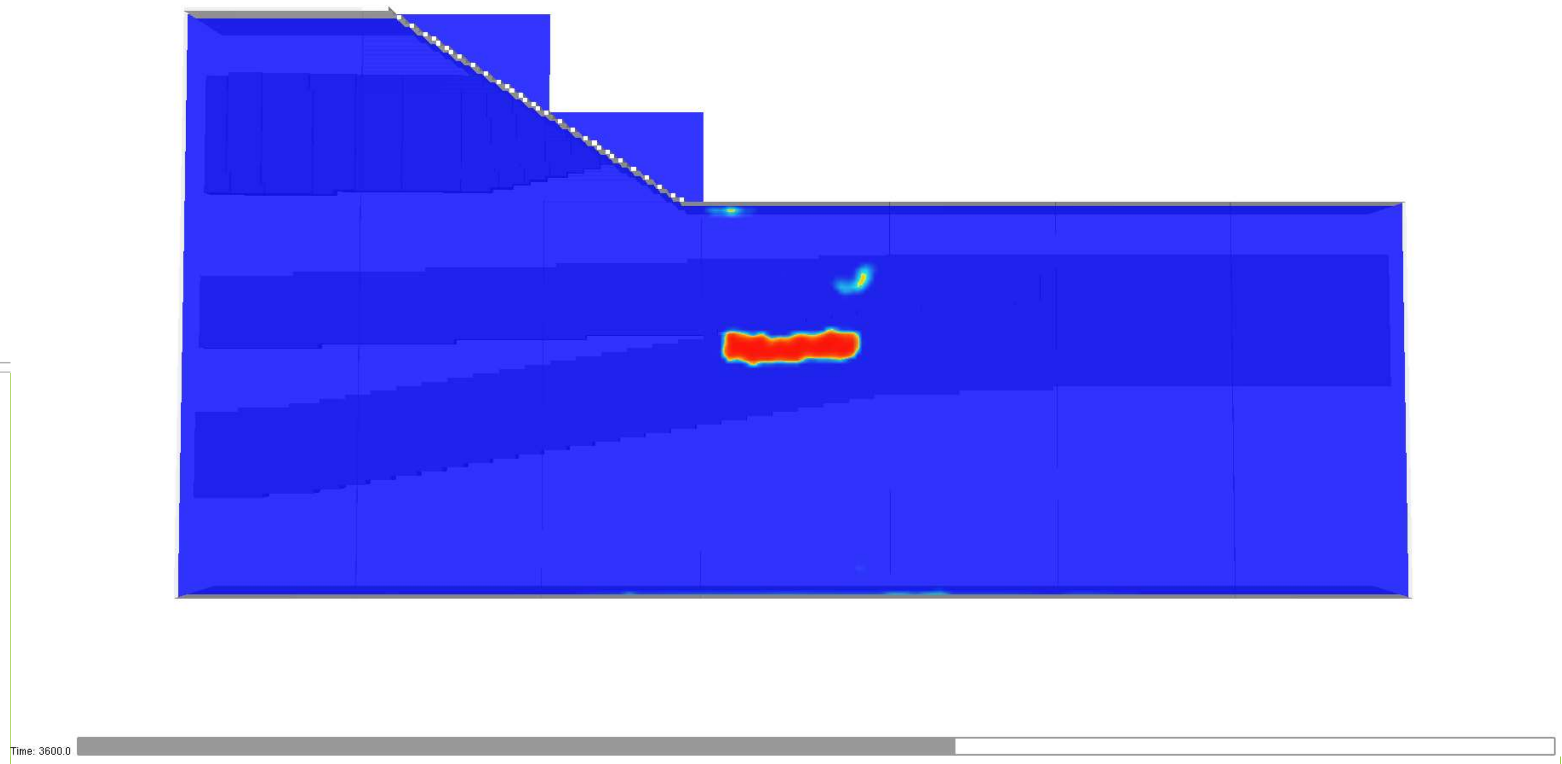
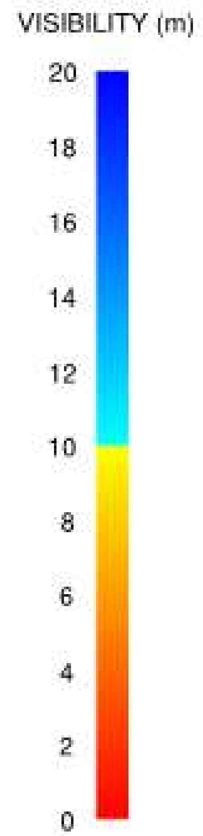
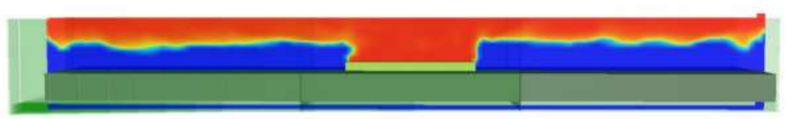
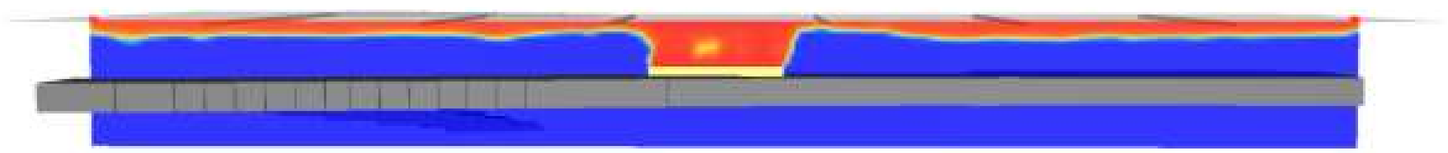
7.3 Visibility – after 15 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

7.4 Visibility – after 20 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

7.5 Visibility – after 60 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	**Scenario 2 – Fire on the elevated Western Distributor**	
Plan – 2m above road			
Long Section			

7.6 Visibility – after 100 minutes

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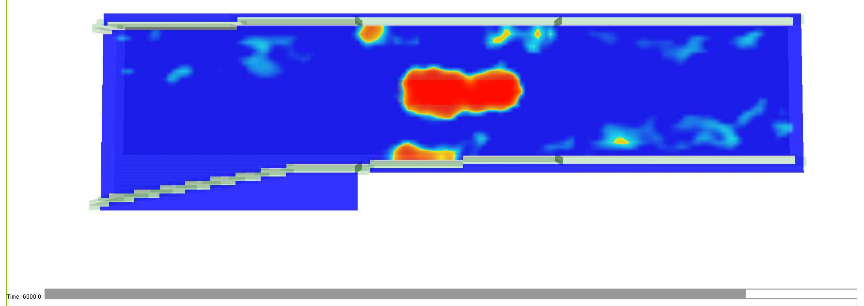
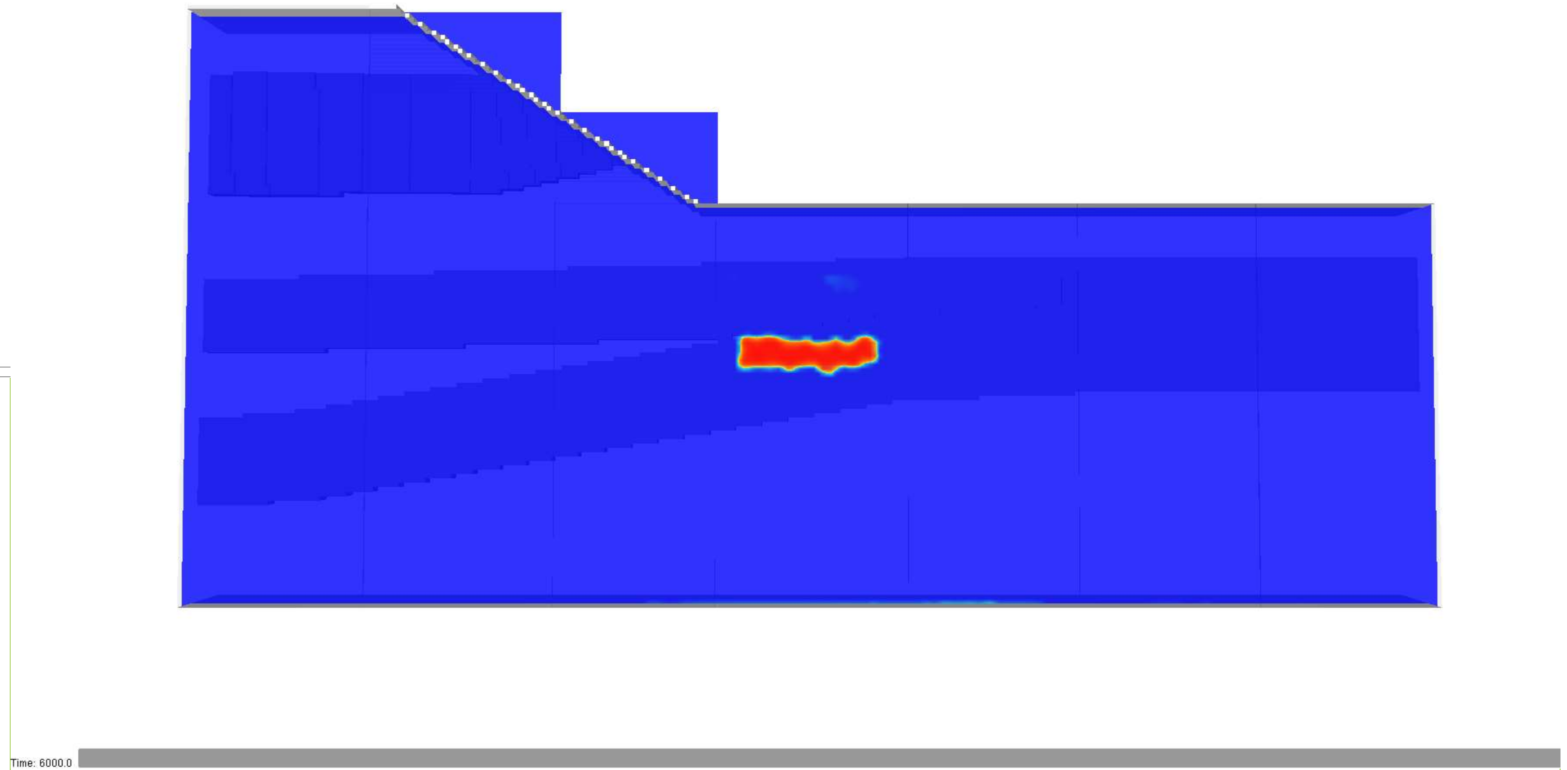
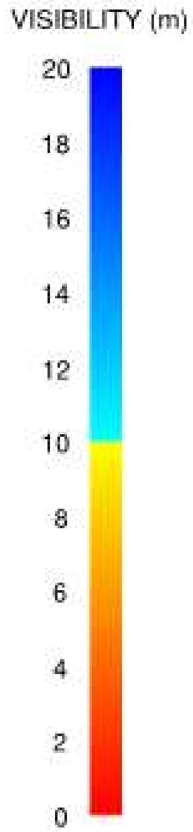
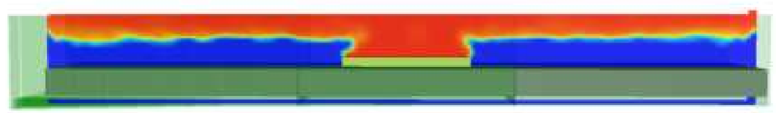
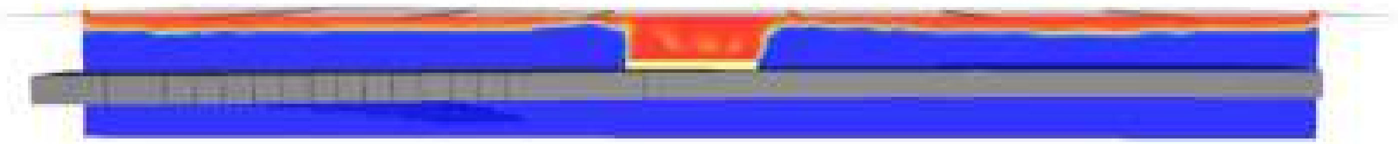
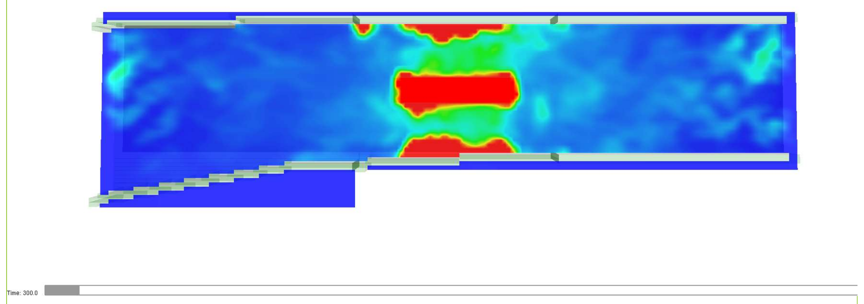
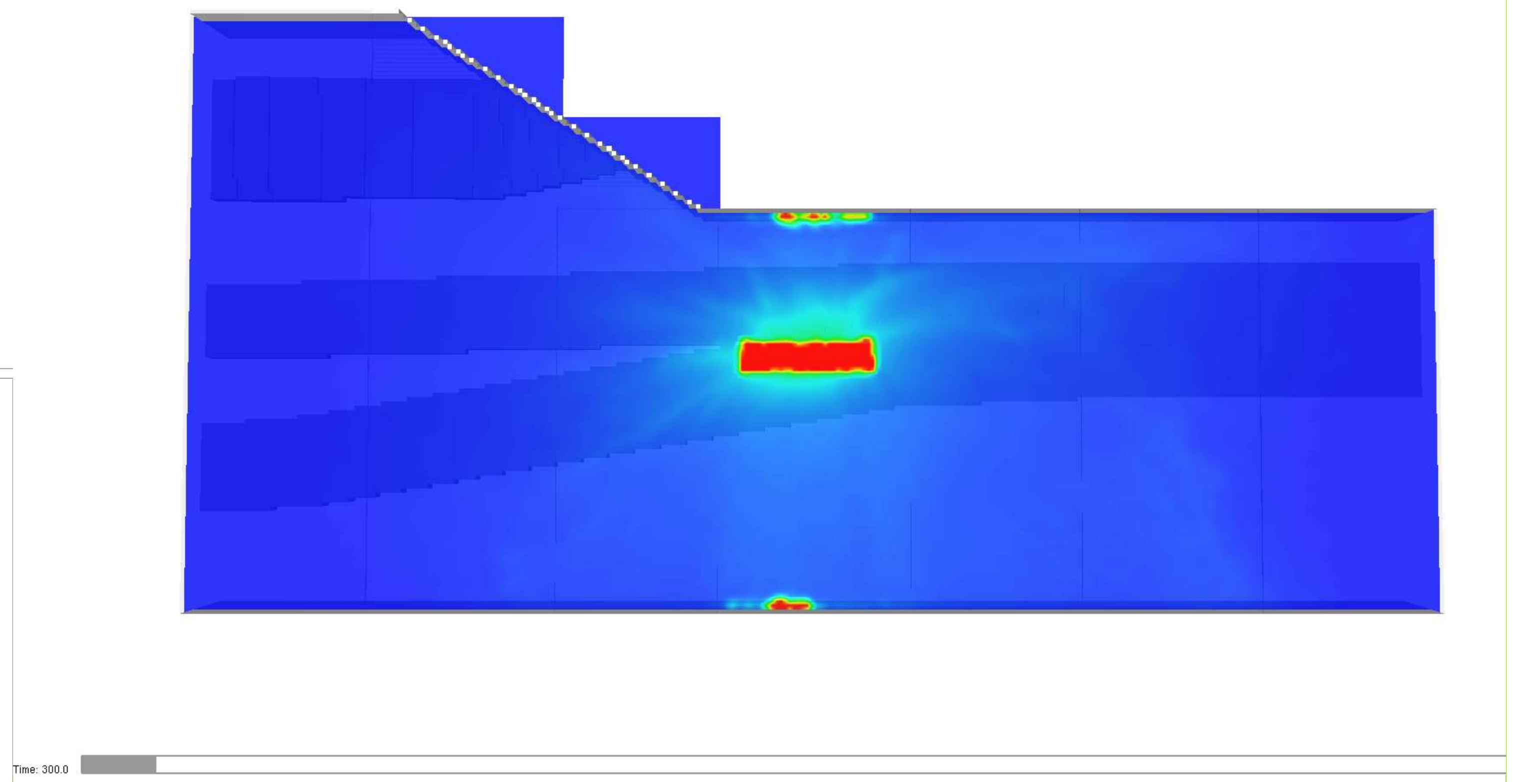
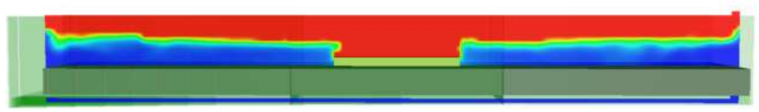
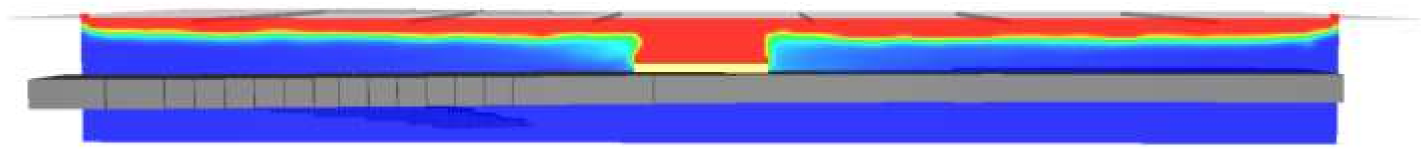
Plan – 2m above road			
Long Section			

7.7 Temperature – after 5 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan - 2m above road			
Long Section			

7.8 Temperature – after 10 minutes

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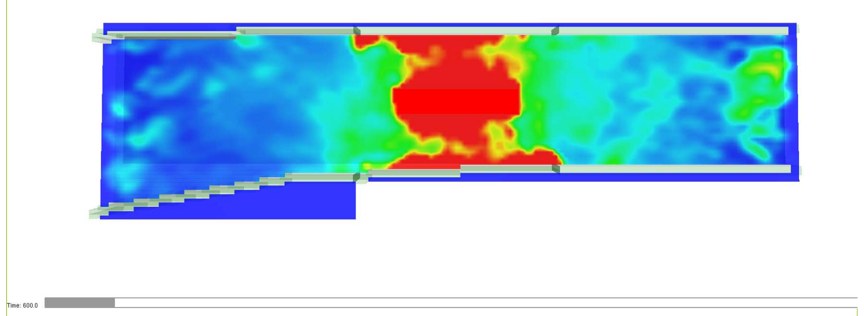
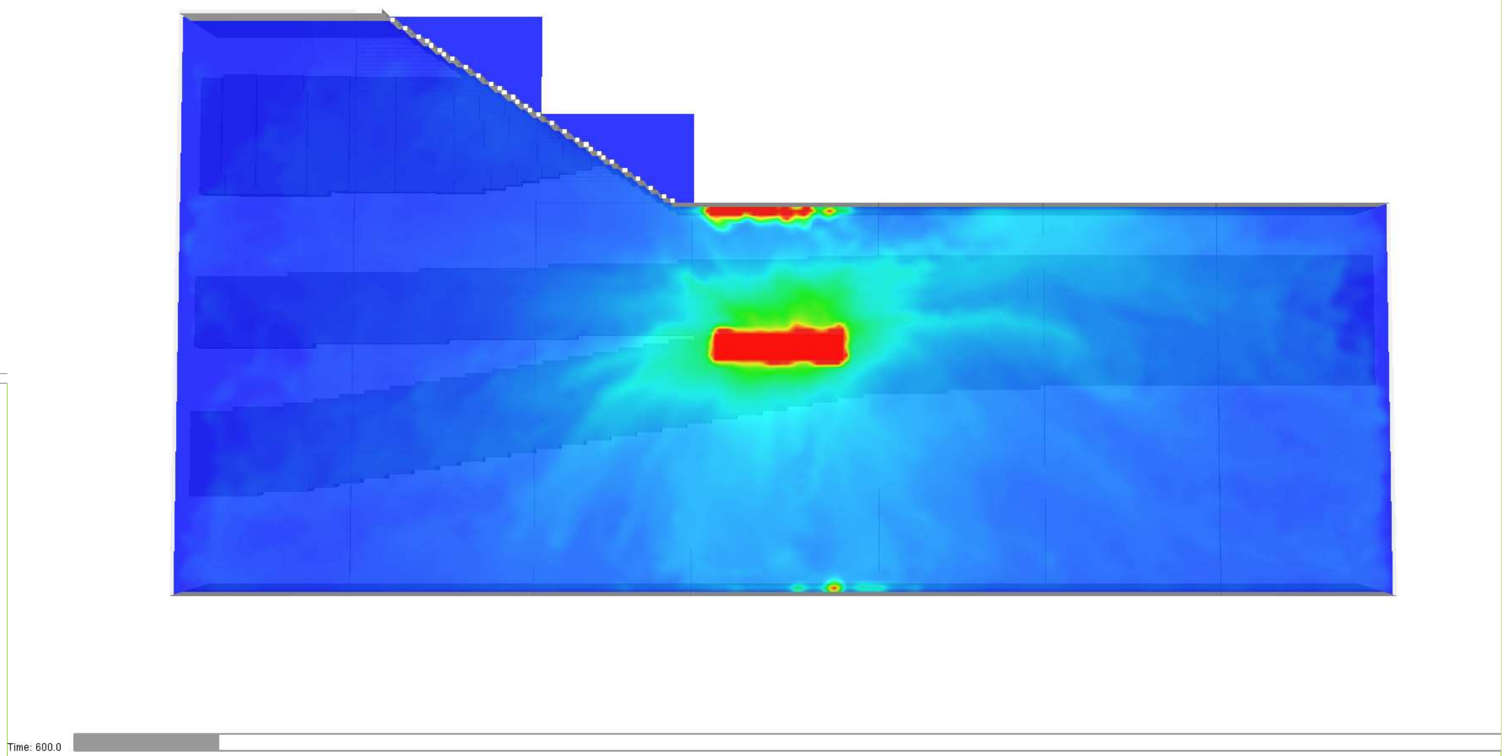
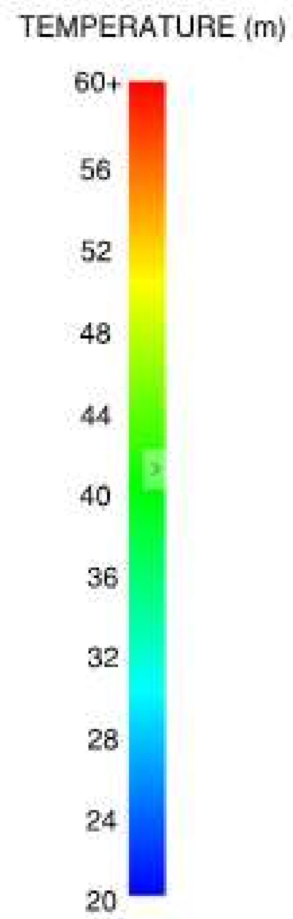
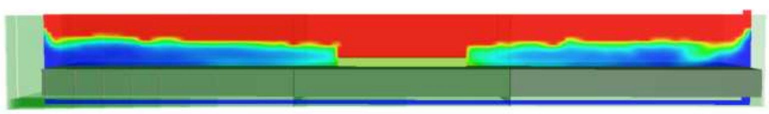
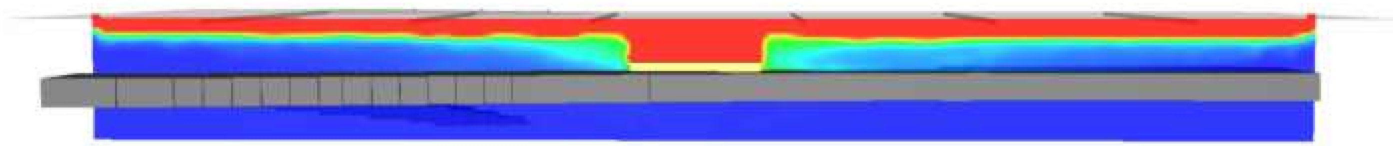
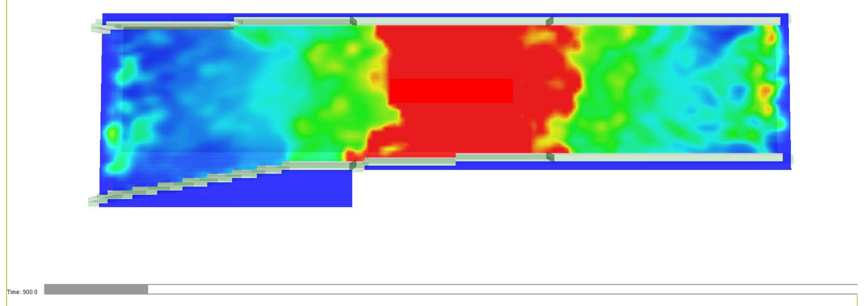
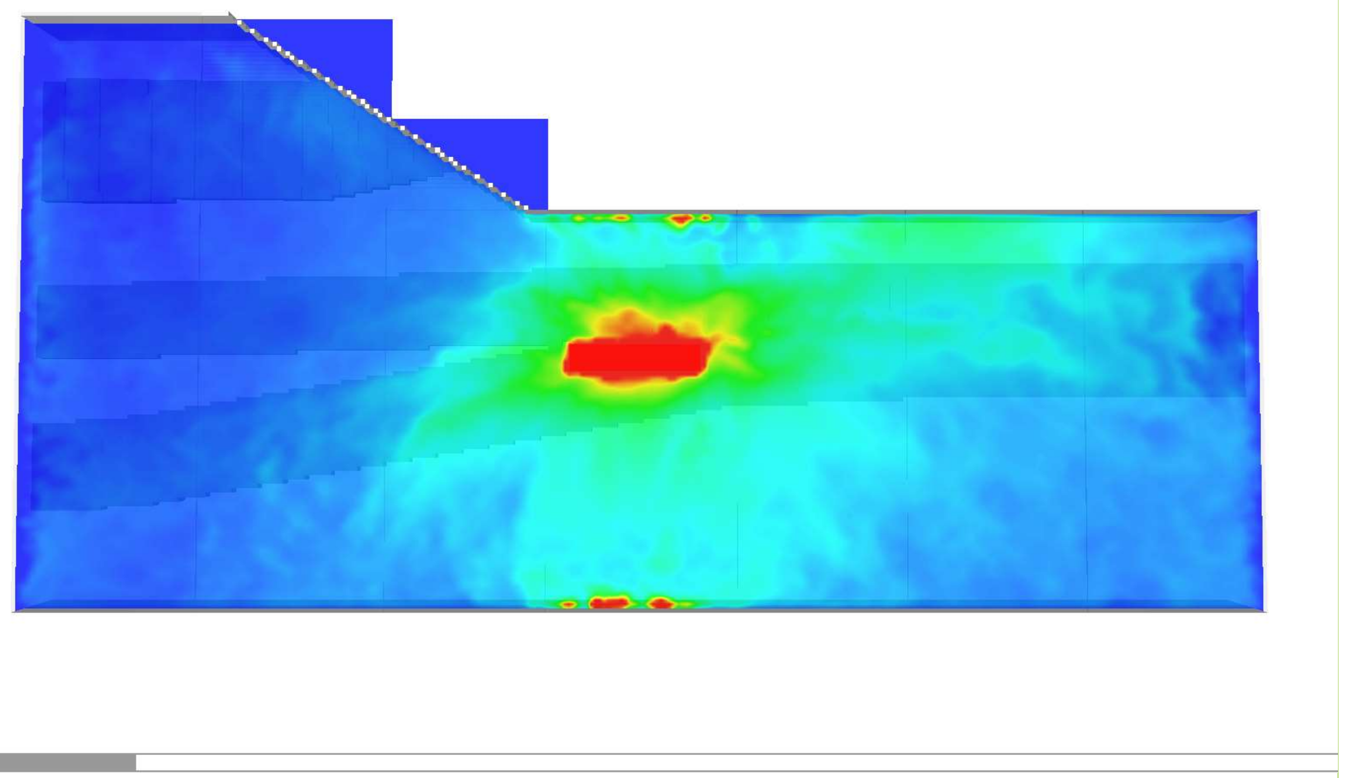
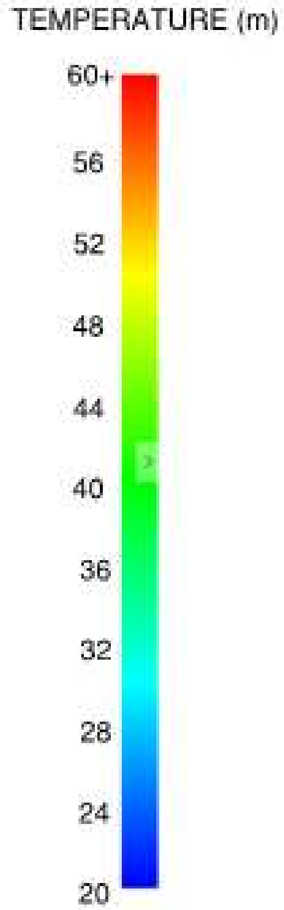
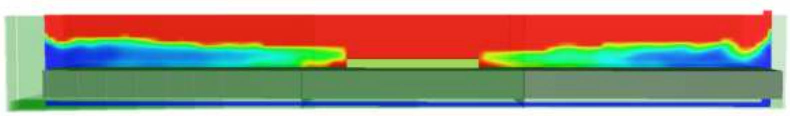
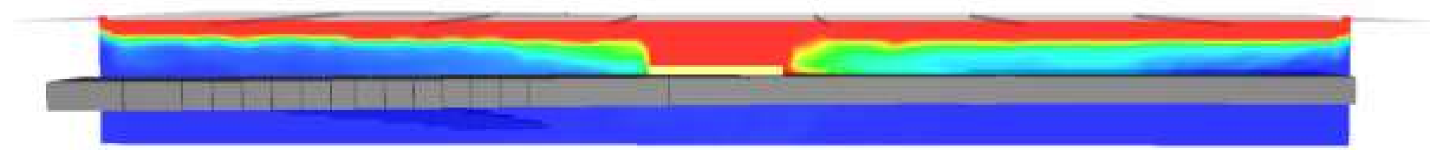
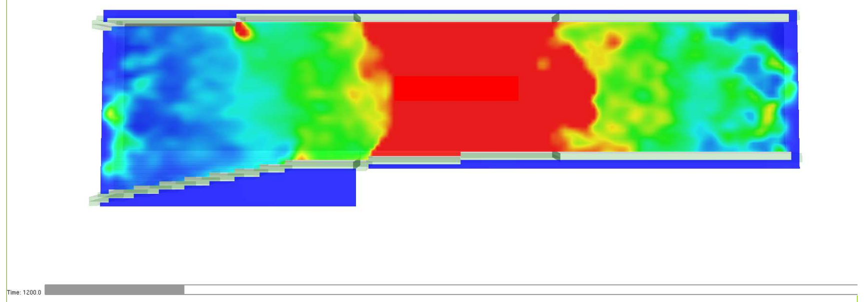
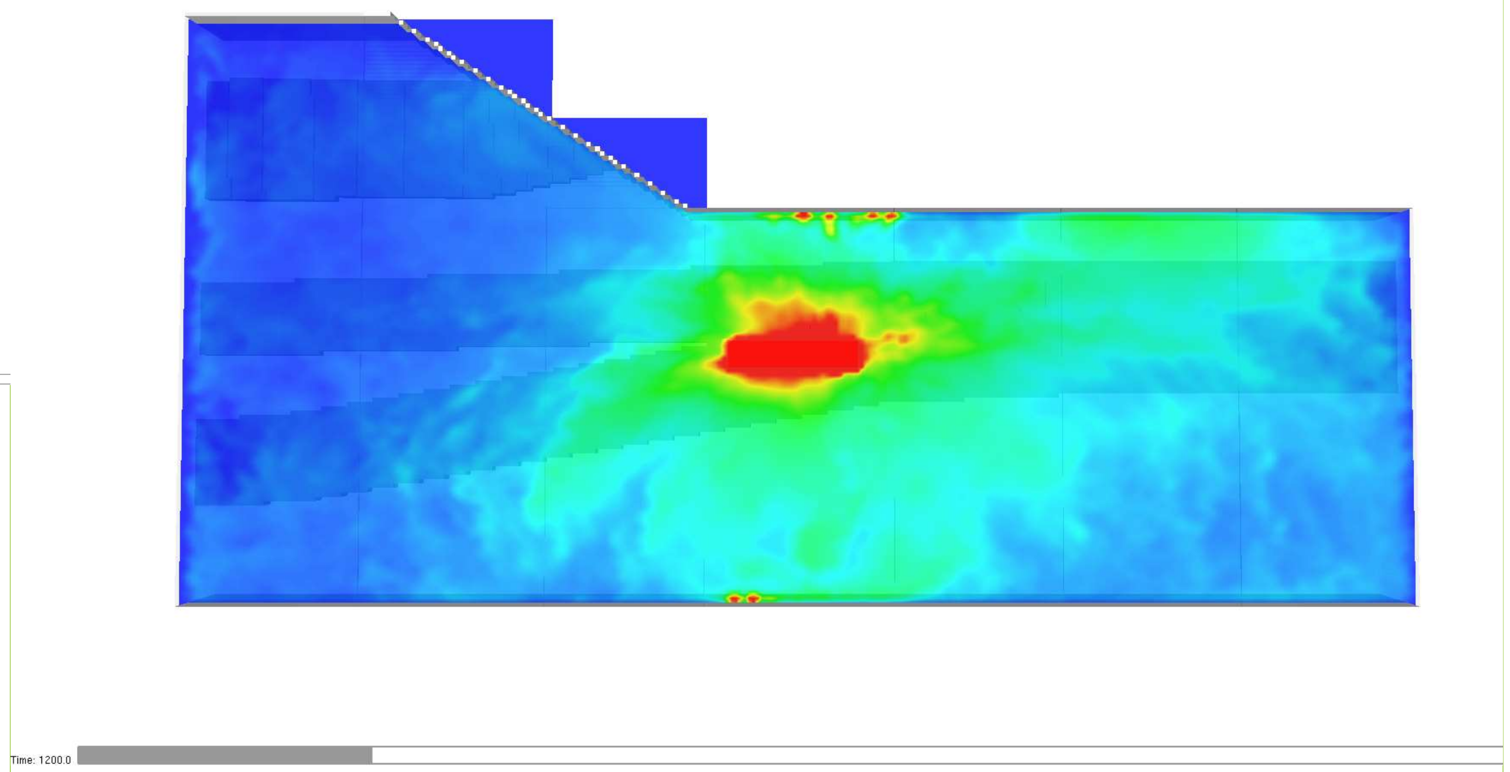
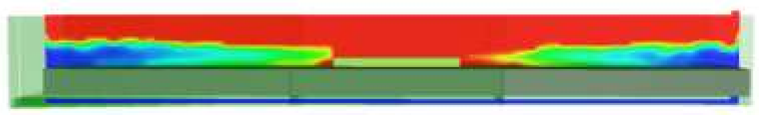
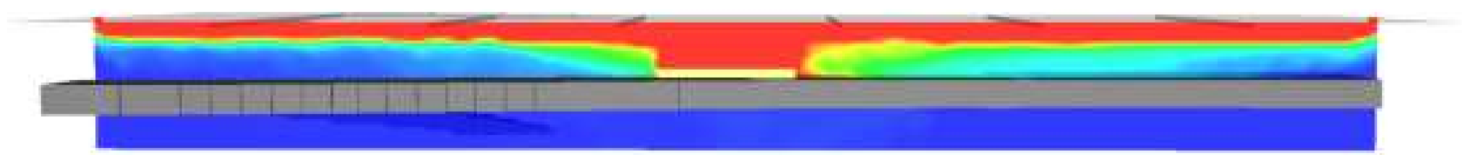
Plan – 2m above road			
Long Section			

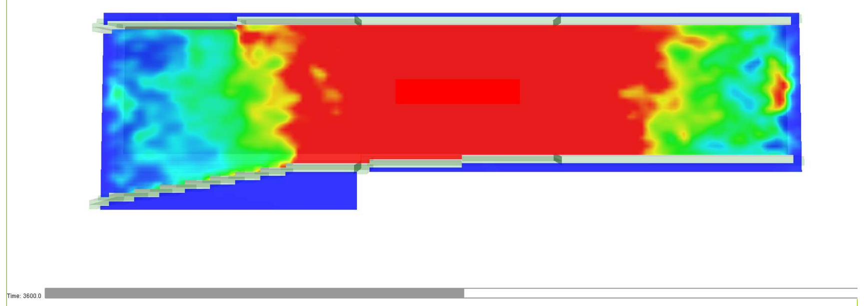
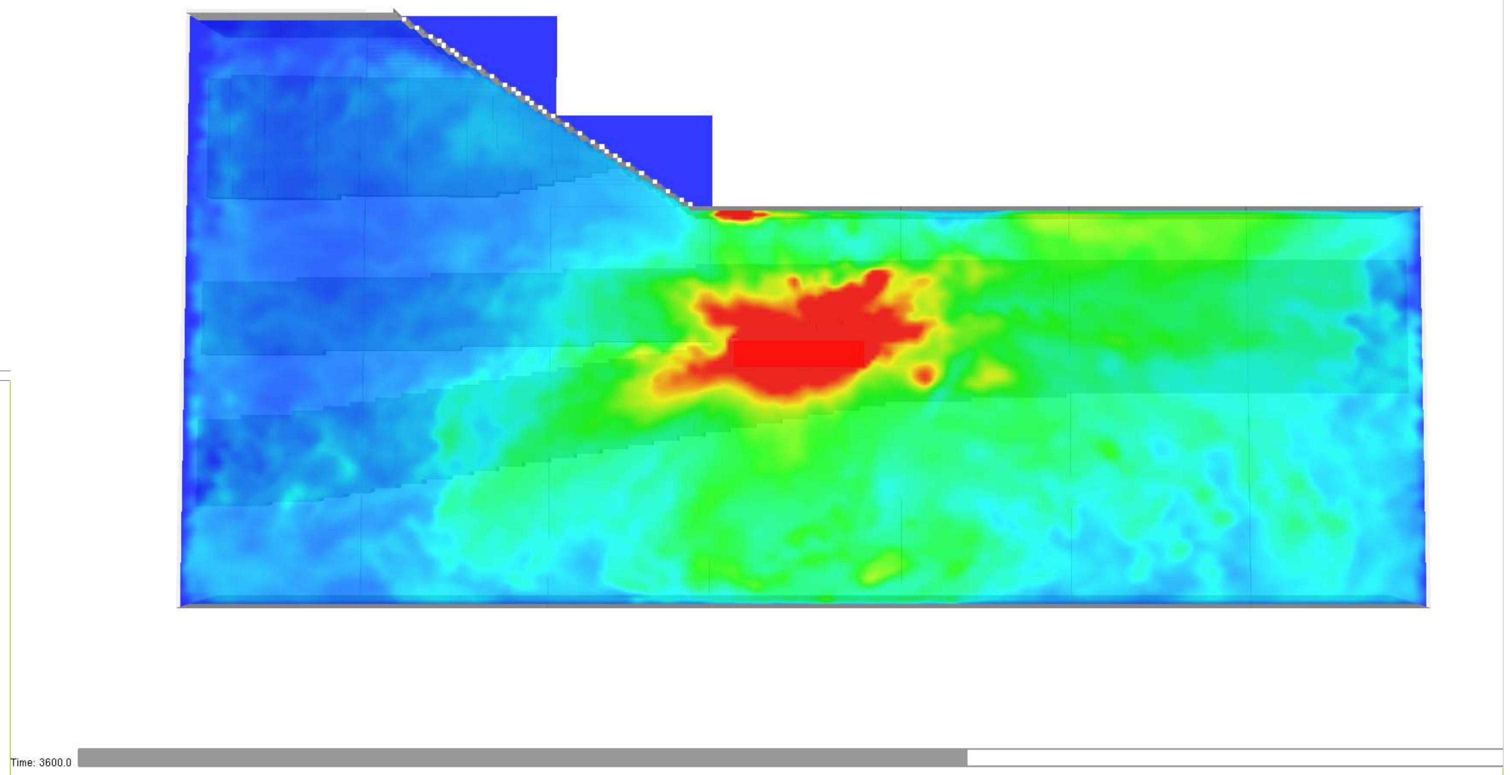
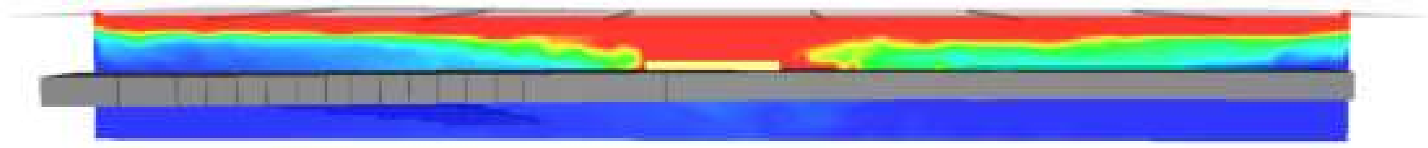
7.9 Temperature – after 15 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

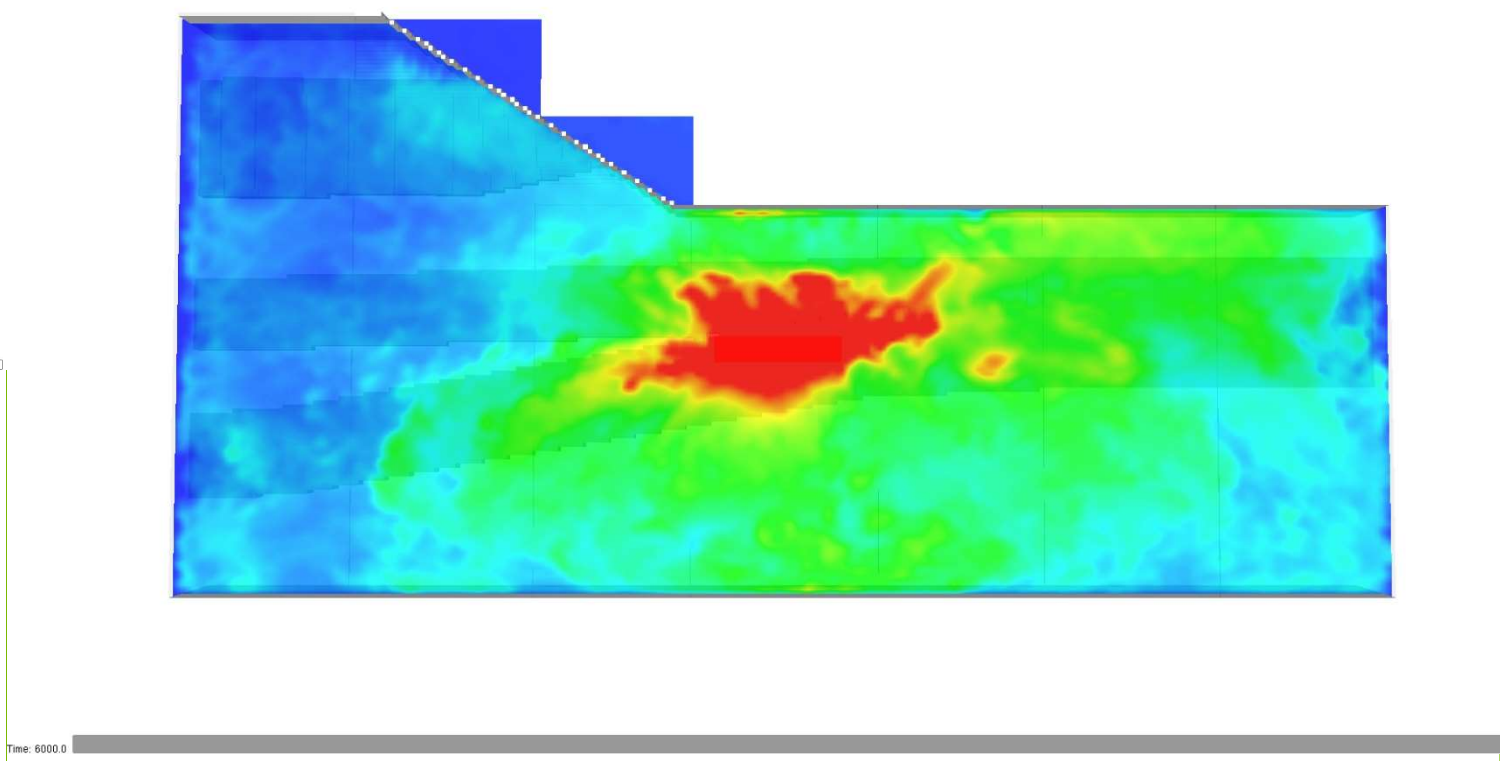
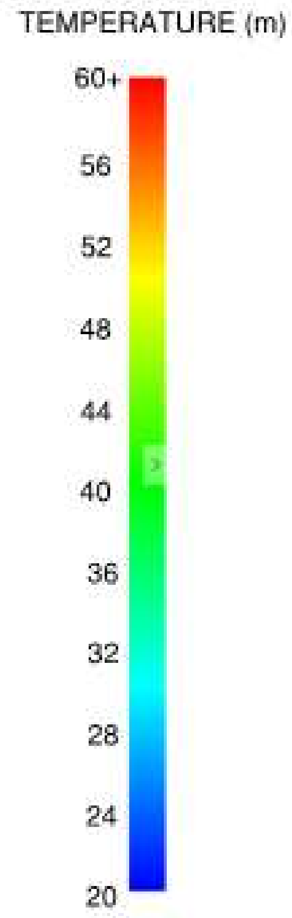
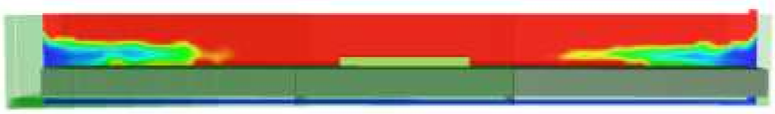
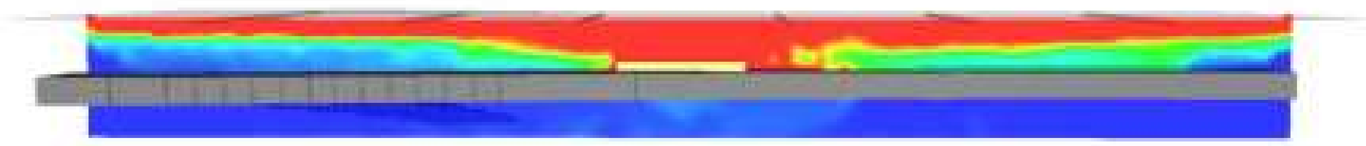
7.10 Temperature – after 20 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

7.11 Temperature – after 60 minutes

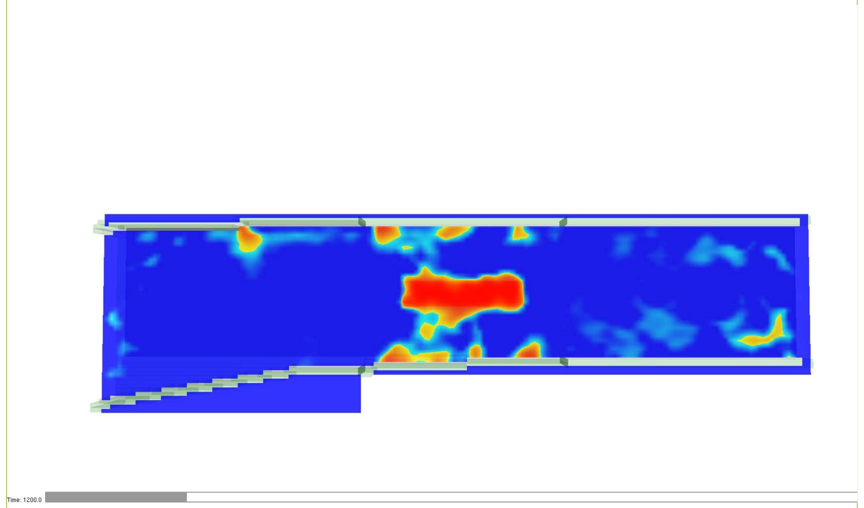
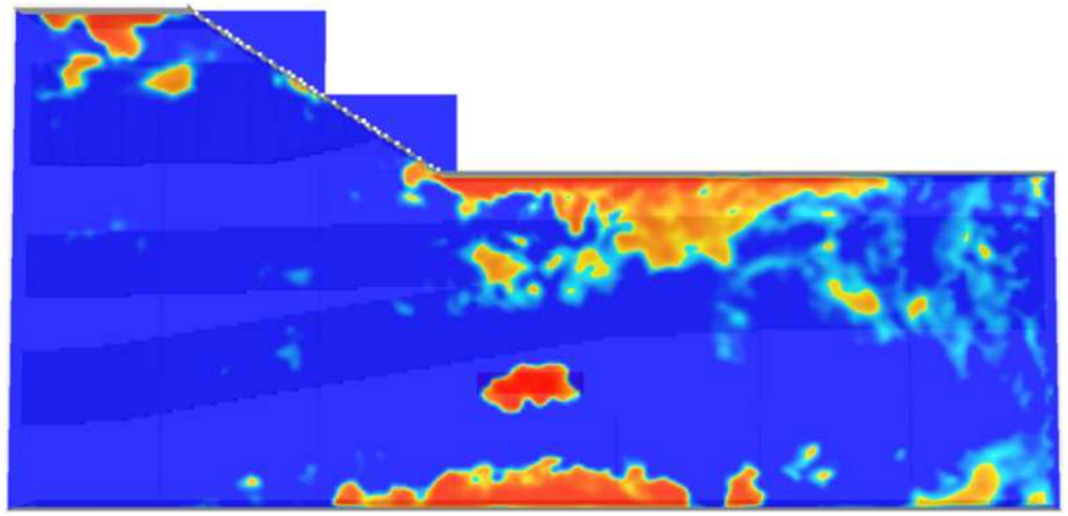
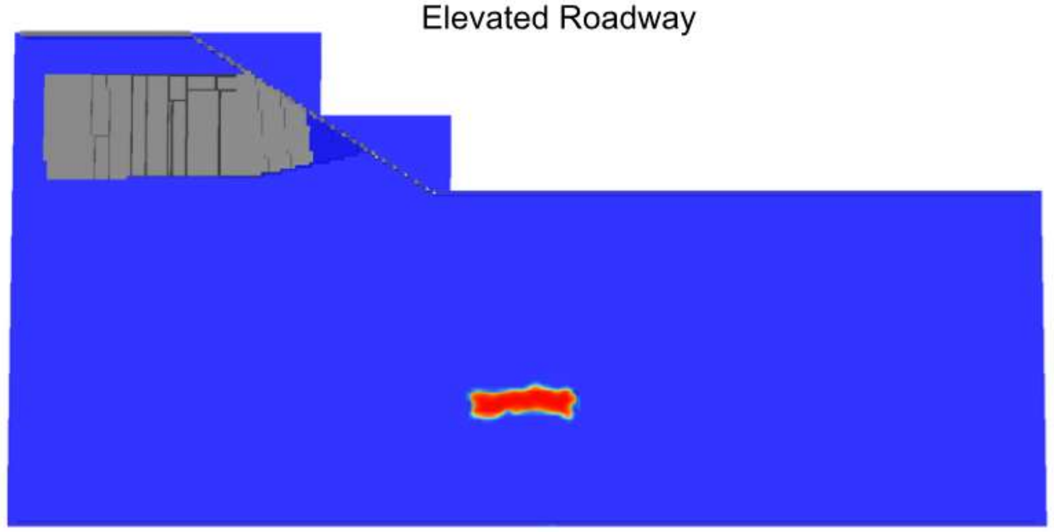
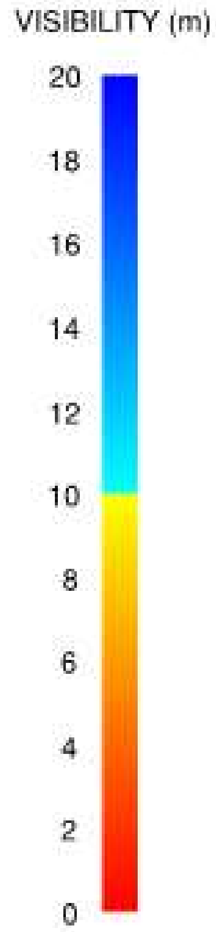
	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

7.12 Temperature – after 100 minutes

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 2 – Fire on the elevated Western Distributor	
Plan – 2m above road			
Long Section			

8 Comparison of Fire on the Northbound Harbour St and 80m Long Datum Tunnel

8.1 Visibility – after 20 minutes
(simulations indicated stable conditions in the underpass after this time)

<table>
<tr><th></th><th>Scenario 1 – Fire in 80m long hypothetical datum tunnel</th><th>Scenario 3 – Fire on the northbound Harbour St</th><th></th></tr>
<tr><td>Plan – 2m above road</td><td></td><td>
Elevated Roadway

Harbour St</td><td>
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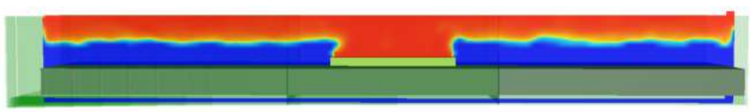
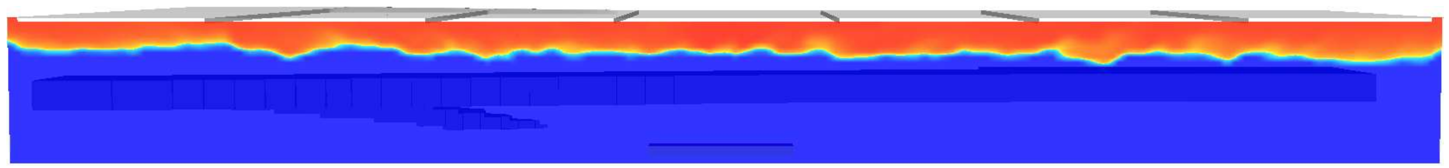
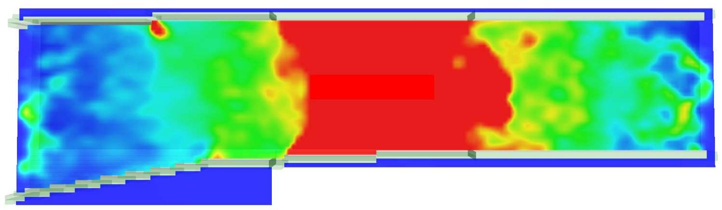
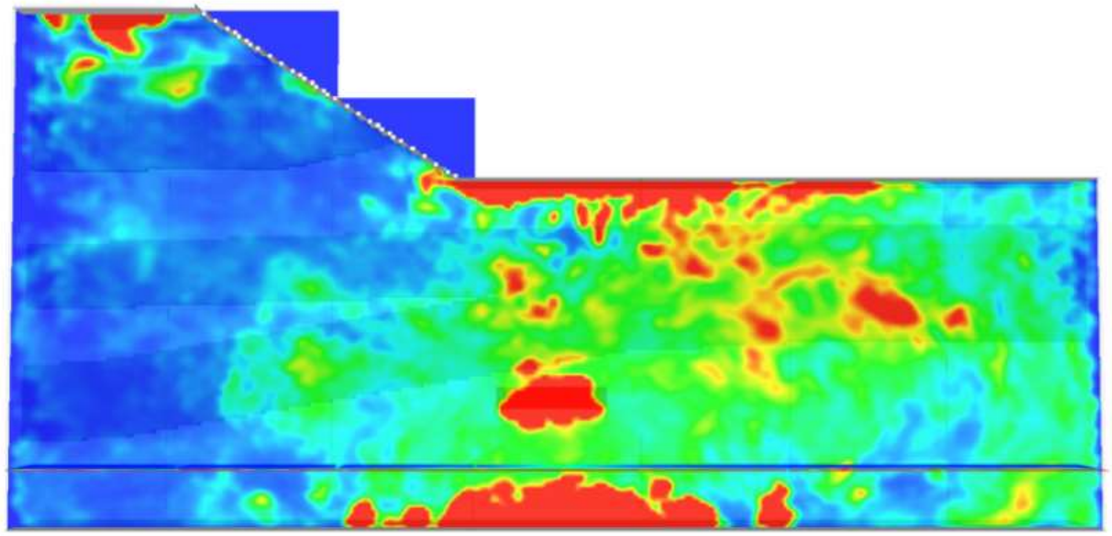
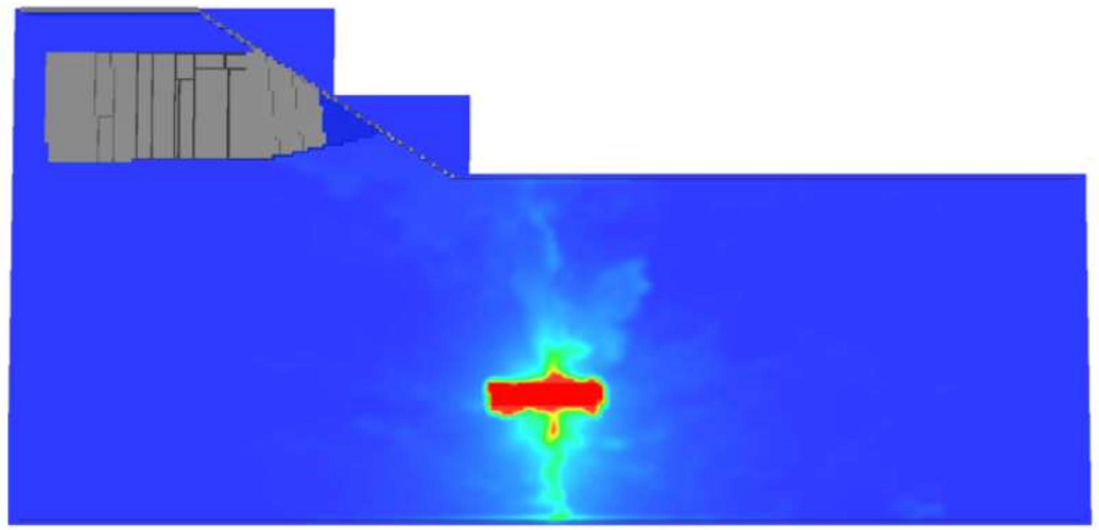
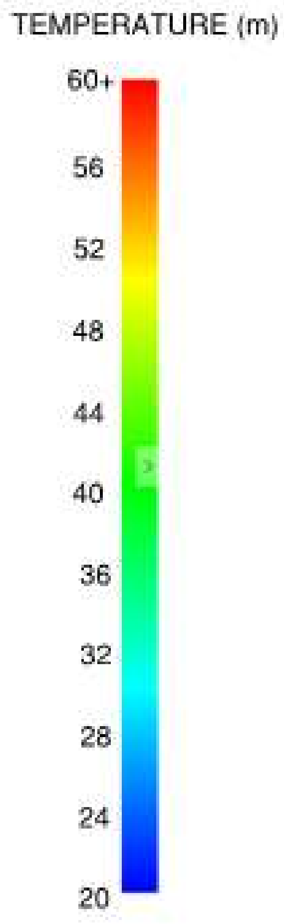
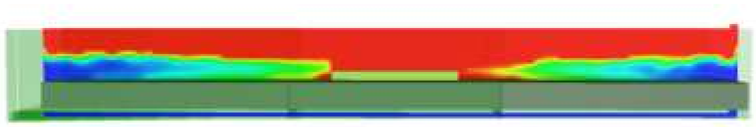
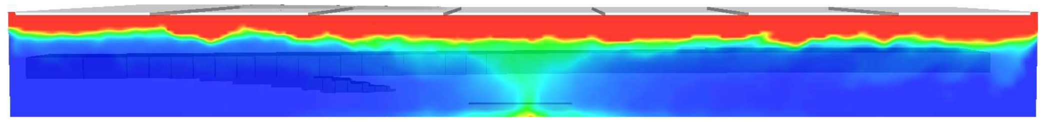
<tr><td>Long Section</td><td></td><td></td><td></td></tr>
</table>

8.2 Temperature – after 20 minutes
(simulations indicated stable conditions in the underpass after this time)

	Scenario 1 – Fire in 80m long hypothetical datum tunnel	Scenario 3 – Fire on the northbound Harbour St	
Plan – 2m above road		 Elevated Roadway  Harbour St	
Long Section			

9 Four Points by Sheraton Western Distributor Underpass Case Study

The Four Points by Sheraton development located at 161 Sussex St is constructed over the top of the Western Distributor motorway approximately 45m from the proposed Cockle Bay Wharf land bridge. This underpass is in excess of 150m in length and features 6 lanes of bi-directional traffic. It was defined as a long underpass.

There are a number of similarities between the Four Points Underpass and the proposed land bridge. These include:

- Comparable length (Four Points by Sheraton Underpass is slightly longer);
- The roads which pass through the Four Points by Sheraton Underpass would also pass below the proposed land bridge resulting in consistency in both volume and type of traffic for the roadways common to both. As the roadways unique to the proposed land bridge only carry traffic from the CBD via Market St or to the CBD via King St it is considered unlikely that there would be a significantly greater number of Dangerous Goods Vehicles (DGV) below the land bridge in comparison to the Four Points by Sheraton Underpass;
- Possibility of vehicles changing traffic lanes;
- Roads are either uni-directional or separated by a median barrier; and
- Egress is via the roadways.

The similarities listed above would indicate that the likelihood of a DGV fire event occurring could at this point be considered as equal between the two developments. The risk analysis undertaken as part of the performance based fire safety engineering assessment for the Four Points by Sheraton project removed the requirement to design for a DGV fire event on the basis that the likelihood of occurrence was approximately 1 fire in 12 000 years without sprinkler protection and 1 fire in 240 000 years with sprinkler protection. As a point of comparison, the maximum earthquake design event in Australia is 1 in 2 500 years. This performance based assessment for the Four Points by Sheraton development also resulted in a significant reduction to the peak heat release rate compared to that considered in the CFD modelling undertaken for this study of the Cockle Bay Wharf development.

The main differences between the two developments are:

- Four Points by Sheraton Underpass is open on the western face with the exception of regular columns. Having a closed western face below the Cockle Bay Wharf land bridge can act as an advantage in the scenario where there is a westerly wind during a fire event.
- Cockle Bay Wharf land bridge has a larger cross section below it than the Four Points by Sheraton Underpass. A comparison is shown below. It is indicative only.

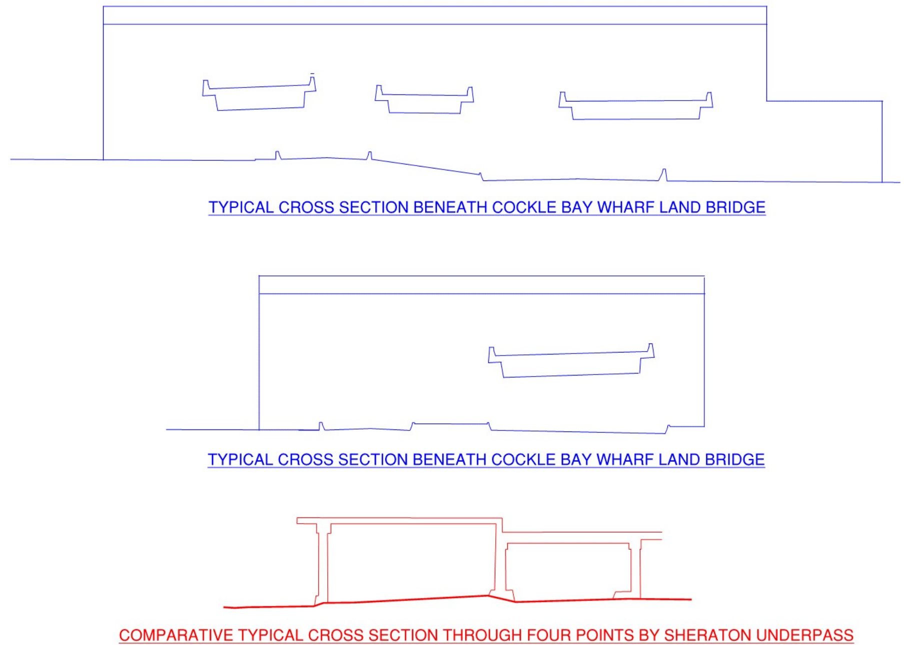


Figure 8: Indicative comparative cross sections between proposed development and Four Points by Sheraton Underpass

The assessment of the roadways beneath the proposed land bridge with regard to fire safety has been deliberately undertaken via a conservative approach as a means of providing a contrast to the Four Points by Sheraton Underpass and an acceptable level of risk at this early stage of project development. This is highlighted in Table 1 below.

Table 1 Fire modelling comparison between Four Points by Sheraton Underpass and the roadways beneath the Cockle Bay Wharf Proposed land bridge

Design Condition	Four Points by Sheraton Underpass Design Modelling Conditions	Cockle Bay Wharf Underpass Modelling Study Conditions
Peak Heat Release Rate (HRR)	50MW with potential failure of the sprinkler system incorporated into the risk analysis 100MW prior to consideration of the benefit of a fire sprinkler system	157MW
Initial growth rate	2.5MW after 4 minutes and then 8MW/min. Therefore 10.5MW fire load after 5 minutes.	11MW/min. Therefore 55MW fire load after 5 minutes.
Mechanical ventilation	Not provided	Not considered
Fire sprinklers	Provided	Not considered
Visibility criteria for tenability	7m	10m
Temperature criteria for tenability	80ºC	60ºC

Tenability time	Noted as being greater than 20 minutes	Continued tenability beyond 20 minutes on the elevated roadway during a fire on Harbour St (test scenario 3). Indefinite on the ground level for a fire on Harbour St (test scenario 3). Indefinite throughout for a fire on the elevated roadway (test scenario 2).
Required safe egress time (RSET)	5.6 minutes for a fire in the centre of the underpass	5 minutes for a fire in the centre of the underpass

The above information regarding the Four Points by Sheraton development is based on the "Fire engineering report R1.2, 161 Sussex Street - Western Distributor Underpass" dated 15 April 2015.

10 Conclusion

The CFD modelling undertaken and the consideration of the work carried out as part of the adjacent Four Points by Sheraton Western Distributor Underpass design indicates that the likelihood of untenable conditions being present within the egress pathways on the roadways beneath the proposed land bridge over the Western Distributor is low.

In undertaking the simulations no means of external provision was used to improve the tenability condition. Tenability was shown to exist by natural means alone.

The CFD modelling indicates that the proposed development has a greater tenability condition than a hypothetical standard tunnel with a length equal to 80m.

Based on the above and with reference to the guidance provided by AS4825 as to the definition of a tunnel being subject to the likelihood of development of untenable conditions, it is concluded that the designation of underpass would be more appropriate for this development.

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