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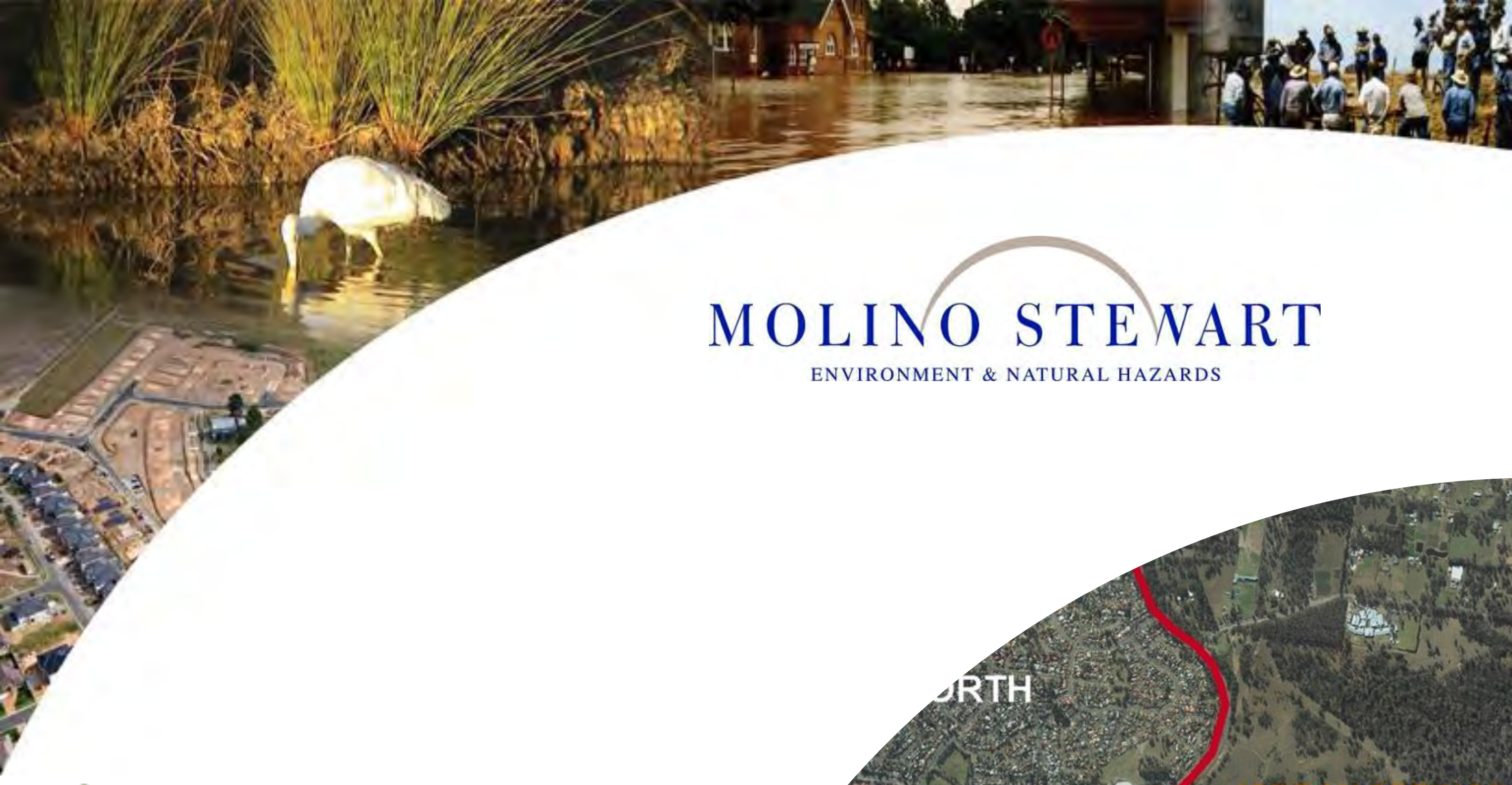
Appendix 4

Additional evacuation assessment prepared by Molino Stewart



MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

lendlease

Jordan Spring East Rezoning

Detailed Evacuation Analysis

Jordan Spring East Modification Proposals

DETAILED EVACUATION ANALYSIS

for

Lend Lease

by

Molino Stewart Pty Ltd
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JULY 2018

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1 BACKGROUND

1.1 BACKGROUND

The evacuation analysis done to date for JSE has been quite conservative with the intention of demonstrating that, under the worst possible combination of circumstances, it would be possible to evacuate all of the residents of JSE from the floodplain without loss of life for residents within JSE or without having to compromise the safety of others evacuating from the floodplain.

This additional information and analysis has been prepared to respond to the issues that NSW SES raised in its letters of 11th May 2018 and 18th May 2018 with regard to the Proposed amendments to Sydney Region Environment Plan No 30 and the Jordan Springs East Precinct Plan, respectively. It specifically addresses some of the comments made by the NSW SES in response to conclusions drawn from earlier analyses. In particular, it provides a more detailed analysis to better describe the conservatism in the former analysis, the range of possible evacuation outcomes and the likelihood of those outcomes.

It must be stressed that the following analyses are based on the best publicly available flood modelling outputs, evacuating vehicle numbers and emergency response plans which are available to Lend Lease and its consultants. We appreciate that INSW and NSW SES are working with different information but that has not been made available to others so it is not possible to use it. Nevertheless, this report provides some indication as to how different assumptions and inputs might impact on evacuation analysis outcomes.

2 WHO IS EVACUATING

Evacuation planning for the Hawkesbury Nepean floodplain is complex and there are multiple sources of evacuation traffic using different routes. Several of these routes converge and there are also towns which need to use different evacuation routes at different stages of flooding. These are shown in

Figure 1 which is taken from the most recently published version of the Hawkesbury Nepean Flood Emergency Sub Plan (NSW SES, 2015).

The NSW SES current plan for Jordan Springs East, although not highlighted in

Figure 1, is for all of the evacuation traffic to evacuate onto The Northern Road from where it will take the Great Western Highway or the M4 east out of the floodplain. These roads are used by other evacuation traffic and there is potential for:

- Traffic from one location taking priority on The Northern Road and preventing other traffic from leaving the floodplain before floodwaters arrive
- Traffic having to queue for extended durations

With regards to the evacuation traffic which needs to use The Northern Road, it is convenient to think of this in three groups:

- Evacuation traffic from the north – this includes all of the traffic from Richmond, Londonderry, Agnes Banks, Berkshire Park and Llandilo as well as some of the evacuation traffic from Windsor, Bligh Park and Windsor Downs if their primary evacuation routes are not open for long enough before being cut by flooding on South Creek.
- Evacuation traffic from the west – this is all of the evacuation traffic in Penrith from Penrith Lakes in the north to the M4 in the south excluding that traffic which enters the M4 via Mulgoa Road
- Evacuation traffic from the east – this includes Jordan Springs East and Werrington.

Figure 2 shows the streams of traffic which enter the Northern Road from the north and the west.

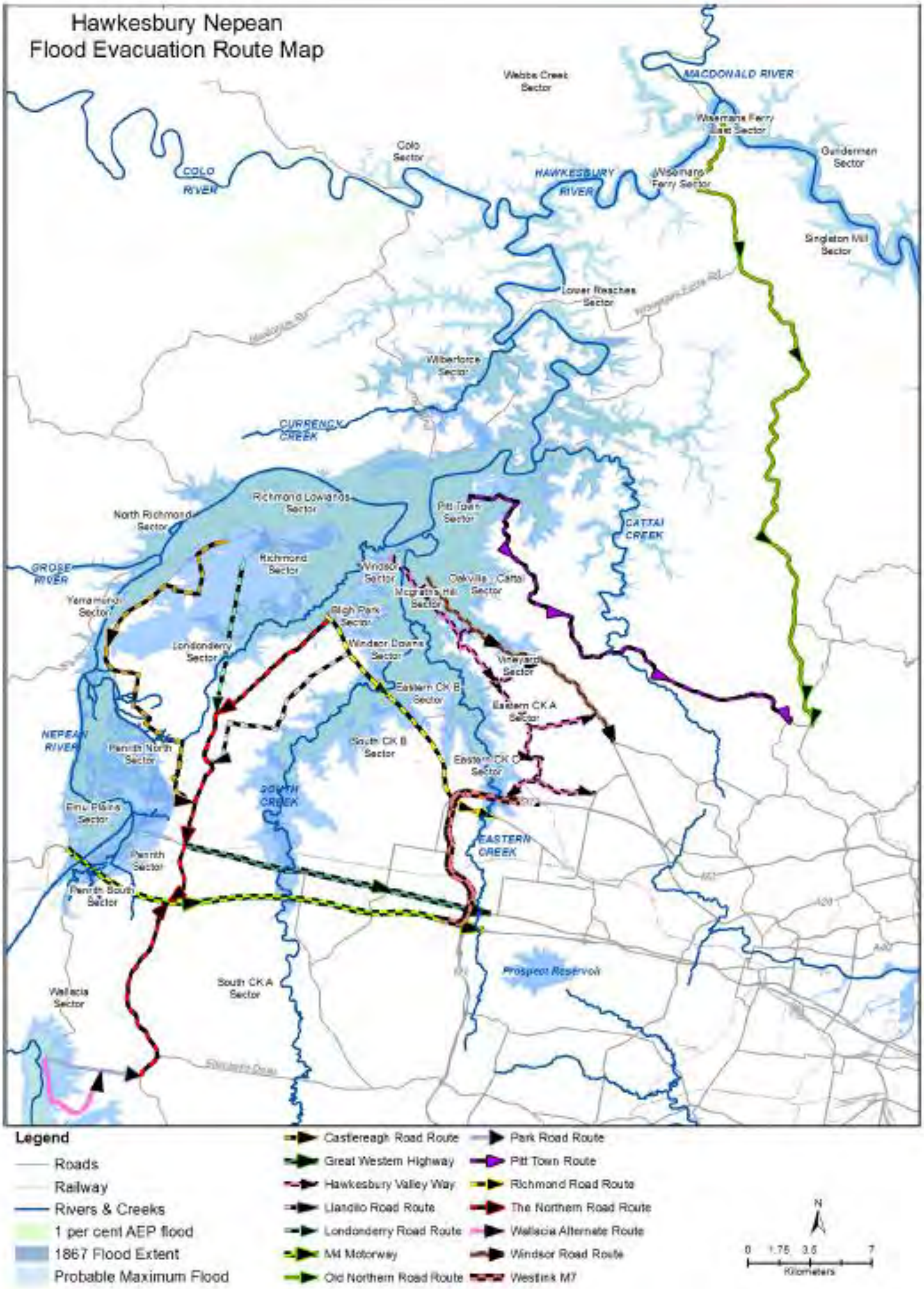


Figure 1: Hawkesbury Nepean Evacuation Routes (NSW SES, 2015)

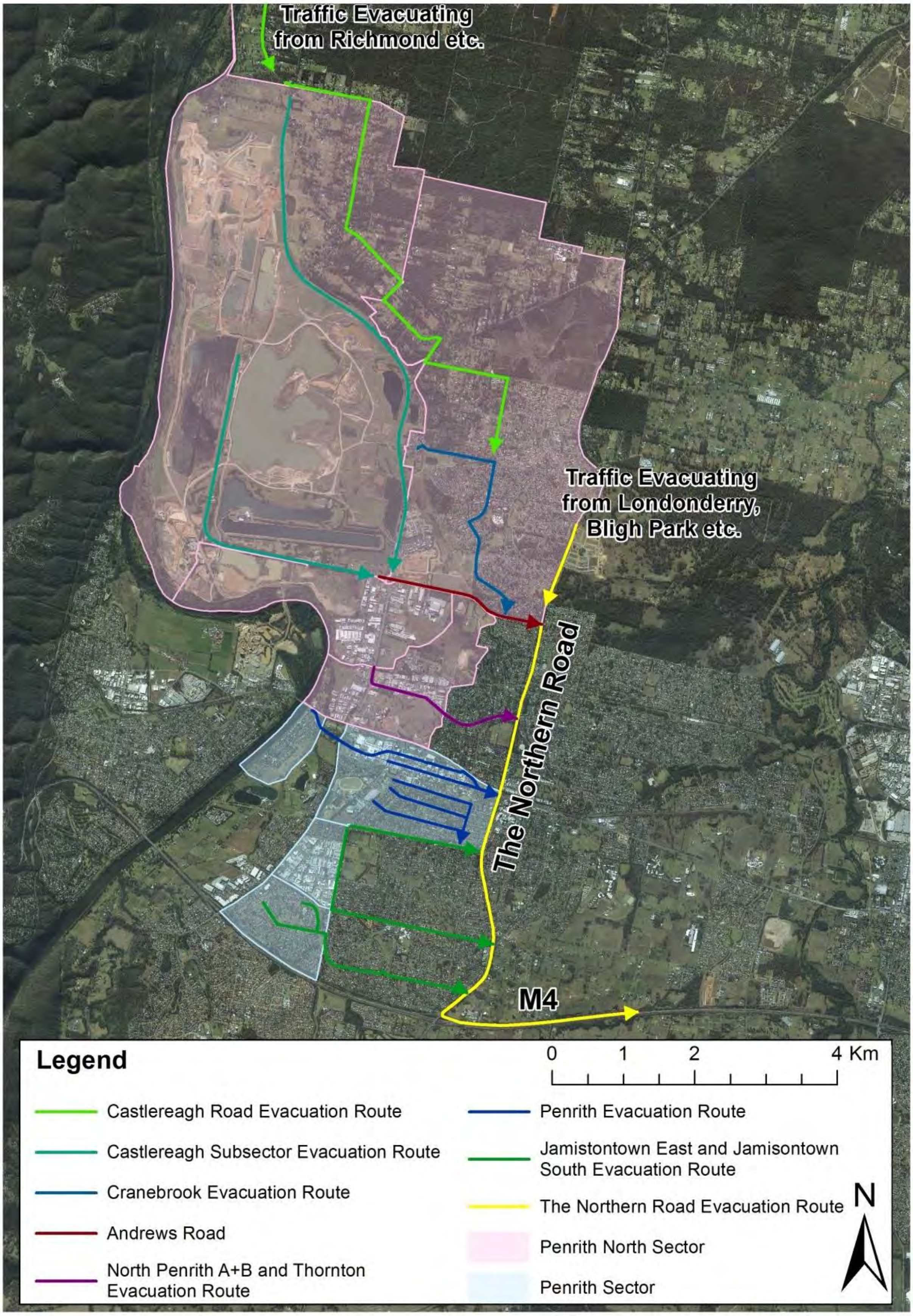


Figure 2: Evacuation Routes to The Northern Road from North and West

3 WHAT TRIGGERS EVACUATION?

Section 6.4.1 of the Hawkesbury Nepean Flood Emergency Sub Plan states that its operational objectives are:

a. *Protection of life (highest priority);*

b. *Minimisation of damage to property;*

c. *Minimisation of interruption to utilities; and*

d. *Effective transition to recovery*

One of its listed strategies to meet the above objectives is:

***Evacuate** people pre-emptively from dangerous or potentially dangerous places created by the flood hazard to safe location away from the hazard.*

3.1 TRAFFIC FROM THE NORTH

The areas to the north which evacuate onto The Northern Road are predominantly classified by the NSW SES as “low flood islands.” These are areas which have evacuation routes which are lower than some or all of the development which itself is lower than the peak of the probable maximum flood (PMF) and, in some cases, much smaller floods. Evacuation of the entire area must take place before the evacuation route is cut otherwise inhabitants run the risk of being isolated and then overwhelmed by floodwaters.

These areas are predominantly affected by flooding from The Hawkesbury River and their evacuation is triggered by forecast levels at Windsor gauge. At the time evacuation is triggered it might not be possible to know whether or not floodwaters would actually reach the buildings but to wait until that time would leave insufficient time available to evacuate.

3.2 TRAFFIC FROM THE WEST

The areas to the west of the Northern Road are mostly areas which the NSW SES terms as having “rising road access”. That is, vehicular or pedestrian evacuation away from rising floodwaters is possible along road routes which rise to above the PMF on a continually rising gradient. Unlike the flood islands which must be evacuated in their entirety, these areas can be evacuated progressively as flood forecasts are updated so that only those buildings which are likely to flood need be evacuated.

Evacuation of these areas is triggered by flood forecasts for the Nepean River at the Penrith Gauge.

3.3 TRAFFIC FROM THE EAST

Areas to the east of The Northern Road also generally have rising road access and the bulk earth works and road layout in the Jordan Springs East subdivision has been designed specifically to provide this.

Evacuation of these areas is triggered by flooding in South Creek. South Creek flooding can occur in one of two ways:

- Floodwaters can come down South Creek and spread out into these areas; or
- Flood levels in the Hawkesbury River can rise sufficiently to back up along South Creek and into these areas.

At both Jordan Springs East and at Werrington the level of a PMF from South Creek flooding is lower than the level of a PMF from Hawkesbury River flooding. Therefore the absolute maximum number of people who would have to be evacuated from these areas would occur when they are flooded by the Hawkesbury River rather than by South Creek.

In the case of evacuation due to Hawkesbury Nepean flooding, these areas would be advised to evacuate based on forecast flood levels in the Hawkesbury River at Windsor in the same way that those who have to evacuate from Richmond, Windsor and Bligh Park etc would be.

In the case of South Creek flooding, there is no flood forecasting and warning system in place because its catchment is too small and the rate of flood rise too fast for this to be particularly effective. Therefore evacuation of these areas would be reactive rather than pre-emptive and would likely occur when floodwaters are close to the at risk properties.

For the purposes of assessing the impacts of evacuating Jordan Springs East on regional evacuation traffic flows, evacuations triggered by South Creek flooding can be ignored because:

- It will generate far fewer evacuees than Hawkesbury River flooding
- It will not in itself generate significant evacuation traffic from areas to the North and will not generate any evacuation traffic from areas to the west so there is a low probability of evacuation traffic convergence in this scenario.

4 VEHICLE NUMBERS

4.1 BUILDING COUNTS

In 2013 Molino Stewart undertook work for Infrastructure NSW to estimate the amount of development in the Hawkesbury Nepean Valley at the time and also what could be expected by 2041.

A Molino Stewart team used high resolution aerial photography of the floodplain from 2011 to plot the location of every individual residential, commercial and industrial building in the floodplain within a Geographic Information System (GIS).

- Google Earth Street View was used to classify buildings as residential, commercial or industrial. It was also use to count letter boxes on properties to estimate the number of dwellings in multi-unit dwellings.
- Dwelling counts were compared with 2011 Census data, where Census statistical areas were fully within the floodplain, and were found to be within 5% in most locations. The exceptions were in Windsor and Richmond town centres where it was surmised that there were dwellings above commercial buildings which were not being counted by the methodology. In these two locations the dwelling counts were increased to match the Census counts.
- It was recognised that there had been further residential development on the floodplain since 2011 when the Census data was collected and the air photos were taken. This included the developments at Pitt Town, Waterside and Thornton which were only partly developed.

To account for development between 2011 and 2041 approved subdivision plans or planning approvals for all developments in the floodplain were used to add in buildings within those approvals which were not constructed in 2011. To these were added development forecasts provided by the Department of Planning and Environment and local councils.

We appreciate that the Department of Planning and Environment has revised future development projections upwards since 2014 but we have not been provided with those numbers but will discuss their implication later in this document.

4.2 VEHICLE ESTIMATES

4.2.1 Residential Vehicles

The number of residential vehicles at each dwelling was estimated in two different ways:

- For existing dwellings and approved residential development the average number of vehicles per dwelling for that subsector from the 2011 Census data was used.
- For any future dwellings it was assumed that there will be 1.8 vehicles per dwelling

There was a wide variation in vehicles per dwelling in existing developments which is a reflection of the differences between rural and urban subsectors and access to public transport. The NSW SES advised that the above ratios should be used and this is what we understand to be used in the INSW modelling.

4.2.2 Commercial and Industrial Vehicles

Estimating the number of vehicles evacuating from commercial and industrial premises is more challenging. In agreement with the NSW SES in 2014, it was assumed that there would be two (2) vehicles evacuating from each business address identified within each sector. Note that the number of business addresses is not the same as the number of buildings because there are some businesses with multiple buildings and some buildings with multiple businesses. The number of businesses addresses was provided by the NSW SES from data collected by Geoscience Australia.

4.2.3 University of Western Sydney Vehicles

The University of Western Sydney Campus at Richmond presents a special case as it has a large student population and staff visiting the site and some students who live on campus. Inquiries to the university revealed that there are 1,503 parking spaces on campus and 257 students live on campus. The parking spaces are usually approximately 80% occupied, which would be 1,202 vehicles. In consultation with the NSW SES, it was assumed that 129 parking spaces would be used by residential students and 1,076 spaces used by daily visitors when an evacuation is called.

4.2.4 Total Vehicle Numbers Used in Model

The maximum number of residential vehicles is likely to occur if an evacuation is called in the evening or at night when most people will be at home. The maximum number of business vehicles is likely to occur if evacuation is called on a weekday when most businesses are open. In accordance with NSW SES advice, the worst case has been modelled with the maximum number of residential and business vehicles evacuating simultaneously which is meant to account for people returning home during the day and then evacuating. However, this is likely to overestimate the quantum of evacuation traffic because:

- Many people who work in the floodplain live outside the floodplain
- The available warning times are of a similar length as work shifts so it is likely that people will not go to work if a flood watch or early flood warnings have been issued.

a) Traffic from the North

Table 1 summarises the total number of vehicles that can potentially be evacuating along the Northern Road from areas to the north. The traffic on Castlereagh Road includes all of the Richmond and Richmond Lowlands sectors plus the Agnes Banks South subsector. Londonderry Road takes the vehicles from the Londonderry subsector. The Northern Road from Windsor takes all of the Windsor Sector traffic and Llandilo Road takes all of the evacuating vehicles from Bligh Park and Windsor Downs sectors as well as the Berkshire Park and Llandilo subsectors.

It should be noted that this is the total potential vehicles but substantial traffic from Windsor, Bligh Park and Windsor Downs will also be able to use other routes so the actual traffic from these sectors using these roads will be considerably less as explained later in this report.

Table 1: Total number of vehicles that can potentially be evacuating along the Northern Road from areas other than Penrith and Penrith North

Areas	Total Vehicles
Castlereagh Road	9,038
Londonderry Road	2,292
The Northern Road from Windsor	6,953
Llandilo Road	5,938

b) Traffic from the West

For operational purposes the NSW SES has divided the floodplain into sectors and subsectors with each subsector having its own evacuation trigger. Table 2 shows the estimated number of vehicles from subsectors to the west which would evacuate via The Northern Road. Note that nearly 50% of the vehicles are estimated to be generated by commercial and industrial development in the floodplain.

Table 2 Number of Evacuating Vehicles from each Subsector in the West onto The Northern Road

Sector	Subsectors	Residential			Commercial and Industrial			Total Vehicles Evacuating
		Flooded and Isolated Dwellings per Subsector	Vehicles per dwelling	Vehicles Evacuating	Addresses per Subsector	Vehicles per business	Vehicles Evacuating	
Penrith North	Castlereagh	24	2.7	**65**	0	2	**0**	**65**
	Cranebrook	136	2	**272**	0	2	**0**	**272**
	Waterside*	566	2	**1,132**	0	2	**0**	**1,132**
	North Penrith A	0	1.2	**0**	384	2	**768**	**768**
	North Penrith B*	1,221	1.2	**1,465**	442	2	**884**	**2,349**
Penrith	Penrith	849	1.2	**1,019**	1,544	2	**3,088**	**4,107**
	Peach Tree Creek West	186	1.2	**223**	2	2	**4**	**227**
	Jamisontown East**	701	1.6	**1,122**	651	2	**310**	**1,432**
	Jamisontown South**	302	1.6	**483**	79	2	**8**	**491**
Total				**5,781**			**5,062**	**10,843**

* Includes residential development beyond 2018 to completion of the approved urban development
** Only those parts of the subsectors evacuating to The Northern Road

c) Traffic from the East

The suburb of Werrington would evacuate onto The Northern Road via Copeland St and it is estimated that about 2,400 vehicles would need to evacuate this way in a PMF.

With regards to Jordan Springs East it was assumed that there would be 1.8 vehicles per dwelling but as the appropriate scale of development at Jordan Springs East is central to the discussion, the total number of vehicles from Jordan Springs in different development scenarios is discussed later.

5 EVACUATION MODELLING

5.1 TIMELINE EVACUATION MODEL

The NSW SES has developed the Timeline Evacuation Model (TEM) as an empirical means of consistently estimating the ability of people to safely evacuate by motor vehicle from floodplains (Opper et al, 2009). It takes into account the time people take to accept a warning, act upon the warning and travel along an evacuation route which may face delays due to incidents along the route. It then compares this estimated “Time Required” with the estimated “Time Available”. The Time Available is derived from information about warning times, flood travel times and flood rates of rise.

The TEM was born out of the 1997 Hawkesbury-Nepean Floodplain Management Strategy, where the NSW SES applied conventional time line project management to the flood evacuation problem. It became apparent that this approach provided a clear and concise method for examining the evacuation process.

Since that time, the approach has been refined into a model that can be easily applied to different developments. The TEM has been used widely within NSW by both the NSW SES and consultants in evacuation planning, with the scale of the model ranging from small sub divisions to towns of tens of thousands of people.

The primary goal of the TEM is to compare the time required for evacuation with the time available for evacuation. This can be represented by the equation:

Surplus Time = Time Available – Time Required

or:

ST=TA-TR

Where the Time Available exceeds the Time Required there can be greater confidence that a community can evacuate safely by motor vehicle. Where the Time Required exceeds the Time Available it is unlikely that everyone will be able to evacuate safely by motor vehicle in all floods.

Time Required

The time required (TR) can be described by the equation

TR = WAF + WLF + TT + TSF

Where:

- **Warning Acceptance Factor (WAF)** accounts for the delay between receiving an evacuation order and acting upon it. The NSW SES recommends a value of one hour.
- **Warning Lag Factor (WLF)** is an allowance for the time taken by occupants to prepare for evacuation. The NSW SES recommends a value of one hour.
- **Travel Time (TT)** is defined as the number of hours taken for all of the evacuating vehicles to pass a point given the road capacity. The NSW SES recommends an assumed road capacity of 600 vehicles per hour per lane. Therefore if an evacuation generates 1,200 vehicles and the evacuation route has one lane, then the travel time is two hours. If there are two lanes the travel time is reduced to one hour.
- **Traffic Safety Factor (TSF)** is added to the travel time to account for any delays that occur along the evacuation route. This includes potential for incidents such as vehicle accidents or breakdowns, fallen trees or power lines or water across the road. The NSW SES has developed a table of traffic safety factors, where the safety factor is proportional to the travel time, ranging from one hour to three and a half hours (Table 3).

The time needed to disseminate an evacuation order also needs to be considered. Generally, the NSW SES will broadcast the order by several means but will also initiate doorknocking of the target premises. The model assumes that the evacuation order is not received at a property until it is doorknocked and that at any one time there will be properties at different stages of the evacuation sequence.

However, this is only true if the number of door knocking teams available is equal to the number that would produce enough traffic to keep the evacuation route at full capacity. Should the number of door knocking teams available be less than this optimal number, then the travel time must be modified to account for this. If more door knockers are provided than the optimal number then the rate of traffic generation will exceed the road capacity and traffic queues will form until no more premises evacuate.

Table 3: Traffic Safety Factors

Travel Time TT (hrs)	Traffic Safety Factor TSF (hrs)
0 to 3	1.0
>3 to 6	1.5
>6 to 9	2.0
>9 to 12	2.5
>12 to 15	3.0
>15	3.5

All of these factors have been used in the analyses of evacuation from Jordan Springs East.

5.2 TIME AVAILABLE

Every flood is different and the rate at which the flood waters will rise at any particular location will be dependent on the spatial and temporal distribution of rainfall across the catchment. The Bureau of Meteorology provides quantified flood forecasts for several gauges along the Hawkesbury Nepean River. The two which are most critical for evacuations onto The Northern Road are the Penrith Gauge and the Windsor Gauge.

5.2.1 Flood Warnings

At the time the earlier analyses for Jordan Springs East were completed, the NSW State Flood Sub Plan (SEMC, 2008) indicated that 8 hours' notice was required at Penrith Gauge of heights of 11.3m and above (equivalent to 25.4m AHD) and 15 hours' notice at Windsor Gauge of heights of 13.7m and above (equivalent to 13.85m AHD) if the peak height is expected to exceed 16m. Previous advice from the Bureau of Meteorology was that realistically only about 7 hours' notice at Penrith and 9 hours' notice at Windsor could be provided with suitable accuracy, based on measured river flows and fallen rain, in extreme flood events. Longer warning times could be provided by using rainfall forecasts but the resultant flood level forecasts would be less accurate. The warning time based on measured rainfall and runoff is referred to as the Quantified Precipitation Forecast (QPF).

Since then the NSW State Flood Sub Plan has been updated twice (December 2017 and March 2018) but the above target warning times have not been updated and have been used to guide the evacuation analyses in the previous reports and this document by Molino Stewart.

5.2.2 Rates of Rise

The only flood modelling data for the Hawkesbury Nepean River which is available to Lend Lease and its consultants is two dimensional design flood modelling data which has been calibrated to the one dimensional RUBICON flood model prepared by Webb McKeown and Associates for Sydney Water in the 1990s. That includes design flood hydrographs for a range of “design” floods from the 1 in 5 annual exceedance probability (AEP) flood through to the probable maximum flood (PMF). These remain the flood model outputs officially adopted by the NSW State Government.

While the PMF represents the largest flood likely to occur and has the most rapid rate of rise of any of the design flood events, it is acknowledged that floods with smaller peaks could rise as quickly as the PMF at critical stages of the evacuation timeline. Therefore, historically, evacuation analyses for the Hawkesbury Nepean Valley have been based on evacuation during a PMF because it represents both the maximum number of vehicles which need to evacuate and the minimum available evacuation time.

Figure 3 is the 72hour PMF hydrograph at Windsor. Actual evacuations are most likely to involve less vehicles with more time to evacuate.

Recently, INSW has commissioned a Monte Carlo analysis of temporal and spatial rainfall distributions in the RUBICON model. A total of 20,000 different rainfall distributions were run but the only output from that work which has been made publicly available is the graph in Figure 4 which shows the time taken for floods to rise from 4m AHD to 16m AHD at Windsor Gauge. This can be contrasted with Figure 3 which shows that it takes about 22 hours for the design 72hr PMF to rise from 4m to 16m AHD. Figure 4 shows that some events with a 1% AEP peak might rise faster than this a few rising in as little at 16 hours. The implications of this are discussed later.

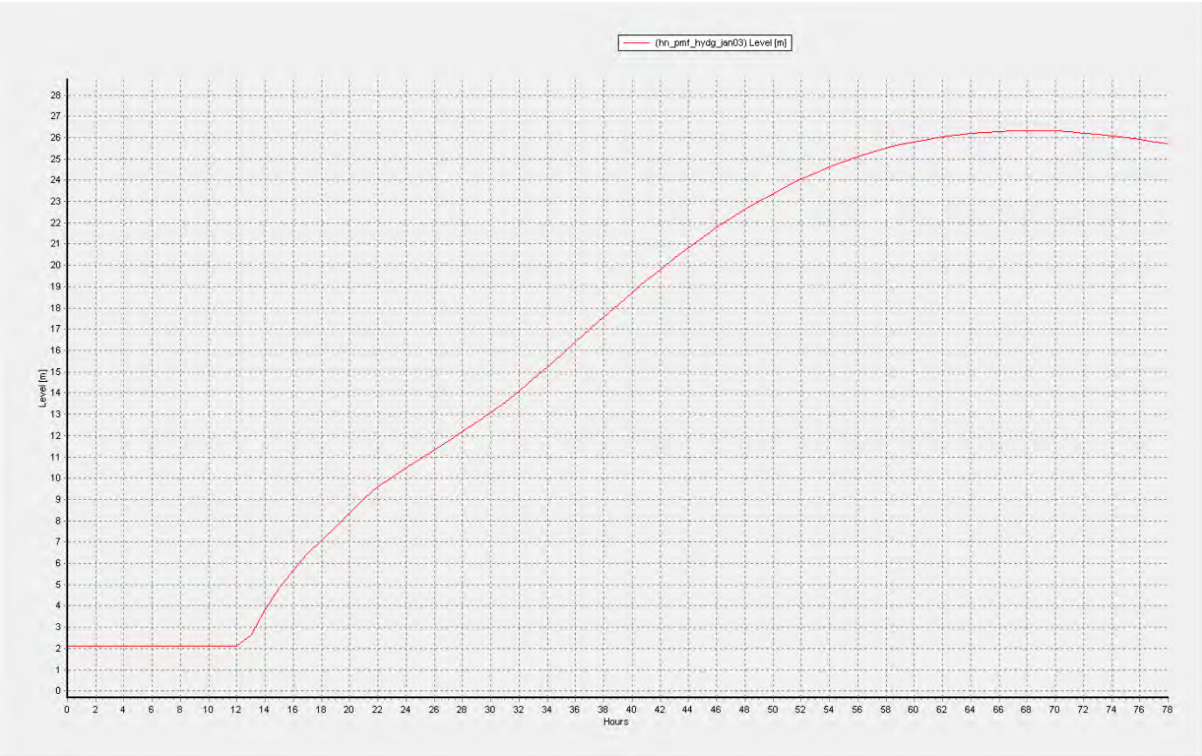


Figure 3: 72 Hour PMF Hydrograph at Windsor

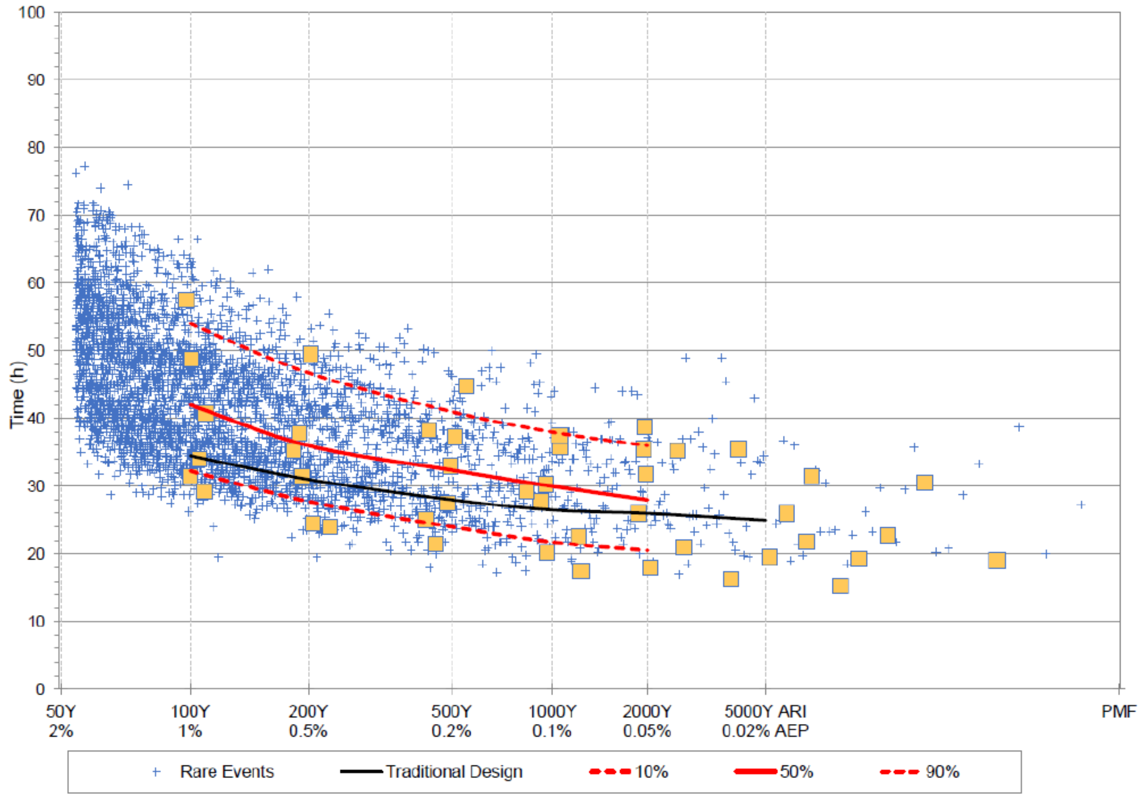


Figure 4: Monte Carlo Analysis of Time for Floods to Rise from 4m to 16m AHD at Windsor

5.3 TIME NEEDED

5.4 TRAFFIC FROM THE NORTH

a) Richmond

According to the Hawkesbury Nepean Flood Emergency Sub Plan, the evacuation route for Richmond and Richmond Lowlands is expected to be cut when flooding reaches 20.2m AHD at Windsor Bridge. These sectors as well as the Agnes Banks subsector need to be fully evacuated by the time flood waters reach this level.

Given that there over 9,000 vehicles which need to evacuate past this point, the TEM suggests that more than 20 hours is needed to evacuate all of these vehicles. This includes two hours for people to respond to the evacuation order (WAF+WLF) and a three hour traffic safety factor (TSF).

With reference to the Windsor hydrograph (Figure 5), it can be seen that evacuation would need to be called at about t=22.5hours. If the BoM can only forecast accurately nine hours in advance, this means that at t=22.5 it would only be able to accurately forecast that the flood level will exceed 13.8m AHD if the flood is rising as fast as a 72 hr PMF. If it is rising more slowly, then the forecast level could be higher. A flood level of 13.8m has about a 1 in 20 chance of being reached or exceeded in any year so there is about this probability that some evacuation of Richmond will be necessary.

There are some houses with floor levels as low as 14m or even lower in this sector so it would not be premature to start evacuation this early providing the lowest lying dwellings are evacuated first.

On this basis it can be assumed that all of the buildings in Richmond, Richmond Lowlands and Agnes Banks will be evacuated along the Castlereagh Route and vehicles will be using the road for 15 hours starting at t=24.5 on the PMF hydrograph.

b) Londonderry

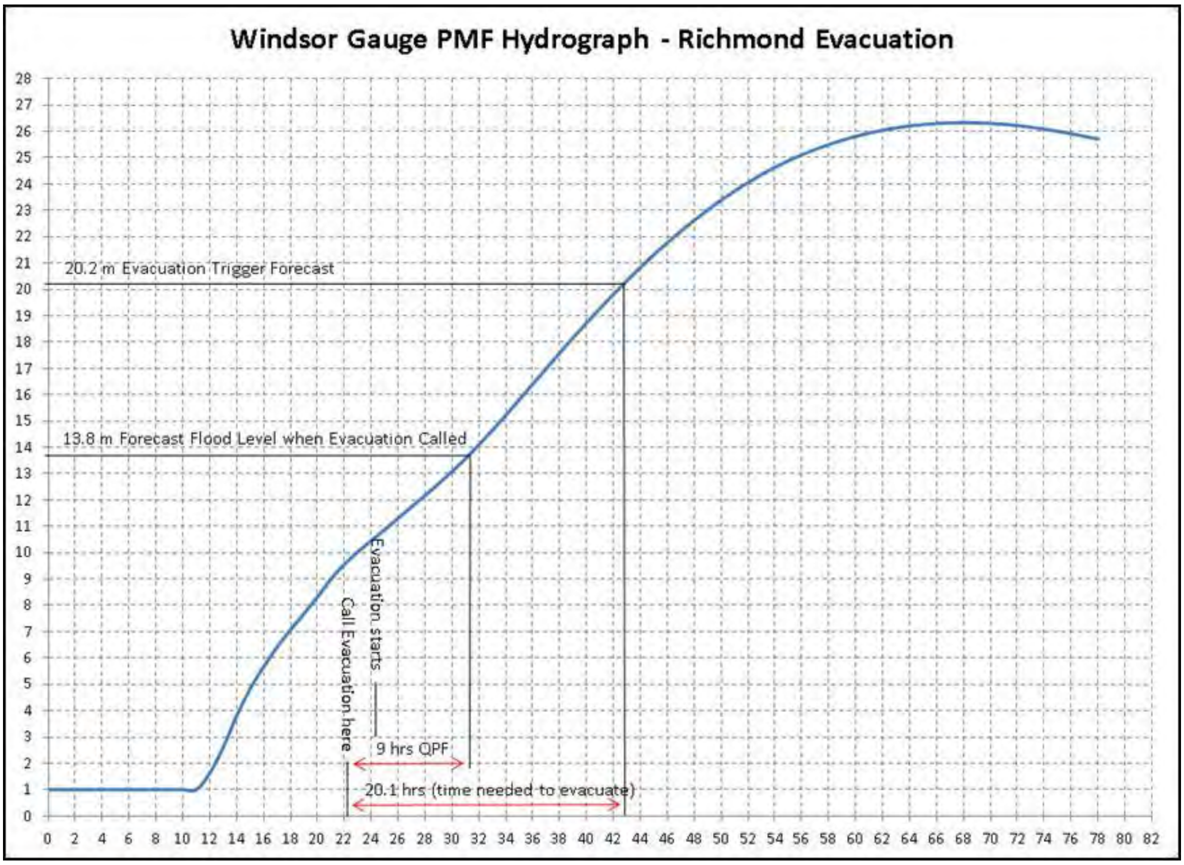
The Londonderry Subsector will be evacuated onto local roads and then onto The Northern Road. Its trigger will be when it is likely to be flooded because the land generally rises towards the evacuation routes.

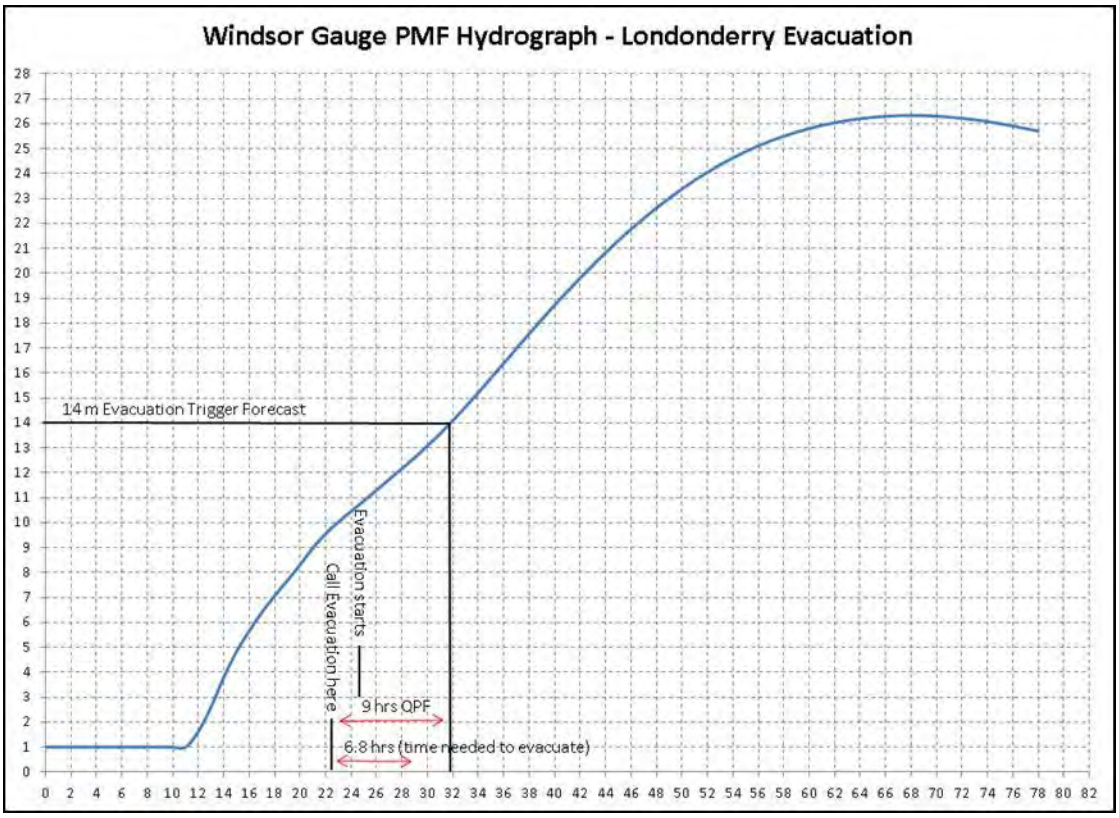
There are scattered rural residential dwellings around Londonderry with floor levels as low as 14m AHD. Evacuation of this subsector therefore needs to start when it is forecast that flooding will exceed 14m AHD. This level would be reached at about t=31.5 so the evacuation order would go out nine hours before that at t=22.5 but the road would start to be used at t=24.5 (Figure 6). The 2,292 vehicles will occupy the road for less than four hours.

In reality however the evacuation of this area would be spread over time as the forecast water level increases over time.

c) Windsor

According to the Hawkesbury Nepean Flood Emergency Sub Plan, evacuation of the Windsor Sector will commence if it is forecast that flooding will exceed 15m AHD at Windsor Gauge. The Plan also indicates that there are two evacuation routes available for Windsor. For the purpose of this analysis, traffic from the Windsor Sector was assumed to be able to evacuate on both the Hawkesbury Valley Way and The Northern Road until access to The Northern Road route is cut on George Street when a level of 15m AHD is reached at Windsor (Figure 7). This is more frequent than about a 1 in 50 chance per year.


Windsor Gauge PMF Hydrograph - Richmond Evacuation
20.2 m Evacuation Trigger Forecast
13.8 m Forecast Flood Level when Evacuation Called
Evacuation starts
Call Evacuation here
9 hrs QPF
20.1 hrs (time needed to evacuate)


Windsor Gauge PMF Hydrograph - Londonderry Evacuation
14 m Evacuation Trigger Forecast
Evacuation starts
Call Evacuation here
9 hrs QPF
6.8 hrs (time needed to evacuate)

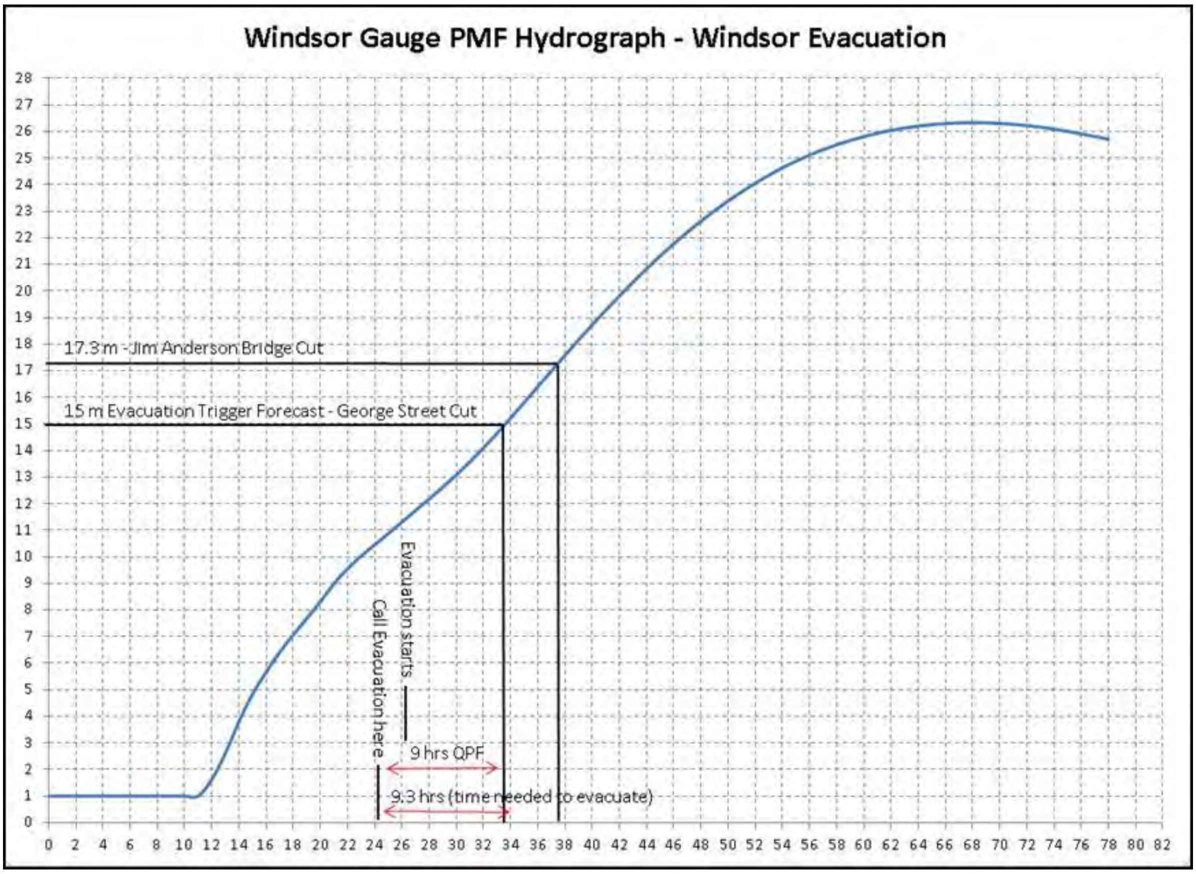


Figure 7: The Northern Road Route trigger and evacuation times for Windsor

This would see evacuation traffic from Windsor start using The Northern Road at t=26.1 until t=33.1. As both routes would be open all of this time it can be assumed that half of the 6,953 vehicles would travel along each route. It was therefore assumed that 3,476 vehicles from Windsor would travel on The Northern Road Route. They would need 5.8 hours to evacuate plus an allowance for traffic delays.

d) Bligh Park

Evacuation from the Bligh Park and Windsor Downs sectors is a little more complicated. This traffic will initially use Richmond Road until it gets cut at 14m AHD when floodwaters back up South Creek from Windsor. After this point they will be diverted from Richmond Road onto Llandilo Road which will take them to The Northern Road where they will be joined by local traffic evacuating from Berkshire Park and Llandilo subsectors. This secondary route would be cut at a Windsor Gauge height of 23.8m AHD.

However, the Thorley St exit from Bligh Park gets cut at 18.5m AHD therefore the NSW SES would have to call the evacuation with enough time before it is expected to get cut at t=39 (Figure 8).

The 5,938 vehicles from these subsectors need 14 hrs to evacuate including WAF, WLF and TSF. Therefore, the NSW SES needs to call the evacuation at t=25 (Figure 8).

At t=32, seven hours after evacuation is called, 14m would be reached. If two hours is allowed for the WAF and WLF then there would be 5hrs of travel along Richmond Rd before it is necessary to use Llandilo Road. At 600 vehicles per hour this equates to 3,000 of Bligh Park's vehicles using Richmond Road instead of Llandilo Road. This puts 2,938 vehicles along Llandilo Road starting at t=32.

There is more than a 1 in 50 chance per year that Bligh Park and Windsor Downs will need to be evacuated and some of the traffic uses The Northern Road.

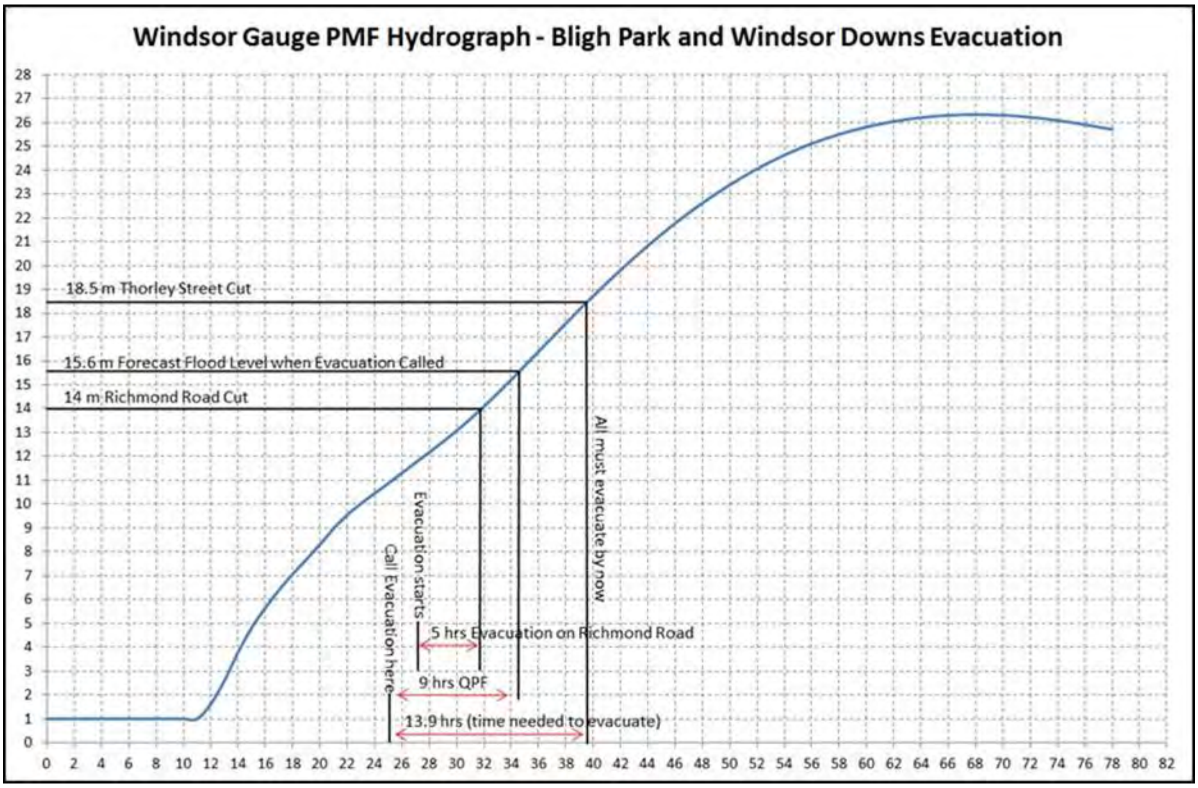


Figure 8: Trigger and evacuation times for Bligh Park and Windsor Downs

e) Summary

Table 4 summarises the relative timings and the total number of vehicles evacuating on Castlereagh Road, The Northern Road, Londonderry Road and Llandilo Road from the sectors to the north.

Table 4 Vehicle Numbers and Relative Timings for Evacuation from Sectors to the North

SES Subsector	Evacuation Via	Vehicles Evacuating on Road	Evacuation commences (hours)[1]
Richmond and Richmond Lowlands Sectors and Agnes Banks South Subsector	Castlereagh Road and The Northern Road	9,038	24.5
Windsor Sector	The Northern Road	3,476	26
Londonderry Subsector	Londonderry Road and The Northern Road	2,292	24.5[2]
Bligh Park Sector, Windsor Downs Sector, Berkshire Park Subsector, and Llandilo Subsector	Llandilo Road and The Northern Road	2,938	32

1. Time first vehicles on evacuation route relative to Windsor flood hydrograph
2. Many of these vehicles will have rising road access so their evacuation can be spread over time.

5.4.2 Traffic from the East

Unlike traffic from the North, which is mostly entire population centres evacuating once it is known the evacuation route will be cut but floodwaters will keep rising, only those parts of Werrington Jordan Springs East which are forecast to be flood affected need to evacuate at any one time. However, it will be the same flood hydrograph at Windsor which triggers both evacuation traffic from the north and evacuation traffic from Werrington and Jordan Springs East.

a) Werrington

Werrington is almost entirely residential development with some local shops. It is estimated about 2,400 vehicles in total will need to evacuate from Werrington with the lowest buildings on land at about 22m AHD. The floor levels of the buildings are likely to be higher than this but for the purpose of this exercise it was assumed that Werrington would need to evacuate when it was forecast that a level of 22m AHD would be reached at Windsor.

The total numbers of vehicles evacuating at a 22m, 24m and 26m forecasts were estimated by visual inspection of the flood extent compared to the building distribution. Assuming a 9 hour warning time of these forecasts, the evacuation trigger time on the PMF design hydrograph was estimated and then two hours was allowed until evacuation commences as per the NSW SES Timeline Evacuation Model. The probabilities of these evacuation events were also estimated. This is all summarised in Table 5.

Table 5: Evacuation Triggers and Traffic for Werrington

Forecast level at Windsor (m AHD)	Approx. Chance per year (1 in X)	Vehicles evacuating	Evacuation commences (hours)[1]
22	2,000	480	39
24	5,000	720	45
26	70,000	1,200	55
Total		2,400	

1. Time first vehicles on evacuation route relative to Windsor flood hydrograph

b) Jordan Springs

Figure 9 shows the indicative layout plan (ILP) for the development which is now proposed with both the increased residential density in the approved residential areas and the conversion of previously proposed employment land to residential land. The development has been divided into six stages which have been further subdivided to reflect the staging of development. Some lots will have multiple dwellings as they will either be duplexes or apartments. Table 6 shows the anticipated distribution of dwellings by both lot and building minimum habitable floor level.

Stage 2 has 348 dwellings and is completely above the reach of the probable maximum flood (PMF). Although a PMF would isolate this stage from the Main Access Road which leads west through Jordan Springs, it has direct access onto the Bus Only Road which leads south through Werrington. This means that the stage would not be completely isolated by flooding and therefore does not need to be evacuated.

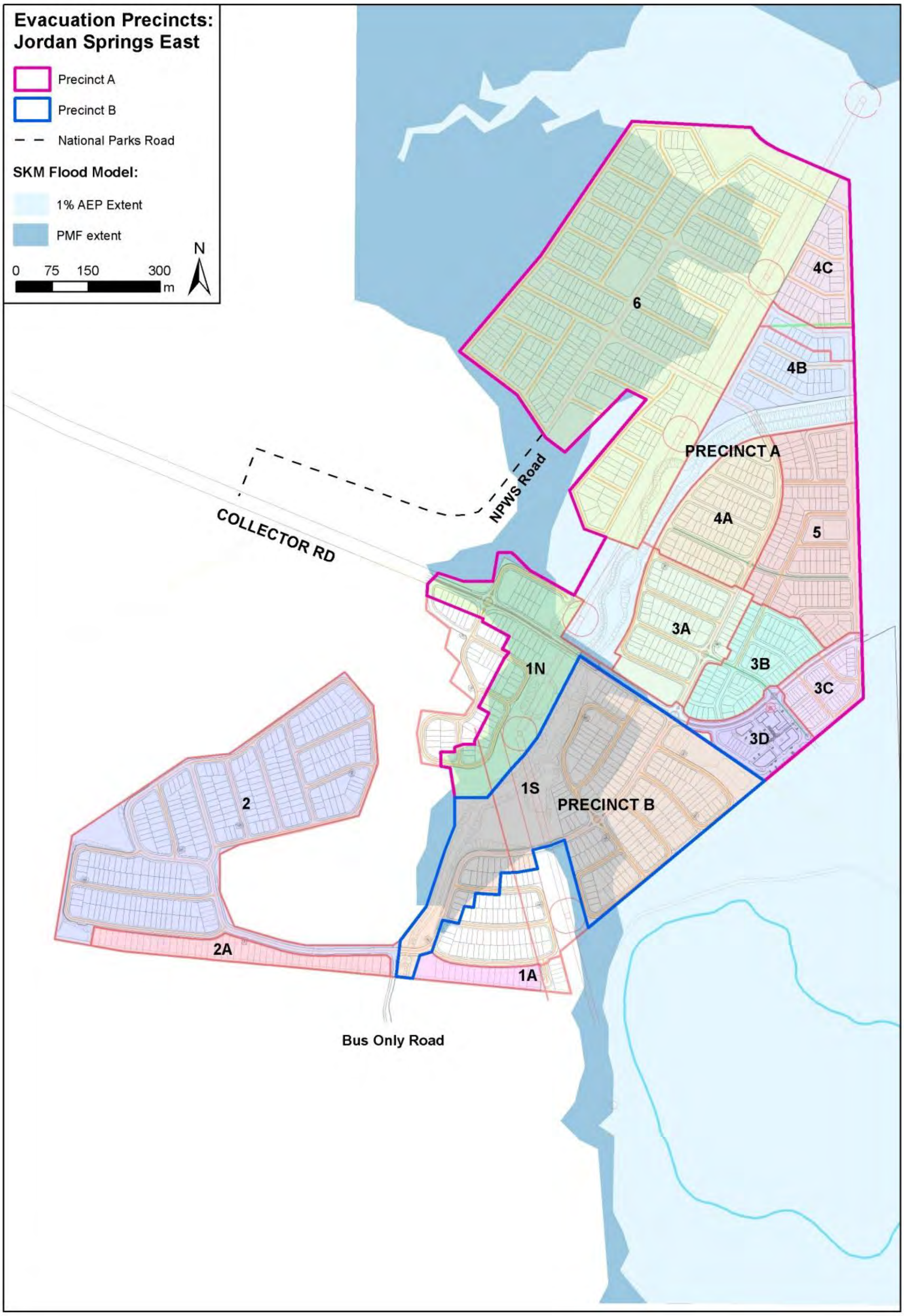


Figure 9: Evacuation sectors and flood extents for PMF and 1% AEP events across Jordan Springs East

Table 6: Jordan Springs East Dwelling Distribution

Stage	MINIMUM HABITABLE FLOOR LEVEL (m AHD)									
	<20	20	21	22	23	24	25	26	27	Total
1	0	0	17	44	46	59	47	63	134	410
1w	0	0	0	0	0	0	0	0	26	26
2	0	0	0	0	0	0	0	0	300	300
2w	0	0	0	0	0	0	0	0	48	48
3A	0	0	11	34	56	2	0	0	0	103
3B1	0	0	0	17	23	12	0	0	0	52
3B2	0	0	1	17	6	8	3	0	0	35
3C	0	0	21	44	0	0	0	0	0	65
3D	0	0	20	80	0	0	0	0	0	100
4A	0	25	50	16	2	0	0	0	0	93
4B	0	25	29	0	0	0	0	0	0	54
4C	0	7	6	0	0	0	0	0	0	13
5A	0	21	61	36	1	0	0	0	0	119
5B	0	23	7	0	0	0	0	0	0	30
6	6	148	129	116	61	34	6	0	0	500
total	**6**	**249**	**352**	**404**	**195**	**115**	**56**	**63**	**508**	**1948**

Table 7: Jordan Springs East Vehicle Evacuation Distribution

Trigger Level (mAHD)	19.7	20	21	22	23	24	25	26
Approx. Chance per year (1 in X)	500	750	1,500	2,000		5,000		70,000
Evacuation commences (hours)[1]	35	35	37	39	42	45	49	55
Total Vehicles	11	461	652	748	361	213	104	117
Travel Time @ 600vph/lane (hrs)	0.02	0.77	1.09	1.25	0.60	0.36	0.17	0.19

1. Time first vehicles on evacuation route relative to Windsor flood hydrograph

Stage 1 has 436 dwellings. For evacuation management purposes it has been subdivided into a north and south zone labelled in

Figure 9Figure 9 as 1N and 1S. The vehicles from 1N would evacuate via the Main Access Road and those in 1S would evacuate via the Bus Only Road. However, not all of the vehicles from either of these zones need to evacuate because they have road access out of the precinct even during a PMF event.

Those in the northern part of Zone 1N have direct access onto the Main Access Road and those in the southern part of Zone 1S have direct access onto the Bus Only Road. These areas are shown in Figure 9. Between these two zones there are an estimated 160 dwellings which do not need to evacuate from Stage 1. This leaves 68 dwellings from Stage 1 which will evacuate west along the Main Access Road and 208 dwellings which will evacuate south along the Bus Only Road.

There are proposed to be a total of 1,164 dwellings in the remaining stages and all will evacuate west along the Main Access Road.

For the purposes of evacuation planning and analysis the development was divided into Precinct A which has evacuation access to the Main Access Road and Precinct B which has evacuation access to the Bus Only Road. Both precincts are shown in Figure 9. Table 7 summarises the number of vehicles which would have to evacuate at each 1m increment in flood forecast, when they would start evacuating relative to the rate of rise of the PMF design hydrograph at Windsor and how long they would take to leave the floodplain (not accounting for delays before leaving or delays on route).

5.4.3 Traffic from the West

Evacuation of the Penrith and Penrith North Sectors will be triggered by flood levels and forecasts in the Nepean River at Penrith. Evacuation of the Richmond, Richmond Lowlands, Londonderry, Windsor and Bligh Park and Windsor Downs, Werrington and Jordan Springs East sectors and subsectors will be triggered by flood levels and forecasts in the Hawkesbury River at Windsor.

Although the Nepean and Hawkesbury Rivers are one and the same river and floodwaters that pass Penrith will flow to Windsor, it is more helpful for evacuation modelling purposes to think of them as two different rivers with semi-independent flood behaviours. This is because the spatial and temporal distribution of rainfall varies from flood to flood and there is a wide range of relative timings of evacuation trigger levels being reached at Penrith and Windsor. This means the relative timings of evacuations from the sectors which these two rivers affect can vary from flood to flood.

There is a computer based flood model which models flood levels along the whole of the Hawkesbury Nepean River from Bents Basin to Brooklyn but it is a one dimensional model which lacks detail about flood behaviour across the floodplain and, in particular, how and when flooding would cut evacuation routes. However, the levels which this model produces along the river have been adopted by the State Government for floodplain planning.

This one dimensional model was originally developed in the 1980s and has been updated a number of times since then and is undergoing further refinement now. Each refinement has not resulted in significant changes in estimated design flood levels along the river.

Several two dimensional flood models have been developed over the years to provide the greater level of detail necessary to understand flood behaviour for evacuation planning purposes. Two have been used for this investigation.

The first model extends from Regentville to Yarramundi and covers the whole of the Penrith Region, including Penrith Lakes. It was developed by BMTWBM in 2014 using the TUFLOW modelling software and was calibrated against levels in the version of the one dimensional model which were available at that time. This is the most up to date two dimensional model available for this section of the river and includes the currently proposed Penrith Lakes final land forms. It also includes details of all of the culverts and bridges in tributaries which will affect the timing of evacuation routes being cut.

The second two dimensional model extends from Yarramundi to Wisemans Ferry and covers the floodplain which takes in the Richmond, Richmond Lowlands, Windsor, Bligh Park and Windsor Down sectors. It was developed using the RMA modelling software in the late 1990s and was calibrated to the levels along the river which the one dimensional model produced at that time. It is the most up to date two dimensional model of this section of the floodplain and is widely used for floodplain development and emergency planning.

a) Penrith Sector

The subsectors in the Penrith Sector are shown in Figure 10 along with the low points which trigger their evacuation. These are summarised in Table 8. The Penrith gauge levels at Penrith which would correspond to the evacuation trigger levels for each subsector were estimated by analysing the flood surface of the TUFLOW model of the PMF at the time step when the trigger level would be reached at the relevant location in the subsector.

The Peach Tree Creek West Subsector is a small group of houses between Peach Tree Creek and the River just south of Victoria Bridge. This subsector would require early evacuation before flood waters back up Peach Tree Creek and cut off their evacuation route. It was therefore assumed that evacuation would be called when it is forecast that flooding would reach 24.0m AHD at Penrith Gauge.

The Penrith subsector has generally rising road access from the low points in the subsector to flood free land west of the Northern Road. It was therefore assumed that evacuation would be triggered when it is forecast that floodwaters would reach 26.8m AHD at Penrith gauge which would be sufficient to flood the lowest points in the subsector.

Vehicles in the Jamisontown East subsector which are east of Mulgoa Road would evacuate on the roads which rise towards The Northern Road. It was therefore assumed that its evacuation would be triggered when it is forecast that flooding would reach 27.3m AHD at Penrith gauge which would be sufficient to reach the lowest point in this subsector.

Vehicles in the Jamisontown South subsector which are east of Mulgoa Road would evacuate along rising road routes to The Northern Road. It was therefore assumed that its evacuation would be triggered when it is forecast that flooding would reach 27.8m AHD at Penrith gauge which would be sufficient to reach the lowest point in this subsector.

b) Penrith North Sector

The subsectors in the Penrith North Sector are shown in Figure 11 along with the low points which trigger their evacuation. These are summarised in Table 9. The same method was used as was used for the Penrith Sector to determine corresponding levels at the Penrith Gauge.

North Penrith A subsector would be cut off by rising floodwaters at Castlereagh Road close to Boundary Creek at a height of 24.2m AHD. This would correspond to a gauge height of 24.4m AHD at the Penrith Gauge during a flood rising as fast as the PMF. It was therefore assumed that North Penrith A would be evacuated when 24.4m AHD is forecast.

North Penrith B subsector was solely an industrial area until the Thornton residential development was commenced a few years ago. It was assumed that the industrial areas in this subsector would begin evacuating when it was forecast that Boundary Creek would start flooding some of the premises which back on to it. They would flood when the level in the creek is 24.0m AHD. This would occur when the flood level at Penrith Gauge is 24.4m AHD in a flood rising as fast as a PMF. A forecast of this level was assumed for the evacuation of the industrial premises in North Penrith B.

Flooding would have to rise higher before the lowest parts of the new Thornton residential development would be flooded. It was therefore assumed that Thornton's evacuation would be triggered when it is forecast that the Penrith gauge would reach 26.2m AHD which would correspond to a level of 25.0m AHD at Thornton and the lowest parts of this development would start to flood.


Peach Tree Creek West
Penrith
Jamisontown East
Jamisontown South
The Northern Road
M4
Legend
Subsector Low Points
Evacuation Route Low Points
Penrith Evacuation Route
Jamistontown East and South Evacuation Route
The Northern Road Evacuation Route
Penrith Sector
0
0.375
0.75
1.5 Km
N

Table 8 Low points triggering evacuation of subsectors within the Penrith Sector

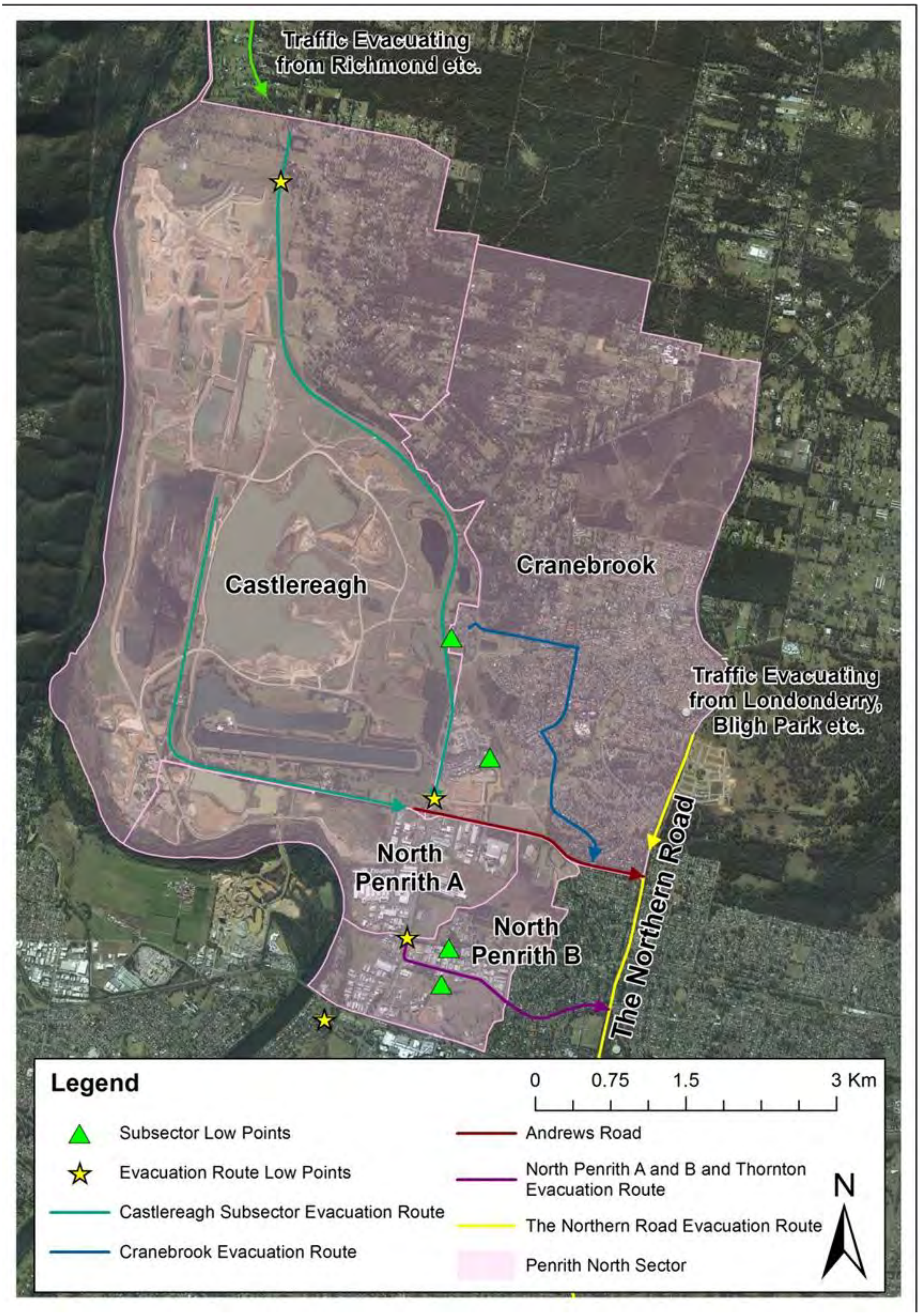
SES Subsector	Low Point Type	Low Point Location	Low Point Ground Level (m AHD)	Inundated at (hours)[1]	Height at Penrith Gauge (m)	Evacuation Commences (hours)[1]
Peach Tree Creek West	Road Cut	Ladbury Avenue (near High Street)	23.6	15	24.0	10
Penrith	Building Inundated (Residential)	Corner of Mulgoa Road and Rodley Avenue	26.8	25	26.8	20
Jamisontown East	Building Inundated (Residential)	Corner of Mulgoa Road and Jamison Road	27.5	27.5	27.3	22.5
Jamisontown South	Building Inundated (Residential)	Snowden Street (near Fairfield Place)	28.4	29.5	27.8	24.5

1. Time first vehicles on evacuation route relative to Penrith flood hydrograph

Table 9 Low points triggering evacuation of subsectors within the Penrith North Sector

SES Subsector	Low Point Type	Low Point Location	Low Point Ground Level (m)	Inundated at (hours)	Height at Penrith Gauge (m)	Evacuation Commences at (hours)[1]
North Penrith A (commercial and Industrial)	Road Cut	Castlereagh Road (near Boundary Creek)	24.2	16	24.4	11
North Penrith B (Commercial and Industrial)	Building Inundated (Commercial and Industrial)	Coombes Drive (near Boundary Creek)	24.0	16	24.4	11
North Penrith B (Residential - Thornton)	Building Inundated (Residential)	Northeast corner of development	25.0	22	26.2	17
Waterside	Building Inundated (Residential)	Fulmar Way	21.7	24	26.5	19
Castlereagh	Road Cut	Castlereagh Road (near Smith Road)	17.4	19.5	25.5	14.5
Cranebrook	Building Inundated (Residential)	Sardam Avenue	20.8	25.5	26.8	20.5

1. Time first vehicles on evacuation route relative to Windsor flood hydrograph


Traffic Evacuating from Richmond etc.
Castlereagh
Cranebrook
Traffic Evacuating from Londonderry, Bligh Park etc.
North Penrith A
North Penrith B
The Northern Road
Legend
Subsector Low Points
Evacuation Route Low Points
Castlereagh Subsector Evacuation Route
Cranebrook Evacuation Route
Andrews Road
North Penrith A and B and Thornton Evacuation Route
The Northern Road Evacuation Route
Penrith North Sector
0 0.75 1.5 3 Km
N

The Cranebrook subsector has two distinct residential developments: the well-established Cranbrook village; and Waterside which is a new development nearing completion.

It was assumed that Cranebrook's evacuation would be triggered when it was forecast that flooding would reach 20.8m AHD locally and start flooding the lowest dwellings. This would correspond to a Penrith Gauge level of 26.8m AHD.

Waterside has dwellings which would be flooded when floodwaters reach 21.7m AHD. This was assumed to be the evacuation trigger for this development which would correspond to a forecast level of 26.5m AHD at Penrith Gauge.

The Castlereagh subsector includes a few existing rural dwellings within the subsector but would also include any development which takes place in Penrith Lakes. Each has been considered separately in the modelling with regards to evacuation triggers.

The northern part of the subsector has a low point on Castlereagh Road near the intersection of Smith St which would be cut when the level reaches 17.4m AHD. This corresponds to a level of 25.5m AHD at the Penrith Gauge and was used as the forecast level for the evacuation of all of the existing development in this subsector.

c) Evacuation Probabilities

The need for evacuation of the Penrith and Penrith North Sectors is much less likely than evacuation of the Richmond and Windsor Sectors because development in Penrith is affected by rarer floods and the subsectors mostly do not have low points on their evacuation routes which trigger evacuation.

Table 10 shows the probability of the various evacuation trigger levels being reached at Penrith Gauge for each of the subsectors in the Penrith and Penrith North sectors. It shows that in a 1 in 100 AEP flood less than 2,200 vehicles would need to evacuate. This would more than double in a 1 in 200 AEP event because of the most recently approved developments of Waterside and Thornton having to evacuate. Close to a 1 in 500 AEP event would be needed before more than 5,000 vehicles would need to evacuate.

Although the table indicates that a 1 in 500 AEP flood would trigger the evacuation of Penrith Subsector, only the lowest lying parts would need to evacuate in such an event. The remainder of the 4,100 vehicles which need to evacuate from this sector would only need to do so if flooding continued to rise. The same would be the case with Jamisontown East and Jamisontown South with the last of the vehicles only having to evacuate from these three subsectors were a PMF forecast.

For all of the vehicles to use the road a PMF would be needed which has a probability approaching 1 in 100,000 chance per year. The probability of the worst possible coincident traffic convergence on The Northern Road during such an event would be something much less probable than 1 in 100,000.

Table 10 Probability of vehicles having to evacuate from Penrith and Penrith North

Flood level probability (chance per year 1 in x)	**Flood Level at Penrith Gauge (m AHD)**	**Subsector**	**Evacuation trigger level at Penrith Gauge (m AHD)**	**Total Vehicles in Subector**	**Cumulative maximum vehicles evacuating**
20	23.5				
		Peach Tree Creek West	24	227	227
		North Penrith A	24.4	768	995
		North Penrith B Commercial and Industrial	24.4	884	1,879
50	24.8				
		Castlereagh	25.5	65	1,944
100	25.9				
		North Penrith B Residential	26.2	1,465	3,409
200	26.5	Waterside	26.5	1,132	4,541
		Cranebrook	26.8	272	4,813
		Penrith	26.8	4,107	8,920
500	27.1				
		Jamisontown East	27.3	1,432	10,352
1,000	27.6				
		Jamisontown South	27.8	491	10,843
2,000	28.7				

6 MERGING EVACUATION TRAFFIC

6.1 MODELLING CONSEQUENCES

6.1.1 Modelling to Date

The evacuation analyses done to date for Jordan Springs East have been conservative and simple. They have assumed that:

- A PMF flood would occur meaning that all of Jordan Springs East would need to evacuate
- The flood would rise as fast as a 72 hour PMF giving minimal time to evacuate
- There would be a maximum of 9 hours warning time
- Evacuation of the whole of Jordan Springs East development would continue as soon as it was determined that at least one dwelling could flood
- The Northern Road would be fully utilised by other flood evacuation traffic when Jordan Springs East would need to evacuate

Even with these extremely conservative assumptions it was able to be demonstrated that:

- There would be sufficient time to fully evacuate a 1,950 lot residential development at Jordan Springs East
- There would be sufficient space within the road network above the PMF for Jordan Springs East traffic to queue until The Northern Road became available.

The recent letters from NSW SES regarding both the Precinct Plan Amendment and the SREP30 Amendment stated that:

"The proposal for queuing of vehicles is problematic due to:

- *Queuing times of 11-20 hours being unacceptable by the evacuating population.*
- *The cumulative impact on the evacuation capacity on the Northern Road regional evacuation route which would affect evacuation capacity for Penrith CBD and for areas in the Hawkesbury LGA (Richmond, Bligh Park, Windsor Downs)."*

It also suggested that:

"To properly evaluate evacuation capacity for the Central Precinct a more detailed analysis of the current and future state would need to be undertaken, taking into account the interaction with evacuation traffic streams from the Hawkesbury and Penrith areas. This would overcome or address the current evacuation timeline analysis (Molino Stewart, November 2017) issues including:

- *Not adequately considering the convergence of regional evacuation traffic streams on to the Northern Road with reduction of effective traffic flow rates resulting in possibly even longer queuing times for Jordan Springs East (Central Precinct) than 11-20 hours; and*
- *Not providing incremental analysis to show increases in queuing times from the current development to the proposed development scale."*

6.1.2 Alternative Approaches

The most thorough way to take into account the interaction of regional evacuation traffic with that from Jordan Springs East is to use an agent based dynamic evacuation model which integrates flood and traffic modelling.

This is the approach which Molino Stewart took with evacuation analysis of the proposed Penrith Lakes development and that model could be adapted to analyse evacuation of Jordan Springs East. However, NSW SES did not accept the outputs of that model because it did not use the future development and updated flood modelling data from INSW nor the latest evacuation route preferences of NSW SES. However, that information is not currently available to use in the analysis for Jordan Springs East. Therefore, modelling evacuation with this level of sophistication would best be undertaken when the latest government data is made available.

Therefore, this report relies upon a simpler method to show how Jordan Springs East traffic might interact with other regional flood evacuation traffic, what that will mean in terms of queuing, how that would vary with different scales of development at Jordan Springs East and how that would change over time.

6.2 EVACUATION TRAFFIC CONVERGENCE

6.2.1 Traffic from the North

As explained in preceding sections of this report, under the existing NSW SES Flood Plan for the valley there are four streams of traffic from the north which converge onto The Northern Road. This will occur irrespective of what development takes place at Jordan Springs East or what evacuation is occurring around Penrith. Figure 12 is a diagram showing the relative timing of evacuation traffic from Richmond, Windsor, Londonderry and Bligh Park using, or wanting to use The Northern Road. This is based on the trigger levels and timings explained earlier in this report along with the various durations calculated using the NSW SES Timeline Evacuation Model.

What can be observed from this diagram is that if three lanes are available for evacuation on The Northern Road as per the NSW SES published plan, and they can travel onto three lanes on The Great Western Highway and the M4, then they would all be able to evacuate before their evacuation routes are cut and they would not have to queue. This is possible if a contra flow lane is provided on The Northern Road.

However, if only two lanes are available for evacuation on The Northern Road or it can only feed into two lanes on either The Great Western Highway or M4, then there is the potential for traffic queuing. In the diagram Londonderry traffic is shown queuing. While the first dwellings in Londonderry may be able to evacuate before Windsor traffic starts using The Northern Road, any vehicles evacuating from the Londonderry Sector from t=26 onwards would have to wait until t=38 and possibly t=41 (if there are traffic delays on the Windsor and Bligh Park streams). That would mean some vehicles queuing for up to 15 hours under the existing NSW SES Plan.

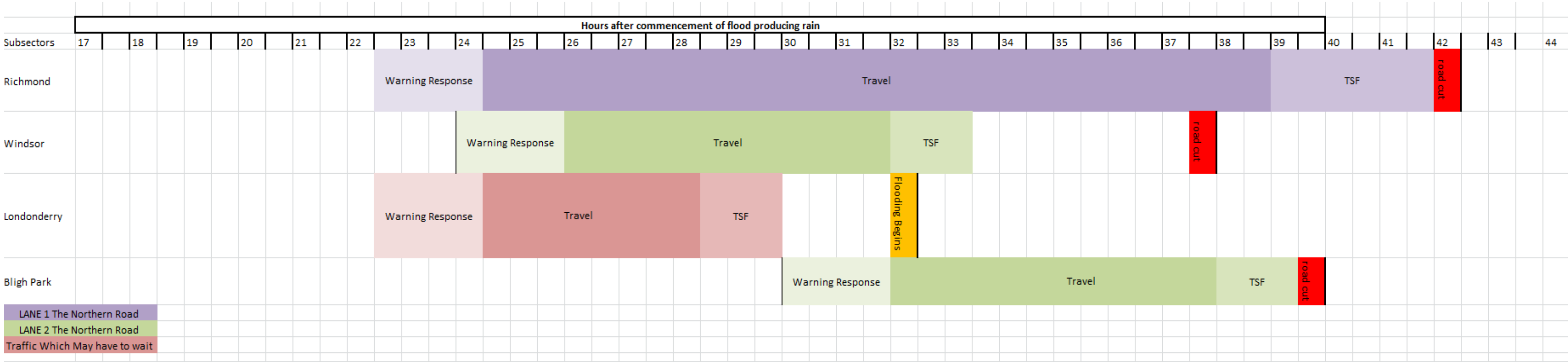


Figure 12 Evacuation Traffic Durations for Traffic from the North

6.2.2 Traffic from the East

Figure 13 is the same diagram as Figure 12 but with traffic from Jordan Springs East (fully developed) and Werrington added in the same way. However, the Londonderry traffic has been split in this diagram to represent the queuing time while it waits for a lane to become available on The Northern Road.

Finally Figure 14 is the same as Figure 13 but with the queuing of Werrington and Jordan Springs East (fully developed) traffic shown. As can be seen from this diagram the longest queuing times for any Jordan Springs East traffic is 7 hours, less than half the queuing time required for existing traffic from the north. The diagram suggests less than 1,900 would queue for 6.5-7 hours, less than 600 for 2.5-4 hours and about 220 could leave so late that they would not have to queue at all.

6.2.3 Traffic from the West

As explained previously, the evacuation of the Penrith and Penrith North sectors will be triggered by flood forecasts at the Penrith Gauge while the sectors further north will be triggered by forecasts at the Windsor Gauge. Similarly, flood modelling around Penrith informs how and when evacuation routes will be cut and buildings flooded in the Penrith and Penrith North sectors and flood modelling around Windsor informs evacuation modelling further downstream.

Flooding at Penrith occurs when floodwaters come down the Nepean and/or Warragamba rivers. A flood exceeding the 1% AEP event is needed for significant evacuation to occur in the Penrith Region.

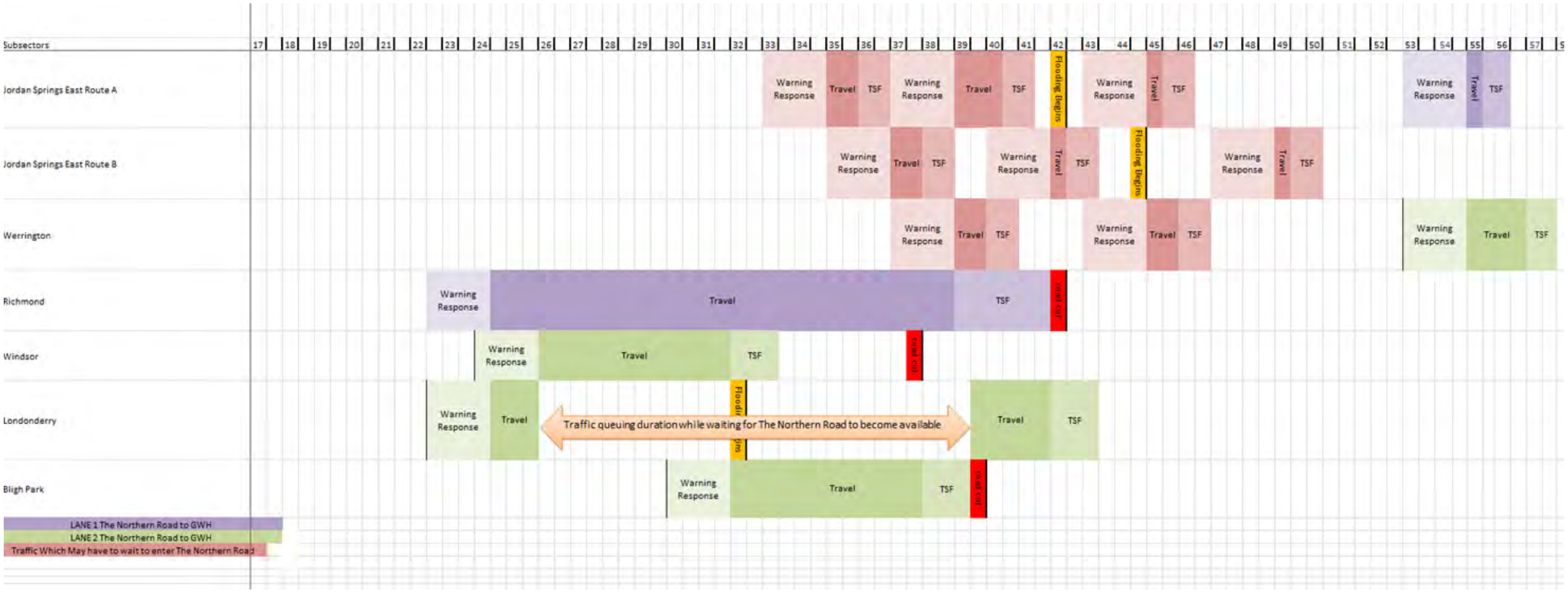
Flooding at Windsor occurs when floodwaters come from Penrith down the Nepean River and/or when they come down the Grose River and/or South Creek. A flood of 15m at Windsor is sufficient to trigger substantial evacuation of the sectors which take their trigger levels from the Windsor Gauge. Such a level is between a 5% and 2% AEP event and therefore much more likely to occur than Penrith evacuation.

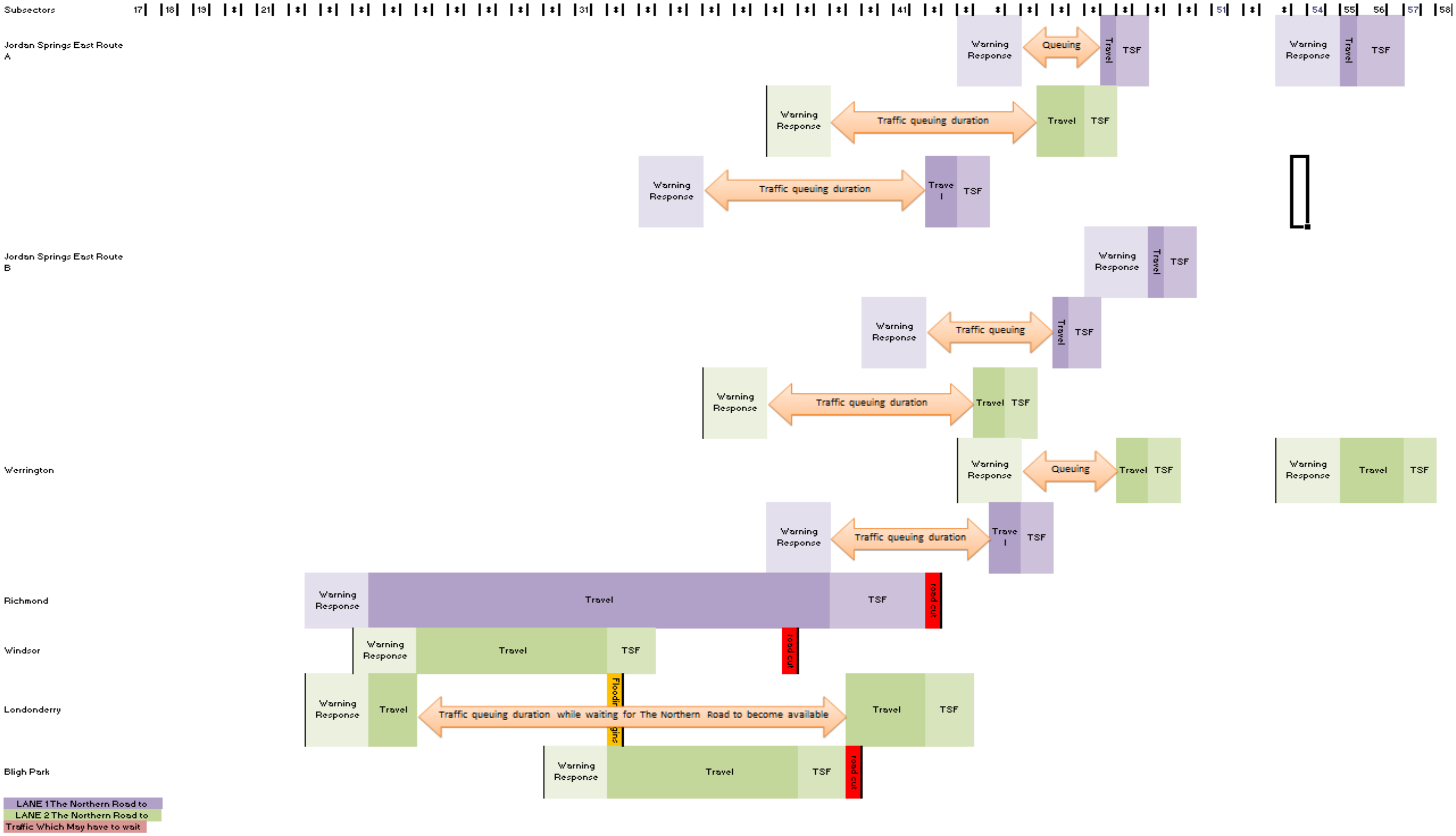
Because of the different possible sources of flooding for the two floodplains and the difference in flood magnitudes which would cause such flooding, it is possible that flooding could trigger evacuation of the Windsor floodplain well before Penrith needs to start evacuating. Conversely, the temporal and spatial distribution of rainfall could result in Penrith evacuating before the areas downstream need to evacuate.

Under some circumstances evacuation traffic from the Penrith Region and sectors further downstream could have to use The Northern Road at the same time. The worst possible case would be if the traffic from Richmond arrives on The Northern Road just as the first of the Penrith Sector traffic begins to evacuate. Under these circumstances maximum simultaneous use of The Northern Road would occur, creating the longest traffic queues and the greatest potential for the evacuation of some traffic to be blocked before it is overtaken by floodwaters.

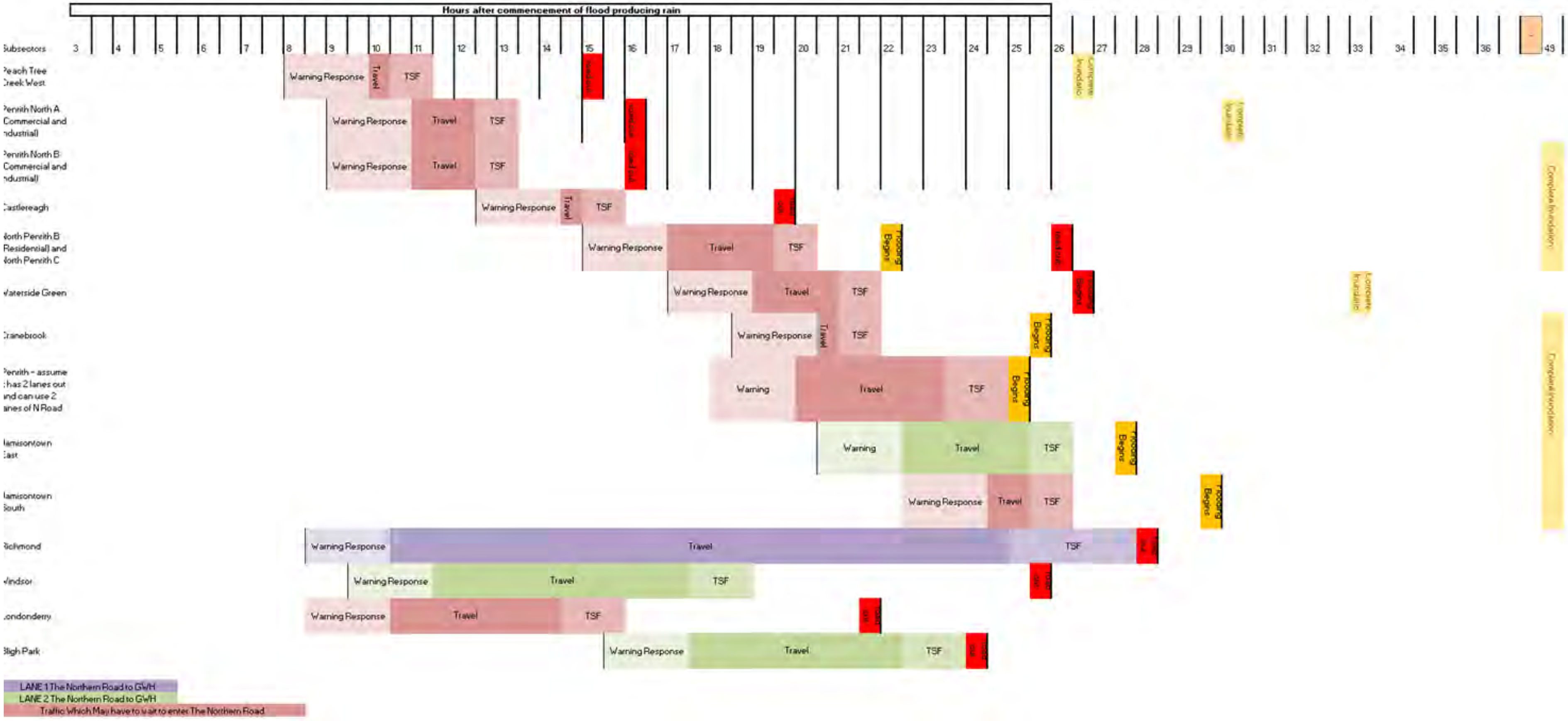
This investigation modelled this absolute worst case scenario assuming that Richmond traffic begins evacuating at the same time as the Peach Tree Creek West subsector. This is shown in Figure 15 with traffic from the east excluded so as not to clutter the diagram. This shows that traffic from the north would almost completely block evacuation from Penrith or vice versa.

Work which Molino Stewart has done for the investigations of Penrith Lakes has demonstrated that there are ways of reducing this congestion so that all of this traffic can evacuate and it is understood NSW SES is exploring some of those options. This includes the traffic from the north turning off The Northern Road at the Great Western Highway and as much of the Penrith traffic as possible entering The Northern Road south of that intersection and heading to the M4 Motorway. If this can be achieved then evacuation traffic from the west and from Jordan Springs East will have little if any impact on each other.


Subsectors
Jordan Springs East Route A
Jordan Springs East Route B
Werrington
Richmond
Windsor
Londonderry
Bligh Park
Warning Response
Travel
TSF
Flooding Begins
road cut
Traffic queuing duration while waiting for The Northern Road to become available
LANE 1 The Northern Road to GWH
LANE 2 The Northern Road to GWH
Traffic Which May have to wait to enter The Northern Road



Subsectors
Jordan Springs East Route A
Jordan Springs East Route B
Werrington
Richmond
Windsor
Londonderry
Bligh Park
Warning Response
Queuing
Travel
TSF
Traffic queuing duration
Traffic queuing
road cut
Floodplains
Traffic queuing duration while waiting for The Northern Road to become available
LANE 1 The Northern Road to
LANE 2 The Northern Road to
Traffic Which May have to wait



Hours after commencement of flood producing rain
Subsectors
Peach Tree Creek West
Penrith North A Commercial and Industrial)
Penrith North B Commercial and Industrial)
Castlereagh
North Penrith B Residential) and North Penrith C
Waterside Green
Cranebrook
Penrith - assume it has 2 lanes out and can use 2 lanes of N Road
Jamisontown East
Jamisontown South
Richmond
Windsor
Londonderry
Bligh Park
Warning Response
Travel
TSF
Warning
Flooding Begins
Complete Inundation
LANE 1 The Northern Road to GWH
LANE 2 The Northern Road to GWH
Traffic Which May have to wait to enter The Northern Road

6.3 PROBABILITIES

As previously explained there is somewhere between a 1 in 20 and 1in 50 chance per year that Richmond, Windsor, Bligh Park, Windsor Downs and Londonderry will have to start evacuating and be arriving on The Northern Road simultaneously. If there is no contraflow lane on The Northern Road to give it a three lane capacity, then queuing will occur. The duration of the queuing will very much depend on how high the floodwaters are forecast to rise. Forecasts will be updated regularly and if it becomes apparent that all evacuation routes will not be cut then evacuation will cease.

In the case of Bligh Park a flood with about a 1 in 200 chance per year would need to be forecast for the whole sector to have to evacuate and for Richmond it would need to be forecast to reach about a 1 in 1,000 chance per year flood level.

A regional flood exceeding a 1 in 500 chance per year event would be needed before any evacuation from Jordan Springs East was necessary and in the case of Werrington a 1 in 2,000 event or larger would be needed. This means that not only would queuing times for Jordan Springs East traffic be about half that of queuing times for existing traffic from the north, they would be more than 10 times less likely to occur.

6.4 SENSITIVITY ANALYSIS

The preceding modelling is based on a number of assumptions and it is important to test the sensitivity of the results to those assumptions.

6.4.1 Vehicle Numbers

a) Jordan Springs East

The modelling has assumed the maximum development proposed for Jordan Springs East with an average vehicle ownership of 1.8 vehicles per dwelling. With household sizes decreasing it is unlikely that the number of vehicles per dwelling will rise very much above this.

It is also noted that the longest queuing times in Jordan Springs East were for lowest lying areas while they waited for regional evacuation traffic to clear. As all of the development scenarios for Jordan Springs East would include development of these lowest areas the queuing times would not reduce if the scale of the development were smaller. Rather, there would simply be less vehicles queuing.

For example, it is understood that the original INSW evacuation modelling allowed for 978 dwellings and 760 jobs in Jordan Springs East with 584 dwellings below the level of the PMF and all of the jobs below the level of the PMF. Without further data from INSW it has been assumed that they have allowed for 1.8 vehicles per dwelling and one vehicle per job giving a total of 1,811 evacuating vehicles.

The evacuation analysis undertaken by Molino Stewart in 2014 in relation to the bulk earthworks development application submitted by Lend Lease assumed that there would 1,333 dwellings and no employment land with 1,168 of the dwellings having to evacuate resulting in 2,164 vehicles evacuating.

The development has been approved with employment lands (760 jobs) and residential development (970 dwellings). The Precinct Plan Amendment submitted by Lend Lease proposes that the yield from Jordan Springs East be increased from the approved to 1,448 dwellings (940 below the PMF) with not changes to the employment lands. This would require the evacuation of a maximum of 2,452 vehicles at 1.8 vehicles per dwelling and one vehicle per job.

Finally, the SREP 30 amendment proposes to convert the employment lands to residential land so that there is approximately 2,000 dwellings across the whole of Jordan Springs with 1,492 of them below the PMF. This would result in a maximum of 2,667 vehicles evacuating.

It is this latter figure which has been used in the analyses set out in Section 5.4.2 and Section 6.2 of this report and represents the worst case scenario in terms of queuing times and the number of vehicles queuing. It showed that the maximum duration that any vehicles from Jordan Springs East would have to queue is 7 hours. This would be the vehicles which are evacuating from the lowest lying dwellings and they would be queuing as they await The Northern Road to clear.

If Jordan Springs East were only developed with 978 dwellings and 760 jobs it would still have development which would need to evacuate when it was forecast the lowest levels of Jordan Springs East would flood and they would still have to wait for the same length of time for The Northern Road to clear, there just might be fewer of them, depending on where in Jordan Springs East the increases in dwelling numbers occurs.

For example, if the precinct plan amendment increases lot density in the areas below 22m AHD then there will be more vehicles queuing for up to 7 hours than under the INSW assumed scenario. However, if the increase in density occurs above 22m AHD then there will be increases in the number of vehicles queuing but their maximum queuing time will be 4 hours or less.

Similarly, the SREP 30 amendment proposes to convert employment land to residential land which would result in 552 additional dwellings below the PMF level or 994 more residential vehicles. However, these would be replacing 760 workers' vehicles, which means that an additional 224 vehicles would be queuing. Of those, only 80% of them (179 vehicles) would be below 22m AHD and be queuing for up to 7 hours with the remainder queuing for 4 hours or less.

Table 11 summarises the number of vehicles queuing for between 0 and 4 hours and between 6 and 7 hours under each scenario, assuming that there is a proportional distribution of medium density housing throughout the development under the proposed precinct plan amendment.

Table 11: Comparative Queuing Durations and Numbers of Vehicles

Development Scenario	**Total Dwellings**	**Total Jobs**	**Total Number of Evacuating Vehicles**	**Vehicles queuing for 6 to 7 hours**	**Vehicles queuing for 0 to 4 hours**
2009 Precinct Plan	978	760	1,811	1,243	559
2016 Precinct Plan Amendment	1,448	760	2,452	1,693	750
2017 Rezoning	~2,000	0	2,667	1,872	795

b) Regional Traffic

Interactions with INSW and NSW SES in recent years suggest that they are use much larger regional traffic numbers in their evacuation modelling that has been used in the analyses in this report. Were there to be more traffic coming from Richmond then its evacuation would have to commence even earlier than has been assumed here because it must get out before its evacuation was cut. That would have no impacts on queuing of traffic from the north nor the queuing of Jordan Springs East Traffic.

More traffic from Windsor or Bligh Park would increase the time that they need to use The Northern Road but again they would need to simply start earlier so as to completely evacuation before their route is cut. This would mean Londonderry traffic would have to wait longer until it could start evacuating. This may in fact compromise the evacuation of Londonderry but, assuming it still has sufficient time to evacuate, then the extra vehicles that have to wait until there is a lane free on The Northern Road would delay the use of The Northern Road by Jordan Springs East. Reading from Figure 14 this could add 1.5 hours to Jordan Springs East queuing times.

6.4.2 Flood Rate of Rise

If the flood were to rise more slowly than has been assumed in the modelling in this report then there would be more time available for evacuation and the evacuation of areas with rising road access such as Jordan Springs East, Werrington and most of Penrith would be stretched out with longer periods between each subsector being evacuated. This will reduce the chance of traffic congestion and queuing.

If floods rise faster than used in this model then the cut off points for traffic from the north and some of the traffic from Penrith will be reached sooner and there might not be enough time for them all to get out. However, this will have little impact on evacuation of Jordan Springs East. The modelling shows they have ample time to evacuate and can queue in areas above the reach of floodwaters. If anything a faster rate of rise will mean that they have to wait less time until evacuation traffic from the north ceases and this in turn will reduce their queuing times.

6.4.3 Warning Time

The NSW SES has suggested that the Bureau of Meteorology may soon be able to give longer warning times than they have previously been willing to commit to because of improvements in forecasting and flood modelling technology. Longer warning times will allow emergency services to call the evacuation of Richmond, Windsor and Bligh Park with more certainty rather than having to rely on forecast rainfall to give sufficient time to fully evacuate these areas. As there is ample time to evacuate Jordan Springs East, there would be not be an imperative to order its evacuation earlier than assumed in the modelling. Therefore, overall longer warning times are likely to simply provide greater certainty to the evacuation rather than significantly impact on traffic convergence and queuing.

7 CONCLUSIONS

The more detailed analyses presented in this report shows that the previous simplified analyses overestimated likely queuing times for evacuees from Jordan Springs East which are likely to be no greater than 7 hours and, for those in the higher parts of the development, they are unlikely to have to queue at all. This compares to the 15 hours or so that existing evacuation traffic from Richmond, Londonderry, Windsor or Bligh Park might have to queue while they wait for each other to use The Northern Road. Furthermore, Jordan Springs East is more than 10 times less likely to have to queue than these areas to the north. There is about a 1 in 500 chance per year that any evacuation of Jordan Springs will be necessary at all and less than a 1 in 70,000 chance per year that it would all have to be evacuated.

Because Jordan Springs East does not have to start evacuating until close to when evacuation routes to the north are cut by flooding, queuing times in Jordan Springs East are not particularly sensitive to the number of vehicles evacuating from these other areas, the rate of rise of floodwaters nor the available warning time. Furthermore, because all of the development scenarios at Jordan Springs East would see the whole of the development area developed, just at different densities, the ultimate scale of the Jordan Springs East development only has an impact on the number of evacuees queuing, not on their queuing times. There might be an extra 640 vehicles queuing for between 6 and 7 hours if the precinct plan amendment is approved and a further 215 if the rezoning is also approved.

It is recognised that in some circumstances evacuation traffic from Penrith may need to use The Northern Road at the same time as Jordan Springs East. If this is the case then the Penrith traffic would have more serious clashes with evacuation traffic from Richmond, Windsor, Bligh Park etc. Whatever is done to deal with that contingency will reduce or eliminate the convergence of Penrith evacuation traffic with Jordan Springs East traffic.