Development of Evacuation Zones

Due to uncertainty over both the location and time of landfall of a cyclone and any associated storm tide, evacuation and the need to shelter at risk persons will occur more frequently and over a larger area than the actual storm tide inundation of an area. This degree of uncertainty and the need to ensure safety will cause emergency planners to err on the side of caution.

Inundation by storm tide is not comparable with riverine flooding. Storm tides will be accompanied by gale force winds, with successive waves of seawater rapidly moving across the foreshore. Trees, building material and other debris may be carried along by the storm tide. Any evacuation must be completed before the onset of these conditions.

Step One: Start with Inundation Data

The National Storm Tide Mapping Model (NSTMM) provides the basis for evacuation mapping in Queensland's. It is the base data from which to develop evacuation zones. It provides for seven inundation zones based on half-metre increments of inundation height above Highest Astronomical Tide (HAT) and referenced from Australian Height Datum (AHD). DEM data provided by the Queensland Government in GIS format and hard copy maps is used in the development of these inundation zones maps.

While DEM data will be provided in increments of 0.25m intervals referenced from AHD, the advised accuracy of the data should be considered in determining whether to align inundation zones to 0.25m or 0.5m (AHD) intervals. It is recommended that 0.5m increments be used to account for any DEM inaccuracies and to align with the NSTMM.

Inundation data indicates the level to which water may rise in a particular area. Inundation data developed by NSTMM does not take into account, wave setup and runup or hydrodynamic effects. As is outlined in the *Tropical Cyclone Storm Tide Warning Response System Handbook,* during an storm tide event, the Bureau of Meteorology is responsible for issuing Storm Tide Advice(s). The Department of Environment and Science is responsible for providing technical advice on storm tide to local, district and state groups.

Figure 1: Example Inundation Zone Map depicting 1m storm tide.

Step Two: Develop Theoretical Evacuation Zones

In developing theoretical evacuation zones consideration will need to be given to the likelihood of the event occurring. The Evacuation: Responsibilities, Arrangements and Management Manual recognises that calculations on event return periods vary from location to location. A return period is defined as an estimate of the interval of time between events of a certain intensity or size. In general, the larger the event, the larger the return period and consequently the less likelihood of it occurring.

If a particularly large event is forecast, then emergency planners will want to err on the side of caution and evacuate a larger number of people to ensure community safety. Evacuation zones for very occasional events are therefore larger than those zones for events that may occur more frequently.

A number of countries have adopted just four (4) zones based on the reasoning that numerous zones are difficult to communicate and may lead to confusion. In addition, the adoption of colours other than those adopted for the NSTMM zones will reduce the possibility of confusion between **inundation** zones and **evacuation** zones.

Mapping in Queensland should use the following four (4) evacuation zones and their relationship to the NSTMM are shown below.

Inundation Zones	Evacuation Zones			
National Storm Tide Mapping Model Zone Colours	**Interval**	**Evacuation Zone**	**Colour Sample**	**Colour Reference**
White (Optional)	2 metres above top of yellow zone	**Blue**		PMS278
Pink : Brown : White	2 metres above top of orange zone	**Yellow**		PMS102
Grey : Orange + possibly Pink	1 metre above top of red zone	**Orange**		PMS151
Green[2] : Purple + possibly Grey	From HAT to approx 1 metre above HAT	**Red**		PMS185

The starting point for the development of theoretical evacuation zones is the determination of the size of the red zone.

HAT may vary along a single local government coastline. Local governments should consider using a single representative HAT datum for the purposes of evacuation mapping covering their jurisdiction so maps along the coastline can be easily compared and represent the same relative information.

HAT values above AHD are available for points along the Queensland coastline in appendices of the Tropical Cyclone Storm Tide Warning-Response System Handbook.

For the purpose of theoretical evacuation zone mapping, it must be remembered that DEM data and forecast storm tide heights have limits on their absolute accuracy and a tolerance of 0.25m should be allowed for in planning.

In attempting to keep the evacuation zones aligned with the NSTMM zones, the size (as measured from HAT) of the red zone will vary from location to location. This presents disaster management planners with two options in determining the size of the red zone. The two options are necessary to ensure that a) the red zone is not so small that few if any people will be impacted, thus rendering the existence of the red zone as superfluous but b) not encompassing an unmanageable number of people if an evacuation is to take place. In determining which option to adopt, consideration needs to be given to the size of the green zone, as determined from NSTMM. This is illustrated in the examples for Townsville and Dunk Island which follow.

On this basis, Theoretical Evacuation Zones are determined in the following manner:

1. The red zone is determined on the map from the HAT level to the next 0.5m AHD interval and then further 0.5m increments[3] until the top of the red zone is as close as practicable to 1.0m above HAT. (See examples for Townsville and Dunk Island.)

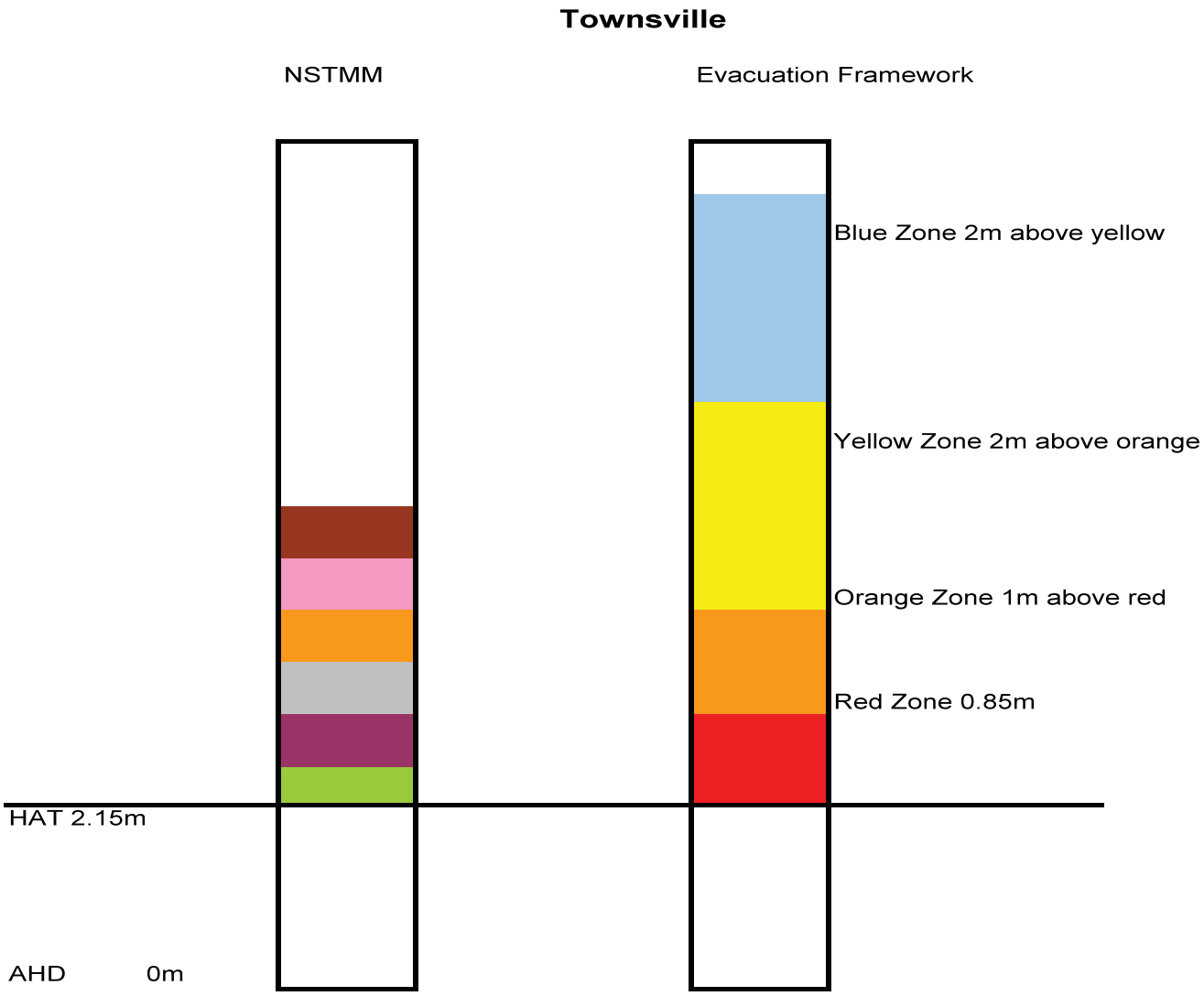
2. The orange zone is determined by a further two 0.5m increments on top of the red zone. The red and orange zones will account for the majority of storm tide events.

3. Yellow and blue zones are each a further four 0. 5m increments. Taking the top of the blue zone to 6.0m will accommodate the probable maximum storm tide event (or 1 in 10,000 Average Recurrence Interval) for Queensland. Disaster management planners may, following careful consideration dispense with the blue zone if they are confident that just three zones will accommodate all likely events.

The process outlined above will determine four (4) theoretical evacuation zones. The zones indicate areas to be evacuated in light of a specific threat. The zones do not indicate the depth of water.

Example One: Townsville

The following example shows the relationship between the NSTMM and theoretical evacuation zones for Townsville which has a HAT of 2.15m above AHD.

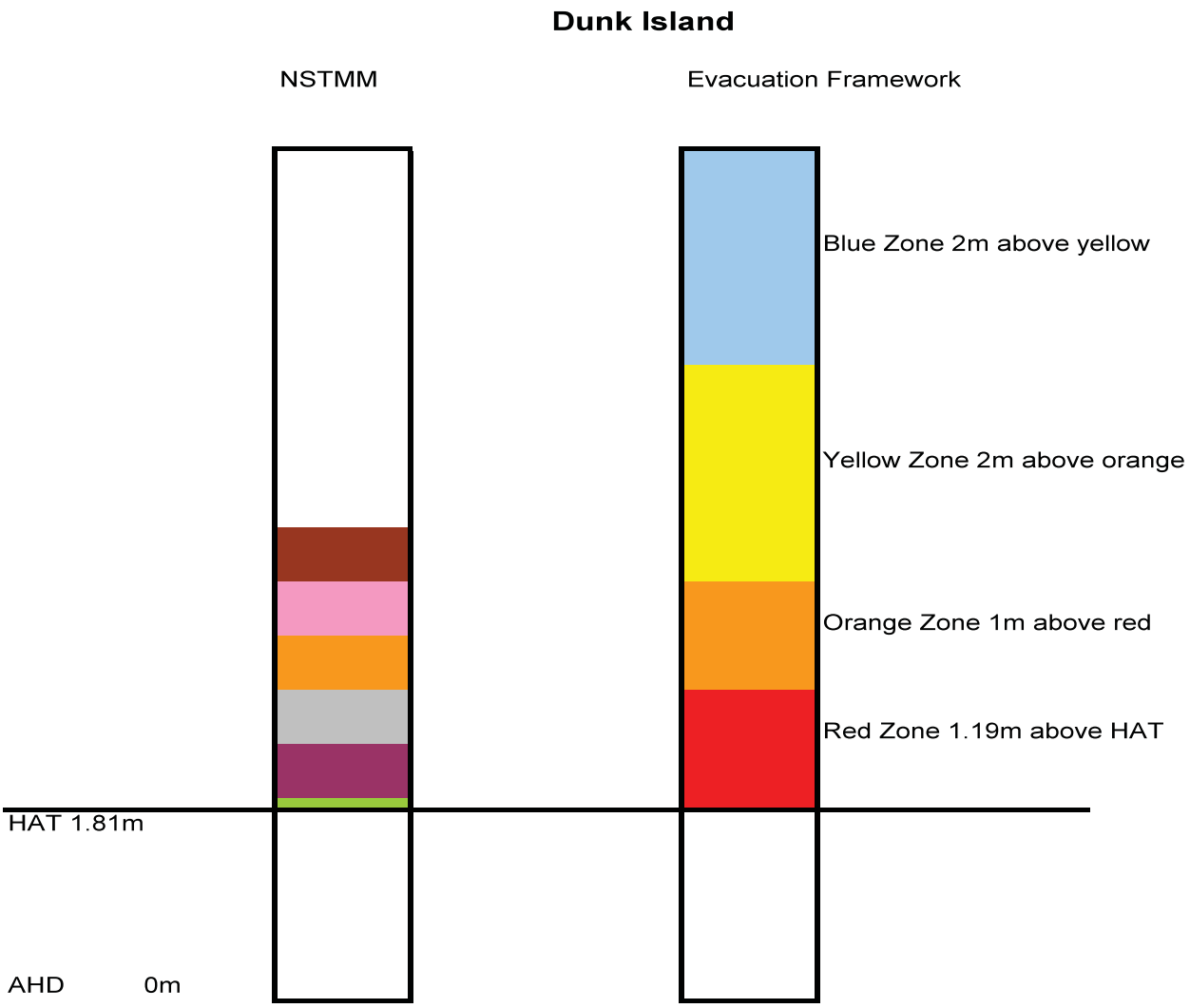


In the above scenario, HAT is just above a 0.5 interval as shown on DEM data. That is; the green zone is 0.35m. Combining the green zone with the purple zone would give a height above HAT of 0.85m.

This is as close as possible to the one metre required for the red zone. In this case where HAT is just above an interval, the red zone equates to the green and purple zones of the NSTMM. It would then follow that the orange zone equates to the grey and orange zones and the yellow zone equates to the pink , brown and white zones.

Example Two: Dunk Island

In this example of Dunk Island, HAT is 1.81m above AHD. If the same rationale as applied to Townsville in example one was followed, then the top of the theoretical red zone (green plus purple) would be only 0.69m above HAT. Therefore in this case, an additional 0.5m is added to the red zone (grey on NSTMM). This variation is to ensure that the red zone is not so small as to be meaningless (ie 0.69m which in most coastal areas would have little impact on residential properties).



It must be emphasised that the ultimate purpose of the theoretical zones is to act as a starting point for the development of practical evacuation zones, which is outlined in the following steps. Practical evacuation zones are a disaster management tool and serve different purposes to those of inundation zones created under the NSTMM.

It is important to note that evacuation zones do not overlap. As illustrated in Figure 4, evacuation zones are discrete; that is, a house can only be in one evacuation zone. This makes it easier for a householder to understand evacuation procedures. “My house is in the orange zone; I should evacuate when orders are given for the orange zone to evacuate.” Dependant on the level of threat, Evacuation Orders may relate to a number of zones. “Residents in the red and orange zones...”

Figure 2: Example Theoretical Evacuation Zone Map depicting the Red Zone.

Step Three: Develop Practical Evacuation Zones

Once the theoretical evacuation zones have been established, they will almost certainly then need to be developed into practical evacuation zones to reflect local conditions and considerations.

The following considerations will contribute to this process. If, and only if, none of these apply, then the theoretical zones effectively become the practical zones. These zones will then equate to, but not mirror exactly, the inundation zones of the National Storm Tide Mapping Model. However, it is anticipated that for the majority of communities the development of practical evacuation zones will be appropriate.

Apply local modelling knowledge

The National Storm Tide Mapping Model is based on rising water height everywhere. It does not take account of the fact that topography may protect some areas from being affected by storm tide. Local knowledge of past storm tide and cyclone events or more precise modelling may give better indications of those areas likely to be affected by a storm tide.

Consider manmade structures and mitigation works

This is an extension of local knowledge modelling and will ensure that those structures that may either accentuate or alleviate the effect of inundation are taken into account. Canals may channel the effects of a storm tide, whilst banks and levees may contain it. Both aspects of manmade structures should be factored into the development of evacuation zones.

Consider effects on property

Consideration will need to be given to the actual effects of inundation on property. Where inundation occurs only on the fringe of a property and is external to dwellings evacuation may not be necessary. This is ultimately a decision for local government, who will need to determine the criteria for evacuation based on internal and external flooding, types of housing stock within the community, construction standards, implications of flooding on high rise dwellings and balance with the consideration of the other factors outlined within this section.

Consider isolated areas

Topography and mitigation works may leave some areas out of the potential inundation zone but their residents will be isolated. In addition, other areas may not be technically isolated but their location may involve lengthy evacuation travel timeframes. These forms of isolation create potential problems due to disruptions to utilities and access to amenities and health facilities. Evacuation zones may need to include isolated areas even if they remain high and dry.

Consider the effects on infrastructure

Even if an area is not physically isolated, inundation may have affected the services and utilities available to that area. Sewerage, power, water and telecommunications all may limit the ability of the community to live in an area for prolonged periods. Those areas likely to suffer degradation of utilities may need to be included in evacuation zones as evacuating people during the aftermath of the event is likely to cause additional problems for emergency managers.

Consider routes

The choice of evacuation routes is likely to be an event-dependent consideration as part of the evacuation planning process. However, in some cases predictable route closures may impact on the development of evacuations zones even when all the above factors have been considered. Likely evacuation routes should be considered for their impact on those communities that may need to be evacuated.

Consider the scale of the task

The slope of the ground and the population density of an effected area, particularly in the yellow and blue zones, may result in a single evacuation zone covering either hundreds or tens of thousands of people. In the case of a large population it may be more practical to plan for sectors within zones to make the warning and evacuation of people more manageable and appropriate.

Disaster management planners should consider the scale of the task implied by the practical zones as applied over their community and, if necessary, break the zones down into sectors. Sectors may not necessarily be based on inundation alone. Other practical considerations may apply and it may be appropriate to designate sectors by locality name or suburbs. By employing sectors within larger zones, the zones will continue to indicate the likelihood of evacuation and allow simple messages for the majority of the population but allow finer control once the potential hazard is predicted.

Example Warning employing sectors (or suburbs):

> *"Residents in red and orange zones should leave now.*
>
> *Residents in yellow zone sectors 1-4 (or Riverside, Mountville and Andertown) should also leave now.*
>
> *Residents in yellow zone, sectors 5-8 (or Seaview, Wilson's Point and Buchanan) need not move, but may consider doing so.*
>
> *Residents in the blue zone do not need to move."*

Consider command and control aspects

When decisions regarding evacuations are made, final directions will be carried out by emergency workers on the ground. The areas selected must make sense to them and their occupants. Local landmarks and easy-to-identify street or road junctions should guide the development of evacuations zones. Care should be exercised to ensure that this process does not include populations which have no need to evacuate simply to make the mapping task simpler.

For example; while inundation zones may dictate otherwise, it may be decided that evacuation zones should not separate properties within the one street, provided that this does not significantly increase the number of people to be evacuated.

Consider consultation with adjacent local governments

Where at risk populations extend across local government boundaries, consider consultation with adjacent local governments to ensure consistency in the application of these principles thereby assisting cross-jurisdictional emergency response.

Figure 3: Example Practical Evacuation Zone Map depicting the Red Zone.

The illustration above demonstrates the application of a number of considerations previously mentioned to arrive at a practical evacuation zone. Comparison with Figure 2 highlights that in this case, streets have been determined as the boundary for the zone. When considering a larger area than shown in this map, it may be that the areas in a particular zone do not join up to create one continuous zone. This simply reflects the topography of the location and there is no need to employ mapping that creates artificial zones for the sake of simplicity.

It should also be noted that once the zone has been determined, all properties are within that zone only and are not considered to be in any subsequent zone(s).

Step Five: Development of Final Evacuation Maps

Following the application of the principles outlined within this framework, two series of maps should be produced being one series for public information and a more detailed series for disaster management response.

Public Information Storm Tide Evacuation Maps

The following specific information should be included when developing public information maps specific to storm tide.

Legend

The legend on public information storm tide evacuation maps should be as depicted below:

LEGEND		
	Red Evacuation Zone	Indicates areas at highest risk of flooding from cyclone storm tide.
	Orange Evacuation Zone	Indicates areas at high risk of flooding from cyclone storm tide.
	Yellow Evacuation Zone	Indicates areas at moderate risk of flooding from cyclone storm tide.
	Blue Evacuation Zone	Indicates areas at low risk of flooding from cyclone storm tide.
	Evacuation Route	

Disclaimer

It is recommended that a disclaimer be included on public information storm tide evacuation maps. The following provides an example of how the disclaimer may be worded. Local government are encouraged to seek their own legal advice on the final wording of the disclaimer.

Disclaimer

Storm Tide Evacuation Zones are based upon geographical data from the National Storm Tide Mapping program. Evacuation Zones are designed to provide an easy to understand method for the public to identify coastal areas that may be affected by storm tides caused by tropical cyclones or severe east coast storms.

Every effort has been made to ensure that the information contained within these Public Information Maps is accurate. However, [*insert local government name*] does not give any warranty or accept any liability in relation to the content of these maps.

Further Information to Support Public Information Storm Tide Maps

The following definitions of storm tide evacuation zones should be included in local government disaster management publications and websites where public information maps are displayed.

How to use Storm Tide Evacuation Maps

1. Identify where your residence is on the map.
2. If you are in one of the coloured zones, you may be at risk from storm tide flooding, during cyclones.
3. Identify your evacuation route to your pre-determined safer location. For further information on evacuation visit: [*insert local government website address*].
4. During a cyclone event tune into warnings, authorities will advise which zones need to evacuate.

Storm Tide Evacuation Zones – What do they mean?	
Residents in the Red Zone represented by the following colour, face the highest risk of flooding from a cyclone storm tide. The Red Zone includes low-lying coastal areas and areas that may experience storm tide flooding up to approximately 1 metre above HAT.	
Residents in the Orange Zone represented by the following colour, face a high risk of flooding from a cyclone storm tide. The Orange Zone may experience storm tide flooding up to approximately 2 metres above HAT	
Residents in the Yellow Zone represented by the following colour, face a moderate risk of flooding from a cyclone storm tide. The Yellow Zone may experience storm tide flooding at levels up to approximately 2 to 4 metres above HAT.	
Residents in the Blue Zone represented by the following colour, face a low risk of flooding from a cyclone storm tide. The Blue Zone may experience storm tide flooding higher than approximately 4 metres above HAT.	
Evacuation Route	
Note: Highest Astronomical Tide (HAT) levels are similar to levels referred to as king tides.	

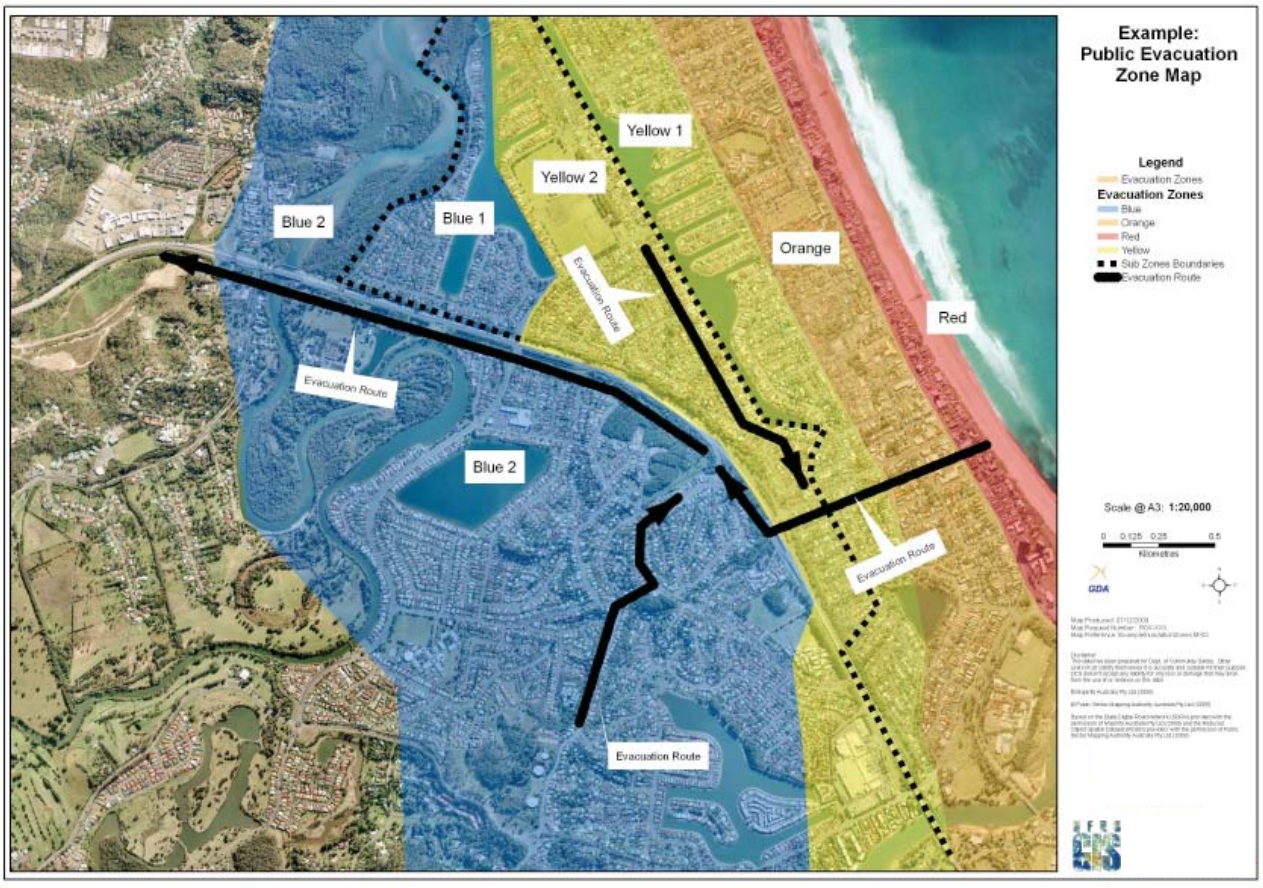


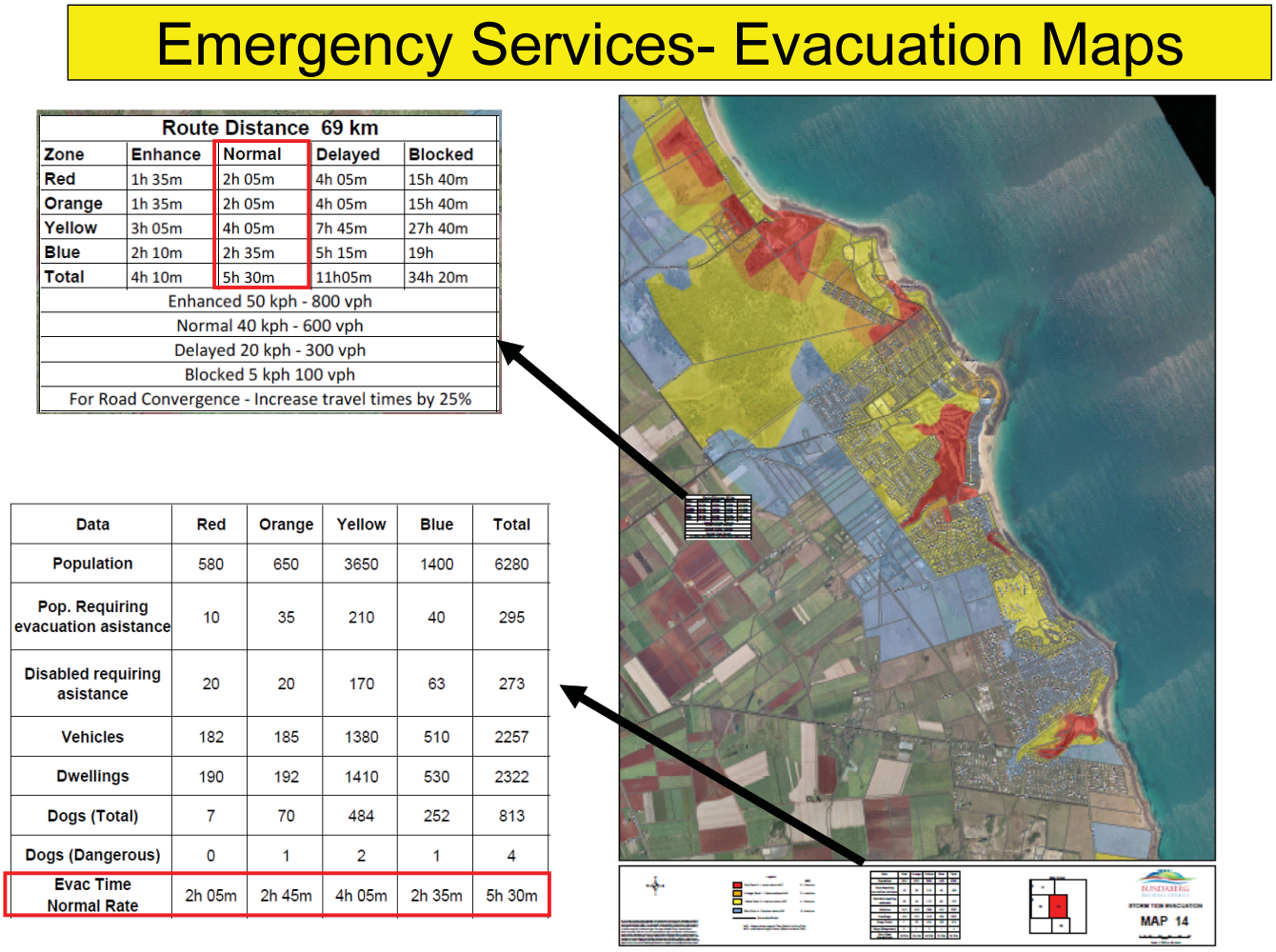
Figure 4: Example of Public Information Map showing Evacuation Zones and Routes.

Disaster Management Response Storm Tide Evacuation Maps

In addition to the inclusions for disaster management response maps commencing on page 15 of the Evacuation: Responsibilities, Arrangements and Management Manual, the following specific factors should be considered when developing disaster management response maps specific to storm tide.

Where appropriate to local conditions disaster management response maps may also include further interval breakdowns of the Yellow and Blue Zones. Further interval breakdowns of these zones may provide disaster managers with more defined areas of evacuation and reduce unnecessary evacuations. Descriptions of these sub-zones would then need to be pre-determined to enable their effective communication to the public. *'Residents within the Yellow Zone who live in Sectors 1 to 4(or particular localities/suburbs) are required to evacuate.''*

Where the application of the principles outlined in Step 3 result in outliers and non-contiguous areas these should not be detailed on public information maps. Outliers and non-contiguous areas should however be included in disaster management response maps and will require specific instructions to residents of these areas if their evacuation is required.



Data	Red	Orange	Yellow	Blue	Total
Population	580	650	3650	1400	6280
Pop. Requiring evacuation asistance	10	35	210	40	295
Disabled requiring asistance	20	20	170	63	273
Vehicles	182	185	1380	510	2257
Dwellings	190	192	1410	530	2322
Dogs (Total)	7	70	484	252	813
Dogs (Dangerous)	0	1	2	1	4
Evac Time Normal Rate	2h 05m	2h 45m	4h 05m	2h 35m	5h 30m

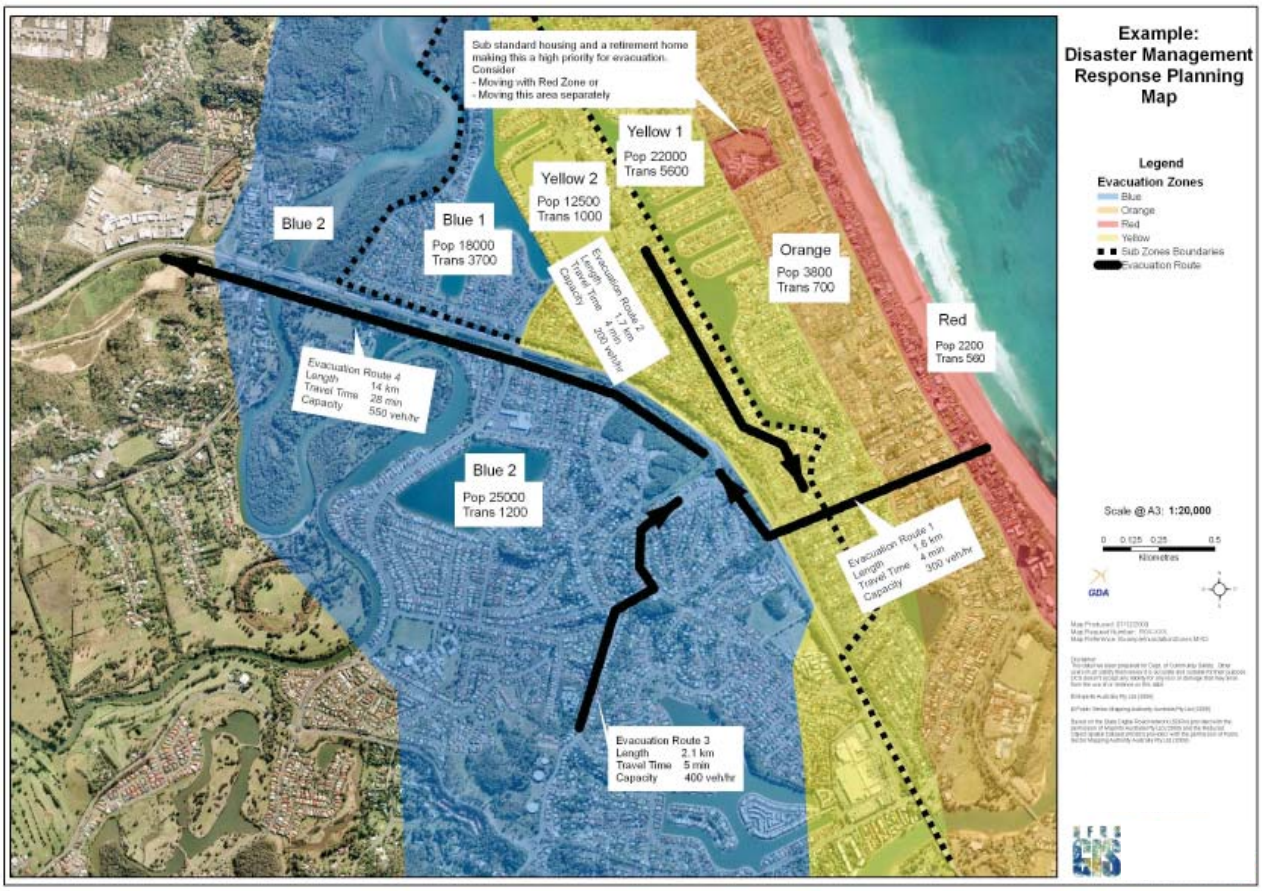


Figure 5. Examples of **Disaster Management Response Maps** including outliers.