

Appendix R

FLOOD WARNING AND EVACUATION

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INTRODUCTION

Imperatives for stream water levels and rainfall recording stations include flood warning and evacuation planning and execution. Both sets of gauges are used by council engineers or the LDMG and BOM.

Stream water level recorders indicate present water level and by tracking rates of rise and correlations with upstream gauges can indicate when road closures might occur.

Rainfall gauges indicate the depth, extent and with other information can indicate the speed and direction of travel of the rain producing clouds.

EVACUATION PLANNING

Evacuation planning requires an examination of the particular circumstances of a settlement when evacuation is possible. The considerations are developed and incorporated into an Evacuation sub-plan of the Local Disaster Management Plan.

The greater the potential evacuation times, the longer is the lead time required. Unfortunately the longer the lead time, the greater the degree of uncertainty in the flood forecast. This is a conundrum for BOM hydrologists who can only issue forecasts to a maximum period of 24 hours. This requires local councils engineers and disaster managers who require longer lead times to make important evacuation decisions without the protection of an official BOM flood forecast. The only way this can be done by council engineers is to examine rainfall and stream water levels collected and distributed through BOM's ENVIROMON system or website. More certainty can be obtained more rapidly if there is a good network of rainfall and stream gauges.

Comments on the evacuation planning process are provided in the Evacuation Planning Background section below.

Briefly, Qld (2013) outlines five stages of evacuation as decision to evacuate, warning, withdrawal, shelter and return.

The first three are critical to the evacuation process timeline.

- The decision to evacuate requires observation, analysis, discussion, seeking accord and making

the decision to evacuate. This can take several hours and early indications of flood magnitude need to be brought to the LDMG as soon as possible so they have sufficient assimilation and preparatory time prior to any trigger point to make the decision to evacuate. Decisions to evacuate large numbers of people will take longer than to evacuate a few.

- Warning delivery time will depend on the number of homes, businesses and congregation areas to be contacted, and their spatial distribution. Factors such as door-knock rates, the number of buildings and other warning delivery processes will affect the remaining withdrawal time.
- Withdrawal times will depend on the number of people, pets and motor vehicles that need to leave an area. Personal decisions on what to take, try and save, raise or remove from expected flood heights will depend on the advised evacuation period and personal flood insurance cover.

The more quickly the analysis, decision to evacuate and warning delivery can be made, the greater the time for evacuation. If that period is greater than 24 hours, the decisions to evacuate must be made without formal BOM warnings. It is for this reason that good relationships must exist between BOM hydrologists and council officers so that pre-official warning discussions can take place with BOM staff having confidence in the competence at council level.

FLOOD FORECASTING

The BOM issues two main types of warnings for flooding: meteorologic forecasts of future storms, cyclones and severe weather that might produce heavy rain and flood forecasts for the 143 flood forecast locations in Queensland. The latter are only issued up to 24 hours in advance which has severe implications for settlements that have a considerable evacuation burden, i.e. when flood wave analysis, decision times, evacuation warning delivery and evacuation will take more than 24 hours.

Rainfall gauge readings are applied by BOM hydrologists to the hydrologic models. Forecast rain can also be added to observed rain to indicate the potential flood behaviour under different rainfall scenarios.

These models provide hydrographs at nominated forecast locations and can give times and flow rates for time of commencement of flood rise, rate of rise and at peak. The flow rates are matched with rating tables to give forecast peak flood heights, usually at a local gauge that is used locally as a reference.

Hydrologic forecasting is not an exact science. More certainty can be built into hydrologic flood forecasts by knowing run-off rates and catchment behaviour during the current event. Catchment behaviour will change as ground absorption and rainfall interceptions diminish. Therefore it is important to hydrologists they receive indications or confirmation of their forecasts by comparison with observed water levels at key locations (through running models in hind cast mode, adjusting parameters and forecasts to aim for greater forecast accuracy.

Stream gauges upstream of the forecast location are essential, particularly if there are significant stream inflows or tributaries where sub-catchment characteristics are different from other catchments.

IMPLICATIONS FOR FLOOD WARNING GAUGE ANALYSIS

Stream water level gauges are useful when located at a settlement that is a forecast reference point:

- to the local settlement as a reference point for evacuation, flood extent and impact, and if rates of rise are known, the time the route will be available
- as a reference point for downstream settlements which indicates upstream flood behaviour
- for confirmation for BOM hydrologists that peak flows and timings generated by hydrologic models are performing as predicted.

When gauges are located upstream of the settlement, they can indicate the flood warning time available. This is a function of average flood wave celerities and distance between gauges.

The warning time needed (and hence the distance upstream) should be function of the first three evacuation stages: time needed for decision making, warning delivery and withdrawal time. Arguably the first, and certainly the last two, are a function of the number of people in the town, regardless of whether there has been a history of flooding, or whether the settlement is built higher than the designated flood. There will always be a bigger flood, and evacuation planning, and the location and density of the flood warning gauge network should be based on population.

Based on the numbers outlined in the evacuation planning background notes below, it would not be

unreasonable to suggest that settlements of 4000 people would require 24 hours warning time. Settlements of 2000 would require 12 hours warning and settlements of more than 4000 might require 24 to 48 hours' notice depending on that settlement's particular circumstances.

This means most of the larger tributaries should have a stream water level recorder connected to the ALERT system and each major tributary catchment should have at least one rainfall gauge for each topographic type.

EVACUATION PLANNING BACKGROUND

Evacuation should be undertaken when forecast flood levels will create the following circumstances:

- overfloor flooding is likely
- supplies of electricity, water and sewerage are cut and are unlikely to be restored for several days
- access to food resupply is longer than three days
- resupply is not feasible with the available resources.

If the flood is likely or can worsen further evacuation is desirable and/or necessary if:

- it will be dangerous for emergency response teams to facilitate evacuation
- residual evacuation numbers are too large a burden for emergency responders
- orderly evacuation is no longer possible and rescue mode commences.

In most floods, evacuation will not be necessary and for more larger floods, residents may have the option of remaining in place. It is only for larger floods that evacuation will be necessary.

EVACUATION PROCESS

The evacuation process is described in the Queensland Evacuation Guideline (Qld 2011) and Commonwealth's Manual 11 Evacuation Planning (COA 2005). Both references outline the five stages of evacuation as:

- 1 Decision to evacuate
- 2 Warning
- 3 Withdrawal

- 4 Shelter
- 5 Return.

These are set out in Figure 1 which is reproduced from Figure 1 of Qld 2011

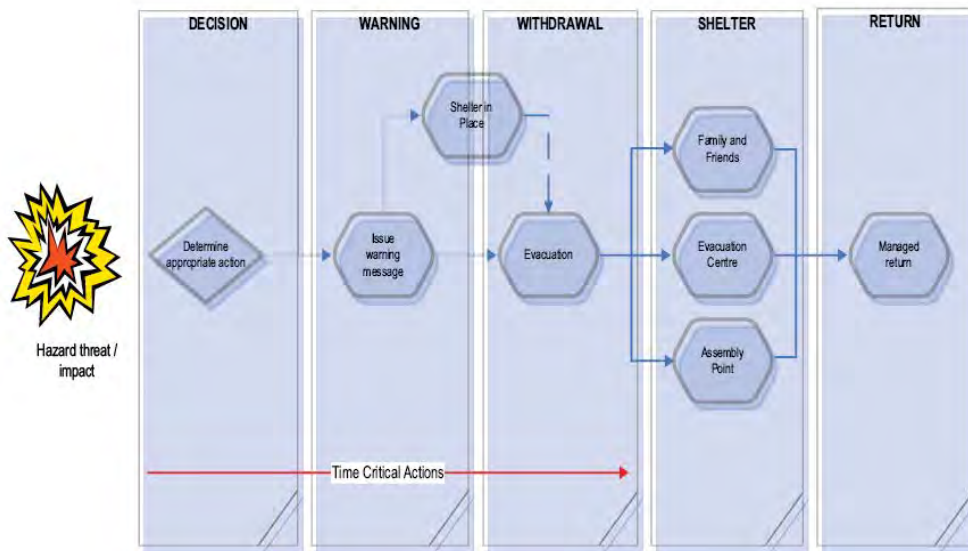


Figure 1 Evacuation timeline

The above figure indicates the first three stages are time critical where delays to any of these may result in rescue rather than orderly evacuation. However, these stages may be further subdivided as outlined below.

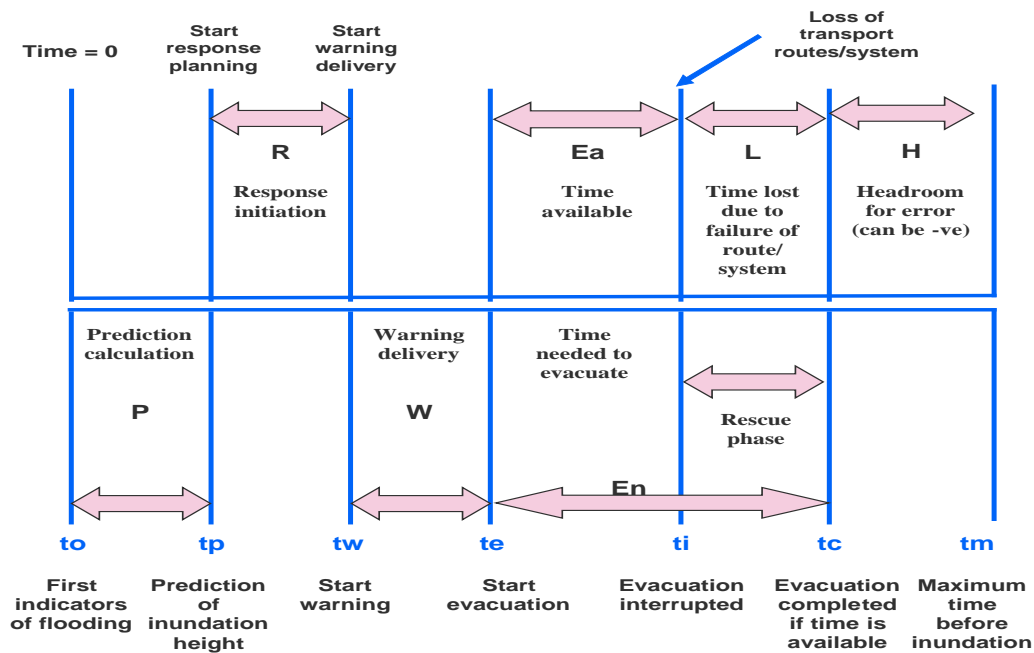
Evacuation planning and execution are predicated on having sufficient warning time available to execute the evacuation process. There are still a number of uncertainties to be determined and this discussion paper does not seek to prove or disprove whether sufficient time is available, but does indicate that there may not be sufficient warning accuracy when the decision to evacuate is made. Warning inaccuracy should be minimised by developing robust and validated examination of both warning and evacuation sequencing processes.

EVACUATION PROCESS TIMELINES

Time pressures also affect decision making processes. A chronology of the evacuation process from the first indicators of flooding to inundation was

developed by Opper (2000). The figure also indicates that time must be provided for prediction error when estimating the time needed for evacuation. These prediction errors can either be hydrologic in nature, or for warning delivery and evacuation. Prediction error becomes part of the risk management process and must be considered an integral part of emergency analysis and planning.

In Figure 2, initial time t_0 is the point at which the first indicator of flooding is apparent. Time P has to be allowed for calculation and prediction of inundation height. Response times $R+W$ are needed by emergency managers to assimilate the information, and prepare and deliver warnings. Time E_n is required for evacuation until time t_c . The gap between t_c and t_m is the headroom for error (which may be negative). If L is the time lost due to a transport route failure, then E_a is the net time available for evacuation. The time between t_i and t_c is the rescue phase of the operation and E_a is less than E_n .



Source: Steve Opper NSW SES (personal communication)

Figure 2 Emergency response timeline

In the warning delivery period between t_w and t_e residents have to assimilate the warning, take whatever actions they can to protect property, prepare for evacuation and commence evacuation. As part of this process residents have to decide when it is necessary to evacuate their homes which may include for how long, and to what flood depth, would they consider remaining in their homes considering ambient climatic conditions.

Parallel considerations by decision makers are under what conditions do flood management experts and disaster managers consider it necessary to warn people to remain in place or evacuate voluntarily, and then at what point should evacuation be forced. It must also be remembered that rescue implies first responders are exposed to danger and may suffer injury or death. In the 2011 Queensland floods, some residents in Rockhampton were advised that once isolated it would be too dangerous to perform a rescue.

The time needed for evacuation will depend on a number of factors as outlined in Figure 2. Once a warning and then an evacuation order are issued: the psychological awareness and willingness of individuals to accept the need for evacuation, whether they have an evacuation plan in place, the number of people/pets to be evacuated, likely model of evacuation, travel distance, etc. The duration of the prediction calculation needs to be as short as possible to maximise the time for emergency response activities that may also include evacuation.

Typical time allocations can be:

- Prediction calculation** 1 to 5 hours depending on catchment size and triggers.
- Response initiation** about 2 hours including set up of Disaster Management Centre.

Warning delivery has been assessed by CHRC as being one hour with vehicle loudspeaker and electronic media. However warning delivery can extend to several hours if doorknocking is required. The critical factor will be the number of people to deliver the warning and the number of people at home. A team of two people can door knock 100 houses in one hour (Opper 2000). If 4,000 houses need to be warned, then 40 team hours are required. Time allocations might be a minimum of:

Table 1 Time allocations	
Warning delivery time allocations	Duration (hours)
Team establishment, instructions and mobilisation	1
Warning delivery if 20 people are door knocking	4
Return for no answer on first knock (assuming occurs within the homeowner decision period)	1
Homeowner decision, delays and packing	2
Total	7 hours

Mobilisation time is the time needed to establish the disaster management centre, assemble team members and issue their instructions. Similarly, warning delivery is a crucial phase and the effectiveness of the warning is dependent on the credibility of the person delivering the message, the means by which it is conveyed, the understanding by the community and potential evacuees, psychological preparedness and the speed at which individuals react.

This takes time (generally a two-person team can doorknock 100 homes an hour) and this time has to be factored into the evacuation timeline. Loud hailers on vehicles may be used to convey messages for entire streets.

Evacuation rates will depend on the mode of travel. Traditionally a single lane has a theoretic capacity of 10,000 vehicles per day (vpd) with the peak hour being 10% of the peak day, say 1,000 vehicles per hour (vph).

Evacuation rates as assessed in a NSW study were 600 vph assuming no hold-ups (Oppen 2004). However in poor visibility, rainy conditions and emergency vehicle strobe lights, that rate could reduce to 400 vph based on a vehicle speed of 10 km/h at a ten metre separation and merging. Allowances also have to be made for merging traffic. Depending on the suburb, each home might have more than one motor vehicle so a 1:1 correlation between homes and vehicles cannot be assumed. For a 4,000 house town evacuating in 4,000 vehicles moving at 600 vph suggest about seven hours will be required assuming there are no delays and all members of the community are aware of the risk and psychologically prepared to evacuate. Under inclement conditions that time could extend to 10 hours or more.

This suggests from the time a flood is first identified, the total decision, warning and withdrawal time could be up to 17 hours.

If the point at which hydrologic certainty of a flood is reached is 12 hours prior to evacuation route closure, then perhaps about 2,000 vehicles could have evacuated if they act promptly. This negative evacuation time has to be reduced to ensure there is headroom for error.

WARNING TIME AVAILABLE

The warning time for evacuation depends on the source of the flood (local stormwater or riverine), the magnitude of the flood which will affect:

- flood wave propagation
- flood extent and depth
- loss of evacuation routes.

Figure 3 appears as Figure 3 in the Emergency Management Australia Flood Warning Manual 20

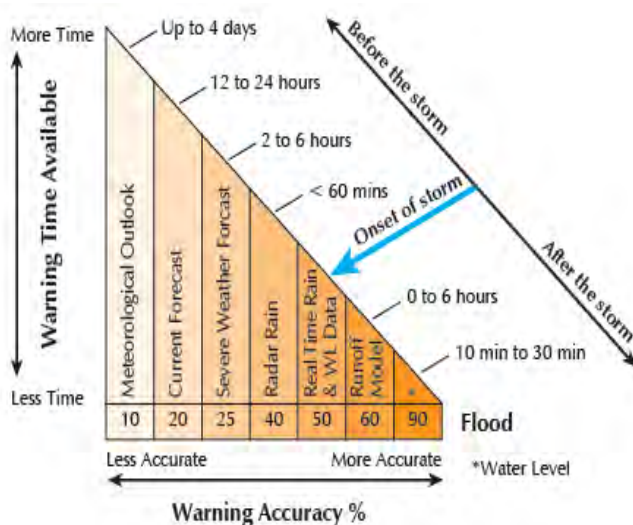


Figure 3 TRADE-OFF BETWEEN WARNING TIME AND ACCURACY

It indicates that the longer the warning time, the less accurate are flood forecasts. This trade-off between forecast certainty and the time available to evacuate is crucial. For towns with a high evacuation burden the less accurate the forecast will be when the decision to evacuate occurs. Given the social and community disruption and cost of evacuation, evacuation decisions are always difficult but should not be delayed so long that the evacuation process becomes a rescue process where the risk to life and injury is much greater.

LIMITATIONS TO EVACUATION

Evacuation must be undertaken under strict control by authorities as it can be a dangerous process. The main considerations are

- evacuation safety
- evacuation burden
- community understanding
- psychological preparedness
- self or assisted evacuation
- access capacity
- hospitality capacity
- special needs evacuees.

REFERENCES

Commonwealth of Australia (COA, 2009a) 'Flood Preparedness', Manual 20, Emergency Management Australia.

Commonwealth of Australia (COA, 2009b) 'Flood Warning', Manual 21, Emergency Management Australia.

Opper, S. (2000), 'Emergency Planning for the Hawkesbury Nepean Valley', presented at 40th Annual Conference, Floodplain Management Authorities of NSW, Parramatta, 2000.

Queensland Government (Qld 2011), 'Queensland Evacuation Guidelines for Disaster management Groups', prepared by Emergency Management Queensland August 2001