

# EMERGENCY RESPONSE PLANNING CLASSIFICATION AT SUB-PRECINCT SCALES

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## Abstract

The categorisation of floodplain communities into Emergency Response Planning (ERP) classifications is a common component of flood studies and floodplain risk management studies. It is required as part of the Floodplain Risk Management process to help assess the relative vulnerability of the community to flooding and assist the State Emergency Service (SES) with emergency response planning.

In 2007, the Office of Environment and Heritage in conjunction with the SES developed a guideline to assist in this classification process. This guideline offers a work flow to assist practitioners in classifying floodplain communities into ERP categories. The work flow is designed for application at broad or precinct scales and involves evaluation of a number of flood-related variables to develop an appropriate ERP classification for a particular area.

This paper describes efforts to automate the assessment of all aspects of this work flow including adaptive assessment of evacuation routes for each model time step based on shortest path network analysis. A computer program was developed to implement the work flow using TUFLOW results, a DEM and GIS layers for roads and precincts.

One advantage of the automated approach to ERP classification is being able to apply the method at much finer scales including individual lots, which can help to identify small problematic areas within larger precincts. Furthermore, a vast amount of additional data is generated as part of the classification process including best evacuation routes ordered by distance and rising road access as well as road inundation depths, timings and durations.

This paper presents the outcomes from this research including examples on its application for the Ourimbah Creek catchment on the Central Coast of NSW. It also discusses potential modifications to the existing work flow and ERP classification scheme that may improve applicability at smaller scales.

## Introduction

The NSW Government's "Floodplain Development Manual" (2005) requires that flood studies, floodplain risk management studies and floodplain risk management plans address the management of existing and continuing flood risk across existing and future development areas. A key component of managing the continuing flood risk is ensuring suitable ERP is completed. This aims to ensure that the variation in emergency response requirements is identified and appropriate planning can be completed to ensure adequate resources are allocated to vulnerable communities during floods.

The Department of Environment and Climate Change (now Office of Environment and Heritage) and State Emergency Service (SES) prepared the “Flood Emergency Response Planning Classification for Communities” (2007) guideline to assist practitioners in categorising floodplain communities into Emergency Response Planning (ERP) classifications in a consistent manner. The guideline provides a flow chart that allows broad scale ERP classifications to be determined based upon a range of flood-related criteria. This flow chart is reproduced in Figure 1 and aims to assign one of the following ERP Classifications:

- High Flood Island
- Low Flood Island
- Area with Rising Road Access
- Area with Overland Escape Route
- Low Trapped Perimeter
- High Trapped Perimeter
- Indirectly Affected Area

The classifications can then be used by the SES to determine the type of emergency response that may be required during a future flood (refer Table 1).

**Table 1: Response Required for Different ERP Classifications (DECC, 2007)**

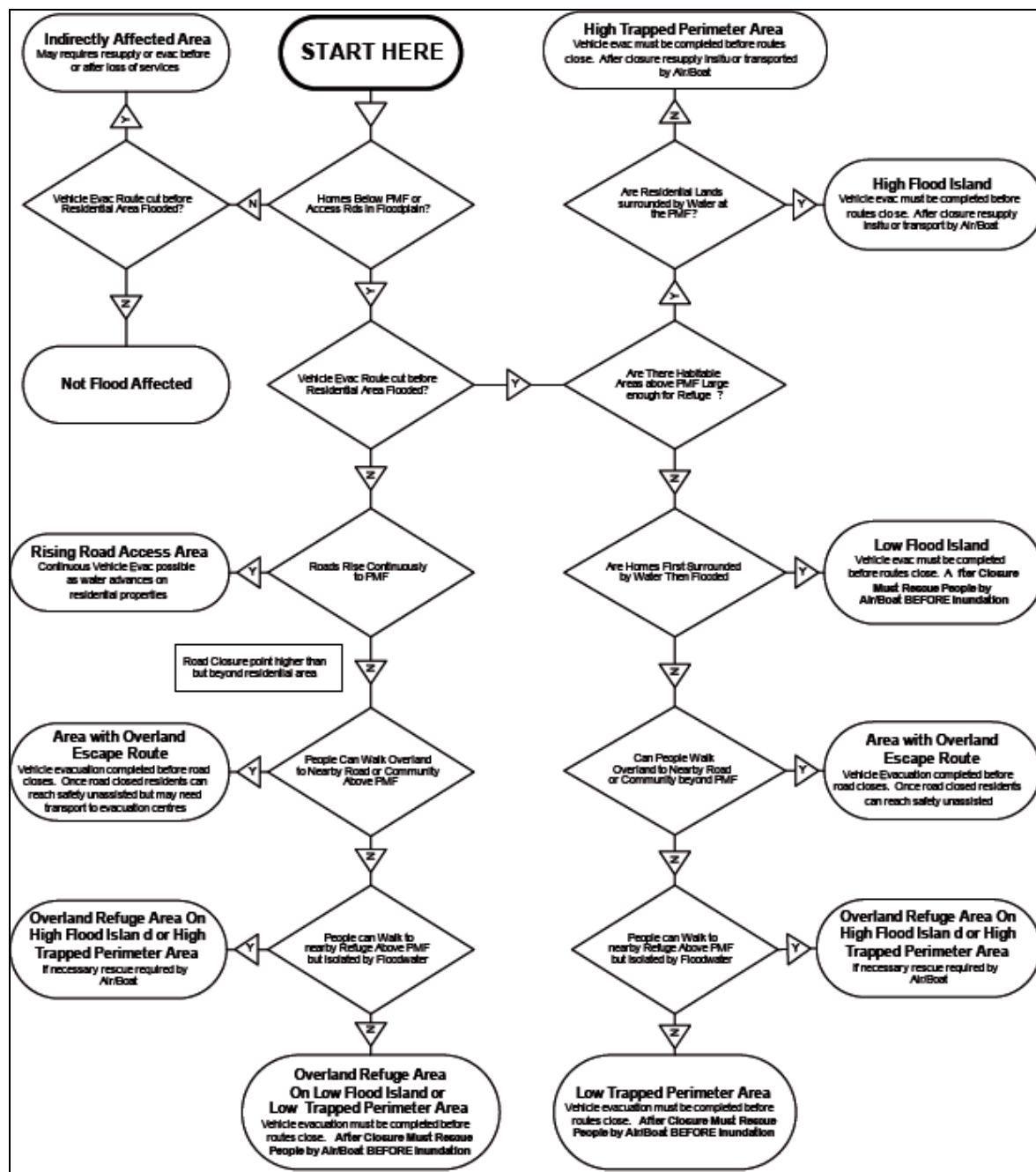
Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Route	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Area	Possibly	Possibly	Possibly

## Limitations of Current ERP Classification Approach

The flow chart depicted in Figure 1 is designed to assign ERP classifications on a broad scale or “precinct” basis. This typically results in whole communities/townships being assimilated into a single ERP classification. This approach often fails to consider the variations in emergency response requirements across the community due to the spatial variation in topography, available evacuation routes and expected floodwater depths/velocities. Accordingly, the emergency response requirements may be overestimated in some areas and underestimated in other areas. This, in turn, can mean that resources can be over or under allocated and/or resources are not allocated to the most vulnerable sections of the community at appropriate times during floods.

In addition, the broad scale approach does not take full advantage of the wide range of detailed spatial datasets that are typically developed as part of contemporary flood studies. For example, flood study datasets can be used to provide a detailed assessment of when areas are expected to become surrounded by floodwater, when roads may become cut, the predicted maximum depth of inundation and how long roads may be cut. This

information can provide valuable insights for those responsible for emergency response management.



**Figure 1: Preliminary Flow Chart for Flood Emergency Response Classification (DECCW, 2007)**

The current approach also does not define what constitutes a “precinct”. Consequently, different practitioners could potentially delineate floodplain communities in a different manner, leading to inconsistency in precinct definition and resulting differences in ERP classifications. Further to this, the precinct approach tends to be primarily focused with the assessment of existing communities, while potential future development areas and their

potential emergency response requirements/issues may be overlooked. Therefore, it may fail to address the continuing flood risk across future development areas that are required by the “Floodplain Development Manual” (2005).

Finally, the current ERP categories provide useful insight into potential emergency response requirements. However, the categories don't necessary provide definitive insight into the type of emergency response action that may be required (note the use of “possibly” in Table 1). They also fail to identify which “high risk” areas should be prioritised ahead of others with regard to potential response times (e.g., which evacuation routes may be cut first).

## Automation of ERP Classification

A computer program was developed to automate the application of the work flow shown in Figure 1 using a variety of flood model outputs and GIS data. Specifically, the software required the following input datasets:

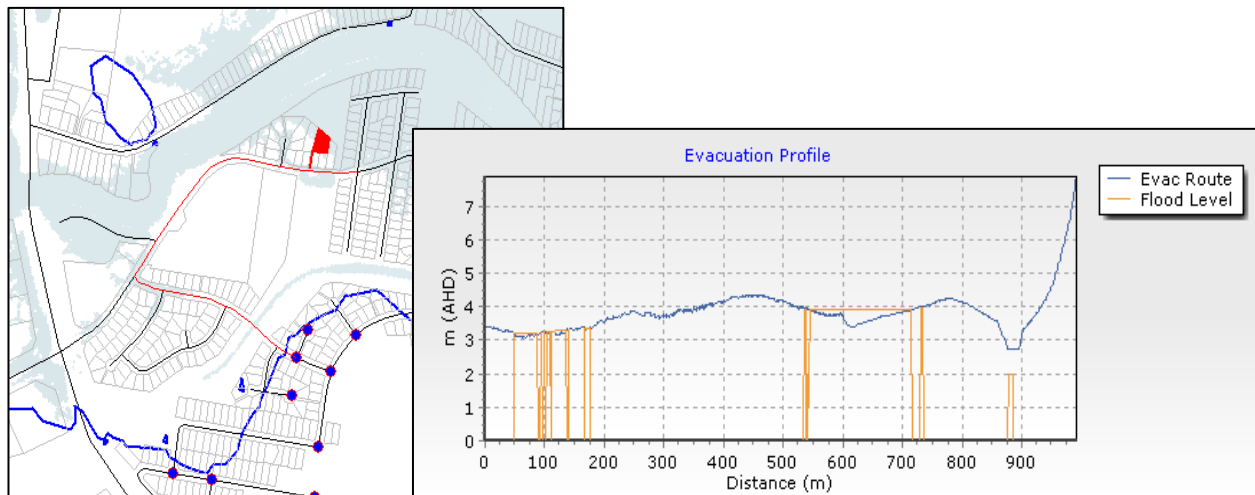
- Probable Maximum Flood (PMF) extent polygon (to define the extent of the floodplain)
- Digital Elevation Model (DEM)
- GIS file of precincts (e.g., lots, broad scale polygons)
- GIS file of road network with some pre-processing including:
  - Polylines are clipped and snapped at all trafficable road intersections. For example, a 4 way intersection should be clipped and snapped at the intersection but a road flyover should not.
  - An attribute representing overriding minimum road elevation, if applicable. This is used when the underlying DEM does not provide a reliable description of the road elevation. For example, if the road includes a bridge, the roadway deck may not be included in the DEM (i.e., the roadway will effectively drop down into the creek/river). Therefore, the deck elevation can be entered as an override elevation to ensure the roadway overtopping elevation is correctly defined.
  - Currently vehicles can only “enter” the roadway network at roadway endpoints/intersections. Therefore, long roads bordering multiple precincts may need to be further subdivided to ensure vehicle ingress locations can be more reliably represented. This component of the pre-processing may be automated in future.
- Data file containing water levels for each time step for the design flood under consideration. Currently this is implemented using a multi-band TIF file prepared using the Tuflow Run Interface Manager (TRIM) software. This allows consideration of multiple different design flood durations to select the critical duration flood for each time step at each location in the model domain.
- A range of default parameters including (values in “{ }” indicate default values that were adopted as part of the case study):
  - *Lot freeboard (m)* – Used to define a maximum allowable depth before a lot is considered “inundated” {0.3m}

- *Surrounded freeboard (m)* – Minimum depth of water across all surrounding areas before a locations can be considered “surrounded” {0.3m}
- *Minimum Habitable Area with Precinct ( $m^2$ )* – Minimum area used to determination if precinct has sufficient habitable areas above flood level to “shelter in place” {250m<sup>2</sup>}
- *Road Freeboard (m)* – Sets a minimum floodwater depth threshold to determine if a road is cut {0.2m}
- *Walking Freeboard (m)* – Maximum water depth before a road is considered impassable by foot {0.8m}
- *Constantly Rising Cut-off (m)* - This parameter governs how much of a dip in the longitudinal road profile is permissible before the evacuation route can no longer be classified as rising road access (i.e., caters for subtle undulations in road profile) {0.3m}
- *Road Proximity (m)* - For determination if an area that is not within a precinct is serviceable by vehicle (Precincts are assumed to be serviceable by vehicle) {30m}
- *Always Wet Cut-off (%)* - If a cell is inundated above the lot freeboard for more than this percentage of the event duration, then it is classified as “Always Wet”. This is primarily used to identify permanent water bodies and waterways {95%}

The software is based around implementing a shortest path network solving algorithm (Dijkstra's Algorithm, 1959) programmatically for each precinct for each time step for several scenarios (vehicular evacuation outside of catchment or only to flood island, rising road and walking evacuation routes). The scenarios are implemented by changing the “cost” of each segment of the route when constructing the network. For example, for finding the shortest vehicular evacuation route, the network is constructed of all road segments that are not inundated above the Vehicle Freeboard and segments are costed based on their length. Thus, the “cheapest” solution found will be the shortest available evacuation route for the given precinct and time step. For walking (along road) based evacuation routes, the procedure is similar except the Walking Freeboard is considered when constructing the network. For assessment of rising road evacuation, the network is constructed similarly based on non-inundated road segments but each segment is costed based on the size of any dips in the road. Thus, the “cheapest” solutions found will tend to have the least drop in elevation along the roadway profile and are therefore most likely to conform to the rising road evacuation criteria which can then be confirmed by assessment of the resultant longitudinal roadway profile.

The software automatically analyses the road network in conjunction with a PMF polygon layer to determine which road nodes represent evacuation points outside of the floodplain and which may be ‘island’ evacuation nodes (above the PMF but surrounded). If evacuation is possible to points outside of the floodplain then this will be selected in priority to ‘island’ only evacuation.

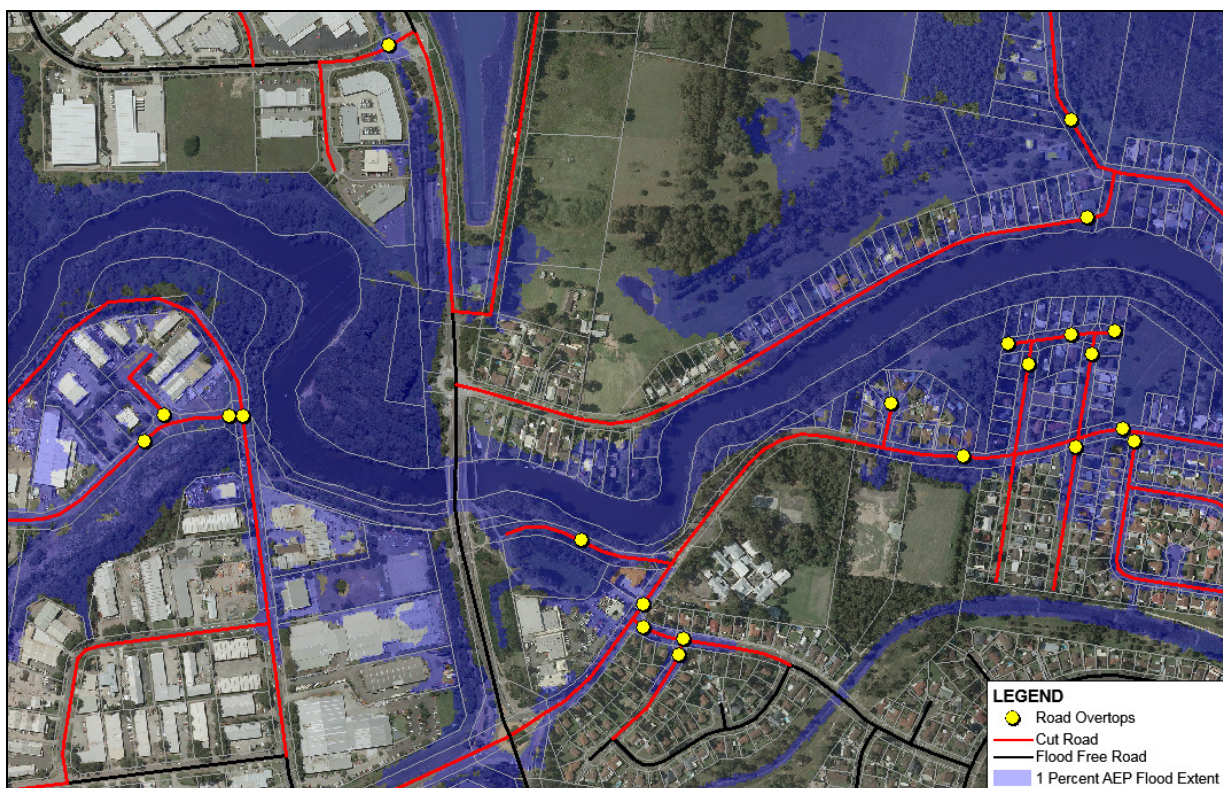
Due to the robust nature of the assessment (i.e., assessing all possible evacuation routes from a given point in the floodplain), it is not uncommon for a given precinct to have different evacuation routes available for shortest vs. rising road vs. walking for a given time step. An example of an evacuation path is shown in Figure 2.



**Figure 2: Sample Walking Evacuation Path and Profile (1% AEP @ 13 hours)**

As shown in Figure 2, a walking evacuation route can be found at this time for the precinct shaded in red. This is the least distance route between the precinct and the road nodes that are outside the PMF extent (dark blue line). It can be seen by comparing the longitudinal profile elevations with the water that this route crosses relatively shallow floodwaters in several locations. However, at one point this depth is greater than 0.2m (i.e., the default road freeboard) making it unsuitable for vehicular evacuation.

The software also generates a spatial map of overtopping points for each road for each time step and aggregates this information to report on the time and duration of impact for all roads during the event. An example of overtopping points is shown in Figure 3.



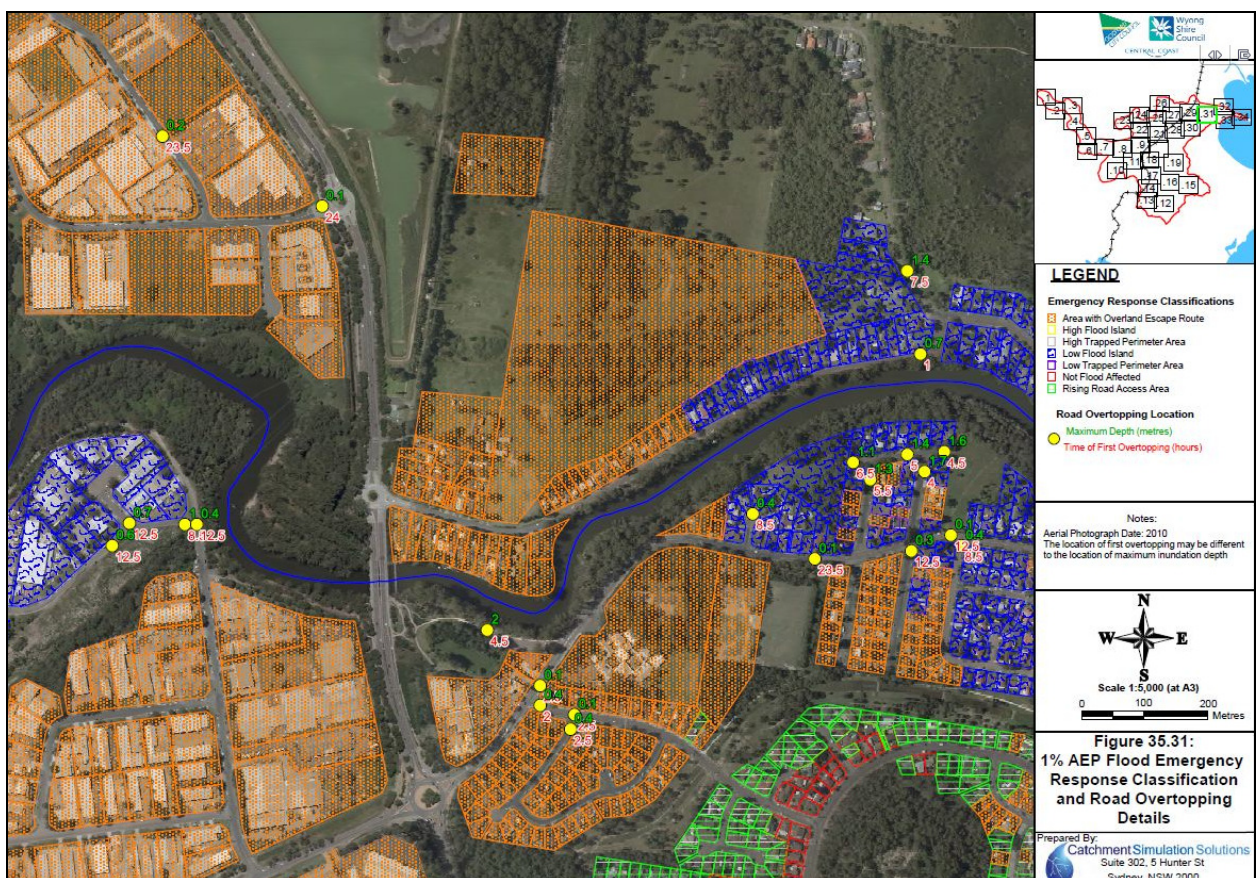
**Figure 3: Cut Roads and Locations of Maximum Roadway Inundation Depth**



Other outputs of the software include:

- Attributes added to the road network GIS file including:
  - Times of first and last inundation (above freeboard)
  - Duration cut as well as time between first and last cut
- Attributes added to precincts GIS file including:
  - ERP classification
  - Is evacuation possible to a point outside of the PMF?
  - Are evacuation routes cut and if so, at what time?
  - Is the precinct flooded and if so, at what time?
  - Is the precinct flooded after the evacuation routes are cut?
  - Does the precinct get surrounded and if so, at what time?
  - Is the evacuation route to a flood island only?
  - Peak flood level and time
  - Elevation of low and high points within the precinct
- New GIS file containing location of maximum roadway inundation depths (max 1 point per road segment) including time of first inundation and maximum depth (above freeboard).
- Tabulated results with 1 row for each time step listing:
  - Lots flooded
  - Roads cut
  - Isolated lots (by vehicle)
  - Isolated lots (by walking)
  - Isolated and flooded lots
- Video Animations (one frame per time step) can be generated showing any combination of roads overtopping points, cut roads flooded and isolated precincts.

All of the data generated is utilised to automatically step through the flow chart shown in Figure 1 and assign the appropriate ERP classification. This results in highly detailed mapping of ERP classifications. An example of the mapping of ERP classifications is shown in Figure 4. In this case, precincts were defined using cadastral polygons. This figure also shows road overtopping points, the time the road is first cut and the maximum depth of inundation. While it is noted that emergency services must plan at broader scales, the mapping can help to identify vulnerable pockets located within or adjacent to otherwise low risk areas. It can also help prioritise the timing of emergency response efforts since classifications are augmented with the times when evacuation routes are cut.



**Figure 4: Sample Detailed ERP Classification Mapping for Ourimbah Creek Flood Study**

## **An Alternative Method – The ERP Risk Gradient**

While undertaking this research, it was noted that there are some ambiguities in the current work flow (Figure 1) which become problematic when applied at small scales. These include some logic fallacies and lack of clarity regarding when the PMF should be considered versus the event in question.

As a result of our research in this field and perceived incompatibilities of the current work flow when applied programmatically at smaller scales, we have also developed an alternative ERP scheme for consideration. This approach considers many of the same factors (high and low flood islands, rising vs. non-rising road evacuation etc.) but presents the results on a gradient of 13 classifications at the individual pixel resolution albeit still influenced by the user defined precincts. The gradient approach still allows identification of key high risk areas such as low flood islands but also presents the entire catchment on continuous gradient of increasing risk of evacuation difficulties and emergency response requirements. This approach has the following advantages:

- **Easier to understand**

The current ERP classification are easy to understand at broad scales but can lose their relevance at smaller scales. A gradient allows emergency services and the community to gain a perspective of their risk in terms of emergency response and evacuation in a simple graduated scale.

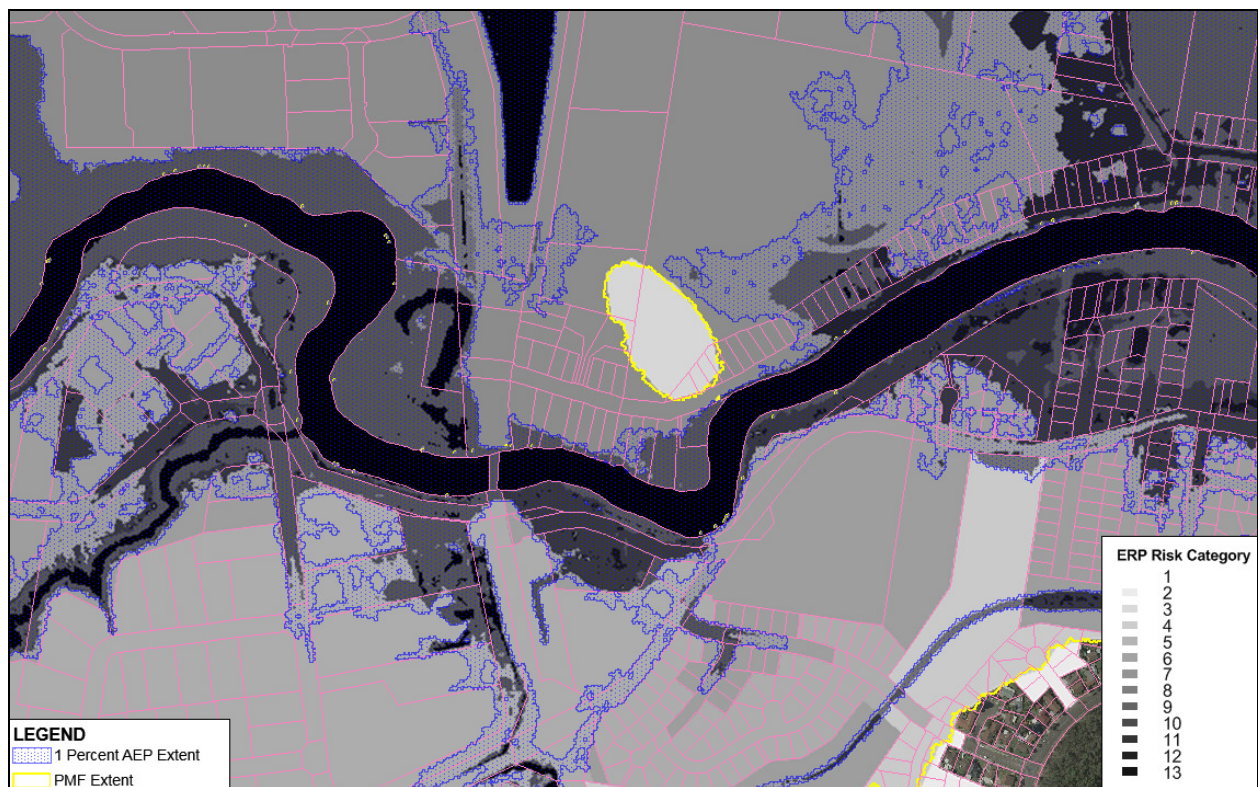


- **Less tied to a theoretical flood**

A general risk profile may give a better understanding of emergency response risk while not being tied to a theoretical flood which is unlikely to ever occur. This is particularly important when the theoretical flood is not even a design event, rather a 'max of max' style aggregation of different design event critical durations. It could be argued that a 1% ARI 'max of max' flood is less likely to occur than any of the 1% ARI design events that contributed to the 'max of max' floods. Therefore, the ERP classifications may be overly conservative. As such a risk gradient may be a better approach than definitive guidance suggesting that Area A will be inundated or surrounded or not. That is, relatively risk of different Precincts is perhaps more relevant than definitive ERP classification for 'max of max' theoretical floods.

The definitions for the 13 categories of increasing ERP classification risk are outlined in Table 2. This table also correlates the categories with the most equivalent of the current ERP classifications.

The computer software was updated to incorporate the new ERP classification risk gradient approach. An example output is shown in Figure 5.



**Figure 5: Sample Results using Risk Gradient for Chittaway Point, NSW**

As shown in Figure 5, the new ERP classification scheme has attributes of reporting both on the grid cell or 'pixel' scale as well as the precinct scale. This will be useful particularly for large rural lots which may exhibit multiple risk categories. Since it is not know which part of the lots is used as the habitable area, reporting the variation of ERP classification

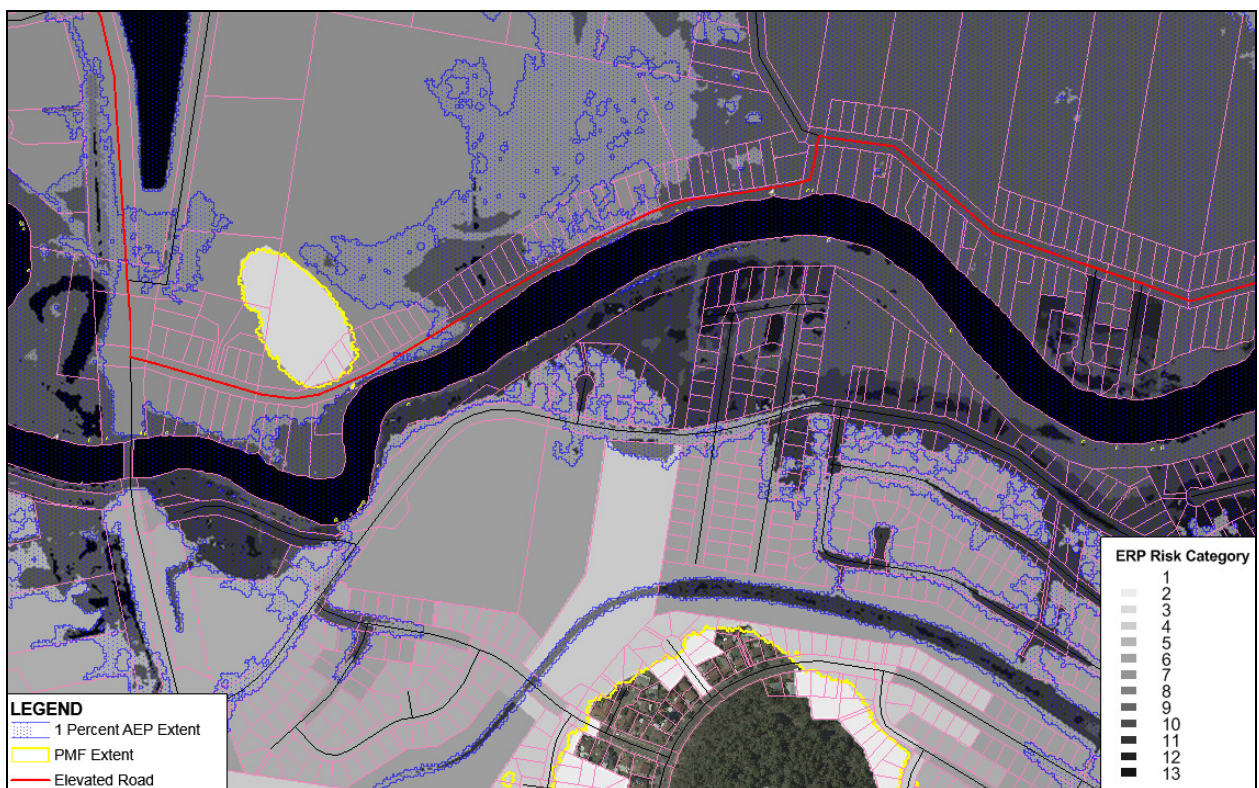
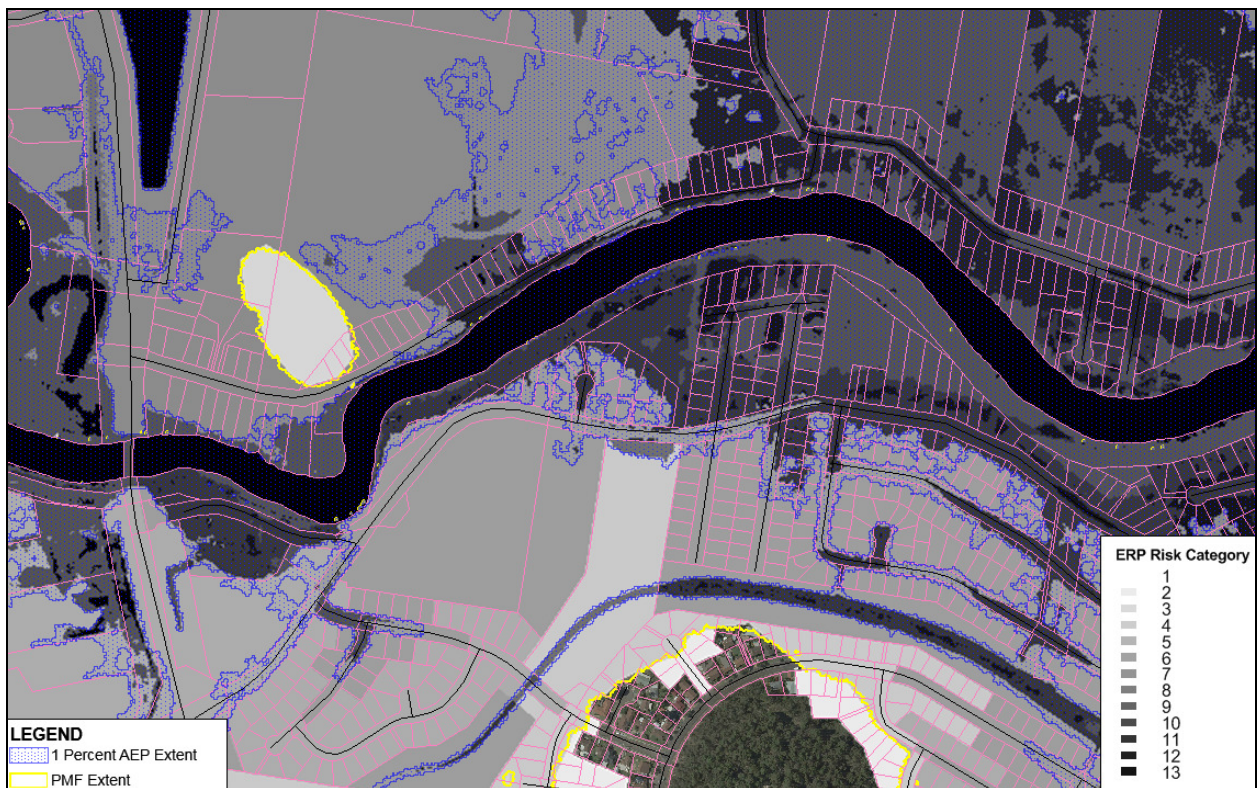
risk as a detailed map is likely to be more useful than a single classification for the entire property.

**Table 2: Definitions of Risk Gradient ERP Classification**

Category	Description	Verbose Description	Most Equivalent Current ERP Classification
1	Not flood affected	Not flood affected	Not flood Affected
2	PMF Isolated	Not flooded during PMF but vehicular access routes may be impassable at time(s) during the PMF	Indirectly Affected Area
3	PMF Surrounded	Not flooded during PMF but may be surrounded by floodwaters at time(s) during the PMF	Indirectly Affected Area
4	PMF liable, no event impact (RR evacuation)	Flood prone during PMF but not during the Event. Rising Road access routes available at all times during Event.	Indirectly Affected Area
5	PMF liable, no event impact (no RR evacuation)	Flood prone during PMF but not during the Event. Non-Rising Road access routes available at all times during Event.	Indirectly Affected Area
6	Isolated by vehicle	Flood prone during PMF and isolated by vehicle at time(s) during the Event.	Indirectly Affected Area
7	Surrounded by floodwaters	Flood prone during PMF and surrounded by floodwaters at time(s) during the Event.	Overland refuge area on low flood island
8	Flooded (RR evacuation)	Flood prone during Event but Rising Road access routes available immediately prior to flooding (prior model time step).	Rising Road Access Area
9	Flooded (no RR evacuation)	Flood prone during Event but Non-Rising Road access routes available immediately prior to flooding (prior model time step).	Non-Rising Road Access Area (not a current ERP category)
10	Flooded and isolated by vehicle	Flood prone during Event and no vehicular evacuation route are available immediately prior to flooding (prior model time step).	Area with overland escape route
11	Surrounded by floodwaters and <b>then</b> flooded (accessible high ground)	Area is surrounded by floodwater and then flooded during the event. However, high ground (above PMF) may be accessible by foot immediately prior to flooding.	High flood island
12	Surrounded by floodwaters and <b>then</b> flooded (no high ground)	Area is surrounded by floodwater and then flooded during the event. However, high ground (above PMF) is not accessible.	Low Flood Island
13	Floodway	Inundated above freeboard for > 90% of event duration.	Floodway (not a current ERP category)

A further advantage of automation of the workflow is that multiple scenarios can be modelled to quantify the effect of topographic or roadway modifications on the ERP classification. Figure 6 illustrates two different classification maps reflecting the change in ERP classification that may occur if a road (highlighted in red) was raised above the 1% AEP flood. This type of scenario testing can provide a useful tool in evaluating the effectiveness of potential mitigation measures during the Floodplain Risk Management Study without the need to re-run the hydraulic model.





**Figure 6: Comparison between “Existing” ERP Classifications (Top Image) and “Proposed” ERP Classifications with Elevated Roadway (Bottom Image)**

## Limitations

The automation of ERP classifications provides a range of advantages relative to traditional manual classification techniques. Nevertheless, several limitations were identified with the current automated approach, including:

- Floodwater depth is currently used as the only criteria to define when an evacuation route becomes cut. Other criteria including velocity and velocity depth product may also need to be considered.
- Currently, evacuation routes from precincts (e.g., lots) are currently based on a “start location” at the nearest road intersection or road end point. Therefore, the evacuation start point may be located a significant distance away for long roads resulting in misleading evacuation routes.
- The outputs are very detailed and may not be suitable for use during a flood (i.e., information overload). Therefore, it is recommended that appropriate time is allocated by those responsible for emergency response management to ensure they understand the implications of the classifications.
- A significant amount of pre-processing may be required to ensure the inputs and, therefore, results generated by the software are reliable.
- Depending on the size of the study area, the automated classification process can take a significant time to run. The Ourimbah Creek study area covers an area of about 60 km<sup>2</sup> and takes about 8 hours to run with a 2m DEM on a mid-range PC.

## Conclusion

This paper has documented the development of computer software to automate the “Flood Emergency Response Planning Classification for Communities” (2007) guideline workflow (Figure 1). Automation allows the assessment to be more transparent and reproducible as well as allowing application at finer scales and even individual lots.

As noted in the Guideline, the ERP classification workflow is intended for broad scale or precinct application and thus it was not surprising when some issues arose during application at finer scales. While these issues were overcome and the automation of the guideline at small scales was ultimately successful, an alternative ‘Risk Gradient’ approach was also developed. It is thought that this method allows additional information to be reported since it reports at the pixel scale as well as the precinct scale. Furthermore, reporting or ERP classification risk on a graduated scale rather than definitive categories allows easier understanding of a lot’s risk profile relative to its neighbours and is less tied to a theoretical flood.

## Future Work

As outlined, several limitations were identified with the current implementation of automated ERP classifications. Therefore, future work will be targeted towards overcoming these limitations. This includes incorporating building floor level information



where available, using additional criteria to determine when evacuation routes become cut and customised assessment and reporting of vulnerable community assets such as schools and retirement villages. Further work on optimising the computer software including multi-threading is also planned since the software is quite computationally intensive.

## References

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