IMPLICATIONS OF THE NEW ARR FOR FLOODPLAIN MANAGEMENT

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1. Abstract

Australian Rainfall and Runoff (ARR) is the national guideline for flood estimation. The guideline is currently nearing the completion of its first major revision since 1987. The new update aims to provide a defendable, more reliable flood estimate based using real data.

The upcoming release of the new ARR has implications for floodplain management in Australia. The new ARR will outline new procedures for design flood estimation. The previous guidelines were developed when computer technology was emerging and calculations were often done by hand. With significant advancements in both computer technology and techniques the new ARR will introduce changes to current practice.

Some current design methods exhibit significant bias in some locations and the new edition of ARR is likely to confirm problems with floodplain management strategies. This paper explores what the changes really mean, what locations and strategies should be reviewed and how this is likely to affect floodplain managers. This paper provides a summary of the changes currently available; however given the length of the paper not all changes can be covered.

2. Introduction

Design flood estimation remains a problem for many professionals involved in the management of rural and urban catchments. Advice is required regarding design flood characteristics for many design problems including the design of culverts and bridges necessary for cross drainage of transport routes, the design of urban drainage systems, the design of flood mitigation levees and other flood mitigation structures, design of dam spillways, determination of design flood planning levels and many environmental flow problems.

For many years, Australian Rainfall and Runoff (ARR) has provided national guidance on design flood estimation. Since publication of the first edition of Australian Rainfall and Runoff (ARR) in 1958 (Nicol, 1958), the aim of the publication has been to provide Australian designers and analysts with the best available information on flood estimation. While previous editions in 1958 (Nicol, 1958), 1977 (Pattison, 1977), and 1987 (Pilgrim, 1987) have served the engineering profession well and have contributed to providing a sound basis for the design and analysis of works and structures that are subject to flood, the National Committee on Water Engineering of the Institution of Engineers Australia believed that the many recent developments in the understanding of rainfall-runoff processes, developments in computer technology, the many new tools available for catchment simulation and the rapidly expanding body of information about rainfall and runoff processes necessitated the production of a new edition.

There has been a series of advances in flood estimation since 1987 but the core design method has remained largely unchanged. Flood estimation is changing in two related ways with many of the key inputs being updated and improved and more robust and defendable techniques are becoming mainstream and are likely to be recommended in the final version of ARR.

3. Improved Inputs

Design flood estimates require a number of inputs. While rainfall is the most important nearly all modelling approaches require inputs on:

- Spatial patterns of rainfall
- How the rain fell temporally
- Losses
- Baseflow.

A number of the key inputs are being or have been revised as part of the ARR revision projects. These include the revised Intensity Frequency Duration (IFD) data, updated FORGE estimates, work on extending beyond FORGE to the PMF (Nathan et al, 2015), temporal patterns, areal reduction factors, losses and base flow.

3.1 Rainfall Data

The updated IFD data was released in July 2013. The IFDs were the first of a number of design flood inputs to be released. The purpose for the early release of the IFD's was to allow the sensitivity of existing infrastructure to the new estimates. Unlike the 1987 IFD the 2013 IFD includes rainfall gauges collected by other agencies and a significantly larger number of continuous rainfall gauges (Green *et al.*, 2012). All data used in the process was quality controlled.

The BoM are developing more frequent IFDs and updating the CRC Forge estimates using the national database developed for the IFDs. As part of the next stage users will be able to download IFDs over an area.

3.2 Spatial Aspects of Rainfall & Areal Reduction Factors

Areal Reduction Factors are used to transform point IFD estimate to spatial rainfall estimates. ARR87 used areal reduction factors derived from a study for Chicago which were presented in a hard to read format that didn't extend to rare events. Since 1987 areal reduction factors have been estimated for longer durations as part of the CRC FORGE project but with zones based on state boundaries. CRC FORGE estimates were available for Victoria in 1999, NSW in 2010. NSW was split into two zones. Work by Jordan et al (2013) as part of the ARR update has developed an approximate between the long and short (18hr/24hr to 1hr) duration ARFs using Bell's (1976) method.

Since then a trial on short duration ARFs in NSW has been undertaken (Babister *et al*, 2014). This work is being extended using short duration IFD's based on high density pluviograph data from greater Sydney, greater Melbourne and the Brisbane/Gold Coast area and any potentially any other regions that fit with in data density criteria is being used to produce short duration areal reduction factors.

It is significantly more defendable to base short duration ARF's based on Australian data rather than UK or USA data. Long duration ARF's are potentially being updated from the revised FORGE estimates. The upcoming BoM IFD products will allow users to extract a spatial IFD output and give an estimate of spatial distribution.

3.3 Temporal Patterns

Temporal patterns are currently being revised. A number of issues with the current Average Variability Method (AVM) have been documented (Retallick *et al*, 2009). The current approach uses a peak burst only rather than a complete storm. Combining pre burst rainfall with traditional burst approach and complete storm methods is currently being investigated.

The use of a single temporal pattern is not suitable for most projects. The new ARR will recommend the use of an ensemble of temporal patterns. The BoM extensive rainfall database means a number of options are available such as using real bursts or storms.

Figure 1 depicts the pre burst to burst ratio for the 1% AEP 60 minute duration event. Pre burst is generally insignificant other than in the Cairns- Rockhampton and Wollongong area. Therefore in these areas a large amount of rainfall, up to 50% of the burst occurring before the burst.

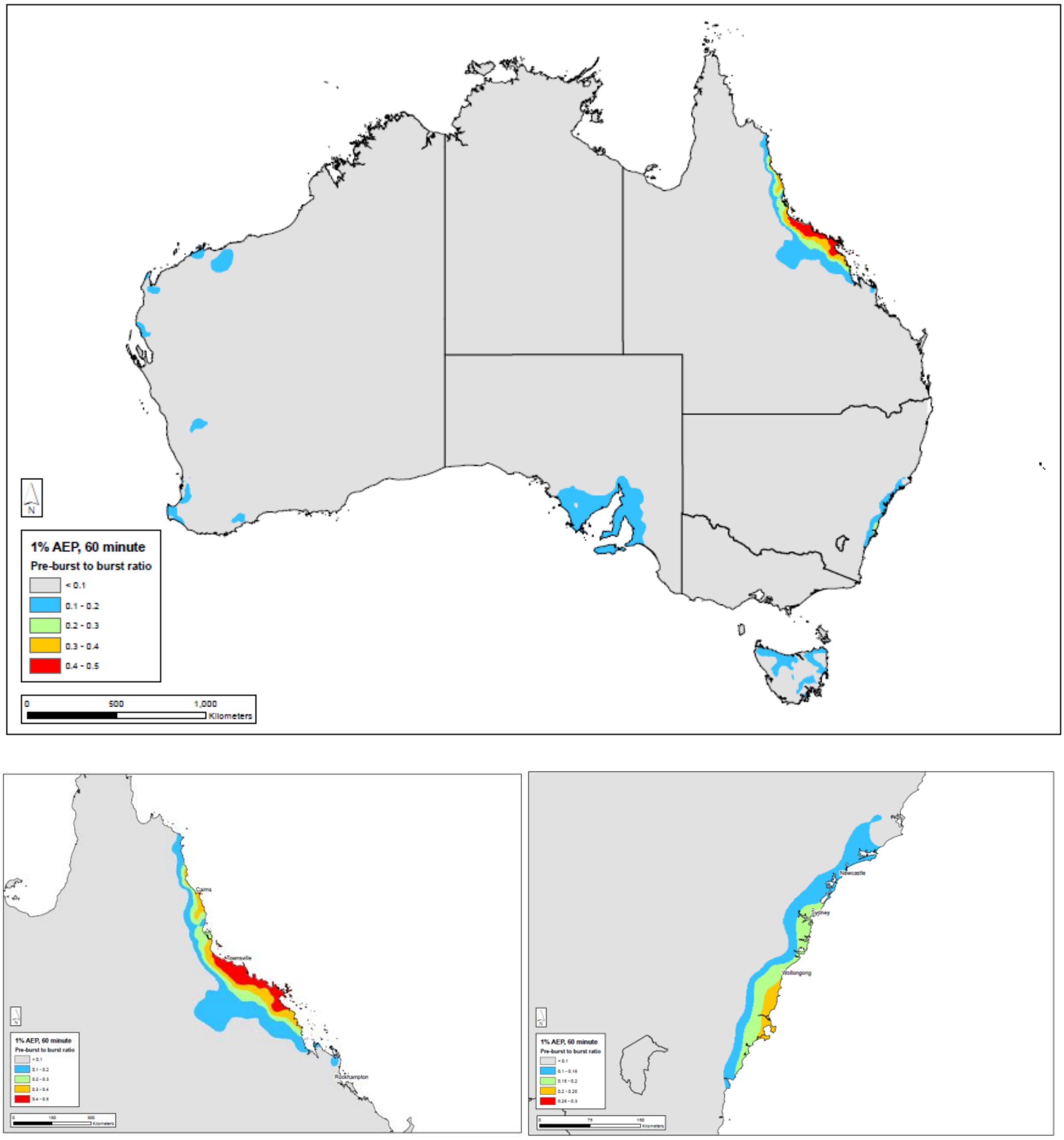

Figure 1: Pre Burst to Burst ratio 1% AEP event 60 minute duration

3.4 Losses

A regional assessment of losses has been undertaken in four phases:

- *Phase 1 – Pilot Study for Rural Catchments* (SKM, 2012b; Hill et al., 2011). Involved a pilot study on a limited number of catchments that trialled potential loss models to test whether they are suited for parameterisation and application to design flood estimation for ungauged catchments.
- *Phase 2 – Collation of Data for Rural Catchments* (SKM, 2012a). Streamflow and rainfall data for a large number of catchments across Australia was collated for subsequent analysis.
- *Phase 3 – Urban Losses*. The phase involves analysis of losses for urban areas and estimation of effective impervious areas (Cardno, 2014).
- *Phase 4 – Analysis of Loss Values for Rural Catchments across Australia* (Jacobs, 2014). Loss values have been derived in a consistent manner from the analysis of recorded streamflow and rainfall from catchments across Australia and then analysed to determine the distribution of loss values. Finally, prediction equations were developed that relate the loss values to catchment characteristics.

3.5 Baseflow

ARR Revision Project 7: Baseflow developed a method for calculating and adding baseflow contribution to design flood estimates. Phase 1 of the project focussed on the physical processes of groundwater-surface water interaction and theoretical approaches to baseflow separation. The identified methods were applied to eight case study catchments across Australia in order to develop a suitable approach for more wide scale application. Phase 2 of Project 7 (SKM, 2011) covers the analysis of 236 catchments across Australia, the development of prediction equations to estimate baseflow parameters and the development of a method for the application of these to design estimates for catchments across Australia. The project produced Baseflow Peak Factor and Baseflow Volume Factor used in the calculation, Figure 2 and Figure 3, which cover the whole of Australia.

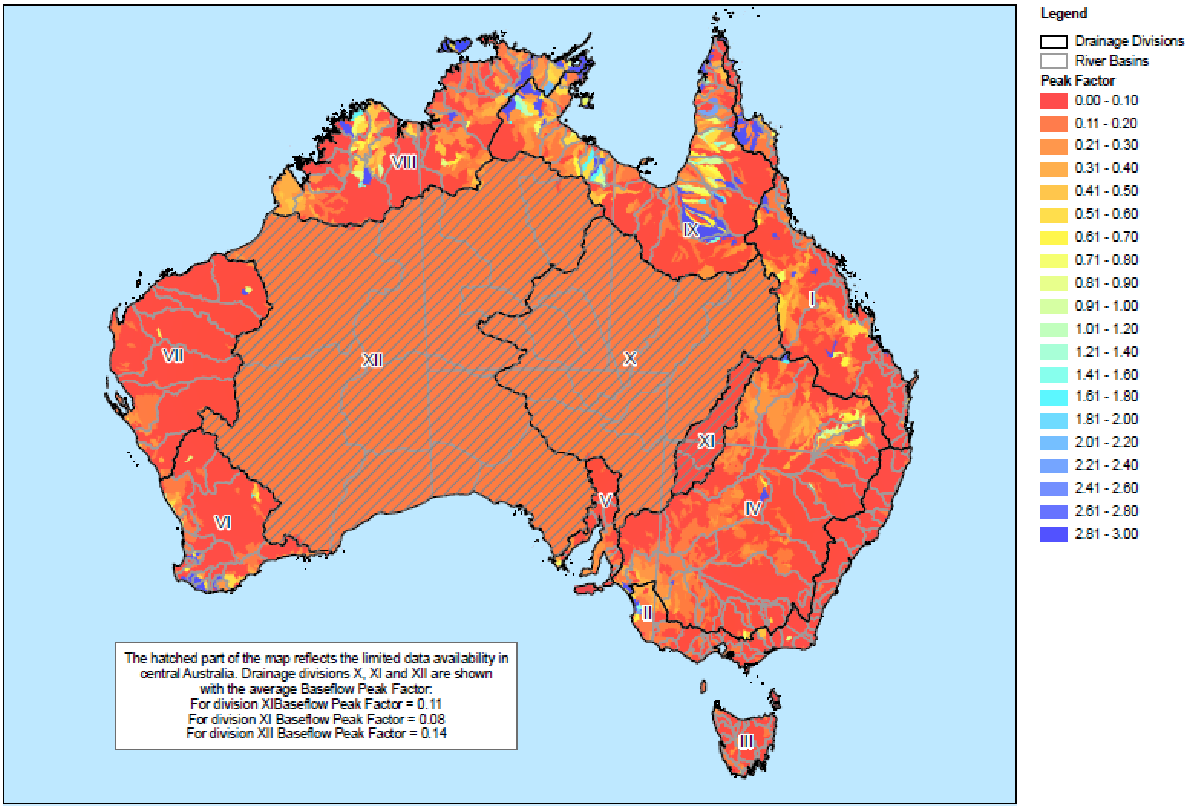

Figure 2: Map of the baseflow peak factor for the 10yr ARI

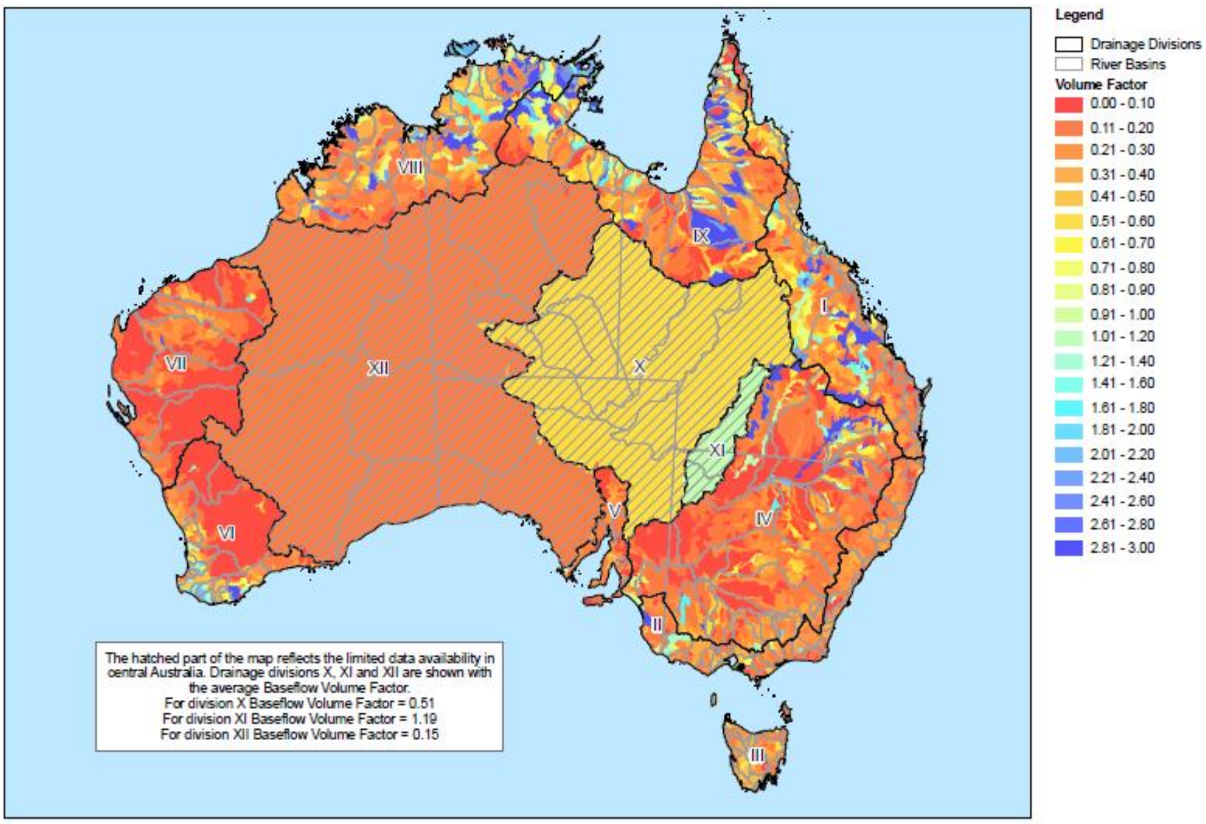

Figure 3: Map of baseflow volume factor the 10 yr ARI.

3.6 Input Availability

In 1987 most parameters either covered very large areas or were read off maps that required each user to interpolate between contours. This lead to problems with exactly reproducing earlier results, this problem was compounded in the transition between zones. It is intended that the revised ARR will deliver all spatially based information electronically via the internet. This will remove problems with reproducibility and standardisation of approaches in the transition zones. This approach will require a change by practitioners and software suppliers who have historically preferred to embed inputs in their software. This has included ARF equations, temporal patterns etc.

Electronic delivery will also aid with updating inputs and the dealing with inevitable inconsistencies and errors found in data sets. As part of this change in practice practitioners or the software they use will be expected to record the date and version number of each parameter set. This approach will also make updates to climate change estimates much easier but will require a shift in approach from practitioners. It is currently proposed to have a facility to extract earlier versions but this might have to be on a cost recovery basis.

4. Changing method

4.1 Regional Flood Frequency Estimation

ARR revision Project 5 has developed a national method for estimating flood flows at any location in the country (Rahman et al, 2015). The project began in 2008 and has undertaken by the team at University of Western Sydney (led by Dr Ataur Rahman). A web interface has been developed for the method to aid with implementation (refer to Section 5).

4.2 Blockage

Blockage of hydraulic structures was not considered in the previous ARR. Often floodplain management studies look at the effect of blocking all structures. The ARR Blockage guidelines outline a methodology for assessing the likely blockage of each structure (Weeks and Rigby, 2015).

4.3 Monte Carlo Methods

The biggest change in design flood estimation to be recommended in the upcoming edition of ARR is the move from fixed representative or mean/medium inputs to ensemble and Monte Carlo techniques.

Monte Carlo techniques move from single inputs to ensembles or distributions with variable inputs able to be sampled from:

- Rainfall
- temporal patterns
- spatial patterns
- losses
- preburst
- timing aspects

While the full application of such complex approaches are not necessary on more simple flood studies representing some aspects of the real variability of real events will improve the robustness of design flood estimates and the objective assessment of options.

4.4 Interaction of coastal and river flooding

Flooding in the downstream regions of many coastal catchments is the result of the interaction between runoff generated by a weather event that elevates sea levels and/or estuary water levels. Historically assumptions have been made regarding either the independence of these events or the timing of rainfall or flood peaks and peak ocean and/or estuarine conditions eg. peak runoff and peak ocean or estuary levels coinciding. Assuming that the weather events that generated elevated ocean or estuary conditions and significant catchment runoff are independent can underestimate flood levels in coastal areas. Conversely an assumption that the flood peak coincides with the peak elevated ocean or estuary conditions can overestimate flood levels in coastal areas. In order to better understand flooding in coastal areas it is necessary to have an understanding of the role that severe weather conditions that create elevated ocean or estuary condition have in generating catchment runoff that floods coastal areas. The importance of this understanding will increase in time as existing coastal communities are threatened increasingly by rising sea level as a result of climate change.

The University of Adelaide team has produced a method that statistically analyses the interaction of coastal and river flooding (Zheng *et al*, 2014). The method has been implemented in easy to use software.

4.5 Hazard

Australian Rainfall and Runoff revision project 10 investigated the hazard to people and vehicles separately. The project developed depth vs velocity curves to define when floodwaters are safe or hazardous. This updated the previous work which was done in the 1970’s. As part of the development of accompanying guidelines for AEM Handbook 7 (Australian Gov, 2013) this work has been extended and combined to create one set of hazard curves that cover buildings, vehicles and people.

5. Online software and methods

Online software is already being used for various methods including Flood Frequency Analysis, regional flood frequency estimation (Project 5) and the interaction of coastal and river flooding (Project 18, Zheng *et al*, 2014). Having software online has made updates, enhancements, corrections and support much easier which is particularly important for "FREE" or minimal cost software. This has been meet with some resistance from some practitioners who have expressed a strong desire to be able to download and save software locally and led to concerns about who will be looking at the locations they are doing calculations and how this will affect confidential studies. There is a commitment that any information that is stored will only be used for diagnostic purposes and will not be shared without consent. Practitioners will of course be able to hide the important runs amongst all their sensitivity or dummy runs.

Figure 4 and Figure 5 show sample input and output screens from the regional flood frequency estimation and interaction of coastal and river flooding software.

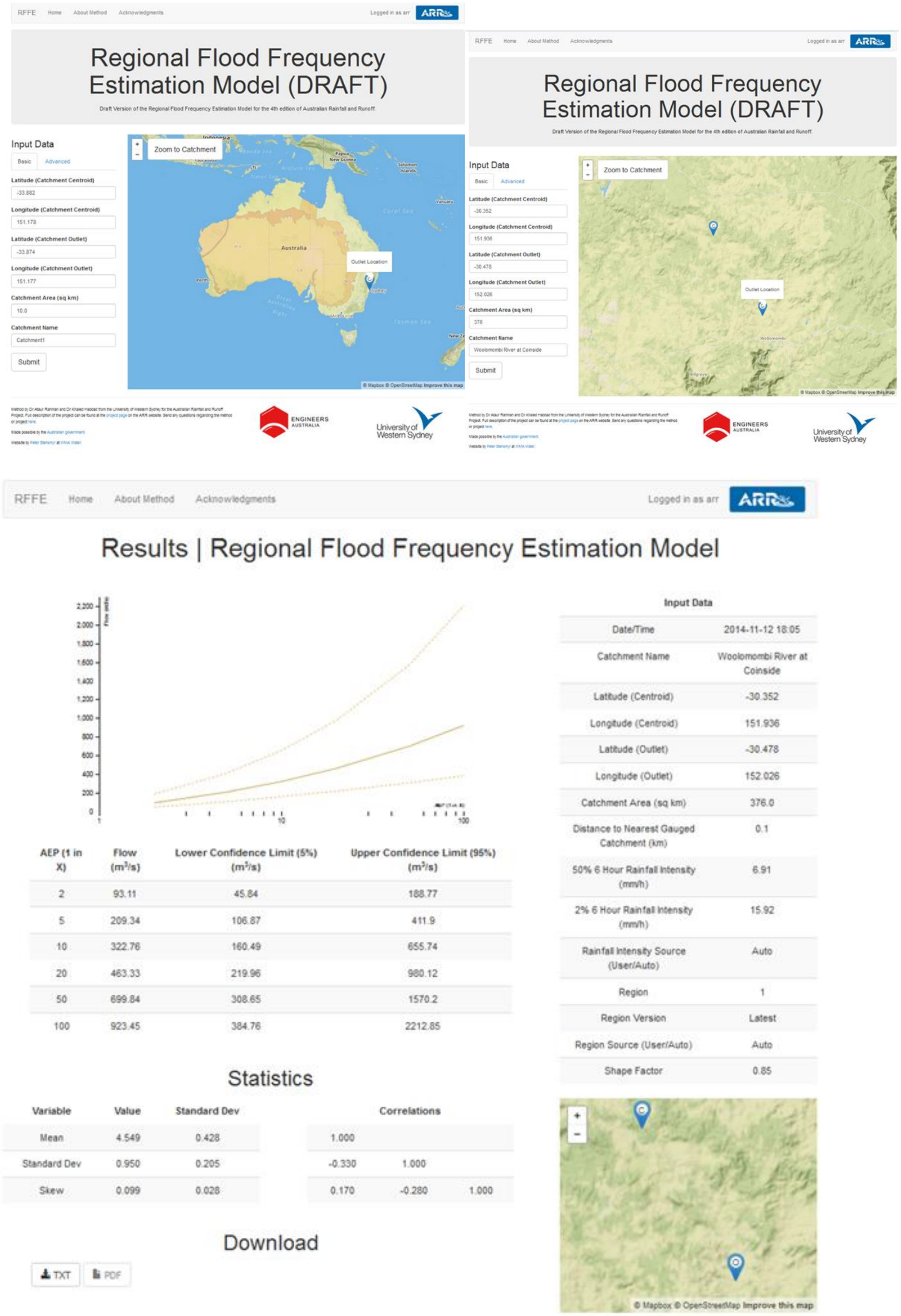

Figure 4: Input and Output screen from Project 5

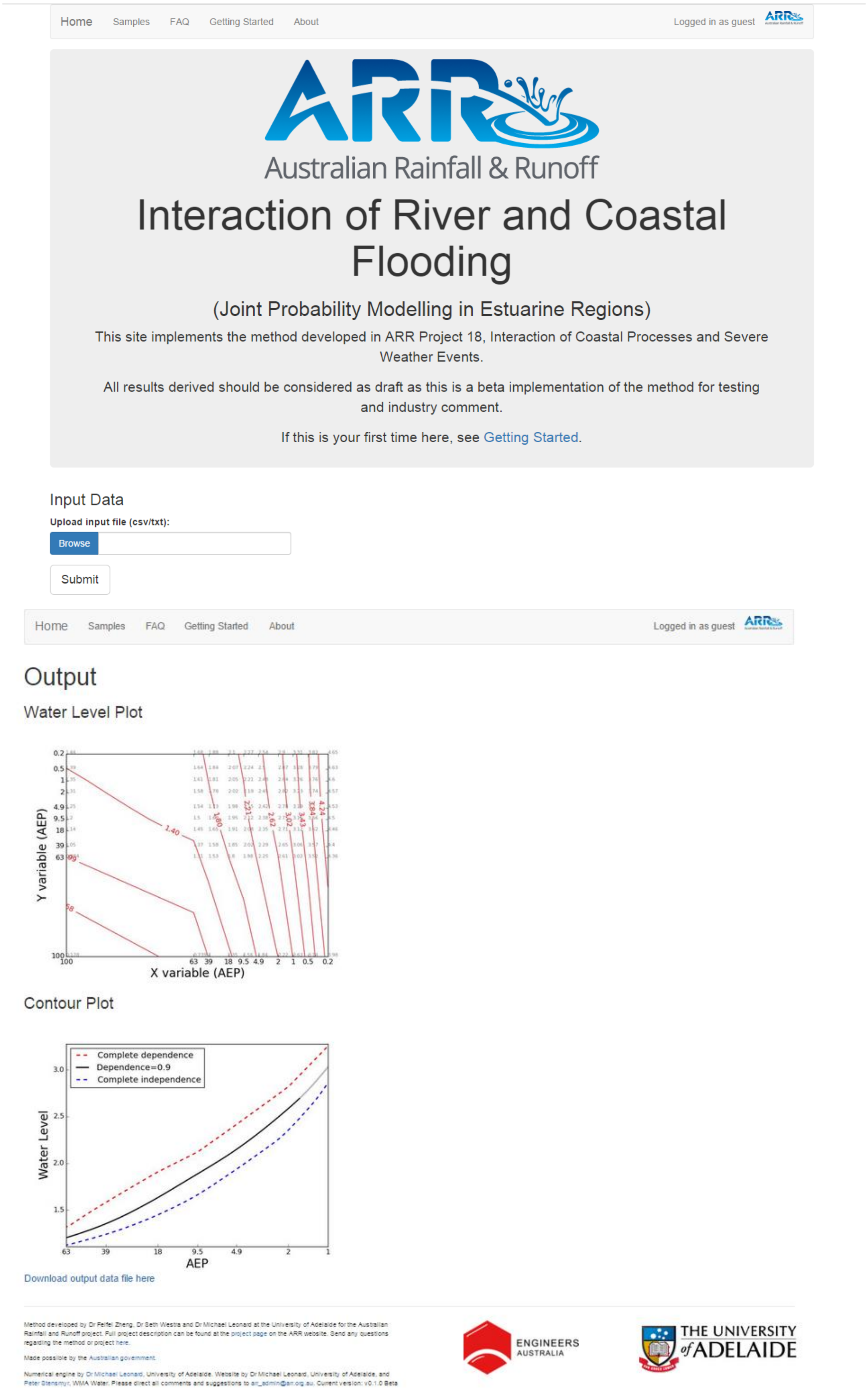

Figure 5: Input and Output screens from Project 18 Software

6. Urban studies

In urban studies there has been changes in the approach arising from changes in community expectations. Approaches in the 1970's were generally focused on improving the efficiency of removal of runoff from the urban areas through improving conveyance with kerb and guttering, pipe systems in the upper catchment and concrete lined channels. Concrete channels significantly reduced catchment responses and are now very out of favour from an aesthetics point of view and once maintenance costs started to become apparent. The 1980's and 1990's saw a strong movement to mitigation based on storage modification with detention basins, onsite detention and even the return of water tanks. The current century has seen a move to an integrated or systems approach with WSUD being widely embraced with a desire to retain natural systems or recreate natural systems. Most flooding was based on mainstream flooding however overland flooding is now also being considered.

The ARR 1987 approach was very applicable to conveyance improvements which can be reliably assessed by peak burst methods. The movement to storage volume based mitigation strategies was more problematic as peak burst methods could only be neutral or low in volume. For more standard basins this was probably only a minor bias but it was possible to design outlet structures to only work for one type of storm.

The new edition of ARR will provide complete storms and require the modelling of an ensemble of events which will significantly improve the assessment of detention basins.

7. Conclusions

The new inputs and methods developed as part of the update of Australian Rainfall and Runoff are aimed at providing a more robust, reliable and defendable flood estimate. This will aid floodplain managers in their task.

8. Acknowledgements

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