Testing the RFFE Model 2015

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Abstract

The Regional Flood Frequency Estimation Method (RFFE 2015) has been developed by the UWS team as part of the update of Australian Rainfall and Runoff (ARR). The method estimates design floods for ungauged catchments across Australia. This paper documents the testing of the method during the implementation phase and the resultant outcomes which lead to the enhancement of the methodology. The objectives of the testing programme needed to test the technical performance of the new procedures as well as the practicability of application. Specifically for the RFFE testing, the process aimed to test the performance of the new procedure against at-site flood frequency results, which is a test of the technical performance of the method. As well the testing was aimed at understanding the performance of the software package written to implement the new procedure. The testing was also designed to provide information on the ease of application of the procedure.

1. INTRODUCTION

Estimation of design floods for a range of applications is an important task for water resources practitioners in Australia, which has a large area of approximately 7.7 million km^2, a sparse population and a small number of stream gauges. This means that most planning and design projects requiring design flood estimates are located on ungauged catchments and will often be remote from any gauged catchments. An important part of Australian Rainfall and Runoff (ARR) is the development of an effective procedure to provide design flood estimates that is simple to apply for routine applications by non-specialist practitioners, gives consistent and accurate results and can be applied to the wide range of Australia's environments.

As part of the update of ARR a number of major research projects have been carried out to develop appropriate procedures and provide a practical means of implementation. Publications on these procedures are in a series of reports on the ARR website (www.arr.org.au) and a series of research papers and reports. Key publications are listed in the references. Some of the procedures have now reached a position where they can be tested more widely by practitioners and this paper outlines the process and initial results of the testing programme for two of these procedures. This testing will ensure that the new procedures are appropriate for release in ARR.

The previous edition of ARR, published in 1987 (Institution of Engineers Australia, 1987), provided guidance on the estimation of design flood peak discharges for small to medium sized ungauged catchments. However this guidance was essentially the formalisation of methods that were currently in use and was state based. The performance of these methods was variable from state to state and region to region and there was no indication of the accuracy or reliability of the methods.

One of the research projects for the new edition of ARR was concerned with the development of a new regional flood estimation procedure that aims to overcome limitations of the previous versions.

2. CURRENT ARR APPROACH

Since its first publication in 1958, Australian Rainfall and Runoff (ARR) has remained one of the most influential and widely used guidelines published by Engineers Australia (EA). The current edition, first published in 1987, retained the same level of national and international acclaim as its predecessors.

The current edition of ARR has procedures for the calculation of design floods and these have provided the basis for design flood estimation on ungauged catchments since the publication in 1987.
These procedures were based on standard practice widely applied in 1987 and while this may have been the most appropriate approach at the time, concerns have increased over the 25 years since ARR publication. The 1987 ARR was state based, which meant that there were totally different methodologies applied for each state, different standards of accuracy and reliability in different regions of Australia and sharp discontinuities on state boundaries rather than hydrological boundaries. Some of the state boundaries and discontinuities occurred within urban areas. In addition, there have been additional years of stream flow data collected and new approaches developed for flood estimation including flood frequency analysis and regionalisation. All of these led to a clear requirement to completely revise the procedures to provide a better and more reliable approach and to overcome the identified concerns.

While there have been concerns expressed within the industry about the existing procedures, they are generally accepted and widely used though limitations are recognised. Practitioners and agencies are familiar with them and are comfortable with the approaches. Therefore Engineers Australia needed to ensure that the new procedures performed as expected and also that practitioners were familiar with the new procedures and satisfied that there was a sufficient improvement from the previous approach to justify significant change. For example, the new regional flood frequency procedures are Australia-wide, have smooth transitions between regions and are based on all appropriate streamflow data and modern analysis procedures.

Because of significant changes from the 1987 publication, and to provide assurance of performance of the new procedures, a testing programme has been undertaken as discussed in this paper.

3. RFFE TEST CATCHMENT APPROACH

The first phase was to carry out testing by invited specialists who have been recognized as being well qualified and experienced in the relevant field, and who could be expected to be able to complete the testing and understand the background of the procedures. In addition, organisations with a particular interest were also invited to be a part of the testing process. These organisations included government and private agencies where accurate design flood estimates were an important part of their activities. Further testing will include a wider range of practitioners who are expected to apply the RFFE for a range of different applications. It was recognized also that routine work carried out by organisations in the specialist group would probably be carried out by junior staff who may not be totally representative of the skills of the senior professionals in these specialist organisations. While the organization of the testing could not fully account for these differences, the objective was to include a number of different organization types and assume that a representative group resulted.

The testing procedure stressed that the testing was designed to test the performance of the new ARR procedures, it was not a test of the performance of specific consultants or individuals and all results are being published anonymously. In addition it was important that the test results should be used purely for ARR testing, EA emphasized that results could not be used by local authorities for example to select a “preferred” design result or for consultants to solicit work.

In general, the testing has been carried out with most testing organisations providing services “in-kind”, as a voluntary contribution to the industry. This has however resulted in a slow implementation, since testing organisations are fitting this work in among their “real work”. At this stage, testing is continuing, but valuable preliminary results have been found and this is the content of this paper, but work is continuing.

4. RFFE TECHNIQUE ADOPTED FOR ARR

The Regional Flood Frequency Estimation (RFFE) method has been developed by a team from the University of Western Sydney, supported by a technical steering committee as well as agencies and individuals from all states of Australia. Details of the method are provided in another paper in this conference (Rahman et al, 2015) and the three ARR progress reports published by Rahman et al, 2009, 2011 and 2015).

The RFFE procedure has been specifically developed for rural catchments, so it cannot be applied to urban catchments. A reasonable amount of streamflow data is available for rural catchments, however insufficient data is available for urban catchments and there is also significant variability in urban catchment conditions to allow development of a similar procedure for urban catchments. The method provides a procedure to calculate design flood peak discharges for annual exceedance probabilities up to 1%.

5. RFFE TESTING

5.1. Methodology

The technical input to the development of the new RFFE procedure has been academically correct with a number of papers published in academic journals and conferences and the general approach has been accepted by industry. Engineers Australia saw a critical need to provide a more comprehensive and practical testing programme, to ensure that the procedure could be applied in a simple, repeatable and practical way by non-specialist practitioners. It was also seen as important that the procedure should be tested for application with independent data sets to assess if unexpected conclusions resulted.

The objectives of the testing programme needed to test the technical performance of the new procedures as well as the practicability of application. Specifically for the RFFE testing, the process aimed to test the performance of the new procedure against at-site flood frequency results, which is a test of the technical performance of the method. The new method was also tested against results from the previously accepted and widely applied methods. As well the testing was aimed at understanding the performance of the software package written to implement the new procedure. The testing was also designed to provide information on the ease of application of the procedure.

Users of ARR include specialist and non-specialist practitioners, who may have specialist skills or who may be more general engineers who need particular flood applications only occasionally. The users also include consultants, government agencies and industry directly.

Initial limited testing has been carried out by the developers and reviewers of the procedure, though this was not seen as definitive testing, and testing reported here has involved practitioners who were not involved in the development of the method.

This paper provides an outline of the current phase of the testing programme for the RFFE component, which covers the testing by these independent organisations. This phase though does give a clear indication of the process and the issues that arise and assists the RFFE development team in identifying issues to be considered in refinement of the RFFE procedure. Valuable insights into the procedure have resulted from this preliminary testing.

The RFFE procedure is an Australia-wide methodology and the software determines the appropriate model parameters from the location information input to the software. In general therefore the analysis can be undertaken for any region of Australia by any consultant. In addition, consultants will often be called on to complete projects in different regions of Australia, so some understanding of other parts of the country is useful. The consultants who took part in the initial testing were therefore assigned catchments from all parts of the country as well as their own local region to assess if there were differences in results where they had less local experience.

A second set of testing was also carried out where major agencies carried out testing with a focus on their particular concerns. The primary objective of this set of testing was to allow a comparison against existing methods, though the performance against recorded data was also possible. This testing also allowed major agencies, who will be applying this new methodology to their applications themselves and also with the assistance of consultants to become familiar with the procedures and performance.

5.2. Specific local concerns

A primary concern of the testing programme was the general performance for the “usual” catchment types encountered in Australia and where design flood estimates are required. The RFFE procedure was developed for large regions of Australia so it essentially “averages” conditions over large areas.

However the method must be applied for all types of catchments and conditions, and some specific regions were targeted for particular attention. These were regions where issues were expected and where there were concerns in the industry from local practitioners. Some specific local conditions that were targeted in the testing were the arid and semi-arid regions, the Pilbara (a part of the arid and semi-arid region), the south-west of Western Australia (recognized as having very distinct hydrological conditions), small catchments (where there is limited data for determination of model parameters) and atypical catchments (knowing that the method has been developed as an “average” approach for generic catchment types).

5.3. Data for RFFE Testing

The data required for this test specifically requires a set of catchments with adequate data for at-site flood frequency analysis. In addition, it would be preferable if the data had not been used for the development of the method, but this was difficult since the development specifically sought all available data. This data set was a high quality set to allow testing of the procedure and the technical performance against the recorded flood frequency analysis. Twenty-seven catchments from around Australia were selected to meet the high standard required for the testing.

For these catchments, the primary testing was to use the recorded data for at-site flood frequency analysis and then to compare the at-site results (assumed to be the “correct” flood quantiles) with the results from the RFFE on the assumption that the catchment was totally ungauged. The assumption that the at-site flood frequency analysis was error-free is not totally correct, but this assumption was impossible to overcome, and in fact this assumption is a feature of the original analysis used to develop the RFFE procedure. Errors in the at-site flood frequency analysis could result from errors in measurement, inaccurate stage-discharge relationships, especially extrapolation, or non-representative periods of record. The objective of this test was to determine the differences between the flood quantiles calculated by the two different methods and to investigate any errors or differences.

A second set of testing was also carried out where major agencies carried out testing with a focus on their particular concerns. In this case, the agencies themselves were invited to select data for their specific application so the testing in this case was somewhat more variable.

These tests had only a secondary objective of investigating the accuracy of the estimates against the actual data, but were aimed at understanding how the results from the updated methods differed from the currently accepted methods and also to determine how agencies considered the answers matched their experience in the operation and management of drainage systems.

5.4. Test Results

The testing programme has been more difficult to implement than was initially considered, so considerable work is still proceeding, but progress to date has provided valuable insights into the performance of the RFFE procedure and also into the process for implementing a testing programme such as this. Preliminary results however are available and these are useful in the review and enhancement of the methodology.

The results for the assessment of the accuracy of the performance of the method have shown a large error band between the at-site flood frequency and the RFFE calculated flood quantiles. While this may be a disappointment to those expecting an accurate result, it was not a surprise, since a similar large error band was noted in the data used to develop the method. A large contribution to the error band is a result of errors in the at-site flood frequency analysis caused by data errors and unrepresentative periods of record. As well the regional relationship used in the model relies on a small number of catchment characteristics, since these were the ones found to be statistically significant. There may however be other characteristics that have a particular impact on a small number of catchments, but there is insufficient variability to impact on the overall performance.

The results to date do not generally show a noticeable bias, which means is there is a similar extent of over- and under-estimation of results. One area though where a bias was detected was in the arid and semi-arid zones. In these zones, the regional relationship was based on an index flood method rather than the parameter regression method that was adopted for the remainder of Australia. Results for these regions indicated that the index flood was estimated reasonably but the grown curves may be inaccurate and further review is required to investigate this in more detail.

Examples of these results are illustrated in the following figures.

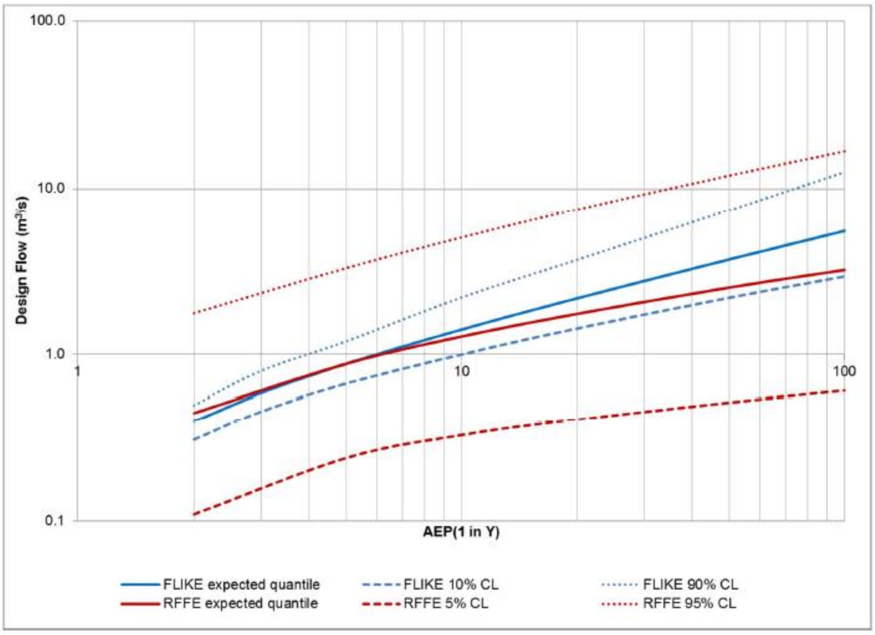

Figure 2: Western Australian catchment – reasonable performance

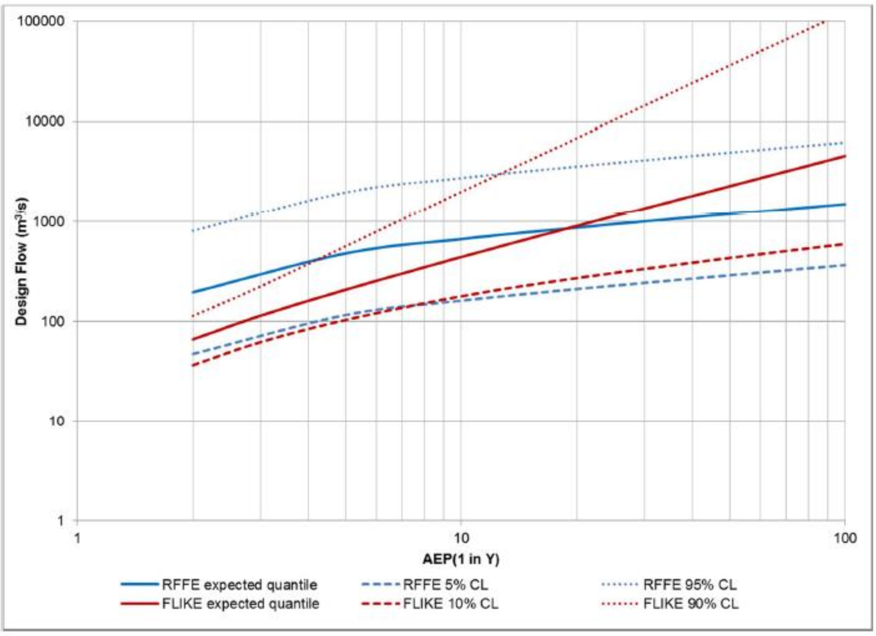

Figure 3: Arid zone catchment with poorly performing growth curve

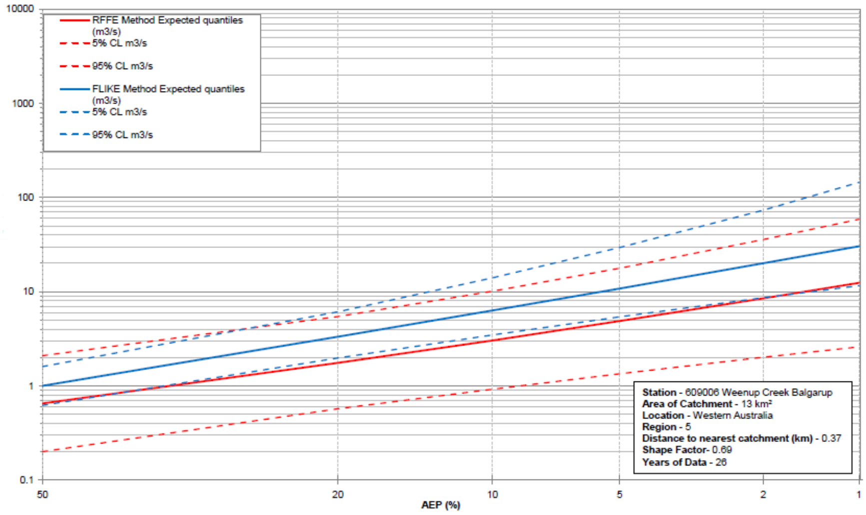

Figure 4: Western Australian catchment with bias in the results

5.5. Test Results

The testing programme for the RFFE, even though the results have been limited to a relatively small number of test locations, has provided some important results that have already led to refinements and improvements to the procedure, which are currently being implemented and will be subject to further testing when completed. Discussion on these particular issues is as follows.

- Bias correction. The testing programme found that there were a number of locations where there were localized biases in the calculated quantiles, which was related to the application of the region of influence methodology. Careful review of the results from the testing was then applied to review the regional errors and a bias correction was applied to improve the performance over larger regions. This correction was applied for all regions of Australia and resulted in an improvement in the overall performance, when comparing to the at-site flood frequency results. Further analysis of the bias correction is recommended though the currently proposed correction does provide a reasonable performance.
- “Atypical” catchments. In some regards, all catchments could be regarded as atypical in some way. The RFFE has been developed to represent average conditions for regional generic catchment conditions. In regions where the catchment is not completely typical, for example where there is extensive floodplain storage, agricultural development, farms dams or dense forest, careful consideration should be made of the catchment type to determine whether the standard RFFE method can be applied or whether an adjustment is needed. The testing programme found a number of catchments where the local conditions were distinct from the “standard” catchment type and the accuracy reduced.
- Pilbara. The Pilbara region is important for the method because of the economic value of the mineral resources of the region, despite the sparse population and remoteness. The testing for the Pilbara resulted in several refinements to the method for this region and also for the remainder of the arid and semi-arid region. Even though the Pilbara region was classified as arid and semi-arid, it was separated from the remainder of the arid and semi-arid region because of the distinct hydrologic conditions of the region, the relatively large number of stream gauges and the economic importance. The boundary separating the region was refined to ensure that it followed a more logical line than was originally proposed, and was moved to the river basin boundary, which also represented a more distinct topographic and geomorphological boundary. The testing also found that the original assumption of applying a partial duration series approach was changed to apply the same procedure as was applied for the remainder of Australia.
- Arid and semi-arid zones. The arid and semi-arid zone (defined in the RFFE as areas with a mean annual rainfall of less than 500 mm) covers a large proportion of Australia and has a very sparse

network of stream gauges representing a wide variety of catchment conditions. This especially a concern since locations suitable for installation of stream gauges are not necessarily representative of typical arid catchments, where stream channels may be poorly defined and flow unconstrained. The testing on catchments in the arid and semi-arid regions found variable results. As in the Pilbara, the testing indicated that the at-site flood frequency analysis should use an annual series similar to that applied elsewhere in Australia. In addition, the testing in this region indicated that more advice should be provided to assist in calculating design flood quantiles in the arid and semi-arid region.

- Small catchments. Catchments with an area of less than 10 km2 are expected to be an important application fort the RFFE, but there are few gauged small catchments so there will be some uncertainty in the calculated results for these catchments. While there was limited data available to test the model performance specifically for small catchments, some additional analysis was carried out on the available gauged catchments with areas less than 50 km^2, and it was found that there was no apparent bias in these results. It was therefore concluded that the method can be applied to any size catchment at the lower end of the catchment area range, with no apparent reduction in performance.
- Regions and fringe regions. The objective of the fringe regions was to ensure that there were no sharp boundaries between the major regions and there was a smooth gradation in results from one region to another. While this is seen as an arbitrary process, it does result in a more reasonable result, especially where projects (such as roads or rail for example) may cross from one region to another. The testing has indicated some issues with the regions and fringe regions and some adjustments were made to these regions.
- South-west of Western Australia. This region has long been recognized as quite distinct from the remainder of Australia, with distinct localized hydrological conditions. The standard RFFE method was developed for this region, with similar catchment characteristics adopted. However as foreshadowed by Western Australian experts, the conditions in this region are influenced by other factors such as land use which have a lesser influence elsewhere in Australia. The testing in the south-west indicated that this relatively simplistic approach that provides adequate results elsewhere does not perform acceptably in this region. The south-west has been determined to require more complex analysis than other regions of Australia and the standard RFFE methodology currently available has been determined to require further development before it can be applied confidently in this region. The testing therefore has resulted in the decision that the RFFE as currently available cannot be applied in this region.
- Catchment centroid determination. The RFFE procedure requires the use of the location of the centroid and outlet of the catchment, and detailed determination of these two points is essential for the calculation of the catchment shape factor, used in some regions. Both are expected to be relatively simple for a competent engineer to calculate and the importance of an accurate location for these two points was stressed in the instructions sent to the testers. However this testing found inconsistent application of these issues and emphasised the importance of accurate determination of these points, so more detailed guidance will be provided in documentation.

The RFFE procedure has been developed using all appropriate stream gauge data, but it has been recognised that the density of stream gauging stations is particularly sparse with only about 850 stations covering an area of 7.7 million km^2. This procedure has been developed using a high quality analysis methodology and the technical performance of the approach has been demonstrated by the developers of the methods in project reports and published academic papers.

The testing programme discussed in this paper has extended the assessment of the performance of the methods to a wider scope and into the realm of the practical application as practitioners will apply them in routine analyses. This practical application is important to allow the developers of the methods to understand better the performance and limitations of the methods and the technical managers of the ARR process to have confidence in performance and to assist them in extension and training for implementation. It also can be used to educate agencies and other “clients” who will rely on these results and assist them in understanding and accepting the methodology, which will be a critical basis for their drainage infrastructure.

In addition, an important objective of the testing programme is to allow any limitations and shortcomings to be identified and corrected before the wider release of the procedures. Identifying these limitations will reduce the risk of serious concerns being raised after release. These concerns will not only decrease the performance of the method, but will also cause a loss of confidence for practitioners.

While the testing programme is still in a preliminary phase, there have been some valuable findings that are guiding the further enhancement of the method and can also assist others who are translating research findings into practice.

While it is probably recognized by practitioners, researchers may often not realise that additional work is required to allow research findings to be implemented in routine practice. In this application, there were localised catchment characteristics that could be used to adjust the regional relationships. Often these localized effects were not sufficient to allow them to be distinguished by statistical tests, but careful review of results showed that there were features that could be included in the regional analysis to alter simple regional results.

6. CONCLUSION

The work to date has undoubtedly only found a portion of the issues that will be critical in gaining a good appreciation of how the new ARR procedures can be implemented, but there are some clear indications of several important concerns that need to be defined for particular testing applications.

However it is important that practitioners who apply the procedures of ARR should at least have some basic skills and the testing therefore should not be expected to define all aspects too closely. Hydrology and hydraulics is a far from exact science and there is scope for application of skills particularly in many regions of Australia where data is limited and there may also be practically no historical observations.

The current edition of ARR has procedures for calculating flood quantiles for ungauged catchments but these vary throughout the country and are of unknown but variable quality. Australia covers a very large area, much of which is sparsely populated and where hydrologic data is very limited. The objective therefore was to apply advanced analysis procedures to develop a suitable procedure that can provide reliable estimates for any part of Australia. Following the development of the draft procedure, this was tested by a group of experienced practitioners to assess both the technical performance of the procedure as well as practical aspects of application. This testing also investigated the comparison between results from the new procedures and those currently recommended in ARR.

7. ACKNOWLEDGEMENTS

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