Monash University

for Brisbane City

BRISBANE RIVER FLOOD STUDY

REVIEW OF HYDROLOGICAL ASPECTS

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SUMMARY

This report provides the findings of a brief overview of the hydrological methodology used for the estimation of the 100 year average recurrence interval (ARI) design flood in the Brisbane River Study (SKM, 1998). [This flood is designated Q100 throughout the report.]

The review concludes that:

(i) the overall approach for the hydrologic component of the Study (ie., calibration of a hydrologic model, verification with independent data, running the model with design inputs, and evaluation of the effect of Wivenhoe dam) is appropriate;

(ii) there appears to be an incompatibility between the design rainfalls (based on data from this century), and the flood frequency curve (dominated by flow events from the last century). It seems preferable more weight be placed on the recent data;

(iii) unless there are compensating factors not yet identified, the Q100 obtained in the Study is likely to be an over-estimate, due to:
- the non-use of an areal reduction factor on the design catchment rainfall
- the use of zero losses for the design event
- the assumption that the Somerset and Wivenhoe Dams are full at the start of the design event.

Recommendations are made as to how to address these issues to refine the estimate of the Q100 event.

Comments are also made on aspects of the frequency analysis used in the study.

1.0 INTRODUCTION

Brisbane City Council (BCC) has recently undertaken a flood study for the Brisbane River. The Study report (SKM, 1988) documents the hydrologic and hydraulic work undertaken to meet a number of objectives. This included the calculation of flood flows and levels at a number of locations on the Brisbane River, and particularly along its lower reaches.

In a letter dated 17 November 1998 from the Manager, Waterways, Urban Management Division (BCC), the author was requested to "review the design event hydrology and process for determining the Q100 flow with dams in place". The commission was for "a high level review rather than a detailed analysis".

To meet this stated objective, this review deals separately with four aspects:

(i) the general hydrologic methodology and approach;
(ii) the input data and assumptions used to estimate the Q100 flood;
(iii) the frequency analyses performed in the Study;
(iv) the apparent incompatibility between rainfall-based estimates and the largest recorded floods.

2.0 GENERAL HYDROLOGIC METHODOLOGY

The approach used for estimating the Q100 flow in the Brisbane River Study (SKM, 1998) can be summarised as :

(i) fitting the XP-RAFTS runoff routing model to data from four observed flood events;
(ii) evaluating the model performance on a further four events (verification);
(iii) estimating the appropriate design storm (with an ARI of 100 years) and loss rates for input to the calibrated model, and
(iv) running the model to estimate the Q100 flows for the Brisbane River catchment, with and without the Wivenhoe Dam in place.

This approach is a well accepted one, and in accordance with best design practice. The use of frequency analysis of recorded data to provide additional information for model calibration, as was done here, is strongly supported.

It should be noted that steps (iii) and (iv) involve assumptions which are critical to obtaining a design flood with the required ARI (100 years). The next section deals with these.

3.0 INPUT DATA FOR THE Q100 ESTIMATE

To estimate the Q100 flow for the Brisbane River, with Wivenhoe Dam in place, a number of important assumptions have had to be made. These are documented in the study report (SKM, 1998) and, for the most part, are considered appropriate for their purpose.

There are, however, three instances where the assumptions would be expected to lead to a conservative result, ie. a high estimate of the 'true' Q100. These are considered separately below.

3.1 Depth of the Design Storm

The area of the Brisbane River catchment modelled in this study is 13 570 square kilometres. The design rainfall for so large a catchment was calculated by (p66, SKM, 1998):

(i) *breaking up the catchment into some 250 sub-areas (each of about 50 square* kilometres in area);

(ii) *computing, for each sub-area independently, the design 100 year ARI rainfall from* Australian Rainfall *and* Runoff *(ARR, 1987), using temporal patterns for zone 3;*

(iii) using these sub-area rainfalls, *without areal reduction factors*, as the design storm input to the catchment model.

The resultant design storm depth raises some concerns. Step (iii) implicitly assumes that every sub-catchment in the Brisbane River catchment will be subjected to its own 100 year ARI storm in a 100 year ARI design storm for the entire catchment. This assumption is a very conservative one, and would correspond to a more extreme event than a 100 year ARI design storm.

A better procedure [as now documented in the draft manuscript of Book VI (ARR, 1998) intended to update and replace Chapter 13 (ARR, 1987)] is to compute a suitable areal *reduction factor (ARF) for* the whole catchment, and apply it to each sub-catchment rainfall.

The question arises as to what ARF is appropriate for the Brisbane River catchment. Figure 2.6 of ARR (1987) does not apply; it only covers storms up to 24h duration and catchments of 1000 square kilometres in area. If it were adopted, this figure, based on USA data, would seem to suggest an ARF of 0.9 or less [*if extrapolated way beyond its range to 36h and 13 570 square kilometres*].

A recent study is more relevant. Using Victorian data, Siriwardena and Weinmann (1996) have produced ARFs which show that ARR (1987) Figure 2.6 is conservative for that State. Their analyses give an ARF of 0.75 for a 36h, 100 year ARF, storm over 10 000 square kilometres.

The figure for Queensland may well be different, and the Queensland Department of Natural Resources is currently analysing Queensland data to determine local ARFs. If the outcome is anything like the Victorian experience, it is quite possible that an ARF of 0.8 or less should be applied to the Brisbane River design storms. A corresponding reduction of around 25% or more in the design rainfall depth used in the Study would have a major impact on the Q100 estimate.

Recommendation 1. That an appropriate areal reduction factor be applied to the input design rainfalls used in the Brisbane River Flood Study.

3.2 Losses from Rainfall

Table 5-22 (p44, SKM, 1998) shows that a range of initial and continuing loss combinations were needed to model the eight events selected for fitting and testing of the XP-RAFTS model. Even for the major January 1974 event, continuing losses of 2.5 mm/h were found to apply.

In normal practice, it would be hard to justify the adoption of zero losses for computation of the design Q100 event, as was done in this study. [See Section 5 for further discussion] All of the evidence, and the recommendations for Queensland in ARR (1987), would suggest the use of a modest initial loss, and a continuing loss of the order of 2.5 mm/h, for an event of this severity. It might be noted here that there is no evidence (eg Hill et al, 1996) that storm losses decrease with event magnitude.

The use of zero losses would be expected to result in an overestimate of Q100.

Recommendation 2. That reasonable (non-zero) design loss rates be used to estimate Q100

3.3 Initial Dam Storage

The Study report notes (p7, SKM, 1998) that the capacity of Wivenhoe Dam at Full Supply Level is 1 150 000 ML. This is a large volume, and significant in comparison to the design flood volumes routed through it for the Q100 calculation.

A similar comment would also apply to the Somerset dam.

The assumption that both Wivenhoe and Somerset Dams are full at the start of the design event may well prove to be over-conservative, and contribute to an overestimate of Q100. A probability analysis, such as being recommended in the draft Book VI (ARR, 1998) would show the most likely state of these reservoirs for use in the calculations. If the outcome of such an analysis shows some level of drawdown is statistically the likely case, then the estimate of Q100 would be reduced as a consequence.

Recommendation 3. That a probability analysis be conducted to determine the most suitable design values of initial storage levels for the Wivenhoe and Somerset Dams for downstream flood calculations.

4.0 FLOOD FREQUENCY ANALYSIS

Given the extent of the data record of flows at gauging stations in the catchment, the frequency analyses of these data could have been given more attention. For instance, a table documenting the annual series of both peaks and volumes would be useful, accompanied by tabulation (in rank order) of the corresponding plotting positions. Parameters of the fitted LPIII distribution would have been helpful for this review.

The adoption of eye-fit curves (Figs 7-12,13,14) is not standard practice; ARR (1987) would recommend the LPIII distribution. For the latter, it would appear that some of the low flows should be removed to reduce the (apparent) negative skew which has lead to the eye-fit curve plotting above the LPIII in Figures 7-13 and 7-14. Such removal would lift the LPIII (similar to Example 2, ARR 1987, p223), perhaps to be similar to the eye-fit curve, but perhaps not.

Recommendation 4 (Less weight). Repeat the frequency analyses with low flows removed, for both peaks and volumes. Use the fitted LPIII distribution, rather than eye-fit curves.

Points for the biggest historic floods could be labelled with event dates. An important reason for this is to highlight the 'fit' of the large events of the 1800s with more recent data, and to show the position in the series of the 1974 event. It would be very useful to examine (if the study hasn't already) the effect of the Wivenhoe and Somerset Dams would have on such as event with different degrees of drawdown.

Recommendation 5 (Less weight). Compute and highlight the effect of the Wivenhoe and Somerset Dams on the 1974 flood using the calibrated model, and the most probable initial state of the storages (assuming Wivenhoe Dam had been in place well before 1974).

5.0 THE APPARENT INCOMPATIBILITY BETWEEN MODEL RESULTS AND THE FLOOD FREQUENCY CURVE

A major 'dilemma' which emerges from the Study can be summarised as:

- the RAFTS model performed satisfactorily for the Brisbane River catchment for a wide range of events, but
- even with a Q100 design storm which is perhaps 25-30% too large (Section 4.1), it still takes zero losses to achieve a 'match' with the Q100 peak from the flood frequency curve.

In other words, there appears to be an incompatibility between the rainfall-based estimate of Q100, and that obtained from the frequency analysis of recorded floods. Each approach is considered further below.

The design rainfalls for the catchment were obtained from ARR (1987), and thus based primarily on recorded data this century. The coverage of the catchment by the gauge network is considered good. Hence, the derived design rainfall, when input with average loss rates into a calibrated catchment model, would be expected to give reasonable estimates of flow.

On the other hand, the flood frequency curve is dominated by flood events from more than 100 years ago. The top four floods used to derive the curve were, in order of rank, 1841, 1893 (1), 1893 (2), and 1844 (as advised by Scott Abby, SKM). The biggest flood for the last 100 years (1974) only ranks as number five in this sequence, and has an apparent AEP of about 1 in 40. The unusual sequencing of these events (and the incompatibility with rainfall-based estimates referred to above) raises some concerns about the homogeneity of the historic data.

A number of reasons for the seemingly high number of large floods which occurred last century can be postulated; they include a more extreme weather environment then, or doubtful rating curves. Whatever reason seems most plausible, a decision has to be made as to whether to put more weight on the more recent rainfall and flow data. It could be argued, with justification, that measurement and checking procedures for both rainfall and flow have improved, and that the recent data are more likely to be representative of the future. This reviewer would certainly adopt such a course.

Recommendation 6. That steps be taken to resolve the apparent incompatibility between rainfall-based estimates and those from the frequency curve; this would include a sensitivity study of the influence of the nineteenth century floods on the Study outcomes.

6.0 CONCLUSION

The correct hydrologic strategy for determining design floods has been used in the Brisbane River Flood Study (SKM, 1998). However, an apparent incompatibility between rainfall-based and flood frequency estimates of the Q100 flood, raises some uncertainties about the Study outcomes. Conservative assumptions in key input variables point to the likelihood that the magnitude of the Q100 obtained in this Study is an over-estimate.

Recommendations for the work needed to address the issues of concern have been highlighted in this report, and repeated below. It will be noted that the first three involve flood volumes; given the non-linearity of the runoff routing model relating flows to volumes, they can be expected to have a proportionately greater effect on flood peaks.

(Note: Recommendations 1 and 6 are considered most important.)

Recommendation 1. That an appropriate areal reduction factor be applied to the input design rainfalls used in the Brisbane River Flood Study.

Recommendation 2. That reasonable (non-zero) design loss rates be used to estimate Q100

Recommendation 3. That a probability analysis be conducted to determine the most suitable design values of initial storage levels for the Wivenhoe and Somerset Dams for downstream flood calculations.

Recommendation 4 (Less weight). Repeat the frequency analyses with low flows removed, for both peaks and volumes. Use the fitted LPIII distribution, rather than eye-fit curves.

Recommendation 5 (Less weight). Compute and highlight the effect of the Wivenhoe and Somerset Dams on the 1974 flood using the calibrated model, and the most probable initial state of the storages (assuming Wivenhoe Dam had been in place well before 1974).

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6.0 REFERENCES

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