Review and Update of GCCC’s hydrological models

Waterways & Flood Management
Planning Environment and Transport

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# Table of Contents

1. Introduction .................................................................................................................. 3
2. Update of Flood Frequency Analysis ............................................................................ 3
3. Update of Hydrological Calibration Parameters ......................................................... 4
4. Update of Rainfall Based Q100 Estimates .................................................................. 8
5. Agreement with Flood Frequency Estimates ............................................................ 10
6. DEA anomalies for events greater than Q100 ........................................................ 11
7. Comparison of DEA and JPA Q100 estimates .......................................................... 11
8. Conclusions ................................................................................................................. 13
9. Recommendations ...................................................................................................... 14
10. Acknowledgements .................................................................................................... 15

References ....................................................................................................................... 16

**Appendix 1:** Comparison of DEA and JPA flood frequency estimates ................. 17

## List of Figures

Figure 1: Round Mountain Calibration using updated rating curve
Figure 2: Round Mountain Calibration using original rating curve
Figure 3: Previous Hydrology: Modelled flows for Clearview
Figure 4: Updated Hydrology: Modelled flows for Clearview
Figure 5: Rainfall Intensities for the Coomera catchment upstream of Canungra
Figure 6: Comparison of DEA and FFA Q100 estimates – Updated Hydrology
Figure 7: Comparison of DEA and FFA Q100 estimates – Previous Hydrology
Figure 8: DEA Anomalies for events > Q100: Clearview Nerang River Stage 2

## List of Tables

Table 1: FFA Q100 estimates
Table 2: Previous and Updated URBS Routing parameters
Table 3: Updated and Previous DEA Q100 estimates
1 Introduction

The purpose of this review is to review the Gold Coast City Council’s (GCCC) current hydrological models. These models were built from the 2008 onwards and cover the Logan, Pimpama, Coomera, Nerang, Loders, Biggera, Tallebudgera and Currumbin catchments. The URBS runoff routing model was used and the outputs from the models are used as inflows to GCCC’s hydraulic model that are used to determine design flood levels throughout the City.

The review required the following work to be completed:

1. Update the flood frequency analyses to include the last 5 years of data
2. Review the URBS models’ parameters for each catchment
3. Review adopted parameters from a regional perspective
4. Improve the agreement between the results flood frequency analysis and the design event approach (DEA). The DEA to be undertaken as per recommendations of GCCC’s peer review group (PRG).
5. Undertake Monte Carlo design flow analysis for comparative purposes
6. Prepare recommendations based on the updated work

This report focuses on 100 year ARI design flow estimates (Q100) which are the primary determinants of design floodplain levels throughout the Gold Coast. Specific details for other ARI’s including flood frequency analysis and modelling details are found in separate companion reports for each of the catchments. These reports including this review will be subject to further review by the Council’s Peer Review Group (PRG) in due course.

2 Update of Flood Frequency Analysis

The flood frequency analysis (FFA) was updated to include 5 additional years of data. Data from the Jan 2013 event was included and it was assumed that this will be the maximum peak flow event for 2013.

The flood frequency analysis was undertaken using the FREQ flood frequency analysis program (Carroll, 1991). This program is similar to the spreadsheet program using in the previous analyses (CRC-CH, 2001) with the exception that parameters are estimated by least squares rather than moments.

Table 1 lists Q100 estimates for the stations analysed. Estimates for other ARI’s are detailed in the separate update reports.
Table 1: FFA Q100 estimates

<table>
<thead>
<tr>
<th>Location</th>
<th>Catchment</th>
<th>Area (km²)</th>
<th>I100, 24h (mm/hr)</th>
<th>Updated FFA Q100</th>
<th>Previous FFA Q100</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicolls Bridge</td>
<td>Currumbin</td>
<td>30.6</td>
<td>23.69</td>
<td>410</td>
<td>428</td>
<td></td>
</tr>
<tr>
<td>Talle. Creek Rd</td>
<td>Tallebudgera</td>
<td>56.4</td>
<td>24.58</td>
<td>758</td>
<td>695</td>
<td></td>
</tr>
<tr>
<td>Canungra</td>
<td>Coomera</td>
<td>97.3</td>
<td>20.78</td>
<td>915</td>
<td>1076</td>
<td></td>
</tr>
<tr>
<td>Clearview</td>
<td>Nerang</td>
<td>250</td>
<td>20.68</td>
<td>237</td>
<td>2754</td>
<td>Pre Hinze Dam only</td>
</tr>
<tr>
<td>Mudgeeraba TM</td>
<td>Nerang</td>
<td>37.2</td>
<td>20.26</td>
<td>300</td>
<td>347</td>
<td>20 years data only</td>
</tr>
<tr>
<td>The Overflow</td>
<td>Logan</td>
<td>502</td>
<td>8.33</td>
<td>1421</td>
<td>1774</td>
<td></td>
</tr>
<tr>
<td>Round Mountain</td>
<td>Logan</td>
<td>1264</td>
<td>8.83</td>
<td>3018</td>
<td>1876</td>
<td>Rating curve revised</td>
</tr>
<tr>
<td>Yarrahappini</td>
<td>Logan</td>
<td>2419</td>
<td>8.55</td>
<td>4579</td>
<td>4596</td>
<td></td>
</tr>
<tr>
<td>Bromfleet</td>
<td>Logan</td>
<td>544</td>
<td>12.22</td>
<td>2227</td>
<td>2311</td>
<td></td>
</tr>
<tr>
<td>Wilflene</td>
<td>Logan</td>
<td>721</td>
<td>12.27</td>
<td>2615</td>
<td>2511</td>
<td></td>
</tr>
</tbody>
</table>

To assess the consistency of the estimates (and implicitly the rating curves used to derive the annual flow series), a multiple regression analysis was undertaken whereby the updated Q100 was regressed in log space with catchment area and 24 hour 100 year ARI rainfall intensity (I100, 24h). The results indicate that the FFA for Mudgeeraba is anomalous and likely to be underestimated. Increasing the current estimate from 300 m³/s to 400 m³/s the regression coefficient is increased from 98.5% to 99.5%. Further the regression results are confined to +/- 10% rather than +/- 25% through adjustment of the Mudgeeraba estimate. The regression equation adopted is:

\[ Q100=0.60A^{0.83}xI100^{1.17} \]

Based on the above analysis, it is concluded that the updated flood frequency analysis is reasonably consistent with previous results with the exception of Round Mountain, whose rating curve required considerable adjustment. This adjustment is discussed later in the report.

3 Update of Hydrological Calibration Parameters

The purpose of the hydrological modelling is to provide design inflows to GCCC’s hydraulic floodplain models so as to determine design flood levels for floodplain management. To do this it is essential to review the calibration for each catchment, keeping in mind potential regionalization of the URBS’ model parameters. It was also considered necessary for those catchments that had sub-models to combine the sub-models into a single model. This process was undertaken for both the Logan and Nerang catchments. This facilitated inclusion of the models into URBS’ windows interface (the ControlCentre) as well as promoting regionalization of the URBS parameters.

As a first step, the URBS model parameter fraction forested (F), was scaled by a factor of 0.5. This adjustment is subjective however the original factor was derived based on equatorial forests whereas the forests in the Gold Coast region are sub-tropical. A scaling factor of 0.5 was used also in earlier modelling work. Whatever factor is used, catchment routing to various degrees can be compensated by adjusting the value of the URBS Beta parameter. However, it is important that the same scaling factor be applied across the Gold Coast to promote regionalization of the URBS’ routing parameters.
A further complicating factor in the regionalization process is the extensive use of channel routing scaling parameter (Factor) as incorporated in catchment definition files. Use of this factor compromises regionalization of the channel routing parameter (Alpha). Judicious use of these factors is recommended and should be undertaken in a future update.

Table 2 lists the routing parameters adopted in the previous modelling and the parameters adopted in this update. A brief discussion for any changes made to the parameters for each catchment follows.

**Table 2: Previous and Updated URBS Routing parameters**

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Alpha Prev.</th>
<th>Beta Prev.</th>
<th>m Prev.</th>
<th>Alpha Update</th>
<th>Beta Update</th>
<th>m Update</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logan</td>
<td>0.22*</td>
<td>1.8*</td>
<td>0.80*</td>
<td>0.20</td>
<td>2.5</td>
<td>0.75</td>
<td>Upper Logan</td>
</tr>
<tr>
<td>Pimpama</td>
<td>0.35</td>
<td>2.5</td>
<td>0.70</td>
<td>0.35</td>
<td>3.0</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Coomera</td>
<td>0.12</td>
<td>1.2</td>
<td>0.65</td>
<td>0.12</td>
<td>1.2</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Nerang</td>
<td>0.22*</td>
<td>1.5*</td>
<td>0.7*</td>
<td>0.10</td>
<td>1.5</td>
<td>0.70</td>
<td>Nerang only</td>
</tr>
<tr>
<td>Tallebudgera</td>
<td>0.11</td>
<td>1.6</td>
<td>0.65</td>
<td>0.11</td>
<td>1.6</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Currumbin</td>
<td>0.14</td>
<td>1.8</td>
<td>0.65</td>
<td>0.14</td>
<td>1.8</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Loders</td>
<td>0.38</td>
<td>3.0</td>
<td>0.60</td>
<td>0.20</td>
<td>2.0</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Biggera</td>
<td>0.55</td>
<td>7.5</td>
<td>0.70</td>
<td>0.20</td>
<td>2.0</td>
<td>0.80</td>
<td></td>
</tr>
</tbody>
</table>

From this Table is seen that for those catchments with hinterland headwaters (Coomera, Nerang, Tallebudgera and Currumbin and Logan (to a lesser extent)) typical values of alpha, beta and m respectively are 0.12, 1.4 and 0.7 respectively. The floodplain catchments have higher values of alpha (Pimpama the highest) and Beta averaging about 2.0 with an “m” value of 0.75. Intuitively this reflects greater storage areas in the lower lying catchments.

For the most part the updated calibration parameters are similar to those of the previous calibration studies. However, it should be noted though similar parameters were adopted the peaks should be higher for highly forested catchments due to scaling of the forest fraction by 0.5 as discussed earlier. For a fully forested catchment, scaling back the forest factor to 0.5 has the effect of reducing beta by approximately 50%. Further there is a reducing effect of forestation (retardation) with increasing ARI which is not accounted for explicitly in the modelling process.

Key changes were made however to the calibration parameters as follows:

**Logan Catchment**

The alpha, beta and m values used were weighted averaged values derived from the 4 sets of parameters adopted for each of the catchment’s sub-models. The calibration achieved was equivalent if not improved over the original calibration.
However, the Round Mountain rating curve is considered to be in error and it is suggested this may be as a result of a datum issue – the revised rating curve is approximately 1.5m to 2m lower for the same discharge. The revised rating curve yielded excellent calibration to the historical data for all events. Figure 1 shows the differences in calibration between the two rating curves for the 1974 event.

![Figure 1: Round Mountain Calibration using updated rating curve](image1)

![Figure 2: Round Mountain Calibration using original rating curve](image2)
Nerang Catchment

The alpha value (channel routing) had to be halved to better match the 1974 verification event. This reduction is in keeping with SKM’s (SKM, 2012) Monte Carlo study for the Nerang which found that the previous calibration yielded equivalent RORB kc values that was outside reasonable bounds. It appears that in the original calibration process, good calibration was achieved for small events, however the 1974 event was not used in the calibration process but used as a verification event. While a good match with peak discharge was achieved the routing characteristics of the calculated 1974 event was poor. Figure 3 provides the original verification. Figure 4 shows the updated calibration.

Figure 3: Previous Hydrology: Modelled flows for Clearview

Figure 4: Updated Hydrology: Modelled flows for Clearview
This issue points to the careful calibration of these models in terms of their event magnitude. While good calibration was achieved for the lower events, the catchment response significantly speeds up with less frequency event indicating a highly non-linear process. It also suggests that less frequent events should be included in the calibration process.

**Loders and Biggera catchments**

The routing parameter set are markedly different from previous estimates. These parameters were revised based on the limited calibration data available and achieving good agreement with the rainfall based estimates using the ARR (1987) Design Event Approach (DEA) as recommended by GCCC’s PRG and discussed in the next section of this report.

### 4 Update of Rainfall Based Q100 Estimates.

This update required using the updated calibration set adopted for each catchment and applying the DEA process as recommended by GCCC’s PRG to determine peak flow estimates for various ARI’s. As already indicated, this review focuses on 100 year ARI peak flow estimates.

Table 3 lists the results for key stations throughout the Gold Coast Region.

<table>
<thead>
<tr>
<th>Location</th>
<th>Catchment</th>
<th>Updated DEA Q100</th>
<th>Previous DEA Q100</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicolls Bridge</td>
<td>Currumbin</td>
<td>413</td>
<td>367</td>
<td></td>
</tr>
<tr>
<td>Talle. Creek Rd</td>
<td>Tallebudgera</td>
<td>741</td>
<td>700</td>
<td></td>
</tr>
<tr>
<td>Canungra Army Camp</td>
<td>Coomera</td>
<td>883</td>
<td>659</td>
<td>Intensity increased by 25%</td>
</tr>
<tr>
<td>Clearview – Pre Dam</td>
<td>Nerang</td>
<td>2398</td>
<td>1783</td>
<td>Pre Hinze Dam estimate</td>
</tr>
<tr>
<td>Clearview – ST2</td>
<td>Nerang</td>
<td>1068</td>
<td>989</td>
<td>Stage 2</td>
</tr>
<tr>
<td>Clearview – ST3</td>
<td>Nerang</td>
<td>595</td>
<td>541</td>
<td>Stage 3</td>
</tr>
<tr>
<td>Mudgeeraba TM</td>
<td>Nerang</td>
<td>472</td>
<td>345</td>
<td></td>
</tr>
<tr>
<td>Neranwood</td>
<td>Little Nerang</td>
<td>584</td>
<td>543</td>
<td></td>
</tr>
<tr>
<td>The Overflow</td>
<td>Logan</td>
<td>1404</td>
<td>1298</td>
<td></td>
</tr>
<tr>
<td>Round Mountain</td>
<td>Logan</td>
<td>3515</td>
<td>2731</td>
<td>Rating curve revised</td>
</tr>
<tr>
<td>Yarrahappini</td>
<td>Logan</td>
<td>4832</td>
<td>3546</td>
<td></td>
</tr>
<tr>
<td>Bromfleet</td>
<td>Logan</td>
<td>2213</td>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>Wolfdene</td>
<td>Logan</td>
<td>2667</td>
<td>2113</td>
<td></td>
</tr>
<tr>
<td>Waterford</td>
<td>Logan</td>
<td>4193</td>
<td>3121</td>
<td></td>
</tr>
<tr>
<td>Kerkin Road</td>
<td>Pimpama</td>
<td>385</td>
<td>339</td>
<td></td>
</tr>
</tbody>
</table>

It is noted that DEA Q100 estimates are typically 10% higher than those previously calculated. However significant changes were found for Canungra results. It was found that the design rainfall intensities were lower upstream of Canungra than those downstream in the lower Coomera catchment – which is counter intuitive given the high altitude of the Canungra catchment (typically elevation 400 m AHD) and the pronounced orographic effects evident for other hinterland catchment across the Gold Coast. To address this issue and without the benefit of the updated ARR IFD tables (expected 2014) it was necessary to scale the IFD table in the upper Coomera catchment by (up to I500 years ARI) by a factor of 25%. It is suggested that this
anomaly has occurred because of interpolation in an area with very strong rainfall gradients and one which adjoins the Logan catchment whose intensities are typically half those of the hinterland catchments. Application of this scaling factor resulted in design intensities similar to those for the Nerang catchment to Clearview — which is considered reasonable. Figure 5 shows the anomaly in which sub-area 100 years ARI 9 hour intensities are highlighted for both the Nerang and Coomera catchments together with contours of average sub-area elevation. Sub-areas intensities highlighted in yellow were up-scaled by 25%. It is recommended upon issue of the new ARR IFD tables that the scaling applied in this update be reviewed.

Figure 5: Intensities (100 yr, 9h) and elevation contours for Coomera and Nerang
5 Agreement with Flood Frequency Estimates

Figure 6 plots the Q100 DEA estimate versus Q100 FFA estimate for various gauging stations throughout the Gold Coast. It can be seen that in general good agreement is achieved with the DEA approximately 3% on average higher than FFA estimates. This is well within the bounds of accuracy and a significant improvement over previous estimates where the DEA is underestimated on average by 12.5% and with a far greater variation – see Figure 7. Accordingly, GCCC’s application of 10% factor to design rainfalls to match flood frequency estimates based on 2008 hydrological modelling work is well justified.

![Figure 6: Comparison of DEA and FFA Q100 estimates – Updated Hydrology](image)

![Figure 7: Comparison of DEA and FFA Q100 estimates – Previous Hydrology](image)
6 DEA anomalies for events greater than Q100

During the update analysis it was noted that anomalies arose in the design estimates for ARI’s greater than 100 years. The reasons for these anomalies were two-fold; (a) in some cases merging of the CRC-Forge and the AWE IFD tables resulted in lesser intensities with increasing ARI for the same duration and (b) the abrupt change from the AWE temporal pattern for design events up to and including 100 year rainfall events to the use of the GSDM/GTSMR pattern for events greater than 100 years ARI. An example of this anomaly is shown in Figure 7 (refer red line).

These issues were addressed through interpolation of intensities and temporal patterns. Intensities that were found be anomalous were replaced with interpolated intensities (in log space) between the 100 year and PMP. Secondly, anomalies that occurred because of the abrupt change in temporal patterns were addressed by interpolating the 100 year temporal pattern with the PMP-DF temporal pattern, again in log space, for the various ARI’s between the 100 year and PMP. It is recommended that where these anomalies occur that both smoothing assumptions (i.e. intensity and temporal pattern interpolation) be deployed as shown by the green line in Figure 7.

7 Comparison of DEA and JPA Q100 estimates

Over the past few years the joint probability approach (JPA) has been under development (often loosely referred to as Monte Carlo estimation techniques, which is an essential component of the joint probability approach). Currently there are two Monte Carlo techniques available; the Total probability theorem approach (TPT) as developed by Nathan & Weinmann (2000) and secondly the CRC-CH approach as developed by Rahman et al. (2001). The former builds on the current critical storm
duration approach whereas the latter generates design storms of variable duration. The CRC-CH approach is more difficult to apply as it requires event based IFD tables which are generally derived from raw pluviograph data whereas the TPT approach uses burst IFD tables as issued by the BoM.

For the purpose of this review, these techniques are deployed for comparative purposes only with the DEA as the DEA is the recommended approach for GCCC by its PRG. This recommendation by the PRG is prudent until such time that JPA techniques have matured and detailed for industry use in the forthcoming ARR’s update. This is expected to finalized within the next 2 to 3 years.

To assist with the DEA and JPA comparative exercise, specifically the use the CRC-CH approach, a relationship was developed between complete storm IFD tables and burst IFD tables for the Gold Coast Region. This was done was obtaining raw pluviograph data from the BoM to derive complete event IFD tables and comparing these tables to their burst table equivalents. The relationship between the tables (Carroll, 2012) was assumed to be:

\[ I_e = p D^q T^r I_b \]

Where \( p, q \) and \( r \) are constants, \( D \) is the Duration (hours), \( T \) is the ARI in years, \( I \) is the intensity, where ‘\( b \)’ denotes burst and ‘\( e \)’ event.

For the Gold Coast area, it was found that \( p = 0.1 \times I_2D_{24} - 0.25, q = 0.6 \times (1 - p) \) and \( r = -0.025 \). The mean duration was found to be approximated by \( 0.9 \times I_2D_{24}^{1.56} \) where \( I_2D_{24} \) is the 2 year 24 hour burst intensity.

In the application of the JPA a beta distribution was assumed for the initial loss whose parameters were sourced from Ilahee (2001) and from the historical calibration events. Temporal patterns were randomly selected based on the multiplicative cascade model (CRC-CH, 2001) and parameterized according to Carroll (2004) with filtering for patterns used for the TPT burst events to ensure that the generated patterns did not contain sub-bursts. It was assumed that dam levels were full according to best floodplain management practice. Both continuous losses and spatial variability were assumed to be constant.

It should be noted that both approaches suffer from limitations. The TPT approach has been developed for large for extreme floods and its application here for the more frequent ARI’s is questionable. The CRC-CH approach while often applied in the derivation of design flow estimates up to and including large floods is not robust in the estimation of rare and extreme floods when compared to the TPT approach. Other limitations are (i) the assumption that the loss distribution applies is consistent across the entire frequency range – generally higher losses are experienced with the more frequent ARI events (ii) convective storms are typically front loaded whereas frontal storms are end loaded which is not accounted for, (iii) storm patterns are likely to be less variable with increasing ARI and (iv) how El Nino/La Nina cycles impact antecedent conditions. It is obvious that further research work is required to apply these technologies over the entire frequency spectrum, but as applied it is likely there will be over-estimation of peak flows for the more frequent design events.
Overall it was found that the TPT approach provided the better fit to the DEA results (as expected as both assume the critical duration assumption) whereas the CRC-CH approach generally underestimated the DEA results. The CRC-CH approach was not suitable for the Logan catchment as it was found the Burst to Complete Event IFD table conversion process was not applicable for areas on the western side of the dividing range. Comparison of the various approaches can be found in Appendix 1.

From these results it is concluded that the Monte Carlo approach supports the DEA estimates and therefore the DEA results are recommended as inputs to GCCC’s hydraulic models.

8 Conclusions

A review of Council’s hydrological models has been undertaken and updated design flow estimates prepared for all catchments within the Gold Coast area. This update work builds on the excellent work already undertaken by Council finalized and peer reviewed in 2008/9. This update incorporated 5 years of additional data (including the Jan 2013 event) as well as Monte Carlo Techniques which are now sufficiently mature to be readily applied by practitioners, though much more work needs to be done in terms of formal publication by the ARR and its applicability over the entire flood frequency spectrum. The update took a regional perspective to design flood estimation and in so doing increased the confidence in the derived estimates. Undertaking Monte Carlo analyses further supported the updated design estimates.

The update has resulted in a better fit of flood frequency analyses to those derived by rainfall based methodologies specifically the DEA approach as recommended by ARR and detailed by Council’s PRG. It is understood that a 10% factor was applied to previous design estimates to better match flood frequency results, the results of this update show that this approach was sound. The updated DEA estimates are now within 3% of flood frequency estimates, compared to an average 13% lower than previous estimates.

Use of Monte Carlo techniques provided excellent results for the Tallebudgera, Currumbin and Nerang catchments and good results for Loder, Biggera and Commera. Results for the Logan catchment were average and it was found application of the CRC-CH technique would require additional background work for it to be used with confidence for this catchment. Overall the Monte Carlo approach supported the DEA results.

The update also highlighted various issues with the previous hydrology some of which have not been fully addressed but will need to be so as part of a continuous improvement process. These issues can be summarized as follows:

Some Rating Curves for the Logan Catchment required amendment, in particular the Round Mountain rating curve required considerable adjustment. These adjustments led to considerable improvements in the calibration process.
The routing parameters adopted for the Nerang catchment in the previous hydrology are too damped and required adjustment. While good calibration was achieved for lower ARI events, verification of the 1974 event was, in the reviewer’s opinion, poor. This conclusion is supported by SKM’s 2012 report. The effect on Nerang River hydrology however is very much diminished because of the presence of Hinze Dam.

The merging of the AWE IFD tables and CRC-FORGE IFD tables resulted in anomalies for design events in excess of 100 years ARI. This issue has been addressed through a two stage smoothing process.

AWE IFD design intensities for the upper Coomera (Canungra area) are anomalous as it was found that design intensities were lower than downstream lower elevation areas. It was required to increase these intensities by 25% to bring the IFD tables into line with similar intensities at equivalent elevations. This anomaly may have been as a result of interpolation in a steep rainfall gradient area.

Routing parameters were adjusted for Loders and Biggera creek resulting in better calibration and parameters that are more in keeping with regional expectations.

The forest fraction F was applied using a scaling factor of 1 in the previous hydrology. This has been reduced to 0.5 as a factor of 1 applies to equatorial forests. The 0.5 factor is subjective however it does allow for quicker response from sub-tropical forested catchments.

It is concluded that the design flow outputs as derived from this update are appropriate as inputs into Council’s hydraulic floodplain models.

It is stressed that this update represents another step in the on-going hydrological modelling programme established by the Gold Coast City Council. Further on-going work is required and these this work is outlined through the recommendations set out in the next section of this report.

## 9 Recommendations

1. This report together with its companion catchment hydrology update reports be submitted to Council’s PRG for review and comment.

2. That upon PRG endorsement design flows derived through this update be used as inputs to Council floodplain models.

3. That the updated models are appropriate for use flood forecasting models for non-tidal areas.

4. That on publication of the new IFD tables by the IE Australia that the DEA approach be updated and any significant differences in both rainfall and flood design estimates explored, particularly for the upper Coomera catchment.
5. The current hydrological models are calibrated only to non-tidal areas of Gold Coast. Work should be undertaken to calibrate these models in tidal areas through comparison with the results from floodplain hydraulic models.

6. Further work needs to be done with regard to parameter regionalization, this would include assuming consistent nonlinearity parameters and relating the channel routing parameter to channel slope and/or floodplain extent. Simplification of some of the catchment vector files should also be investigated.

7. Much work was undertaken for the Logan catchment by Gold Coast City Council. The vast majority of this catchment lies outside the Gold Coast Council administrative area, and as such there is merit with sharing this work with other agencies, such as Logan City Council and SEQWater. Further modelling agreement should be sought between stakeholder agencies including adopting common rating curves.

8. The Round Mountain rating curve (Logan catchment) should be further investigated to explain the significant adjustment required as part of this update.

9. Further work is required in the applicability of Monte Carlo techniques across the entire flood frequency spectrum. This work could be done through a partnership approach with research institutes – however at this stage it is recommended to wait until publication of the new ARR in which some of these issues may be addressed.

10 Acknowledgements

The reviewer would like to thank [redacted] for setting the overall direction for this update project and to Elton Chong, Supervising Engineer in ensuring that work was effectively managed and completed in a timely manner. The extensive hydrological work undertaken by [redacted] is very much appreciated. Their work underpins the findings of this report and their continuous feedback about arising issues greatly strengthened project outcomes and processes.
References
Appendix 1
Comparison Plots of the various methodologies for select stations

Peek Flow ($m^3/s$) vs ARI (yr) @ Nicolls Bridge Gauging Station, Currumbin

Peek Flow ($m^3/s$) vs ARI (yr) @ Tallebudgera Creek Rd Gauging Station, Tallebudgera
Review and Update of GCCC’s Hydrological Models

Peak Flow (m³/s) vs ARI @ Clearview St2 2010

Clearview, Nerang River

Peak Flow (m³/s) vs ARI (yr) @ Canungra Army TM, Coomera

Canungra Army Camp, Coomera
Review and Update of GCCC’s Hydrological Models

Peak Flows (m$^3$/s) vs ARI (year) @ Yarrahappini AL

Yarrahappini, Logan River

Peak Flows (m$^3$/s) vs ARI (year) @ Wolffdene AL

WolffDene, Logan Catchment

Peak Flows (m$^3$/s) vs ARI (year) @ Broomfleet AL

Bromfleet, Logan Catchment
Review and Update of GCCC’s Hydrological Models

Loders Dam, Loders Creek

Biggera Dam, Biggera Creek

Biggera Dam Inflows, Biggera Creek