A High Resolution Point Rainfall Model Calibrated to Short Pluviograph or Daily Rainfall Data

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December 2006

Ph.D. Thesis

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ABSTRACT

The design of hydraulic systems that have to cope with natural flows of flood magnitude is risk-based The estimation of flood risk relies on joint probability theory where the combination of stochastic inputs such as rainfall and a description of the hydrological/hydraulic runoff process determine the probability distribution of flooding events. To date both the design storm approach presented in Australian Rainfall and Runoff (Institution of Engineers Australia, 1987) and continuous simulation through a Monte Carlo approach have provided workable methods for deriving empirical flood probability distributions as an estimate of this flood risk. While the continuous simulation approach has long been viewed as the best way to evaluate the probabilistic behavior of surface water systems, the design storm approach has remained the preferred choice due to its simplicity and ease of use. However with the onset of powerful personal computers providing the ability for increasingly complex analysis within the required timeframes, the tendency towards using a continuous simulation approach will continue to grow.

The idea behind the Monte Carlo continuous simulation approach is that a long model simulation will eventually sample all possible joint probability interactions (i.e. all combinations of rainfall input and runoff model conditions etc) within a system. If this is the case, the derived flood distribution from these simulations can be viewed as an accurate inference of the true flood distribution and therefore can be used for engineering analysis and evaluation of flood risk. A drawback of the Monte Carlo approach is the required input of a long rainfall record. In the absence of a significant historical record, rainfall models can be used to provide the required data but are in turn reliant on adequate historical data for calibration. Accurate calibration of rainfall models is particularly important in Australia where the variability of rainfall at short and long term time scales is large.

Australia does have an extensive network of rainfall recording stations. These sites record rainfall data in various forms ranging from a daily time step down to six-minute resolution. While the size of historical daily records is often large, there are very few six-minute (Pluviograph) records available of significant length. Indeed,

analysis of Australia's pluviograph records indicates that the average length of the more than 900 pluviograph data sets available from the Bureau of Meteorology is approximately 15 years. Only a small number of sites have a record length exceeding 40 years and of these only 40 or so remain active. Even with the high quality of rainfall data in Australia, periods of missing or corrupt data are often present. Not only does this lack of significant short time scale data provide a major obstacle in the application of a Monte Carlo approach to risk estimation, it also inhibits the application of rainfall simulation models that use this data for direct calibration. This lack of data is particularly important if we consider the tails of the flood probability distribution where it is unlikely that a 15-year historical record can provide accurate estimates of a 100 year flood event. While the advent of numerous stochastic rainfall models provide methods for extending historical rainfall records, without adequate historical rainfall data available for calibration their accuracy is questionable.

This thesis describes the development of a new technique which significantly extends the applicability of stochastic point rainfall models that require historical data for calibration. The technique is demonstrated using a high-resolution point rainfall model based on wet-dry alternating storm events. The original model presented by Heneker *et al.* (2001) uses storm events which are defined by the observed event distributions of dry periods, storm event durations and storm intensity conditioned on storm duration and replicates this event structure during simulation.

Significant improvements to the original model are presented as the first part of this thesis. The parameterisation used to describe the event distributions has been simplified and the number of parameters reduced resulting in a model that is more robust and easier to calibrate. In addition, the Metropolis algorithm (Metropolis *et al.* (1953)) was incorporated into the model providing a description of the posterior distribution of model parameters and as a result enables a description of parameter uncertainty within the model structure. These improvements have produced a model that is well defined and can be vigorously compared against numerous observed statistics in a quantitative manner. Simulation results indicate that the model is able to replicate both calibrated and non-calibrated statistics at various time scales.

The original model required the use of a long pluviograph record at the site of interest to ensure an accurate calibration of model parameters. To circumvent this restriction in the application of the model a new 'master'- 'target' scaling relationship has been developed and incorporated into the model. A model calibration is undertaken at a 'master' site with a long pluviograph record which is then updated and scaled to the 'target' site of interest using the information from either a short pluviograph or daily rainfall record. This structure has removed the need for significant pluviograph data at the 'target' site and enables the rainfall model to be applied at sites with short pluviograph or daily rainfall records.

The approach has been tested at numerous pairs of sites providing evidence of its success in generating accurate synthetic pluviograph data across the country and within various climatic regions. Model results are presented and compared for both the observed pluviograph data (for individual storm and sub-daily statistics) and daily data (for longer aggregated statistics) available at the target sites and compares well to Australian data. The rainfall model presented in this thesis can be used to provide accurate synthetic rainfall data at sites with minimal historical rainfall data providing a powerful tool for application in hydrological risk analysis across Australia.

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