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Queensland Floods Commission of Inquiry
GPO Box 1738
BRISBANE QLD 4001

By Email

Attention: [redacted]

Dear Madam

FLOODING BEHAVIOUR

I refer to your email of 7 November, requesting comments on the science of flood behaviour mapping. I provide the following responses to each item of the request.

Mapping Flood Behaviour

1. ***A description of how a study that describes how a flood behaves, i.e. severity, depth, velocity, rate of rise, duration ('a flood behaviour study'), is conducted.***

2. ***If more than one method can be used to produce the study described in item 1, a comparison of the advantages and disadvantages of each method by reference to:***

   a) ***what is best practice;***

   b) ***the uncertainties associated with each method; and***

   c) ***the feasibility and practicality of each method, including an estimate of the complexity of the investigations and the time and cost involved.***

Different types of flood studies can be conducted to provide a range of information relating to flooding behaviour. At its most basic, a flood study requires consideration of two things:

- The hydrology of the storm event which is being modelled, where hydrology in this context can be described as the quantity and distribution of rainfall generating surface runoff and discharge over the catchment area being considered. The hydrologic investigation will return the magnitude of the flow discharge in cubic metres per second, either as a single value relating to the maximum value of the discharge, or as a variation of discharge over time, which is described as a flood hydrograph.

- The hydraulics of the runoff event, where hydraulics describes the physical behaviour of the water as it passes over (and in the case of a piped stormwater drainage system, through) the land surface. Put simply, the hydraulic study must take into account the magnitude and variation of the discharge with time, the shape and texture (skin roughness) of the surface over which flow occurs, and the varying longitudinal gradient of the flow as it travels downstream.

The hydrology and hydraulics of the storm event are equally important in determining flooding behaviour. The more intense the rainfall (generally registered in mm per hour), the greater the rate of flow generated, and the greater the impact on flood levels and flow velocities.

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There are a range of systems, methods, procedures and computer programs which are used in hydrologic and hydraulic analysis. It is well beyond the scope of this current report to consider in detail or even list the full number of such systems available. However, some limited explanation is probably useful.

Engineers use a number of methods to determine hydrologic and hydraulic behaviour, depending not only upon the complexity of the system being analysed, but also on the time and effort available to be spent on the task. The Rational Method is the simplest hydrologic procedure available to estimate peak flow rate, and it relies on knowing only the average rainfall intensity of the flood event to be considered, the area of the contributing catchment and a value known as the Coefficient of Runoff which determines the proportion of rainfall which is converted into runoff. The Rational Method is still in very widespread use in the engineering profession, and it has traditionally formed the basis of stormwater drainage design, ie the determination of sizing and location of stormwater drainage elements such as gutters and pipes.

Further along the hydrologic scale of complexity are various runoff routing models such as RORB, RAFTS and WBNM which enable the prediction of a flow hydrograph, ie a description of the variation of the quantity of discharge with time at a specific location. These models are computer-based and rely on significantly more knowledge about the storm and catchment, such as the spatial and temporal variation of the rainfall intensity over the entire catchment, the area, degree of urbanisation and average gradient of each sub-area making up the catchment, and the flow path taken in each sub-area (ie either overland or channel flow). Except for very small catchments, where the Rational Method is still the procedure of choice, runoff routing models are now routinely used to determine a flood hydrograph for subsequent hydraulic analysis.

There are also rainfall-runoff models, which model the direct conversion of rainfall to runoff at a micro scale based on catchment characteristics. Such models are typically used for catchment wide daily flow assessment, rather than for detailed flood studies.

Hydraulic modelling is probably considered to be a more complex landscape than hydrology, but hydrologists would almost certainly disagree. The simplest form of hydraulic modelling is the use of the Manning Equation. This is an empirical formula applicable primarily to constant flow rates and uniform channels. This would be described as uniform steady flow. The Manning Equation requires knowledge only of the constant shape, surface resistance and longitudinal gradient of the channel, and the magnitude of the single flow rate being considered. An extension of the Manning Equation is backwater analysis, where the channel dimensions, gradient and surface resistance to flow are permitted to vary in space, and the flow rate may also vary spatially. Backwater analysis is usually performed using a computer program known as HEC-RAS, but it can also be calculated manually, using the simplified equations of flow.

While flow in the real world is generally non-uniform (ie the channel dimensions vary) and unsteady (ie the flow rate changes over time), backwater modelling is still widely used in situations where its assumption of one-dimensional flow conditions is considered valid. In particular, it provides accurate peak water levels in situations where the flow is largely confined to a defined channel, and flood storage is not important to flow behaviour

However, in many cases, flow is significantly more complex than a backwater model can represent. There are therefore a range of hydraulic models which provide increasingly complex descriptions of flow behaviour. In general, these are classified according to the assumed dimensionality of the situation being modelled. For example, a one-dimensional (1-D) hydrodynamic model such as MIKE-11 assumes that the velocity of flow is constant throughout the cross-section of flow being considered. A two-dimensional (2-D) depth-averaged model, such as MIKE-21, assumes that velocity varies according to plan position.

This form of representation generally provides an acceptably accurate simulation of flow for riverine and floodplain hydraulics, such as those experienced in Brisbane River flooding. A recent development has been linked 1-D 2-D models, such as MIKE-FLOOD, TUFLOW and SOBEK, which enable the use of 1-D elements such as culverts and weirs in a general 2-D landscape. At the current limit of analysis are three-dimensional (3-D) models which solve the full equations of flow to provide a complete description of the flow process in a situation such as deep ocean current modelling. However, even in these circumstances, there are some assumptions which are used to simplify the analysis, since the physical world that we are attempting to model is more complex than assumed.

These are the general issues which underlay mathematical modelling of floodplain processes. To specifically answer the questions posed above, I would respond as follows in relation to a description of a flood behaviour study:

- A flood behaviour study is conducted by undertaking a number of contiguous steps. Firstly, there is a requirement to select and use a hydrologic model to predict either the peak rate of flow for the storm under consideration, or a flood hydrograph which demonstrates the flow rate varies with time. The hydrologic model can be based on a simulated design event with a certain frequency (such as the design 100 year Average Recurrence Interval event), or on measured information collected from an historical event (such as the 1974 flood). In either case, the same information is required, such as variation of rainfall intensity both spatially and temporally, and the physical condition of the catchment which can be used to define a Coefficient of Runoff.

- Secondly, it is necessary to choose a suitable hydraulic model to enable determination of the required parameters such as depth and duration of flooding, rate of rise and variation of velocity. In general, the model selected is that which enables an acceptably accurate outcome to be achieved at the least cost (ie in time and/or money). For example, while a backwater model is easy to setup and run, it would generally not be considered suitable for the study of a major coastal stream such as the Brisbane River where flood storage in and around the floodplain is likely to be significant.

- Thirdly, a physical description of the area affected by flooding has to be derived. This consists of survey data which enables a Digital Terrain Model (DTM) of the area to be produced, together with a determination of the varying surface resistance over the area, eg frictional resistance to flow increases with density of vegetation.

- Fourthly, if possible, the models are calibrated against a known historical event. That is, based on measured rainfall intensities and flood levels, the models parameters are modified until there is a good match between actual and predicted behaviour.

- Lastly, the models are rerun using design information, eg to determine impacts during the critical 100 year Average Recurrence Interval flood event.

In relation to differences between forms of models, I provide the following information:

- As noted above, hydrologic studies for riverine flooding analysis are usually conducted using runoff routing models. The most commonly used in Australia appears to be WBNM (Watershed Bounded Network Model) which was developed at the University of Wollongong.

- For hydraulic models, the current best practice for riverine flooding is the use of linked 1-D 2-D models such as TUFLOW and MIKE-FLOOD. Such models allow adequate descriptions of areas of two-dimensional flow while also allowing for the efficient use of one-dimensional structures, thereby substantially reducing analysis time.

- As to uncertainties associated with different hydraulic models, the accuracy of all models is dependent upon the data which is entered to represent the physical characteristics of the actual areas being modelled. However, it is hardly worthwhile to adopt a higher dimensional model unless the extent of data available for calibration and analysis purposes is commensurate. Consequently, there is a reasonable level of judgement and experience required by the modeller to ensure that the appropriate model is selected for the specific task at hand. In addition, the physical situation must correlate adequately with the assumptions built into the solutions of the equations of motion for each type of model. For example, it would be pointless to use a 1-D hydrodynamic model to simulate a site with obvious two-dimensionality of flow conditions. The reverse is also true, however. If the situation being modelled is a relatively linear channel with no significant overbank or floodplain flow, then there is no reason to choose other than a 1-D model.

- The cost of analysis generally increases with increasing dimensionality, and the type of hydraulic model must be carefully selected to suit the task. The advent of accurate Aerial Laser Survey (ALS) has enabled large areas to be mapped quickly and relatively cheaply. This has facilitated the growth in the use of 2-D and linked 1-D 2-D models for riverine and floodplain analysis in particular.

3. *A description of best practice methods for converting information obtained in the flood behaviour study into a graphical representation on a map.*

One of the significant difficulties associated with the use of 2-D hydraulic models is the complexity of the results which are obtained. Large models may contain hundreds of thousands to millions of data points, and a full time history of flow conditions and water levels is maintained at each data point. This clearly makes numerical manipulation of data an onerous task. Graphical methods have usually been adopted to allow visualisation of results, with ranges of flood levels for example being specified by different colours. While this has the advantage of conveying information quickly to the observer, it is also the fact that visualisation generally loses some of the fine detail which may be critical in assessing potential flooding impacts.

In my opinion, the only successful way to capture this data is to either review the full detail of numerical results, or allow direct interrogation of the results from the computer screen, eg placement of the mouse over a specific location may provide the time history of flood level variation, or the maximum flood level experienced at the site.

Most, if not all of the complex 2-D programs listed above include graphical post-processors, which allow numerical manipulation and mapping output of the results data.

4. *Whether a flood behaviour study:*

a) ***involves different work to a flood study intended to determine flood risk (ie height and flow of floods of different Annual Exceedance Probabilities) ('flood risk study'); and***

b) ***would involve less time or cost if it were combined with a flood risk study, and an estimate of the savings in time and cost.***

5. *The advantages and disadvantages of combining a flood risk study and a flood behaviour study for a catchment.*

Flood risk studies and flood behaviour studies are only different representations of detailed flood modelling. The 2-D computer programs referred to above allow a user to determine the time history of certain hydraulic parameters such as velocity and flood level, throughout the area of interest. Manipulation of the results allows for determination of further parameters such as flood hazard, which is defined as the product of velocity x depth at a location, or flood damage which is a dollar amount normally correlated in some way to flood height. Flood duration can also be assessed, so that the time of non-availability of a transit path such as a road could be determined.

A flood behaviour study can only realistically be undertaken if the flood study analytic method permits time histories to be calculated. For example, while a backwater analysis may be sufficient to allow determination of the peak water level likely to be experienced for a flood with a certain Average Exceedance Probability, no time history can be derived, eg the duration of occurrence of flood levels above a specified level, or the variation of velocity with time cannot be determined using this method.

The same may not be true in respect of flood risk. In that context it is normally only the peak level and velocity values which are important. While a home owner might have an interest in how long his or her house is likely to be subject to inundation, it is the actual act of inundation which is normally most important. That is, damage is assessed normally against a water level, and once a floor has been inundated, the damage has been incurred.
However, any recent and future risk assessment of a significant riverine system would usually utilise 2-D or linked 1-D 2-D computer models. In that case, the flood risk assessment will already have produced the information needed to allow flooding behaviour to be reviewed and assessed.

In general, therefore, if a flood risk study is to be undertaken, it would be sensible and cost-effective to choose an analytic method which would also permit a flood behaviour study to be undertaken concurrently.

Implementation Review

I have also been asked to comment on Section 7 of Ipswich City Council's Implementation Guideline No 24 (Stormwater Management), specifically:

a) whether the Guideline represents best practice for assessing flood impact as part of the development assessment process of local governments;

In my opinion, the Guideline is largely representative of current best practice among Queensland local authorities, incorporating as it does:

- discussions on selection of appropriate hydrologic and hydraulic models
- a listing of the hydraulic parameters requiring analysis and assessment
- designation of the data sources to be used, such as Australian Rainfall & Runoff for rainfall intensities and storm temporal patterns
- nomination of requirements for survey and historical flood data

I note only one very minor typographical error, in 7.2 where VxD is referred to as a ratio, when it is of course a product.

I should also note that I would expect to be able to give much the same imprimatur for the flooding guidelines of other large Queensland local authorities, particularly those in the south-east corner of the state.

b) the time, cost and complexity associated with producing a report in accordance with the Guideline;

This is a difficult question to answer with any degree of uniformity, since the time, cost and complexity of hydraulic reporting will be correlated closely with the size, complexity and importance of the nominated watercourse. A study for a proposed urban development could generally cost between $20,000 and $200,000, depending upon the amount of survey information required and the sensitivity of the areas potentially affected. On the other hand, a study of the Brisbane River could cost in the order of several millions of dollars if it was completed at a detailed scale. I consider that the extent of work required is necessary to ensure that development does not have unacceptable adverse impacts.

c) ***whether a report consistent with the Guideline is necessary to assess flood impact in all instances, and if not, a description of the instances in which it is:***

i) ***not necessary at all; or***

ii) ***necessary only in part (identifying which parts);***

and the basis for that conclusion.

The Guideline is reasonable in that it permits different levels of assessment to be undertaken depending upon the size of the affected catchment, the complexity of the flow behaviour and the sensitivity of the receiving environment. For example, the Rational Method can be used to estimate peak flow rate provided that this value is to be used in a 1-D steady state analysis (such as in the backwater model HEC-RAS) for a catchment with a time of concentration of no more than 30 minutes.

While I might argue that the Rational Method should also be acceptable for larger catchments in non-critical areas, I expect that I could debate this point with Council engineers if I was so minded. In my opinion, it is necessary that suitable standards be put in place to ensure that inexperienced practitioners are given adequate guidance over what they should or shouldn't do.

Some form of assessment/calculation should be necessary in any situation where there is potential impact from or interference with, sources of flooding. In some cases, this might only consist of hand calculations, provided that the situation under consideration was very straightforward, or the analysis so conservative as to ensure that no adverse impact could occur. In other cases, full 2-D modelling may often be warranted. The principal concept here is that the level of assessment undertaken must be commensurate with the complexity of the situation under review. I believe that the Guideline would allow this process to be followed.

To answer the question directly, therefore, some assessment would always be necessary, but the detail and extent of that assessment, including choice of modelling software, is clearly situation-dependent. The level of analysis must be sufficient to ensure that the assumptions inherent in that form of analysis are supportable in real life.

Yours faithfully

[redacted]

Dr Trevor Johnson
Director
for **Cardno**