Flood damage analysis using GIS at Gold Coast City Council

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This paper is a modified version of a paper presented to the NSW Floodplain Management Authorities Conference at Wentworth May 2001 co-authored by Don Carroll and Haydn Betts titled Integrating GIS and Flood Damage Analysis.

Introduction

The Gold Coast City has extensive floodplains, most notably the Nerang River floodplain, which is 90 sq km in area and contains nearly 60, 000 dwellings, 40% of which are flood prone.

Many of the residential areas were filled to the 1:100 year flood level—however, once this level is exceeded many thousands of dwellings become affected by above floor flooding. Therefore, it is critical to Council that no increases in flood levels occur through new floodplain development.

A GIS based Flood Damage model was developed to assist the Council with assessment of the economic benefits of proposed flood mitigation options and secondly to assess proposed floodplain developments. This paper describes the development of the model and how it is used within a GIS environment.

A prerequisite of the model is that it could be run quickly and the results could be integrated with Council's GIS based data. Therefore it was also decided from the outset that MapInfo/Vertical Mapper would be used as the model platform. This facilitated direct access to Council's property database and visual interpretation of results.

The overall philosophical approach was to estimate flood damage for each property and then accumulate property flood damage over a prescribed region. This approach requires that for each property, the floor and garage levels for each dwelling on the property are known.

The dwelling type is also required to be determined i.e. whether it is detached/semi-detached, a town house, multiplex unit etc.

The dwelling type is then used to assign flood damage costs based on the estimated depth of inundation above floor level.

Model inputs

The model requires five basic input components. These are:

- a property database
- a floor level survey database
- a topographic Digital Elevation Model (DEM)
- flood surface DEMs
- stage damage relationships for differing dwelling types.

These components are combined to form a property flood damage database. Once formulated, standard SQL techniques using MapInfo's MapBasic are used to perform statistical analysis by suburb or by electoral division. Each component is discussed, in turn, below.

Property database

A series of 14 property databases were created using information from the Digital Cadastral Data Base (DCDB) and Citipac (Council's property rating database). Each database represents a catchment. Each property entry in the database is geocoded as using the property centroid. (Properties over 1500 square metres are excluded from the analysis as the centroid of the property may not pass through the dwelling).

The location of this centroid is used to 'inspect' flood and topographic surfaces described later in this section. The Citipac database fields contain information on fire, town planning and land use codes. These codes, when combined with lot plan numbers are used to determine the number of ground floor dwellings/units per property and whether the dwellings are part of a single or multi storey complex.

Survey database

This is a MapInfo database containing fields detailing floor, garage and road levels for each surveyed dwelling. It also contains descriptions of the dwelling such as age and building material type. These descriptions are for explicit checking that the survey sample is fairly representative of the whole.

The database is geocoded as points using property centroids.

The database has two purposes:

- to establish the relationship between estimated property level (from topographic DEM) and floor, garage and road levels as surveyed
- to update the flood damage database with surveyed floor, garage and road levels, replacing those levels estimated by statistical relationships.

The database is updated periodically through field survey.

Topographic DEM

This consists of a grid of the X,Y and Z values for the area under investigation. The X and Y values represent the coordinates of a grid point on plan, whereas the Z value represents ground level at that point. Grid location points are equally spaced in the X (east) and Y(north) directions.

For the Gold Coast area fine resolution grids are used—typically a 5m grid is preferred as coarser grids resulted in interpolation errors for properties close to canal estates where sudden changes in land profile sometimes caused misleading results. The grid information is also used to establish a relationship between estimated property levels (Z value at property centroid) and surveyed floor levels.

Flood surface DEMs

These are grid surfaces generated by hydraulic models, for example MIKE21 (DHI), MIKE11 (DHI) or USF (Qld State Govt). The flood surface grid is used to determine the flood level at each property. This is done by point 'inspection' of the flood surface using the property centroid. Mike11 and USF are 1 dimensional models.

The generation of flood surface grids using the results of these models is described by Khan & Betts (2001) in a paper presented at the NSW conference. This method takes the peak flood level at the end and 'mid points' of each hydraulic model cross-section, triangulates them, deletes spurious triangles, and then develops the rectilinear grid using Vertical Mapper (a MapInfo 'plug-in').

Residential stage damage relationships

The residential stage damage relationships were extracted from a Water Studies report titled 'Assessment of Flood Damage across the Nerang River Floodplain' dated 1997 and the March 2001 extension of that study. These reports contain tables of internal, external, structural damages related to flooding depth. Clean-up and financial costs are also included. The latest unit costs include inflation rates and an allowance for the impacts of GST.

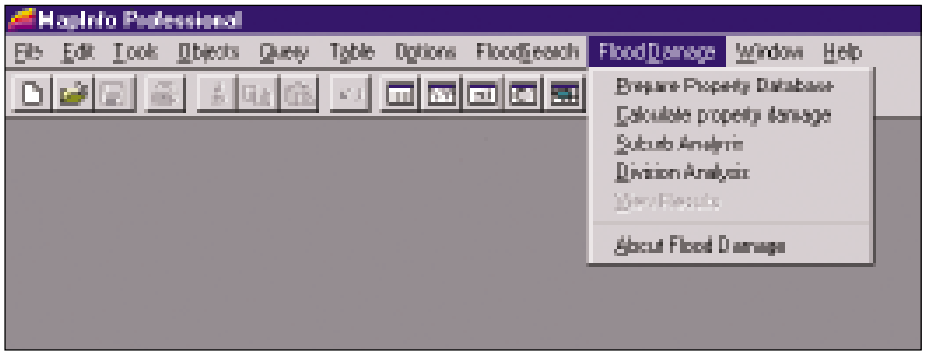

Figure 1: MapInfo flood damage model menu.

Model process

There are 4 basic steps to undertake flood damage analysis. These are:

- prepare the property database
- calculate the property damage on a property by property basis
- analyse the data by suburb or by division
- view the results.

These steps are incorporated into the flood damage MapInfo menu as shown in *Figure 1*.

Broad outlines of each step are shown in *Figure 2 (opposite)* and a brief discussion on each step follows.

Prepare the property database

The purpose of this step is to create the property damage database by defining the area or catchment to be investigated and adding topographic and flood surface levels to each selected property in the database. The property polygon centroid is used to determine these levels. The property database is a subset of the catchment-wide property database.

Calculate property damage

The purpose of this step is to estimate the number of ground floor dwellings per property, and calculate floor and garage levels using pre-determined relationships for each dwelling within each property. Where dwelling survey data are available, the estimated levels are replaced with surveyed levels. Where a dwelling is found affected by flooding, the damage is also calculated.

Once the property, garage and floor levels have been established, the damage statistics can be calculated for each dwelling. These include the number of dwellings per property; whether the dwelling(s) are flooded above property, garage and floor levels; and if so, the calculated dollar flood damage for that property.

Typically damage estimation for a 60,000 property sized database using 7 floods takes approximately 30 minutes to complete using a Pentium 600 machine.

Analyse results

The purpose of this step is to undertake statistical flood damage analysis by suburb or by Council division (electoral boundaries). The analysis involves estimating the number of properties affected in each suburb or division and calculating the total dollar cost by suburb or by division.

The results for each flood surface are stored in a MapInfo table. Each table contains damage statistics for each suburb or division, e.g. number of dwellings flooded above property, garage and floor level, the damage cost per suburb/division etc.

View results

The purpose of this step is to view the results prepared in the previous step. Various degrees of flooding can be viewed through selecting the depth of flooding - as shown in *Figure 3*.

An example of the results is shown in *Figure 4*. Stars indicate potentially affected properties.

Model limitations

In its current form the model has several limitations. These are:

- Unless a property is surveyed, it cannot be said with any confidence that the property will be actually flooded for a given event. This is because the dwelling floor level is derived from a statistical relationship between the estimated topographic level for the property centroid and surveyed floor level. This relationship, while providing reliable average results, is not correct on a property by property basis.
- This model does not calculate commercial or industrial damage. However,

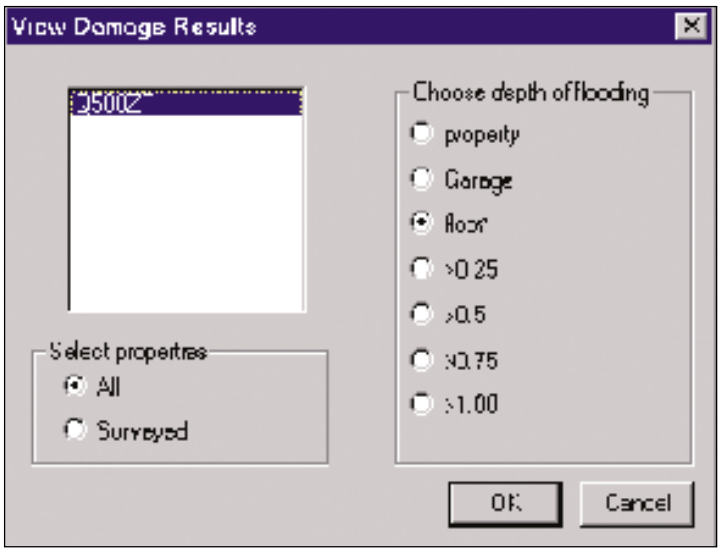

Figure 3: Menu to view results.

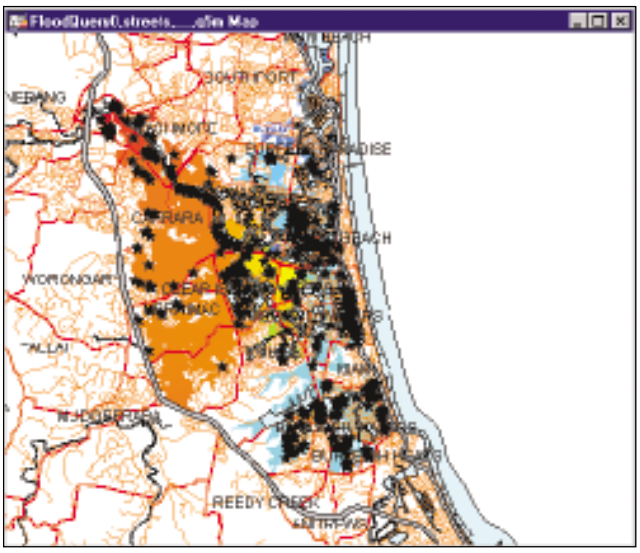

Figure 4: Typical results from flood damage model—note also the flood surface grid.

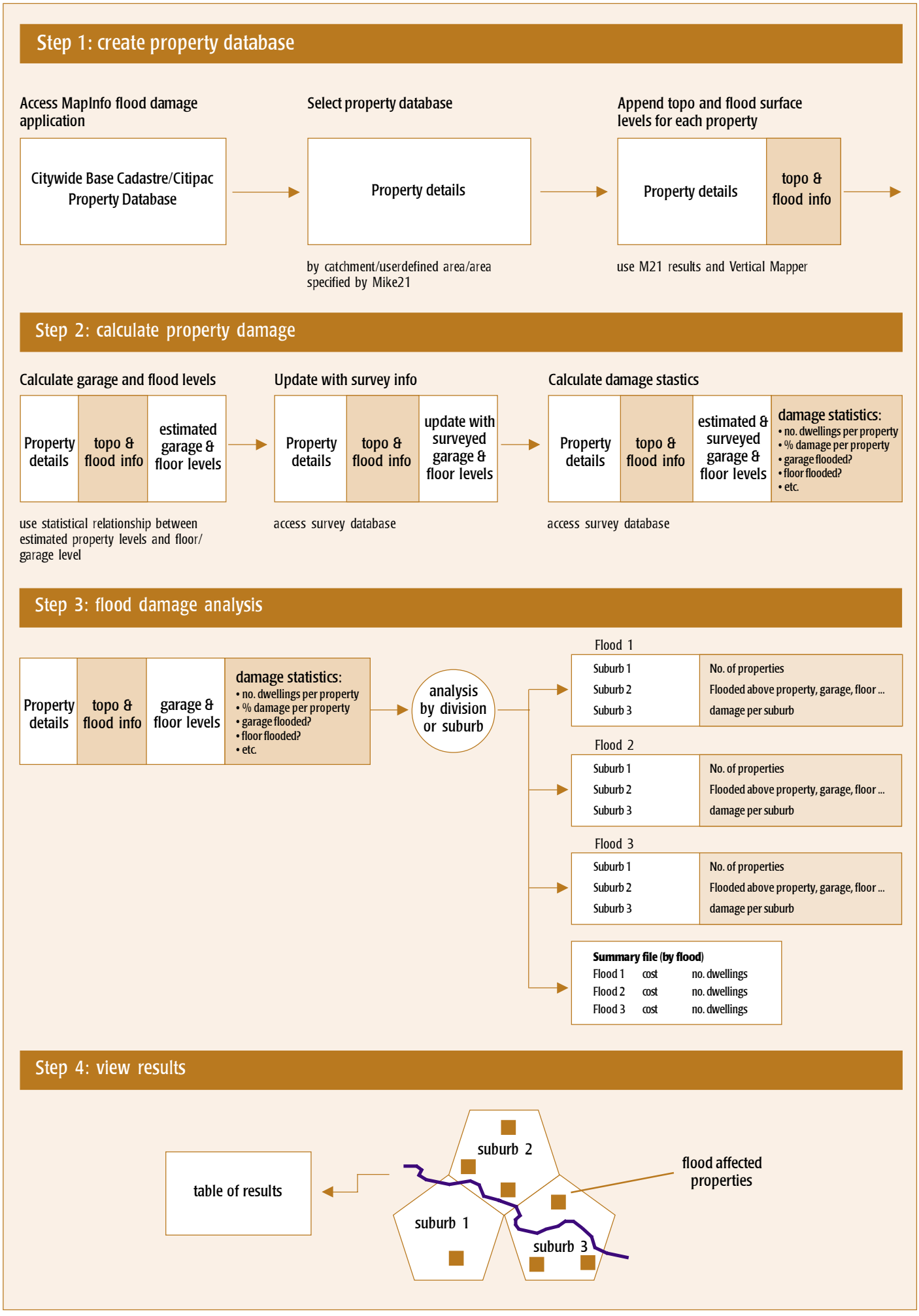

Figure 2: Formation of the flood damage property database.

these can easily be incorporated using dollar damage–square metre relationships predominantly used for commercial and industrial properties.
- The model does not take explicit account of the duration of flooding that a dwelling may experience. This is currently an area of research and has not been widely applied in practical applications throughout Australia.
- Finally, the stage-damage parameters, and parameters that define the relationship between topographic DEM and floor level are 'hardwired' in the model. However, changes are being made to allow the user to define these parameter values. This will be done by creation of a special initialisation file that the model can read and assign parameter values accordingly.

Model testing/calibration

The results of the model were tested against those results prepared by the Water Studies 1997 report 'Flood Damage across the Nerang Floodplain' (Water Studies, 1997).

The Water Studies approach used distributions of flooding depth derived from surveyed properties, and applied this distribution on a suburb by suburb basis to all flood affected dwellings.

The flood damage results of both models were found to be within 20% of each other, after allowance was made for use of differing surveyed dwelling data sets.

Flood damage model use

The flood damage model has now been used several times in different ways.

Development testing

Testing the relative impacts of development by comparing the flood damage statistics pre- and post-development. This not only provides the number of properties/dwellings affected by a particular development but the financial impacts and individual identification of properties that would be disadvantage by the development.

Flood mitigation works

Flood mitigation projects that would reduce the impacts of flooding can be similarly assessed. The results provide the financial benefits of mitigation projects that can be used in benefit-cost studies. Such projects currently being examined include dredging, bridge replacement or modification, weir modification, and dam raising.

Floodplain planning

Council has recently completed a study of the Tallebudgera and Currumbin Creeks in the southern part of the City, conducted under the auspices of the Natural Disasters Risk Management Studies Program. Both creeks are subject to the coincident events of storm surge and flooding and in this study, it was found that storm surge is a significant problem. A series of rainfall and coincident storm surge events were routed through hydrologic and hydraulic models and the flood damage model.

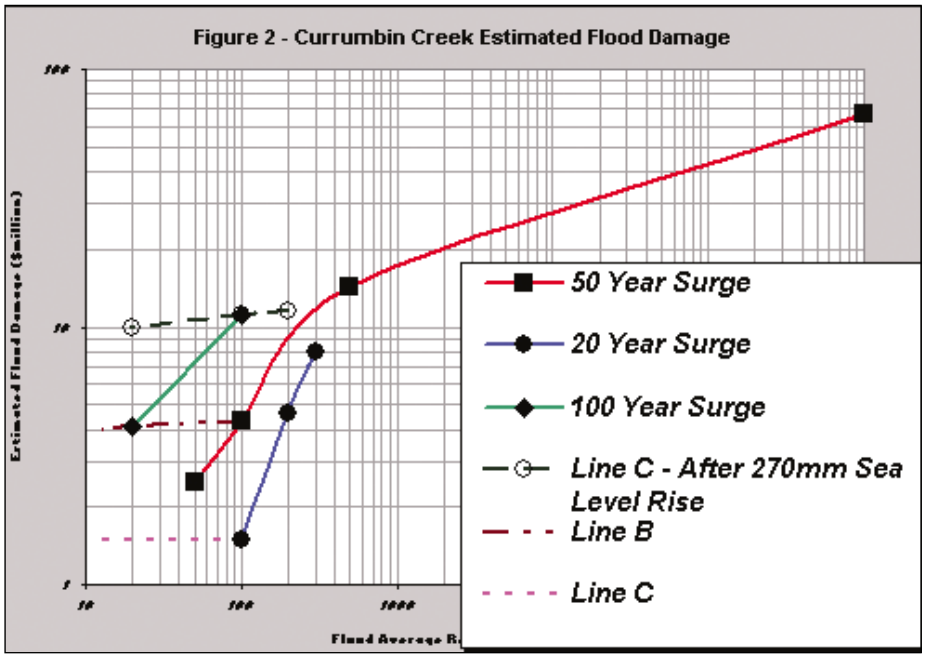

Figure 5: Currumbin Creek—residential property damage

It was postulated that:
- For any given tidal surge, there is a flood of sufficient magnitude to force the saltwater prism from an estuary. A larger surge requires a larger flood. The form of a plot of the envelope of flood and surge probabilities will be different for each riverine system depending on the shape and hydraulic capacities of the waterways and floodplains, as well as the relative locations of the floodplains.
- In fully developed floodplains, flood damage is a coarse indicator that could suggest the interdependence of storm surge and flood magnitude and the shape of the envelope.

Plots of flood damage vs. inundation probability are shown in *Figure 5* (a reprint of Figure 2 in the NSRMSP report – GCCC 2001). A series of dotted lines (A, B & C) have also been drawn on the graph.
- Line B is a line drawn between the 1:100 year surge/1:20 year flood and 1:100 year flood/1:50 year surge points. (This line most closely represents the likely coincidence of flooding and storm surge as now perceived).
- Line C is a repetition of Line B except that an amount of 270 mm has been added to the storm surge levels as an allowance for future sea level rise under 'Greenhouse' climate change conditions.

Note that the damage is for residential property only. The area below Line C and to the left of the 1:100 year flood probability represents the likely future risk to existing development, and provides an inundation envelope below which future development should not be permitted.

Further analysis is required to examine the likely impacts of higher rainfall intensities and storm surge impacts when global warning scenarios are further advanced. (The same conditions are being recommended for Tallebudgera Creek).

Conclusion and future directions

A flood damage model has been developed that integrates the Gold Coast City Council's property and rating databases, flood model results (via grids) and topographic DEMs. The model, while sophisticated in its database access, management and analysis, is very simple at the elemental level i.e. the calculation of flood damage for each property.

The model has been successful because the flooding impact of development proposals and flood mitigation options can now be routinely assessed in dollar terms.

Furthermore model outputs can be viewed visually, so that risk assessors can assess where key damage areas are. The results can be also analysed by electoral division so that elected representatives can get a better sense of flooding problems within their division.

The model when used in combination

with other GIS/Hydrological model routines provides Council the ability to assess the city-wide flood damage impact due to proposed changes in land use/town planning zones.

It is anticipated that as more dwelling floor levels become surveyed, the model will be used in real time to assist Emergency Services personnel prioritise evacuation strategies in the event of the major flood.

At some time in the future it would be desirable for the model to be extended to include commercial properties but that will mean the development of appropriate stage-damage curves.

References

Carroll D. & Betts H. 2001, 'Integrating GIS and Flood Damage Analysis', *NSW Annual Floodplain Management Authorities Conference Papers*, Wentworth, 8–11th May, 2001.

Gold Coast City Council 2001, *Tallebudgera and Currumbin Creeks Flood Risk Management Study- Risk Assessment Report*, Gold Coast City Council, September, 2001.

Khan S. & Betts H, 2001, 'Real Time Flood level forecasting for the Nerang River System using integrated Hydrology, Hydraulic and GIS Models', *NSW Annual Floodplain Management Authorities Conference Papers*, Wentworth, 8–11th May, 2001.

About the Author

Haydn Betts heads the Gold Coast City Council's Flood Strategies Section within the Strategic and Environmental Planning Branch, where he acts as Council's hydraulics expert with respect to hydrology, hydraulic modelling, flooding implications for town planning and flood mitigation projects.

In the last 6 years, Haydn has been involved in several contentious development applications and provided advice in a number of Planning and Environment Court Appeals.

Prior to moving to Gold Coast in January 1996, he was employed by Launceston City Council on a number of flood mitigation projects, was the City's Flood Warning Officer and was Executive Officer for the Tamar River Project Improvement Committee. Haydn has also worked for State Government and in private industry as a consultant.

Haydn is a Fellow of the Institution of Engineers, Australia and is currently undertaking part-time study towards a PhD in floodplain management.

This article has been refereed