CAN YOU BELIEVE THAT MODEL?

A Collaborative Approach to Interpreting Model Results.

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ABSTRACT

As part of the Dunedin City Council's (DCC) 3 Waters Strategy project, 10 Integrated Catchment Management Plans (ICMPs) were developed to support resource consent applications for discharge of stormwater to the marine environment.

Objectives for stormwater management used in The ICMPs are based on those contained in the DCC 3 Waters Strategic Direction Statement (2010-2060); the over-arching document setting the scene for DCC's three waters' management. Issues, options and recommendations from each ICMP are incorporated into a city-wide framework as part of the wider Strategy project.

The development of hydraulic models of the stormwater, water supply, and wastewater systems was an integral part of the scope of works for the 3 Waters Strategy project. The stormwater system modelling relied on a large range of background data, including flow monitoring, tide and rainfall analysis, and climate change assessment.

For DCC, however, the use of reported flooding (customer complaints), anecdotal information, photos, and the knowledge base of DCC staff was essential. The ultimate usefulness of the ICMPs relies on DCC's team understanding the process and believing the outcomes – in this vein, the client/consultant relationship is vital to achieve the necessary collaboration.

This paper outlines the interpretation process followed by the team for the ICMPs, how the model results were reviewed and translated, and how the client/consultant relationship impacted on the outcomes of the project.

KEYWORDS

Integrated Catchment Management, Stormwater Modelling, Model Interpretation

PRESENTER PROFILE

Helen is a Principal Water Resources Engineer with URS New Zealand. For the past 15 years, Helen has worked in both the public and private sector, focusing for the past 10 years on Integrated Catchment Management Planning, predominantly for urban land uses. Over the last four years, Helen's only project has been the Dunedin City Council's 3 Waters Strategy; as the technical principal for stormwater, Helen has been responsible for leading the combined URS/OPUS stormwater team in the delivery of 10 ICMPs, for DCC to use in-house to plan capital works programmes, but also to support consent applications for discharges to the Otago Harbour.

1 INTRODUCTION

The development of hydraulic models for stormwater, water supply and wastewater management purposes provides a set of tools and level of information not previously available to staff at the Dunedin City Council (DCC).

The council's GIS and Hansen Database systems have comprehensive data sets that are used extensively by DCC staff in the field; laptops are a common feature in the maintenance teams' vans. The step from asset data to predictive information offered by hydraulic models provides a new opportunity for DCC staff; capacity, grade, and flow information, not to mention 2-Dimensional flood surfaces will enable staff to confirm areas of risk and identify hydraulic pinchpoints.

Model outputs can be highly valuable, however as we are often told, the usefulness of the information is only as good as the data that goes in (garbage in, garbage out). This paper discusses ways in which model confidence can be improved, therefore increasing the likelihood that the model is used by a wide range of staff.

1.1 BACKGROUND

DCC owns and manages assets valued at $1.6 billion (gross replacement cost), across all three waters (stormwater, water supply and wastewater). Specifically, Dunedin's stormwater network comprises 363 km of pipes and 11 pumping stations.

The 3 Waters Strategic Direction Statement, adopted in 2010, outlines the principles, priorities and planning assumptions that underpin decisions regarding three waters infrastructure planning and service delivery in Dunedin for the next 50 years.

The 3 Waters Strategy Project, running between 2008 and 2011, involved the development of hydraulic models for the City's water supply and wastewater systems (macro level during stage 1 and more detailed for focus areas in stages 2 and 3), and detailed stormwater network models for ten of the city's stormwater catchments. Stage 1 of the project included a pilot ICMP (South Dunedin), with the remaining 9 catchments studied during Stage 2.

The hydrological and hydraulic models of the stormwater catchments have been used to provide information regarding network performance and flood risk, feeding into an Integrated Catchment Management Plan (ICMP) for each of the ten catchments discharging to the marine environment via piped networks.

2 STORMWATER MODEL CONSTRUCTION

2.1 MODELLING APPROACH

InfoWorks CS v10.5 (an MWH Soft Software package) was used to model the stormwater catchments. The software enables the construction of a hydrological, hydraulic and 2-D overland flow model of a catchment. The hydrological model calculates the runoff from various land uses during rainfall, while the hydraulic model routes the calculated runoff through a 1-Dimensional (1-D) representation of the reticulated network. The 2-D component of the model maps the catchment's surface in order to direct any flows leaving the reticulated network via overland flow paths.

2.2 DATA SOURCES AND CONFIDENCE

2.2.1 ASSET DATA – HYDRAULIC MODEL

The hydrological and hydraulic models for all 10 stormwater catchments were constructed using a number of sources of information, the basis of which was DCC's Hansen and GIS asset databases. Additional information was obtained from as-built drawings and reticulation sheets, flow monitoring, manhole inspections, LiDAR (Light Detection and Ranging) data, site visits and operational knowledge. Where no data was available, engineering judgment and interpolation / inference rules were applied.

The data hierarchy used in the construction of the hydraulic stormwater model is as follows, where level 1 is considered most reliable and level 6 least reliable:

Level 1 – Asset survey, monitoring results

Level 2 – Site visits, operational data, as-built plans

Level 3 – LiDAR (cover levels only)

Level 4 – GIS / Hansen

Level 5 – Paper plans / reticulation sheets

Level 6 – Design drawings

Table 1 below outlines the approximate percentages of data that was missing from GIS or Hansen databases, across the ten stormwater catchments modelled during the 3 Waters Strategy project. Further, a number of open channels in the catchments had little or no data relating to channel dimensions or gradients.

Table 1: Percentages of Missing Data for Stormwater Model Catchments

Data Type	Pipe Diameter	Pipe Upstream Invert Level	Pipe Downstream Invert Level
Missing Data	3 %	24 %	20 %

A limited number of manholes had depths measured and configuration confirmed on site, and site walkovers were used to gather approximate sizes for critical open channels. Remaining data was interpolated or assumed to complete the data set.

2.2.2 GROUND AND IMPERVIOUSNESS DATA – HYDROLOGICAL MODEL

All ground level data was obtained from a recent LiDAR survey of the Dunedin area; this was used for both manhole lid levels and the ground model for the 2-D model.

A city-wide study of imperviousness undertook analysis and calculated typical imperviousness levels for each land use type, and this was used as an initial estimate prior to calibration adjustment. Hydrological parameters were based on those developed for the calibrated pilot catchment model (South Dunedin).

2.2.3 FLOW AND RAINFALL MONITORING

Flow monitoring was undertaken at five sites in South Dunedin, and at a single site in each of the nine remaining catchments. While the South Dunedin flow monitoring was for a period of twelve weeks, the remaining monitors were in place for a period of one year; simultaneous rainfall monitoring gave sufficient data to estimate spatial variability of rainstorms across the city.

2.2.4 CUSTOMER COMPLAINTS

DCC have been collecting and collating customer complaints for a number of years. However, the format of complaints information has varied over time, and the usefulness of the information has been limited. Location data has been reasonably accurate (documenting an address or road name); however description of the issue has been variable, and may not accurately describe the issue in each location. This study was able to collate complaints data collected between 2005 and 2010. DCC are currently upgrading their complaints recording system to ensure information gathered in the future is more robust.

2.2.5 DCC KNOWLEDGE

Throughout the project, a number of meetings and site visits were held, with DCC staff in attendance. The idea of these meetings was to obtain as much anecdotal information as possible regarding flood history in the city.

DCC staff provided a number of photographs from historical events, most particularly from a large storm in February 2005. The February 2005 storm event had a short duration, however approximately 27 mm fell in 20 minutes; a return period in excess of 1 in 100 years. This far exceeds the design criteria for a stormwater system; hence flood reports from this event can only be used to validate model results from extreme events.

3 MODEL CALIBRATION AND VALIDATION

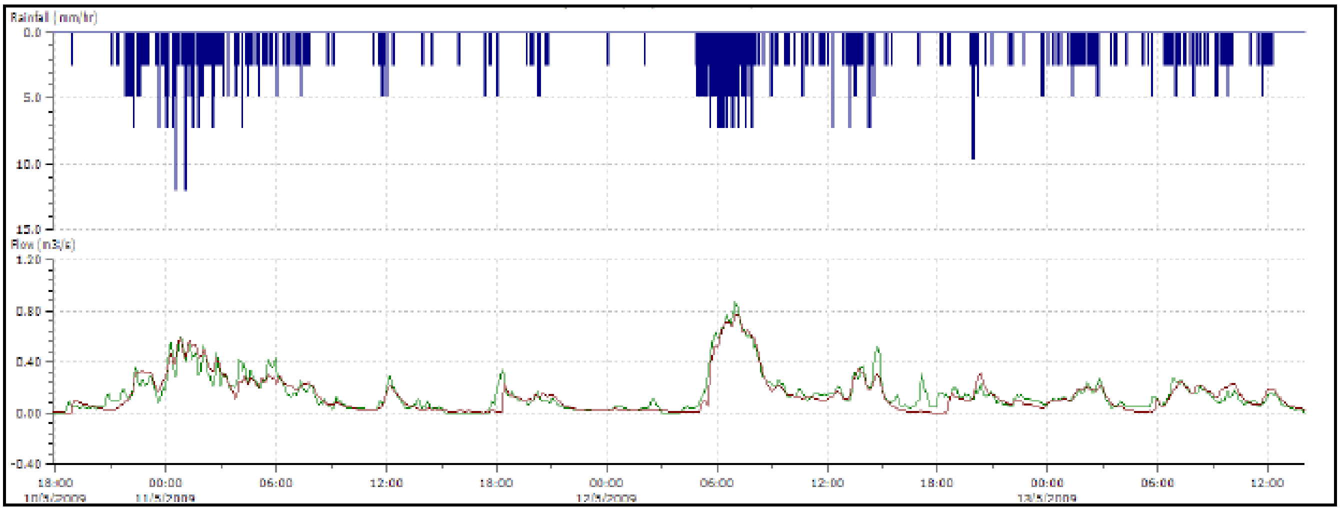
3.1 CALIBRATION

Due to the year's worth of rainfall and flow monitoring data, it was possible to select three suitable events for model calibration that could be used across all catchments. The events ranged in size, with depths of 18, 44 and 88 mm respectively.

As discussed above, the February 2005 event (a very short duration, high intensity event) was used to validate the models using complaints data and photographs taken by DCC staff and the community during the event.

A number of the models achieved a good level of calibration with small recorded events at the flow monitoring point, as shown in Figure 1 (from URS, 2011a). However it is acknowledged that this does not necessarily mean that the upper sections of the model are calibrated, or that large events are accurately replicated.

Figure 1: Kitchener Street Catchment Calibration Plot



3.2 SENSITIVITY ANALYSIS

Sensitivity analysis was undertaken to check the model's response to changes in data such as pipe roughness, catchment response, and imperviousness; none of these factors were found to significantly affect model results. It is acknowledged, however, that limitations in asset data would have a significant effect on model results; the interpolation or estimation of up to 25 % of pipe invert data is likely to have resulted in errors in the model results in specific locations.

3.3 VALIDATION

Use of complaints data for model validation was also subject to some uncertainty; a lack of robustness in collation of complaints data meant that the description of issues (including the extent, depth and exact location of flooding) was not always accurate.

Use of the address and general location information was useful for validating model results, as shown in Figure 2 (from OPUS, 2011). however the different level of detail in reported vs. predicted flooding reduced the level of confidence in this comparison.

Figure 2: Reported Flooding vs. Predicted Flooding

4 MODEL RESULTS

The modelling analysed a number of influences on the system, as follows:

- Two alternative catchment imperviousness figures; one for the current land use, and one for the future, representing the likely maximum imperviousness (because of low growth predictions for Dunedin, often there was little or no difference in imperviousness between current and future scenarios).

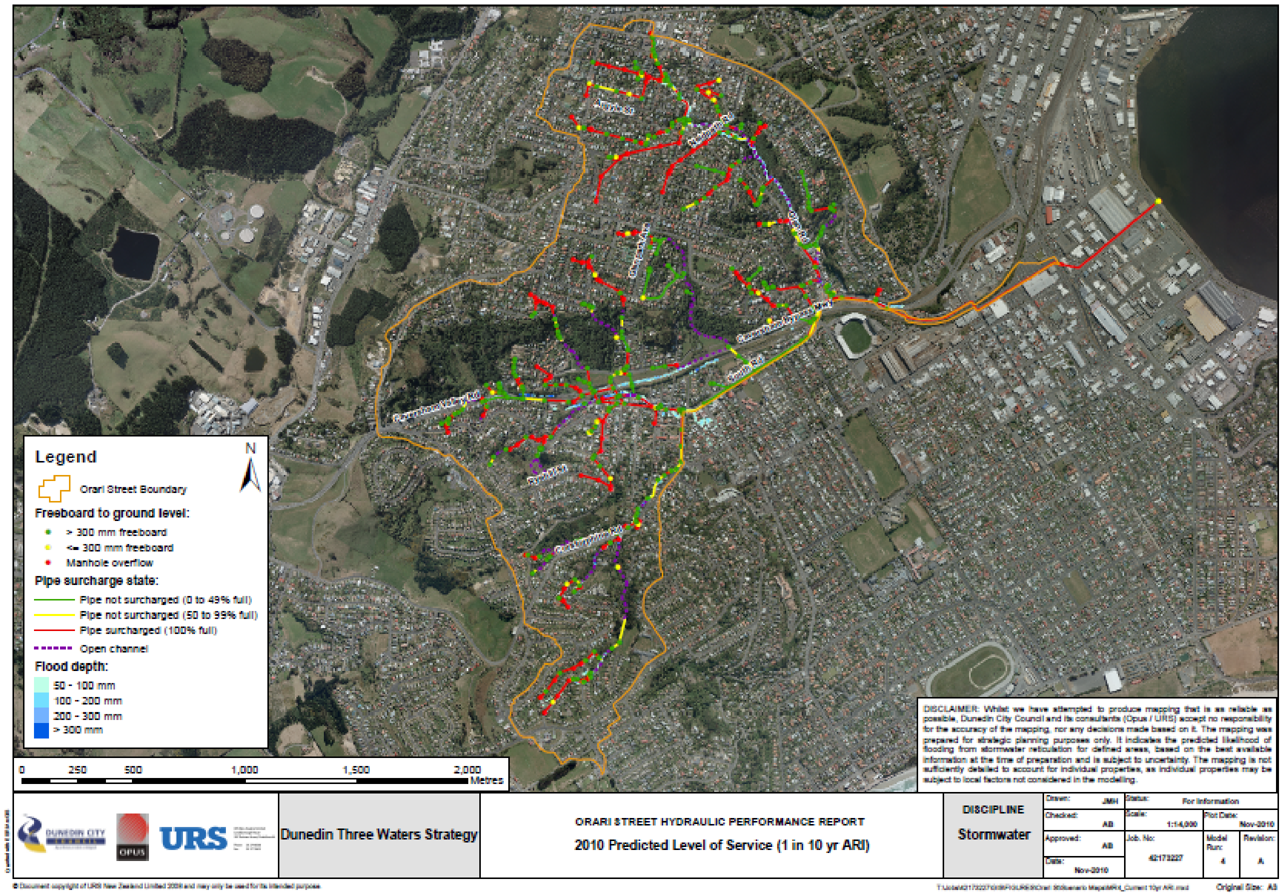
- Seven different high tide situations; current mean high water springs (MHWS); MHWS with 2030 and 2060 medium and extreme climate change scenarios; and two storm surges (1 in 2 yr ARI (average recurrence interval) applied to current, and 1 in 20 year ARI applied to 2060 extreme climate change).

- Five design rainfall events; 1 in 2 yr, 1 in 5 yr, 1 in 10 yr, 1 in 50 yr and 1 in 100 yr ARI events.

- Three climate change scenarios; no climate change, mean climate change, and extreme climate change (for 2031 and 2060 design horizons).

This produced a total of fourteen model runs (note that not all permutations of rainfall and tide combinations were valid), and numerous flood hazard and system surcharge maps. Figure 3 (from URS, 2011b) provides an example of the model outputs from this project. As can be seen, this information can be extremely useful for catchment planning and system analysis, provided there is a good level of confidence in the data.

Figure 3: Model Results; Orari Street Catchment, 1 in 10 yr ARI (current land use)



5 ISSUES WORKSHOPS

Because of the level of detail provided by model outputs, initial model results were met with skepticism from some DCC staff. In order to ensure that models were used to their best potential in the future, it was decided that direct input from DCC's Network Management and Maintenance staff was necessary to further corroborate model results.

Workshops with DCC were held for each of the catchments studied. The purpose of these workshops was to present model results, and provide an opportunity for staff to confirm (or otherwise) predicted flooding in each catchment.

At each workshop, the model itself was used to present issues to the team – this provided an opportunity to educate the team on the capabilities of the model, using one of their own catchments as a working example. The use of long sections, the ability to 'drag and drop' any of the 14 model results onto the screen, and the ability to query any of the inputs proved to be very useful during the discussions.

The workshop also provided an opportunity to discuss design levels of service, and the use of boundary conditions such as mean high water springs. The application of climate change and the usefulness of design storms were also debated; as a result, a more thorough understanding of the model and its limitations was gained by all.

In each catchment, 'issue areas' were highlighted, and each was discussed in turn. Information was sought on the following:

- Confirmation of historic 'problems' in that area – was this an area that maintenance staff had been called to?
- Confirmation of causes of complaints – often the real issue behind an ambiguous public complaint could be identified via the operations team.
- A discussion regarding the frequency and severity of each problem.

In some cases, asset data or network configuration was confirmed via the workshops – using the model to view the area in question provided a much better context for discussion than a plan map.

6 ISSUES PRIORITISATION

The outcome of the workshops was that 'issues' identified by the model could then be grouped into 'confirmed' and 'unconfirmed'. In some catchments, all areas identified as flooding were confirmed by DCC staff, however usually there were differences between the severity predicted, and that experienced. It was agreed, however, that this was likely the result of the model using a 'worst case' combination of tide level and design storm; anecdotal evidence was often based on different storm and tide combinations.

Within the ICMPs, the workshop outcomes enabled issues to be divided into 'priority' issues (those that had been confirmed), and 'further study' issues. While the modelling results that had not been corroborated by the network maintenance and management team were not discarded completely, they were recognised as requiring further study – either via calibration of particular parts of the modelled network, or simply via site visits during rain events to confirm (or otherwise) issues in a particular area.

Table 2 is an example from the Orari Street Catchment ICMP (URS, 2011c). This catchment had a model that was unable to be calibrated (due to difficulties with the flow monitoring site), and the workshop provided highly valuable feedback in terms of areas of confirmed flooding. Confirmed areas were then able to be progressed to options development, whereas the remaining areas have been tabulated, and a recommendation made that these locations are investigated further to confirm the level of flood risk.

By reporting information as shown in Table 2, with more focus on general observations, rather than raw numbers, model results are not taken as 'gospel', however provide sufficient detail to enable further investigation to take place.

*Table 2: **'Unconfirmed'** flood locations; Orari Street Catchment*

Area	Location	Predicted flooding
The Glen Valley	Durham and Lawrence Street	Low to moderate flooding along most of stormwater branch from bottom of Durham Street to main Glen Valley watercourse at 26 Dalry Street.
	Maryhill Terrace to Glenpark Avenue	Low to moderate flooding from 17 Maryhill Terrace along Springhill Park to Glenpark Avenue
	Neidpath Road	Moderate to significant flooding from 104 Glenpark Avenue along 80 and 106 Neidpath Road.
	Ventnor Street and Argyle Street	Low to moderate flooding near the vicinity of 43– 46 Ventnor Street and 52 Argyle Street due to overflow of manholes and undersized pipes
	Aiken Place	Low flooding near the vicinity of 10– 12 Aitken Place due to overflow of manholes due to undersized pipes and low gradients
	Reynolds Street	Low to moderate flooding near the junction of Reynolds Street and Glen Road due to overflow of intake at 82 Glen.
Central: North and West of Caversham Motorway	Renfrew Street	Low to moderate flooding along Renfrew Street and Oakwood Avenue due to manholes overflowing, i.e. undersized pipes.
	Railway corridor near South Road and Caversham Place	Low to moderate flooding near 114 Caversham Valley Road, 378 - 380 – 447 - 498 – 500 and 522 South Road due to overflows from surrounding areas, surcharging manholes and intake restrictions
Southern: South of South Road	Corstorphine Road	Low to moderate flooding at 10 and 29 Corstorphine Road, due to transition from open to piped watercourse. Becomes deep flooding during a 1 in 50 yr rainfall event, flowing overland into the South Dunedin catchment.

CONCLUSIONS

In conclusion, the development of hydrological and hydraulic models for a number of stormwater catchments in the Dunedin City area provides an opportunity for DCC to access a significant amount of information about the capacity and likely performance of their network under a number of different scenarios.

Model calibration, sensitivity analysis and validation with customer complaints amongst others, served to improve confidence in the model outputs. However, it was through the use of 'issues workshops' that the confidence in (and hence likely future use of) the models was greatly enhanced. These workshops enabled DCC Network Management and Maintenance staff to undertake the following:

- Increased knowledge in the model outputs and uses;
- Discussion of model limitations and assumptions;
- Critique of model results;
- Discussion of key issues and likely causes;
- Brainstorming of options.

The outcomes of the meetings have resulted in the ICMPs for each catchment achieving a greater level of confidence in outputs and recommendations, where model results are not just relied on, but require confirmation and / or further investigation.

ACKNOWLEDGEMENTS

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