

FLOOD INTEGRATED DECISION SUPPORT SYSTEM FOR MELBOURNE

Abstract

Melbourne Water (formerly the Melbourne and Metropolitan Boards of Works (MMBW)) is the statutory drainage authority for metropolitan Melbourne. As part of this function, the business collects real-time water resource data, performs floodplain mapping and modelling, maintains waterways, and develops both structural flood mitigating works and non-structural flood management options.

MMBW became involved in flood forecasting and warning following a severe riverine flood event in May 1974 (see Figure 1). In September 1975 the MMWB began collection real-time data collection of water level and rainfall, which enabled flood forecasting, flood warning and flood intelligence such as flood maps.

Since 1975, MMBW and then Melbourne Water (MW) have made many improvements to its flood forecasting and warning capability. The most recent is the creation of a Flood Integrated Decision Support System (FIDSS) for the nine river systems that MW issues flood warnings, and ultimately will include many of the small catchments which are susceptible to flash flooding.

FIDSS is being developed to integrate MW's telemetry systems, URBS hydrologic models, and flood maps with the latest Nowcast Products from the Bureau of Meteorology (BoM). The benefits of this cutting edge system will be real-time flood predictions that will enable MW to raise faster, more precise flood warnings via the BoM and FloodZoom, which will allow the State Emergency Services and flood prone residents to take early action to mitigate the impacts of flooding.

In October 2014 the FIDSS Prototype was completed and the entire system will be operational in the first half 2015. The presentation and paper will describe the evolution this state of the art total flood warning system.

History - why is Melbourne Water involved in flood forecasting?

In 1970 the Supervising Engineer for Planning and Investigation of the Main Drainage Division of the then Melbourne and Metropolitan Board of Works (MMBW) recommended that new developments in telemetered data recording should be investigated for use in real-time flood warning. The recommendation was approved in principle but it took a major flood in 1974 to provide the necessary impetus for the project to be implemented. The winter flood of May 1974 was a major flood on the Maribyrnong and Lower Yarra River catchments following 120 mm of rainfall over about three days, commencing on 13 May (Figure 1). The event caused the flooding of over 500 properties and several million dollars damage. Following the event, the then Harmer Liberal Government requested MMBW as the responsible drainage authority to - do something! The State Government directed the MMBW to implement an automated flood warning system as an immediate measure. This responsibility passed to Melbourne Water (MW) following the reorganisation of MMBW.

The primary aim of the flood warning system was to gather data to enable flood predictions to be made in sufficient time to:

- Prevent loss of life and reduce risk to the community and to;

- Enable residents to relocate possessions and other items such as motor vehicles away from the area liable to flood. In this way, damage costs would be minimised and the socio-economic stress for the people on the floodplain would be lowered.



Figure 1: Flooding in the Maribyrnong in 1974

The Drainage Hydrology System

In September 1975 the Drainage Hydrology System (DHS) became operational. It ran on a DEC Digital PDP 11/40 computer in conjunction with the Drainage Telemetry Network (DTN), initially comprising 15 remote telemetered rainfall and river level gauges, using Telecom dedicated leased line telephone communications established exclusively for flood warning requirements and providing data every six minutes

At the time, the DHS was a state of the art data collection, monitoring and flood warning system development with cutting edge solutions such as real time data collection, graphical visualization of hydrographs, real time flood forecasting and text report flood inundation information.

When rainfall or stream levels and flows exceeded a threshold, alarms were activated by the computer. Operations room staff would then inform the Senior Flood Warning staff of potential flooding issues.

The DHS's primary aim was to gather sufficient data to enable accurate flood predictions to be made and timely warnings to be disseminated on the larger waterways in Melbourne. The object being to allow sufficient time to prevent loss of life, reduce risk and loss of valuables for the community.

The DTN grew steadily from the original 15 sites installed as Stage 1, in 1975, with another 3 stages over the coming years.

With the advancement in technology MMBW moved from the PDP 11/40 to a VAX/VMS cluster of mainframe computers. A suite of drainage tools were then developed to run on the computer the VAX/VMS computers. These were called the Drainage Application Suite. A few are described below.

A program called Radar was also developed to display rainfall across the catchments. The program interpolated between the rain gauges to show average catchment rainfall totals. This was a very useful tool as operators could quickly see where rainfall was occurring and how much was falling.

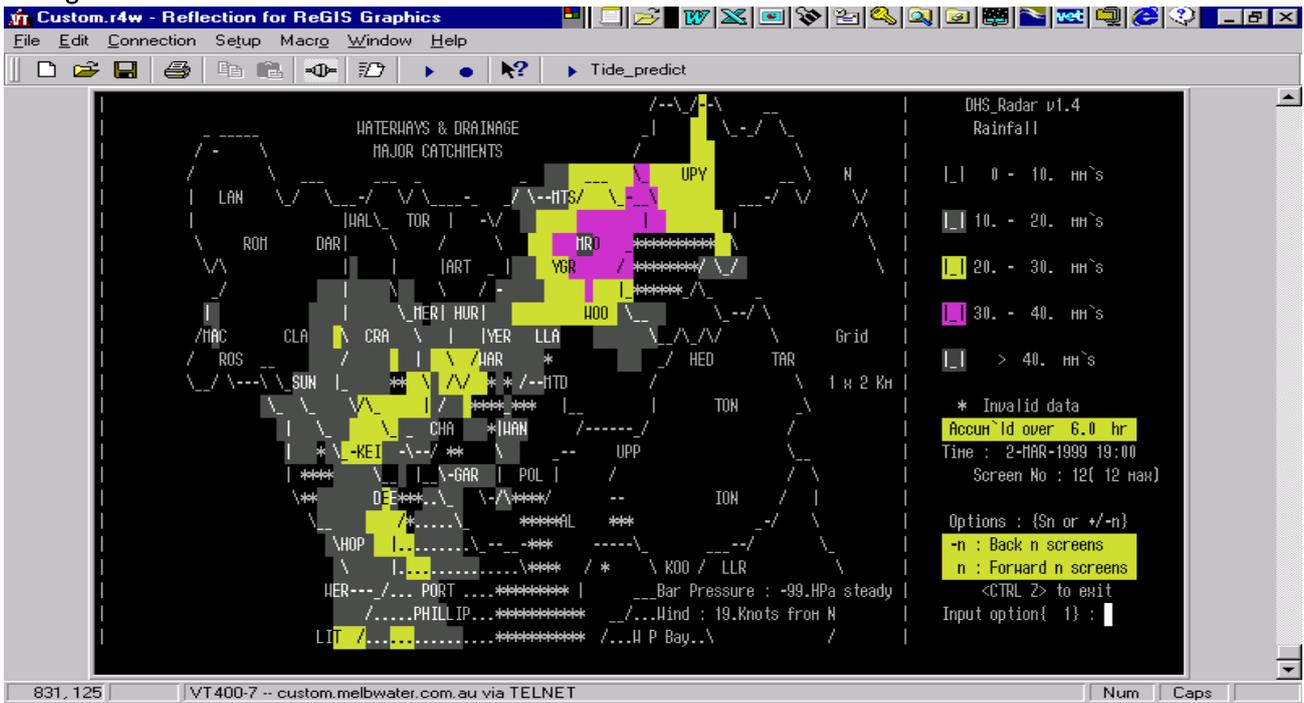


Figure 2 – Radar

There were several other DHS programs within the system, which provided rainfall reports, catchment summary reports and other outputs; too many to mention. Some utility programs were also developed. An example is the Flood Inundation Program (FIP) which calculated flood levels for specific residential addresses and provided the water level for the property and the floor (Figure 3). Having access to good survey data for specific flood prone areas enabled this tool to be a very effective means of information to flood responders, especially State Emergency Services (SES).

FIP OUTPUT

15/08/2003 14:49.59
DHS FIP Version 1.0

M E L B O U R N E W A T E R

Page: 1

Design Flow (cumecs) = 870
Design Tide Level (m Chart Datum) = 1.00
Floor Level Difference included (mm) = 300
M E L B O U R N E W A T E R
DHS FIP Version 1.0

ADDRESS	CAL. FLOOD LEVEL (m AHD)	GROUND LEVEL (m AHD)	FLOOR LEVEL (m AHD)	DEPTH ABOVE GROUND (m)	DEPTH ABOVE FLOOR (m)	
1 CHIFLEY DR	4.29	2.50	3.22	1.79	1.07	** R2 T1
3 CHIFLEY DR	4.30	2.45	3.23	1.85	1.07	** R2BC1
5 CHIFLEY DR	4.31	2.40	3.30	1.91	1.01	** R2 T1
7 CHIFLEY DR	4.32	2.35	3.36	1.97	0.96	** R2BV1
7A CHIFLEY DR	4.33	2.30	3.34	2.03	0.99	** R2 T1 (also No.9 on rate info)
13A CHIFLEY DR	4.37	1.85	3.19	2.52	1.18	** R2BV1 (also No.15A on rate info)
17 CHIFLEY DR	4.39	1.85	2.70	2.54	1.69	** R4BV1 Lower STOREY
19 CHIFLEY DR	4.39	1.85	3.20	2.54	1.19	** R2BV1
21 CHIFLEY DR	4.40	1.80	2.76	2.60	1.64	** R4 T1 Lower STOREY & GARAGE
23 CHIFLEY DR	4.41	1.80	3.18	2.61	1.23	** R2 T1
27 CHIFLEY DR	4.42	1.85	3.16	2.57	1.26	** R3 T1
29 CHIFLEY DR	4.43	1.85	3.11	2.58	1.32	** R3 T1
31 CHIFLEY DR	4.44	1.90	3.15	2.54	1.29	** R3BV1 Lower STOREY
33 CHIFLEY DR	4.45	1.90	3.12	2.55	1.33	** R3 T1
35 CHIFLEY DR	4.45	2.40	2.45	2.05	2.00	V G11 Shed only (MMBW)
83 CHIFLEY DR	4.63	2.30	2.91	2.33	1.72	** R BV7 GARAGE only (No.90 Esplanade)

Page 1

Figure 3 – Flood Inundation Program

In 1988 a very unique development proceeded and was completed in 1989. RTRORB or real-time RORB was developed based on the RORB runoff routing software which was first developed in 1975 (then called RORT). RTRORB was developed in-house by MW engineers to perform in real-time enabling flood forecasting based on observed rainfall and flows. Figure 4 shows an example of the output of RTRORB.

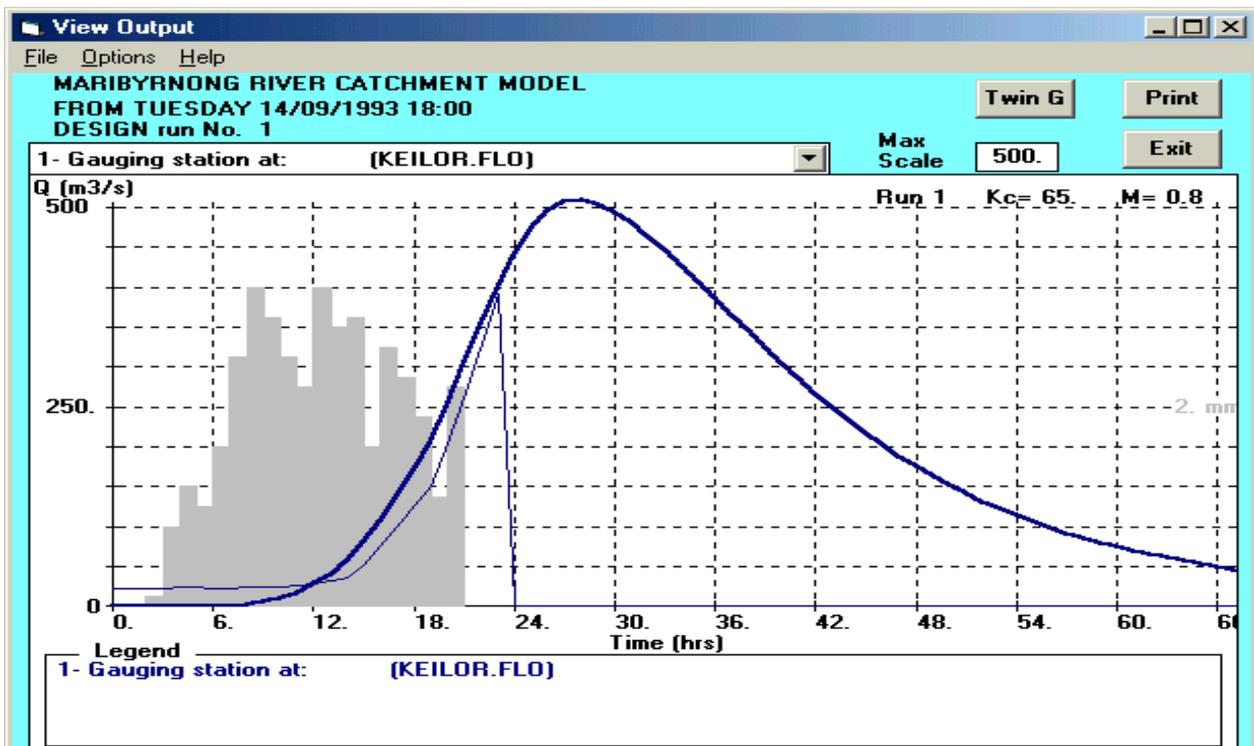


Figure 4 – RTRORB plot

The program extracted real-time data (rainfall and river level/flow) from the DHS database and prepared a data file that could be used with the RORB model to predict flood hydrograph at a specified point on the stream of interest.

As a result of the DHS development, quantitative flood warning services were developed and established for the larger waterways in Melbourne such as the Maribyrnong and Yarra River catchments and for several other minor waterways.

RTRORB was replaced by the flood forecasting modelling software called Unified River Basin Simulator (URBS) in 2006, which is still in use today.

Flood Forecasting Arrangements

The Victorian State Disaster Response Plan (DISPLAN) now called Emergency Management Manual Victoria (EMMV) outlined that the MMBW had an obligation to “The Maintenance of an organisation which, when flooding from natural causes is possible, monitor the Board’s telemetry systems and provide advice to the Bureau of Meteorology”.

The current EMMV requires MW to:

- Continue to develop the flood monitoring system for our Waterway Management District.
- Provide flood predictions to the Bureau of Meteorology for Melbourne’s water courses for which flood warning systems have been developed.

Although the BoM is the Authority responsible for issuing flood warnings to the public, the MMBW and then MW had all of the necessary instrumentation, systems and expertise for providing flood forecasting in its area of operating jurisdiction.

In 1988 flood warning advice was provided by the MMBW officer in charge over the phone to the BoM, and also as deemed necessary to the SES, some councils and Victoria Police.

Although MW still continue to have discussions with the BoM flood warning staff prior to potential floods, a lot more automation of systems has been developed. MW flood forecasts are translated in to flood warning templates and emailed to the BoM. The warnings have meteorological and SES flood safety information added before they are sent out to SES, Local Government and media.

Flood Response

Flood Alert manuals were developed in 1983 and revised in 1988 to assist flood warning staff to use the systems and follow the agreed processes for managing flood events. These comprehensive manuals listed all of the steps that needed to be followed; they included flood intelligence for each forecasting catchment, phone and fax numbers and hard copies of flood maps where these were available (Figure 6 below).

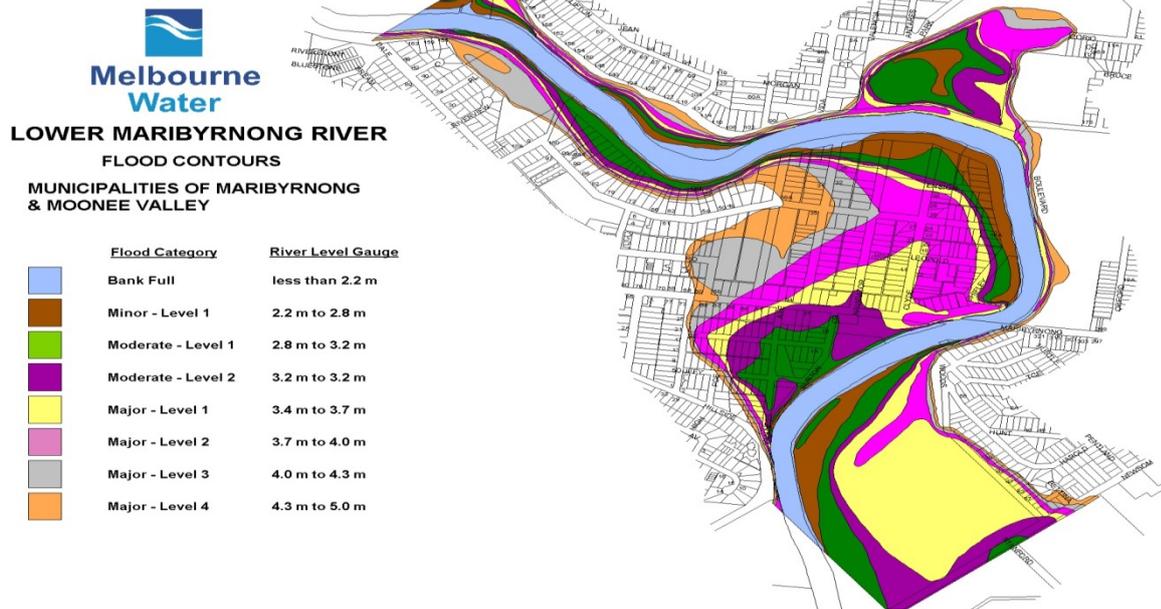


Figure 6 – Maribyrnong Floodplain flood class levels

With good survey data and a very good history of flooding on the Maribyrnong floodplain, a flood marker was established showing the previous years of flooding and their respective flood levels (Figure 7)



Figure 7 – Historic Flood Pole

The levels were related back to each property on the floodplain, enabling resident specific flood plans and awareness for each property owner of their flood risk. The Flood Preparedness of the Maribyrnong Township is acknowledged as being one of the best examples anywhere in Australia.

More recently a Flood Warning Manual (FWM) was developed electronically as an html document containing all information required by the flood forecasting team.

Floodplain Mapping

In the late 1990's to early 2000's MW undertook a huge project to flood map the urban areas of Melbourne. The mapping project determined flood affected properties in Melbourne where urbanisation had occurred prior to any planning controls. Flood maps were mainly created for the 1:100 year flood extent, and this data was then transferred to MapInfo GIS where it is still frequently used today. From this, Special Building Overlays (SBO's) were developed to assist with assessing and planning for flood remediation projects, section 32 property statements and other requirements.

Flood Warning Service

At MW the flood warning operations involves three separate levels of activity:

(a) Alert Phase

The Alert Phase involves the general awareness of catchment conditions from regular monitoring of system summary reports. Contact is made with the Bureau of Meteorology to seek detailed weather forecasts if potential flood conditions are identified. Pre-set rainfall, flow and fault alarms, tidal and storm surge alarms, when triggered, are relayed directly to the Flood Warning team by Melbourne Water's Operations Room at Brooklyn or to South East Water during after-hours.

Pre-event planning may occur to ensure resourcing is available to respond to the event. Recent changes have seen the inclusion of a Flood Watch to this phase. This is prepared for Melbourne by the BoM in consultation with MW.

(b) Prediction Phase

The Prediction Phase mobilises staff to begin full-scale monitoring. Predictions are made for the maximum flood level, timing of the flood, and where available, the number and location of individual properties inundated. These predictions are regularly updated as more information becomes available.

During this phase the duty officer regularly contacts the BoM and SES, keeping them informed of possible flooding and obtaining updated weather forecasts.

(c) Warning Phase

Once the magnitude and timing of a flood has been predicted, the following procedures are followed:

- MW prepares and issues a flood warning to the BoM. The BoM and MW agree on the wording of the warning before issue. A standard template was recently developed by the BoM which MW uses to prepare and send for issuing to SES.

- The SES is advised of the flood predictions in areas likely to be inundated and residents in these areas are notified.
- The flood is continuously monitored and the BOM and SES kept informed of flood progress and any changes in information.
- MW's Flood Response Plan (FRP) may be activated. MW has developed a FRP to manage the flood event. This is a comprehensive document that guides the flood incident response team through all phases of the flood event, including details of incident rooms, processes, resource contact details and other contingency information.

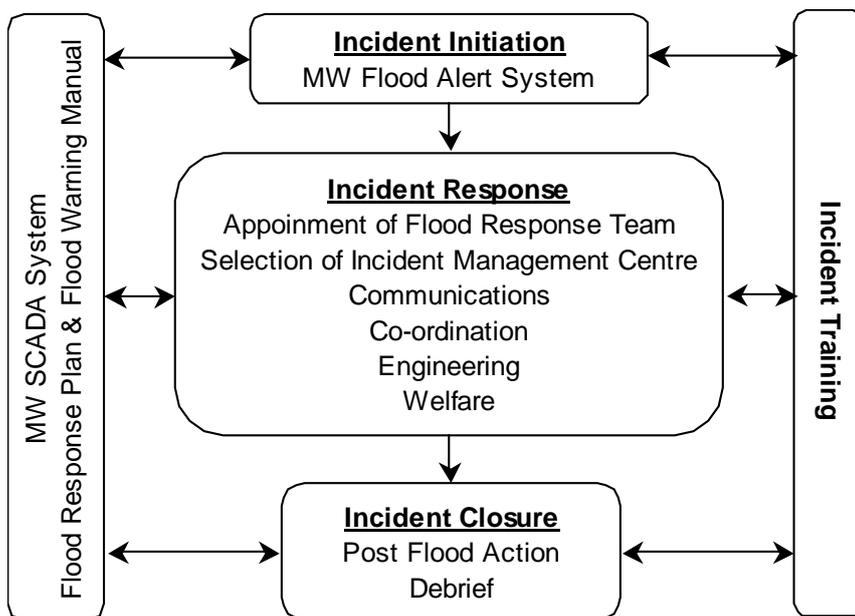


Figure 8 – Flood Response Process

Flood Education

The community on Maribyrnong River floodplain have been involved in flood education and awareness for many years. In more recent times SES education and awareness called FloodSafe and StormSafe has been released to the community.

In 2009 MW commenced a partnership with SES to assist development of Flood Management Plans and Flood Emergency Plans, and expansion of community education and awareness to flood affected areas. The partnership has recently been extended until 2019.

System Expansion and Changes

In 1987-88 the former Dandenong Valley Authority (DVA), also commenced development of a real-time telemetry and flood warning system using Hydsys (now Hydstra). This system developed over about 6 years. In 1995 this system was replaced with Event Reporting Radio Telemetry System (ERRTS) and Prophet (data management software).

MW was formed during the mid-1990's merging the MMBW, DVA and some other water authorities. As part of the merger the hydrometric-flood warning system operated by the DVA was connected to the DHS making it a substantial system, with some 250 monitoring locations.

In the late 1990's to early 2000's most of the remote telemetry devices were upgraded to ERRTS devices. The project was undertaken to reduce the high operational costs, particularly associated with the dedicated Telstra land lines, and to improve safety by eliminating the need for devices using high purity nitrogen at the gauges. The \$1M capital outlay was repaid in less than two years.

The DTN remained in place for about 25 years before the operating environment was replaced in 2000 with the Master Open System Architecture and Control (MOSAIC) SCADA system.

Flood Integrated Decision Support System Dream

A review of the DHS in the mid 2000's found that MW had considerable high quality data, floodplain mapping and modelling applications, yet this rich information was not integrated, and during a flood incident response three or more separate systems were needed to be accessed.

At this time research into systems which provided an integrated system for flood forecasting, warning and management of flood mapping commenced. The research project commenced in the middle of Melbourne's worst drought and it was difficult to justify funding a major upgrade to the flood warning service.

In February 2011 one of the widest spread flood events in Melbourne history occurred as the remnants of cyclone Yasi travelled down from Queensland (Figure 8). This event certainly signified the end of the drought, if it had not already broken. It also prompted a project to enable integration of disparate systems to enable better management of flood events.

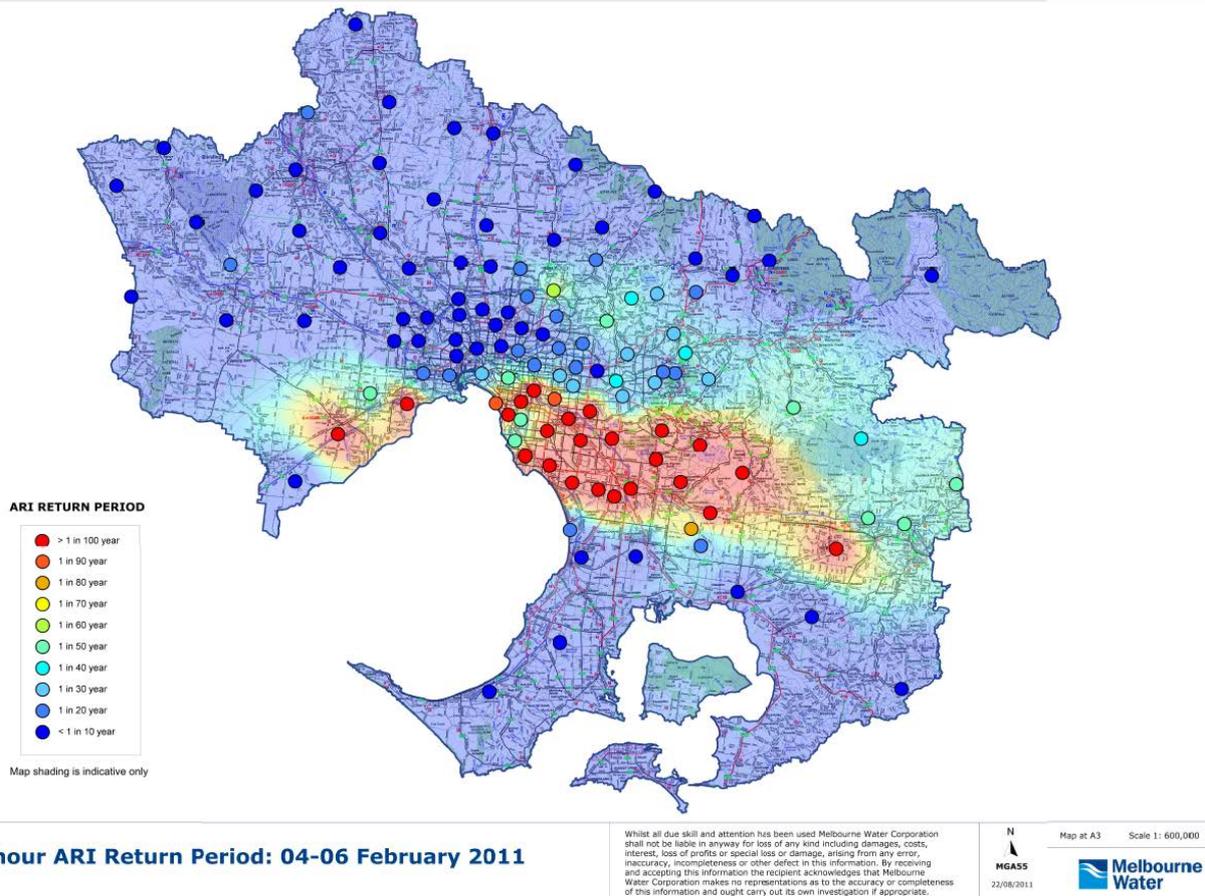


Figure 9 - Rainfall map

In 2014 MW commenced a tender process for an off-shelf solution which could be configured to integrate flood forecasting, flood models and flood maps. The Deltares Flood Early Warning System (FEWS) was selected as the best solution for MW's needs.

FIDSS Overview

Complete total flood warning system

FIDSS is at the heart of MW's Total Flood Warning System (TFWS); being an integrated decision support system, it enables all the components of a TFWS to operate.

The Australian Emergency Management's Flood Warning Manual 21, 2009 (the Manual) describes a TFWS as a system made up of six of interdependent and linked components, that to be fully effective must be present and operating appropriately. The components are shown in Figure 9.

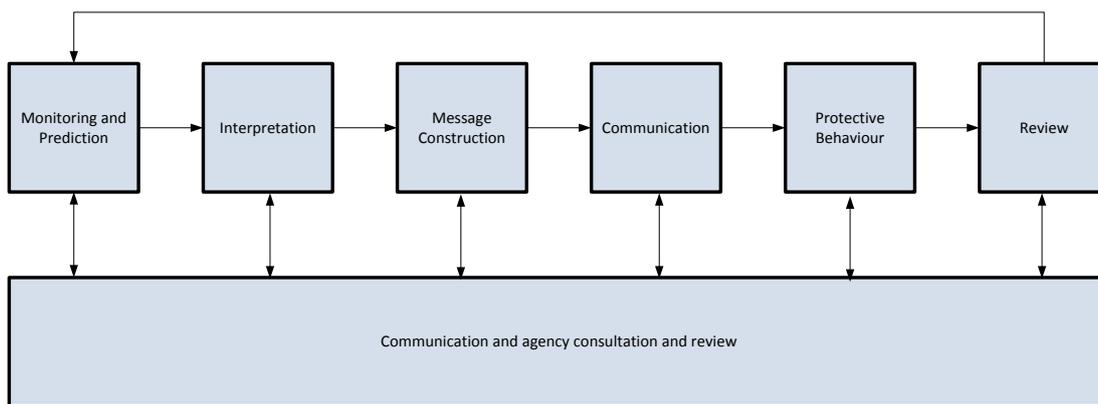


Figure 10 Components of a TFWS (based on Australian Emergency Management’s Flood Warning Manual 21, 2009)

These six components are defined in the Manual is and are show in in Table 1 below, together with how they are achieved as part of the FIDSS project.

Table 1: Flood Warning Components in FIDSS

Flood Warning Manual 21 Description	How the component is realised through FIDSS
Monitoring and prediction: detecting environmental conditions that lead to flooding, and predicting river levels during the flood	The FIDSS system incorporates key Bureau of Meteorology weather prediction products as well as all MW’s rainfall and river level gauge data. These are reviewed in FIDSS and warnings generated if environmental conditions indicate future flooding.
Interpretation: identifying in advance the impacts of the predicted flood levels on communities at risk	FIDSS incorporates tailored flood extent maps for river gauge heights This gives forecasters access to extents of flooding for given predications of flows and levels. These flood extents have been used by MW and other agencies to develop community flood preparedness information and advice.
Message construction: devising the content of the message which will warn people of impending flooding	MW does not issue warnings directly to the public, this is the responsibility of the BoM. MW does issue information to the BoM to enable warnings to be issued to the public and FIDSS will also provide information to the Department of Environment, Land, Water and Planning’s (DELWP’s) FloodZoom initiative which will give a wide range of agencies and particularly the SES access to reliable information to activate various management activities such as evacuations or road closures
Communication: disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood	The FIDSS system has been built to enable effective communication with the key agencies BoM and DELWP.

Flood Warning Manual 21 Description	How the component is realised through FIDSS
Protective behaviour: generating appropriate and timely actions and behaviours from the agencies involved and from the threatened community	MW and the key agencies have worked together to building appropriate plans based on given levels of flooding (minor, moderate, major) for the catchments for which MW are responsible, and to support individuals in flood prone areas to prepare individual and community flood plans.
Review: examining the various aspects of the system with a view to improving its performance	The entire portion of the review process cannot be incorporated into a software application. However FIDSS enables past events to be replayed to assess if the right warnings were issued at the right time based on the best available data, and to determine the effectiveness of the underlying predictive flow models, compared to actual results.

For a flood warning system to work effectively, these components must all be present and they must be integrated rather than operating in isolation from each other.

Incorporation of best available information

The FIDSS system has been configured to consume real time data from a variety of sources. Having the latest information is vital for the prompt warning of flash floods where even a few minutes notice can mean a substantial reduction in the consequences of flooding.

The latest information also enables the best hydrological modelling and incorporation of available flood mapping products. In the future FIDSS could involve real time flood modelling based on a FEWS-TUFLOW adapter that has recently been developed.

FIDSS Communications

Flood Warning is only useful if the tool enables effective communication.

FIDSS is designed to be able to communicate with the key agencies BoM who issue public flood warnings and the Department of Environment, Land Water and Planning (DELWP's) FloodZoom system which will issue warnings to Victorian government agencies.

MW does not issue riverine warnings to the public however MW attracts a lot of public interest during major storms. There are further opportunities to develop mobile phone applications for crowd sourcing information, flash flood warning, improving flood investigations and web based services and information such as online flood maps. MW's website may receive 50,000 hits a day during or after a storm event.

In developed areas of Melbourne where structural solutions are very costly and may take many years to deliver, or may not be feasible, FIDSS can assist residents through provision of timely information to direct to the stakeholders to reduce flood impacts.

FIDSS will enable MW will supply BoM textual warnings as they have for many years, the quality and timeliness of these messages will be enhanced by the integration of a variety of data sources and the addition of new products such as Nowcast data that are incorporated into the URBS hydrological modelling.

The data released to FloodZoom will include references to libraries of shared flood extents for the rivers which MW's has responsibility for Flood Warning, together with snap shot graphical information on predicted rainfall in each catchment.

FIDSS can also provide MW's internal contractors with reports on predicted and actual rainfall totals and river flows to assist in programming and scheduling of works.

How FIDSS works

The FIDSS system has been created on Delft-FEWS, which is an open data handling platform that was initially developed as a hydrological forecasting and warning system in Netherlands. The Delft-FEWS application was developed at Deltares, an independent Dutch-based institute for applied research in the field of water, subsurface and infrastructure.

Delft-FEWS is a sophisticated collection of modules designed for building hydrological forecasting systems and offers many options for the user to interact with the system. For a modern operational (forecasting) system this interaction is crucial.

The FIDSS system uses many of the modules to deliver services to the flood forecasters at MW.

Configuration and customisation

The main focus of this section of the paper is on the configuration and customisation of Delft-FEWS to create the FIDSS solution.

The development of FIDSS was contracted to BMT WBM and its partner Deltares. However the realisation of FIDSS required the input from a wide range of stakeholders including many departments inside MW, and a number of MW outsourced service providers, contractors and vendors, and most importantly the dedicated future system users. FIDSS also relies on the flood mapping developed by consultants over the last 20 years. FIDSS has also involved interaction with its customers most notably DELWP and BoM.

The FIDSS solution has been created on a number of MW servers in various environments. The server set up is critical for the success of the project and the consumption of various external data sources to enable the critical integration aspects of FIDSS. This paper does not focus on the software or hardware architecture that supports the function of FIDSS, much of this is unique to MW overarching IT Environment.

The development of solution was in two phases:

- Design and prototyping; and
- Implementation and testing.

The design and prototyping was an interactive development of the functional and business requirements of MW, resulting in a design document which defined how many of the aspects of FIDSS would be built and many of these features were incorporated into the prototypes. The first phase of the project was delivered in a series of sprints, where by every few weeks an updated product with increased functionality was demonstrated for one catchment Kororoit Creek.

The second phase continued to develop the prototype into a fully functional model and then expanded into building out similar configurations for MW's other watercourses.

Extent of the Flood Forecasting

FIDSS focuses on the catchments that MW has Flood Forecasting responsibility for these are:

- Bunyip
- Dandenong
- Kororoit
- Maribyrnong
- Werribee
- Yarra (and the main Yarra tributaries)

FIDSS incorporates the flood extent mapping that have been created over years for these watercourses. MW's more advanced 2D flood models have been reworked to provide improved flood intelligence that could be integrated into FIDSS.

In addition to these catchments MW is also developing FIDSS to include a number of catchments that are prone to flash flooding, including Gardiners Creek and Elster Creek.

MW is responsible for over 250 retarding basins across the metropolitan area and the first version of FIDSS is trialling the incorporation of a critical retarding basin and its dam break effects, as well as an early detection system at the site to detect potential outflow blockages.

FIDSS will also concentrate on 20 areas of interest. These areas are listed below and shown in Figure 11.



Figure 11 Melbourne Water Areas of Interest

The preliminary areas of interest are:

1. Dandenong Ck d/s of Police Road RB
2. Diamond Ck Hurstbridge to Yarra River
3. Deep Creek at Darraweit Guim
4. Deep Creek at Bulla
5. Maribyrnong River Keilor Gauge to Footscray Road
6. Jacksons Creek Rosslynne Reservoir to Calder Highw
7. Merri Creek Bell St to Yarra River
8. Plenty River Greensborough Gauge to Yarra River
9. Lerderderg River u/s of Goodman Creek
10. Werribee River at Bacchus Marsh
11. Werribee River at Ballan
12. Werribee River at Cottrell St Ford
13. Watts River at Healesville
14. Yarra River at Yarra Glen
15. Yarra River at Warrandyte
16. Yarra River d/s of Banksia St
17. Bunyip River and Yallock Outfall
18. Koornang Rd Main Drain at Cadby Avenue
19. Elwood Canal / Elster Ck d/s of Asling St
20. Kororoit Creek

FIDSS Key Components

The overall architecture of FIDSS is shown in Figure 12.

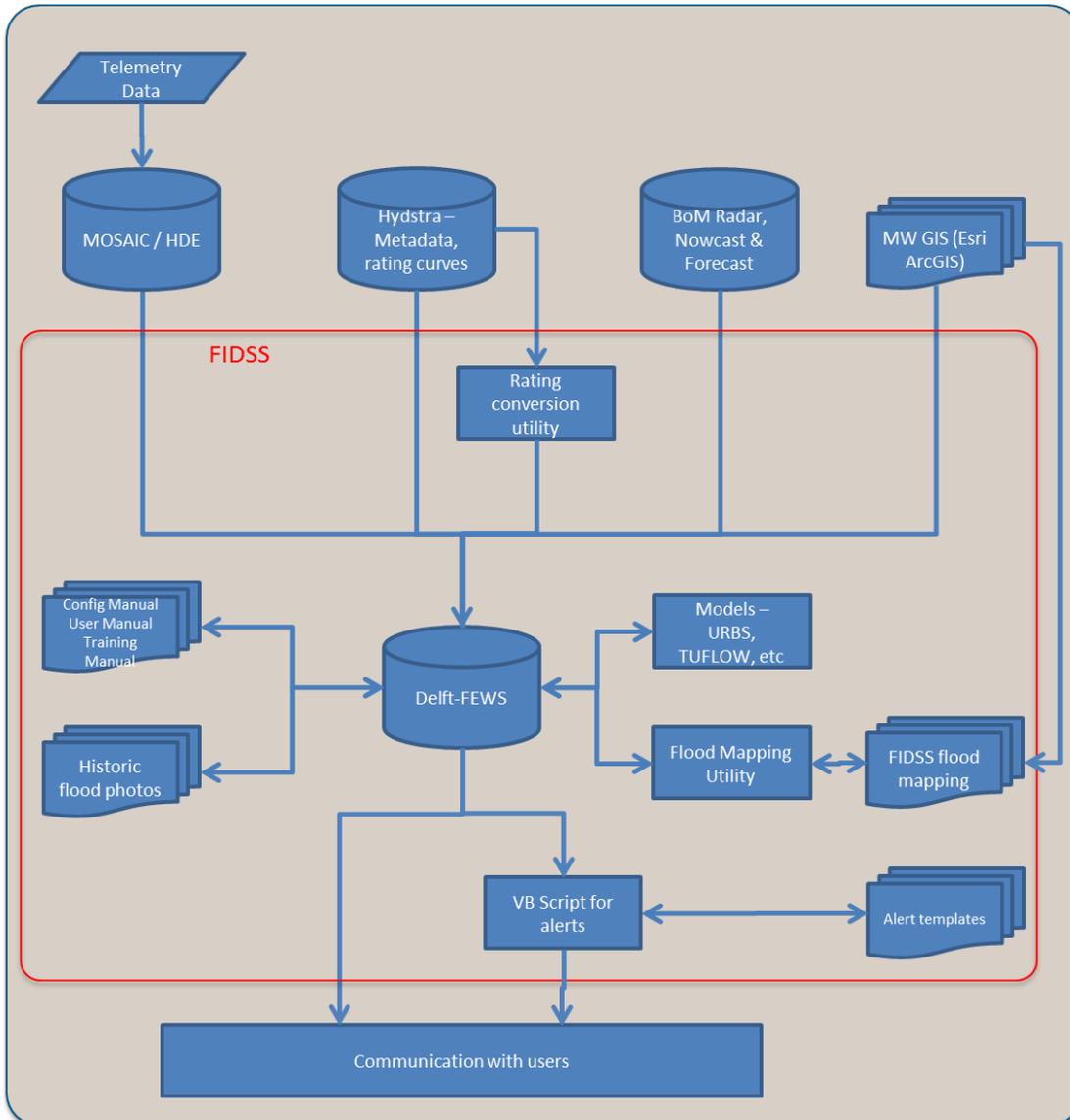


Figure 12 FIDSS Architecture

ERRTS Data – rain and river level stations throughout the catchments are transmitting data via a VHF radio network, using the ALERT/IFLOWS protocols. These data are being collected using ERRTS receivers and decoders, feeding a binary data stream into MOSAIC and HDE. There are seven frequencies being used, resulting in 7 receivers and 4 decoders.

MOSAIC – the existing SCADA system used by the various divisions within MW is MOSAIC. For all other users of MOSAIC data, the exchange of data occurs via HDE. For the flood forecasting operations, data are directly outputted from MOSAIC via CSV file.

HDE – the Historic Data Exchange receives data and processes output data on to a defined folder on the MW network. Various internal and external users pick up the HDE data from these folders.

Hydstra – the Hydstra database is a repository of data, including station metadata, rating curves and IFD.

Delft-FEWS – the core of the FIDSS system, where data are ingested and external models and modules are controlled. Alerting output from Delft-FEWS is via e-mail.

Rating Conversion Utility - an Excel spreadsheet containing a macro for conversion of Hydstra format rating curves into the Delft-FEWS compatible format.

Models – hydrologic and hydraulic models are automatically managed by Delft-FEWS, which pre-processes data, executes the model, and post-processes model outputs for viewing within FIDSS.

Flood Mapping Utility – the utility extracts the flood extents mapping from the flood mapping database for display in FIDSS.

Forecasts

FIDSS ingests rainfall forecasts provided by the BoM. Different forecasts can be displayed by manually adjusting the system time so that the latest forecast applicable to that time is displayed. These forecasts are saved as shown in Figure 13

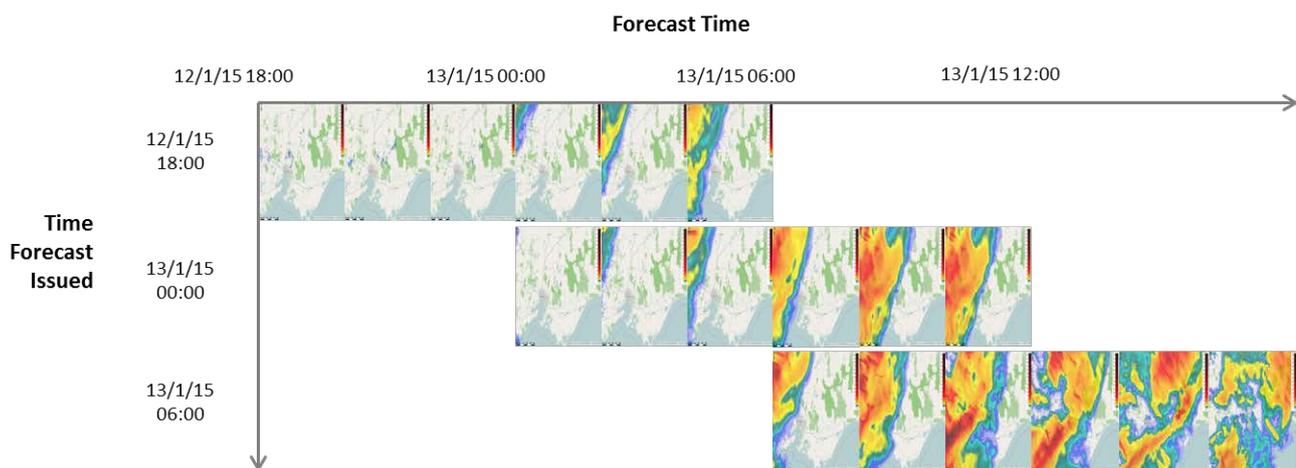


Figure 13 Display of Forecasting

Forecasting Data

MW was one of the agency's that funded the Smart Water project for the BoM to develop Nowcast rainfall, although the project has finished BoM are continuing to provide this product via their Registered User Service on subscription to Melbourne Water in NetCDF4 format.

MW is also accessing the following key BoM forecast products via the Registered User Service: ACCESS-R12, ACCESS-C, ACCESS-G, and GFE. These forecast products, examples of which are shown in Figure 14, 15 and 16 are used differently by FIDSS operators to forecast floods and advise agencies during floods.

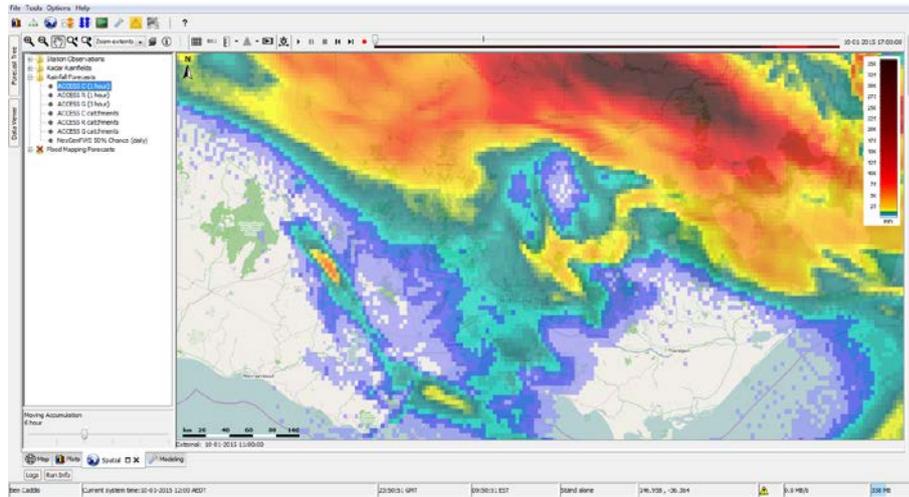


Figure 14, ACCESS-C forecast

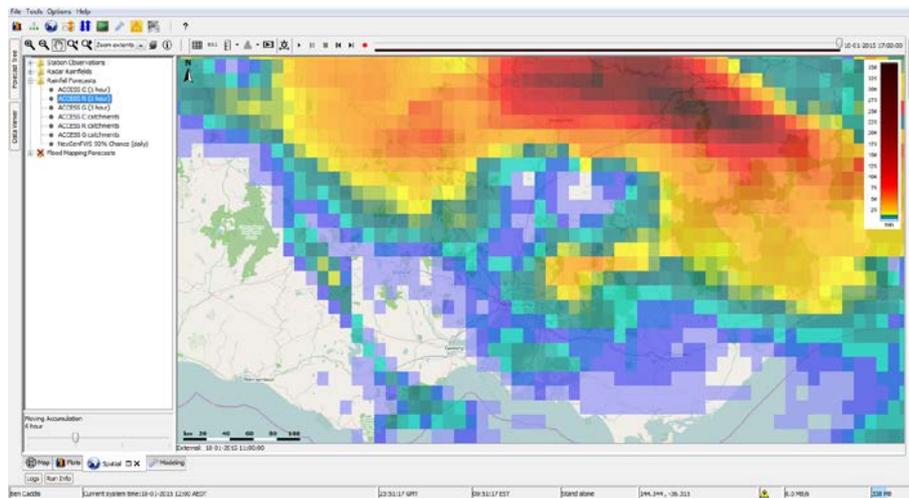


Figure 15, ACCESS-R forecast

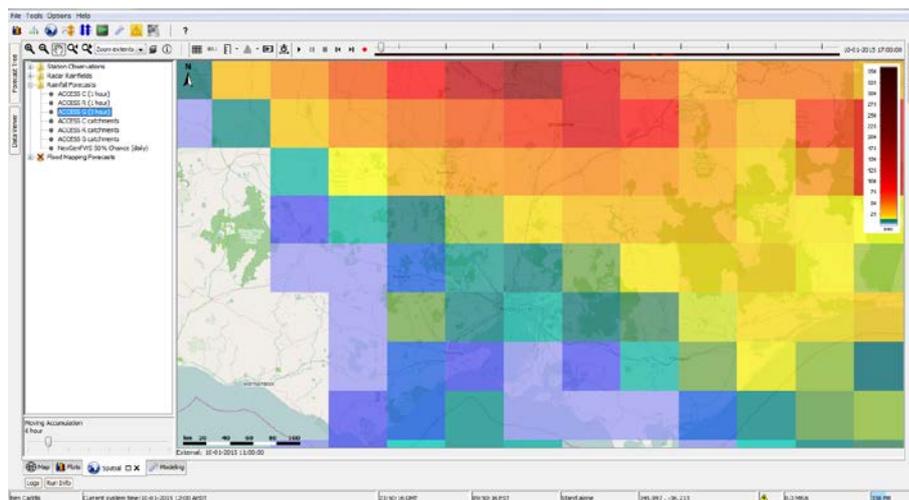


Figure 16, ACCESS-G forecast

Table 2 is a summary of all the observation, Nowcast and forecast data ingested by FIDSS, including source, method of transfer, frequency, resolution and format.

Table 2 Observation and forecast data scheduling

Description	Observed forecast	Source	Method of Transfer	Time Step	Availability	Forecast Period	Spatial Resolution	Format
Telemetry	Observed	MOSAIC / HDE	File		Every minute	1 -	Every gauge	CSV
QPE – bias corrected radar	Observed	BoM	FTP - BoM Registered User Service	6 minute	Every minutes	6 -	1km	NetCDF4
Blended rain gauge and radar data	Observed	BoM	BoM to investigate if available	30 minute	Every minutes	30 -	1km	NetCDF4
Nowcast – 5 different ensembles	Forecast	BoM	FTP - BoM Registered User Service	10 minute		12 hours	2km	NetCDF4
Access-R12, Access-C and Access-G	Forecast	BoM	FTP - BoM Registered User Service	3 hour	Every hours	6 3.5 days	varies	NetCDF4
GFE (BoM's official forecast)	Forecast	BoM	BoM to investigate if available	3 hour	Every hours	6 10 days (forecasts are most accurate to 5 days)		NetCDF4

These different products are processed inside FIDSS to enable a simple visualisation of average rain over the various (sub) catchments. An example of the depth averaged rainfall based on the one product, Access-C is shown in Figure 17.

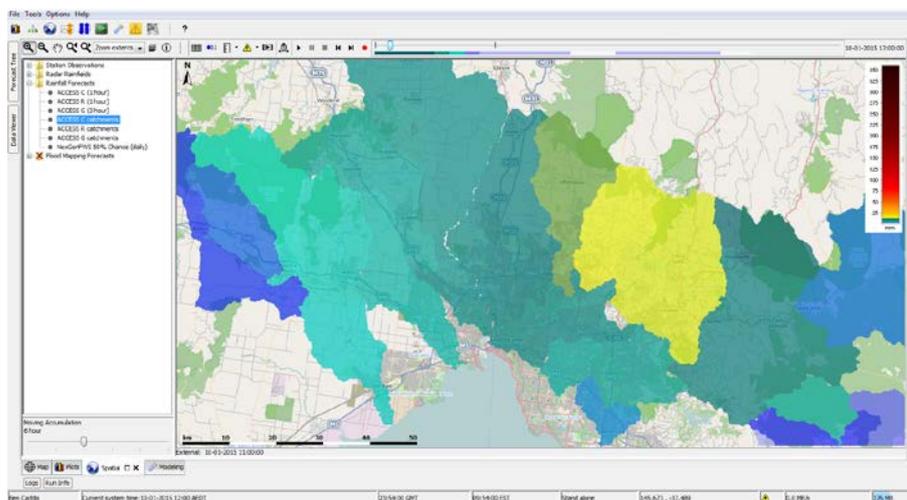


Figure 17 Depth averaged rainfall over the catchments based on ACCESS C forecasts.

URBS Models

The forecasters at MW use the rainfall forecasts as inputs into hydrological models. Different products are useful for different duration storms and different forecast times, the forecasts therefore consider an ensemble of rainfall forecasts to generate flows.

Forecasters on their local machines run a number of forecasts through URBS to consider the impact on flood flows. An example of an ensemble is shown in Figure 18; the ensemble is composed of the following products:

- Observed gauge rainfall with ACCESS-C, G, and R NWP forecast
- Observed gauge rainfall with Nowcast forecast
- Rainfall Policy scenario forecast.
- Observed gauge rainfall with zero mm rainfall in the forecast period.
- Rainfall What-if Scenario forecast.

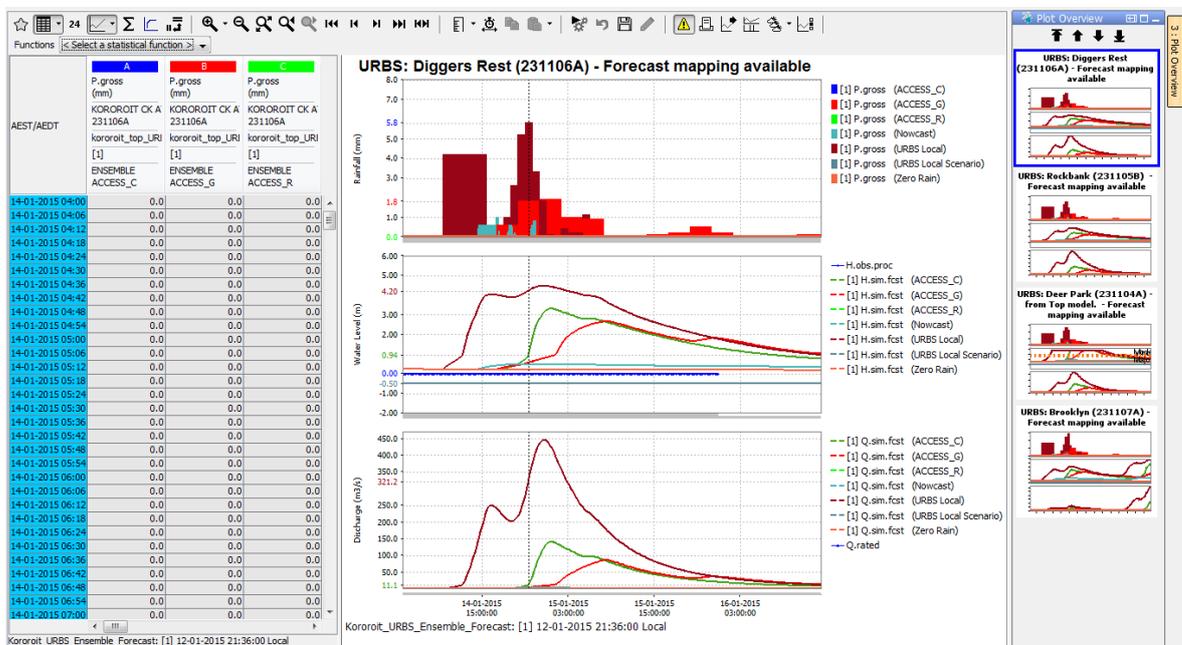


Figure 18 Ensemble run output in Plots display

HDE Data from Melbourne Water Gauges

The observed rainfall accumulations are routed to FIDSS every minute, rather than the historical norm of every six minutes, this is because FIDSS can process the data efficiently and provide reliable warnings for flash flood catchments where 1/10 hour is too great a time step, and emergency services could miss out on precious minutes in a flash flood situation.

The accumulated rainfall can be gridded and then visualised with an open street maps background and depth averaged for each subcatchments as in Figure 19.

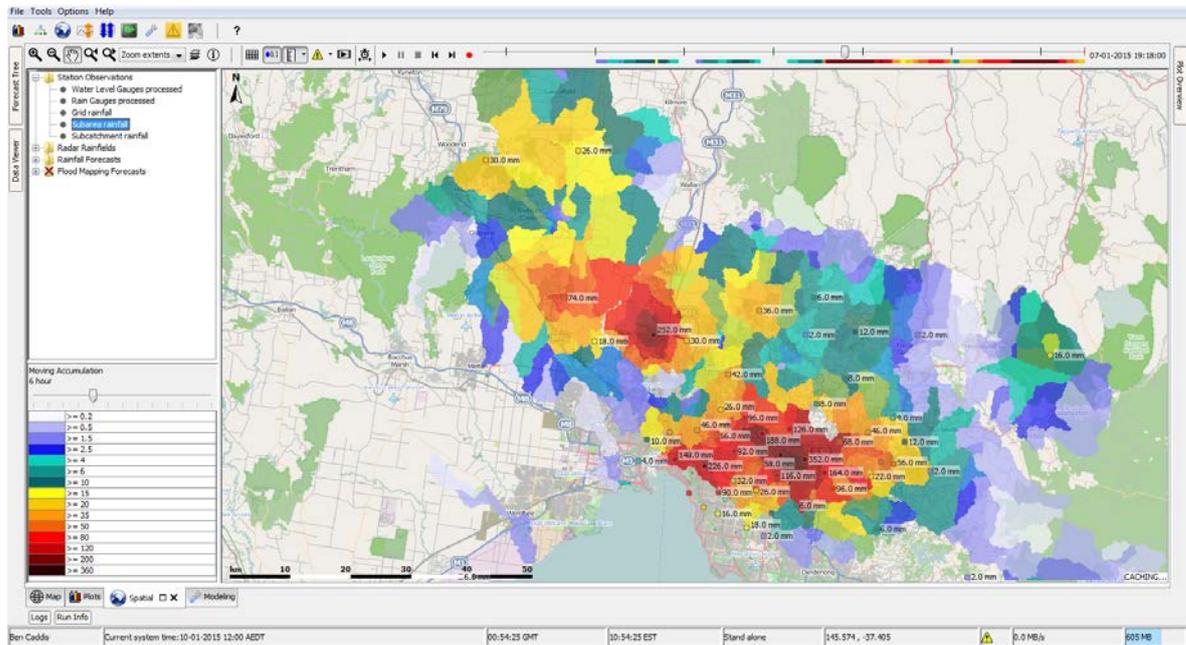


Figure 19 Interpolation of observed rainfall for sub catchments

Hydraulic models

The outputs of numerous MW hydraulic models have been incorporated into FIDSS. These outputs have been related to peak heights at river gauging stations so that appropriate flood extents can be shown for various predicted and actual gauge levels.

Some of the advanced 2D hydraulic models were modified to provide improved flood intelligence for the FIDSS model.

Integration

FIDSS works to integrate all the data, hydrology and hydraulics. This is demonstrated in the bespoke Flood Mapping Utility that uses a pre-defined library of flood surfaces corresponding to a Zone of Influence around each forecast location. Zones of Influence for each catchment are available in the GIS mapping layers associated with each catchment. Based on the level of the provisional forecast, the Flood Mapping Utility returns a peak flood extents grid representing the 'next highest flood map' for that location (Figure 20).

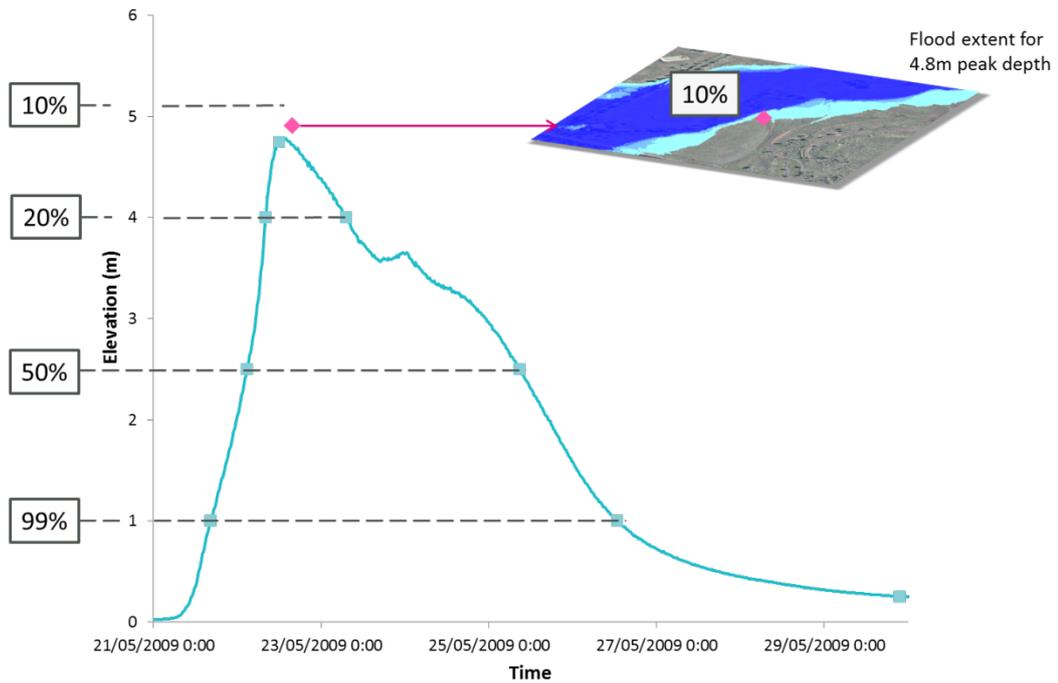


Figure 20 Selection of peak flood map for provisional forecast

The Flood Mapping Utility also uses the time series of the simulated forecast to return a time series of flood maps. The users are able to animate the flood extents in the time series mapping display (Figure 21).

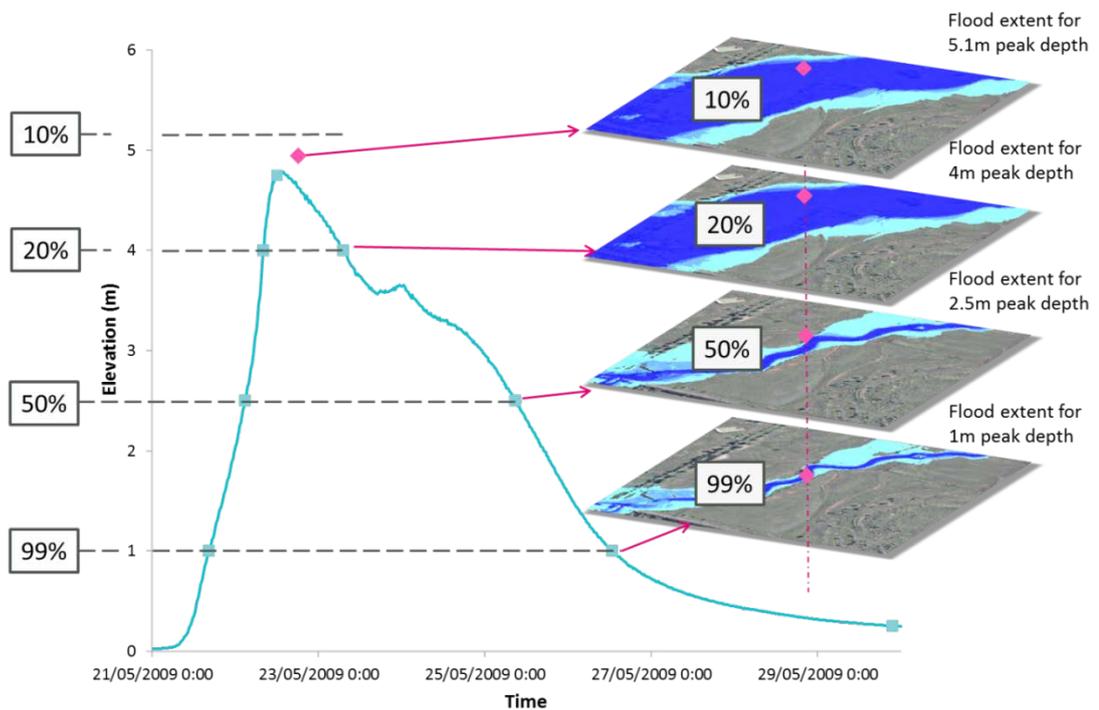


Figure 21 Selection of time series flood maps for simulated forecast

These time series maps provide considerable flood intelligence to be able to assess when various flood thresholds will be breached to allow SES and other agencies to plan evacuations and road closures more effectively than it has been possible to do in the past.

Alerts and warnings

FIDSS issues warnings and alerts by emails. Alerts are based on gauged river levels and, observed rainfall for a range of durations and intensities. These alerts have been developed to provide instantaneous information for internal MW staff and contractors to better manage their work and the safety of their crews. This information will be provided by email to a group within Melbourne Water. It will also potentially feed into future mobile apps.

The development of FIDSS will also assist Melbourne Water to inform more than just its flood affected customers. The “Integrated” part of FIDSS will enable additional functions such as an ability to warn customers of high tides and of potential flash flooding. In addition to providing a TFWS for Melbourne Waterways Area the FIDSS project also provides a decision support system for low flow diversions. The combination of river gauge readings and weather forecasts and histories will enable effective decisions to be made with regard to the operation of flow diversions that operate on many of the MW river catchments

Operational Usage of FIDSS

As we approach the operational stage of FIDSS the number of potential uses are increasing beyond the core functionality and original business requirements. There is considerable untapped potential for FIDSS to be at the centre of all water course activities.

Acknowledgements

Geoff Crappers comments on the paper are much appreciated.

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