REAL-TIME IRRIGATION FORECAST SYSTEM –RANGITATA DIVERSION RACE, CANTERBURY, NEW ZEALAND

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ABSTRACT

DHI were engaged by Barrhill Chertsey Irrigation Limited (BCI) to build a real-time flow forecasting and optimisation system for the Rangitata Diversion Race (RDR). The inclusion of the BCI irrigation scheme into the RDR diversion race and associated, complex, water swapping required that a “smart” real-time forecasting and optimization system be designed, developed and implemented.

The RDR diverts water to 64,000 hectares of Canterbury agricultural pasture, making it New Zealand’s largest irrigation system. The construction of the race began in 1937 and was completed in 1941. The canal is 67 kilometres long, 10 metres wide and 3 metres deep. Structures along the canal include siphons, check gates, radial gates and spillways. The RDR delivers water to four irrigation schemes: Mayfield Hinds; Valetta; Ashburton Lyndhurst; and Barrhill Chertsey (a recent addition). The RDR also delivers water to a number of stockwater off-takes.

Since the 1940’s when the scheme was commissioned it has been able to be successfully managed by the application of water restriction rules by the duty operator, until recent expansion of the system. In 1998 groups combined to form BCI. In 2001 consent was granted to BCI to extract 17m^3/s from the Rakaia River to irrigate 40,000 hectares, bringing the total irrigated area to over 100,000 hectares. The BCI Scheme has a long term contract with TrustPower Limited to take water from the Rakaia River and pump it to the district’s existing irrigation canal, the RDR. The BCI scheme includes small scale storage/buffer ponds, off-takes and control structures that allow complex water delivery to be undertaken.

Key system components:

- Calibrated hydraulic model representing the existing RDR canal (pre BCI)
- Hydraulic model representing future RDR canal (including BCI) which optimises on storage and spills back to the rivers
- Web based Dashboard Interface (DI) to allow for system inputs, displays of forecasts and capture of data
- Real-Time Software Shell that links the input data, real-time field data and the models together

Currently the irrigation demands and river restrictions are operated at a daily resolution. The DI allows all four irrigation schemes to submit a water order and the RDR operator to submit river inflows. Also the DI allows the input of BCI time varying storage pond water levels and RDR flow control structure settings that are not controlled by telemetry (manually controlled), such as maintenance gate openings.

The DHI system carries out full hydrodynamic calculations (in 1D) and produces future set points to deliver an optimised water allocation by balancing supply to demand priorities across the whole scheme. Model simulation times are less than 1 hour with the model running 24/7.

The system can also be used in parallel mode to allow for use in emergency situations that could develop during operation. The software platform used for the system is the MIKE by DHI software (MIKE 11 – channel flow and control structure operation; MIKE AUTOCAL – system optimization; Dashboard Manager – to develop and publish the Dashboard Interface; MIKE FF – forecasting).

Currently the DI is in final stages of testing and the model is undergoing real-time testing. It is expected that this project will be completed over the next few months. Likely future expansions to this project are additional large scale storages and inflow forecasting.

KEYWORDS

Flow forecasting, Real- Time, Irrigation, Optimisation**,** MIKE by DHI

1 INTRODUCTION

Modern water systems require water to be delivered efficiently to people, agriculture, industry and the environment. DHI is leading the way with smart forecasting systems in New Zealand and overseas calling on more than 40 years' experience in water modelling and technology development combined with state of art techniques in data assimilation and non-linear multi objective optimisation.

The RDR is the largest irrigation scheme in New Zealand, irrigating 63,380 hectares. It consists of a 67km canal that runs between the Rangitata and Rakaia rivers which was built in the 1940s. The canal provides irrigation water during the summer months and electricity via two power stations, Montalto and Highbank, in the winter.

The RDR has been run manually, or has needed operator intervention, since its construction. Due to the river flow abstraction restriction rules and RDR irrigation scheme allocations being clearly defined, this was manageable.

However, in 2010 construction began on the Barrhill Chertsey Irrigation Scheme, which is linked to the RDR. This extension to the RDR has been made possible by obtaining additional water from the Rakaia River via a new pumping station at Highbank. The additional water allows some "water swapping" to occur over the length of the RDR and essentially irrigates a much larger area between the Rangitata and Rakaia Rivers. But by constructing with more than double the total number of additional off takes, storage ponds and a complex water swap structure, it is no longer possible to run the system "manually".

DHI were engaged by Barrhill Chertsey Irrigation to build a real-time control system of the RDR new system, that was capable of capturing the full non-linearities of the system (variable travel times, channel storage effects, etc.) avoiding simplifications that could falsify the forecasting system response.

The system consists of a calibrated hydraulic model that includes control structures such as in-take gates, off-take gates, bridges and siphons. Rules and priorities in the system are accounted for and optimal criteria are sought for certain variables during each forecast cycle. Variables in the system that are included in the optimisation are storage pond volumes, canal water levels and releases back to the rivers.

It is desirable to keep storages as full as possible, as often as possible, so that irrigation can continue for some time after any reduction in river inflows to the RDR. The other important goal is to minimise water wastage in the form of releases back to the rivers from water allocated for irrigation.

The system receives real-time observations of water levels and flows which are used to assist in producing accurate forecasts and hence system settings (primarily gate settings) for the next two days in advance. The system is run hourly, so that fluctuations in irrigation demand, pumped water available or emergency situations (such as a gate failure) can be accounted for.

The ultimate vision for this system is to be essentially automated with only irrigation demands being input by the operator. System settings that are forecast, once approved by the operator, will be automatically sent out to the field equipment controlling the in-take and off-take gates.

2 AUTOMATED CONTROL SYSTEM CONCEPT

The RDR Automated Control System (ACS) is combination of real-time data, a calibrated hydraulic model, a real-time shell and a web based control interface. The backbone of the system is a MIKE 11 1-Dimensional hydrodynamic model which is widely used for open channel modelling in New Zealand.

2.1 GENERAL DATA FLOWS IN SYSTEM

The data flow for the ACS is between the RDR master database, field measurements, forecasting computer and the webserver computer. Figure 2-1 shows the two way data flow between all of these objects.

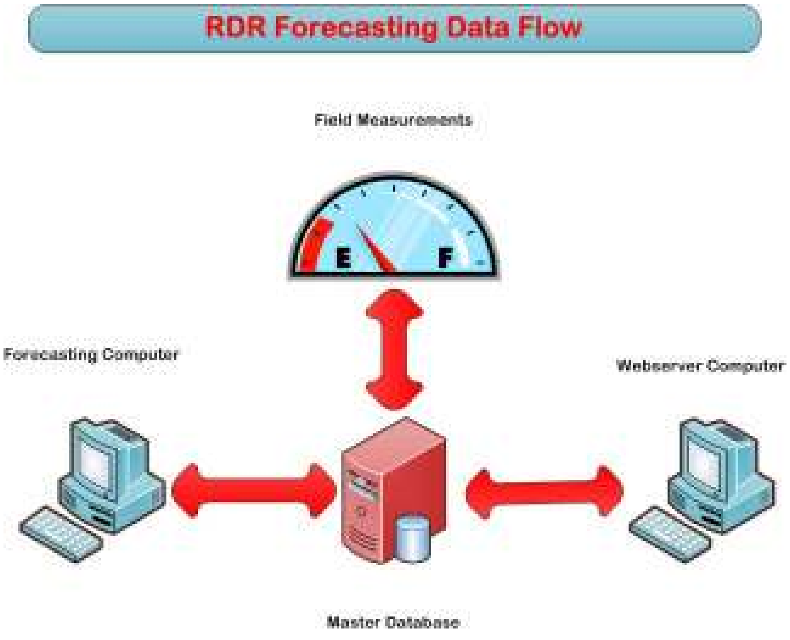


Figure 2-1 RDR Data Flow

The Master database receives and stores all observed data from the field, input data from the Webserver Computer and forecasts from the Forecasting Computer. The Field Measurements object represents SCADA observed data from water level sensors, gate setting and such like.

This item also receives forecast gate setting from the Forecasting Computer via the Master Database.

The Forecasting Computer receives all observed data and user input data from the Master Database and sends forecast setting to the Master Database. The Webserver Computer receives observed data and forecast setting for display on the relevant webpages. It also sends user inputs to the Master Database. It stores a local copy of user inputs for webpage display purposes.

Figure 3-3 in the next section shows the detailed forecasting work flow of the ACS.

2.2 MODELLING TOOLS & CALIBRATION

2.2.1 HYDRAULIC MODEL BUILD

This section offers a brief description of the model schematisation with respect to the branches, structures and boundaries included.

BRANCHES INCLUDED IN THE MODEL

The MIKE 11 model includes only 1 major channel and a small side branch. These branches are listed in Table 2-1. Figure 2-2 shows the river alignment.

Table 2-1 Branches included in the model

Branch Name	**Comment**
RDR	66.7 km from the intake at Rankitata River to High Bank Power Station.
Sth Ash Spill	127 meter representing the spill structure at South Ashburton.

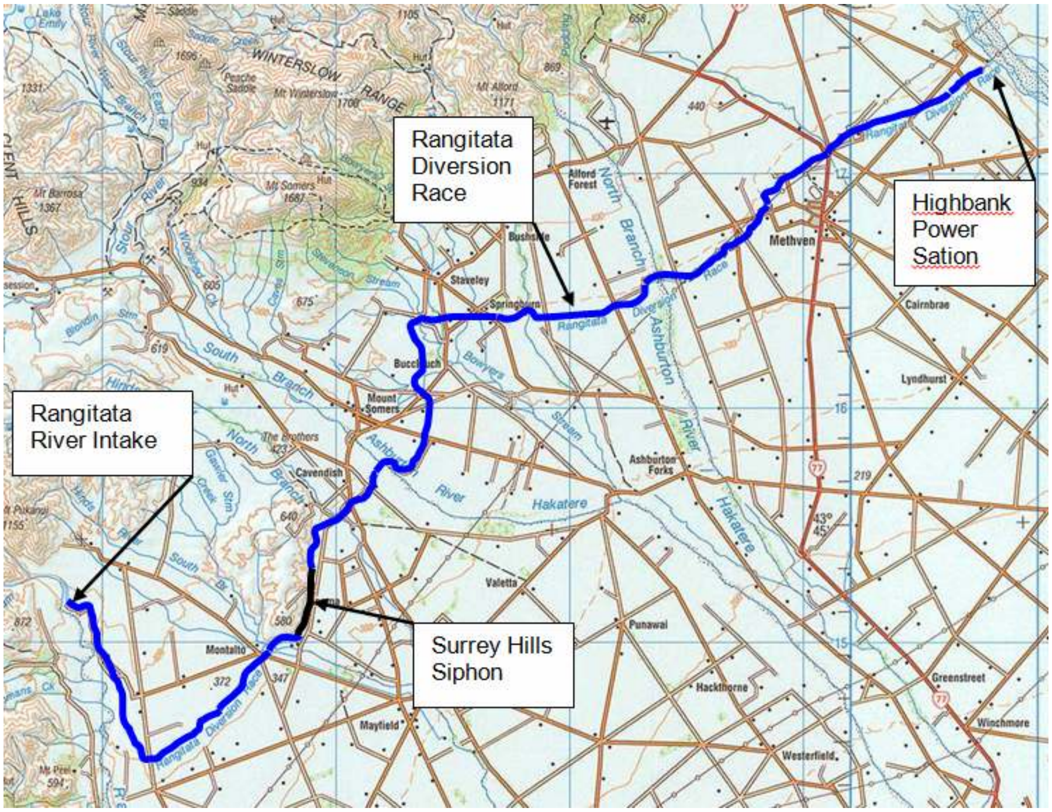


Figure 2-2 Canal alignment of the Rangitata Diversion Race

STRUCTURES INCLUDED IN THE MODEL

The model includes 28 structures used to describe the different weirs, siphons, check gates and spills in the system. The structures included in the model are listed in Table 2-2. The following subsections will offer a brief explanation on the modelling approach for each structure.

Table 2-2 Structures included in the model

No.	Branch Name	Chainage	Comment
1	RDR	1772	Side weir representing the spill at BAFF
2	RDR	1970	Weir representing the first weir at the sandtrap
3	RDR	2100	Weir representing the second weir at the sandtrap
4	RDR	10243	Mayfield-Hynes weir
5	RDR	16573	Weir at Montalto Power Station
6	RDR	27369	Velatta weir, modelled using two parallel weirs
7	RDR	53422	Weir by-passing stockwater from Methven check gate
8	RDR	1862	Culvert representing bridge
9	RDR	3821	Culvert representing bridge
10	RDR	5200	Culvert representing bridge
11	RDR	6146	Culvert representing bridge
12	RDR	8540	Culvert representing bridge
13	RDR	10109	Culvert representing bridge
14	RDR	17996	South Hinds siphonic spillway modelled as a side culvert
15	RDR	59014	Dry Creek Siphon modelled as an inline culvert
16	RDR	136	Intake at Rangitata modelled as a control structure
17	RDR	1842	BAFF culvert modelled as a control structure
18	RDR	16573	Montalto weir modelled as a control structure
19	RDR	18011	South Hinds Check Gate1 modelled as a control structure
20	RDR	18011	South Hinds Check Gate2 modelled as a control structure
21	RDR	29560	South Ashburton Check Gate1 modelled as a control structure
22	RDR	29560	South Ashburton Check Gate2 modelled as a control structure
23	RDR	49563	North Ashburton Spillway modelled as a side control stucture
24	RDR	53422	Methven Check Gate1 modelled as a control structure
25	RDR	53422	Methven Check Gate2 modelled as a control structure
26	RDR	66650	Penstock Intake modelled as a control structure
27	Sth Ash Spill	84	South Ashburton Siphon Spill modelled as a control structure

WEIRS

The weirs included in the model are listed as number 1 to 7 in Table 2-2. These are all static structures and are modelled in a straight forward way. However, the weir at Montalto is not the only structure used to mimic what takes place at Montalto. The model also contains a control structure that aims at maintaining an upstream almost constant water level of RL 360.29 metres.

CULVERTS

The culverts included in the model are listed as number 8 to 15 in Table 2-2. The culverts listed as number 8 to 13 represents bridges and are as such static structures that are simply included in the model.

The culvert listed as number 14 represents the South Hinds Siphon Spillway, this siphon is modelled as a culvert, unfortunately no measurements of spilling from this culvert are available.

The remaining culvert listed as number 15 represents the Dry Creek Siphon.

CONTROL STRUCTURES

The control structures included in the model is listed as number 16 to 27 in Table 2-2. This section provides a brief documentation of how the calculation/optimisation of structure discharges at the offtakes is calculated. It also provides a description of how the control structures have been configured.

The whole purpose of the model is to optimise set points for the different offtakes in order to maximise usage of available water as well as ensuring a fair distribution between the different irrigators.

Several different offtakes exist. Some offtakes are controlled by a single gate only. Others are controlled by two gates. Further, an offtake (with one or more gates) can deliver water to different irrigators with different rights which add to the complexity of how the calculation is performed.

GENERAL FEATURES OF THE OFFTAKES

One common feature of all the offtakes is that the discharge is calculated differently depending on the time of the simulation. The total model simulation period is made up of a hindcast period and a forecast period with the time of forecast (ToF) separating the two periods. During hindcast period the discharge is based on measurements. After the ToF the discharge can be user defined or formulated as a target discharge left open for optimisation or a combination of both. This is shown in Figure 2-3. Since an optimisation is expected to take place only once every hour it is considered appropriate to use user defined discharges from the ToF and until the new optimised set point is transferred to the SCADA system.

Another feature that is common for the different offtakes is that the model is not discharging more through the structures than is physical possible. Nor should the optimisation result in discharges in excess of what the irrigators have asked for. This means that the smallest discharge of three options is selected:

1. Target release i.e. the request for water made by the irrigator
2. The amount that can be abstracted according to optimisation
3. The maximum physical amount that can be abstracted.

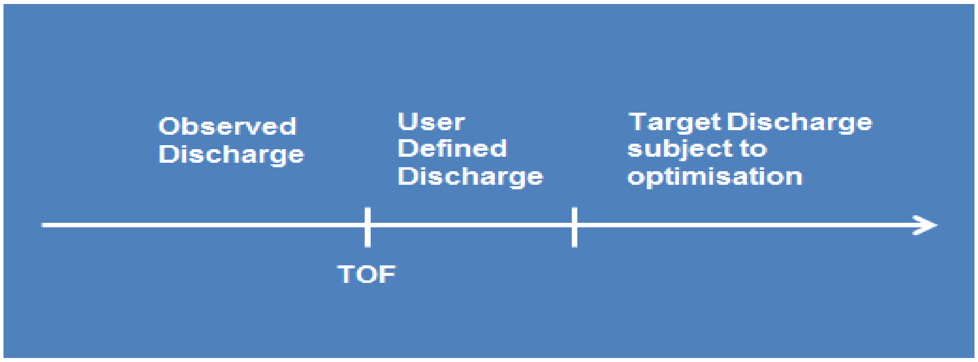


Figure 2-3 How the discharge is calculated

Table 2-3 Notation used in Figure 2-3

Notation	**Interpretation**
od	Observed Discharge
ud	User Define Discharge
td	Target Discharge/ request placed by irrigator
Q	Discharge
PhysMax	Maximum discharge capacity of structure
udMax	Maximum discharge as defined in business agreement
f	Restriction Factor for the irrigator. It is subject to optimisation

INLET STRUCTURE AT RANGITATA

The intake structure at Rangitata is difficult to manage especially when flushing the sand trap. For this reason it is modelled as a discharge structure discharging the same amount as the sum of the measured discharge above the sand trap and the discharge at the BAFF fish bypass. Since there will be an effect of flushing downstream of the sand trap it is relevant to include the sand trap and the inlet structure in the model.

THE BAFF FISH BYPASS

The BAFF fish bypass is listed as number 17 in Table 2-2. It is modelled as a control structure using a time series for specifying the discharge. If no time series is available a Q-h relation is used. This Q-h relation is derived from the culvert geometry. When done in this way it is possible to assimilate measured discharge into the model during the hindcast period and to calculate the discharge based on structure geometry during forecast.

MONTALTO WEIR

The regulation at Montalto is based on an assumption that the water level will be maintained at 360.29 meter. To do this a static weir and a control structure are located at the calculation point representing Montalto. The control structure will aim at releasing more when the water level rises too high above the required and release less when the water level drops too far below the required.

CHECK GATES AT SOUTH HINDS, SOUTH ASHBURTON AND METHVEN

The check gates are all modelled as individual control structures. The two check gates at South Hinds and at South Ashburton are all modelled as fully opened sluice gates. The two check gates at Methven are modelled as time controlled sluice gates.

PENSTOCK INTAKE AT HIGH BANK

The intake at the penstock at High Bank has been modelled as a control structure controlled by measured values. However, due to a possibility for too large a drawdown the discharge at the intake will start fading out when the depth reaches 1.2 meter. At a depth of 1 meter inflows at the penstock stops.

NORTH ASHBURTON SPILLWAY

The spillway at North Ashburton is listed as number 23 in Table 2. It has been modelled as a control structure using a Q-h relation derived from measurements of both water level and measured spill. The applied Q-h relation is shown in Figure 2-4 and is derived based on analysis of combined water level and discharge data at the spill. In the future model measured spills will be applied during the hindcast period.

SOUTH ASHBURTON SPILLWAY

The spill at South Ashburton has been modelled as a time controlled control structure in which the measured spill is used as the discharge.

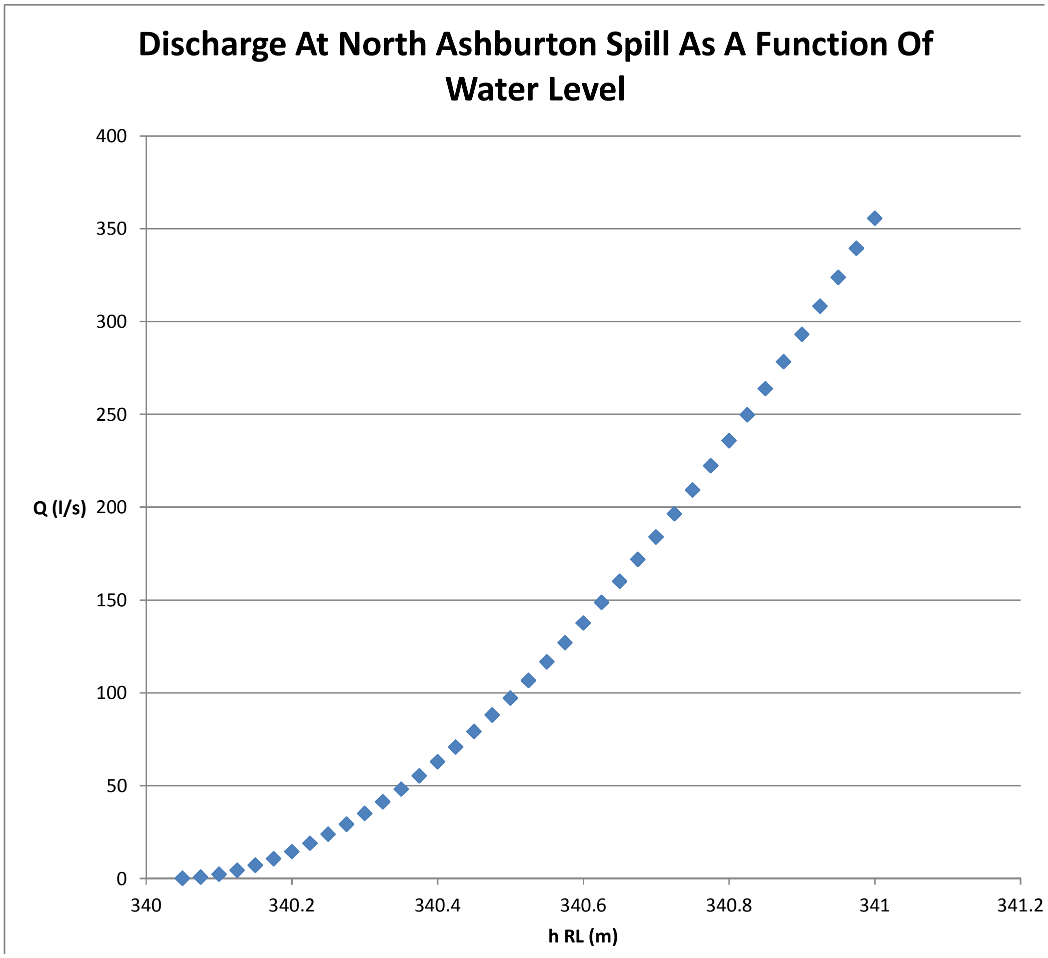


Figure 2-4 Q-h relationship at North Ashburton Spillway

2.2.2 CALIBRATION

Calibration of a MIKE11 model requires besides reliable data, that the water balance is ensured. In a river/race system like this it is also necessary to include a proper description of all the structure contributing to the regulation of the flow. For the present study the topography of the race is well described and measurements of abstractions and inflow discharges seems to a large extend to be consistent. Also the structures regulating the flow seem well documented. Further, it was realized that the inflow at the intake gate at Rangitata could be difficult to be estimated during flushing. For this reason another approach was adopted for this study. This approach will ensure an inflow at the intake gate that balances the sum of the measured discharges at the BAFF fish bypass gate and above the sand trap.

The model calibration period has been setup for the 1st of January 2010 until the 17th of May 2010. In Table 2-4 the measurements making up the boundary conditions for the model are listed. In addition to the listed measurements the model has two more side structures used for spilling. These structures are modelled as either weirs or culverts based on geometrical considerations.

Table 2-4 Measurements used in the model

Branch Name	Chainage	Comment
RDR	1842	Abstraction at BAFF fish bypass
RDR	1862	Flow above sand trap
RDR	10131	Abstraction at Mayfield Hinds
RDR	10186	Abstraction at Klondyke Stockwater ADC
RDR	27255	Abstraction at Valetta Intake Gate
RDR	28564	Intake from South Ash
RDR	50445	Abstraction ALIS Pipe
RDR	53350	ALIS Lateral 1
RDR	53412	ALIS Intake Gate
RDR	66700	Water Level at Dws. Power Station
Sth Ash Spill	84	Measures spill from South Ashburton Spill

Two examples of the calibration are shown and described below. In Figure 2-5 below the simulated water level at Mayfield Hinds head pond is compared with the measured water level. In general the calibration is satisfactory at this location with the deviations between measured and simulated water levels being within a few centimetres. The measurements show some sudden dips in the water level which are caused by flushing of the sand trap. It demonstrates the influence of flushing and suggests that flushing of the sand trap should be included in the model.

Similar results are seen in Figure 2-6 showing a comparison of measured and simulated water levels at Valetta head pond. Again the calibration results are satisfactory with only a few centimetres difference.

Overall the calibration has given good results. There were problems with the mass balance during parts of the simulated period which have now been resolved. Further, the description of the Methven Check gates as well as High Bank have been improved in order to overcome occasional obvious errors in the simulated results.

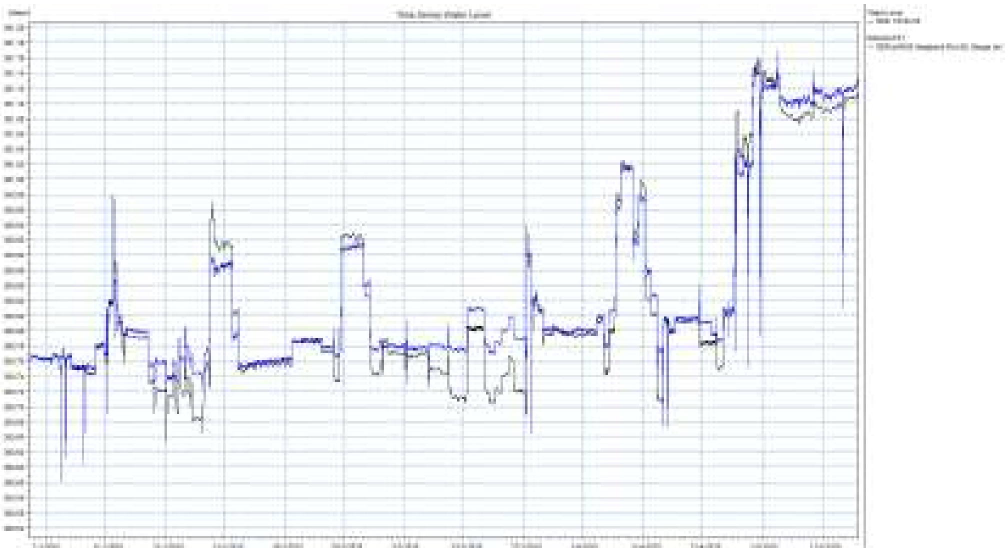


Figure 2-5 Comparison between measured and simulated water level at Mayfield Hinds Pond. The measured are shown in blue.

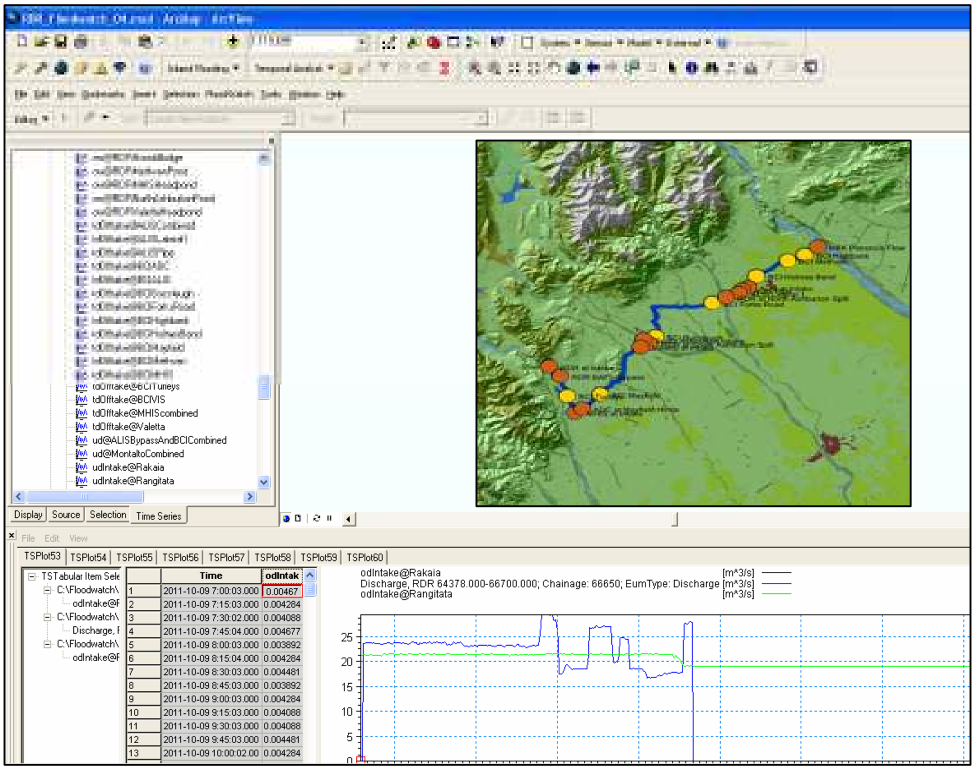
Figure 2-6 Comparison between measured and simulated water levels at Valetta Head Pond. The measured values are shown in blue

3 REAL TIME SHELL AND USER INTERFACE

3.1 REAL TIME SHELL

Based on 30 years experience in the development and implementation of flow forecasting systems worldwide, a modern and extremely robust forecasting shell system is available with the objective to integrate real time data management, forecast models and dissemination methodologies in a single system.

The system is GIS based and runs under standard Windows operating systems. It is a map based forecasting system that runs as an ArcView extension. The map based interface allows the display and analysis of timeseries data in a spatial context, such as rainfall isohyets, rainfall radar plots and inundation maps.



	Time	odIntak
1	2011-10-09 7:00:03.000	0.00467
2	2011-10-09 7:15:03.000	0.004284
3	2011-10-09 7:30:02.000	0.004088
4	2011-10-09 7:45:04.000	0.004677
5	2011-10-09 8:00:03.000	0.003892
6	2011-10-09 8:15:04.000	0.004284
7	2011-10-09 8:30:03.000	0.004481
8	2011-10-09 8:45:03.000	0.003892
9	2011-10-09 9:00:03.000	0.004284
10	2011-10-09 9:15:03.000	0.004088
11	2011-10-09 9:30:03.000	0.004088
12	2011-10-09 9:45:03.000	0.004481
13	2011-10-09 10:00:02.00	0.004284

Figure 3-1 Screen shot of the RDR forecast system.

Designed for use in real-time environments integrates spatial data, real-time data, forecast models and dissemination tools in a GIS or web based environment. The system includes a GIS client designed for use by staff working in office and a web client designed for use by duty staff working remotely. The real time shell is a user friendly system that is straightforward to use. In normal operation the system runs automatically, but manual user inputs to override, or supplement the automatic forecasts are possible.

The system includes the following features:

- Robust and resilient single user or client-server solution – supports a range of different database systems, for instance Microsoft Access (Professional edition) and Microsoft SQL Server, ORACLE Server, INFORMIX server and DB2 (Enterprise edition)
- User-friendly software solution designed for ease of use – produces highly visual forecast information

- Proven and documented interfaces to real-time data sources – includes point based and spatially distributed data
- Interfaces to DHI models and third party models - includes AUTOCAL, MIKE 11, MIKE 21, MIKE FLOOD, MIKE BASIN, MIKE SHE, MIKE URBAN
- Scenario Editor – enables users to define model scenarios, carry out comparative assessments and establish a firm decision basis
- Task Editor – allows users to configure, examine and control system duties, including telemetry polling, scenario simulations, publications and – generally – and user defined process
- Simulation Editor – allows users to examine simulation details, including log files, input and output time series, animations and warning maps
- Statistics Editor – allows users to carry out forecast statistics and evaluate model performance
- Publication Editor – allows users to compose dedicated reports and disseminate information manually, automatically or on an event driven basis. The information can be forwarded to a range of recipients, including ftp, email, fax, web and SMS
- Event Editor – allows users to examine event messages issued by system processes and monitor system status
- Alarm Editor – allows users to define single or aggregated events that cause the system to initiate task runs ranging from the dissemination of simple warnings to comprehensive action plans
- Web interface – allows users to control the system remotely using a Microsoft Windows based web client

Figure 3-3 shows the detailed forecasting work flow for the ACS system.

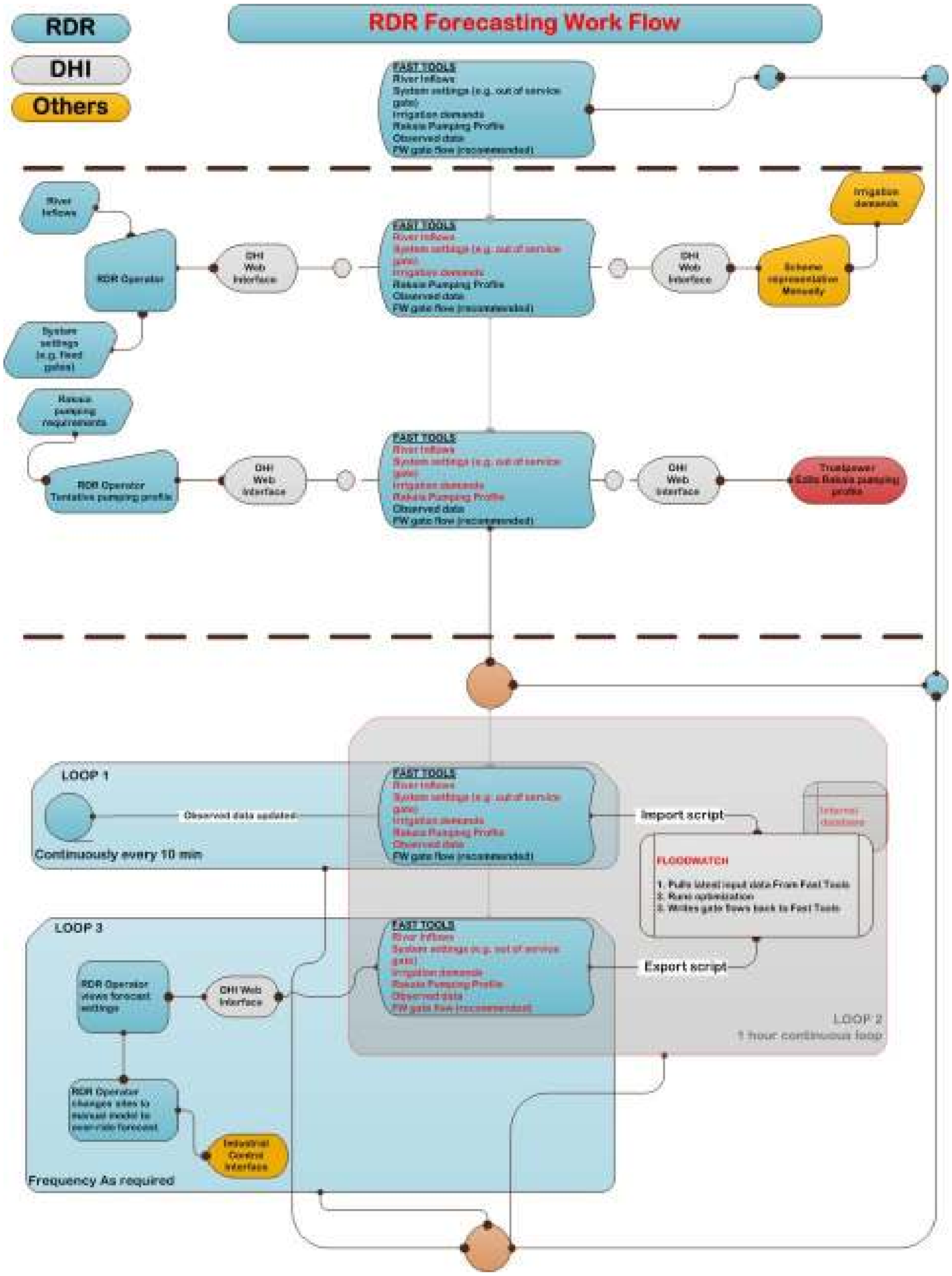


Figure 3-3 Detailed Real-Time Work Flow

3.1.1 REAL TIME DATA ASSIMILATION (DA) MODULE

MIKE 11 includes a data assimilation (DA) module which is used to increase the forecast accuracy of the MIKE models.

In order to improve the estimate of the initial state of the system at the time of each simulation runs and to reduce the simulation errors in the forecast period a data assimilation procedure, or updating procedure, is applied. Data assimilation is a feedback process where the model prediction is conditioned to the observations of the river system (typically water levels and discharge measurements), see Figure 3-3. The benefit of this technology is that the model will match observed data as long as observations exist and apply an error forecast to improve the model prediction in the forecast period.

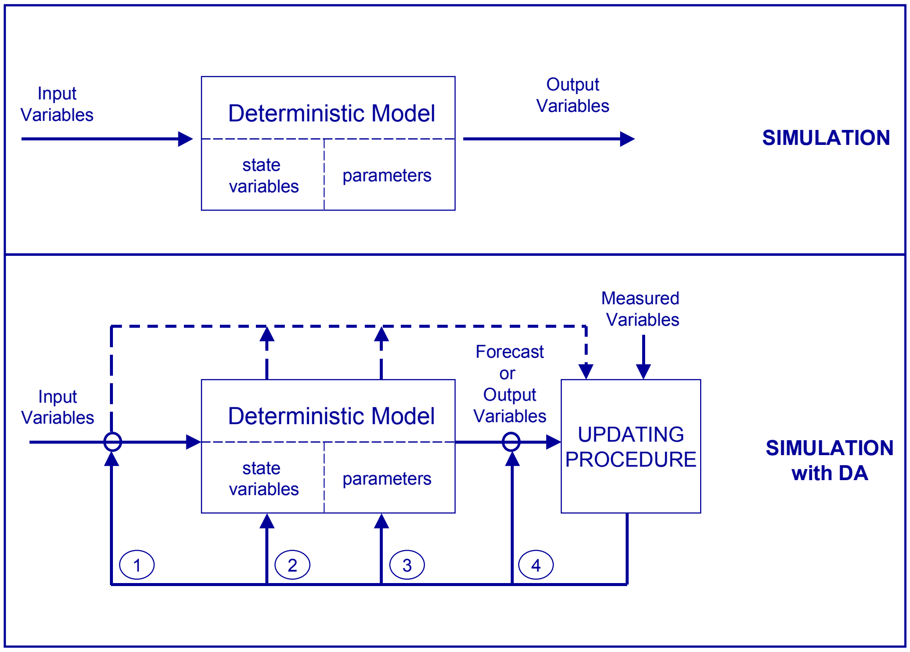


Figure 3-3 State updating in a hydraulic model

The DA module operates on the hydraulic model as a two part process. Up to the time of forecast (ToF), or the last time of measurement, real time measurements, water levels or flows, are compared to those being simulated by the model. Discrepancies between these two values are minimised by an implicit updating of the system state. At the same time, the distribution and variability of the observed errors is analysed and then used to further correct the model output into the forecasting period. The updating and error forecasting operates automatically without need for user intervention. The advantages of this system are:

- Where updating is carried out the data assimilation module ensures a perfect match between simulated and observed values (water level or discharge) up to the time of forecast.

- The update parameters at each monitoring point adapt to the local conditions prevailing locally in time without the need for adjustment of forecasting parameters from one forecast to the next.

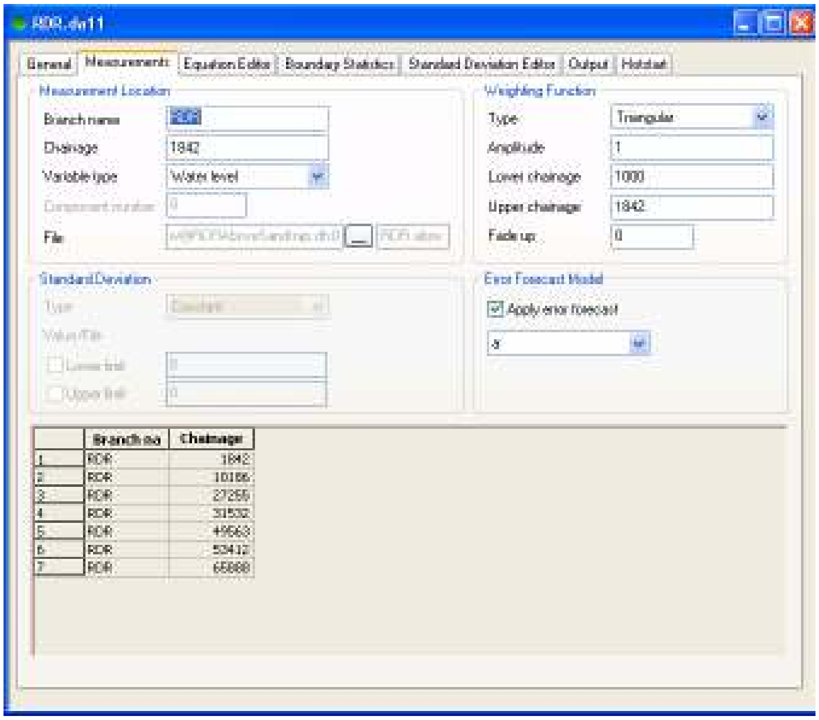
- The data assimilation method runs without any need for user intervention or iteration

- Data assimilation can use either real time discharge or water level data.

- An error forecast model can be defined for each update point to describe both structured and unstructured errors.

- At a given update point, should data not exist up to time of forecast, error forecasting will be initiated earlier, hence taking advantage of all data supplied by the telemetry.

It is standard best practice to include updating in real time forecasting systems and the general experience is that the benefits in terms of improved model forecast accuracy can be substantial.



Branch name: RDR
Chainage: 1842
Variable type: Water level
Component number: 0
File:

Type: Triangular
Amplitude: 1
Lower chainage: 1000
Upper chainage: 1842
Fade up: 0

☑ Apply error forecast

	Branch na	Chainage
1	RDR	1842
2	RDR	10186
3	RDR	27255
4	RDR	31532
5	RDR	49563
6	RDR	53412
7	RDR	65888

Figure 3-4 Data Assimilation setup in the RDR model for real time updating

3.2 USER INTERFACE

A user interface has developed using a set of standard web "building blocks" developed by DHI specifically to allow customised web access to our modeling tools as well as external data systems. These building blocks have been combined into a tool termed the Dashboard Manager (DBM), which facilitates the configuration of web pages to meet specific needs in terms of functionality, look and feel. The DBM includes many controls, including labels, buttons, images, time series plots, tables, GIS maps, animations, hydraulic profiles, gauges, alarms and reports. Each control is populated with data provided by DHI Software tools or third party data sources, as available. For this study a number of specific objects were created which are now part of the DBM library for use in other projects.

The login page of the web-based interface is shown in Figure 3-5. It has a GIS map with selectable items that show the current and forecast state of the system. A message board has been included that allows users to make suggestions, ask questions or post the current status of system items such as gates out of service or suchlike.

Twenty five users are setup with varying degrees of access to certain parts of the interface. The central menu item contains three main selectable options, river inflows, water orders and approvals.

The River Inflows button allows the RDR system operator to view current flows in the Rakaia, South Ashburton and Rangitata River while also shows the current restrictions and allowable take calculated by Environment Canterbury. There is the option to over-ride the current restrictions which is part of the newly agreed self-management regime trial between Environment Canterbury and RDR. The Water Orders button allows the user access to their irrigation scheme water order page. Water orders are for the next 2-7 days, depending on the scheme, and have maximum values associated to the input windows so as errors are minimized.

The Approvals button allows the RDR system operator to override forecast values produced by the model but also values in the current irrigation day. This is an interim stage to build confidence in the forecast predictions but also to allow the RDR operator an override option.

Looking Good!
DHI, the site is proving useful and easy to use.
wrote [illegible] on 21-09-2011 03:38

Water Orders
The population of water order forms with previous orders has now been fixed
wrote DHI on 19-09-2011 09:57

System Testing
Testing underway, comments welcome. Click on Message Board tab above
wrote DHI on 15-09-2011 01:43

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Figure 3-5 Login page of Interface

4 CONCLUSIONS

The RDR ACS is nearing completion and will be a seemless integration of real-time data, a calibrated hydraulic model, a real-time software shell and a web interface. The irrigation scheme operator has the ability to input demands and view the current and forecast flows for of any parts of the system. The RDR operator also has the ability to view the current and forecast flows across the system but has the ability to override any forecasts made by the ACS. The ACS itself carries out full hydrodynamic calculations (in 1D) and produces future set points to deliver an optimised water allocation by balancing supply to demand priorities across the whole scheme.

Control Structures have been widely used throughout the MIKE 11 model and are used to allow the optimisation of structure discharges at the various off-takes.

Data Assimilation is used to increase the accuracy of the forecast by updating the state variables in the hindcast period by using observed measurements.

ACKNOWLEDGEMENTS

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Ben Curry, CEO, Rangitata Diversion Race Management Limited

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