Real-time management of river systems by using a hydrodynamic model with optimisation

by

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Declaration

On submitting this thesis, I declare that this work in its entirety is my own, original work, that I am the authorship owner of the copyright thereof (unless explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

Real-Time management of river systems by using a hydrodynamic model with optimisation

In this research a Real-Time hydrodynamic optimisation model of the Orange-Fish-Sundays River (OFS) system which uses real-time data in order to forecast release hydrographs, is evaluated. The OFS system stretches over three catchment areas in the Eastern Cape namely Great Fish, Little Fish and Sundays Rivers. The OFS supplies water from the Orange River through a 800 km system of canals, tunnels, dams and rivers to registered water users in this area.

In order to cope with increasing pressures on water saving, water demand, water quality and dam safety, the Department of Water Affairs implemented this Orange Fish Sundays-Real Time (OFS-RT) system to calculate the optimal water flow, by running customised Danish Hydraulic Institute (DHI) MIKE11 software. The system utilizes an optimisation module that evaluates the simulated outcome at seven water release structures (dams, weirs and tunnels). Then during the optimisation process performs more adjustments to reach the objectives of the system to obtain the forecast release hydrographs.

This OFS-RT model aims at target based objectives, using:
(i) Hydras real-time field data of dam water levels, river flows and water quality from the area sent to the control office main computer at four hourly intervals via SMS and
(ii) abstractors weekly water requests.

This system takes irrigation and domestic demand into account as well as water quality, evaporation, rainfall, dam levels, dam safety, instream flow requirements and tributary flow. In order to manage the water flows through the OFS system the OFS-RT model forecasts the release hydrographs and uploads the predictions to a website to smooth operational procedures.

The target outcomes were tested and evaluated during this research and it was found that the OFS- RT model succeeded in delivering release forecasts for the seven control structures to manage the OFS system. This research proved that management of river systems by using a real-time hydrodynamic model with optimisation is a useful tool for the optimal utilisation of water resources.

Opsomming

Intydse bestuur van rivierstelsels deur die gebruik van 'n hidrodinamiese model met optimisering.

Die doel van hierdie navoring is die evaluering van 'n intydse hidrodinamiese optimiseringsmodel van die Oranje-Vis-Sondagsrivier (OVS) stelsel wat intydse data ontvang en loslatings hidrograwe verskaf. Die OVS stelsel strek oor drie opvangsgebiede in die Oos-Kaap: naamlik die Groot Vis-, Klein Vis- en Sondagsriviere en voorsien water vanuit die Oranjerivier deur 'n 800 km stelsel van kanale, tonnels, damme en riviere, aan geregistreerde waterverbruikers in die gebied.

Ten einde te voldoen aan die eise van waterbesparings, stygende vraag na water, die verskaffing van goeie water gehalte en damveiligheid, het die Departement van Waterwese 'n intydse rekenaar model (OVS-IT) geïmplimenteer om die optimale watervloei deur middel van die aangepaste MIKE11 sagteware van die Danish Hydraulic Institute (DHI) te bereken. Hierdie stelsel maak gebruik van 'n optimisering module wat die gesimuleerde uitkomste van verstellings aan sewe waterloslatingstrukture evalueer. Met optimisering word die verlangde hidrograaf deur verder aanpassings verkry.

Data wat nodig is om die OVS-IT model se doel te bereik is:
  (i)   Hydras intydse velddata van damwatervlakke, riviervloeie en water gehalte van die gebied ontvang deur die beheerkantoor se hoofrekenaar via SMS elke vier ure, en
  (ii)   water verbruikers se weeklikse wateraanvrae

Die stelsel neem die besproeiing en huishoudelike aanvraag in ag, sowel as soutgehalte, verdamping, reënval, damvlakke, dam veiligheid, stroom vloei vereistes en sytak byvloei. Die OVS se watervloei word beheer deur voorspelde loslatings hidrograwe, opgesom op 'n webwerf wat die uitvoer prosedures aandui.

Die intydse hidrodinamiese model met optimisering het volgens hierdie navorsing daarin geslaag om vir die beheer van die OVS stelsel, die loslatings van sewe beheerstrukture akkuraat te voorspel en bevind dat die model 'n waardevolle instrument is vir die optimale bestuur van waterhulpbronne.

Acknowledgements

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Glossary of Terms

DHI	Danish Hydraulic Institute
DOS	Disk Operating System
DWA	Department of Water Affairs
EC	Electric Conductivity
EOS	End Of Simulation
FISUN	Fish Sundays
FSC	Full Supply Capacity
FSL	Full Supply Level
GB	Giga Bite
GHz	Giga Hertz
GSM	Global System for Mobile
GP	Gauge Plate
HFL	High Flood Level
IFR	Instream Flow Requirement
LSWUA	Lower Sundays Water User Association
MCM	Million Cubic Meters
MOL	Minimum Operating Level
NOC	Non Overspill Crest
OFS-RT	Orange-Fish-Sundays Real-Time
RAM	Read Accesses Memory
SMS	Short Message System
SOS	Start Of Simulation
TDS	Total Dissolved Salts
TOF	Time of Forecast
WL	Water Level
km	Kilometre
m^3/s	Cubic metre per second
masl	Metres above mean sea level
mg/l	milligram per litre
yy/mm/dd	Date: year/Month/Day

1. Introduction

The Orange-Fish-Sundays River (OFS) system is located in the Eastern Cape Province in South Eastern South Africa. The OFS system covers a total of 800km of canals and tunnels as well as four main dams (Grassridge, Elandsdrift, DeMistkraal and Darlington Dam) and three rivers (Great Fish, Little Fish and Sundays River). In this area water from the Orange River is supplied to registered water users, ranging from private individuals, to irrigation boards, and municipal councils.

The river system is controlled from the Uitkeer offices of the Department of Water Affairs (DWA) by using Fish-Sundays (FISUN) software, an in-house water routing model. The control officers used this DOS based software tool to assist them with decision making on water flows. However this in-house developed software FISUN has become inadequate. It was no longer reliable and to move the software from the DOS based environment to Windows created a coding problem. With newer technologies available DWA expected more from the decision making tools. For example water losses in the FISUN were manually calibrated and fixed in the model, the water quality module was not operational and the model did weekly forecasts without optimisation, and without considering the local runoff in the mass balance of the system.

Upon considering the influence of climate change on water resources together with an ever increasing human water demand, DWA set out to upgrade the control officers' decision making tools.
In this research an optimisation hydrodynamic model is evaluated to ensure that the right amount of water of the right quality is supplied on time in the OFS system.

1.1 Literature Study

Before building the OFS-RT model for the OFS system, literature on other existing models in the world were investigated. Various papers were found on computer aided

system forecasting, especially for flood forecasting. Little information was found on optimisation models for flood forecasting and irrigation releases with operational optimisation on multi reservoir systems. This was also observed by Melvill (2006).

In 2007 the International Commission On Large Dams (ICOLD) stipulated the need for real-time water management in the watershed or river basin. Decisions that need to be made regarding releases from reservoir projects to achieve optimum releases to meet domestic, industrial and agricultural demands in the river basin, require an accurate and reliable data management system. (Berga, 2007) These real-time decisions for OFS-RT are driven by real-time data collection, modelling and optimising of release forecasting. These control the dam levels, river flow and quality of the system in real-time.

A flood forecasting model in Tasmania, uses the HYDSTA model on the Pieman River catchment to forecast possible flooding 48hours ahead of time. An automatic alarm system sends SMS's and email the flood warning to the personnel of relevant agencies. The catchment covers $2500km^2$ including 54 dams in the warning system, which gathers information to a central control office database, from where the forecasting is done. The flood warning system undergoes continuous improvement and is evaluated annually to validate the use of the model for the system. (Peterson, 2004) It can therefore be expected that the OFS-RT model will also have to undergo a smooth out process implementation period to improve operations once commenced.

Flood forecasting is done in Korea for multipurpose dams by the KOWACO flood analysis model. The model uses meteorology and hydraulic observations to forecast the weather and to simulate flooding conditions of the system. The flood forecasting is done by rainfall forecasting and runoff forecasting which results in a dam inflow. The dam inflows with the dam stage and downstream conditions plus the dam operational rules are then channel routed. The result is relayed to the flood control office for decision making on flood warning and gate releases. Limited water resources can effectively be used by optimising river regulations and storing flood waters for use in the dry season. (Lee and King, 2004)

The SHYSKA real-time model is used to simulate and predict flash floods in the southeast semi-arid part of Spain. SHYSKA is a GIS-embedded model using real-time hydrometeorological information. A rainfall-runoff model uses a digital elevation model to create the detail of the basin from which flood simulation and forecasting can be done. This model includes soil moisture conditions to improve the runoff model accuracy. Interactions occur between government agencies and civil institutions with the aim to lessen the effects of flooding. This interaction supplies efficient information to improve forecasting of extreme hydrologic risk events, like floods, (Garcia, 2004).

In a review on optimal operation of multi-reservoir systems, Labadie (2004) warns that analytical approaches for most real-world multi reservoir systems are of high complexity and practical applications are difficult. The reviewer also states that with computer technology a greater degree of realism can be accomplished in reservoir system optimisation. This brings the added "curse of dimensionality" with application of dynamic programming and the computational efficiency lowers. When a fully dynamic unsteady flow hydraulic system simulation with optimisation is attempted and a computational nightmare reveals itself. The control of a reservoir system in real-time add more stress on the computational efficiency which is restricted by the clock-time.

In South Africa, the Department of Water and Environmental Affairs (DWA) is responsible for flood management of large area floods. The Vaal- and Orange System comprises 49% of the total area of South Africa and justifies special attention from the Department's Head Office. To do so, a nearly 24 hour operation room monitors weather systems and hydrological data from the catchment area and uses in-house developed software for real time flood routing, but without optimisation. The main objective of the OFS-RT system is to ensure structure safety, minimising damage, whilst guaranteeing the dams are at least 100% full at end of the flood. The system's flood management could be improved (Du Plessis, 2009).

The OFS-RT system is more than just a real-time flood forecasting model. The model has to forecast the day to day operational release for the system in real-time, including

the water quality, which most of the forecasting models do not account for. The computational complexity was softened by state of the art computing power and custom made software for the OFS-RT model. The model has been used in real-time by DWA since July 2008. (Visser and Basson, 2009)

2. Introduction to the Orange Fish Sundays River System

2.1 Physical outline of the area

The Orange-Fish-Sundays (OFS) system covers a total of 800km of rivers, canals and tunnels. This region in the Eastern Cape is supplied with water from the Orange River. Figure 2.1-1 shows a Google Earth satellite image of Southern South Africa with prominent landmarks of the OFS system. The local tributaries carry little water and contribute on average five percent of water volume for the system. Figure 2.1-2 indicates a layout of the topographical area under study. The local tributaries as well as the irrigation return flows contain high concentrations of total dissolved salts (TDS), which make the local water unsuitable for human or irrigation purposes. It is therefore necessary to release better quality water from the Orange River to the Fish Sundays system to flush it. The river network will be discussed in more detail below and in Table 2.1-1.

Figure 2.1-1 View of Southern South Africa with land marks of the OFS system
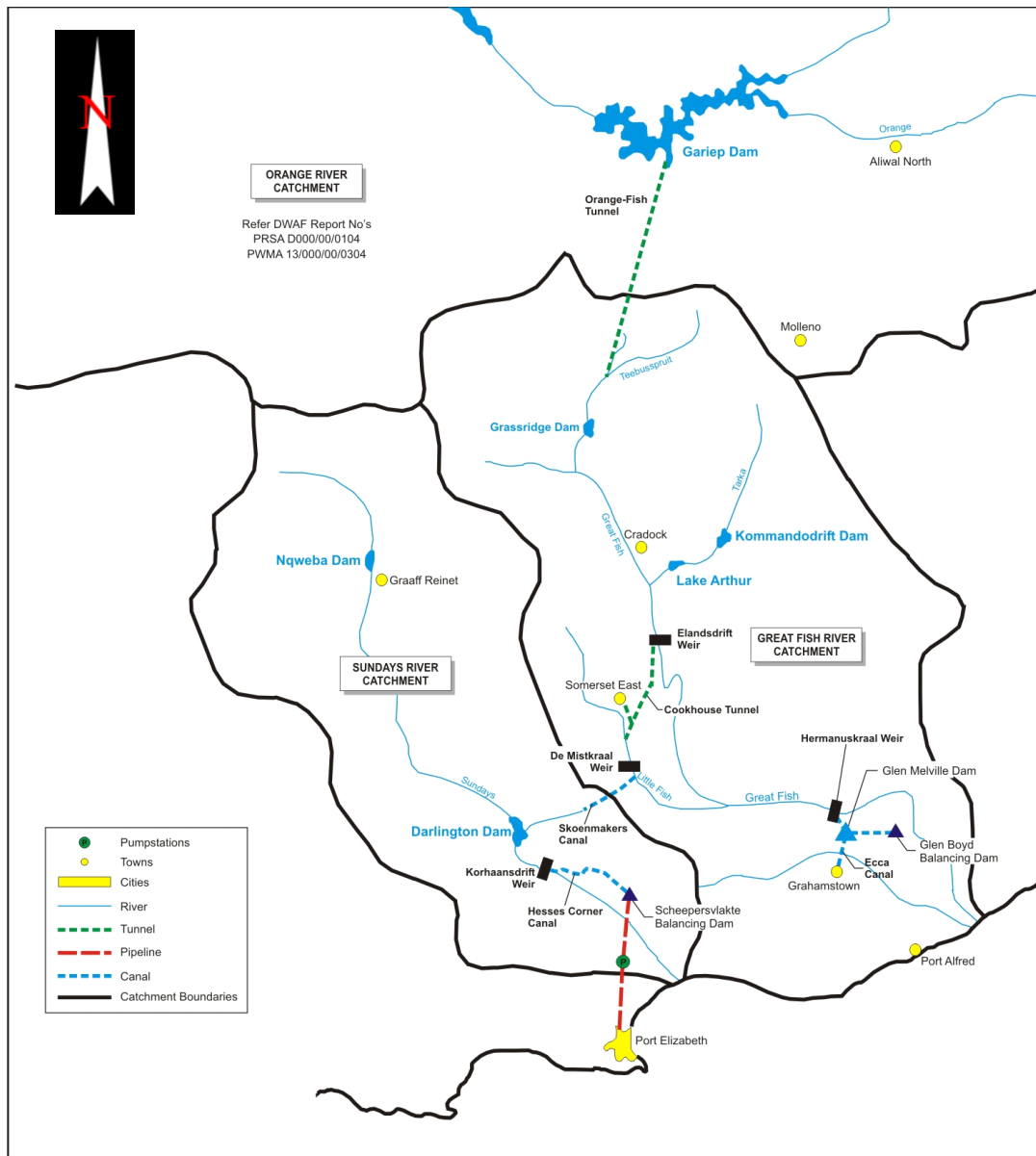
Figure 2.1-2 Layout of the Great Fish and the Sundays River system

The Orange River originates in Lesotho and flows west towards the Atlantic Ocean. Water is dammed at the Gariep Dam, where water is diverted from a tunnel entrance at the town of Oviston to the Eastern Cape Province and exits the tunnel in the Teebus River. This transferred water is then diverted through the natural river channel into Grassridge Dam. Releases are then made from Grassridge Dam down the Great Fish River past Waaikraal Weir and into Elandsdrift Dam. At Elandsdrift Dam water is released further downstream into the Great Fish River and also diverted to the Little Fish river. The water released down the Great Fish River flows past Sheldon Weir and the confluence with the Little Fish River at Junctions Drift. From here the Great Fish

River flows to Fort Brown where it can be diverted to the Glen Melville Dam for Grahamstown's consumption. From Fort Brown the water flows naturally down the Great Fish River to the Indian Ocean. The diverted water at Elandsdrift Dam flows via the Cookhouse Tunnel to the Little Fish River, which leads down to the DeMistkraal Dam. At DeMistkraal Dam water is diverted to the Sundays River, but releases are also made down the Little Fish River to Junctions Drift where the Little Fish River joins the Great Fish. The diverted water from DeMistkraal Dam flows via the Skoenmakers Canal into the Skoenmakers River and ends up in the Darlington Dam on the Sundays River. From the Darlington Dam releases are down the Sundays River to Korhaansdrift from where water is diverted via Scheepersvlakte to Nelson Mandela Bay Metro for consumption.

Table 2.1-1 Layout of Reaches in the OFS System.

	River Name	Start location of reach	End location of reach	Length (km)	Number of users in reach	Average water demand in reach (% of Total)
1	OVIS Tunnel	Gariep Dam	Teebus OVIS Outlet	80	0	0%
2	Teebus River	Teebus OVIS outlet	GrootBrak	29	12	7.61%
3	Groot Brak	GrootBrak	Grassridge Dam	30	4	1.25%
4	Groot Brak	Grassridge Dam	Great Fish River	17	6	4.21%
5	Great Fish River	Great Fish River	Waaikraal Weir	40	5	13.18%
6	Great Fish River	Waaikraal Weir	Elandsdrift Dam	74	12	20.23%
7	Great Fish River	Elandsdrift Dam	Sheldon Weir	146	30	16.3%
8	Great Fish River	Sheldon Weir	Junctions Drift	28	0	0%
9	Great Fish River	Junctions Drift	Fort Brown*	136	12	1.42%
10	Little Fish Canal	Elandsdrift Canal	Little Fish River	45	23	8.77%
11	Little Fish River	Little Fish River	DeMistkraal Dam	41	10	1.01%
12	Little Fish River	DeMistkraal Dam	Junctions Drift	58	12	0.83%
13	Skoenmakers canal	DeMistkraal Dam	Skoenmakers River	28	9	3.67%
14	Skoenmakers River	Skoenmakers River	Darlington Dam	80	9	0.54%
15	Sundays River	Darlington Dam	Korhaansdrift*	49	5	20.97%

* End of model

The Fish-Sundays system includes 4 main dams: Grassridge, Elandsdrift, DeMistkraal and Darlington Dam. Controlled releases are made from these dams to supply the downstream water demands. There are seven release points:

1. Teebus Tunnel outlet

2. River releases at Grassridge Dam

3. Canal releases at Elandsdrift Dam

4. River releases at Elandsdrift Dam

5. Canal releases at DeMistkraal Dam

6. River releases at DeMistkraal Dam

7. River releases at Darlington Dam

The system ends in two main control points: at Ford Brown on the Great Fish River and at Korhaansdrift on the Sundays River, but there is a third downstream control at Junctions Drift on the Little Fish River.

Apart from the Orange-Fish Tunnel transferred water, the local runoff from tributaries together with the upstream parts of the main rivers also contribute to water volume. The tributaries considered in the study are:

- Klein Brak River (upstream inflow)
- Groot Brak River
- Great Fish River (upstream inflow)
- Pauls River
- Tarka River
- Baviaans River
- Little Fish River (upstream inflow)
- Skoenmakers River (upstream inflow)
- Volkerus River (upstream inflow)
- Voël River
- Sundays River (upstream inflow)

A more visual display of the system and the gauging stations used in this study is shown in Figures 2.1-3 to 2.1-13.

Figure 2.1-3 Main river and canal area of the OFS system and stations
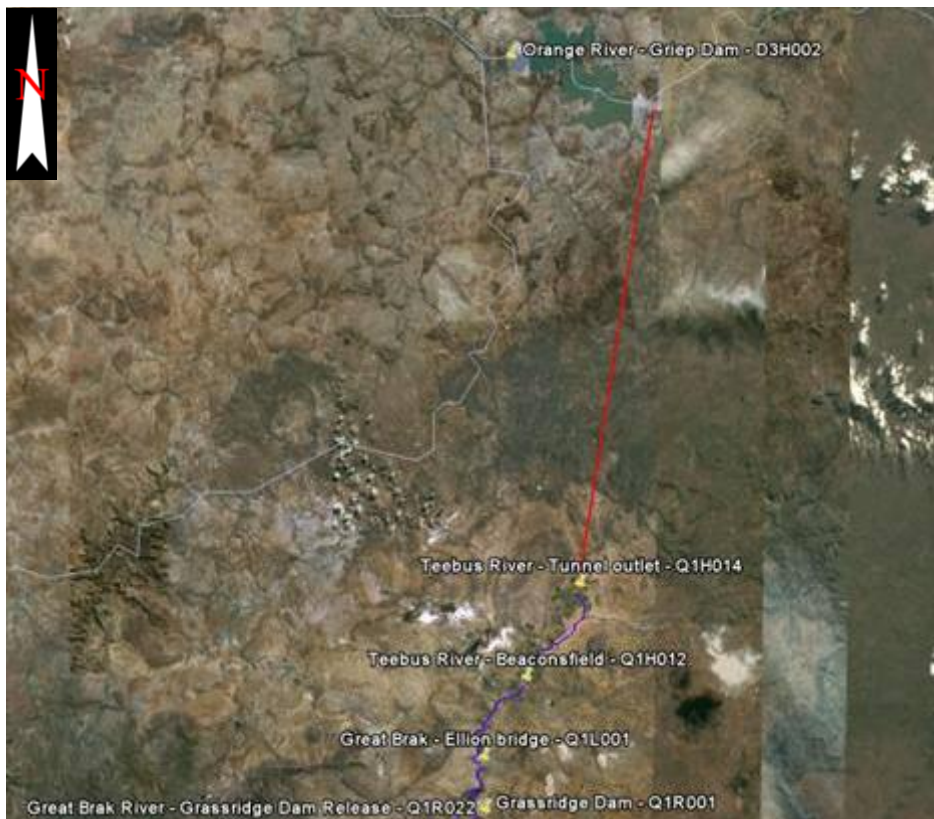
Figure 2.1-4 OVIS tunnel outlet at the start of the study area

Figure 2.1-5 Grassridge Dam to the Great Fish River via Waaikraal

Figure 2.1-6 Waaikraal to Elandsdrift Dam on the Great Fish River

Figure 2.1-7 Elandsdrift Dam close-up on dam stations
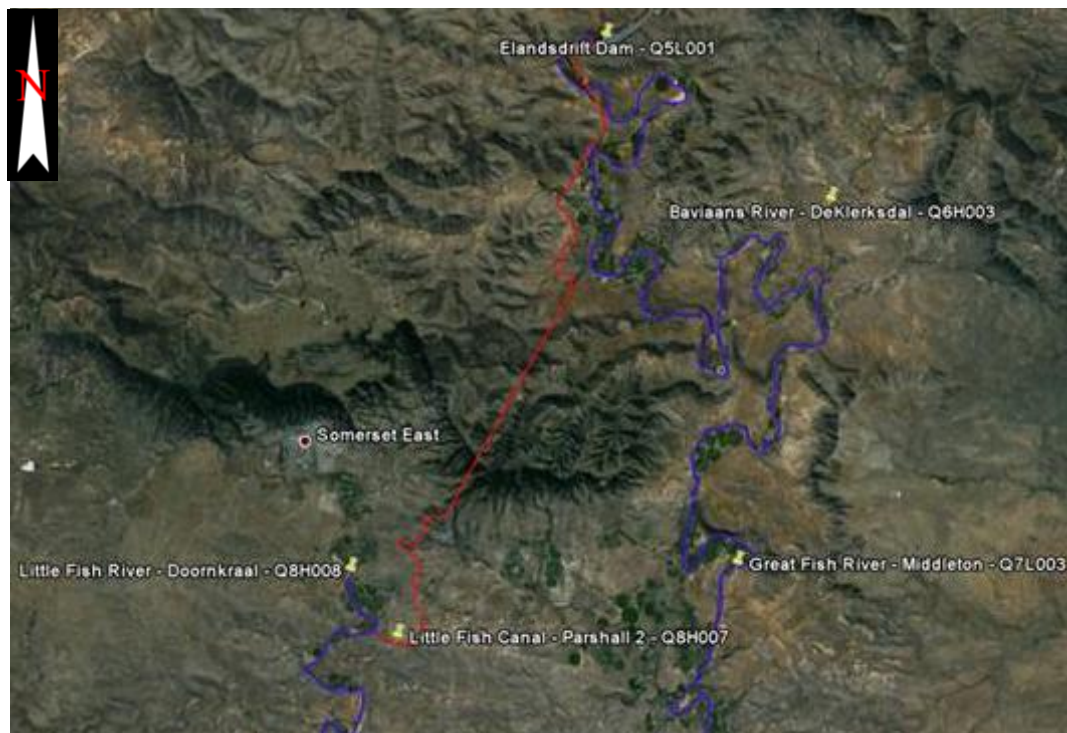
Figure 2.1-8 Elandsdrift Dam diversion to Little Fish Canal and River, modelling continue on the Great Fish River

Figure 2.1-9 Little Fish and Great Fish River joins at Junctionsdrift

Figure 2.1-10 DeMistkraal Dam close-up of dam stations

Figure 2.1-11 Great Fish River from Junctionsdrift to Fort Brown (Study area ended at Fort Brown)

Figure 2.1-12 DeMiskraal Dam to the Sundays River and Darlington Dam (Study area ended at Korhaansdrift)

Figure 2.1-13 Darlington Dam close-up of dam stations

Table 2.1-2 is a list of all the stations and the type of loggers at the station which is used in the OFS-RT model. The tributaries as well as the irrigation return flows have high concentrations of Total Dissolved Salts (TDS), which make the local water unsuitable for human or irrigation purposes. Figure 2.1-14 shows the monitored water quality at Zoutpans Drift in the upper Great Fish River. The values soar well above the 600 mg/l requirement for irrigation. Figure 2.1-15 shows TDS values on the upper Little Fish River, the average being above 1000 mg/l. The concentration of salinity increases as one moves down the system. Due to drier summer months and high salinity concentrations the logger probes became clogged and error readings are obtained from the stations, especially in the lower reaches of the river system.

Table 2.1-2 Field stations loggers

Station number	Station Name	Logger		
		Water Level	Electric Conductivity	Rainfall
D3R002	Gariep Dam	x		
D3R003	Van der Kloof	x		
N2R001	Darlington Dam	x	x	x
Q1R001	Grassridge Dam	x	x	x
Q5L001	Elandsdrift Dam	x	x	x
Q8R001	DeMistkraal Dam	x	x	
Q1L001	Great Brak at Ellion Bridge	x		
Q1H012	Teebus at Jan Blaauwskop	x	x	
N2L001	Parshall no. 3 at Skoenmakers River	x		
N2H010	Darlington Dam Release to Sundays	x		
N2L009	Volkers at Skoenmakers	x	x	
N4H001	Sondags at Korhaansdrift	x	x	
Q1H022	Outlet to Great Brak	x	x	
Q1L002	Great Fish at Kat Kop	x		
Q3H005	Great Fish at Waaikraal	x	x	
Q5L002	Great Fish current gauging site	x		
Q5L003	Great Fish at Mortimer		x	
Q7H005	Great Fish at Sheldon	x	x	
Q7L003	Great Fish at Middleton		x	
Q8L011	Little Fish at Junctiondrift	x	x	
Q9H012	Great Fish at Piggot's bridge	x	x	
Q9L002	Great Fish at Fort Brown	x	x	
N2H007	Sondags at DeDraai	x	x	
N2H008	Riet at Groen Leegte	x	x	
Q1H013	Little Brak at Zevenfontein	x	x	
Q2H002	Great Fish at Zoutpansdrift	x	x	
Q3H004	Pauls at Coutzenburg	x	x	
Q4H013	Tarka at Bridge Farm	x	x	
Q6H003	Baviaans at DeKlerksdal	x	x	
Q8H008	Little Fish at Doornkraal	x	x	
N4H006	Canal from Sondays at Korhaansdrift	x	x	
Q1H014	Teebus tunnel out-let	x	x	
Q5H006	Canal from Elandsdridft Dam	x	x	
Q8H007	Little Fish Canal - Parshall section 2	x	x	
Q8H013	Canal from DeMistkraal Dam	x	x	x
Q9H031	Tunnel outlet at Glen Melville Dam	x	x	
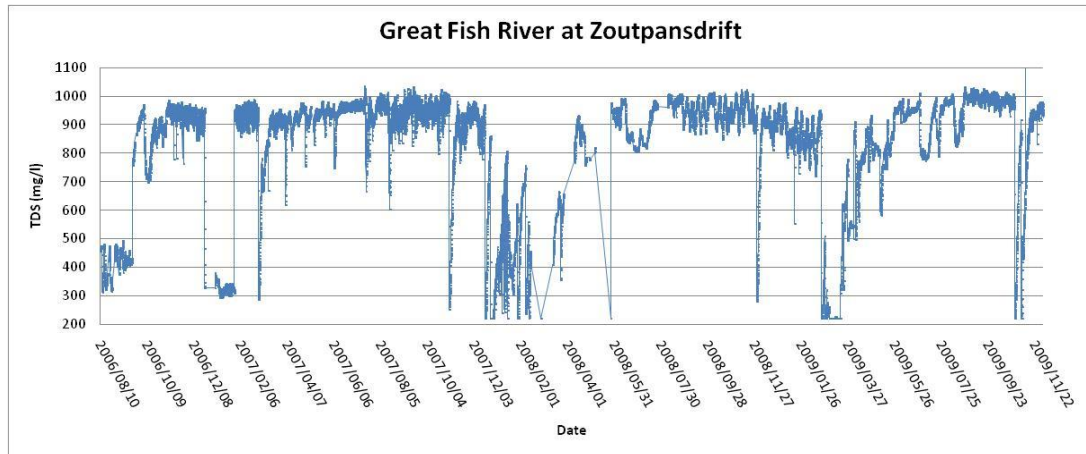
Figure 2.1-14 Observed water quality of Zoutpansdrift on upper Great Fish River
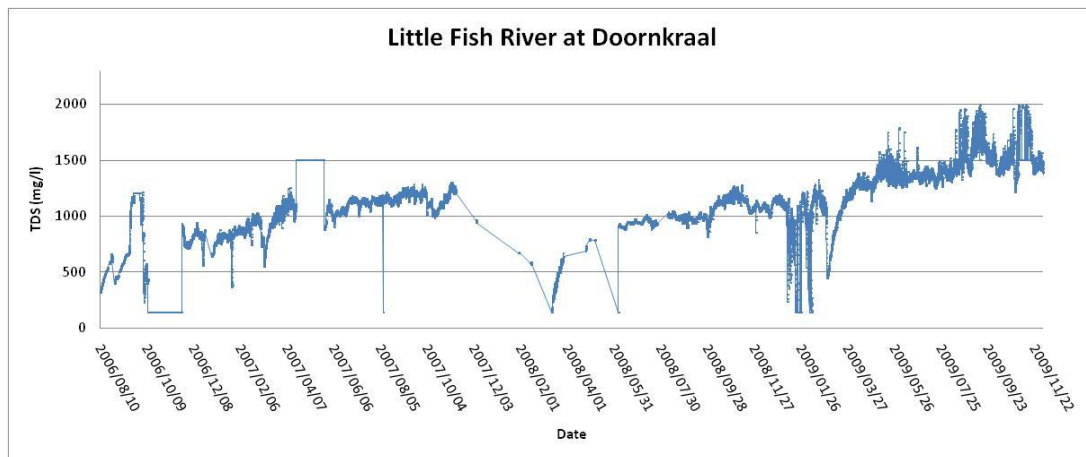
Figure 2.1-15 Observed water quality at Doornkraal on upper Little Fish River

2.2 Objectives

The main objective in this thesis was to evaluate the use of a hydrodynamic optimisation model which could use real-time data in simulations in order to forecast release hydrographs for the OFS system.

Methodology

The methodology followed in this research project was as follows:

- Combine a standard hydrodynamic model with an optimisation module.
- Developed pre- and post processors to deal with real-time data and model outputs.
- Calibrate and validate the model in real-time.

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2.2.1 System operational requirements

In order to improve the state of water in the OFS-System, the current conditions were analysed. It was found that on average enough water was supplied to the users, but large volumes were "spilled" to the ocean. The water salinity also increased from Grassridge Dam to the end of the system and the quality was improved by diluting the local water with transferred Orange River water. This created a good solution for both the volume of required water and the quality desired by users.

The old FISUN decision making tool was refined by using a set of targets. These targets were obtained as inputs from different interest groups. This led to interlocking contradicting target expectations.

The final targets were categorised as follows:

a. Dam safety:

   The catchment areas of the dams are prone to thunderstorms during the summer, resulting in high runoff and large flood peaks. The dams must not fall victim to unexpected floods by overtopping and failing, endangering downstream occupants.

b. Water conservation:

   Release only the minimum water required. When excess water is available store it as high up in the system as possible to limit spillage losses.

c. Water demands:

   The hundred and forty-nine main water users must each receive their quota of water on time as reasonably demanded by them.

d. Water quality:

   The water users require a TDS concentration below 600mg/l. During water transfer from the Great Fish River to Glen Melville Dam the water concentration must be below 300mg/l.

e. Instream flow requirements:

   Instream Flow Requirements were set in place as the minimum water flow needed in the rivers and the required quality.

f. Flexibility:

   All the target values must be set individually for sections of the system and it must be possible to change these easily as priorities change with time.

There are only seven control points throughout the system at which the specified volume of water and quality, as well as timing must be accomplished. It can be noted from the above-mentioned targets that overlapping priorities occur. This dilemma has to be solved by the decision making model and is discussed in section 6.2.

2.3 Configuration of a Hydrodynamic Model

It was decided that a mathematical hydrodynamic model with additional modules would be the best way to combine all the targets into "one equation" and so help the operator. Although there were a few standard hydrodynamic software packages available for the river systems, none combined flood forecasting and dam safety with irrigation demand routing and water quality in real time. When the amount of work and detail needed to set up a user friendly model was considered, it was decided to make use of the Danish Hydraulic Institute software (DHI) with customised upgrades to cover all the required target fields.

A basic hydrodynamic model was set up in DHI's Mike11 software. The Mike series of software consists of different modules to be used as required by users, with Mike11 being a one dimensional (1D) hydrodynamic model from which mass balance flows and water levels can be interpreted. The main rivers, canals, dams and short sections of side tributaries were surveyed and put together to form the Orange Fish Sundays River Real Time (OFS-RT) model area from Teebus Tunnel outlet to Fort Brown in the Great Fish River and to Korhaansdrift in the Sundays River. The area was sub divided into nine reaches. Stretching between existing gauging stations, each reach was then constructed from surveyed river data but for most of the reach, data were captured from 1:50000 maps. The maps only gave detail of the valley and general slopes, neglecting the main river channel. In this instance the river channel was taken as a default trapezoidal shape and the hydraulic characteristics were calibrated to it. Flow calibration was undertaken for the reach with relevant historical flow data. The decision not to survey every kilometre of the system physically was made due to the time delay and cost implications such a survey would have. It was decided rather to calibrate the model hydrodynamically (Melvill, 2006).

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The calibration was done by simulating a river reach with historically gauged upstream water flows in the river and comparing the downstream simulated flow with the downstream gauged flow of the river reach. To match the two sets (simulated and observed) of flows, adjustments to hydraulic roughness and volume gain/losses were made and confirmed by re-simulating with different input data. A calibration example is shown in Figure 2.3-1, from which it can be seen that the observed and simulated flows differ very little (less than 5%) and the calibration factors are acceptable.
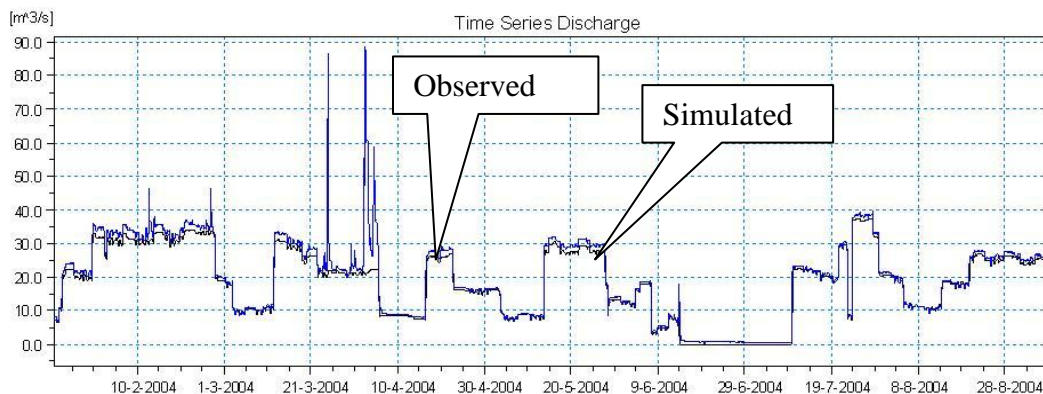
Figure 2.3-1 Calibration of model: observed vs. simulated

At this stage, making use of only historical data, the OFS model was a fully hydrodynamic calibrated model, being able to model flows, dam water levels and water quality. In order to model a river system in real time, one however requires real-time field data on water levels, flows and water quality from the modelled area.

Hydro, a department within DWA, has a real-time monitoring system in place in the country as well as in the OFS catchment area and data could be used for the OFS-RT model. The challenges included transforming this data to real time quality in order for the software to be effective. Hydro also has stations fitted with Global System for Mobile (GSM) equipment which provide data by manually "dialling-in" to the station to retrieve logger data.

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3. Hydras

The Real-Time data for the operational tool is managed by German Hydras Software. With sufficient GSM equipment, the field logger stations communicate with a remote user. The selected 39 stations of the OFS-RT model were fitted with the relevant water level (WL) and electro conductivity (EC) loggers. Rainfall loggers were also added to the system at the four dam sites. Loggers on the river station were calibrated to give flow (m^3/s) of the water and the dam logger stations were calibrated to give dam capacity and dam levels in metres above mean sea level (masl). The water quality data was then converted to TDS concentration (mg/l) from the EC readings.

3.1 Real-time data quality and limits

The authenticity of raw field data is evaluated and confirmed by Hydro experts, before the uninterrupted and accurate data could be released to the public domain for use. However, for the OFS-RT system to be kept real-time 24hours a day, the computer had to be expert in evaluating the data and rules or "Limits" that were assigned to the plausible data. Limits were included so that water levels in the dams and river flows would not be negative and TDS for the dams would not exceed specified maximum levels. When the raw data was out of bounds, the computer reduced it to the limited value and this value was used in simulations. Table 3.1-1 shows the set of limits for each station in the system. The table was derived from historically available data for the stations and then customised as lower and upper thresholds to assist the computer in the validation processes.

Table 3.1-1 Station TDS Limits

Station number	Station Name	TDS (mg/l)	
		Min	Max
N2R001	Darlington Dam	200	700
Q1R001	Grassridge Dam	80	350
Q5L001	Elandsdrift Dam	100	700
Q8R001	DeMistkraal Dam	200	750
N2L009	Volkers at Skoenmakers	161	1823
N4H001	Sundays at Korhaansdrift	104	680
Q1H022	Outlet to Great Brak	80	350
Q3H005	Great Fish at Waaikraal	89	387
Q7H005	Great Fish at Sheldon	54	2589
Q7L003	Great Fish at Middleton	171	1336
Q8L011	Little Fish at Junctiondrift	182	2396
Q9H012	Great Fish at Piggot's bridge	126	1498
Q9L002	Great Fish at Fort Brown	225	2269
N2H007	Sundays at De Draai	89	2277
N2H008	Riet at Groen Leegte	250	3050
Q1H013	Little Brak at Zevenfontein	76	1381
Q2H002	Great Fish at Zoutpansdrift	228	1185
Q3H004	Pauls at Coutzenburg	161	1377
Q4H013	Tarka at Bridge Farm	195	2253
Q6H003	Baviaans at DeKlerksdal	88	1373
Q8H008	Little Fish at Doornkraal	139	1499
N4H006	Canal from Sundays at Korhaansdrift	290	1383
Q1H014	Teebus tunnel out-let	80	204
Q5H006	Canal from Elandsdridft Dam	122	828
Q8H007	Little Fish Canal - Parshall section 2	48	879
Q8H013	Canal from DeMistkraal Dam	206	995
Q9H031	Tunnel outlet at Glen Melville Dam	99	1300

3.2 Obtaining real-time field data

3.2.1 Auto Dialling

To obtain the raw field data, the Hydras software calls the field station and prompts it to provide the latest data. Individual stations can be called manually for retrieving instantaneous values, or can be dialled automatically before each simulation. The automatic dialling can be used as a backup feature to the SMS system, for assuring suitable real-time field data for the decision making tool database.

3.2.2 SMS Receiver

The key feature of the Hydras software is that the field station can automatically send out data via the GSM. All the stations were then set up to send their data at four hourly intervals to the main computer running the Hydras software. The four hour interval for data sending is due to the time the real-time forecasting simulation takes to run to completion and then be ready for the next run. The incoming SMS system requires less effort than dialling for the data.

3.3 Outputs

Hydras collects and manages the system data as mentioned above up to the point of forecasting the next set of release flows. The output files generated by Hydras contains the latest system data available from SMS's or dialling. The data is trimmed according to the limits and extended with the prediction curves in a format for the steering model software.

3.4 Prediction curves

As part of the pre-processor forecast, prediction curves for the field data were developed by Melvill (2006). These curves were applied by the pre-processor to the Hydras data to extend the data from the point where real-time data stopped, to a future point in time for which the forecast for the system was needed. Figure 3.4-1 shows tributary inflow of Q8H008, the recorded data stopped at the 18th 00:00 and the prediction curve forecasted a flow record for the station, for the length of the simulation period.
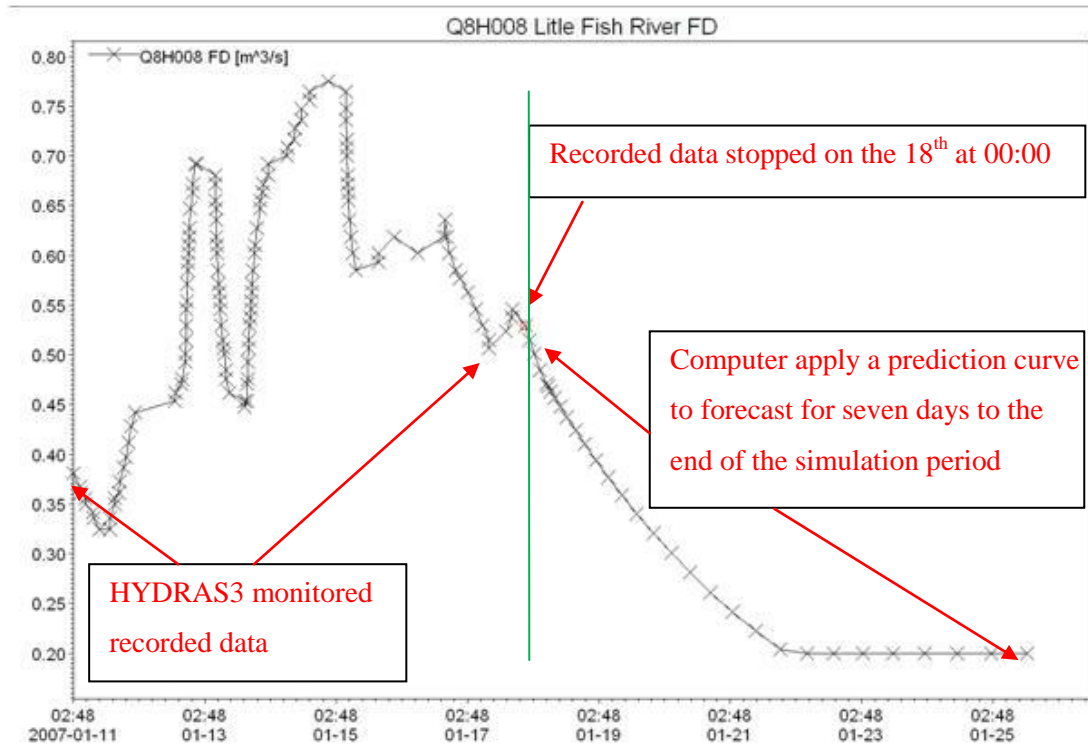
Figure 3.4-1 Prediction curve application on Little Fish River (Q8H008)

3.5 Problems

Some problems arose from the real-time data side, one being the infield measurements of the data and the other being the software processing of the data. The infield EC probes clogged quickly in very high salinity water as is typically found in the tributaries. This resulted in an even higher reading. Due to the remoteness of some of the locations, the GSM which sent through the data also experienced signal problems and loss of communication resulted in no automatic data. The same result occurred when the solar panels were stolen and when other acts of vandalism occurred at the station. In the office some problems occurred due to the continuous updating of the database and over-writing of export files by the Hydras software resulting in unrecoverable "job stall". This could affect all the stations or only one data string. By closing and restarting the software periodically, memory build-up of the software was avoided.

Action was taken to install backup safety systems to cope with as many of the problems as possible.

Hydras as managing software worked well because DWA personnel are familiar with it. It allowed the operator to verify the data that is fed to the steering model or the auto process ran by itself. See Appendix B for a quick user's guide and more details, which were developed as part of this research.

4. Abstraction Pre-Processors

The OFS-RT system's water year starts the first week of July and is divided into weekly water periods. The OFS-RT system has a hundred and forty-nine water users/abstractors. The system supplies water to the users upon their weekly requests which they submit on a Thursday. These water abstractor's water demands vary weekly. The Abstraction Pre-Processors is a custom coded Visual Basic software program imbedded in Microsoft Excel. The aim of the Abstraction Pre-Processor is to consolidate all the requested water demands into one database on a weekly basis. This allows the operator to keep track of the requests and water accounts of water users. The program runs from a main menu guiding the user to the sub menus. After all the requests are entered into the pre-processor, the software compiles a database and output data files in the format which FLOODWATCH can import. FLOODWATCH is the steering modelling software for the new decision making tool. More details are given in chapter five.

4.1 Water Requests

The water requests are the driving side of the pre-processor for they allow the user to enter the water demand on every abstractor's account. The demand flow stream entails a start date (yy/mm/dd), start time (hh:mm), number of hours of flow (h) and flow stream (m^3/h). Each user can have up to eight flow streams per week, starting from Sunday 00h00 and ending Saturday (23:59), a duration of hundred and sixty eight hours. These requests are then added up and validated against the user's water quotas for a week. Figure 4.1-1 shows an example of an abstractors request input screen.

4.2 Water Scheduling

The water streams from the abstractors' requests are summed to a single hydrograph for the week and saved into the database. The scheduling side also displays a graph and table of each abstractor's water demand for the week. Figure 4.2-1 shows an example of the Scheduler screen: Abstractor details, graph and schedule table.

Figure 4.1-1 Example of the water requests data input: date, time, hours and flow rate by an abstractor
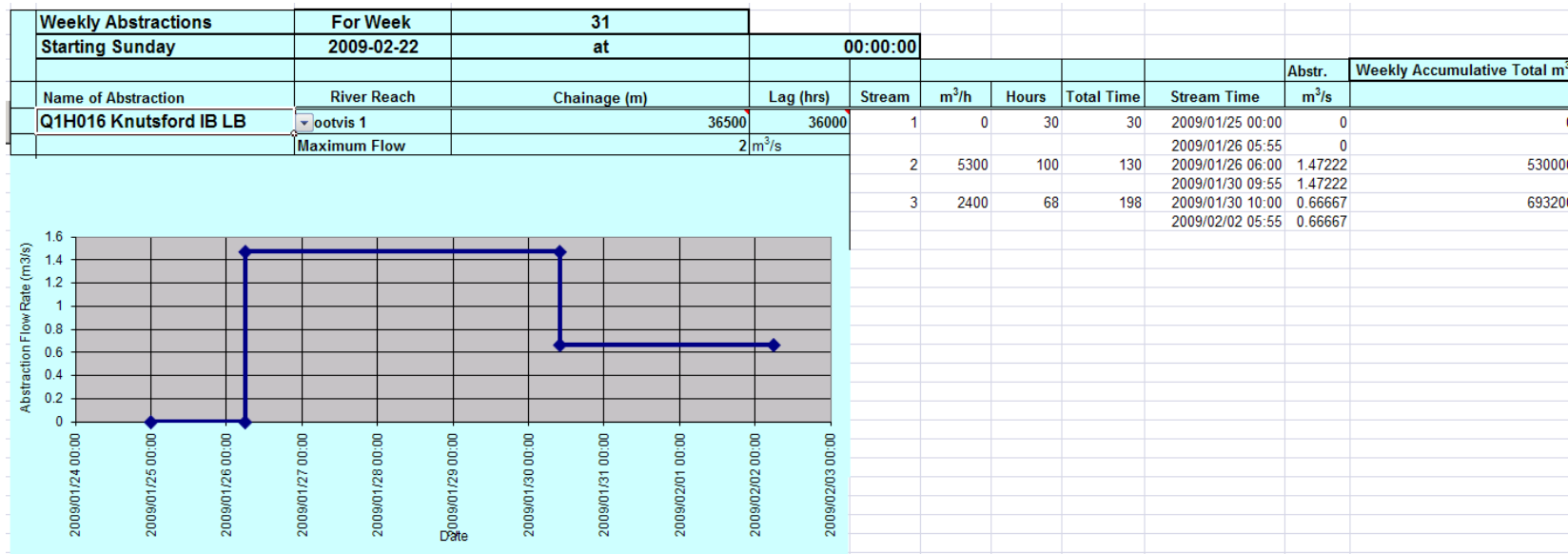
Figure 4.2-1 Example of the water Scheduler: Scheduled flow graph and table for an abstractor

4.3 Water Account

Each water user has an annual water allocation and a maximum demand stream. On the water account from the pre-processor is a summary of all the water users' weekly demands and total demands. The demand for each period is summed for easy viewing and decision by the operator.

4.4 Target Values

The targets selected for the model are entered on the pre-processor and if the targets did not change from week to week, the user can disregard them, for the program will by default use the same targets as for the previous week. Table 4.4-1 and Table 4.4-2 show the selected operating targets with which the systems function harmonically.

The target values for each dam level were derived from an operational practical point or negotiated with dam neighbours. The Full Supply Level (FSL) of Grassridge Dam was fixed on 50% of the full capacity of the dam due to a leak on the dam wall. For purposes of dam safety, the water level should not rise above 50% FSC. When the geotechnical problem is fixed the FSL can be set to 100% of the original design FSC. The High Flood Level (HFL) is to be fixed at the Non Overspill Crest (NOC) of the dam. Elandsdrift Dam has an earth embankment side which is vulnerable to over topping. The minimum water level in the dam due to siltation, left the Minimum Operating Level (MOL) at 70%, to supply the dam with some live storage. The FSL was fixed at 90% and the HFL at the NOC level. This left the dam with a small live storage and some safety during flooding. At DeMistkraal Dam the FSL was fixed at the full supply level and the MOL at a level that would ensure that the canal releases could still be done. The dam was not considered as a high risk during over topping. The HFL was fixed at 268%. The MOL of Darlington Dam was negotiated by Nature Conservation to keep the level of the dam in the park at 25.5%. The FSL was fixed at 24.2% which is the level of the open auxiliary gates when they are in an open position and the HFL at 80% of the full supply capacity. Environmentalists were consulted about the Instream Flow Requirement (IFR) and Total Dissolved Salts (TDS) targets and an agreement was reached by role-players.

Table 4.4-1 Target values for the pre-processor on the dams

Dam	Grassridge	Elandsdrift	DeMistkraal	Darlington
MOL (masl)	1054.62	741.17	549.76	241.50
FSL (masl)	1056.04	471.87	550.96	243.48
HFL (masl)	1058.84	744.00	555.00	246.00

Table 4.4-2 Target values for the pre-processor on the rivers

River	Great Fish River	Little Fish River	Sundays River
IFR (m^3/s)	0.7	0.5	0.5
TDS (mg/l)	600	600	600

4.5 Archiving

After changes were made to the pre-processor, the user has to archive the data. Archiving stores the data to the archive and exports it to water stream files which are imported by FLOODWATCH for simulations.

Running the abstraction Pre-Processor is not compulsory for each simulation except when the requests or targets are changed. It is however necessary at least once a week to enter the week's new requests. See Appendix C for the quick user's guide and more details.

5. Mike 11 Simulations

The core of the work consisted of simulations which were managed by FLOODWATCH. The first steps included the collection of data followed by an initial simulation which ordered the flow data into an initial river flow result. This was then optimised by the AUTOCAL in the optimisation simulation step to generate the best possible output for the system. AUTOCAL is the optimisation module see chapter six.

5.1 Starting simulations

The simulation process starts with FLOODWATCH calling the Pre-Processors and Hydras output files containing the REAL-TIME data. This data is then converted to a format which FLOODWATCH imports into its database. From here FLOODWATCH builds the time series for the simulations. The time series of a simulation contained only the relevant time span for a simulation and not all the data in the database. At the starting point of the simulation, the operator wants forecasted hydrographs from the time the simulation will be completed (in four hour's time), for seven days into the future.

   To summarize:

   Real-Time data is send through to the computer, validated and stored to a database. More than 20 minutes could pass since the last readings were taken and in addition it is known that the simulation will take up to four hours to complete, so the real-time data is not up to the same point in time as the time the forecasting has to be made for. The hydrodynamic model however needs data to cover the full length of the simulation period.

FLOODWATCH then extends the time series from the point the real-time data stops according to predetermined rules. Previous simulation data is used for dam levels and dam TDS of which the last reading value was taken as a constant for the period. The tributary flows are extended according to the prediction curves which can be seen in Figure 5.1-1. The release points hydrographs are extended from the previous simulation and then the last value of the graph is taken as a constant to the time of forecast (TOF). From the TOF, FLOODWATCH extends the hydrograph with the value -999999 (Figure 5.1-2). This -999999 value triggers a switch function in the

model to stop modelling flow data and to use AUTOCAL to control the flow at the control structure. These time-series extensions are also part of the robustness of the model, for if the real-time stations' data does not enter the database, FLOODWATCH can still perform forecasting based on a good estimation for the system.
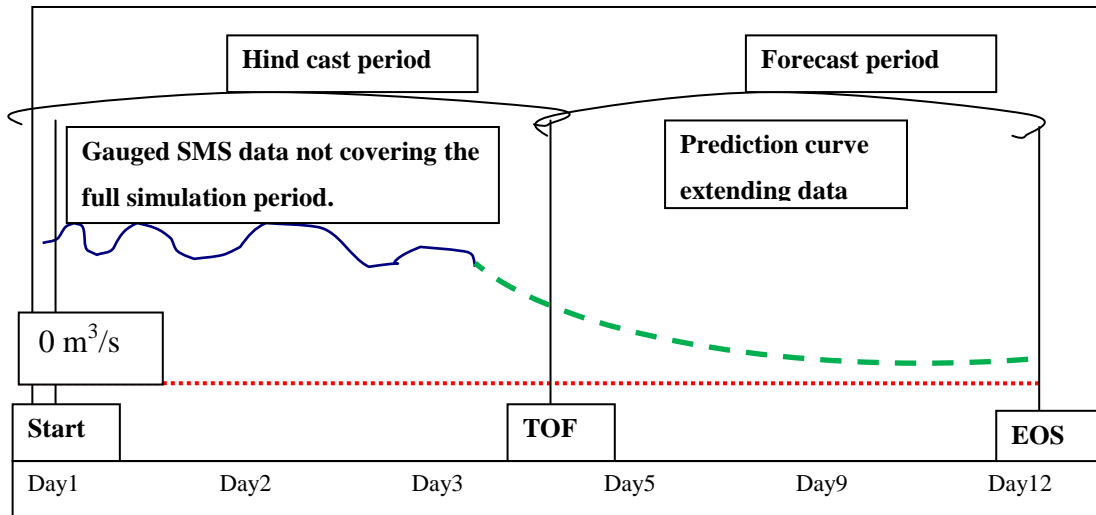
Figure 5.1-1 Time series with observed data and extended to cover the full simulation period
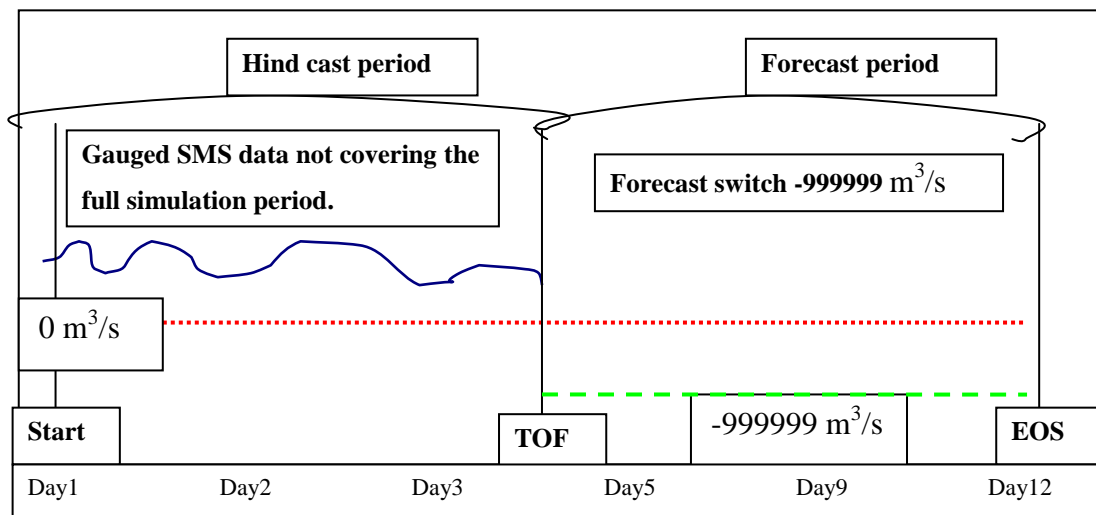
Figure 5.1-2 Time Series with switch from observed to variable values

(When the "file value" < 0 m³/s AUTOCAL controls the structure)

The model is a hydrodynamic model using water flows and quality with evaporation as input data and simulates to optimise flow releases at the control structures at the dams. The model does not include rainfall-runoff module, for a real-time rainfall

forecasts over a wide spread area such as the Karoo the required number of inputs and accuracy is difficult to accomplish. Instead the model uses the actual recorded flow.

5.2 Initial simulation

The data for the initial simulation was drawn from the FLOODWATCH database by using the monitored four days' data from start time of simulation (SOS) to the Time of Forecast (TOF) for Data Assimilation; a clever way to build the current flow quality and dam levels data into the simulation by routing the known water data through the system. The initial simulation then lags all the water demands from the TOF to the EOS to its release points. Starting from the lowest release point it determines the reservoir volume shortage to reach the desired minimum operating level (MOL). The shortage is then lagged up to the next release point as an additional demand and the back calculation continued until it reached the Teebus tunnel release which is the highest release point of the system.

Once these Initial Releases of water were calculated, they were simulated through the system and the Simulation result (Initial Results) was saved to the FLOODWATCH database.

5.3 Optimisation Simulation

The Optimisation Simulation draws its data from the FLOODWATCH database which included the Initial Results from the Initial Simulation. Optimising the system can only be accomplished by increasing or decreasing the seven release points flow. The Optimisation Simulation uses the AUTOCAL Module of FLOODWATCH to adjust the seven releases using the Initial Results as a basis. The Optimisation Simulation routed the seven adjusted released hydrographs through the system. This new result was evaluated against the set targets for water levels, TDS and IRF, by the AUTOCAL and thereafter the releases were readjusted. This totalled 295 simulations in the four hours available between simulations. The optimum system release hydrographs and the simulation were approved and saved to the database for post-processing. A schematic drawing of the data flow and module interaction for a

simulation loop is illustrated in Figure 5.3-1. A quick user guide is attached in Appendix D.
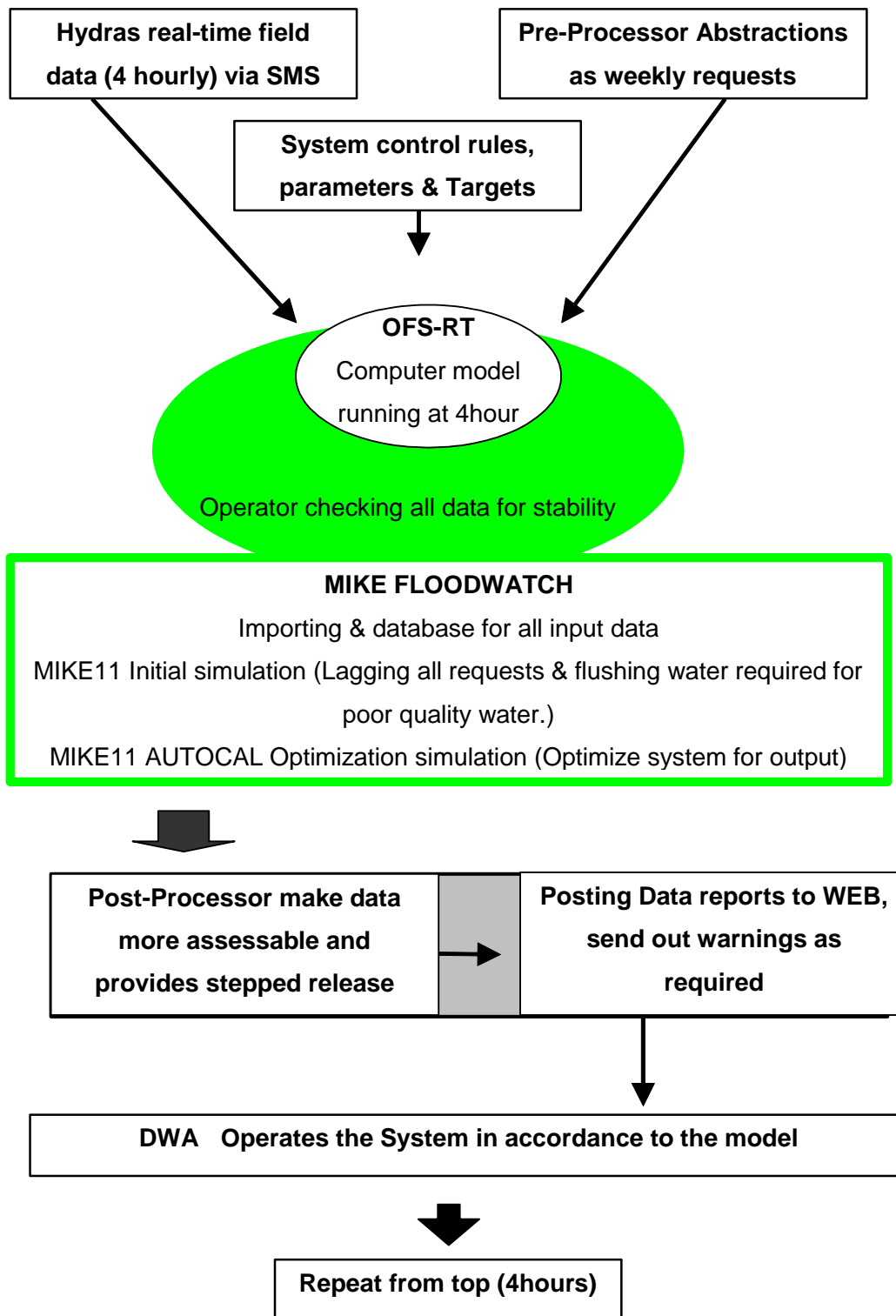
Figure 5.3-1   Schematic of module interaction

6. Optimisation methodology of AUTOCAL

The Optimisation Simulation set up in MIKE11 has the AUTOCAL module implemented. The AUTOCAL adjusts seven release structures with their specified release parameters and then evaluates the outcome of the adjustment during the optimisation and performs more adjustments to reach the objectives of the system and obtain the required flows.

6.1 Model Parameters

The seven release points of the model were set up as variables and the model parameters consisted of a set of permissible variations which each point can undergo during optimisation. In order to start, the initial forecasted flow hydrograph used, was obtained from the initial simulation during the optimisation process. It can also be obtained from the previous "best" result of the evaluation. From the initial forecasted flow hydrograph, forty-three variance parameters were used to create the statistical population for an evaluation loop.

6.2 Targets

To achieve the Objectives and Targets, the development of the system was approached as follows:

a. Dam safety

The catchment area of the dams is prone to scattered thunderstorms during summer, leading to high runoff and large flood peaks. The dams must not fall victim to unexpected floods by over topping and failing, endangering downstream occupants.

This resulted in a two step high water level system, one the Full Supply Level (FSL) which can be reached and spilling occur, two a High Flood Level (HFL) not to be reached during flooding. Figure 6.2-1 illustrates a schematic layout of the target levels. A Minimum Operating Level (MOL) in the dams was implemented which was the targeted level for normal operating dam water level for the model.
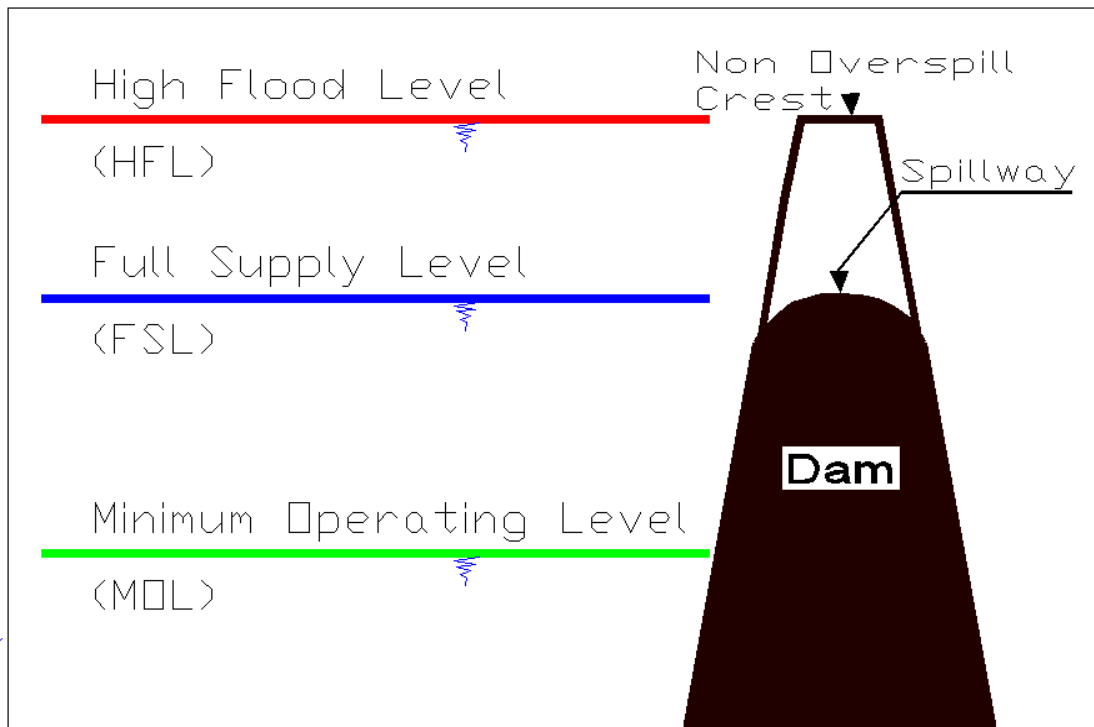
Figure 6.2-1 Schematic dam water level targets

The HFL should not be higher than the dam's non overspill crest (NOC) but can be at a lower level determined for the specified dam. The FSL is by definition at the spillway or dam full supply capacity level. For the model the FSL could be lower than the spillway crest. At the FSL the model stops to divert water into the dam. The model aims the dams' levels at the MOL and recharges the dams when the level drops below the MOL. The operational volume for the model is between MOL and the FSL.

b. Water conservation

By releasing only the minimum required discharge and compensating for natural losses and return flows in the system, water can be saved. If excess water in the system occurs it is stored as high up in the system as possible, i.e. storing water firstly in Grassridge then in Elandsdrift, DeMistkraal and Darlington Dams. Excess water in the Orange River is defined as the spilling of Van der Kloof Dam, in this case, flow may be diverted through the tunnel to the OFS system and the excess protocol is followed.

c. Water demands

The hundred and forty-nine water users must each receive their quota of water on time as reasonably demanded by them. This is controlled by an Abstraction Pre-Processor which scheduled the flows. The flow modelling is assisted with water lag tables for each of the users. A lag table is the predetermined travel time a demanded volume of water will need to flow from its release point to the abstractor. This flow time is affected by the overall flow in the river, e.g. if the river flow is high, the demanded release volume reaches its destination more quickly than during low flow conditions.

d. Water Quality

The water users require a TDS concentration below 600mg/l, except during water transfer from the Great Fish River to Glen Melville Dam where quality must be below 300mg/l. The OFS system operator's method to maintain the desired water quality is to dilute the systems' water with water from the Orange River of which the TDS is below 200mg/l.

With excess water in the system the quality will be improved by releasing more water than required under normal conditions from the dams and which flushes the river reaches. The first flushing occurs from DeMistkraal Dam downstream on the Little Fish to Junctions Drift lowering the TDS concentration. If excess water persists, the flushing process continues in the Great Fish River and Sundays River. By executing this process the excess water flowing to the ocean is put to use to improve the quality of the aquatic ecosystem.

e. Instream Flow Requirements

Instream Flow Requirements (IFR) are set in place as the minimum water flow needed in the river is $0.7m^3/s$ at 600mg/l. The requirement control points are set up at Fort Brown weir and Korhaansdrift weir at the end of the system. A third point is set up at Junctionsdrift at the downstream end of the Little Fish River. In order for the IFR to pass at the three control points successfully entailed that the flow had to pass through the system meeting the IFR upstream as well.

f. Flexibility

The target values must be set individually and it must be easy for the operator to alter them as priorities change with time.

The target values were built as variables and interfaced in the Pre-Processor for the operator to edit. Each of the four dams had three control target water levels (twelve in total) and one quality target. In addition to this, there were also quality controls at three IFR locations (seven quality controls). Besides the main targets, control switches were built into the model to communicate operating rules to the model and operated as follows:

- Is the tunnel operational from Gariep Dam to Teebus River and is water available from Gariep Dam? (Yes or No) The tunnel could be closed for maintenance or operational restraint.
- If there is excess water during spilling of Van Der Kloof Dam, water may be transferred through the tunnel to the OFS system? (Yes or No)
- Is Darlington Dam's auxiliary spillway gates operational or closed for the period? (Open or Closed)

6.3 Objective Functions

The Targets are built into mathematical Objective functions which are used during the evaluation of simulations. AUTOCAL uses a penalty system to allocate values to targets not met. In order to allocate appropriate penalty values for different targets, the objective functions are scaled by weights to produce equal penalty values. The different targets are also scaled with weights to emphasize priority targets, see Figure 6.3-1 which shows the objective function window. First, all unmet targets get scaled to a dimensionless value for the target location, then a priority is added to the value to emphasize the deviation on the objective. Table 6.3-1 shows the Objective functions priority weights and Table 6.3-2 the scaling weights to de-dimension the targets. This is done by calculating each dams storage fraction as a percentage of the systems total storage, for each target the sum of the four dams equal to one. These dimensionless objectives exist in order for the four dams to be seen at equal risk base. During the evaluation a simulation scenario result is compared to the objectives time step by time step, deviations on the objective are then penalized accordingly. All scores for a

simulation add up to a single Objective function value. For the best scenario this value is zero, all targets are met during the simulation. When the objective value is penalised with the priority weights it emphasizes the importance of a specific objective. For instance, the HFL of a 1000 overrules the TDS quality of 10 by a factor of hundred. The FSL overrules the MOL with a factor of three and the MOL overrules the TDS with a factor of ten.

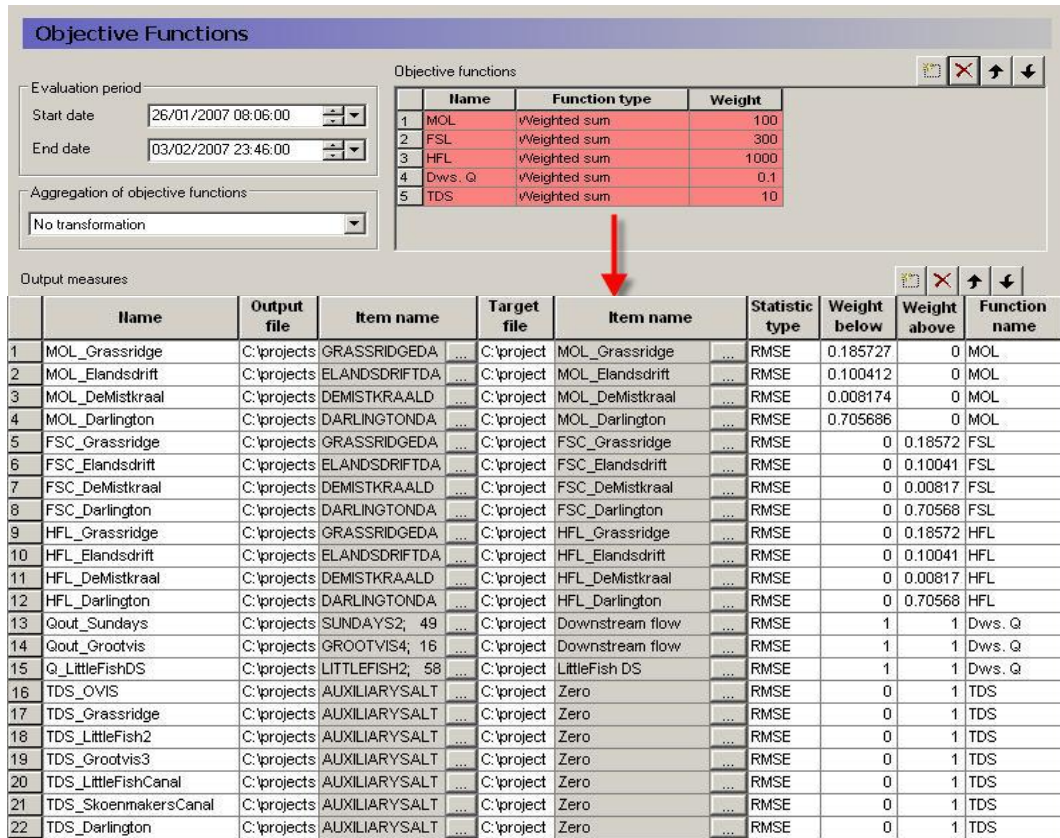**Figure 6.3-1.Objective functions window**

Table 6.3-1 Objective Function priority weights

	Objective	Weight
1	HFL	1000
2	FSL	300
3	MOL	100
4	TDS	10
5	Downstream IFR	0.1

Table 6.3-2 Objective Function scaling weights

		Weight below	Weight above
1	HFL Darlington Dam	0	0.705686
2	HFL Grassridge Dam	0	0.185727
3	HFL Elandsdrift Dam	0	0.100412
4	HFL DeMistkraal Dam	0	0.008174
5	FSL Darlington Dam	0	0.705686
6	FSL Grassridge Dam	0	0.185727
7	FSL Elandsdrift Dam	0	0.100412
8	FSL DeMistkraal Dam	0	0.008174
9	MOL Darlington Dam	0.705686	0
10	MOL Grassridge Dam	0.185727	0
11	MOL Elandsdrift Dam	0.100412	0
12	MOL DeMistkraal Dam	0.008174	0
13	Downstream IFR	1	1
14	TDS	0	1

6.4 Simulation Loops

The AUTOCAL module controls the optimising simulations. At start up it reads the initial simulation for a starting flow release hydrograph. Then from the model parameters it builds 42 parameter sets to the simulation population for the first loop. After the 42 simulations have being completed the AUTOCAL module receives the outcomes of these 42 simulations and evaluates them and obtains the "best" parameter set. With the "best" result known this was the first loop! Based on the above results this optimisation iteratively repetitively by finding the "best" result. Using the previous "best" result the AUTOCAL calculates a new population of 42, simulates it and evaluates it. Figure 6.4-1 shows a simulation window where the first loop of 42 simulations was completed and evaluated and the next set has been calculated and submitted for simulation. In this example the best objective function value is 37.8 and the worst objective function value is 19000. Seven loops will be done or the process will be repeated until convergence is found. This takes just less than four hours to run.

During testing it was found that convergence under normal system conditions starts to occur after 210 simulations in 5 loops. Under more extreme conditions convergence requires more time. The best of the parameter sets are used to do a final simulation which will then be approved by the model as the optimised result. A quick user guide with step by step operations of the system is attached in Appendix F.

The above simulation calculations are computatinally intensive. That is why the model was implemented on a DELL Precision 490 workstation with two Quad core Intel® Xeon® E5345 2.33GHz processors and 4 GB of RAM. This processing power is supported by a 320 GB hard drive storage capacity and an uninterrupted power supply of 4 hours battery operation. With the DHI software package this level of computing power is appropriate. Appendix A has all the hardware and software specifications used on the system.
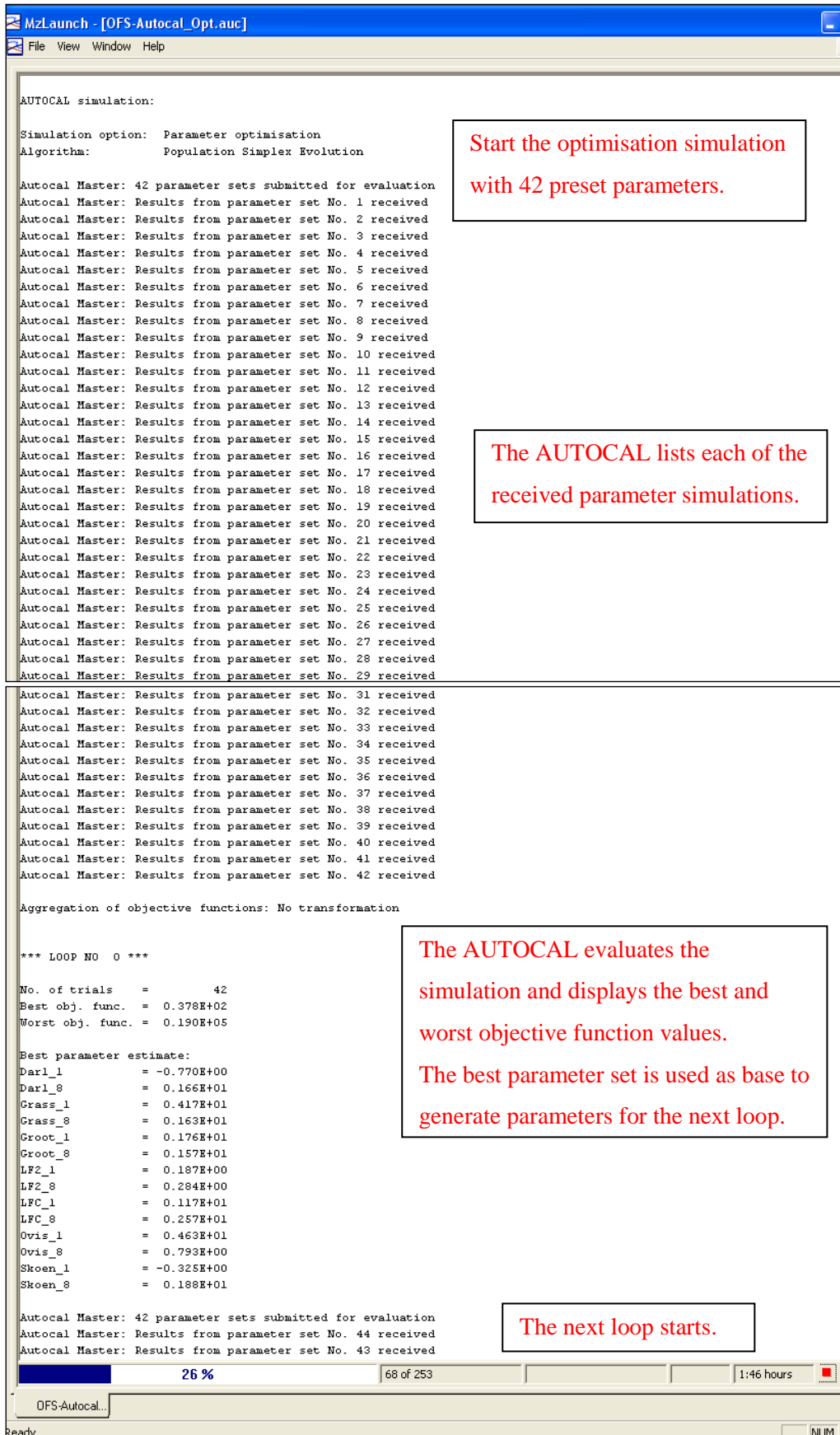
MzLaunch - [OFS-Autocal_Opt.auc]

File   View   Window   Help

```
AUTOCAL simulation:

Simulation option:   Parameter optimisation
Algorithm:           Population Simplex Evolution

Autocal Master: 42 parameter sets submitted for evaluation
Autocal Master: Results from parameter set No. 1 received
Autocal Master: Results from parameter set No. 2 received
Autocal Master: Results from parameter set No. 3 received
Autocal Master: Results from parameter set No. 4 received
Autocal Master: Results from parameter set No. 5 received
Autocal Master: Results from parameter set No. 6 received
Autocal Master: Results from parameter set No. 7 received
Autocal Master: Results from parameter set No. 8 received
Autocal Master: Results from parameter set No. 9 received
Autocal Master: Results from parameter set No. 10 received
Autocal Master: Results from parameter set No. 11 received
Autocal Master: Results from parameter set No. 12 received
Autocal Master: Results from parameter set No. 13 received
Autocal Master: Results from parameter set No. 14 received
Autocal Master: Results from parameter set No. 15 received
Autocal Master: Results from parameter set No. 16 received
Autocal Master: Results from parameter set No. 17 received
Autocal Master: Results from parameter set No. 18 received
Autocal Master: Results from parameter set No. 19 received
Autocal Master: Results from parameter set No. 20 received
Autocal Master: Results from parameter set No. 21 received
Autocal Master: Results from parameter set No. 22 received
Autocal Master: Results from parameter set No. 23 received
Autocal Master: Results from parameter set No. 24 received
Autocal Master: Results from parameter set No. 25 received
Autocal Master: Results from parameter set No. 26 received
Autocal Master: Results from parameter set No. 27 received
Autocal Master: Results from parameter set No. 28 received
Autocal Master: Results from parameter set No. 29 received
```

Start the optimisation simulation with 42 preset parameters.

The AUTOCAL lists each of the received parameter simulations.

```
Autocal Master: Results from parameter set No. 31 received
Autocal Master: Results from parameter set No. 32 received
Autocal Master: Results from parameter set No. 33 received
Autocal Master: Results from parameter set No. 34 received
Autocal Master: Results from parameter set No. 35 received
Autocal Master: Results from parameter set No. 36 received
Autocal Master: Results from parameter set No. 37 received
Autocal Master: Results from parameter set No. 38 received
Autocal Master: Results from parameter set No. 39 received
Autocal Master: Results from parameter set No. 40 received
Autocal Master: Results from parameter set No. 41 received
Autocal Master: Results from parameter set No. 42 received

Aggregation of objective functions: No transformation


*** LOOP NO  0 ***

No. of trials    =         42
Best obj. func.  =  0.378E+02
Worst obj. func. =  0.190E+05

Best parameter estimate:
Darl_1           = -0.770E+00
Darl_8           =  0.166E+01
Grass_1          =  0.417E+01
Grass_8          =  0.163E+01
Groot_1          =  0.176E+01
Groot_8          =  0.157E+01
LF2_1            =  0.187E+00
LF2_8            =  0.284E+00
LFC_1            =  0.117E+01
LFC_8            =  0.257E+01
Ovis_1           =  0.463E+01
Ovis_8           =  0.793E+00
Skoen_1          = -0.325E+00
Skoen_8          =  0.188E+01


Autocal Master: 42 parameter sets submitted for evaluation
Autocal Master: Results from parameter set No. 44 received
Autocal Master: Results from parameter set No. 43 received
```

The AUTOCAL evaluates the simulation and displays the best and worst objective function values.
The best parameter set is used as base to generate parameters for the next loop.

The next loop starts.

26 %   68 of 253   1:46 hours

OFS-Autocal...

Ready   NUM

Figure 6.4-1 Simulation Window of the AUTOCAL Optimisation

7. Post-Processors

After the simulations are done the raw output data has to be processed for the users to generate the output into Release Hydrographs. This is done by the Release Rescheduler module and web based imbedded Microsoft script programs started by the approval message from the Optimised simulation. These operations follow directly after the simulation to give user friendly web outputs.

7.1 Release Rescheduler Module

The Optimum Release Hydrographs' outputs are given at five minute intervals, but it is not possible to make these small field adjustments every five minutes manually. The acceptable normal operational adjustments allowed by DWA are: No adjustment should be smaller than 0.2 m^3/s and only three or less adjustments per working day of DWA (7:15 to 16:15) are allowed. This is where the Release Rescheduler Module, a custom coded Visual Basic software program imbedded in Microsoft Excel, plays a role. The Release Rescheduler looks at each release point of the optimum hydrograph over the forecasted 168 hours (seven days). It defines the three possible adjustment times under normal conditions, during working hours, or if the reservoir is under flood threat, every thirty minutes. The Release Rescheduler then places the three adjustments to follow the optimum hydrograph as closely as possible and minimising the flow volume with the time difference from the optimum to the new hydrograph. This is done by looping through 10000 scenarios of adjustments for the period. The volume of water of the optimum hydrographs and the new release hydrographs will be the same for the seven days. The operational rules for the Release Rescheduler can be adjusted in the Post-Processor as follows:

- The minimum adjustment discharge can be changed on the system
- The number of adjustments in a day can be altered
- The work day hours can be changed
- Flood mode switch reservoir water levels can be altered
- The flood mode adjustment interval can be edited

The output is saved as graphs and table format in *.htm files, which will be discussed in Section 7.3 Flow Release Presentation.

7.2 Dam Data Presentations

7.2.1 Dam levels

The water levels of four dams in the system were output by the Optimising Simulation as water level above mean annual sea level (masl). The users and operators of the dams use the dams' local gauge plate level (GP) or the % of water volume in the dam. The final dam level graph output contains seven days of historical hind-cast dam water level and seven days of the new forecasted dam water level with the target levels (MOL, FSL, HFL) for fourteen days. The graph is then converted to gauge plate and % of water volume. This is done for all four dams and saved as *.htm files for web upload.

7.2.2 Water quality

Seven days of the observed water quality in TDS (mg/l) from HYDRAS as well as the forecasted period's simulated water quality data were combined to create the water quality output graphs. The graphs of the four dams and the three downstream control points also included the target levels for the two periods in the output. The graphs were saved as *.htm file ready for web upload.

7.3 Flow Release Presentation

From the Hydras database and the Release Rescheduler Module's output, *.htm files were saved for web upload. These files contain the data for:

- Tunnel Flow
- Dam Release
- Instream Flow Requirements

7.3.1 Tunnel flow

The Tunnel flow file contains a summary table of the transferred water for the year and a graph of the last weeks' observed flow from HYDRAS. The summary table consists of:

- The irrigation year start date
- The available data's end date
- Total transferred water through the Teebus tunnel

- Excess water transferred through the tunnel

The summary table and the graph were saved as 'Tunnel-1.htm' and read for web upload.

7.3.2 Dam Release

The seven release hydrographs from the Release Rescheduler Module containing the optimised simulation hydrograph as reference with a release schedule table for the release to be made over the forecasted period were saved. Figure 7.3-1 shows an example of a forecasted dam river release at Grassridge Dam.

Date & Time	Discharge (m^3/s)
2008/10/24 13:05	49.6
2008/10/25 08:25	51.6
2008/10/25 11:25	46.2
2008/10/25 15:45	12.2
2008/10/26 07:50	12.8
2008/10/26 12:05	15.6
2008/10/26 15:40	35.6
2008/10/27 07:05	60.2
2008/10/27 11:55	54.4
2008/10/28 07:15	37.6
2008/10/28 13:20	22.2
2008/10/29 09:25	30.6
2008/10/29 12:35	35.0
2008/10/29 15:50	51.6
2008/10/30 07:05	42.6
2008/10/30 11:40	53.4
2008/10/30 16:00	28.4
2008/10/31 07:05	11.8
2008/10/31 09:45	11.6
End of Simulation	

Figure 7.3-1 River release at Grassridge Dam

7.3.2 IFR

The Post-Processor created flow and water quality graphs for the three control points. Each of the graphs contained seven days of HYDRAS observed data, the simulated forecast period's data and the target value for the control point. These six graphs were saved as *.htm files ready for web upload.

7.4 Monitored System Data

The water flow and quality data of all the tributaries and upstream monitored stations were collected from HYDRAS and plotted per station. These graphs were saved into one file as Tributaries.htm for upload to the web.

7.5 Web based output

The OFS-RT software tool forms part of the DWA infrastructure for water management. As part of the Post-Processors operations the system's output data were published to the web in real-time for the authorised users to view and be informed of the current state of water.

7.5.1 Website framework

The web site consists of a main page with fixed sub menu system which guides the user through the site for different data display options. The simulated and observed data are contained in variable files and are updated with every simulation to the site. The main page has log in requirements. Then there is the sub index page from where the browser can find menu options for:

- Release
- Dam info
- system TDS
- Tributaries
- OFS Tunnel summary
- Simulation summary
- Log out

From these menus the web site selects available data grouped under the menu and displays to the browser, e.g. under 'release' the browser will find Elandsdrift Dam Canal and River releases separately, under the Dam info menu Elandsdrift Dam's water level, Canal and River releases and TDS graphs will be displayed.

7.5.2 Administration of website

The web site was implemented on the Stellenbosch University server. The address and login details of the site are:

http://www.sun.ac.za/OFS-RT

Username: ofs

Password: rt

7.5.3 Updating of website data from simulations

The last part of the Microsoft script which was started at the approval of the Optimised simulation opened the FTP transfer script. This connected to the Internet and replaced the existing data on the web site with the latest version of the Post-Processor's output data.

7.5.4 Uploading of special data

The web site also has the ability for one user to share limited compacted data in Zip-data format with other authorised users.

7.5.5 Additional data on project

The last page of the web site is general informative data on the OFS-RT system. This contains a short abstract map view of the area and also a Google Earth fly over video. A print out of the web site is attached in Appendix E.

8. Testing the model for implementation

Different scenarios were artificially imposed on the model to simulate extreme conditions and additional protocols were developed for evaluating the outcome.

8.1 Testing of AUTOCAL optimisation

For testing the model's optimisation principles the AUTOCAL's population size and number of loops were queried. A series of tests were done on the OFS-RT set up with population sizes of 16 to 60.

In Figure 8.1-1 a & b The Objective function values of runs with different Population sizes, for the same model conditions were plotted. The decrease in the objective value over time is visible; in this case for every population the value starts low and rises with every simulation in the population. In the next loop it starts lower and the process is repeated. Figure 8.1-1b shows a blown up version of the convergence point and one can see that there were small value improvements occurring after 220 simulations.

The required population size is empirically developed from these simulations. The minimum population size would be the number of variables, but this results in a sub-optimal condition and faster convergence. Figure 11.8-8b shows that Run 9 with a population size of 20 convergence sub-optimally quickly in 120 simulations. Run 5 with a population of 40 reached lower Objective function values over more simulations. The final selection is a compromise between fast convergence and a best optimised condition.

From the above tests it was found that the OFS-RT model converges in the population size range of 28 to 44 with 220 or more simulations (see Figure 8.1-1 a &b).

47
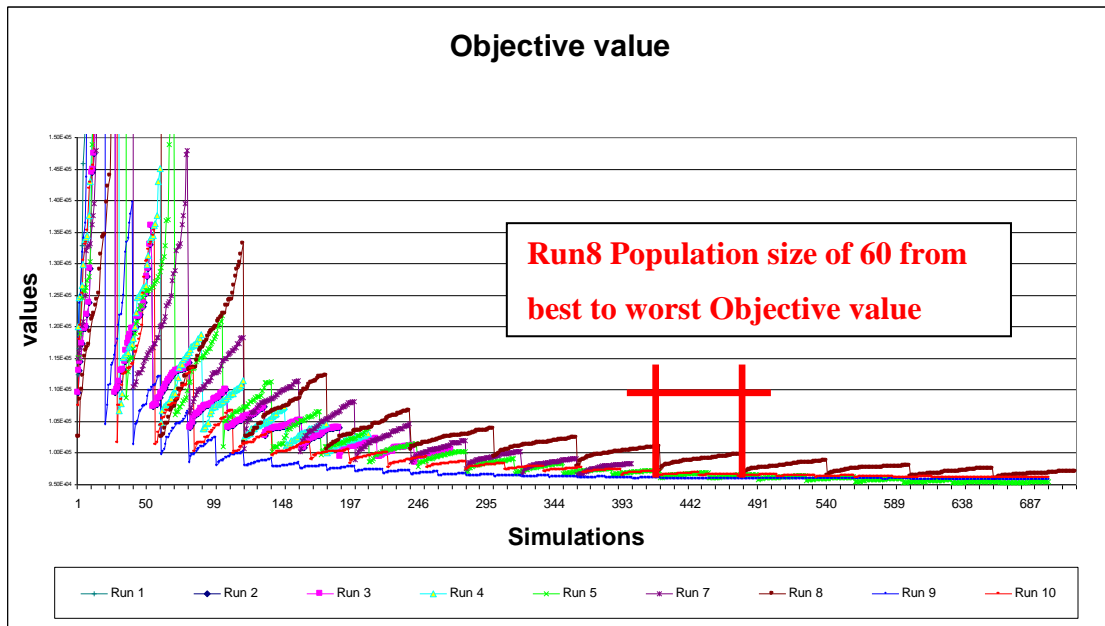
Figure 8.1-1 a. Objective values for tested population sizes
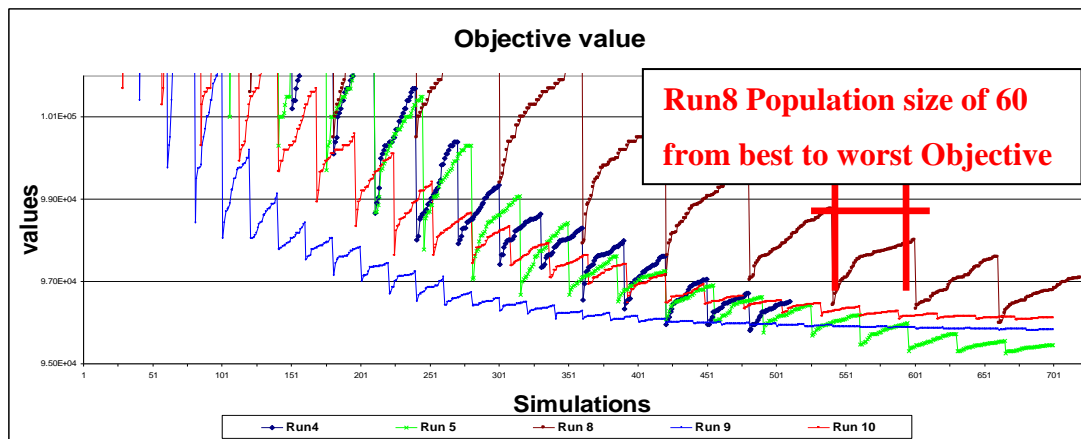
Figure 8.1-1 b Objective values for tested population sizes, zoomed on convergence spot

For the best usage of the DELL workstation running the OFS-RT model in under 4 hours from the time of receiving data to producing the output, 7 of the 8 cores are being fully harnessed with the simulation set up as follows: Population size of 42, which gives 6 simulations per CPU core for each Loop to run. The number of simulations to fit into 4 hours is 294. This gives seven Loops of population generation. After all the evaluations are done, the best scenario is simulated and the result is given as output, giving a total of 295 simulations. When the computing power

increases or if the 4h real-time window increases these values can be adjusted to find a new balance for best optimised condition.

8.2 Evaluation during floods

Dam safety considerations mean that the model must be able to "handle" floods and warn the operators of the flood risk

8.2.1 Flood set up

Three floods were simulated in the system during the wet period of 26 Feb to 5 March 2006 at gauging stations N2H007 (Upper Sundays River), Q8H008 (Little Fish River) and Q2H002 (Upper Great Fish River). The flood peaks of these floods were: 1530 m^3/s, 1200 m^3/s and 900 m^3/s respectively. The flood peaks were determined from statistical analysis of the flow gauging station data and represent 1:100 year floods. In reality, however, the 1:100 year floods are much larger, based on deterministic and empirical methods. The floods that were added to the system are shown in Figures 8.2-2 to 8.2-4. Figure 8.2-1 is a map showing where the floods were introduced.
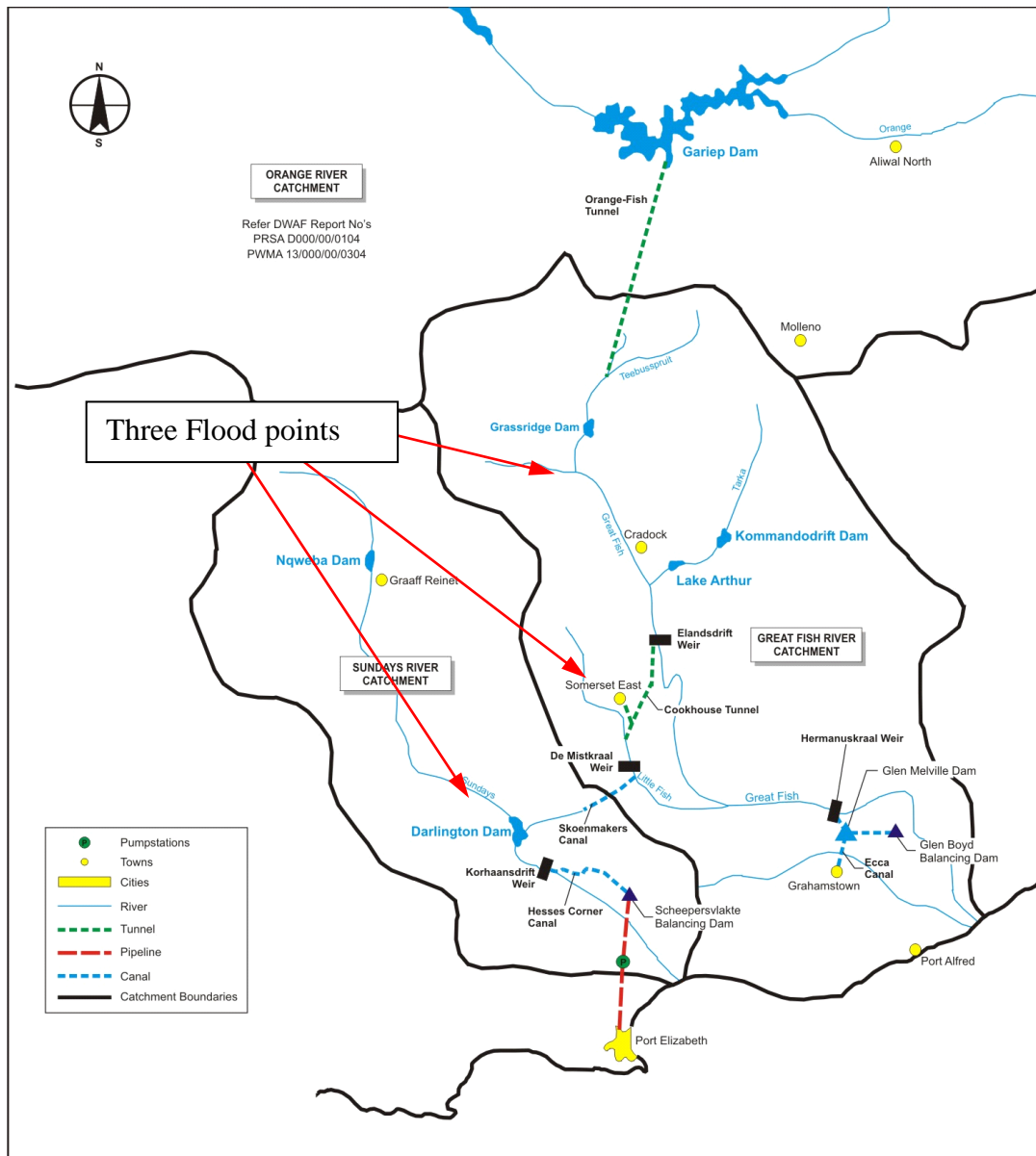
Figure 8.2-1 Map of three artificial flood locations
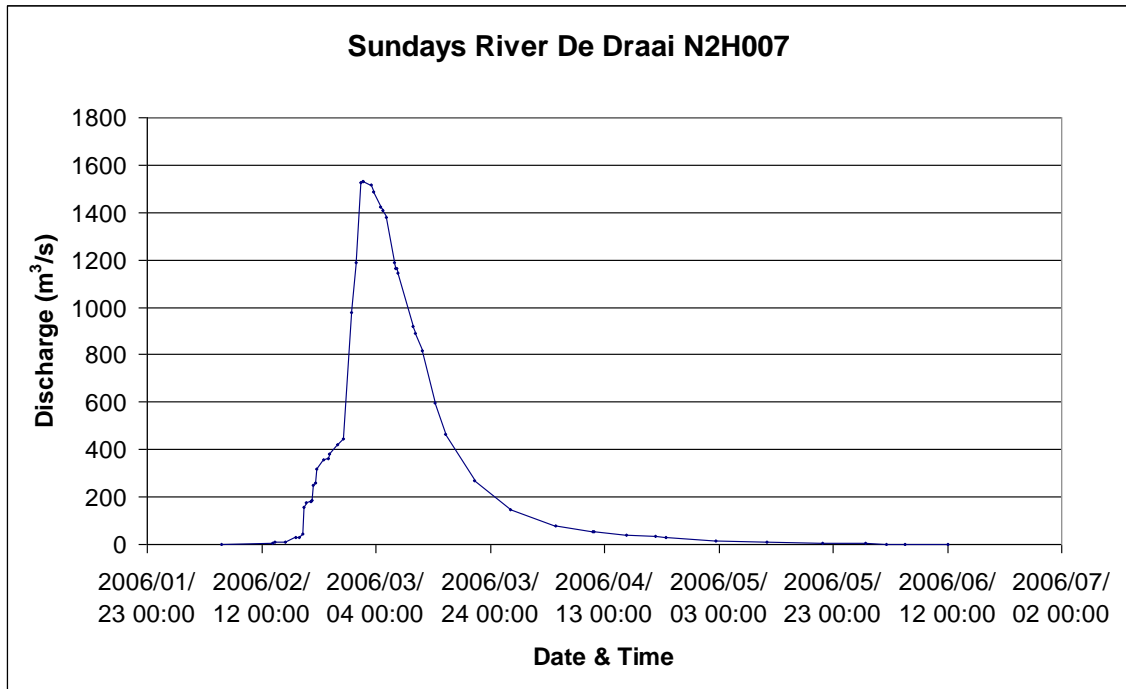
Figure 8.2-2 Flood added at upper Sundays River (N2H007)
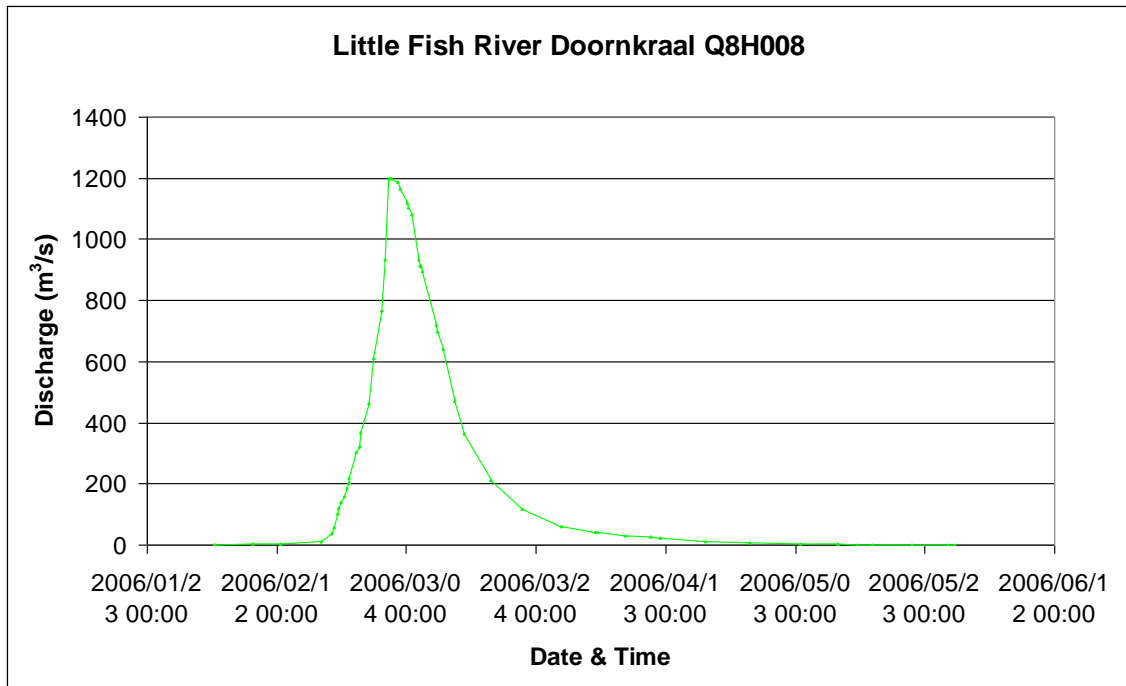
Figure 8.2-3 Flood added at Little Fish River (Q8H008)

51
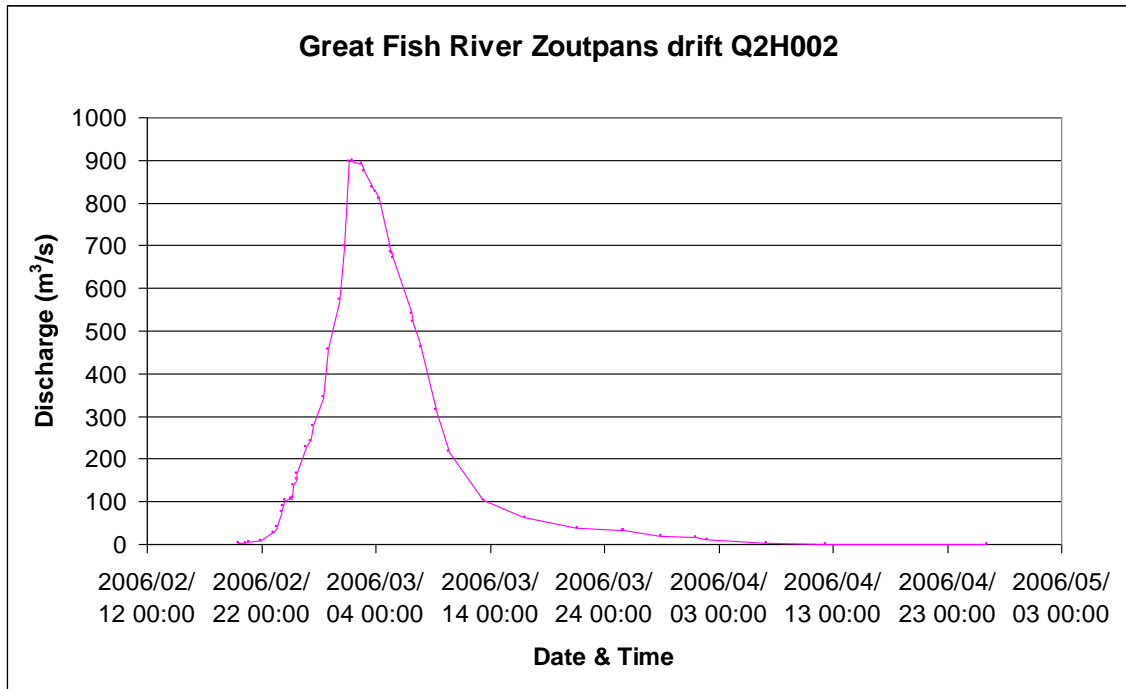
Figure 8.2-4 Flood added at upper Great Fish River (Q2H002)

The results of the floods simulated at each dam are described below:

8.2.2 Grassridge Dam

During this test no flood was added upstream of Grassridge Dam and normal operation was experienced. In Figure 8.2-5 the Grassridge Dam water level is shown in black on the left hand scale (masl) and on the right hand scale the discharge (m^3/s). Teebus Tunnel flow is indicated in green and Dam river release flow in blue. The Dam starts below its MOL (in pink) and fills up from the Teebus tunnel releases.
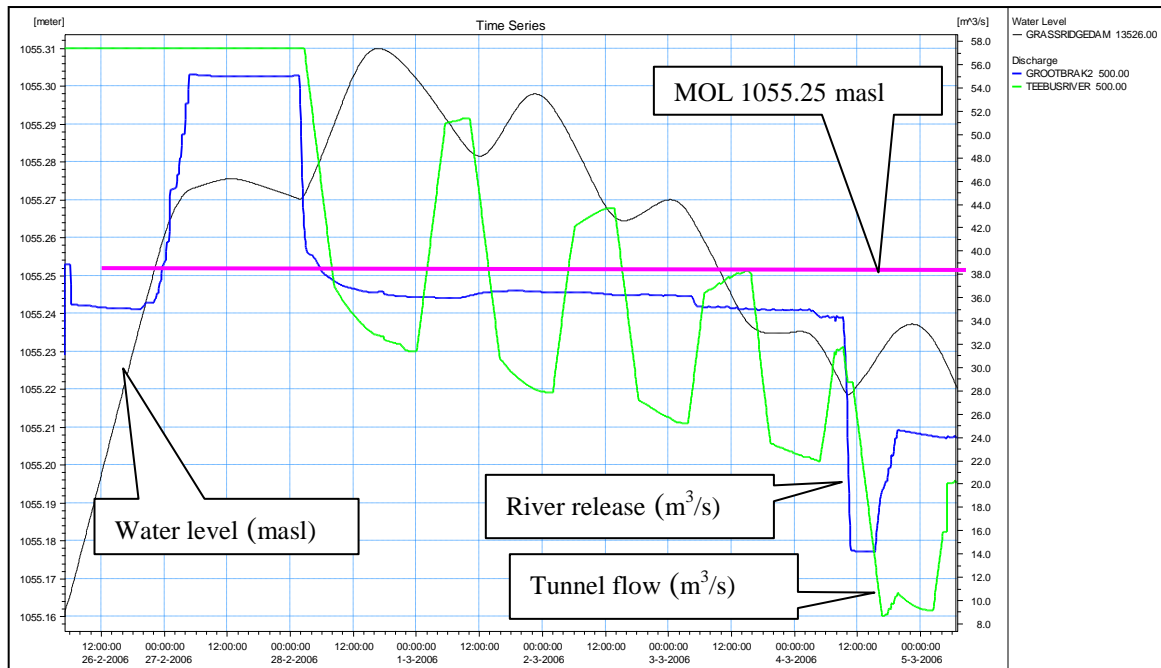
Figure 8.2-5 Grassridge Dam's simulated water level, Teebus Tunnel flow & Dam release

8.2.3 Elandsdrift Dam on the Great Fish River

The high inflow during the flood test caused Elandsdrift Dam to fill up to its FSL and it started to release water through the radial gates (Figure 8.2-6). At the beginning of the flood the water level was drawn down to the safe level below the FSL and the river release spillage out of the system was kept to a minimum. During the whole flood duration the Canal releases to DeMistkraal Dam were at a maximum to transfer water to DeMistkraal and Darlington Dams where water could be stored safely. The water level in the dam did not reach the HFL.

53
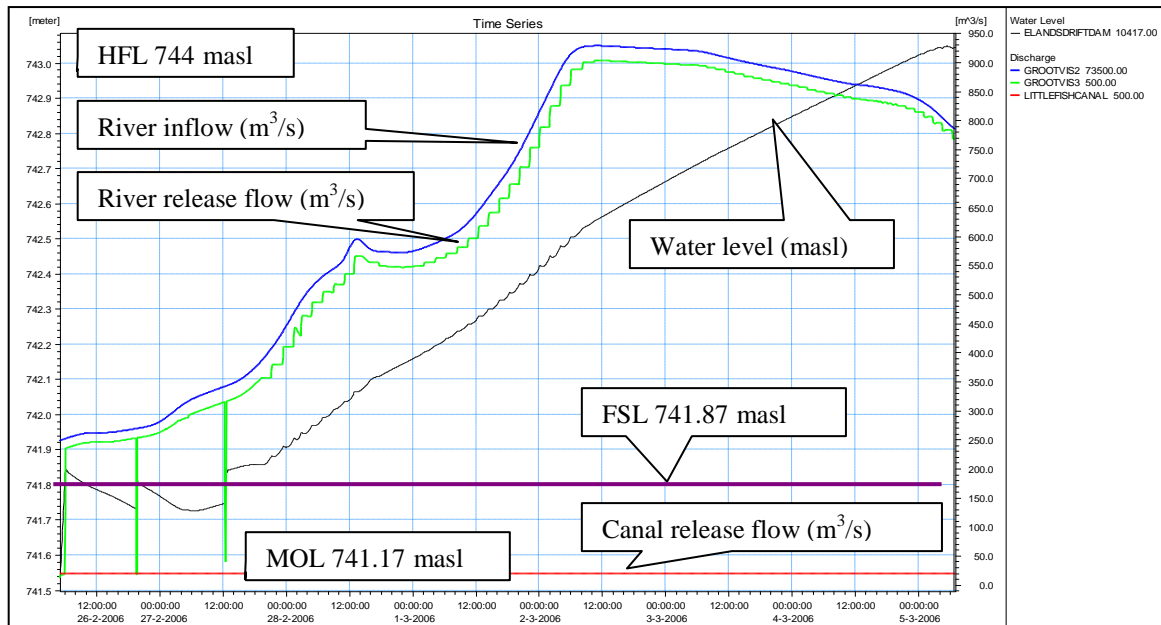
Figure 8.2-6 Elandsdrift Dam simulated water level, river inflow, release and canal release.

8.2.4 DeMistkraal Dam on the Little Fish River

DeMistkraal Dam's water level started from FSL and rose during the flood inflow. The inflow was equal to the river outflow plus Canal release. The Canal flowed at full capacity to transfer water to Darlington Dam. Figure 8.2-7 shows the dam water level which operates between the HFL and FSL on the left hand scale, and the flows on the right hand side.
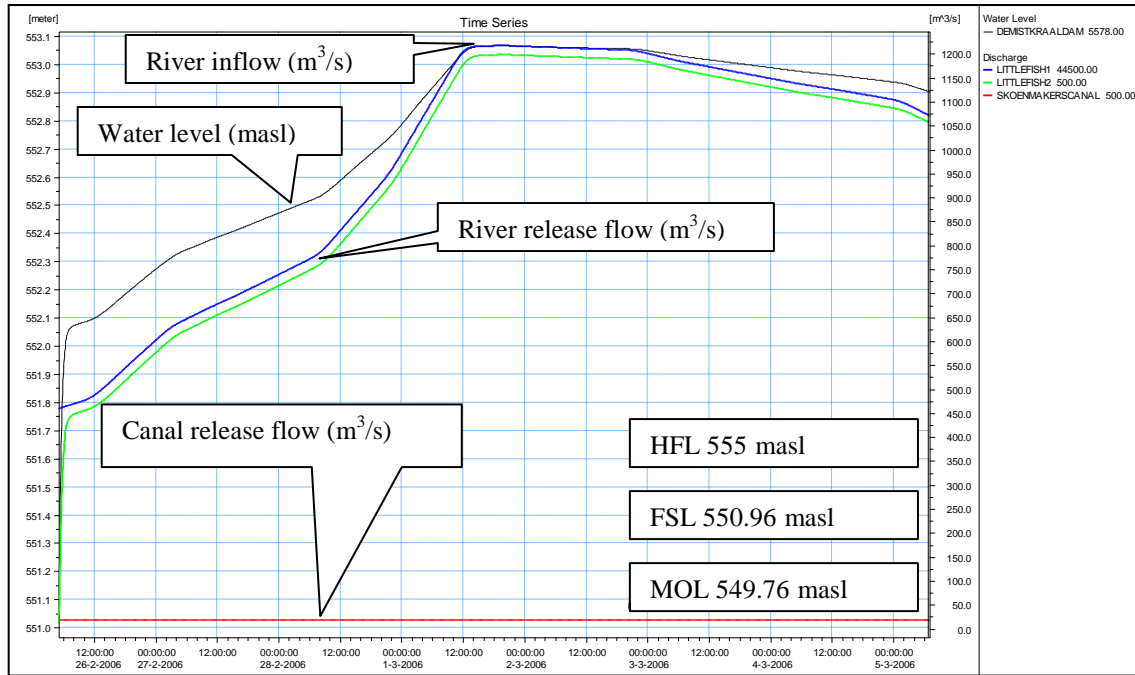
Figure 8.2-7 DeMistkraal Dam's simulated water level, River inflow, river and canal releases.

8.2.5 Darlington Dam on the Sundays River

Darlington Dam had two inflows during the testing of the floods, the Sundays River in flood and the transfered water from DeMistkraal Dam via the Volkerus River. The outflow is displayed as river release. In Figure 8.2-8 the water level rises to FSL and additional spillage occurs.
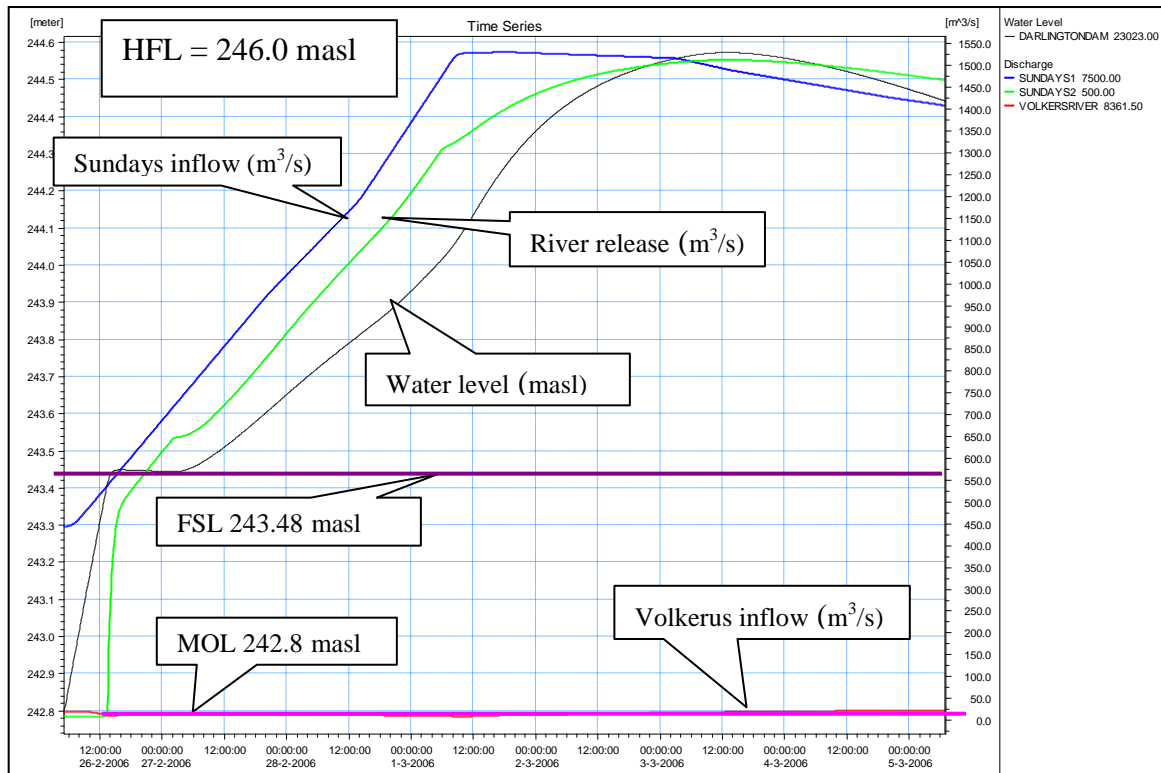
Figure 8.2-8 Darlington Dam's simulated water level, Sundays River inflow, Volkerus inflow from DeMistkraal and River release

8.2.6 System outflows

Figure 8.2-9 shows the flow of the Great Fish River (in red) upstream of the Little Fish River confluence. Junctions Drift flow (in green) is also plotted and the total system outflow at Fort Brown (in blue), peaks at 2000m^3/s.
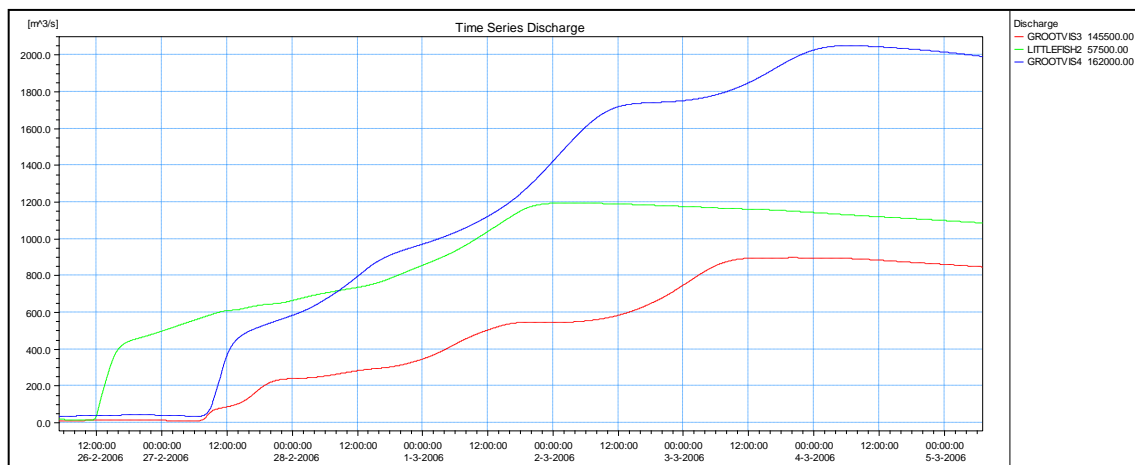
Figure 8.2-9 Simulated outflows of the Fish River

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Figure 8.2-10 shows the simulated outflow of the Sundays River at Korhaansdrift. The flow was normal at the beginning but as the flood moved into the dam and the FSL was reached the spillage peak of 1500m^3/s was carried through the system to Korhaansdrift.
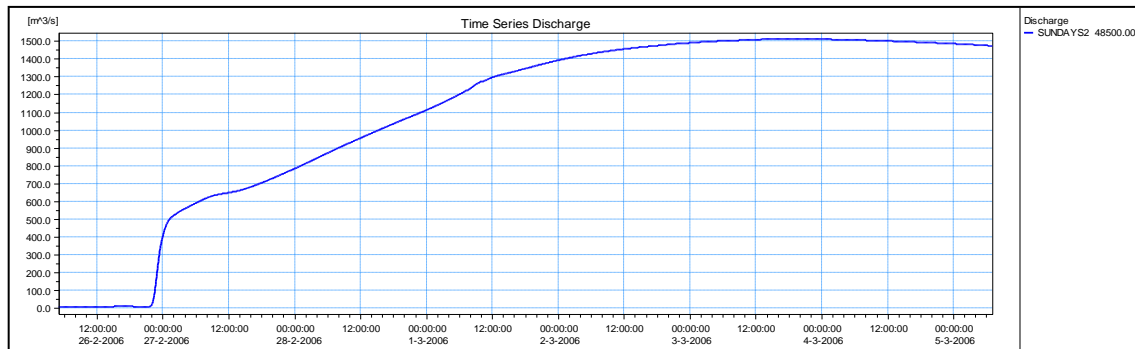
Figure 8.2-10 Simulated outflow of the Sundays River at Korhaansdrift

8.3 One year simulation test with optimisation

The hydrodynamic operational model was run for the historical period 07/07/2005 to 10/07/2006. Forecast periods of 7 days were used in each simulation, with 4 days hind-casting. The overlapping period between simulations was 3 days. In each simulation 252 optimisation runs were carried out. The model prediction required flow releases at the 7 control structures, from Teebus Tunnel to Darlington Dam river releases, at each simulation, which were updated every 4 days. The normal operating levels used in the reservoirs for the current water demands and system operation are indicated in Table 8.3-1.

Table 8.3-1 Target normal operating water levels at reservoirs for current scenario

Reservoir	MOL (masl)	MOL (% original FSC)*	FSL (masl)	FSC (% original FSC)
Grassridge	1055.25	35.9	1056.04	51.7
Elandsdrift	741.17	70.0	741.87	90.1
DeMistkraal	549.76	70.0	550.96	100
Darlington	242.8	34.7	243.48	45.5

Note: *% based on most recent survey.

The computer runtime for the above current scenario was 14 days using 24 h as one day. A total of 92 simulations x 254 optimisation runs each were carried out, giving a total of 23368 simulations of the complete system.

The simulation results are shown in Table 8.3-2: tunnel flow, Great Fish outflow and Sundays River outflow, as well as storage conditions at the major dams.

Table 8.3-2 Operational model simulation results (2005/06)

Description	Current scenario
Average system inflow at Teebus Tunnel (m^3/s)	25.2
Average Great Fish River outflow (m^3/s)	9.0
Average Sundays River outflow (m^3/s)	3.3
Elandsdrift Dam average water level (masl)	741.5
Maximum water level (masl)	743.2
Minimum water level (masl)	739.9
Grassridge Dam average water level (masl)	1055.5
Maximum water level (masl)	1055.9
Minimum water level (masl)	1055.2
Darlington Dam average water level (masl)	243.0
Maximum water level (masl)	243.2
Minimum water level (masl)	242.8

Figure 8.3-1 shows the simulated water levels in Elandsdrift Reservoir. The water levels remained between the MOL and the FSL, except during one spillage.
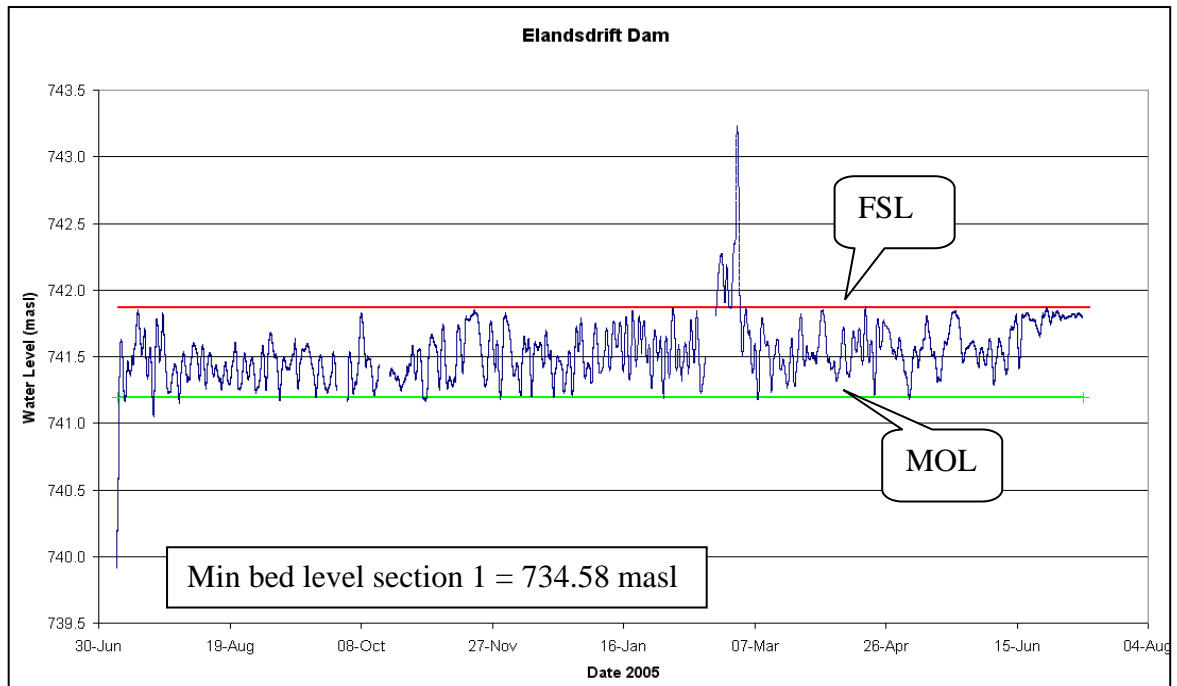
Figure 8.3-1 Simulated water levels in Elandsdrift Reservoir for the current scenario

Figures 8.3-2 to 8.3-4 show the simulated water levels at Grassridge Dam, DeMistkraal Dam and Darlington Dam respectively. At Grassridge Dam the initial water level was drawn down and the dam operated mostly within 0.3 m above the MOL.
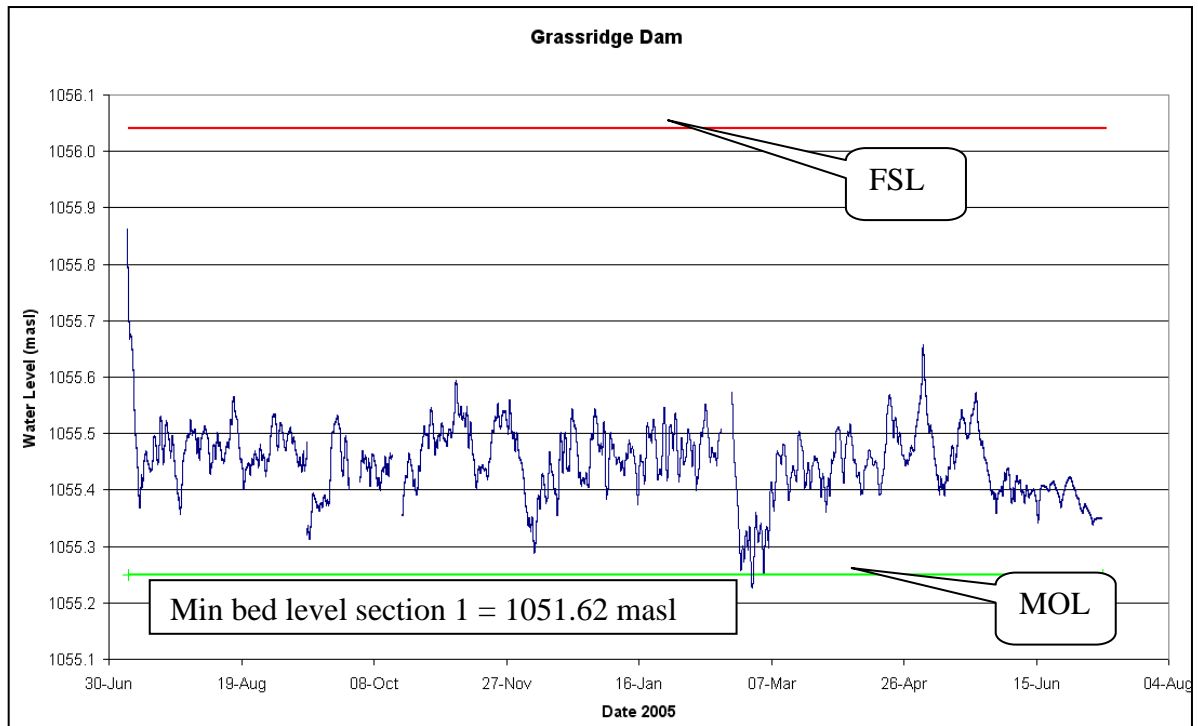
Figure 8.3-2 Simulated water levels at Grassridge Reservoir for the current scenario

At DeMistkraal Dam spillage was minimal. The water level dipped below the MOL from time to time, but this was mostly less than 0.3 m below MOL (Figure 8.3-3).
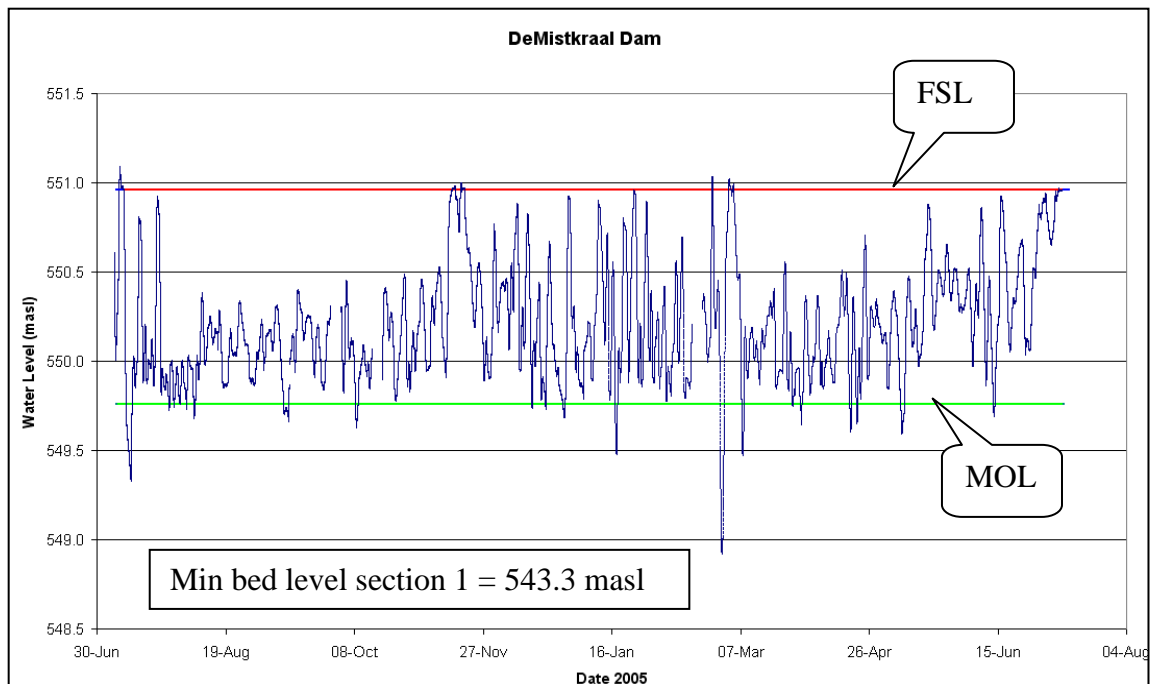
Figure 8.3-3 Simulated water levels at DeMistkraal Dam for the current scenario

60
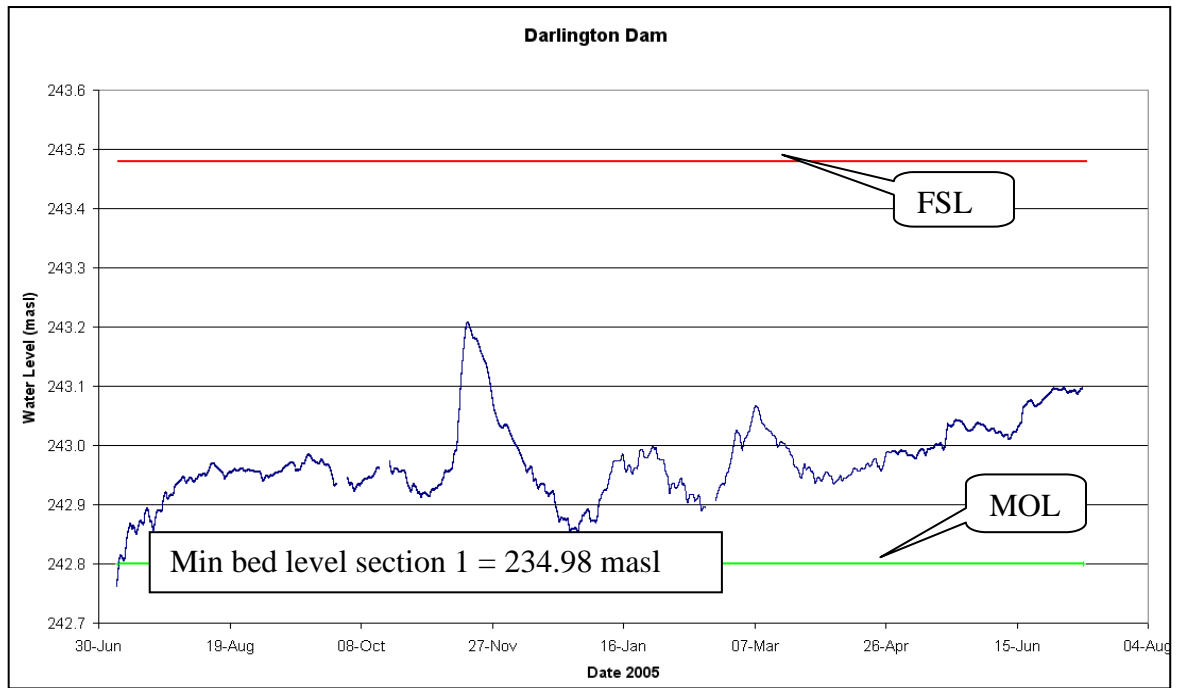
Figure 8.3-4 Simulated water levels at Darlington Dam for the current scenario

At Darlington Dam the water level remained close to the MOL and at maximum only about 0.5 m above MOL. The dam did not spill.

Figure 8.3-5 shows the simulated OVIS tunnel discharge at Teebus. The average tunnel flow was 25.2 m^3/s. The maximum discharge is limited by the Gariep Dam water level.
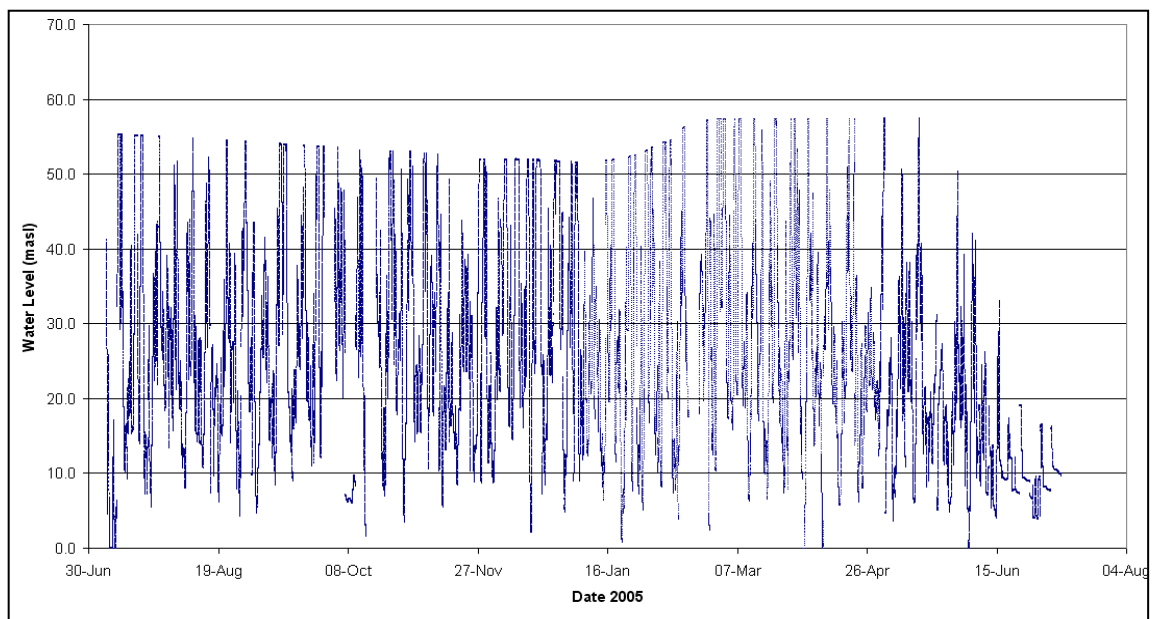
Figure 8.3-5 Current scenario flow at Teebus Orange-Fish Tunnel outlet

At Fort Brown the Great Fish River's simulated flow is generally below 12 m³/s, with some higher peaks during floods. The IFR specified in the model is 0.5 m³/s which is much less than what is simulated. The higher base flows at Fort Brown are therefore due to salinity flushing requirements (Figure 8.3-6).
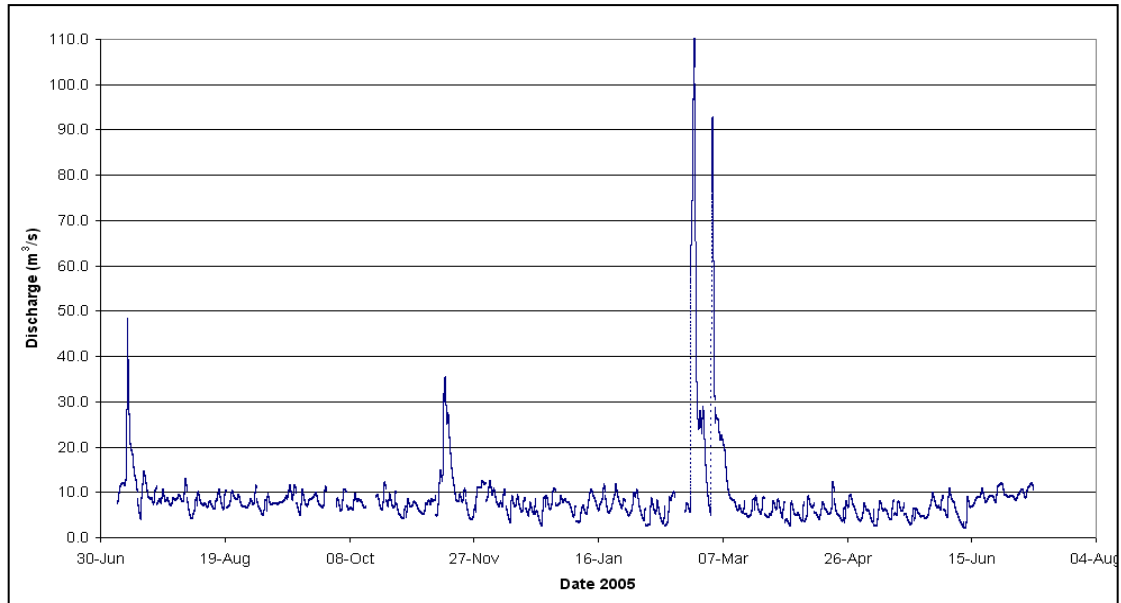
Figure 8.3-6 Current scenario Great Fish River system outflow (Fort Brown)

At Korhaansdrift the average river flow is 3.3 m³/s. Flows of up to 12 m³/s are possible and can be ascribed mainly to the nature of the irrigation demand block specification. The requested irrigation demand from LSWUA, 49km downstream of Darlington Dam rose steeply at the beginning of the of the week where after a constant value,falling to zero at the end of the week. The block release from the dam attenuates over the river reach. To compensate for this, the model started to release more water at an earlier stage which resulted in water spillage at Korhaansdrift.
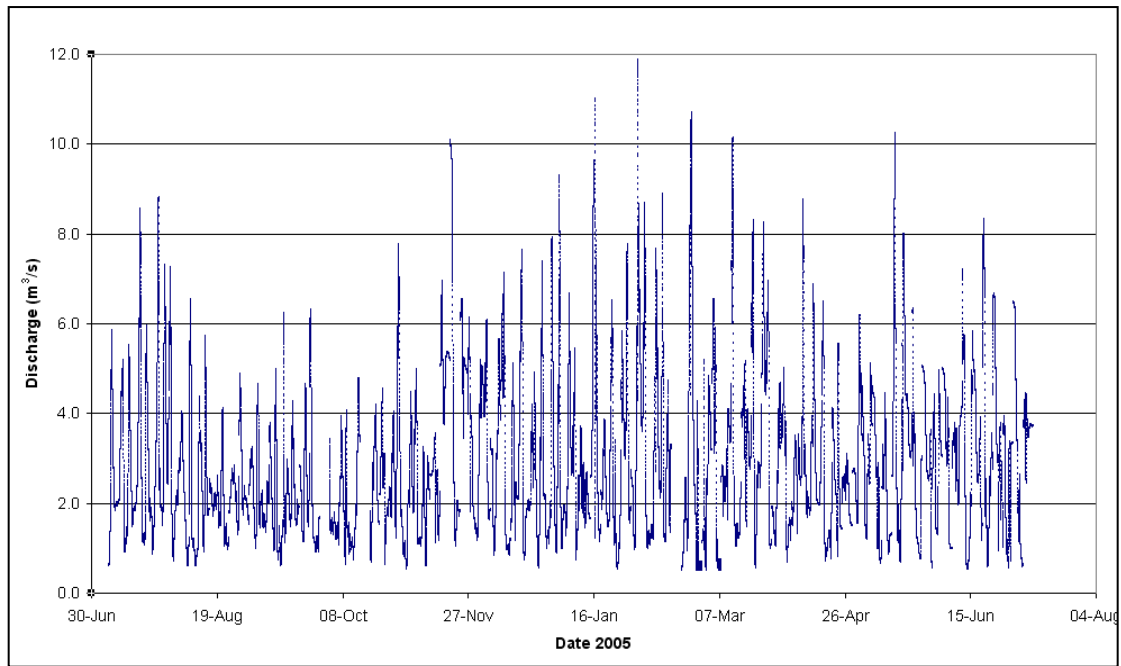
Figure 8.3-7 Current scenario Sundays River system outflow (Korhaansdrift)

9. Real time field tests

Field tests were carried out in real time during January and April 2007. The field tests proved that the model's predictions were not always realistic, and several changes had to be made to improve the model reliability.

9.1 Real-time field test: 20 to 27 January 2007

A field test was carried out with the Mike 11 optimisation model during January 2007 for one irrigation week. The model uses 4 days' historical data with data assimilation to initialize the model by routing irrigation request with lags up the river to the control structures for an initial estimate of the required release patterns. Then, from the time of forecast, the model optimizes for a 4 day forecast by doing over 200 simulations. Target dam water levels, system outflows, and capacity limitations are taken into account. During this test week flow adjustments were made every 6 hours in the field at 11h00, 17h00, 23h00 and 05h00, except at Darlington Dam where this was done at 11h00 and 23h00. The required releases were averaged over each 6 hour period.

The FISUN model was also run on Thursdays as usual, once a week. The new model was run every day, based on real time data received until the morning at 08h00. The Mike 11 model was run without the FLOODWATCH interface which automises the process of pre- and post processing, and therefore the boundary files had to be created for each run by hand, about 200 of them, which was a slow process.

The reservoir minimum water levels for which the model were aiming were set low for the week from 20 January, but in the following week the levels were made high again similar to the current DWA water levels to compare with FISUN. During the first week (test week), water levels in dams were drawn down, while for the second week dam levels generally had to rise.

The outflow boundaries at the Sundays, Great and Little Fish rivers were set at 2 m^3/s during the first week and 0.5 m^3/s during the second week.

During the test week problems were experienced with the Data Assimilation module until Thursday 25 January and predictions until then were therefore not reliable. In the following figures it can be seen that the optimisation simulations were repeated after the field test using a modified model, optimising for 7 days to compare directly with the FISUN model runs. It is however only the second week (to the right of the vertical line on the graphs) that is directly comparable with the FISUN model targets (reservoir water levels). The HYDRAS observed real time data are given for interest sake only. Only the second week's HYDRAS data can be compared to the FISUN model prediction. The models optimised for flow and TDS.

9.1.1 Discussion of optimization simulations

9.1.1.1 Control structure releases

In the attached graphs the second week (right of vertical line) was simulated and operated by FISUN and is compared with the new model (same target water levels).

    a)   **Teebus Tunnel outlet** (Figure 9.1-1)

Due to reduced releases in the first week, Elandsdrift Dam was drawn down to about 20 % storage in a week and had to be filled. During the second week OFS-tunnel transfers close to its capacity were simulated.
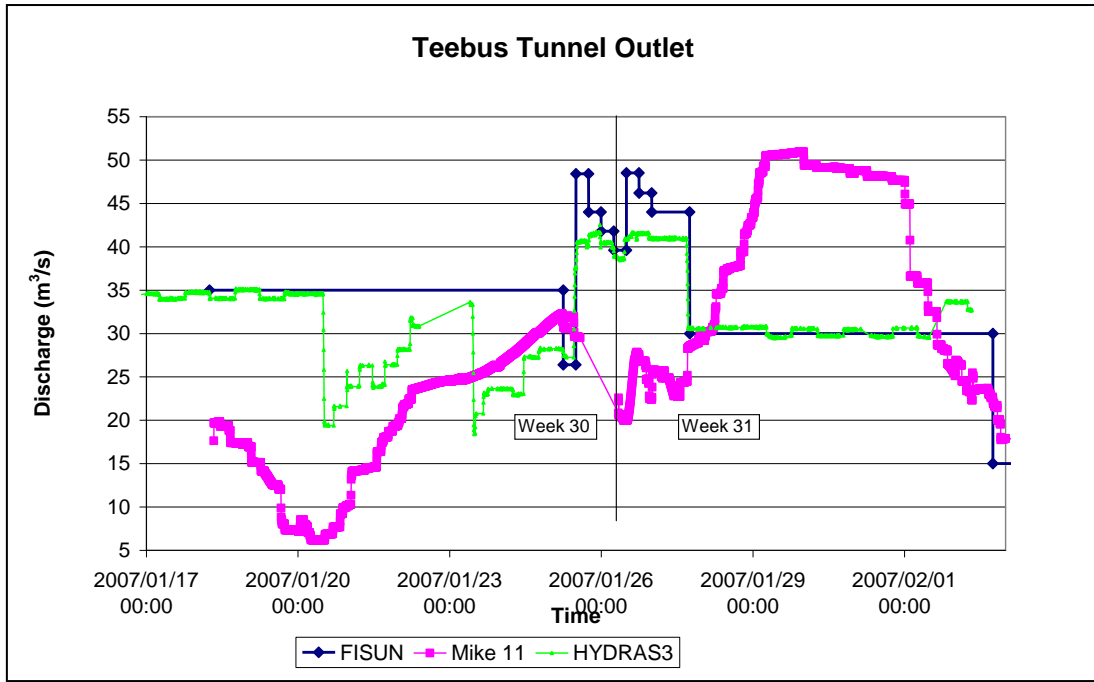
Figure 9.1-1 Teebus Tunnel outlet: Discharge (m³/s)

(Note that the HYDRAS series is observed data)

b)   Grassridge Dam outlet (Figure 9.1-2)

The same flow patterns as at Teebus are seen.
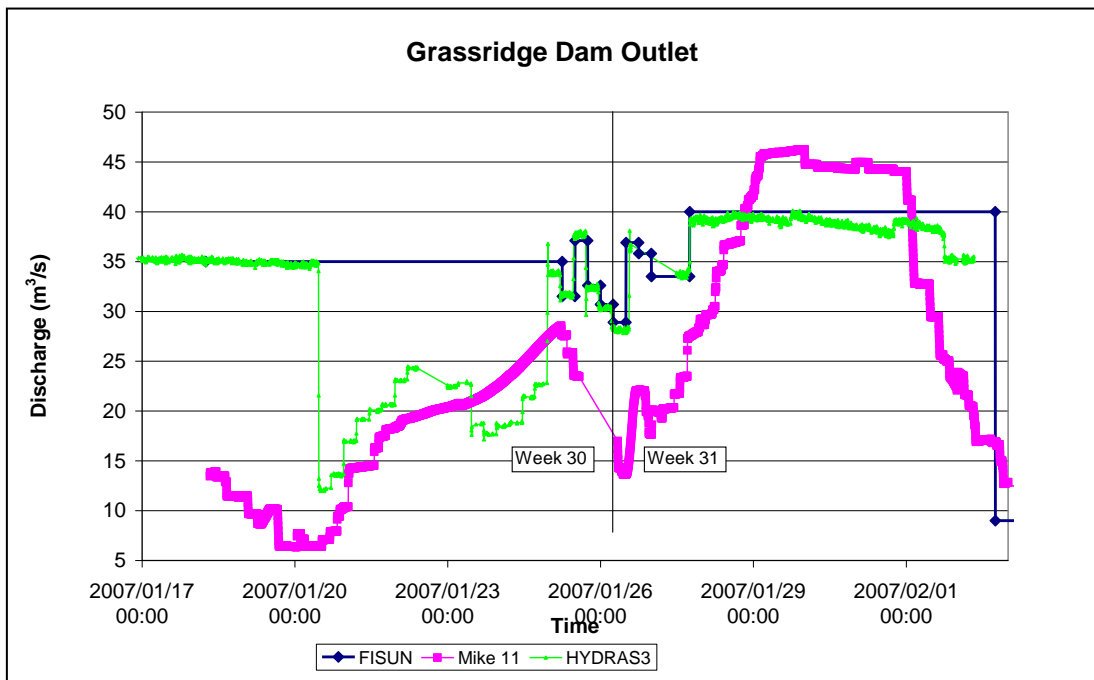
Figure 9.1-2 Grassridge Dam river outlet: Discharge (m³/s)

c)   Elandsdrift Dam River outlet (Figure 9.1-3)

The actual river release is up to 2 m^3/s more than the FISUN model calculation. At the end of the second week the observed reduction in flow occurs later than specified by FISUN.

Mike 11 specified similar peak releases as FISUN during the second week. The Mike 11 releases start rising earlier at low flows, but are about 6h later at peak flows. The Mike 11 flow reductions are also later at the end of the week, more in agreement with how the release was actually operated in the field during the second week.

Elandsdrift River Outlet
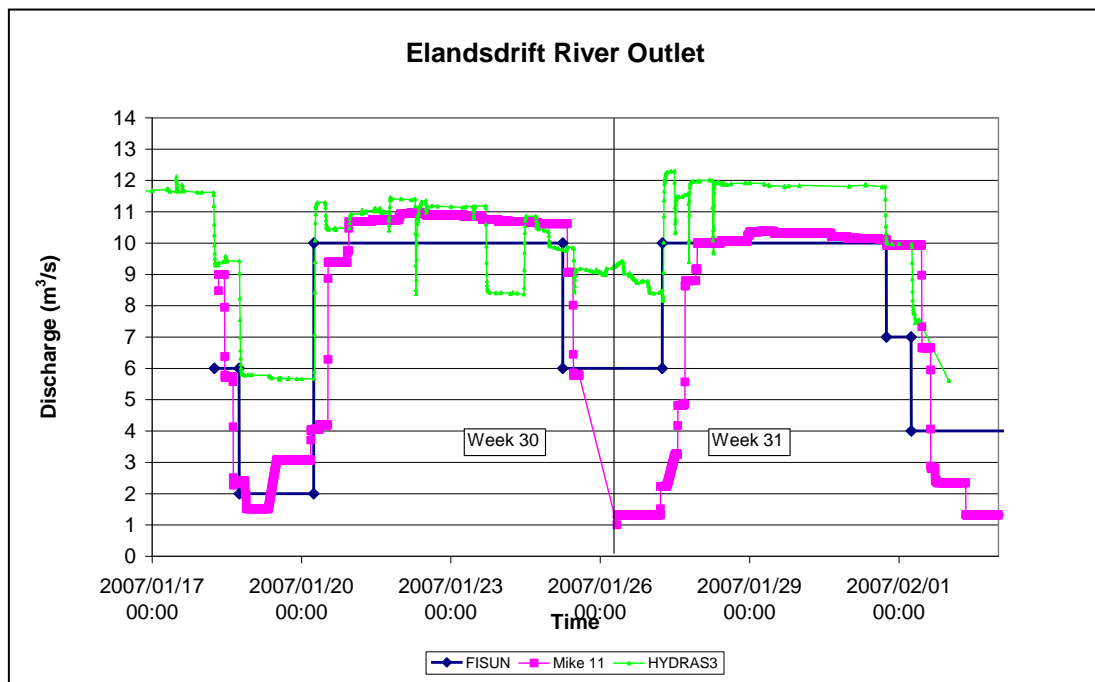
Figure 9.1-3 Elandsdrift Dam river outlet: Discharge (m^3/s)

d)   Elandsdrift Canal outlet (Figure 9.1-4)

During the two weeks the new model released low flows at Elandsdrift in the canal, which increased to the maximum canal capacity during the second week to increase the downstream dam water levels during the second week.
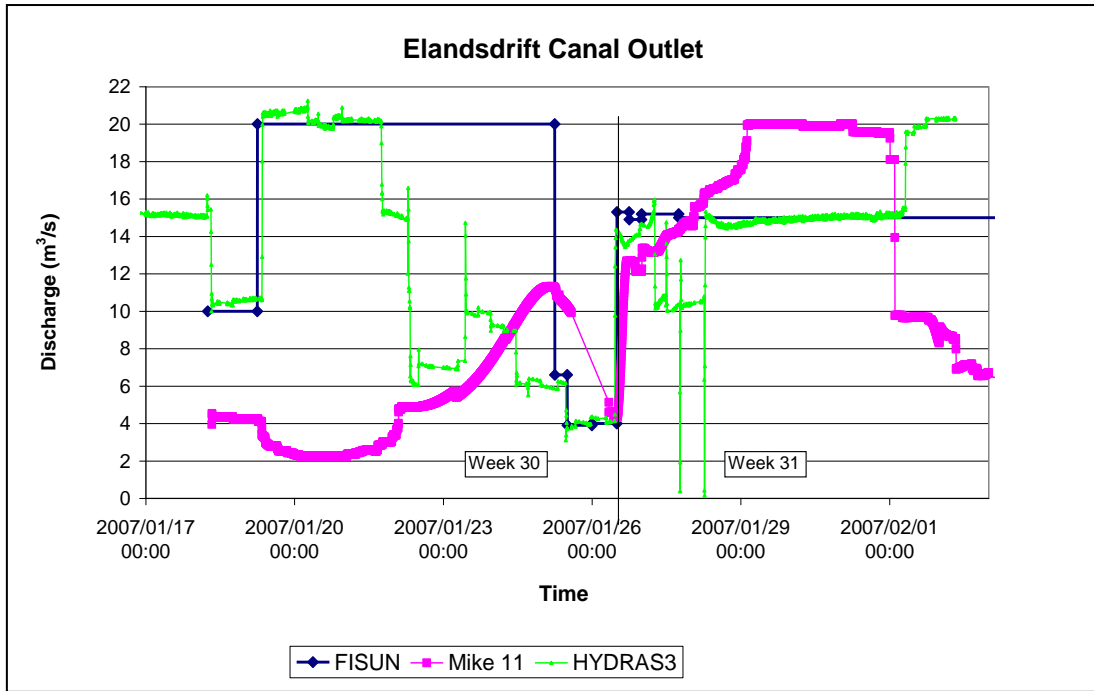
Figure 9.1-4 Elandsdrift Dam canal outlet: Discharge (m³/s)

e)   **DeMistkraal Dam River outlet** (Figure 9.1-5)

The new model release prediction is generally higher than the FISUN model's, except on Sundays where 5 m³/s blocks are added by the FISUN operators to flush the system.
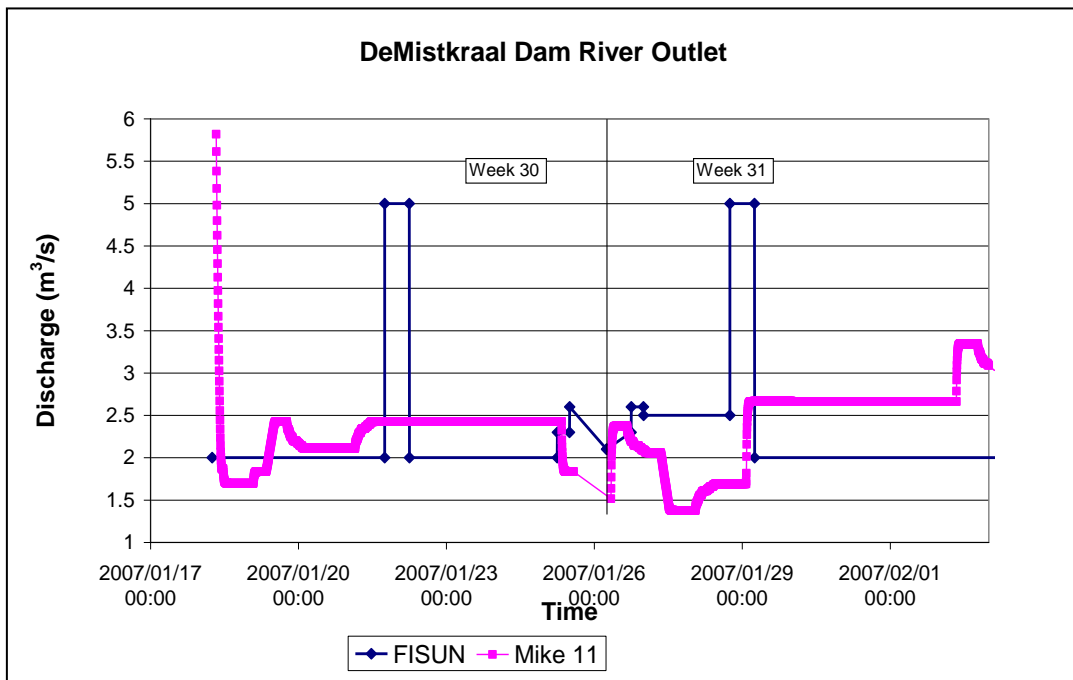
Figure 9.1-5 DeMistkraal Dam river outlet: Discharge (m³/s)

f)   DeMistkraal Dam Canal outlet Figure 9.1-6

During the first week canal transfer is based mainly on irrigation requests since downstream dam water levels are reduced based on lower targets set. The second week Mike 11 prediction transfers more water to raise the level of Darlington Dam.
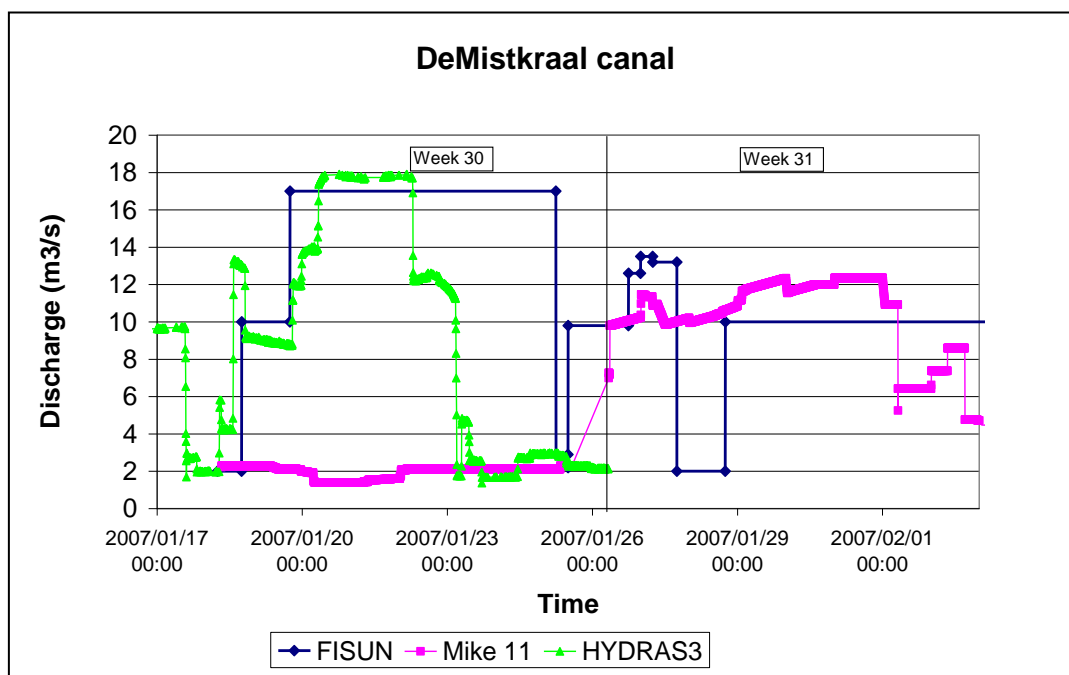
Figure 9.1-6 DeMistkraal Dam canal outlet: Discharge (m³/s)

g)   Darlington Dam river outlet (Figure 9.1-7)

The FISUN model does not consider requests downstream of Darlington Dam and the requests are managed by the Lower Sundays WUA. The Mike 11 predicted release (week 1) starts earlier than that of the LSWUA (based on their experience). During the second week the Mike 11 prediction is lower than the actual release.
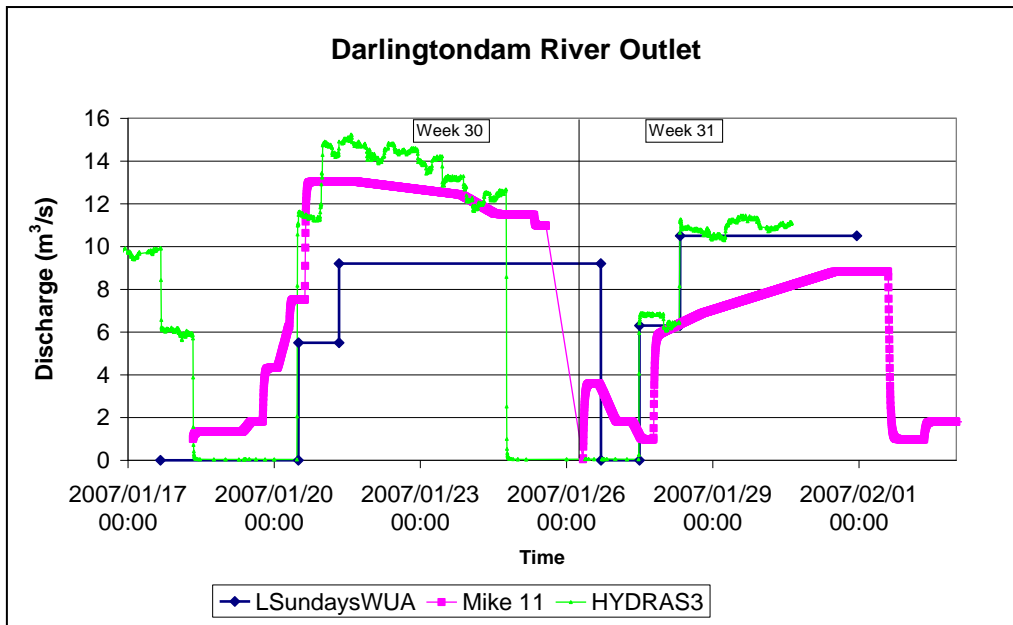
Figure 9.1-7 Darlington Dam river outlet: Discharge (m³/s)

(LSWUA assumes 2.5 m³/s leakage from dam which they consider in their release).

9.1.1.2 Dam water levels

a)   Grassridge Dam (Figure 9.1-8)

During the second week the new model starts below MOL and ends higher. Most of the water released at Teebus is however transferred downstream to Elandsdrift Dam. The new simulations are based on the observed HYDRAS data at the start of each time of forecast (see vertical line). Daily water levels were taken in the field to check the HYDRAS data which agreed perfectly. The FISUN model water levels were converted from the % storage output of the model, but are plotting too high based on observed data. This over estimation by the FISUN model could be attributed to the fact that the model uses a 1984 reservoir survey while the new model uses a 2000 survey, which was taken into account when plotting the graph.
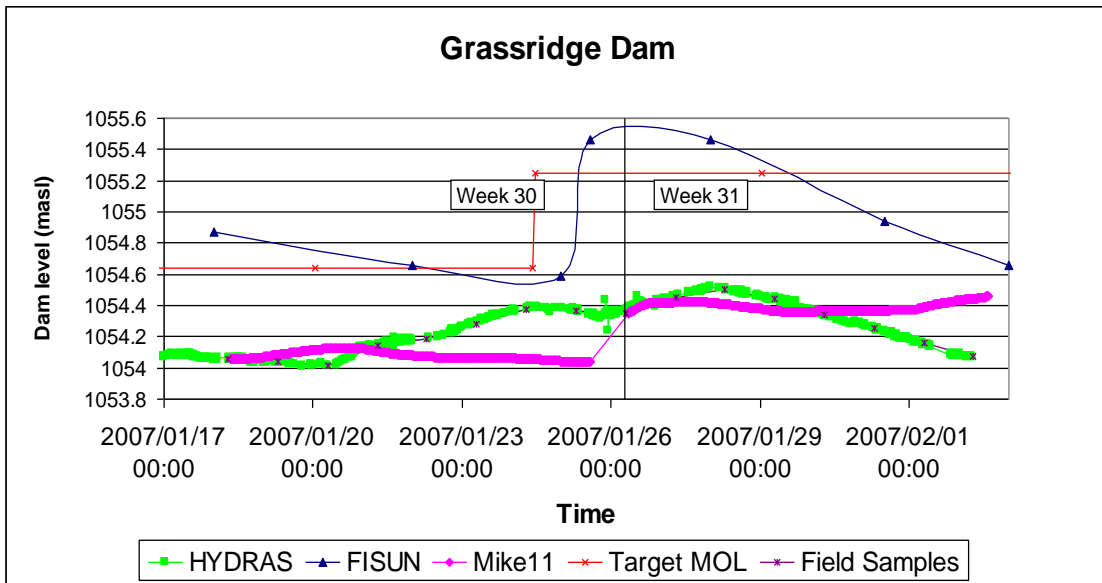
Figure 9.1-9 Grassridge Dam: Water level (masl)

b) **Elandsdrift Dam** (Figure 9.1-10)

The water level dropped to close to the MOL during the first week. During the second week the higher target water level caused the water level to rise again in both models.
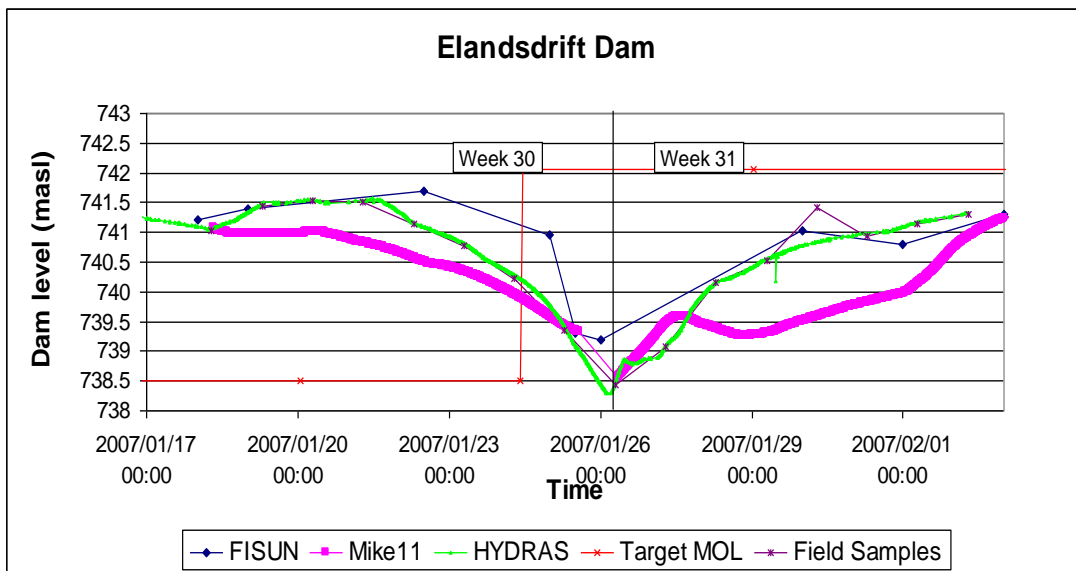
Figure 9.1-10 Elandsdrift Dam: Water level (masl)

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c)   **DeMistkraal Dam** (Figure 9.1-11)

During the first week the new model tries to lower the water level correctly, while in the second week the model tries to maintain the level close to the higher MOL.
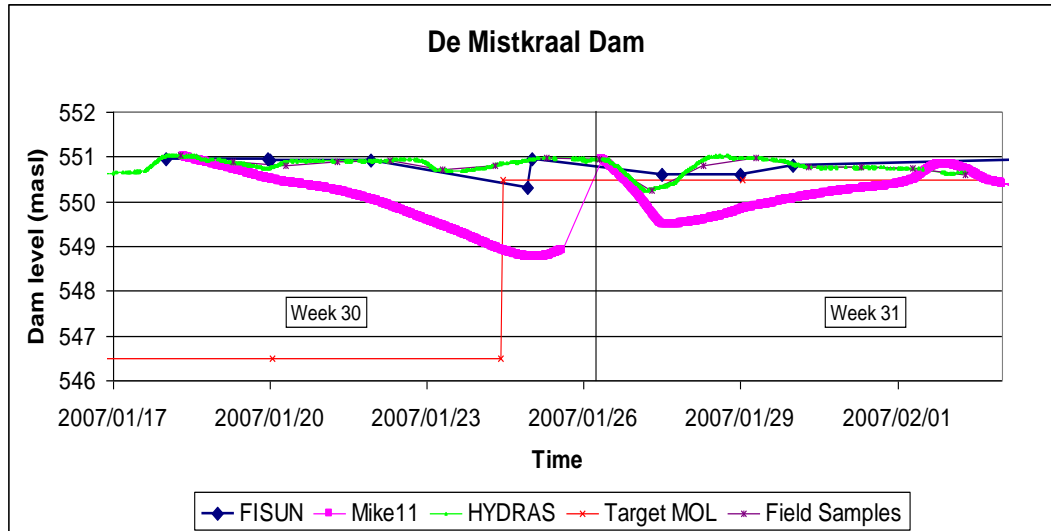
Figure 9.1-11 DeMistkraal Dam: Water level (masl)

d)   **Darlington Dam** (Figure 9.1-12)

The new model predicts correctly based on the target water levels. Water level changes are slow due to the large storage capacity.
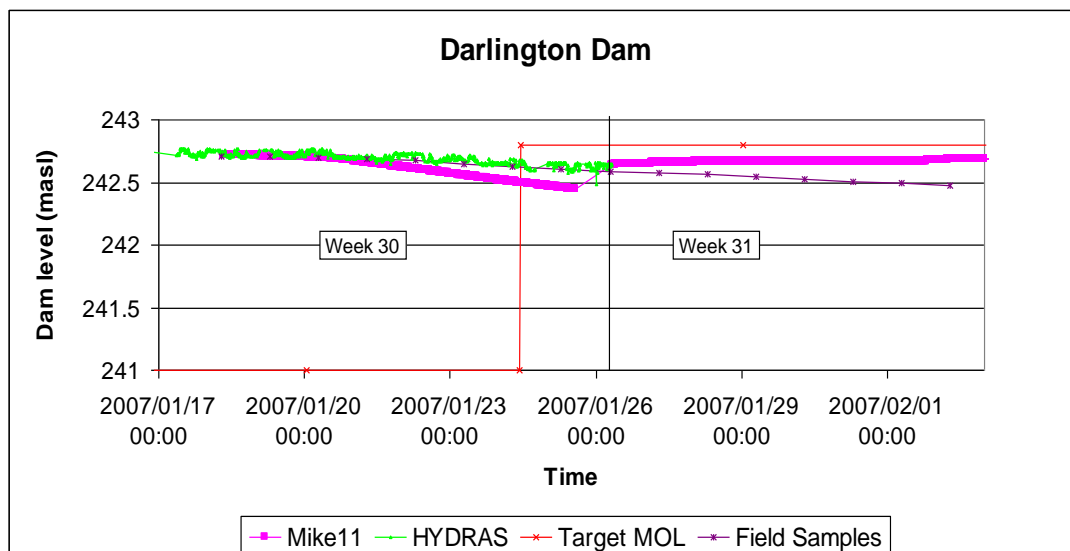
Figure 9.1-12 Darlington Dam: Water level (masl)

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9.1.1.3 Dam salinity

a) Grassridge Dam (Figure 9.1-13)

Field grab samples show lower but similar TDS values as HYDRAS (observed logger data). During the second week the new model is in agreement with field data and ends at the same final TDS value as FISUN.
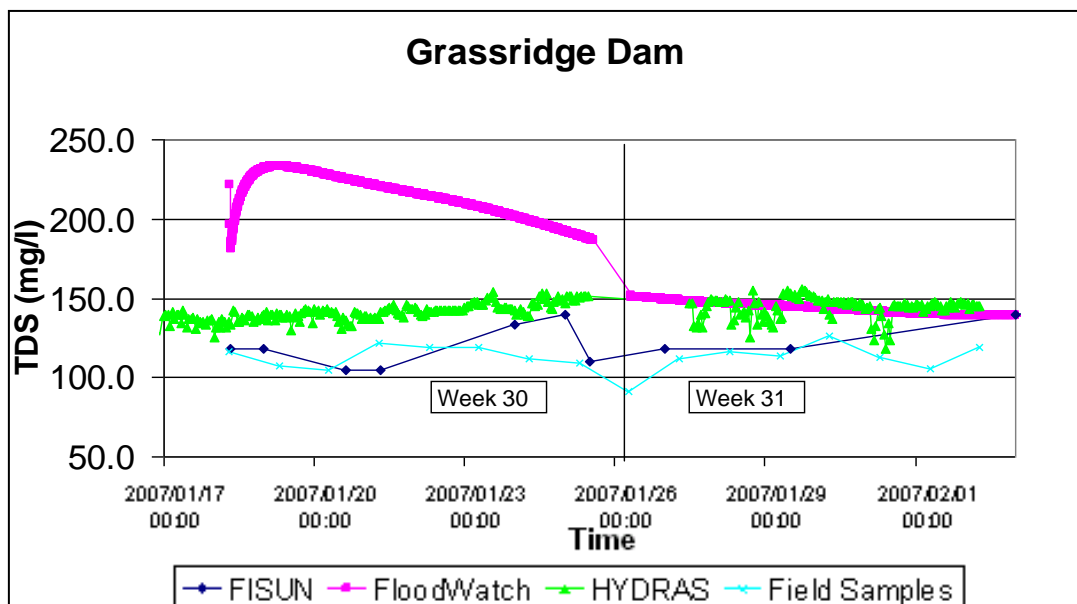
Figure 9.1-13 Grassridge Dam: Salinity (mg/l)

b) Elandsdrift Dam (Figure 9.1-14)

The field grab sample data TDS are much higher than the HYDRAS data. As the dam level lowered during the first week, TDS increased. The new model prediction is higher than the FISUN prediction.
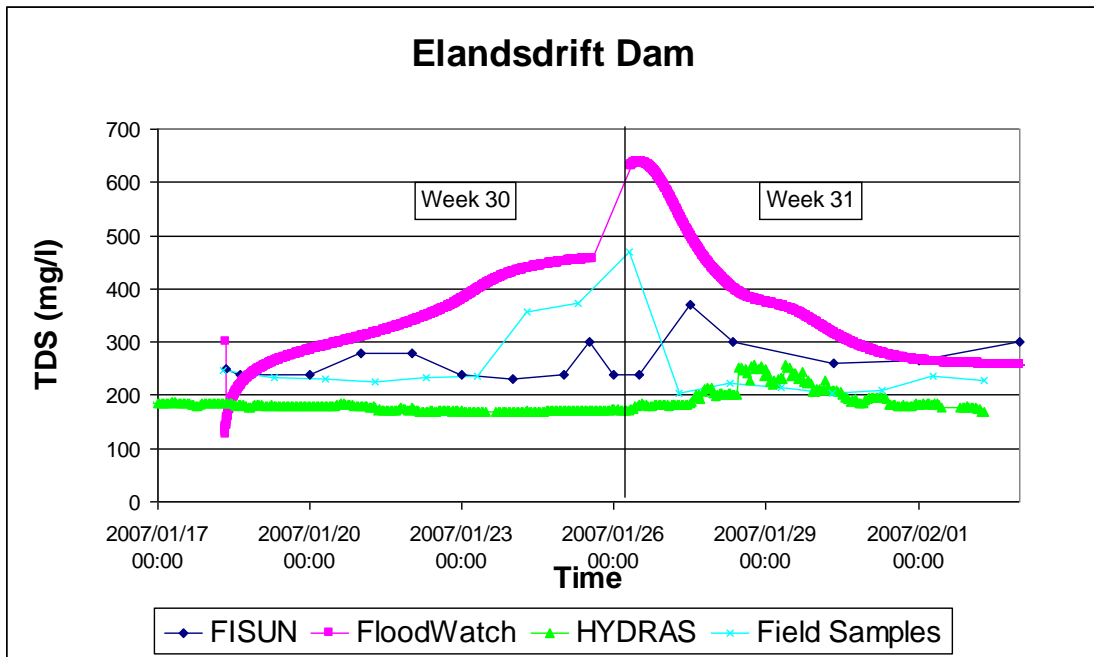
Figure 9.1-14 Elandsdrift Dam: Salinity (mg/l)

c) **DeMistkraal Dam** (Figure 9.1-15)

Once again the HYDRAS data are low compared to hand grab samples. The FISUN model uses hand sample data.
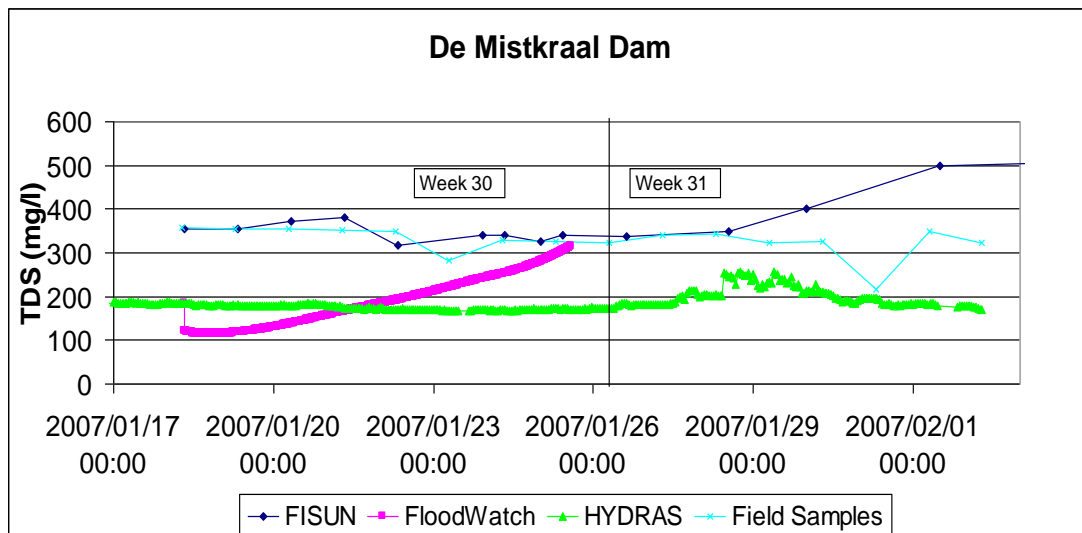
Figure 9.1-15 DeMistkraal Dam: Salinity (mg/l)

d)   Darlington Dam (Figure 9.1-16)

The HYDRAS data are incorrect compared to hand samples. The new model used an initial value of 500 mg/l. The high HYDRAS data could result in large flushing volumes released from Teebus to lower TDS < 600 mg/l. Pre-processor checks have been built in to prevent this but the logger needs to be corrected.
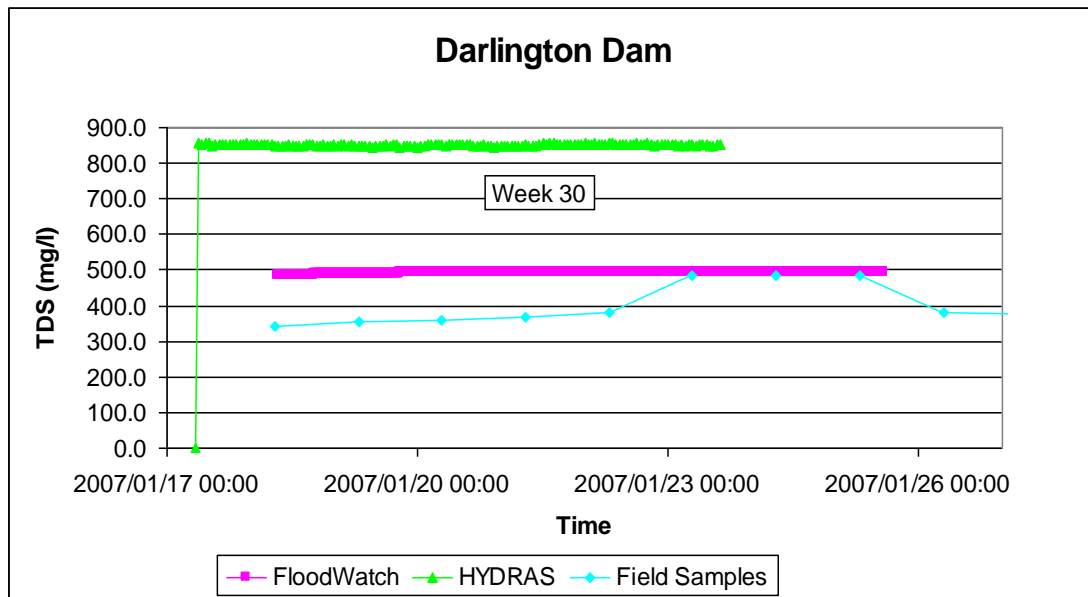
Figure 9.1-16 Darlington Dam: Salinity (mg/l)

9.1.1.4 System/river outflows

a)   Piggot's Bridge outflow (Figure 9.1-17 and Figure 9.1-18)

The new model requires much more water than the target during the second week, in order to limit the TDS to below 600 mg/l on the Great Fish River downstream of Elandsdrift Dam.
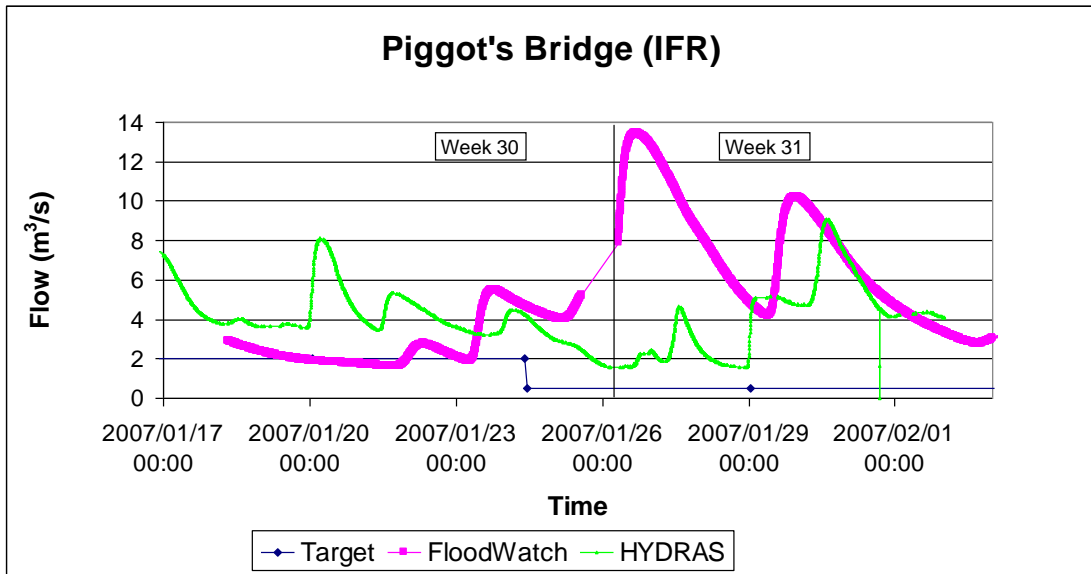
Figure 9.1-17 Great Fish River at Piggot's Bridge: Discharge (m³/s)
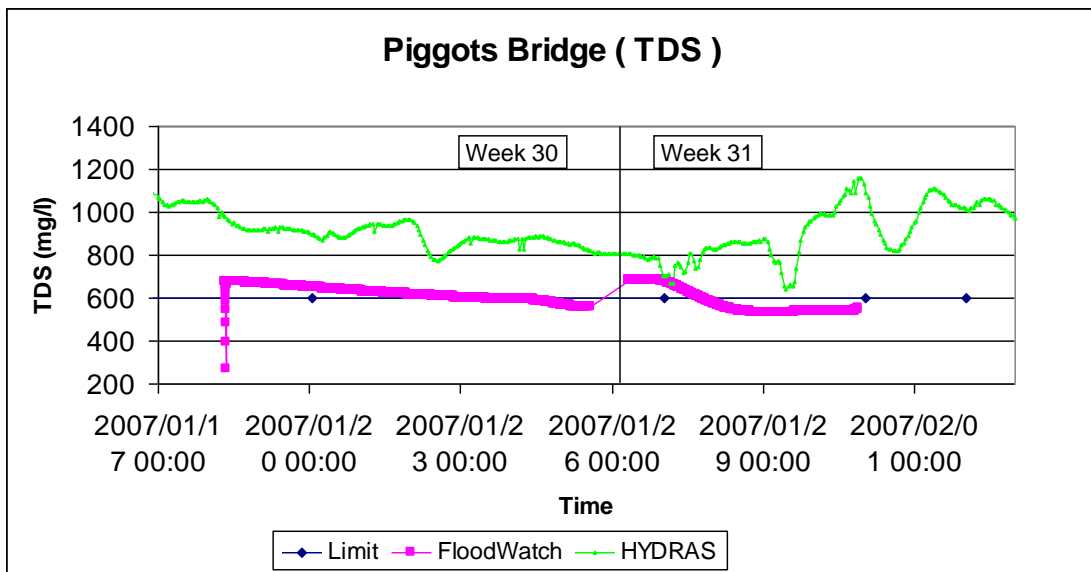
Figure 9.1-18 Great Fish River at Piggot's Bridge: Salinity (mg/l)

b) **Junctionsdrift outflow Little Fish River** (Figure 9.1-19 and Figure 9.1-20)

At Junction Drift on the Little Fish River the second week predicted IFR flow is slightly above the target. Apart from the two flushing flows released on Sundays from DeMistkraal Dam which creates river outflow, the observed (HYDRAS) river is

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empty for long periods (20 to 29 January, and again after 1 February 2007). This is because of higher irrigation abstraction than requested.

The optimisation model tries to achieve the 600 mg/l target TDS. Note that TDS was taken as zero when observed flow is zero in HYDRAS.
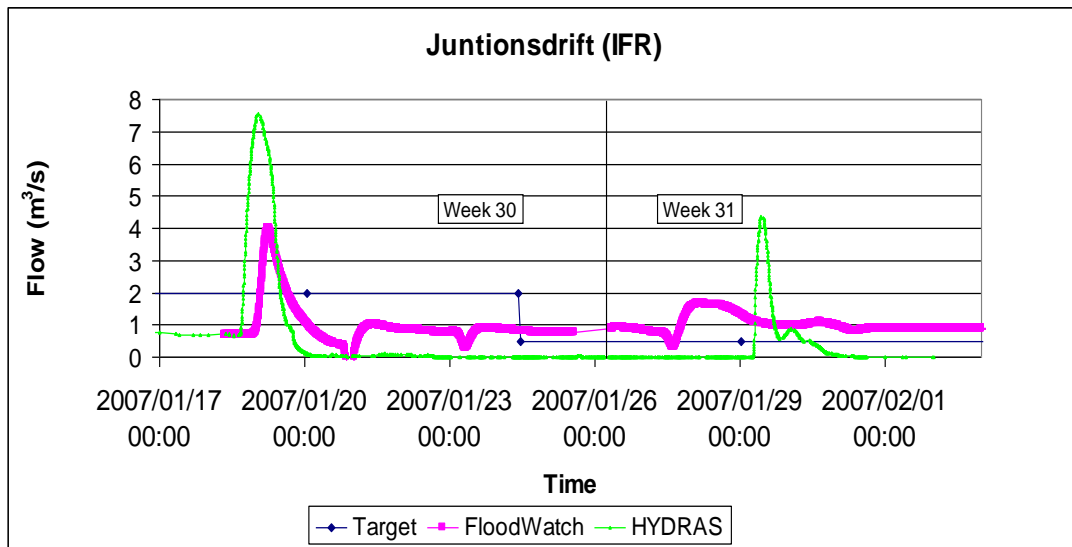
Figure 9.1-19 Little Fish River at Junctionsdrift: Discharge (m³/s)
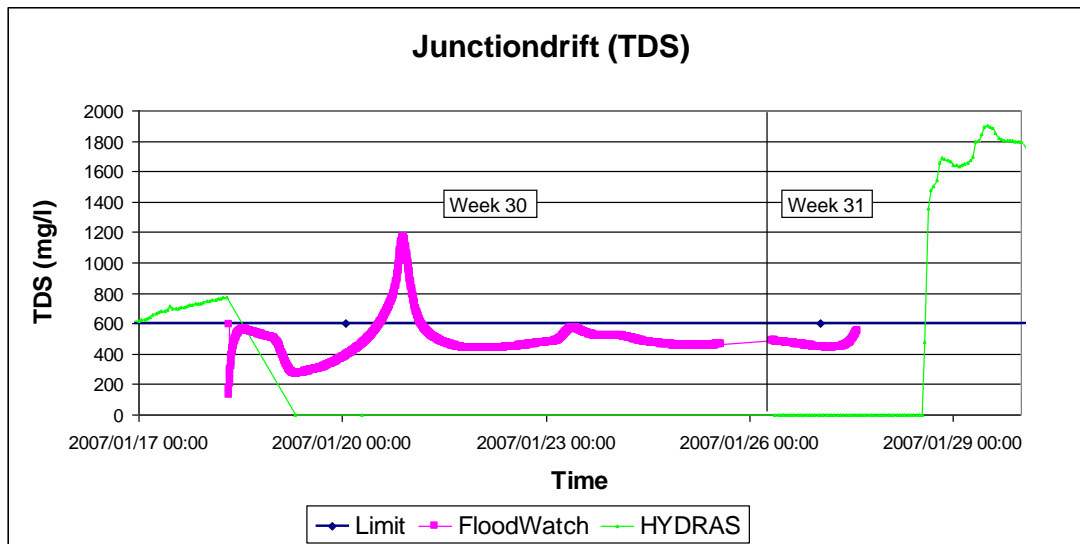
Figure 9.1-20 Little Fish River at Junctionsdrift: Salinity (mg/l)

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c)   Korhaansdrift outflow Sundays River (Figures 9.1-21 and 9.1-22)

The new model correctly predicts Sundays River outflow at Korhaansdrift based on the target. During the second week all the water is diverted for irrigation for a long duration.The predicted and observed TDS stays below 600 mg/l.
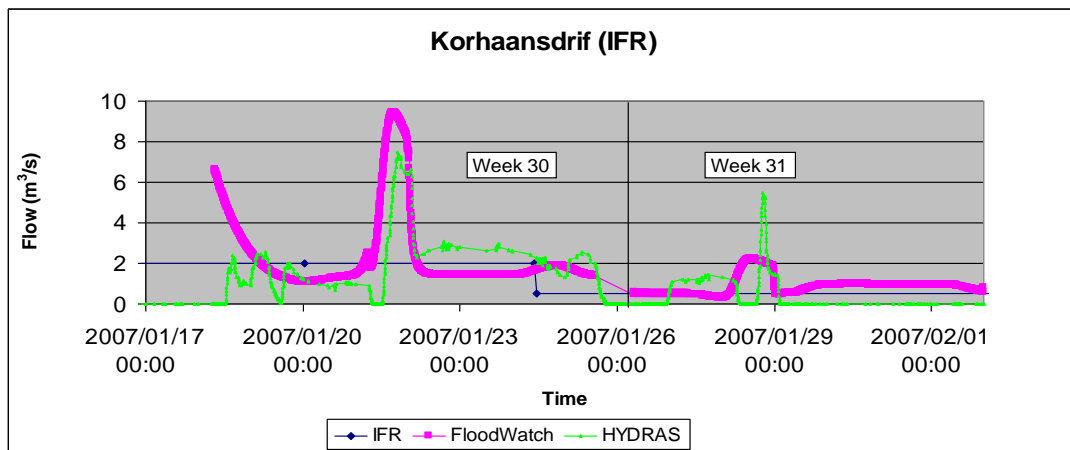
Figures 9.1-21 Sundays River at Korhaansdrift: Discharge (m³/s)
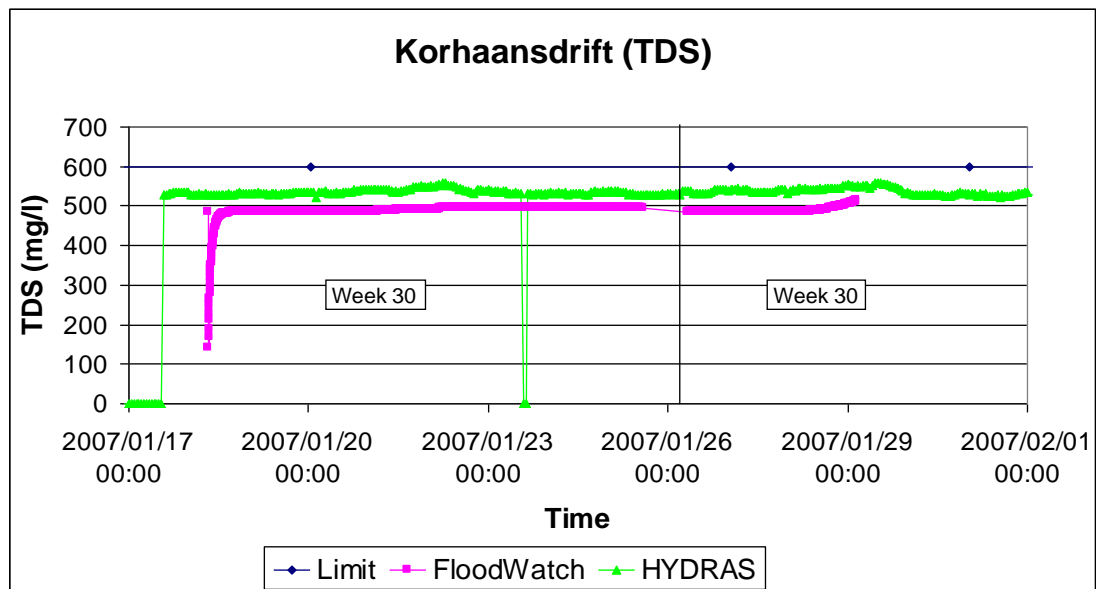
Figures 9.1-22 Sundays River at Korhaansdrift: Salinity (mg/l)

9.1.2 Actual irrigation abstraction versus request

Only the Lower Sundays WUA has been evaluated due to readily available data. In Figure 9.1-23 the LSWUA actual use was lower than the requests during the peak flow periods. In general the correct pattern was followed as requested.
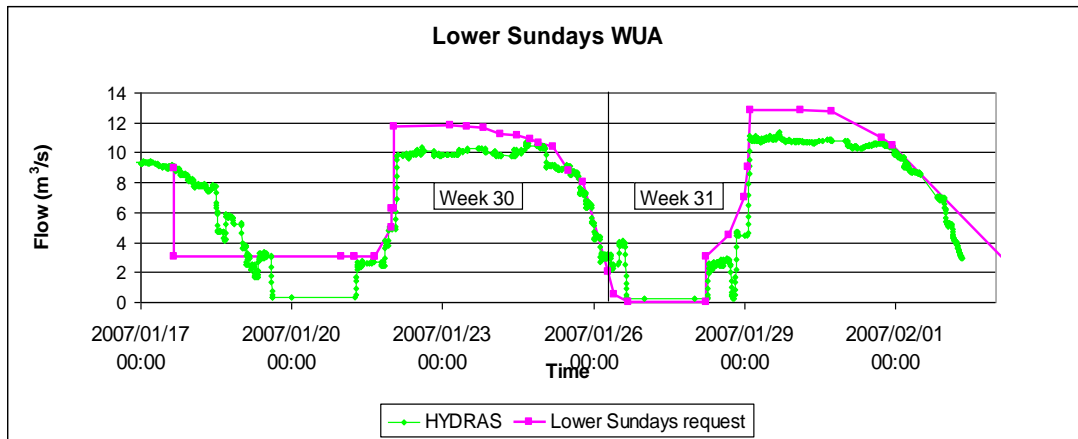
Figures 9.1-23 Sundays River abstraction by Lower Sundays WUA at Korhaansdrift: Flow (m³/s)

9.1.3 Model volume comparison

The FISUN model and Mike 11 model prediction for the second week (same targets for water levels) were compared as shown in Table 3.1. The data are quite similar.

Table 9.1-1 Model release volume comparison for the week starting 26 January 2007 (million m^3)

	FISUN	MIKE 11
Teebus	26.98	25.28
Grassridge	22.80	22.76
Elandsdrift River	4.96	4.86 (0.5 m^3/s IFR included)
Elandsdrift canal	9.17	10.37
DeMistkraal River	2.10	1.79 (0.5 m^3/s IFR included)
DeMistkraal canal	6.65	6.94
Darlington	3.91*	3.76 (0.5 m^3/s IFR included)

* Note: LSWUA data

9.1.4 Summary of first test week

The field exercise was very important to understand real time data reliability and accuracy, and to develop and refine the Mike 11 model further.

Key conclusions are:

a) TDS HYDRAS data in many dams are not reliable, especially at Darlington Dam, and probably also at some river stations.

b) Little Fish irrigators downstream of DeMistkraal Dam used more water than requested, or not enough water is released, or both.

c) When the inflow into Elandsdrift Dam in the field is lower than 10 m^3/s, the irrigators have difficulty to abstract the water. Pump intakes probably need to be modified in the field.

d) Elandsdrift Dam needs a relatively high MOL due to its relatively small storage capacity.

e) Office grid software is required to reduce model runtime to less than 8h for 4 day optimisations, by using parallel processing.

f) Another field test and further tests were required as soon as FLOODWATCH was installed as the steering model.

9.2 Real-time field test: 13 to 20 April 2007

Following testing of the model's first field test in January 2007, some changes to the software were made. A second field test was carried out with the FLOODWATCH optimization model during April 2007, for one irrigation week. The model used 3 days' historical data with data assimilation to initialise the model by routing irrigation requests with lags up the river to the control structures for an initial estimate of the required release patterns. Then the time of forecast was set 8 hours in advance with the current release pattern as input. The model then optimised for a 4 day forecast by doing 210 simulations. Target dam water levels, system outflows, and capacity limitations were taken into account. During this test week flow adjustments were made every 8 hours at the seven control structures in the field at 06h00, 14h00 and 22h00, except at Darlington Dam which was operated by LSRWUA. The LSRWUA release pattern and requests were however given as input to the model. The required releases at structures were averaged over each 8 hour period.

The FISUN model was also run on Thursdays as usual, once a week. The new model was run three times a day, based on real time data received at 04h00 for the 14h00 request, 12h00 data for the 22h00 request and 20h00 for the 06h00 request. The Mike 11 model was run with the FLOODWATCH interface which automises the process of pre- and post processing and simplifies the in- and output model requirements.

The reservoir minimum operating levels for which the model was aiming were set similar to the current DWA water levels in order to compare the results with the FISUN model simulation.

The outflow boundaries (IFR) at the three rivers were set at 0.7 m^3/s for the Little Fish River, 1.2 m^3/s for the Great Fish River downstream of Piggot's bridge and 0.5 m^3/s in the Lower Sundays River.

During the test week problems were experienced with the multi processor usage of FLOODWATCH, which resulted in longer simulation times. At the start of the test

week HYDRAS which supplies the input data was not working at Elandsdrift Dam and during the week some data were received late, corrupted or missing at times. In the following discussion the HYDRAS observed real time data are given for comparison with forecasting. The model optimisation was carried out for flow and TDS.

9.2.1 Discussion of optimisation simulations

The following target levels for the dams were used in the simulations (Table 2.1).

Table 9.2-1 Target water levels

Dam	MOL (masl)	MOL (% original FSC)	FSL (masl)	FSC (% original FSC)
Grassridge	1055.25	35.9	1056.04	51.7
Elandsdrift	741.17	70.0	741.87	90.0
DeMistkraal	550.6	90.0	550.96	100.0
Darlington	242.8	37.9	242.925	39.2

9.2.1.1 Control structure releases

a)   Teebus Tunnel (Figure 9.2-1)

Due to an error in HYDRAS, the Grassridge Reservoir water level was raised from about 35% storage to 43%, corrected on the 17 April. During this period the predicted Teebus tunnel release required was more than that of the FISUN model.
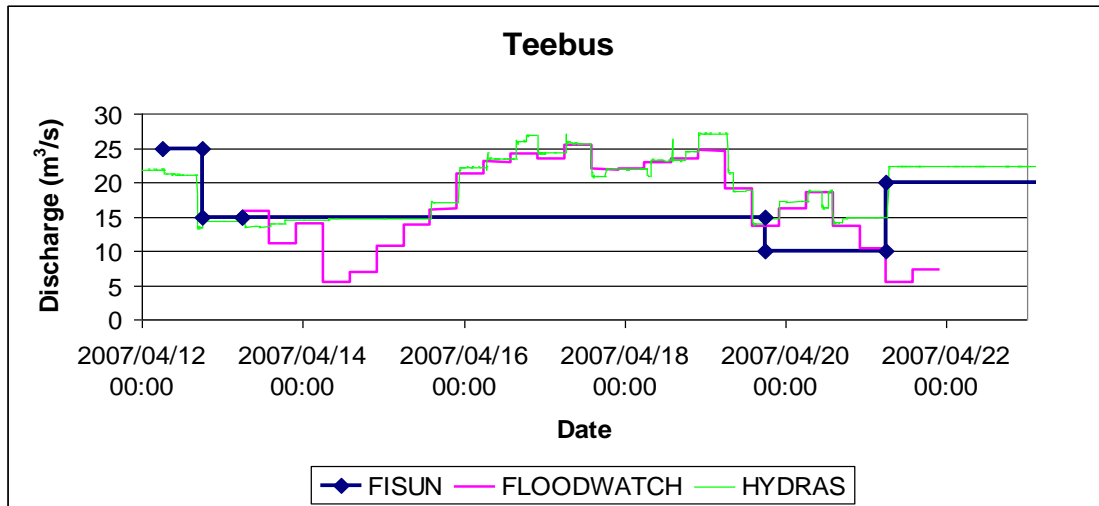
Figure 9.2-1 Teebus Tunnel outlet: Discharge (m^3/s)

(Note that the HYDRAS series is observed data)

b)   Grassridge Dam (Figure 9.2-2)

The same flow patterns as at Teebus are seen until 17 April. Grassridge Dam released more than Teebus to draw down the dam water level from 17 April.
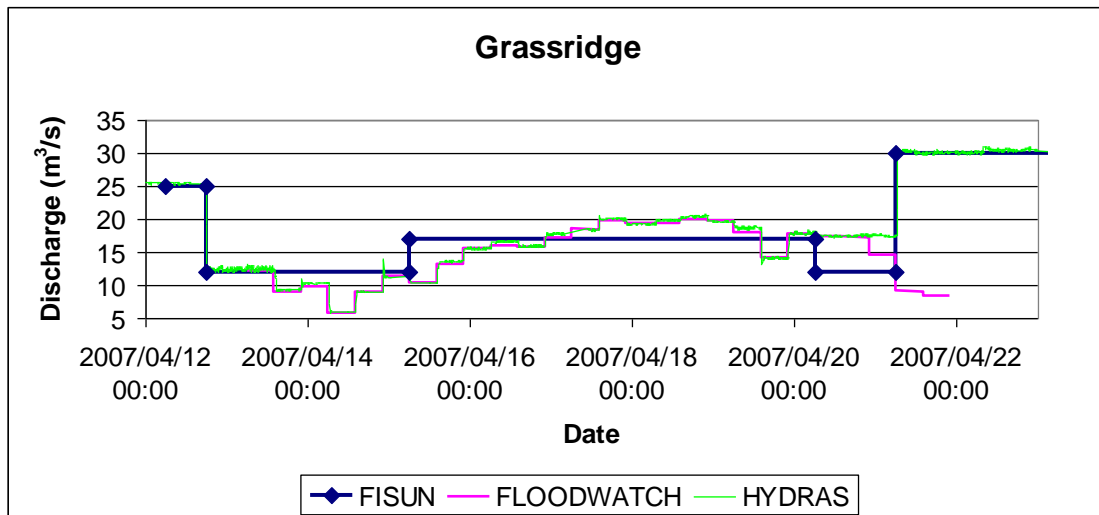
Figure 9.2-2 Grassridge Dam river outlet: Discharge (m^3/s)

c)   Elandsdrift Dam River (Figure 9.2-3)

At the start of the test week Elandsdrift Dam initially had more water in its upstream river reach than what the model simulated and as a precaution water was released

until the water level was at 741.8 masl. From there the FLOODWATCH release pattern was followed.

The FLOODWATCH river release was up to 4 m^3/s more than the FISUN model calculation. During the week, observations showed that operational flow was up to 2 m^3/s more than specified at low flows.

The FLOODWATCH releases started rising earlier at low flows, while the flow reduction was also later at the end of the week to control downstream TDS quality.
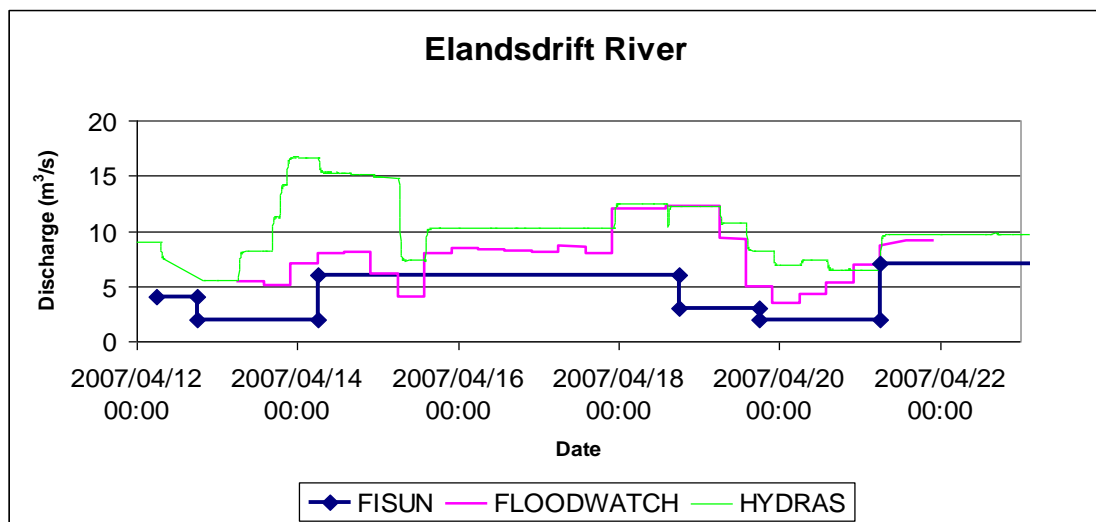
Figure 9.2-3 Elandsdrift Dam river outlet: Discharge (m^3/s)

d)   Elandsdrift Canal (Figure 9.2-4)

During the week the FLOODWATCH model released low flows at Elandsdrift to the canal, which compensated for DeMistkraal being nearly 100% full. At end of the week more water was released to raise the DeMistkraal Dam level. In the week some abstractors had trouble taking their water. Their off takes were too high. This was the case at Hopefield on Monday morning the 16th, when the canal released flow was less than 4m^3/s.
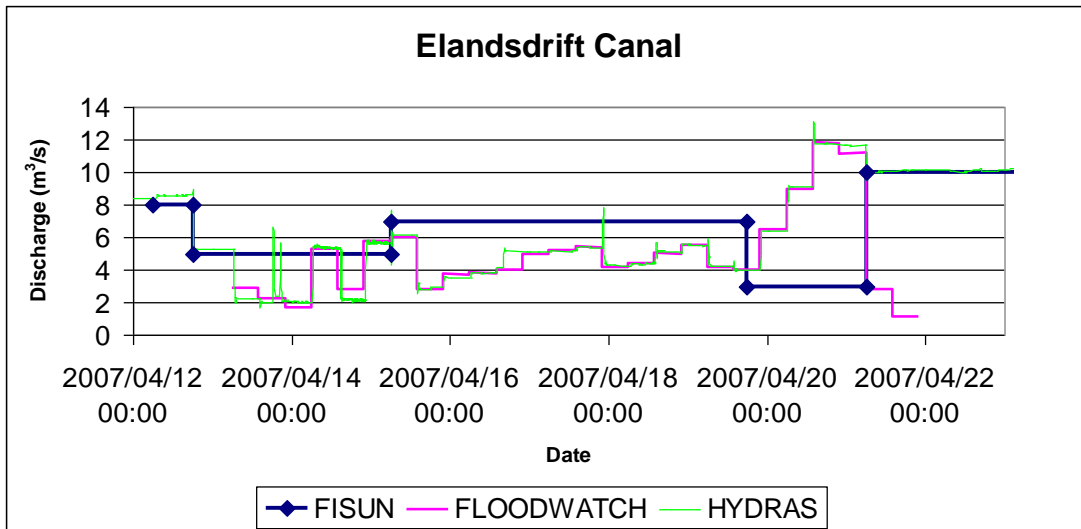
Figure 9.2-4 Elandsdrift Dam canal outlet: Discharge (m³/s)

e)   DeMistkraal River (Figure 9.2-5)

The FLOODWATCH model release predicted was generally the same as that of the FISUN model, except on Sundays where 5 m³/s blocks are added by the FISUN operator to flush the system. A flushing peak is shown at the beginning and at the end of the week. DWA releases this water on Sundays to allow farmers to get their animals across the river.

In the original set up Turbulom irrigation was a request which was a river release. During the test week the request of 0.83 m³/s for Turbulom was treated as a canal release by subtracting the flow from the model output for the river and adding it to the model canal release total.
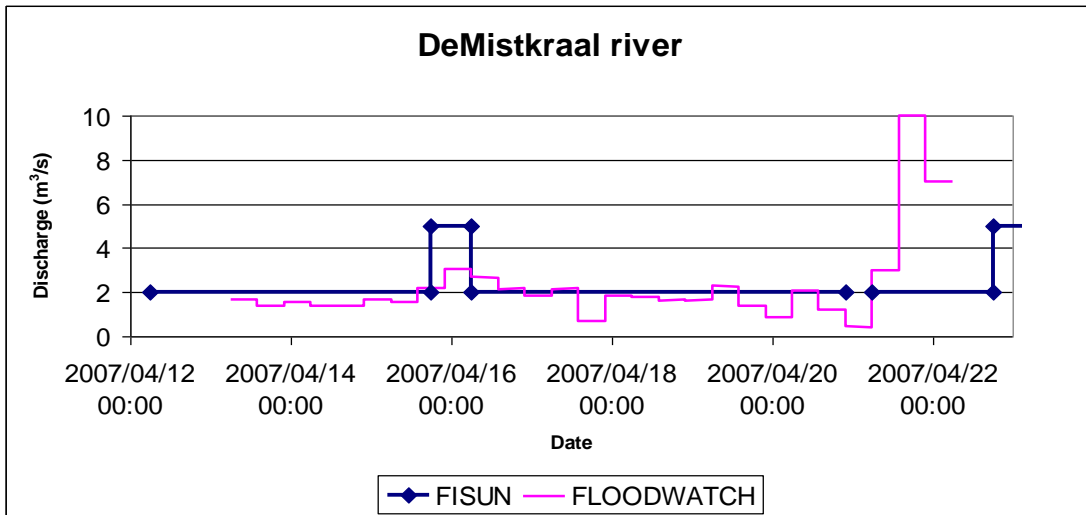
Figure 9.2-5 DeMistkraal Dam river outlet: Discharge (m^3/s)

f)   **DeMistkraal Canal** (Figure 9.2-6)

During the week the canal transfer was based mainly on irrigation requests since the downstream dam water levels were above targets set.
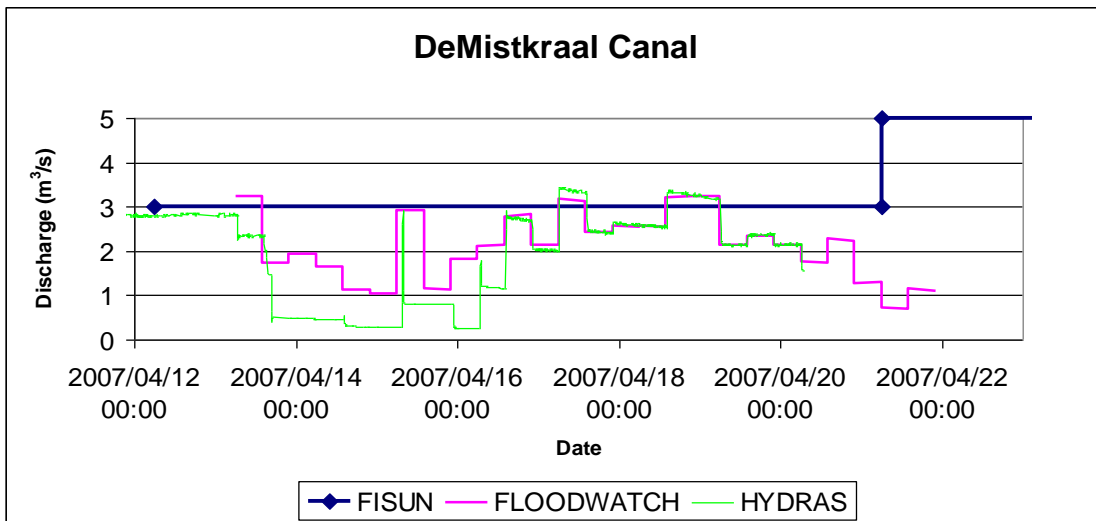
Figure 9.2-6 DeMistkraal Dam canal outlet: Discharge (m^3/s)

g)   **Darlington Dam River release** (Figure 9.2-7)

The FISUN model does not consider requests downstream of Darlington Dam and the requests are managed by the Lower Sundays WUA. The FLOODWATCH predicted release is much higher than that of the LSWUA. The LSWUA release is based on the demand and the dam was spilling over the auxiliary spillway during the test week which LSWUA does not include. At the end of the test week FLOODWATCH flow increased due to the model TDS predictions. The spillage predicted by the model was later found incorrect after a survey of the correct auxiliary spillway level which was found higher than indicated on design drawings.
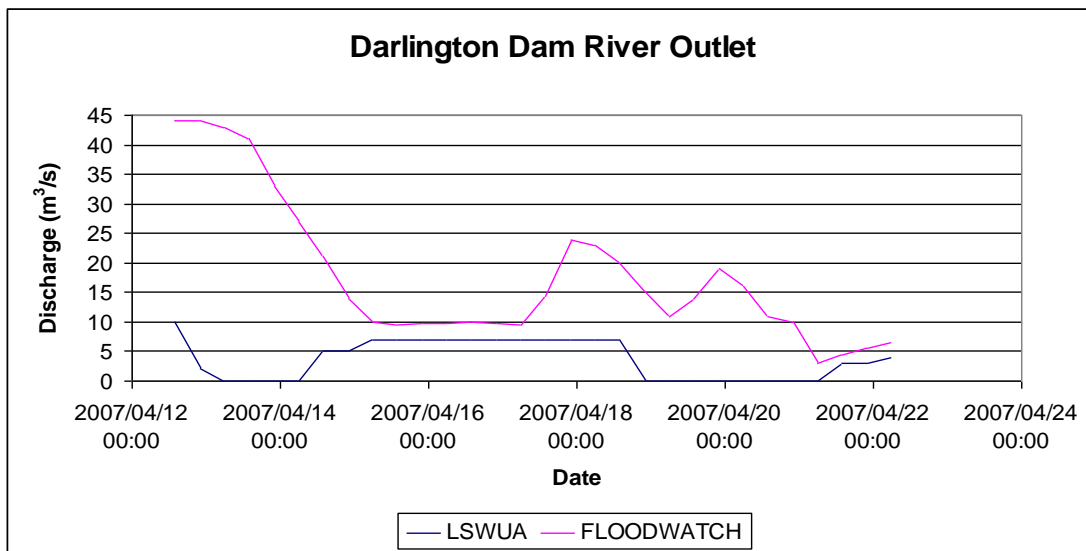
Figure 9.2-7 Darlington Dam river outlet: Discharge (m^3/s)

(LSWUA assumes 2.5 m^3/s leakage from dam which they consider in their release).

9.2.1.2 Dam water levels

a)   **Grassridge Dam** (Figure 9.2-8)

At the start of the test week the dam was below the MOL and the FLOODWATCH model raised the water level. On Monday 16 April an error in the HYDRAS discharge

table (DT) was found and corrected. After the error FLOODWATCH corrected the high water level.
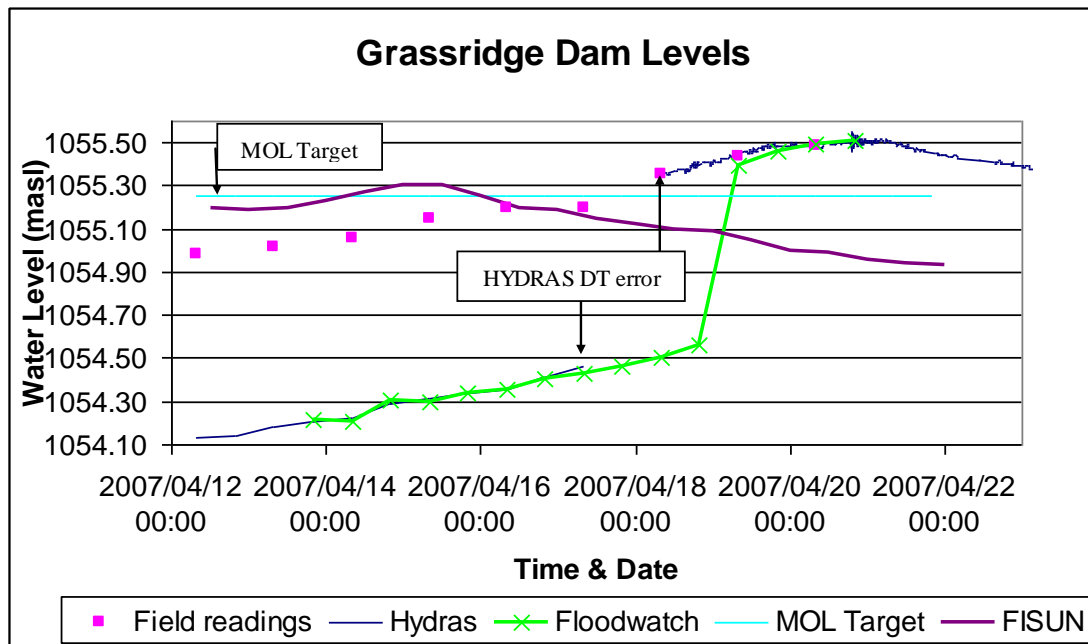
Figure 9.2-8 Grassridge Dam: Water level (masl)

b) **Elandsdrift Dam** (Figure 9.2-9)

The water level dropped 1.2m below the MOL during the week. The water level however changed at the end of the week. Reasons for the low water level were observed high downstream river TDS and too much releases to the river during operations.
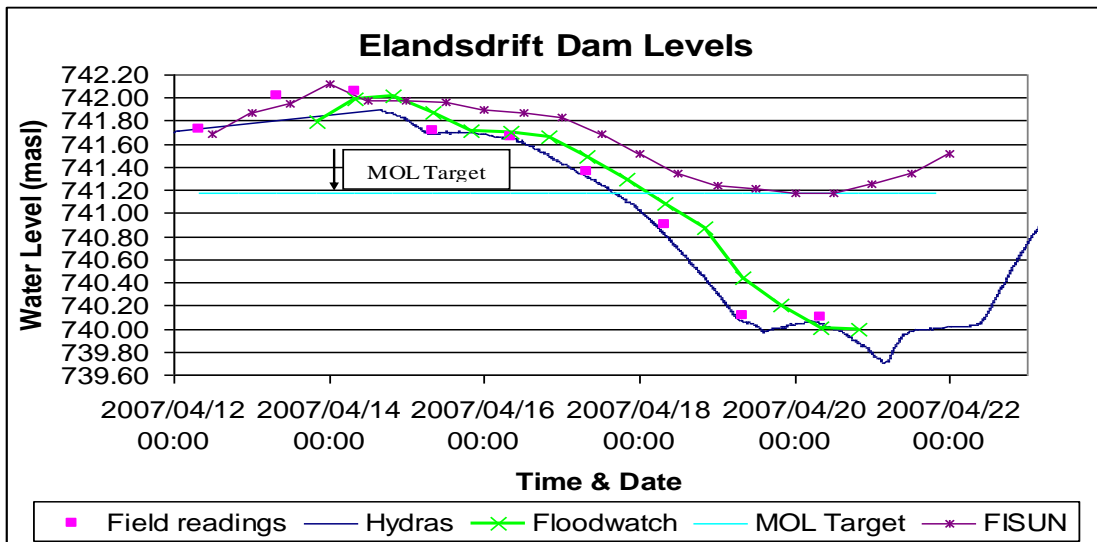
Figure 9.2-9 Elandsdrift Dam: Water level (masl)

c) **DeMistkraal Dam** (Figure 9.2-10)

During the week the FLOODWATCH model lowered the water level correctly and at the end of the week it was only 0.2m below MOL.
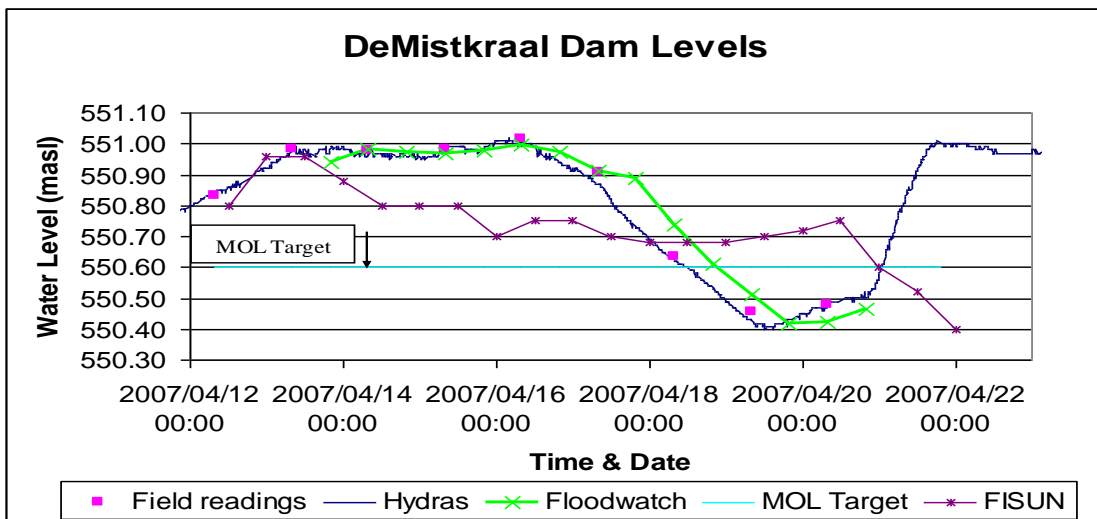
Figure 9.2-10 DeMistkraal Dam: Water level (masl)

d)   Darlington Dam (Figure 9.2-11)

The dam was not part of the test but its operations were included in the FLOODWATCH model which predicted correctly based on the target water levels. Water level changes are slow due to the large storage capacity. The dam was spilling through the open auxiliary spillway at the start of the week at 5 m^3/s and by the end of the week it was 2 m^3/s. (Later found to be incorrect due to an incorrect spillway crest level).
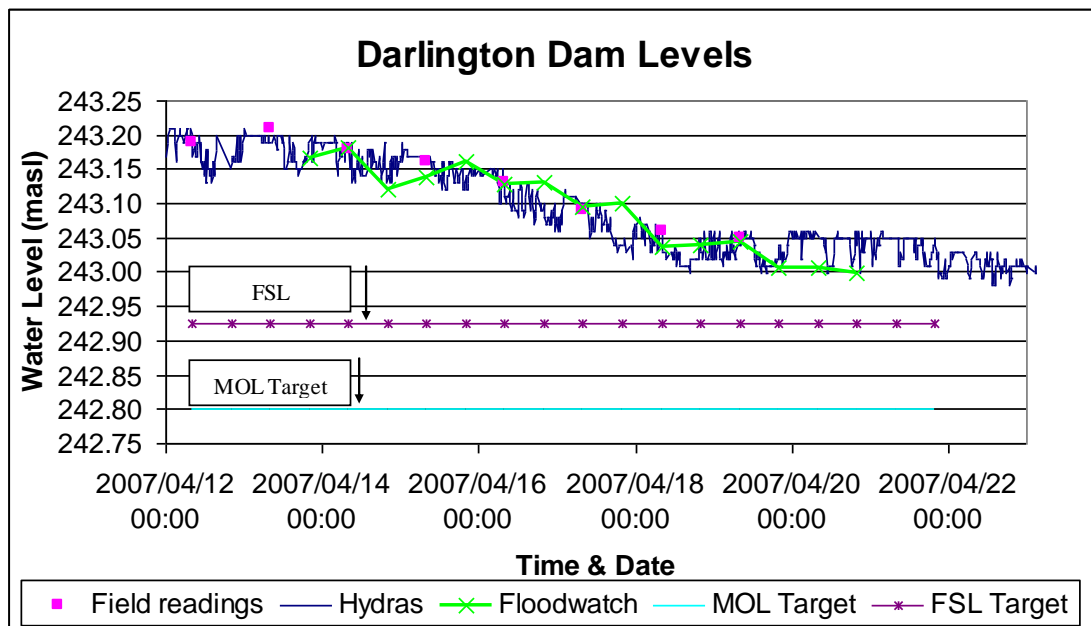
Figure 9.2-11 Darlington Dam: Water level (masl)

9.2.1.3 Dam salinity

a)   Grassridge Dam (Figure 9.2-12)

Field grab samples showed lower TDS values than the HYDRAS (observed logger data). During the week the FLOODWATCH model followed HYDRAS. On the 17th and 18th the field data and HYDRAS data corresponded better. TDS values in FISUN came from field sample data, while FLOODWATCH used HYDRAS data.
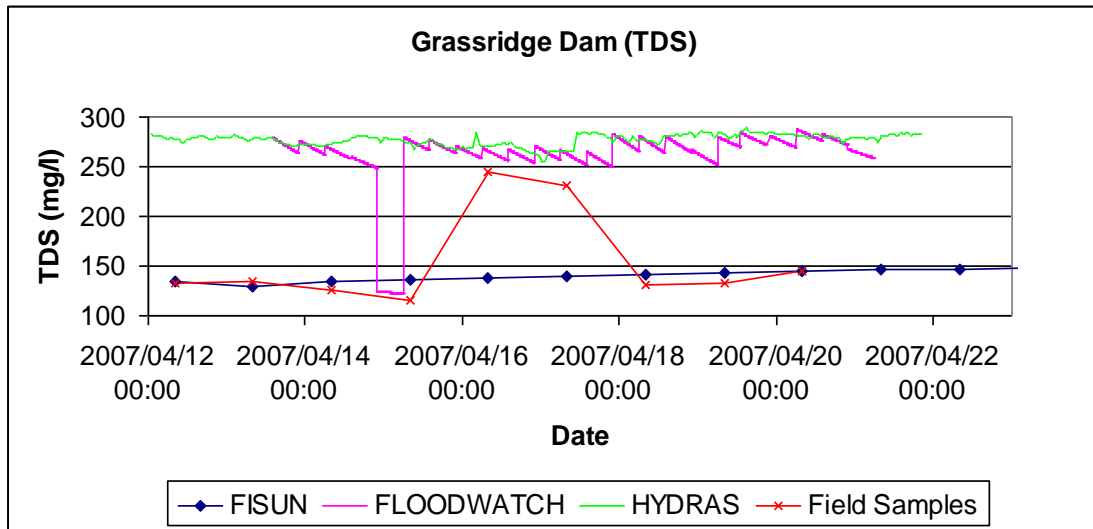
Figure 9.2-12 Grassridge Dam: Salinity (mg/l)

b) **Elandsdrift Dam** (Figure 9.2-13)

The field grab sample TDS data were constantly lower than the HYDRAS data. As the dam level lowered during the week the TDS increased as expected. The FLOODWATCH model predicted TDS values were higher than the FISUN prediction but lower than the HYDRAS observations.
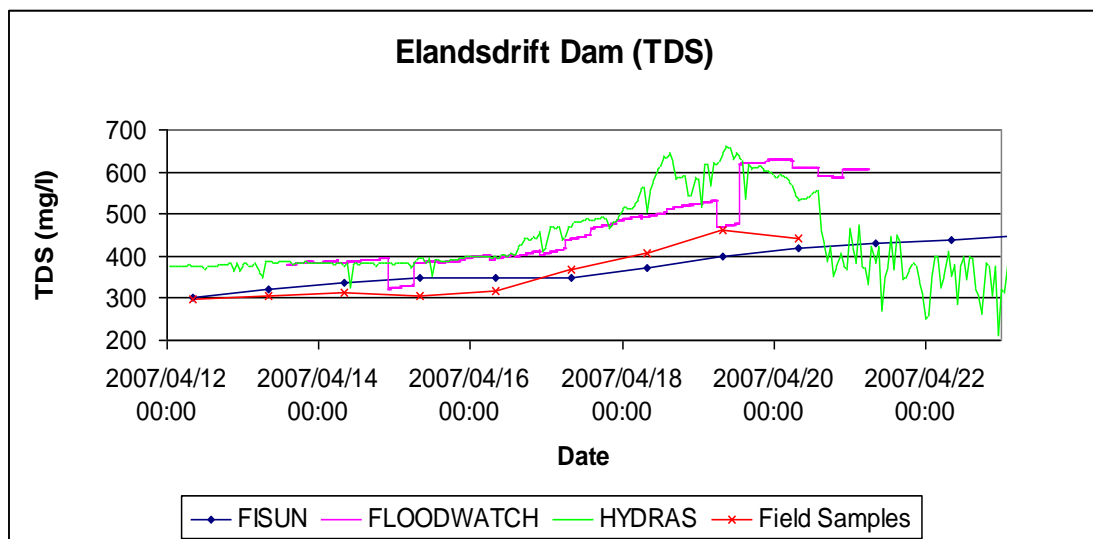
Figure 9.2-13 Elandsdrift Dam: Salinity (mg/l)

c) **DeMistkraal Dam** (Figure 3.3)

The HYDRAS data were low compared to hand grab samples. The FISUN model used hand sample data and therefore had higher TDS predicted values. On the other hand the FLOODWATCH model resets TDS to lower HYDRAS data at the start of each 8h run.
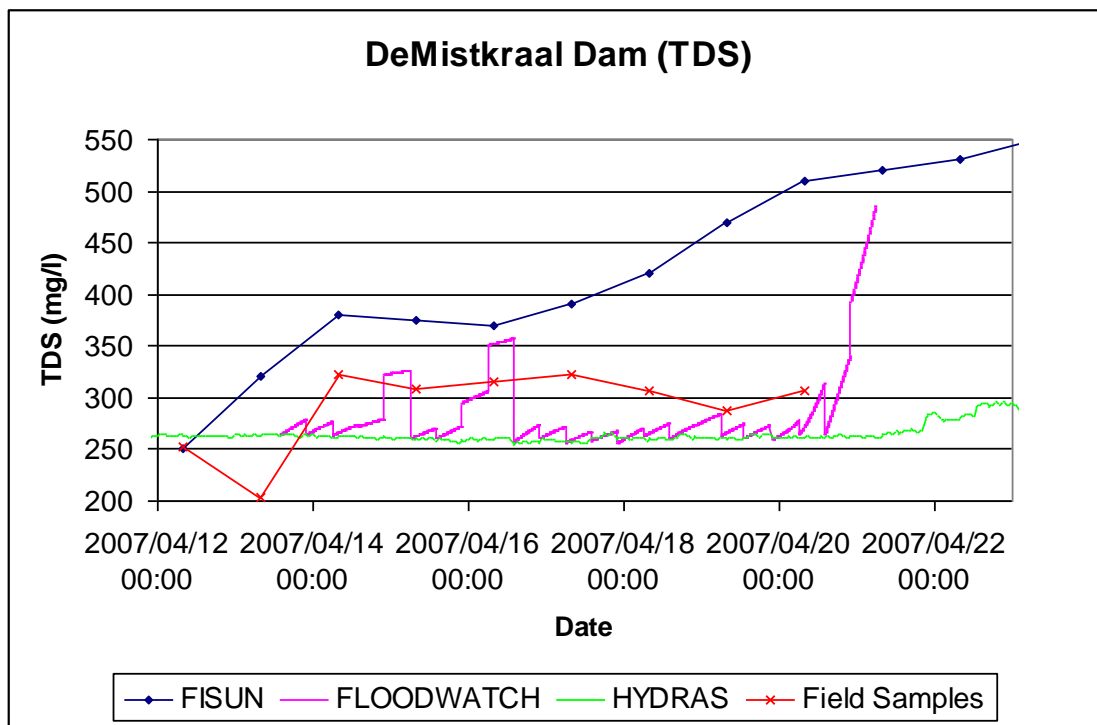
Figure 9.2-13 DeMistkraal Dam: Salinity (mg/l)

d) **Darlington Dam** (Figure 9.2-14)

The FISUN model did not calculate TDS at Darlington Dam. The FLOODWATCH model used HYDRAS data and started to increase the TDS. At each (8h) run input TDS was reset in the model. This fast rise of predicted TDS is not correct and was later found to be caused by a dam inflow concentration (HYDRAS) of above 20000 mg/l, which was not correct.
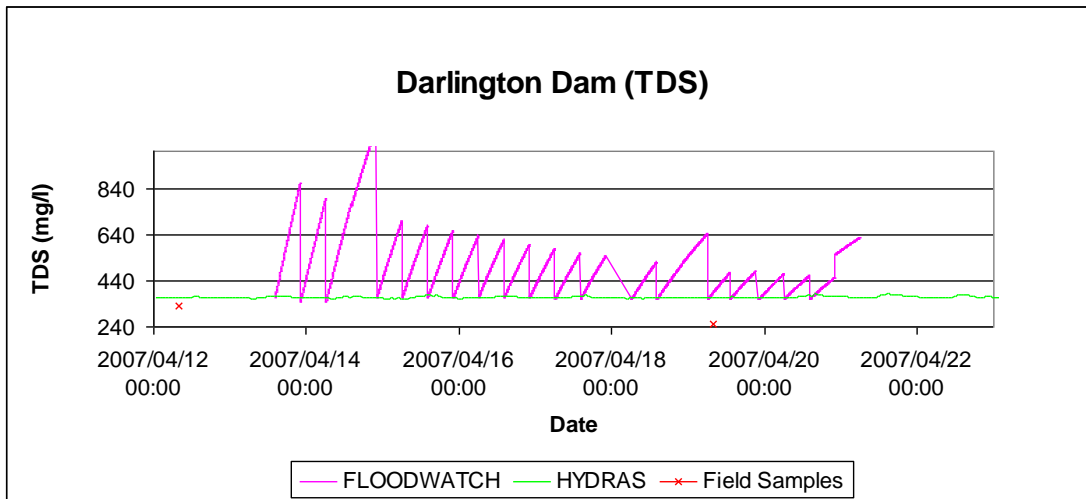
Figure 9.2.14 Darlington Dam: Salinity (mg/l)

9.2.1.4 System/river outflows

a) **Great Fish at Piggot's Bridge** (Figure9.2-15 and Figure 9.2-16)

The FLOODWATCH model required much more water than the target (1.5 m^3/s) during the week, in order to limit the TDS to below 600 mg/l on the Great Fish River downstream of Elandsdrift Dam. Even with extra river releases, however, the downstream river section did not reach the target TDS during the week.
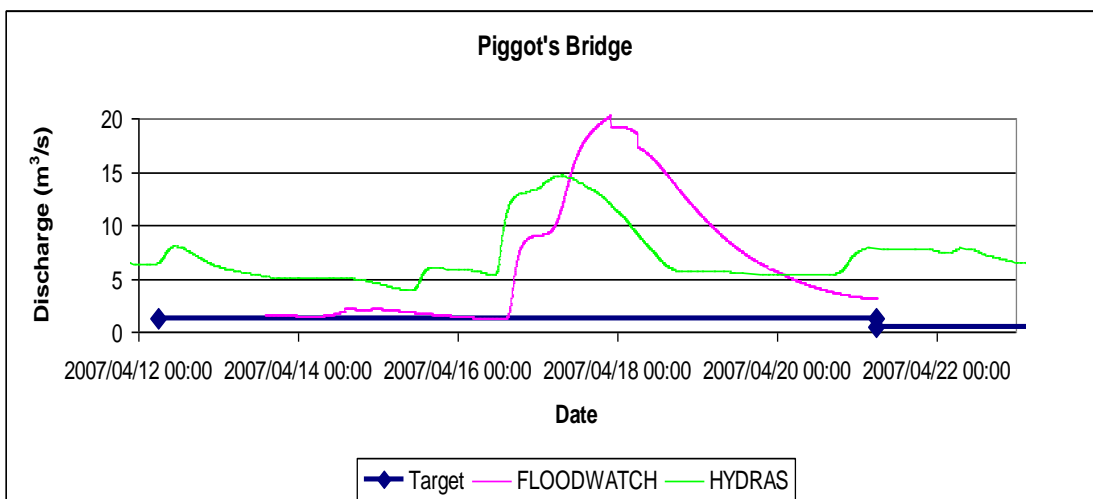
Figure 9.2-15 Great Fish River at Piggot's Bridge: Discharge (m^3/s)
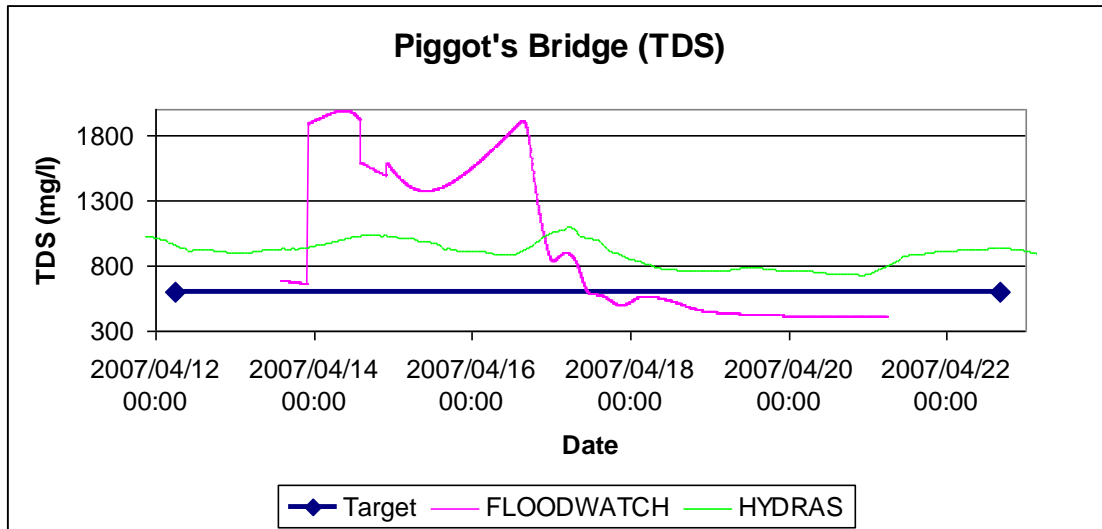
Figure 9.2-16 Great Fish River at Piggot's Bridge: Salinity (mg/l)

b) **Little Fish at Junctions Drift** (Figure 9.2-17 and Figure 9.2-18)

At Junction Drift on the Little Fish River the week's predicted low flows were slightly above the target. Apart from the flushing flows released on Sundays from DeMistkraal Dam which create river outflow, in the observed HYDRAS, the FLOODWATCH model released water to maintain the TDS quality.

The optimisation model tried to achieve the 600 mg/l target TDS. The HYDRAS station gave some corrupted data during the week. Figure 9.2.18a shows the data plotted raw and Figure 9.2-18b has a limit of 1500 mg/l enforced on the data. If a peak value was above 1500 mg/l the previous accepted value was taken in its place.
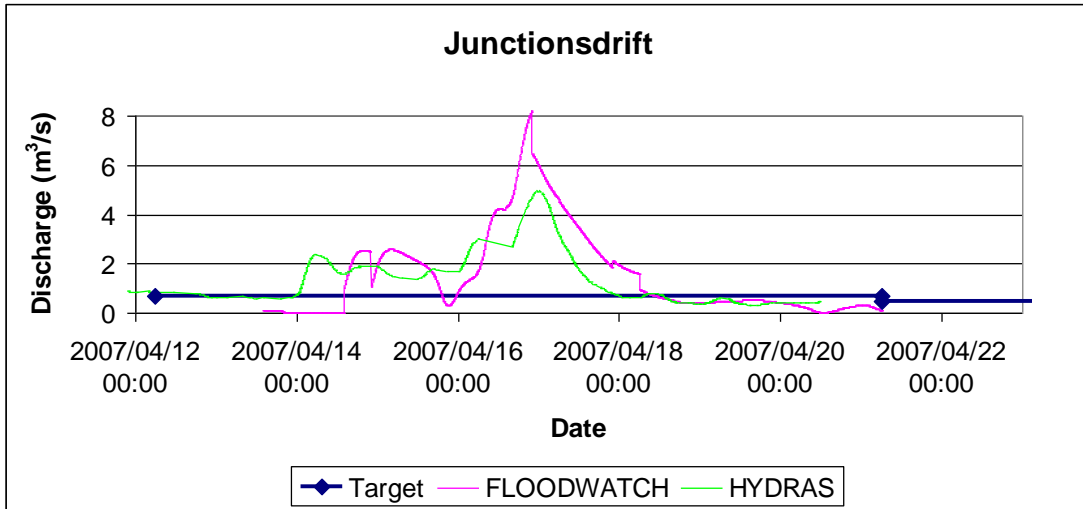
Figure 9.2-17 Little Fish River at Junctionsdrift: Discharge (m³/s)
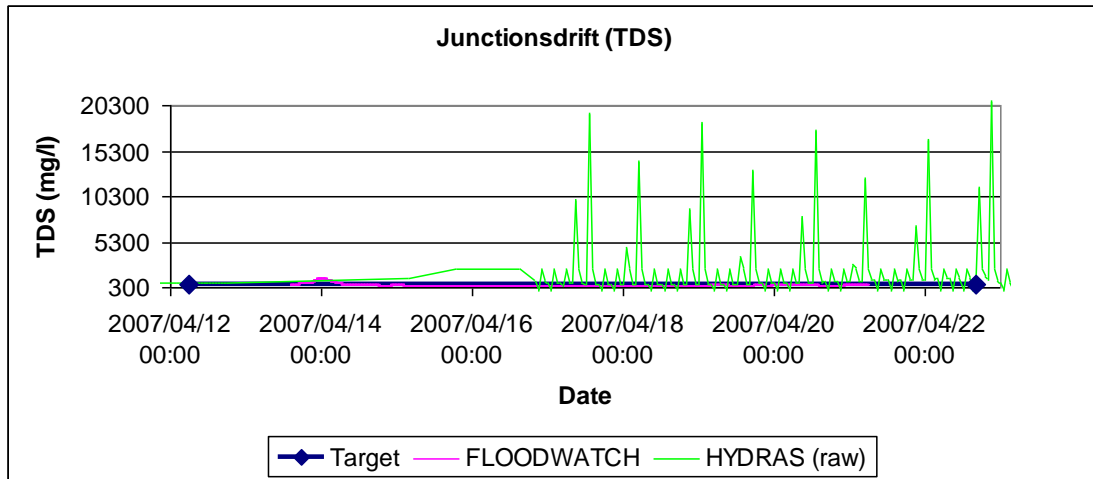
Figure 9.2-18a Little Fish River at Junctionsdrift: Salinity (mg/l)
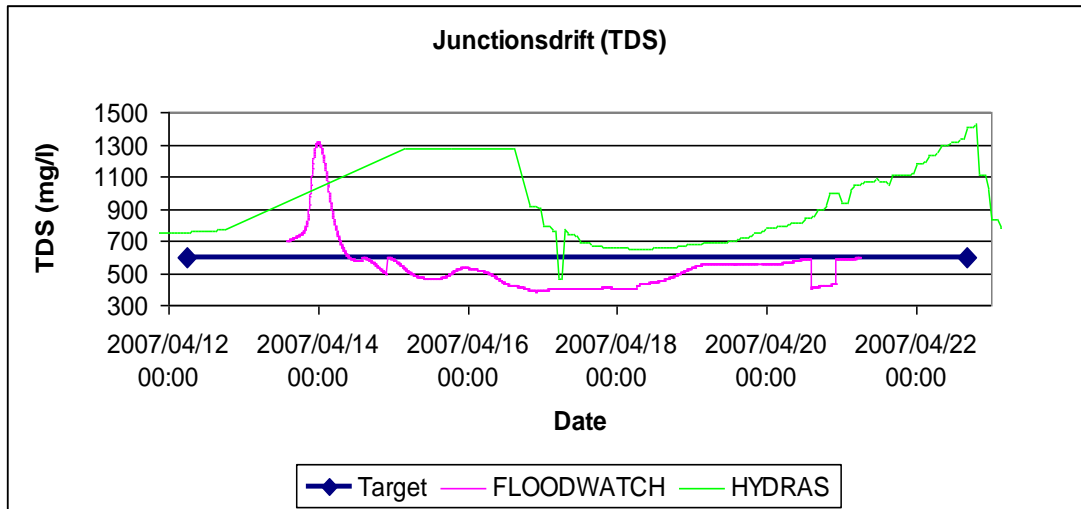
Figure 9.2-18b Little Fish River at Junctionsdrift: Salinity (mg/l)

c)   **Sundays River at Korhaansdrif**t (Figures 9.2-19 and 9.2-20)

The FLOODWATCH model predictions are not relevant to the Sundays River outflow at Korhaansdrift because the upstream dam was not operated as requested by the model to achieve the targets set out for the model.

The predicted and observed TDS stayed below the target of 600 mg/l.
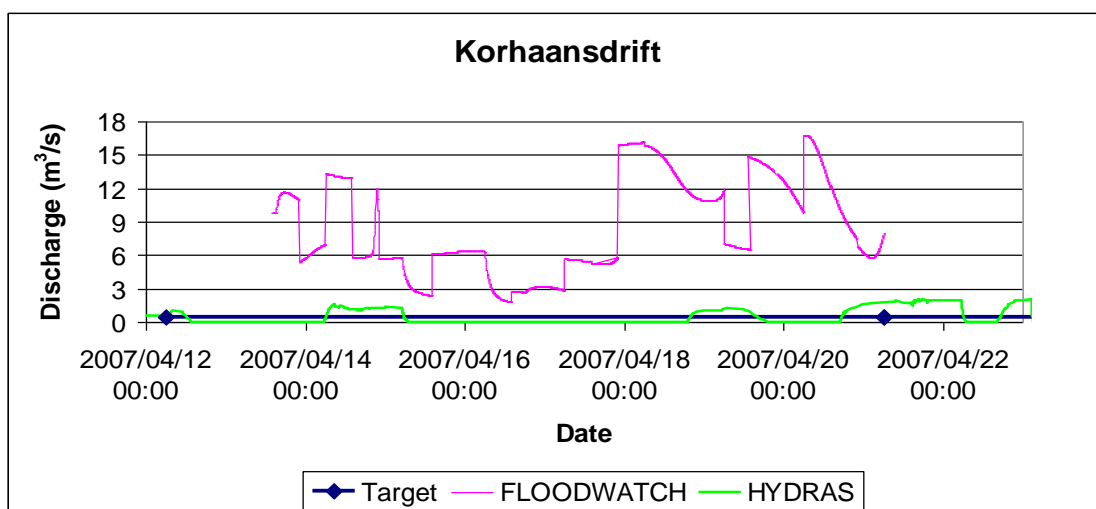
Figure 9.2-19 Sundays River at Korhaansdrift: Discharge (m³/s)
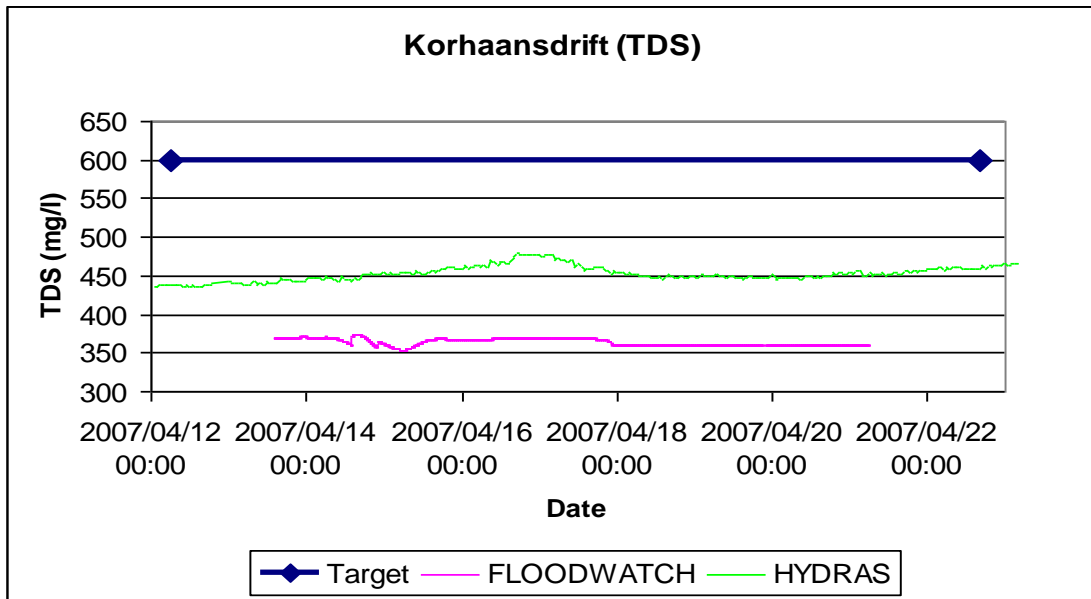
Figure 9.2-20 Sundays River at Korhaansdrift: Salinity (mg/l)

9.2.2 Actual irrigation abstraction versus request

Only the Lower Sundays WUA was evaluated due to readily available data. In Figure 9.2-21 the LSWUA's actual use was lower than the request during the peak flow periods by about 1 m^3/s. In general the correct pattern was followed as requested.
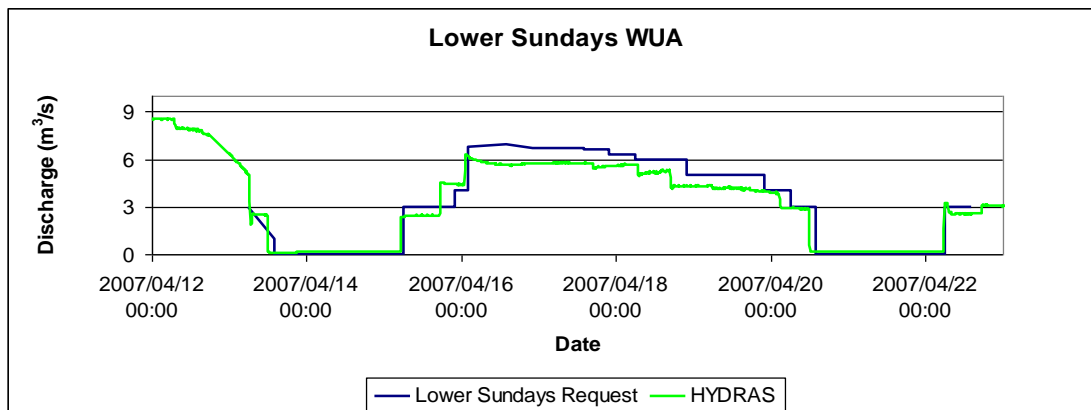
Figure 9.2-21 Sundays River abstraction by Lower Sundays WUA at Korhaansdrift

9.2.3 Model volume comparison

The FISUN model and FLOODWATCH models' prediction for the week (same targets for water levels) were compared as shown in Table 6.1.

Table 9.2-2 Model release volume comparison for 9 days starting 06:00 13 April 2007

Control Structure	FISUN (million m^3)	FLOODWATCH (million m^3)
Teebus	10.27	12.4
Grassridge	11.06	10.95
Elandsdrift River	3.14	5.69 (0.37MCM IFR included)
Elandsdrift canal	4.17	3.64
DeMistkraal River	1.63	1.52 (0.52 MCM IFR
DeMistkraal canal	1.68	included)
Darlington	2.8* + 2.3 (spillage) = 5.1	1.57
		12.7 (0.37 MCM IFR
		included)

* Note: LSWUA data.

9.2.4 Summary of second test week

The field exercise was very important to improve real time data reliability and accuracy, and to develop and refine the FLOODWATCH and the Mike 11 optimization model further.

Key conclusions are:

a)   TDS observed HYDRAS data were not reliable, especially at Grassridge Dam, and at Fort Brown and Juntionsdrift.

b)   On the Elandsdrift canal irrigators cannot abstract all their water during low flows (dam release < 4 m^3/s) at Hopefield.

c)   Elandsdrift Dam needs a relatively high MOL (say 70 % FSC) due to its relatively small storage capacity.

d)   Office grid software is required to reduce model runtime to less than 8h for 4 day optimisations, by using parallel processing.

e)   FLOODWATCH output format tables and graphs need to be refined for reporting.

f)   An error was found in the Darlington Dam auxiliary spillway crest.

g)   The FLOODWATCH model wanted to draw down Darlington Dam by releasing water through the gates. This and the high dam TDS values were looked into when refining the model.

h)   At Elandsdrift Dam the water level was drawn down below the MOL, partly due to higher actual releases to the river than simulated. The outlet discharge table needs to be refined as well as the model optimisation.

The model set up used during the field testing was selected to optimise for low flows and floods.

10. Operational results in real-time

The OFS-RT computer aided software tool came into operation in August 2008. It was a real-time training session and for the first few months more attention was given to the operations. The following discussion covers the first year of real-time operations by comparing simulated discharge and quality with observed data. Each of the figures below presents monitored data from June 2007 to December 2009, a red line divides the graph on August 2008 into pre real-time operations and real-time operations. The main focus of this section was to show how the computer aids the operations. Unfortunately, there were many exceptions in the system and deviations from the forecasted release values and a full comparison was not possible.

10.1 OVIS Tunnel

The tunnel releases from the OVIS Tunnel shown in Figure 10.1-1 show an increase in average discharge from the old system to the real-time operations. The transferred volume for water year 2007/2008 was 671 million cubic metre (MCM) of water and for the water year 2008/2009 the transferral was 841 million cubic meter of water. These results made it necessary to inspect the data and the inspection showed that the station logger was offline in both periods, but more so in the pre real-time year. The 130 MCM increased transferral is not an absolute value, but from the graph the increased released trend is clearly visible. The requested abstraction water for this period was 681 MCM and the additional 160MCM water was used to increase dam storage volume and improve system water quality for the period. The OVIS tunnel has a discharge capacity linked to the Gariep Dam level (Figure 10.1-2) namely a maximum of 57.5 m^3/s flow when Gariep Dam is full. Due to infrastructure on the canal downstream of the tunnel outlet and problems with control valves, the discharge is limited to 45 m^3/s for operations.
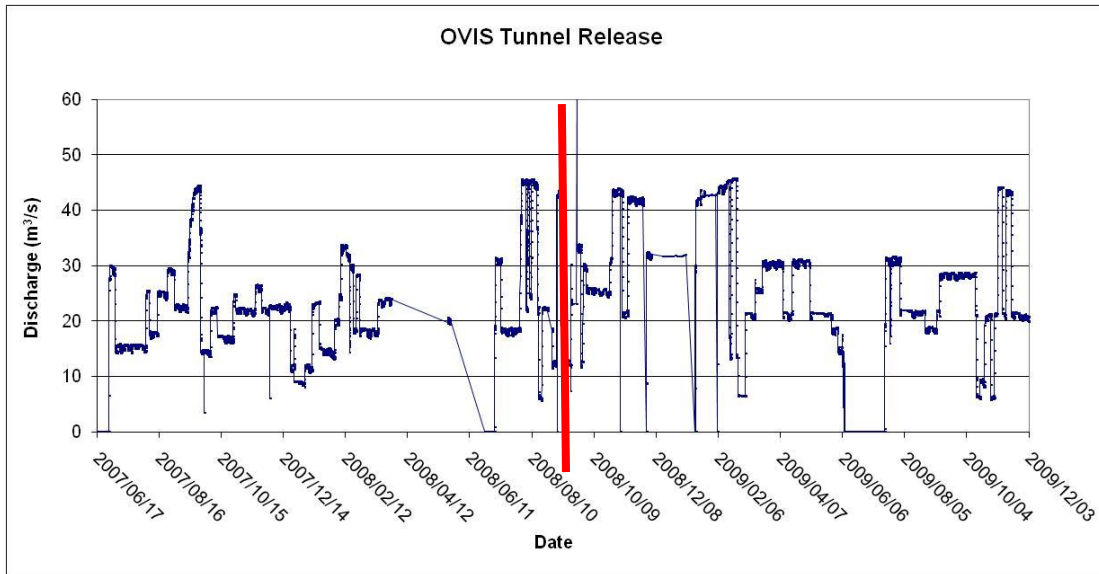
Figure 10.1-1 OVIS Tunnel release
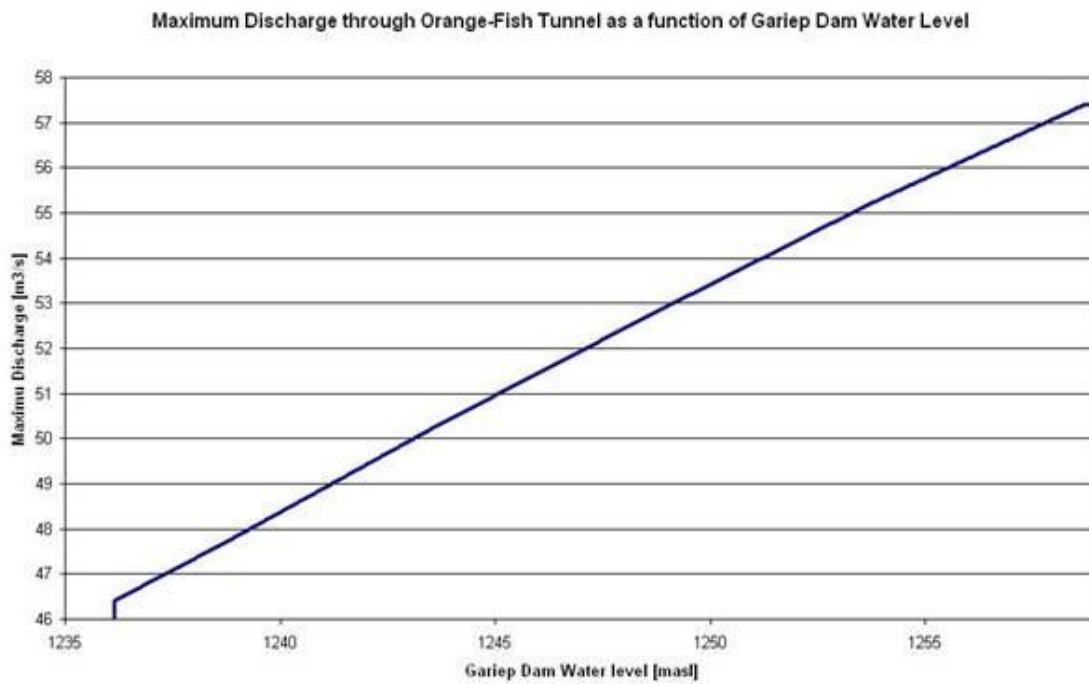
Figure 10.1-2 OVIS Tunnel release vs Gariep Dam water level

10.2 Grassridge Dam

Figure 10.2-1 shows that the Grassridge Dam river release increased from 623 to 806 MCM for the two periods. This seems to correspond to the OVIS tunnel release increase. The Grassridge Dam water level in Figure 10.2-2 shows that the dam was

operating below the MOL pre real-time. With implementation of the real-time operations the level dropped below the MOL once and again during the July dry period. Operational restrictions occurred at Grassridge Dam sluice gates, one gate was fixed in a half open setting and another gate was on manual operating during the first two months of real-time operations. This means that the flow was not reduced to the required low flow, the opening did not occur in time and the maximum flow was not obtained. The operator averaged the forecasted releases into flows the gate operator could handle. The computer did not have a formal option to handle this gate error, but with the hind cast data assimilation method, the computer kept forecasted water releases balanced. On the TDS water quality of Grassridge Dam averaged on 150 mg/l under normal operations and the water quality deteriorated during the July dry period.(Figure 10.2-3) Pre real-time the TDS readings averaged 250 mg/l mostly due to the dam level being lower than the MOL. Logger errors are visible in the sudden step up or down in the data, during both periods in June.
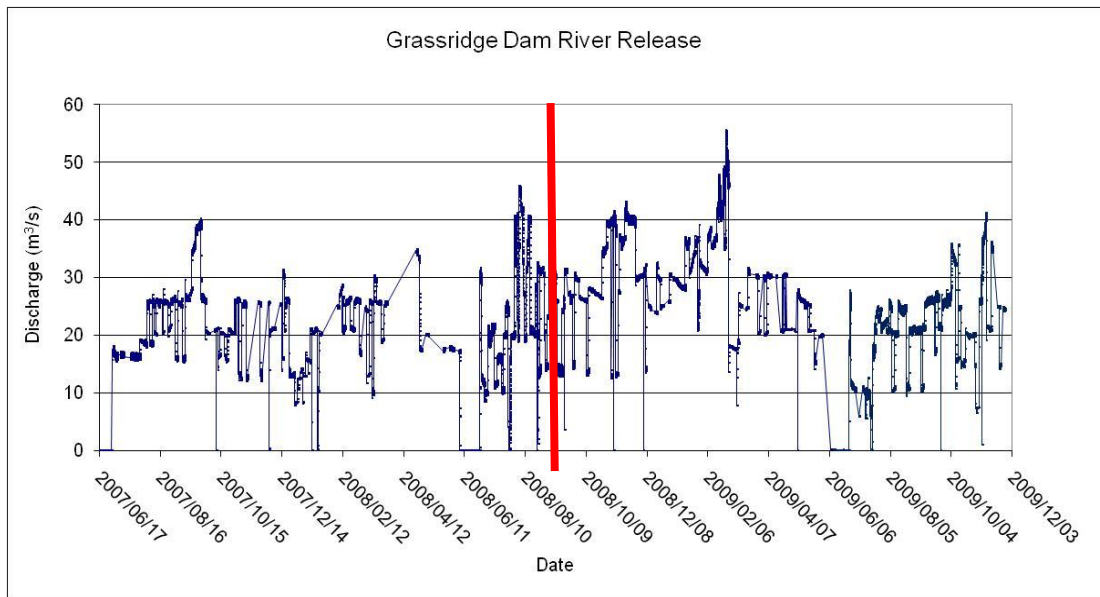
Figure 10.2-1 Grassridge Dam river release
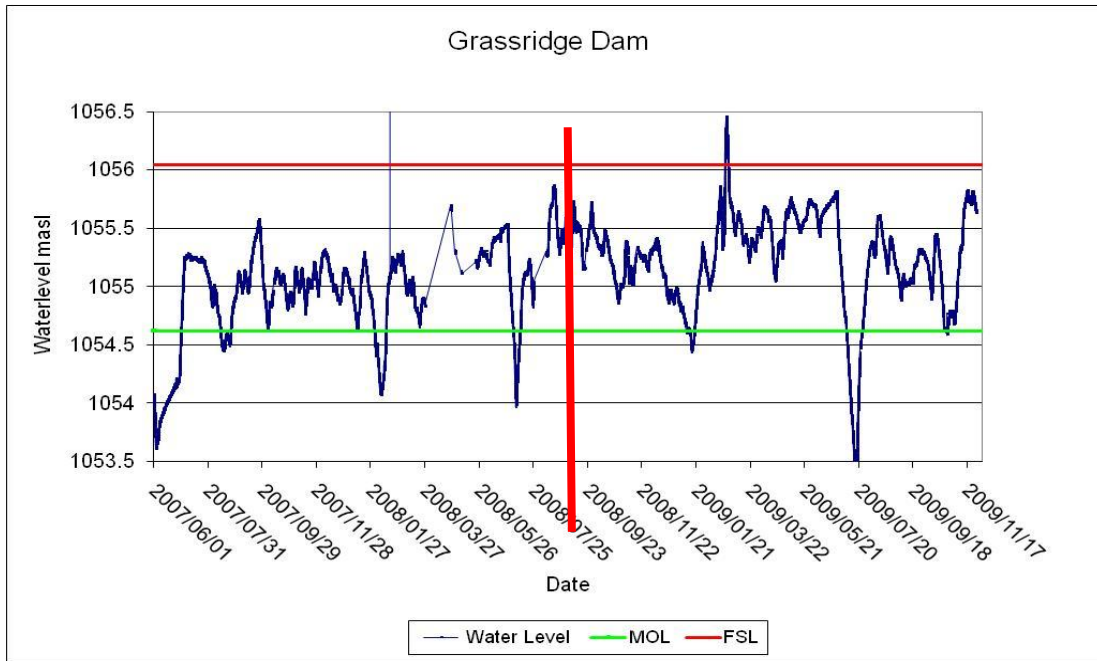
Figure 10.2-2 Grassridge Dam water level
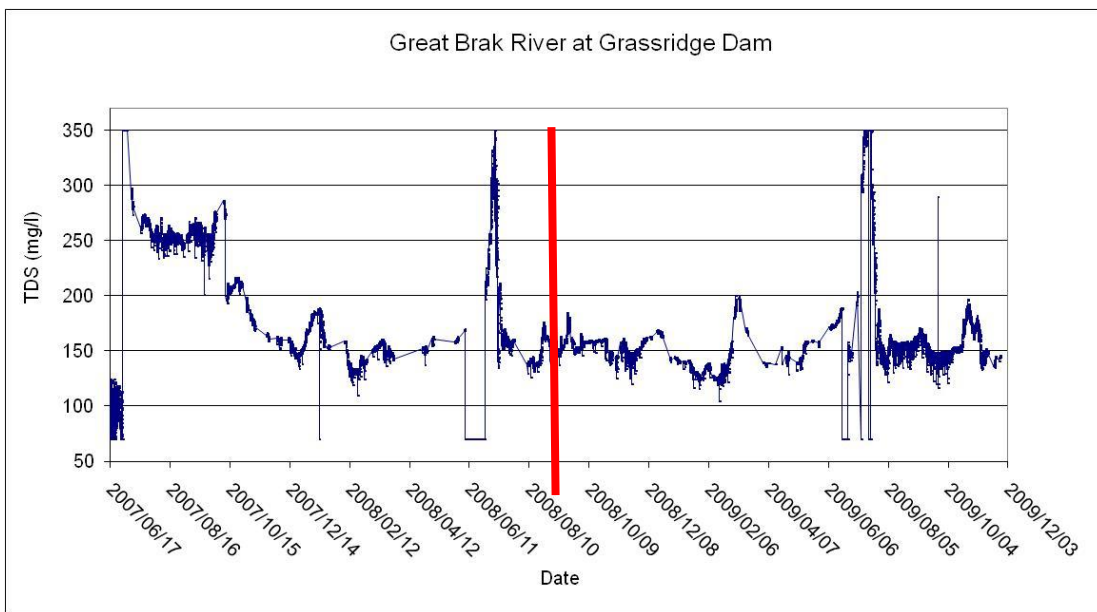
Figure 10.2-3 Grassridge Dam TDS

10.3 Elandsdrift Dam

Elandsdrift Dam river release as shown in Figure 10.3-1, shows an average decrease in the river flow. For 2007/2008 the flow was 274 MCM and with the real-time in operation 244 MCM flows in the river. Figure 10.3-2 shows that the extra water in the

system was transferred by canal from Elandsdrift Dam to DeMistkraal Dam. The canal transferred volume increased from 270 to 369 MCM; the increased trend is clearly visible. Figure 10.3-3 shows the dam level was operated between the MOL and the FSL, during in pre- and real-time operations frequently spills and runs below the MOL. The water quality in Figure 10.3-4 pre real-time operations averaged at TDS at 400 mg/l. With the real-time in place the average dropped to 250 mg/l for as long as attention was given to the system. Based on the following four figures it can be seen that there are often communication losses between the field station and the real-time computer. The fact that this was spotted on a three year graph means the data losses occured over a long period of time.
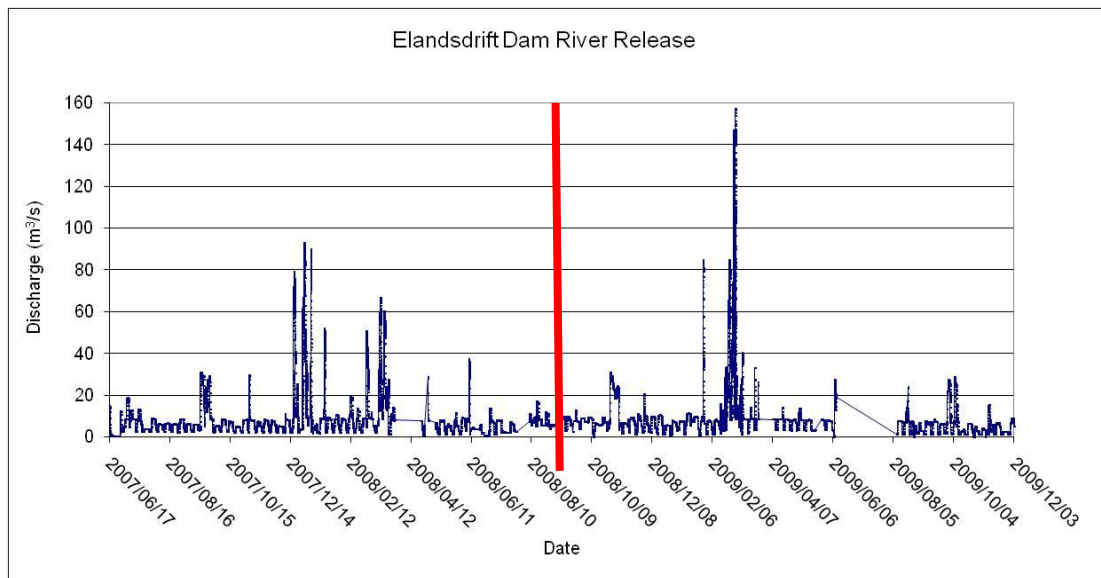
Figure 10.3-1 Elandsdrift Dam river release
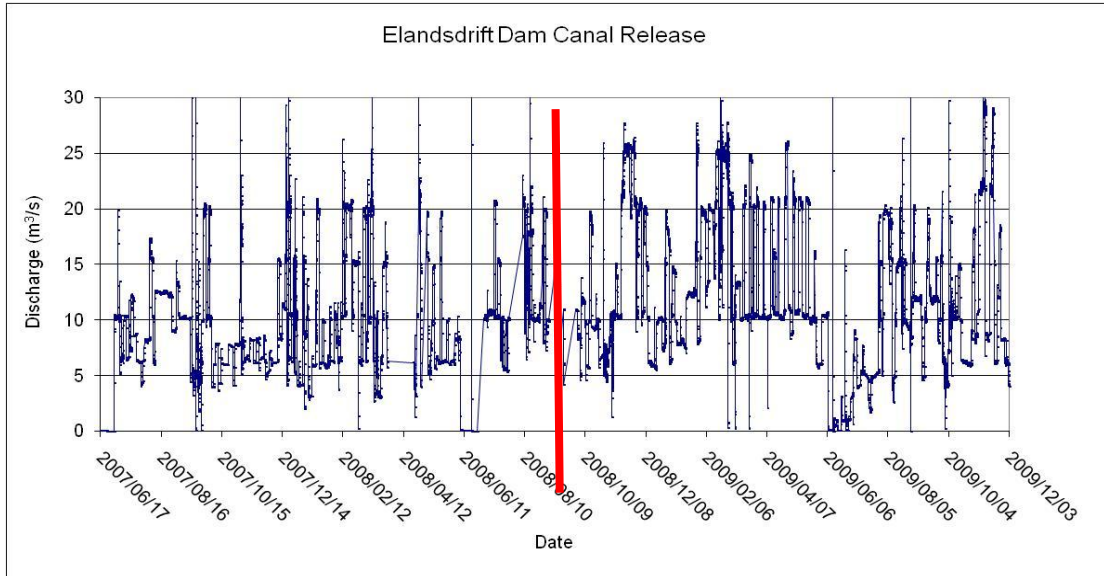
Figure 10.3-2 Elandsdrift Dam canal release
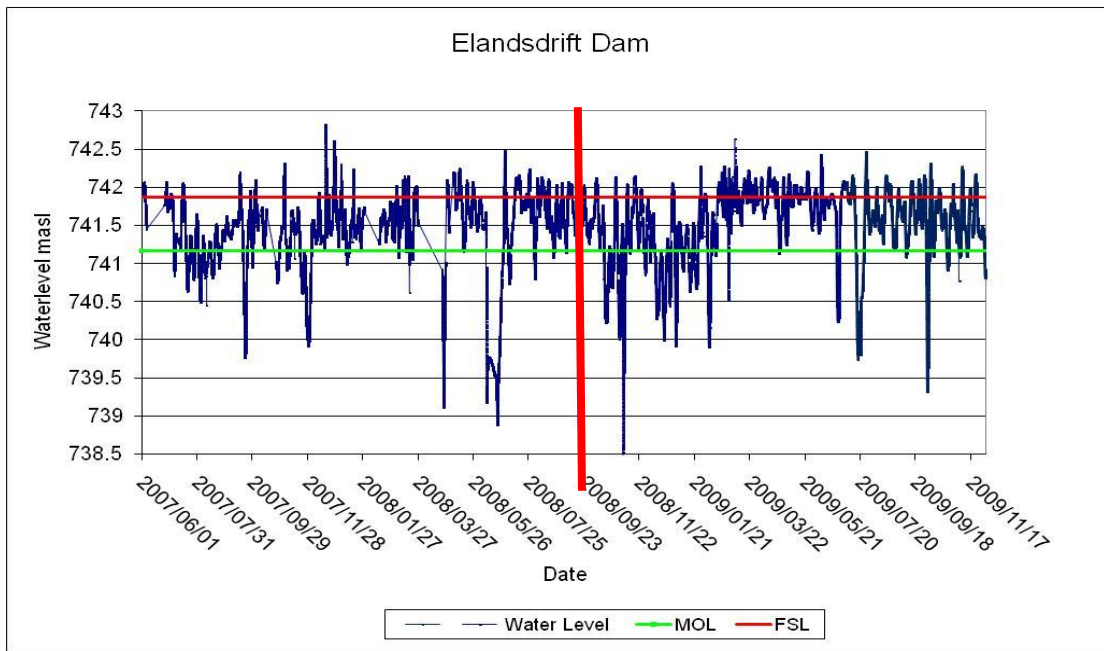
Figure 10.3.3 Elandsdrift Dam water level

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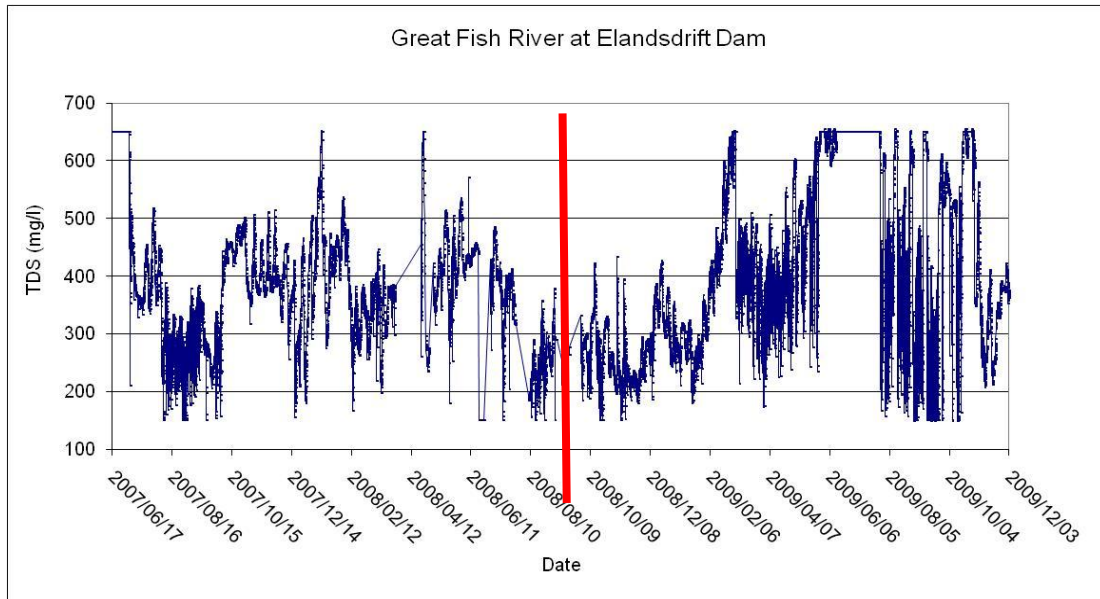
Figure 10.3.4 Elandsdrift Dam water quality

10.4 DeMistkraal Dam

From Figure 10.4-1 it can be seen that the DeMistkraal Dam canal release increased after the real-time came to operation (pre real-time 252 MCM to 275 MCM). Logger gaps do occur in the graph and affect the accuracies of the release volumes. The river release from DeMistkraal Dam down the Little Fish River was not monitored until the end 2008 and the station is not connected to the OFS-RT system. (See section 10.6.2) System outflow controls for insight into the Little Fish River. DeMistkraal Dam have debris problems blocking the release gates openings, this causes that releasing water to the Skoenmakers canal is not always up to the required flow. Figure 10.4-2 shows that pre real-time logger gaps occurred frequently. The dam was operated within the MOL and FSL for the both periods. More spilling occured during real-time operation due to the fact that the canal could not release its full required discharges. The operator let the dam spill to flush the floating debris out and draw it down lower than MOL to remove the lower debris at the gates. This created a temporary solution. More attention must be paid to the debris problem for the integrity of the system. The water quality at DeMistkraal Dam is shown in Figure 10.4.3. The TDS pre real-time was below 600 mg/l and dropped during real-time average to 400 mg/l, a visible improvement on the quality with the real-time.

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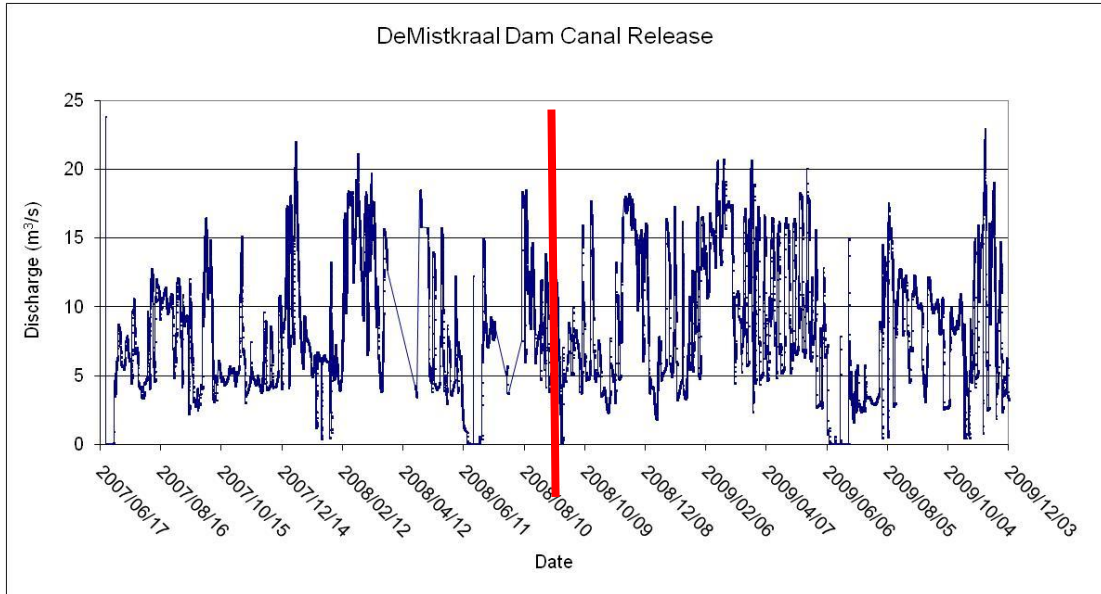
Figure 10.4-1 DeMistkraal Dam canal release
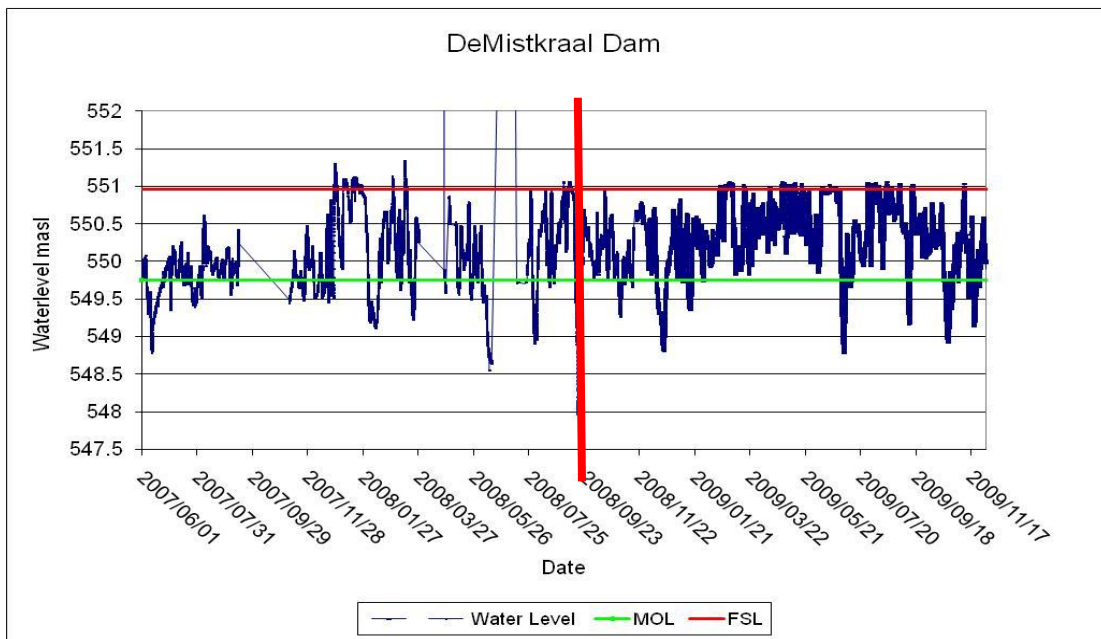

Figure 10.4-2 DeMistkraal Dam water level
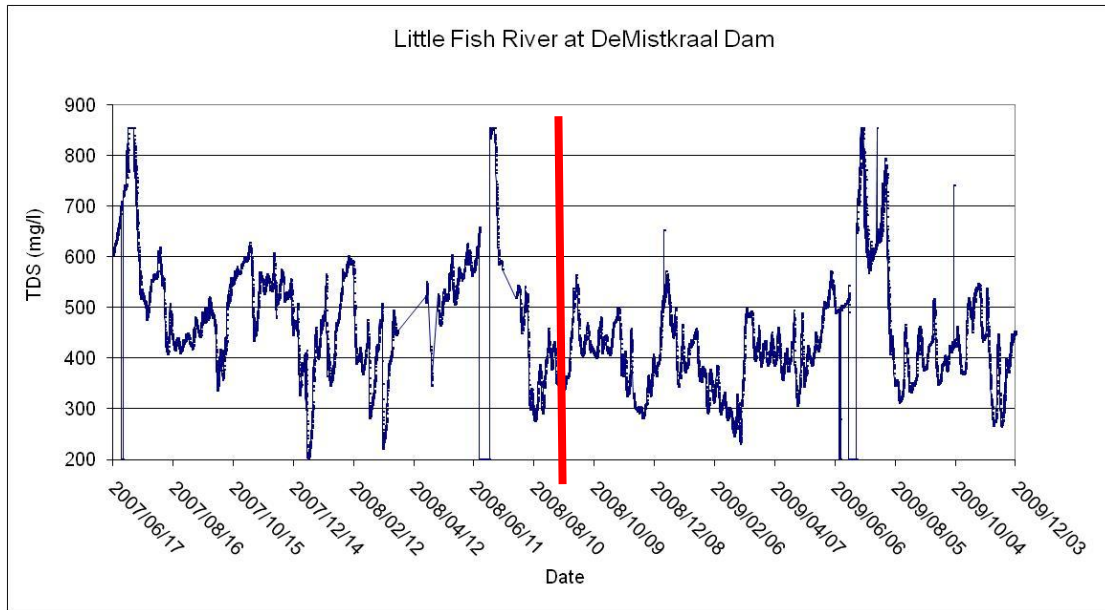
**Figure 10.4-3 DeMistkraal Dam water quality**

10.5 Darlington Dam

It must be noted that releases from Darlington Dam to the Sundays River were not controlled by the OFS-RT system, but by the LSWUA. The water requests from LSWUA were not received as for the rest of the system on Thursdays, instead the requests were taken to be the previous week abstraction. This creates a delay in the dam water balance volume; with the real-time only being able to recharge Darlington Dam from the previous week discharges. Darlington Dam river release decreased from 171 MCM pre real-time to 161 MCM during the real-time operations, Figure 10.5-1 shows gaps in the logger data and from the graph trend one would say the release increased during the real-time operations. The dam level in Figure 10.5-2 shows the drawdown of the dam level to the MOL and a tendency to be close to the MOL. The Darlington Dam level was affected by the estimated water request and the blockage at DeMistkraal not being able to recharge the volume in real-time. From Figure 10.5-3 the water quality logged data is of poor quality and the logger was offline for long periods. The remoteness of Darlington Dam made it difficult for service personnel to attend to the station's needs.

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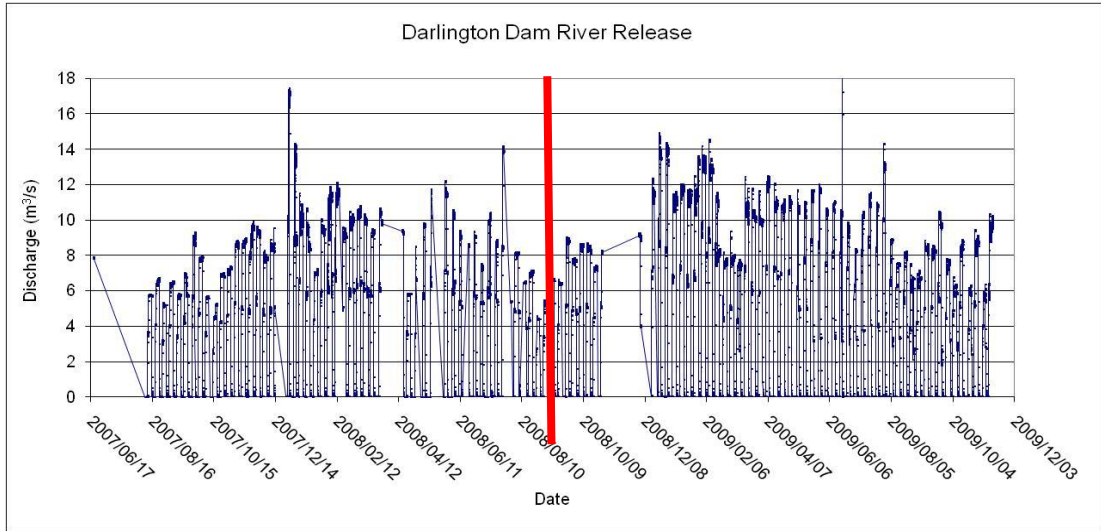
Figure 10.5-1 Darlington Dam River release
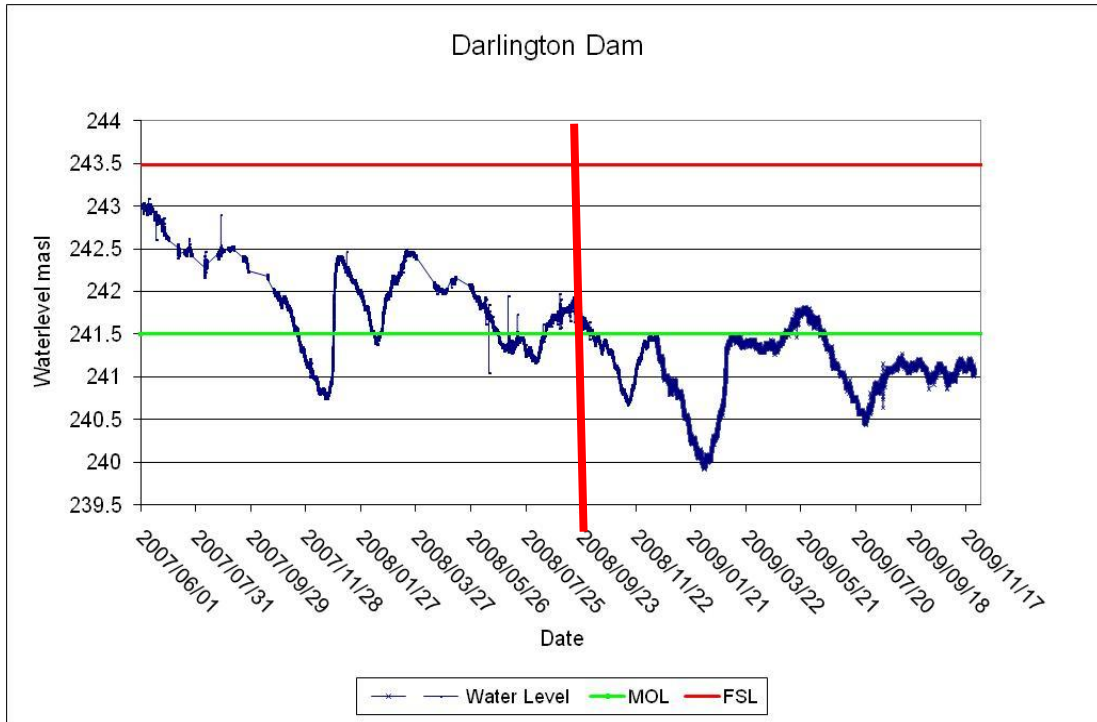
Figure 10.5-2 Darlington Dam water level

110
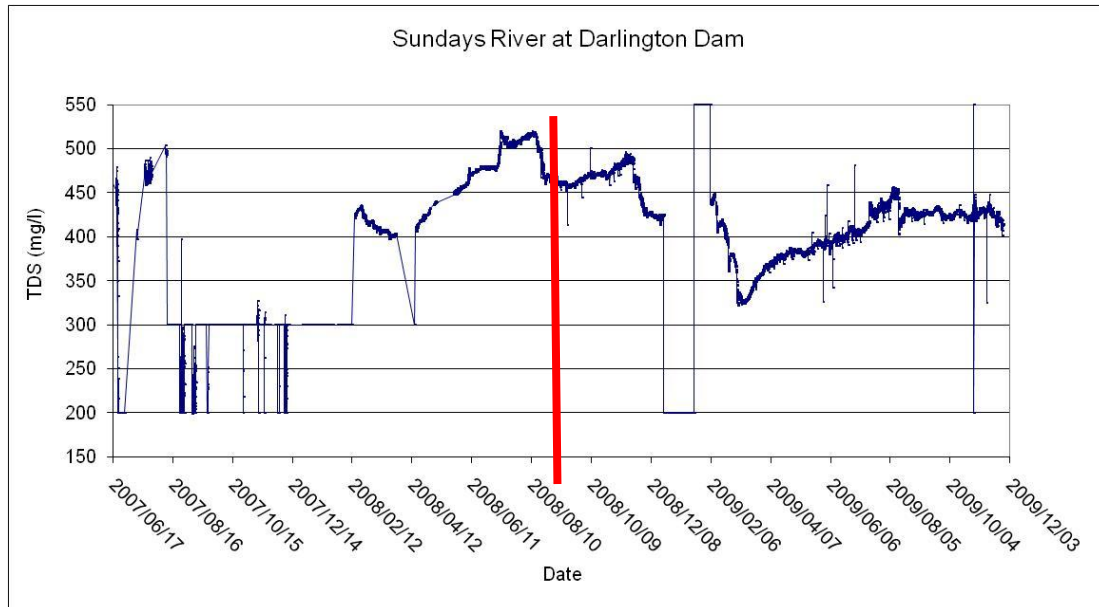
**Figure 10.5-3 Darlington Dam water quality**

10.6 System outflow controls

10.6.1 Great Fish River at Fort Brown

The Great Fish River outflow at Fort Brown shows an increase in the base flow, but due to less flooding in the real-time operations the outflow volume decreased from 268 MCM pre real-time to 239 MCM (Figure 10.6-1). No target was set for quality pre real-time. During the first few months of real-time operations the TDS count was below 600 mg/l which was the target. In November 2009 the target was raised to 900 mg/l in a attempt to transfer less water from Gariep Dam to the OFS system by lowering the standards. Figure 10.6-2 shows the increase in the target to 900 mg/l and the system outflow TDS were kept within bounds until late 2009, then water shortages caused further cutbacks on release.
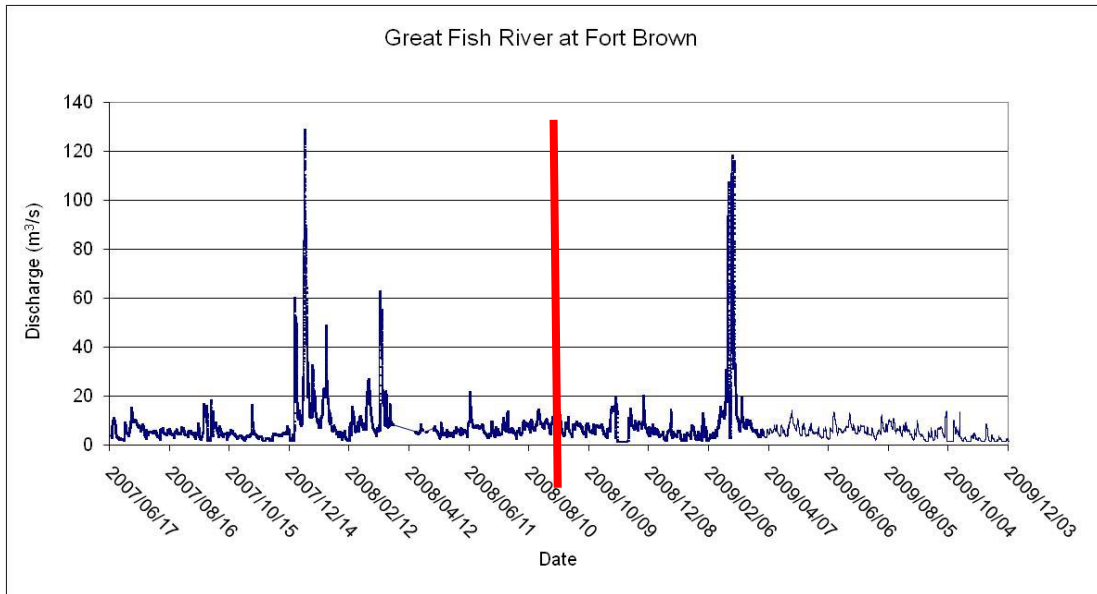
Figure 10.6-1 System outflow on Great Fish River at Fort Brown
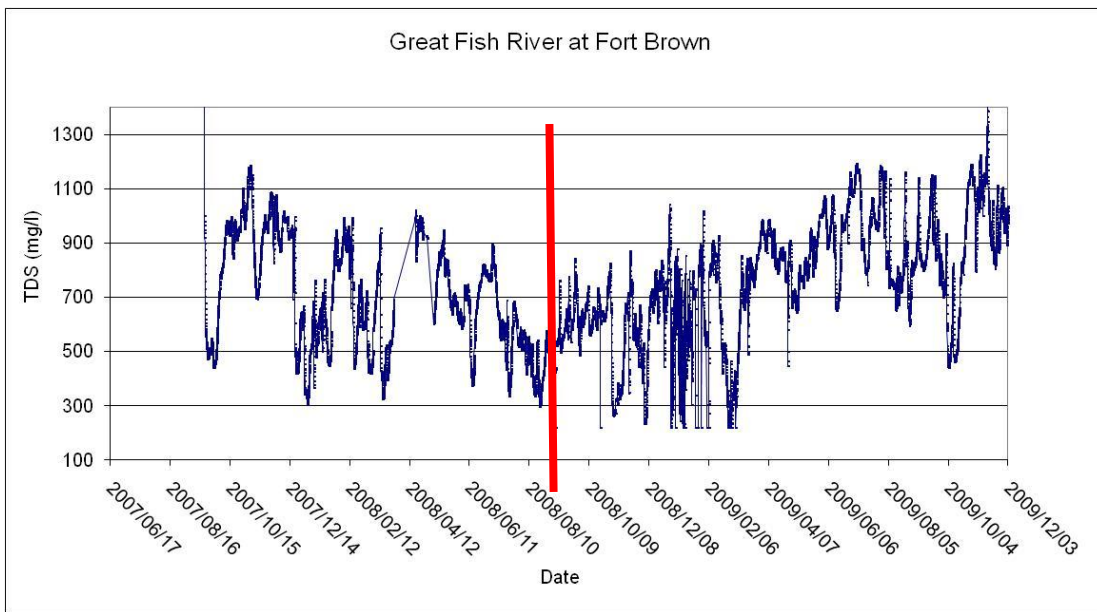
Figure 10.6-2 System outflow quality on Great Fish River at Fort Brown

10.6.2 Little Fish River Junctionsdrift

For completeness Junctionsdrift flow volumes were measured and found to be 40 MCM pre real-time and 37 MCM during the real-time period. The logger data as seen in Figure 10.6-3 started only mid December 2007 and failed in July 2009 giving an error in the pre real-time volume. Figure 10.6-4 shows that the water quality at Junctionsdrift was less than acceptable; the logger logged random values until

September 2007, being offline in April 2008 and April 2009 and there were numerous data interruptions throughout the monitoring period.
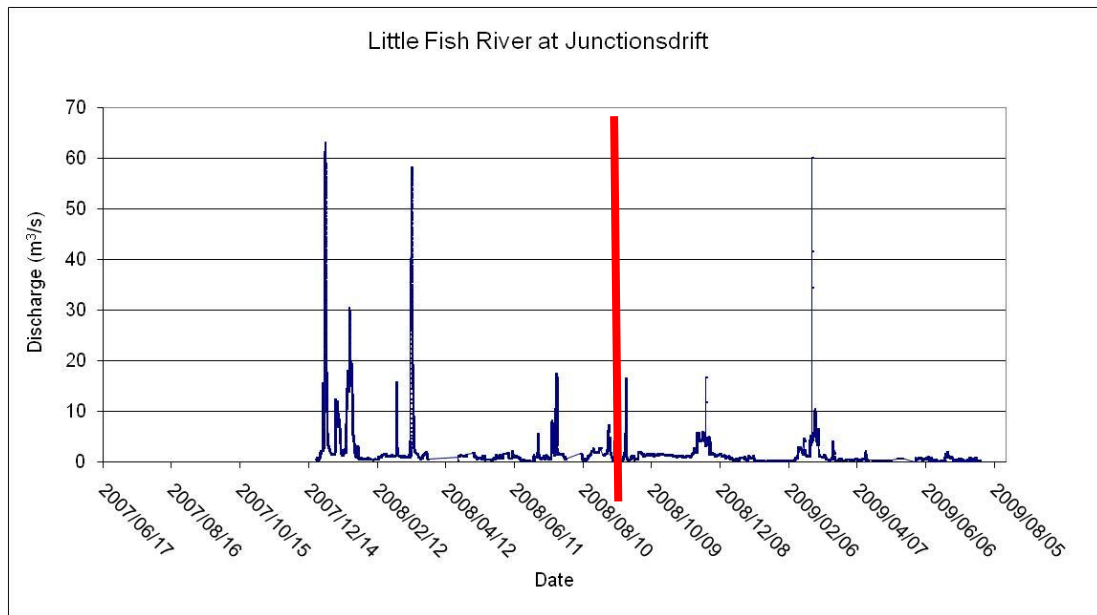
Figure 10.6-3 Little Fish outflow at Junctionsdrift
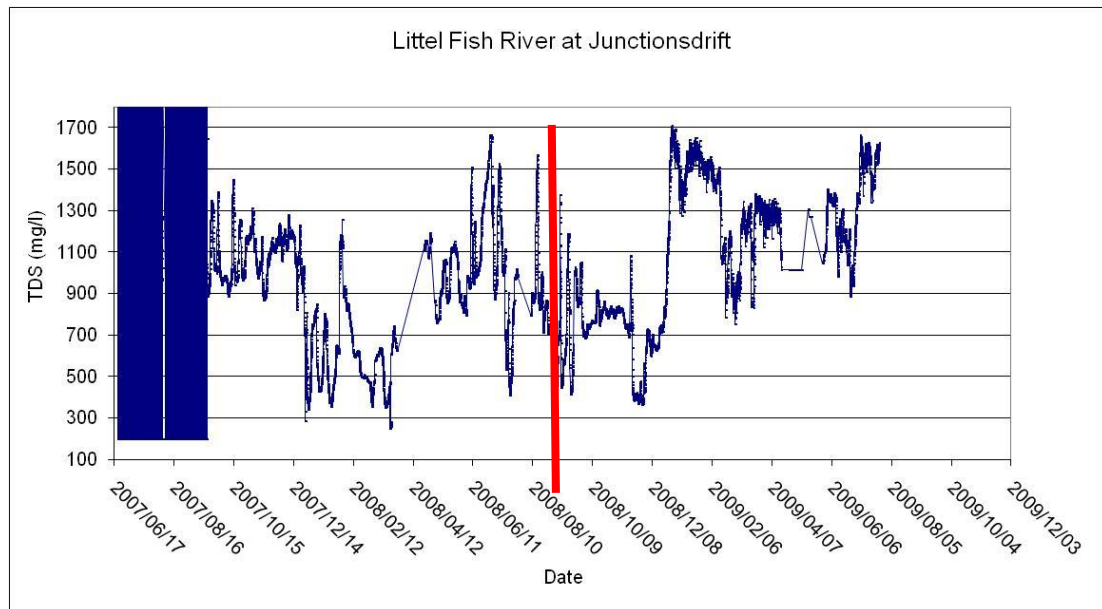
Figure 10.6-4 Little Fish outflow quality at Junctionsdrift

10.6.3 Sundays River Korhaansdrift

Korhaansdrift outflow increased from 21 MCM pre real-time to 23 MCM. During November- Desember 2007 and March 2008 the logger was offline, (Figure 10.6-5), thus causing an error in the volume pre real-time. The quality was below 600 mg/l for both peroids (Figure 10.6-6). Korhaansdrift is in the Sundays River downstream of Darlington and is operated by LSWUA, the spilling and dry out of the weir is not controlled by the OFS-RT operational system.
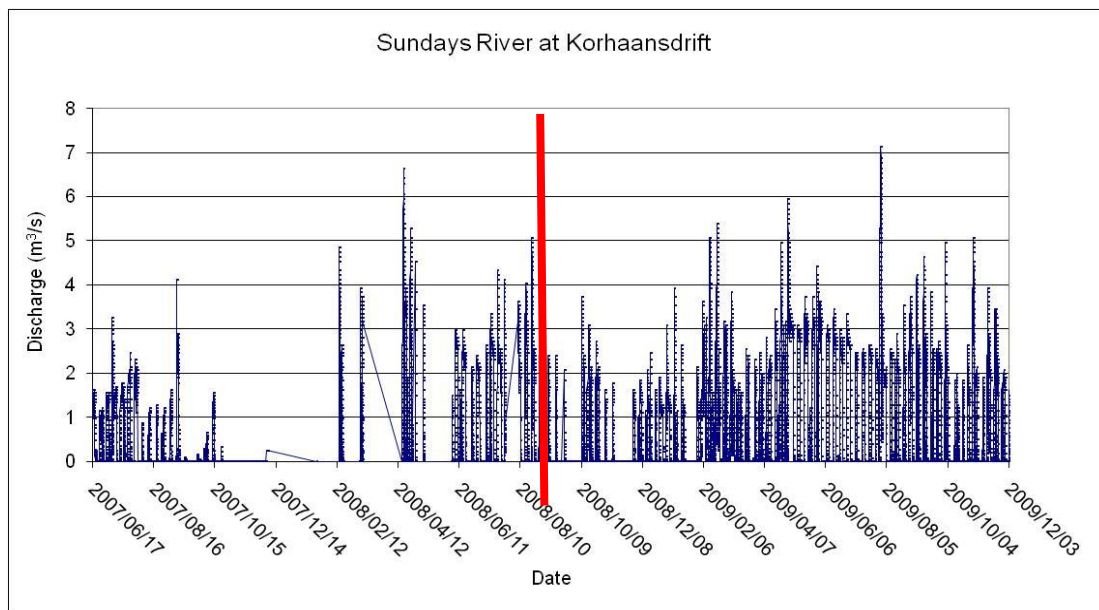
Figure 10.6-5 System outflow on Sundays River at Korhaansdrift
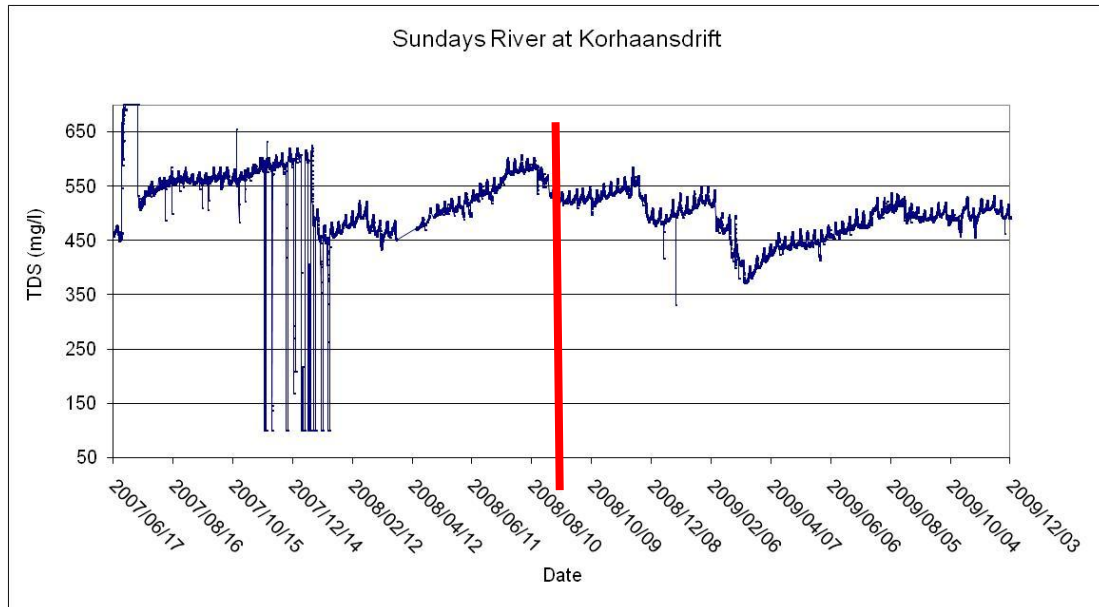
Figure 10.6-6 System outflow quality on Sundays River at Korhaansdrift

10.6.4 Great Fish River Waaikraal weir

Waaikraal situated between Grassridge Dam and Elandsdrift Dam is a good check point on the Great Fish River. Pre real-time 651 MCM was recorded to flow past Waaikraal in the Great Fish River and 681 MCM for the real-time period. This points to an increase but not of the same magnitude as the tunnel and Grassridge release. From Figure 10.6-7 it can be seen that the flow average was a constant 8 m^3/s. There was a flood event in the same month for both periods, pre and during real-time operation and during both periods the logger was offline for a month. Figure 10.6-8 shows the water quality at average TDS of 200 mg/l. The logger was offline for the same period as the discharge occurred. During the July dry period of 2009 the logger probe clogged and the reading was out of station limits.

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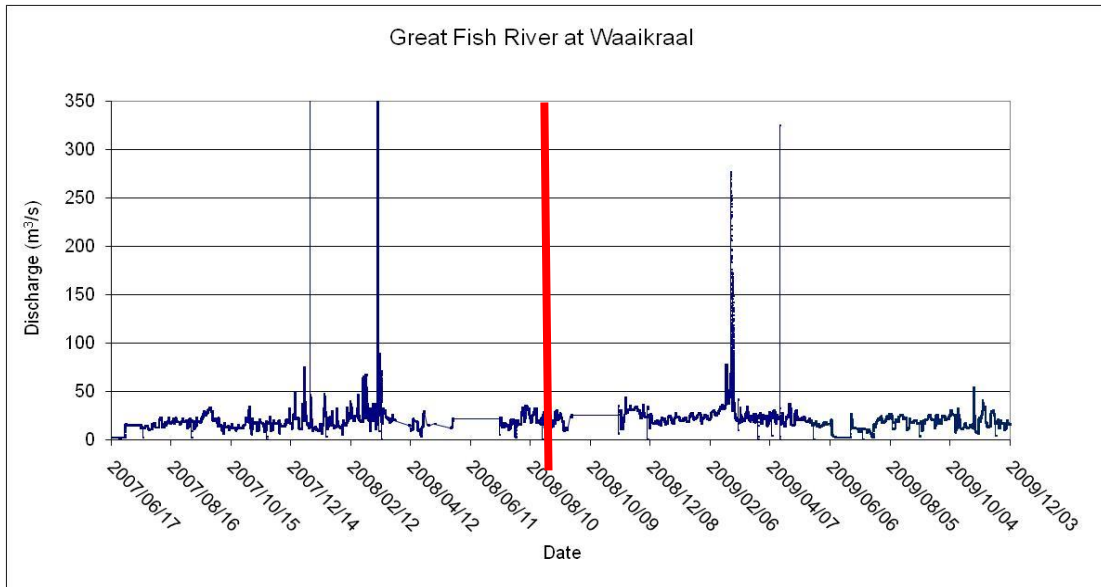
Figure 10.6-7 Waaikraal weir discharge on the Great Fish River
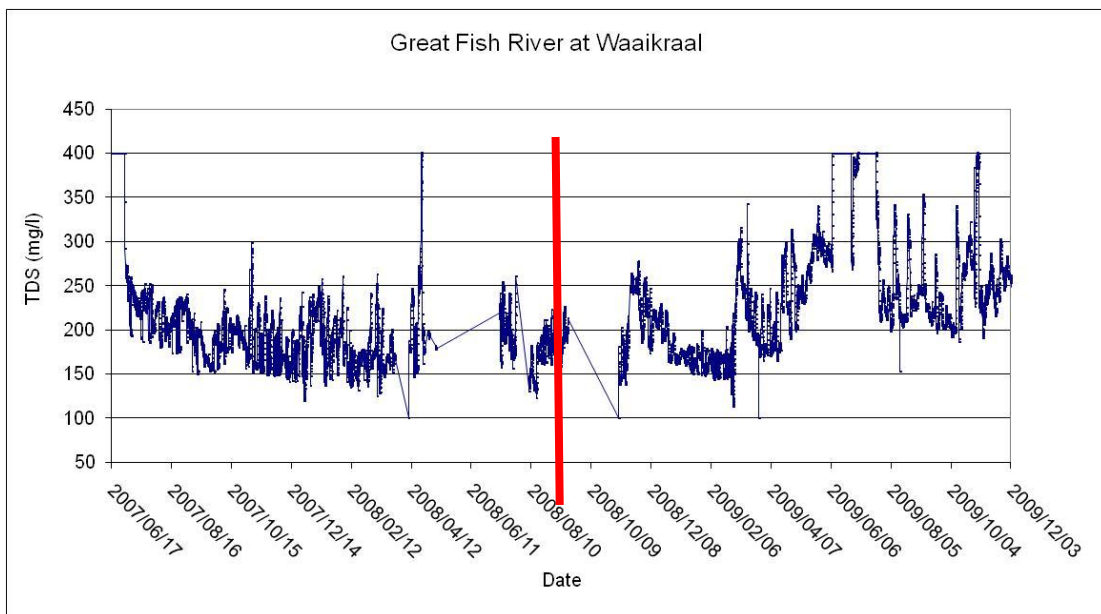
Figure 10.6-8 Waaikraal weir water quality on the Great Fish River

10.7 Summary of first year of real-time operations

In order to summarise the first year of real-time operations and to compare them with the previous year's operations one must look at the new targets the real-time brought to the system. These new targets and methods were new to the operators and the water users within the system and not always fully understood at first. The water year

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2008/2009 was more of a steep learning curve for the field and office operators as to what to expect of the new OFS-RT system than a smooth year of operation. The operational dependence on data and data accuracy from the field became much greater than in the past.

11. Conclusions and Recommendations

The Orange-Fish-Sundays River system operation is dependent on a mathematical computer model to assist with the release patterns for the system. The old FISUN DOS based computer program became outdated and a new tool was developed. The fully hydrodynamic mathematical software model OFS-RT came to life in DHI FLOODWATCH software imbedded in ARCMAP shell using the 1D simulation tool MIKE11 and custom made pre- and post-processors.

The OFS-RT model requires real-time field data, which was supplied and maintained by DWA HYDRO Department and with OTT HYDRAS software. The field data includes flow and quality (TDS) on the rivers, water levels and quality at the dams and discharge flows from the control structures. The real-time data was received at four hourly intervals by the control office main computer. The data also undergoes plausibility validation before being incorporated into the real-time database for simulation.

Water users have control of the time and quantity of water they request from the system and weekly submit their water requests and have the option to change the requests three days prior to the delivery. The scheduling of water requests for the users to the simulation computer was done by an Abstraction Pre-Processor, this software also does the in-house accounting of the water users' request against. their quota for the water year.

The hydrodynamic model running with salinity, Mike11, routes water flows and quality through the system. The model optimises forecasted releases and summaries it on to a website to smoothen operational procedures.

The new OFS-RT model incorporated target based objectives for the system to cope with the increasing pressure on dam safety, water demand and quality. The objectives were built into targets which the model aims at for during the optimisation. The target outcomes were tested and evaluated during this study and it was found the model

succeeds in delivering release forecasts for the seven control structures to manage the OFS system.

The OFS-RT model was set up and calibrated against current system conditions but as time passes the river and the water usage along it will change. The robustness in the model can handle some of these minor changes, but recalibration will be necessary to keep the real-time optimisations accurate.

Maintenance on the model will include updating the water users' data in the OFS system. New dam surveys will improve the model accuracy on storage capacity and dam safety aspects. The model is not a rainfall runoff model, but uses the monitored stream flow for input data. Monitoring more of the smaller tributaries and including the data in the simulation process will improve the model. For the initial simulation during the hind cast period, use more data stations for data assimilation to generate a better starting condition of the system before forecasting optimisation begins.

The forecasted output of the hydrodynamic model was given in a 5 minute time step hydrograph, which was then rescheduled to fit the operational limits of the system. The output result as well as summaries on the system are published to a website. For future development the website can evolve to a more interactive website. The water abstraction requests program can be built into the web site and the water users will be able to access their own data history and enter new requests. Public access can be incorporated on the less sensitive data and use can be made of a ranking order of user rights via passwords on viewable data and editable data can be applied to share the system responsibly.

The monitored data quality is the model's Achilles heel, the mathematical model response to the input data and the result is as good as the data. Through various counter measures and data limits the model was set up to be robust and with thorough testing the OFS-RT model passed on the assumption that the input data is fair. The human factor on data checking will be required until the collected data quality can be guaranteed. Only then can the OFS-RT model be used as a Black Box tool for release forecasting with no human interfacing.

With this thesis the integrity of the OFS-RT model was proven and by doing so the Orange-Fish-Sundays River system entered into a new real-time operational era.

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APPENDIX A

Software and hardware specifications

Appendix A: Software and hardware specifications

Software specifications:

- **HYDRAS3 OTT   2.10.0**

- **OTT SMS Receiver   1.03.0**
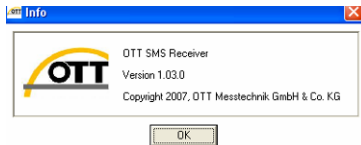
- **DHI MIKE11   2007 October special build**
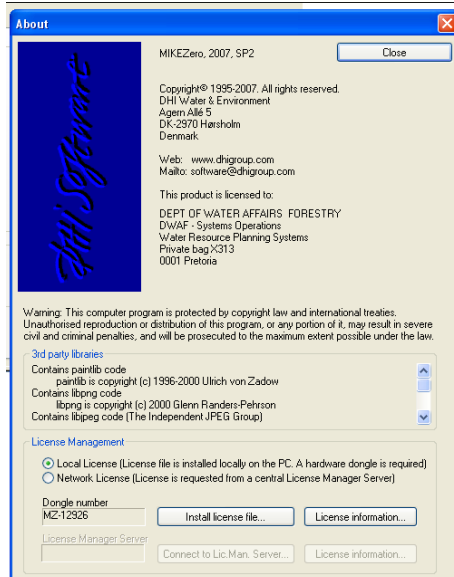
- **DHI GIS Extensions**
  DHI FLOODWATCH   2007 October special build
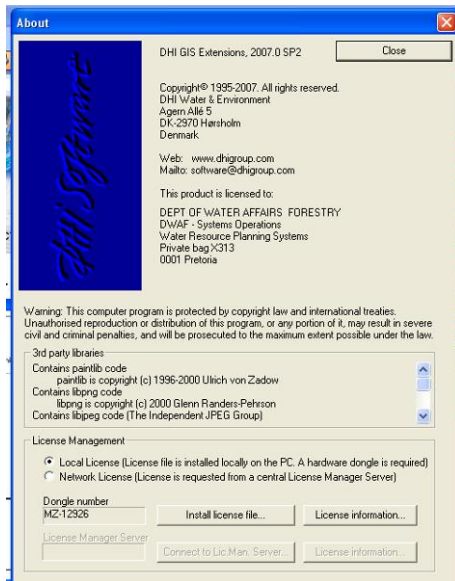
- **ESRI   ARC MAP   9.1**
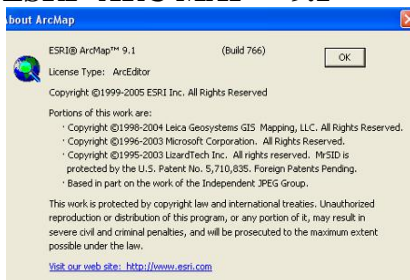
- **Rock Solid Software**
  Abstraction Pre-Processor 2.1
  Post-Processor – Rescheduler 5

- **MS Excel 2003**

- **Windows XP (SPII)**
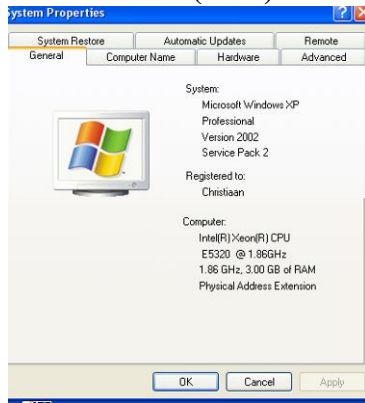
Hardware specifications:

- **Dell Precision 490**

    Operative system:

    Original Windows® XP Professional Edition (English) med Media (not the x64 bit version)

    Processor:

    2 x Quad Core Intel® Xeon® E5345 (2.33GHz,1333 MHz,2x4MB Cache)

    Cabinet:

    Mini tower (Vertical Chassis Orientation) with 2 x 5.25" and 2 x 3.5" Front Bays in horizontal orientation
    Dell System & Operating System Media Kits:

    System Drivers & Resource Recovery Kit

    Grafic card:

    128MB nVidia Quadro FX550 Graphics Card –

    RAM:

    4GB DDR2 667 Quad Channel FBD Memory (8x512MB)

    Harddisk 1:   73GB (15,000rpm) SAS Hard Drive
    Harddisk 2:   320GB (7,200 rpm) SATA 3.0Gb/s Hard Drive

    As you can see from the specs this computer has two quad core processors which should be the stat of the art, a total of 8 cores.

- **Uninterrupted Power System (UPS)**
    BS-800L
    Battery

- **Siemens Cellular Engine**
    MC35 Terminal
    Rs232 converter

A.   - 4 -

APPENDIX B

Hydras 3 OTT (Quick user guide)

Appendix B: Hydras 3 OTT (Quick user guide)

HYDRAS 3 is the interface between field gauging stations real-time data and computer distance user.

HYDRAS has a GMS map interface that was set up to give a visual image of where the field stations are (Figure 1). On the left hand side is a list of stations in setup for user friendliness. The data can be accessed by means of clicking on the map or choosing one from the list. Data is still locked up in the database and must be edited and transformed before external programs can gain access to it.
(For more information see HYDRAS help files.)

This quick reference guide deals with the following aspects of HYDRAS 3:

1. ADDING A NEW STATION
2. ADDING NEW SENSORS
3. LIMITS ON DATA
4. VIRTUAL SENSOR Virtual sensor located
5. DIALING FOR DATA
6. SMS RECEIVER
7. EXPORTING DATA
8. HYDRAS CONVERTER
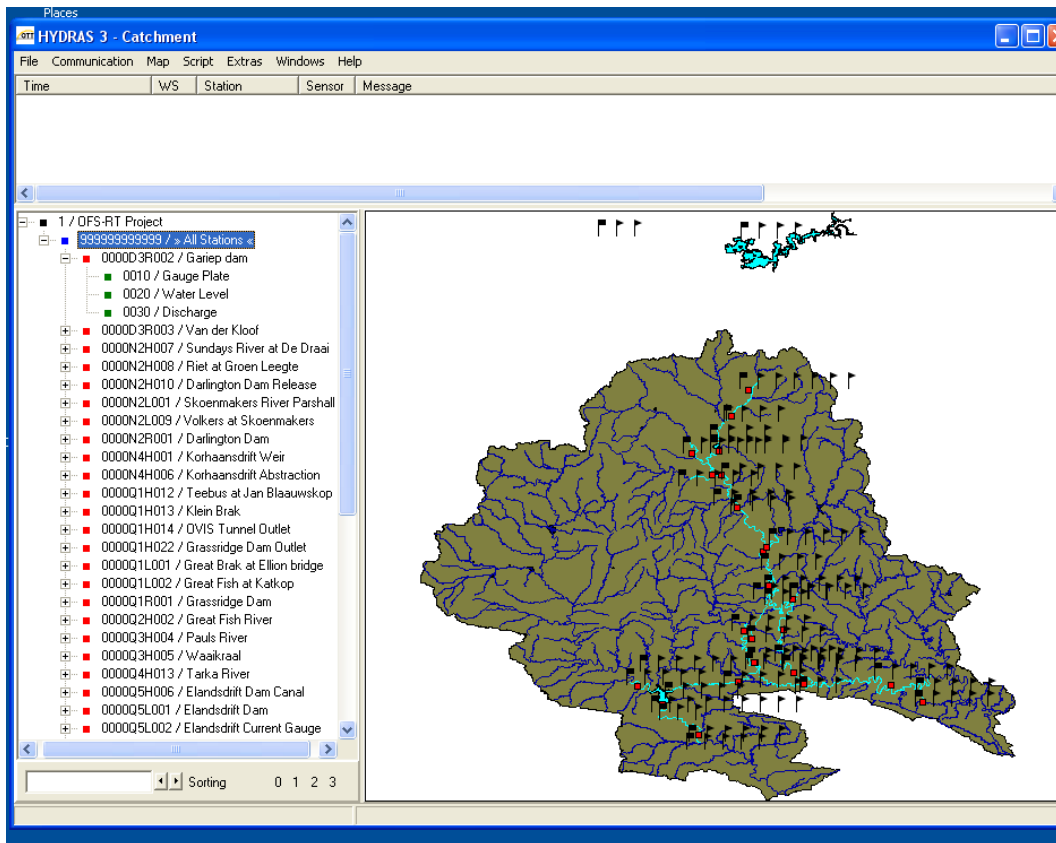
Figure 1 OTT HYDRAS3 Interface.

1. ADDING A NEW STATION
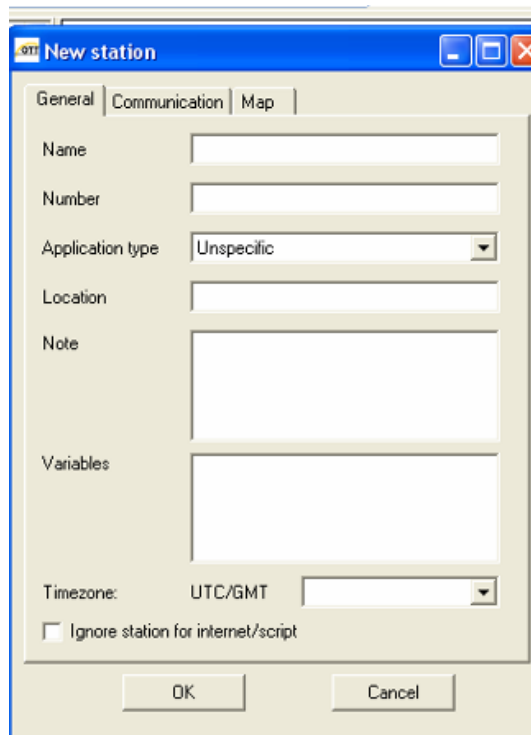
Figure 2 New station window with three tabs at top.

In HYDRAS view (Figure 2) right click on top of list from menu pick "New station"

Three Tab's on top of "New station" (Most fields are auto filled) Lead to the following:

1.1   General: Filling in the required station information – Name, Number

1.2   Communication: Fill in the data dialling number

1.3   MAP: Supply Map coordinates

2.   ADDING NEW SENSORS

Right click on station, from menu "New sensor" supply sensor information (Figure 3).
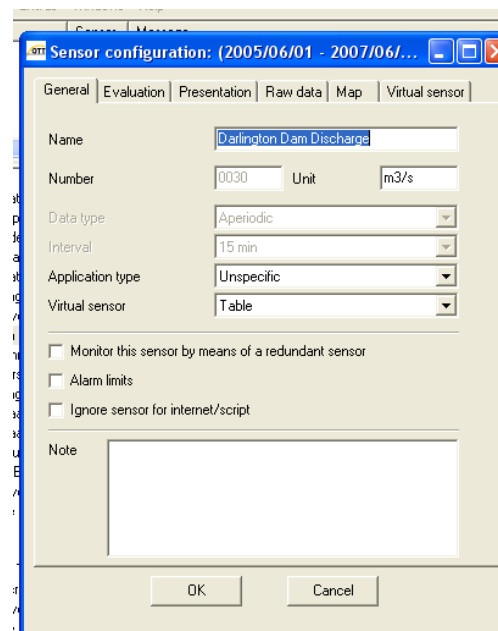
Figure 3   New sensor configuration window with six tabs at top.

2.1   General: Name, Number and Unit. Data Type – Dropdown list "A periodic"

Application Type – from dropdown list pick appropriate type.

If not a Primary sensor, pick appropriate Virtual Type.

2.2   Evaluation: The auto fill is appropriate, change if need develops.

2.3   Presentation: Scaling of graph can be useful for visual interpretation.

2.4   Raw data: Plausibility checks can be added to data.

2.5   Map: Supply coordinates of sensor and display info for map.

2.6   Virtual sensor: If not primary sensor (see section 4).

3. LIMITS ON DATA

Real time data can be checked as follows: (Figure 4)

3.1   Raw data can be limited in the sensor Configuration. the Minimum, Maximum and Gradient.

3.2   Virtual sensor - Formula can be amended to keep data in plausible range. Typically TDS operating in band of max and min, a list of these values are in the "C:\OFS DATA\Hydras Limits\"

3.3   Virtual sensor – Table typically DT transformation but if water level drops below outlet or under crest, extrapolation will result in negative flow. Limits on Tables are enforced by adding a top row of "-9999" reading and "0" flow, to ensure max "99999" reading and "max" flow (same as lower readings flow).

4.   VIRTUAL SENSOR

In the current setup two types of virtual sensors are employed – Formula and Table.
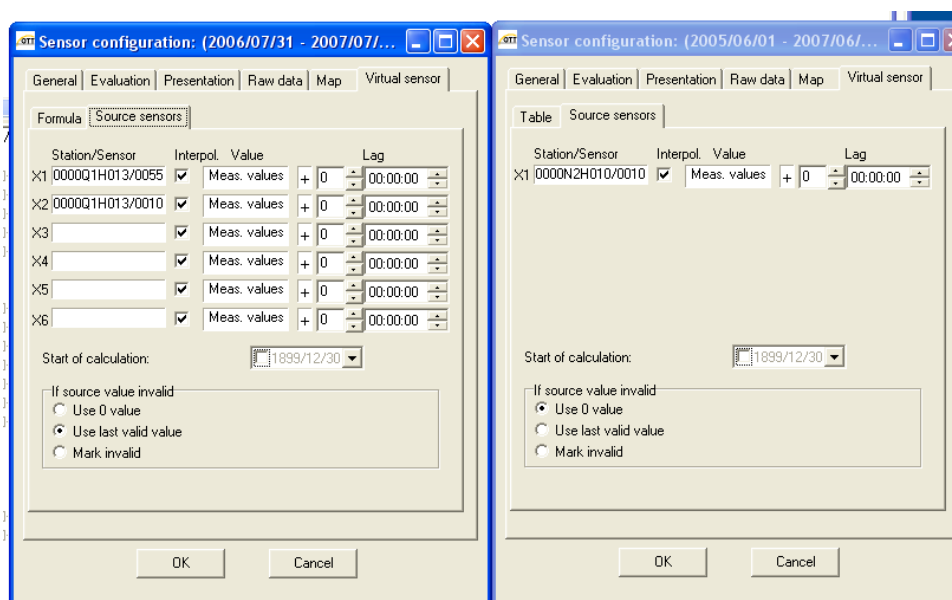
Figure 4   Tab Virtual sensor configuration, Formula and Table – Source sensors.

4.1   Formula (Figure 5):

From the Sensor Configuration, tab Virtual sensor (position Configuration window so that station/sensor list in Hydras is visible)

4.1.1   Source sensor: From station/sensor list, drag & drop appropriate sensors to table position X1, X2 etc.

If source value is invalid: Pick appropriate option between "Use 0" or "Last valid value".
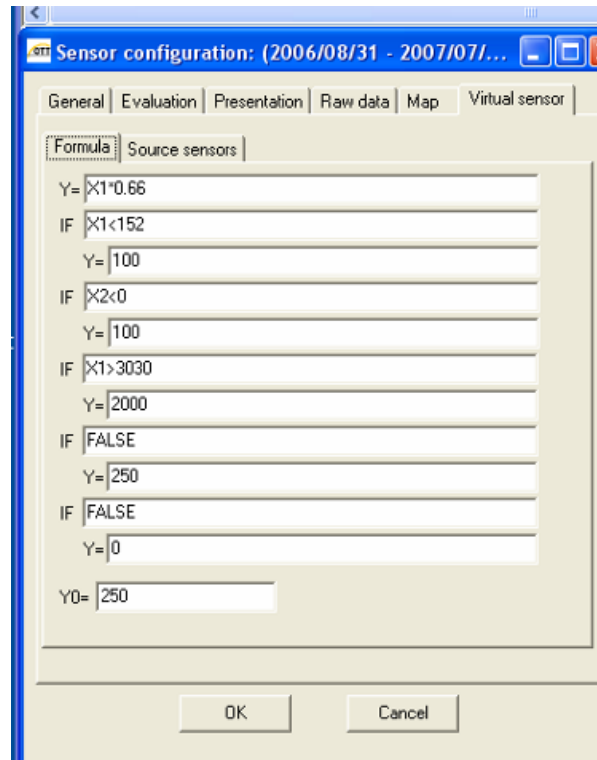
Figure 5   Virtual sensor configuration, Formula tab.

4.1.2   Formula: Enter formula "Y= X1*…" The "IF" options can be called upon to evaluate and control the Y values.

4.2   Table (Figure 6):

From the Sensor Configuration, tab Virtual Same first step as Source sensor.

Creating/Adding a new Table

4.2.1   A table will typically be from a DT (discharge table) regularly available and updated for hydraulic a fix pattern.

In current setup the DT information is stored on the computer at:

C:\OFS DATA\DT Data

Raw DT text files are kept in "RawDTfiles".

B.   - 5 -
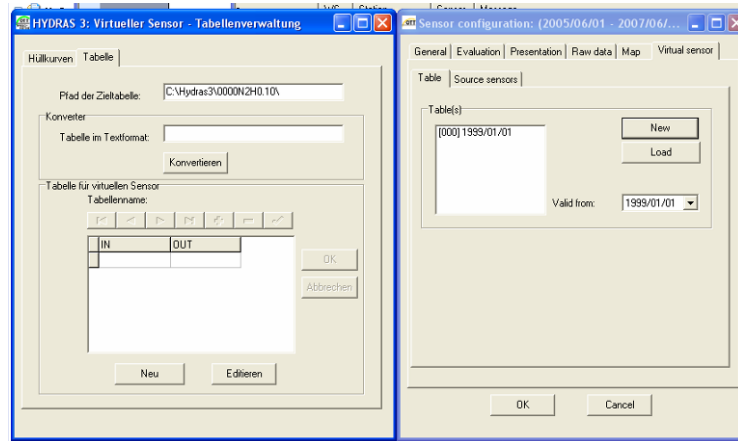
Figure 6   Virtual sensor Table configuration, converting new table.

4.2.2   Create a text table for Hydras, format in list: "Reading Value"

i) Open the Excel file – "C:\OFS DATA\DT Data\ OFS MACROS.xls"

ii) Open "Gauging Station DT Data.xls"

iii)   Find corresponding sensor tab, rename to [sensor code –old] and insert
        new worksheet rename to [sensor code]

iv)   Copy and paste raw text DT into top left of sheet.

v) Data – Text to Columns, ensures the table display in cells.

vi)   Delete all text headers and blank rows

vii) Type "end" in last cell under table.

viii) Tools – Macro – Macros, (All Open Workbooks) Run: "RepTrans"

ix)   Scroll down through new list of table; Delete all conforming data rows
        (exp. 0 or bank values)

x) Save "Gauging Station DT Data.xls".

xi)   Copy column A & B values to notepad (data displayed as list in 2
        columns) save Notepad to: "C:\OFS DATA\DT Data\" with sensor
        name and extension as text file.

xii) Close all text and Excel files.

4.2.3   Hydras – Station – sensor – Config – Virual sensor – Table - New Table:

i) In popup window Cancel (Abbrechen)

ii) Check that "Pfad der Zieltabelle" is the location and name of the station, autofill is usually correct.

iii) Type location and name of text table in "Tabelle im Textformat:"

C:\OFS DATA\DT Data\ - - -.txt.

iv) Click on "Konvertieren"

v) Close window.

4.2.4 Load Table: Click Load and browse to desired table.

This new table is in the Hydras database under station code with name "STBT0 * .DB". More than one table can be allocated per station and also according to time stamp to a sensor (sorting by date/time newest table for sensor can by found).

4.2.1) Old table can be deleted from list and from database (carefully). If more tables are used on one sensor "Valid from:" date must be set before loading the table.

5.   DIALING FOR DATA

If data has not been transmitted and are still on the station logger, the operator can dial to retrieve data from field loggers (Figure 7).

5.1   To dial for data the SMS Receiver module must be closed.

5.2   Right click on desired station and pick "Read / Operate"
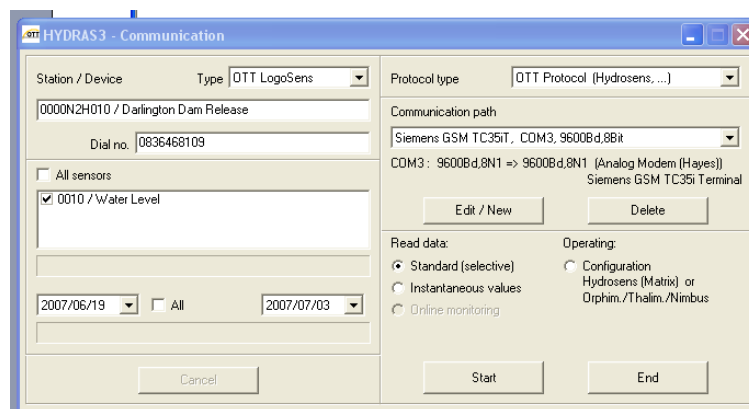
Figure 7   Read/Operate window for station data dialing.

5.3　　From the Communication window confirm:

   i)　　　　Station name and number.

   ii)　　　The Dial number.

   iii)　　　The sensor data to retrieve.

   iv)　　　The period for which data is required.

   v)　　　　Communication path, the type of devise and settings.

   vi)　　　Click Start

   vii)　　　Close Communication window and open SMS Receiver.

6.　　SMS RECEIVER

The SMS receiver receives data from field loggers via SMS. A module of Hydras "SMS Receiver" handles this. The setup in "File – Options – Communication" is standard from auto fill. The "Export" holds the location to which the SMS-files are saved:

   "C:\Hydras3\Imported Data"

Received SMS time- sender- and info display in top window. Bottom window displays Log messages (errors) (Figure 8).
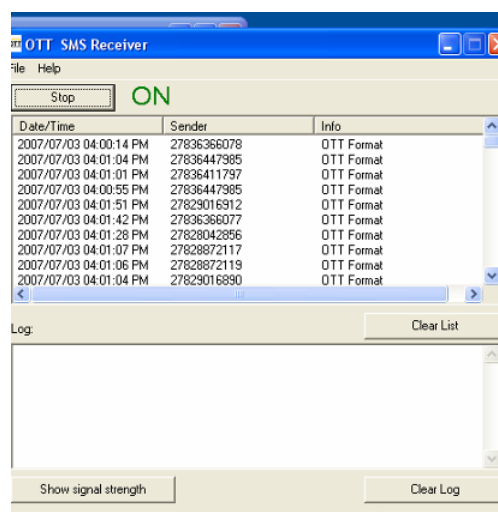
Figure 8　　Module OTT SMS Receiver window.

7. EXPORTING DATA

Data in the Hydras database is not accessible to other programs. To access, export the data to text files: Location: "C:\Hydras3\Exported Data".

From HYDRAS menu options "Extras":

7.1   Multiple Export – Configuration – New:
   i)   Name, configuration
   ii)   Drag and drop from HYDRAS sensor list a sensor to window.
   iii)   Check that Export format ="flexible textformat" and "Headline", "Date", "Time" & "Value" are checked. The field separator ="Tabular" Dec. separator =" . " and Check "Replace".
   iv)   Fill in a file name with extension "txt" and supply Path (location) "C:\Hydras3\Exported Data".
   v)   Multiple sensors with different or same file name can be added to one Configuration.
   Example: "GetData" exports all sensors to "OFS-RT Data.txt" for inspection.
   "(Quick) Export All" exports all sensors to own text file.

7.2   Multiple Export – Configuration – Edit:
   i) Select "Export Configuration" set to be edited
   ii) Edit the settings.
   iii)   Confirm: Sensor, Filename & Path valid (Figure 9).
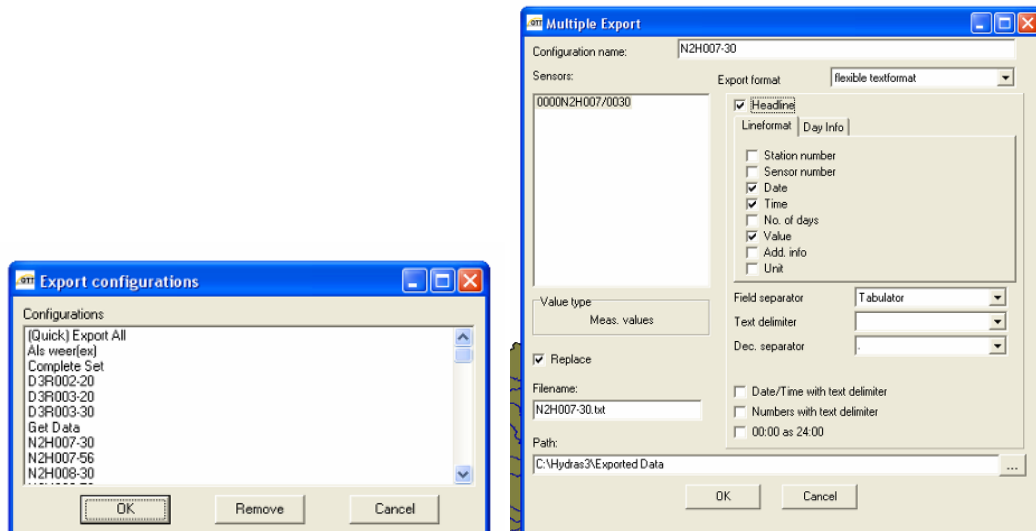
Figure 9   Export configuration setup window.

7.4   Multiple Export – Execute (A quick run of single job):
   i) From dropdown list pick Exporting configuration
   ii) Select Time period of data to be exported.

7.5   Job Manager: Window displays Jobs to be executed at specified time
        (Figure 10).
Configuration displays selected Jobs settings (changes can not be made while Job is
active)
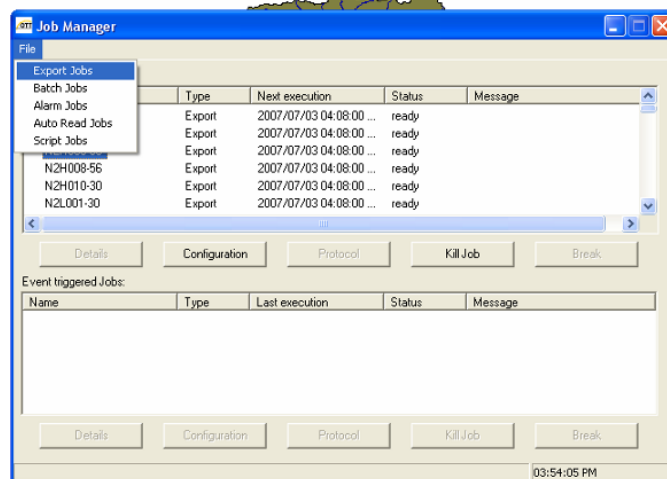
Figure 10   Job Manager: atomization of HYDRAS functions.

Kill Job, remove Job from execution list.

Jobs can be edited from "File – Export Jobs – Edit" setting can be change if not activated.

Jobs can be added by "File – Export Jobs" (Figure 11):

i) New: selection a name, workspace, Export configuration (pre-setup in 7.1)

ii) Check off "Auto start" and "Last days", current setup is set to 7days.

iii) Set Timer configuration: Interval, 4h and start at 00:09 (The offset start at 9min is a safe time for data to be received, before exporting it.)

iv) Active Job, to add new job to execution list.
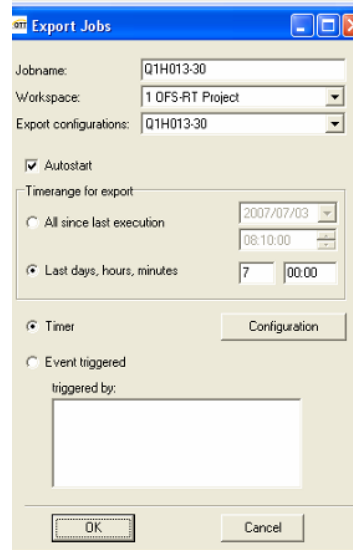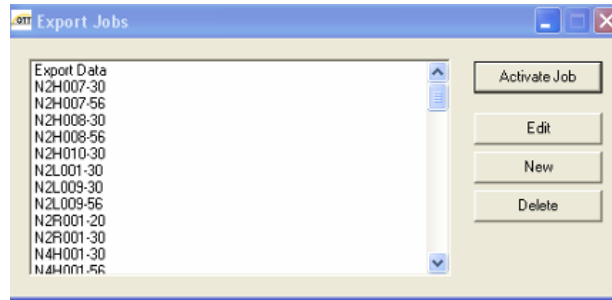
Figure 11 Job Manager – Export Job – Configuration window.

8.   HYDRAS CONVERTER

Data from the Hydras database exported to text files in
"C:\Hydras3\ExportedData" cannot be imported directly to FLOODWATCH.

A Visual Basic script in the form of an Excel macro will convert text data and
calculate an extension on data into the forecast period.

The file location: "C:\Pre-Processors\RealTime PreProcessor" with Excel file
names: "RT-Pre-Pro.xls" and "RT-Pre_Pro.vbs" script to be run. This will create
FLOODWATCH importable txt files in: "C:\Pre-Processors\RealTime-Files".
This data converter is sensitive to folder tree with file location. Do not move these
files.

APPENDIX C

Abstraction, Return flows, Target water levels and TDS, and IFR pre-processor (Quick user guide)

Appendix C: Abstraction, Return flows, Target water levels and TDS, and IFR pre-processor (Quick user guide)

The Abstraction Pre-Processor is an Excel & Visual Basic program, and location sensitive on the computer:

C:\Pre-Processors\Abstraction PreProcessor\PreProcess-Abstractions.xls

The Program running from Excel needs two more files in the following location:

C:\Pre-Processors\Abstraction PreProcessor\ OFS-Archive.xls

C:\Pre-Processors\Abstraction PreProcessor\ Dam Levels Data.xls

Figure 1 is the main interface view of the Pre-Processor displaying the Irrigation week number, start & end date. Buttons for "Instructions and Help", the four sub directories of the program plus the Executable "Convert Archive to FLOODWATCH Format". The Week number/Date can be set back and forward one week relative to the computer's Date & Time properties, by clicking on the arrow buttons. (If more than one week is required adjust computer's time for short period of time, but close other software first.)
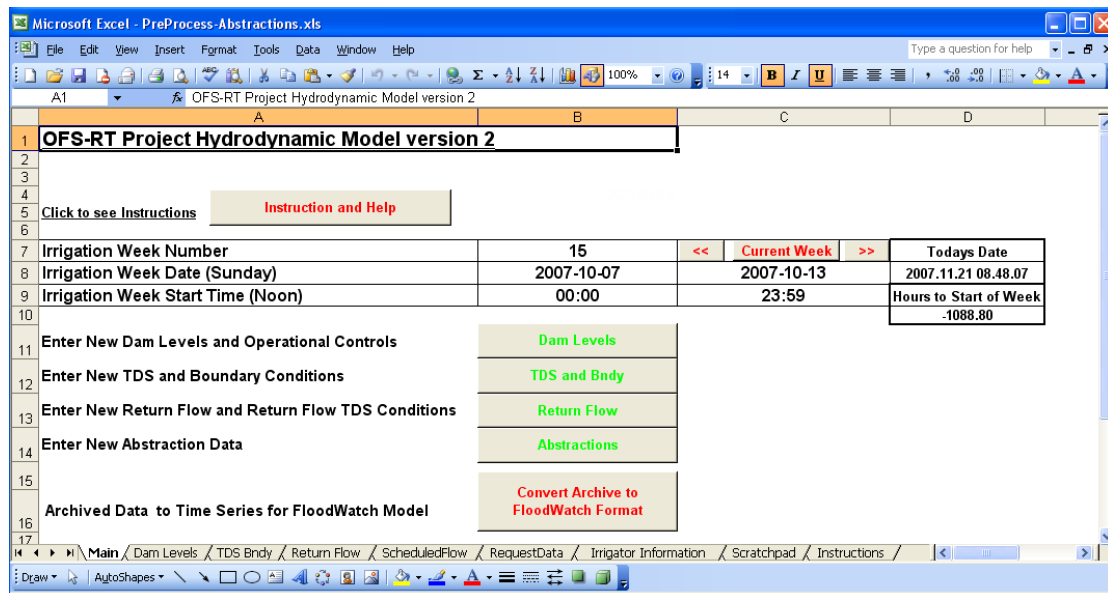
Figure 1 Main Interface of the Abstraction Pre-Processor

Keep in mind that this interface is a spreadsheet interface (Excel) only use the Buttons and supply the necessary data to the Pre-Processors. Effort has been made to keep it user friendly & safe for the user & computer.

Going into the Pre-Processor's sub directories:

The following aspects of pre-processor will be discussed in more detail:

1. Dam Levels
2. TDS and Boundaries
3. Return flow
4. Abstractions
5. Conversion to FLOODWATCH Format
6. Manual tab settings (Other sheets)

1. Dam Levels

Figure 2 Pre-Processor's Dam Levels (targets)interface

On the Dam Levels Tab the relevant week number and week start date & time is visible. The data to be changed columns are marked in Green.

The first 12 rows are the four dam levels Control Target values on MOL, FSL & HFL.

The columns read: Station Name; Dam Name; Last Weeks value (GP); This Weeks Value (GP); Hours from start (offset hours); The Start Time; End Time; Code; Water level (masl) Last week; Water level (masl) This week.

By changing the Gauge Plate target value for this week, the Water Level (masl) value will adapt from the Lookup Table in *Dam Levels Data.xls*. One can offset the start of the new target by entering a value in the "Hours from Start" column.

Two FLOODWATCH switches are activated on the tab:
   a. Add Surplus flow if VanderKloof Dam is Spilling
      Use "1" if surplus water can be drawn to OFS system, "0" if not.
   b. Is water available from Gariep Dam (Tunnel operational)
      Using "1" if Tunnel is operational and "0" if not.
   A start of a switch can be offset from start of week by entering offset hours.

If no change is made to the tab the Pre-Processors will predict & use previous week's values for this week.

The "Archive Data" button is for saving changes in data to the database.

The "Back to Main" button is used to navigate to the main page. Changes to data will be kept on the sheet but will not yet be saved to the database.

Note that this sheet (Figure 2) should normally <u>not</u> be adjusted on a weekly basis and the default values should be used.

2. TDS and Boundaries

Figure 3 Pre-Processor TDS and Boundaries interface

The first ten rows contain Maximum TDS Targets for locations in the system. The last four rows are the downstream Flow Targets in the system.

Columns are: Station number; Location Name; Last Week's value; This Week's value; This week's start offset hours; Start Time; End Time; Code; Last week's value; This weeks proposed value.

The columns in Green are changeable with TDS in mg/l unit and the Flow in m^3/s. By setting the Offset hours the new Target will only be activated from the specified start time.

If no change is made to the tab the Pre-Processors will predict & use last week's values for this week.

The "Archive Data" button is for saving changes in the data to the database. The "Back to Main" button is used to navigate to the main page. Changes to data will be kept on the sheet but not yet be saved to the database.

Note that this sheet (Figure 3) should normally <u>not</u> be adjusted on a weekly basis and the default values should be used.

C.   - 4 -

3. Return flow

Figure 4 Pre-Processor Return flows interface.

The Return Flow and corresponding TDS values are calibrated values and do not change unless the model it is updated and based on new calibrations it is shown that values should change.

The first eleven rows contain Return Flow (RF) for river reaches in the system. The next eleven rows are the Return Flow TDS (RF TDS) for river reaches in the system.

Columns are: Location Name; Last Week's value; This Week's value; This week's start offset hours; Start Time; End Time; Code; Last week's value; This week's proposed value.

The columns in Green are changeable with RF in m^3/s and the RF TDS in mg/l unit.

By setting the offset hours the new values will only be activated on a specified start time.

If no change is made to the tab the Pre-Processors will predict & use last week's values for this week.

The "Archive Data" button is for saving changes in data to the database.

The "Back to Main" button is used to navigate to the main page. Changes to data will be kept on sheet but will not yet be saved to the database.

4. Abstractions

Figure 5a Pre-Processor Abstractor requests table

The Request tab is the input menu for the Abstractors from the drop down menu Figure 5b. The user can select a specific abstractor whose data needs amending. Scrolling up and down by using the "Previous" & "Next" buttons will save changes to data. The "Go to schedule" button will save & show the request strings in schedule form, (Figure 6).

Figure 5b Pre-Processor Abstractor requests table

By default all abstractors have a zero request string in the first line.

The Pre-Processor then looks up the previous week's requests and supply it as request for this week.

On the Request tab the user is required to supply the water request string, consisting of:

Start Date; Start Time; Number of Hours; Flow rate.

The Pre-Processor will fill the rest by allocating it to a schedule for the Abstractor. Viewing the "Go to schedule", a graph & table is displayed for the user to confirm the input, (Figure 6).
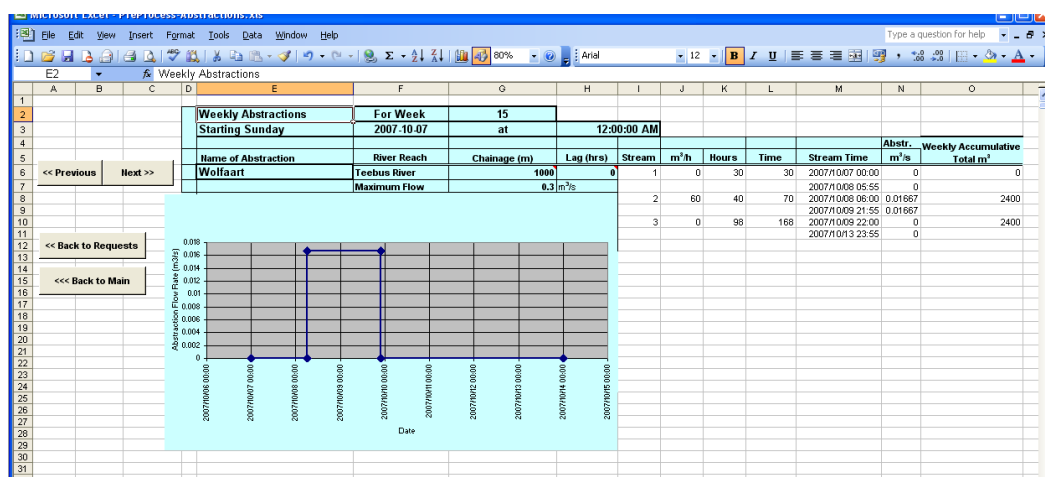
Figure 6 Pre-Processor Abstractor Schedule tab.

5.   Convertion to FLOODWATCH format

Run the Pre-Processor Engine by clicking on the "Convert Archive to FloodWatch Format" button on the main page.

This will save all changes in the Pre-Processor to the "*OFS-Archive.xls*" file and convert the set of 3 week's data to text files for FLOODWATCH to import.

6. Manual tab settings

For setting up the Pre-Processor before use there are specified tabs to take note of:
(i) Irrigator Information
(ii) Scratchpad
(iii) Instructions
The data contained in these tabs are not for everyday use or editing and is protected by a warning if changes are made.

Irrigator Information:

Contains the details of Irrigators, Name, location, flow limits
It also contains the relationship between Week number and Date for the
running year and needs to be updated at the turn of the Irrigation year.

The Scratchpad is a tab used by the program to do calculations and the user
should not delete or amend the data on it.

The Instructions tab, "Instructions and Help", can be accessed from the main
page for help.

APPENDIX D

Mike 11 DHI Software (Quick user guide)

Appendix D: Mike 11 DHI Software (Quick user guide)

Running MIKE11 in Demo or Licensed.

1D. Starting from MIKE ZERO: Time series

Open "New file" From List:
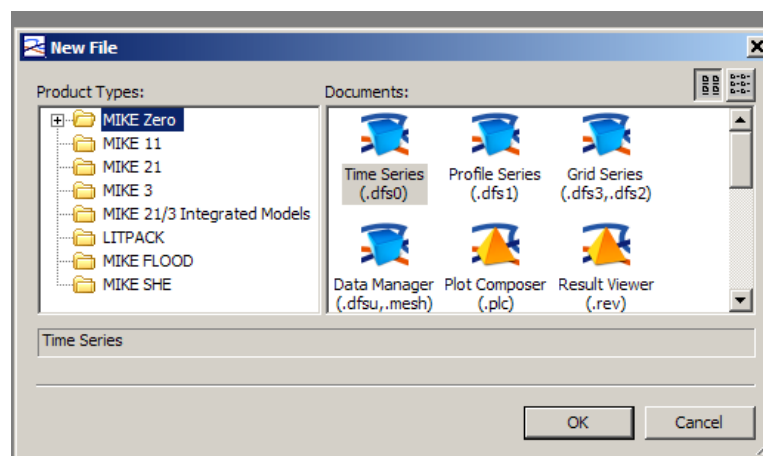
i)   MIKE Zero

ii)   "Time Series(.dfs0)" File used as input data for MIKE11 simulations.
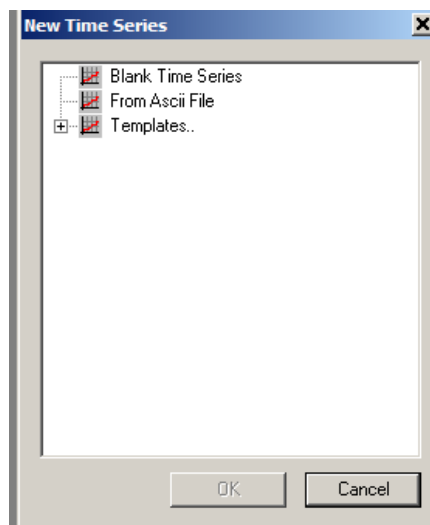
iii) Options for creating Time Series file.

Blank Time Series: User defines all settings.

From Ascii File: User defines Source locations and setting of imported data.

Templates: Pre setup template available to user.

iv) Blank Time Series Setup:
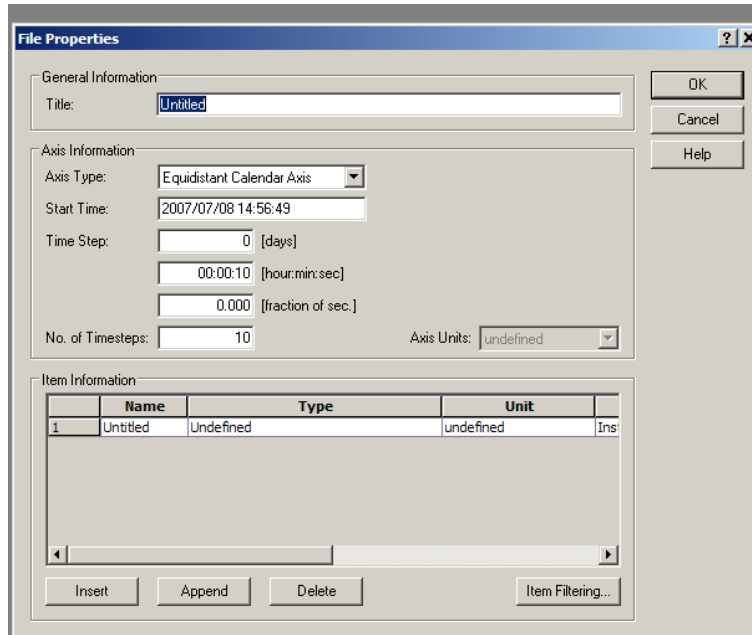
User defines: Title

Axis Information as Type, Start time, Time step, No of time steps.

Item Information as Name, Type, Unit, TS Type, Max, Min information.
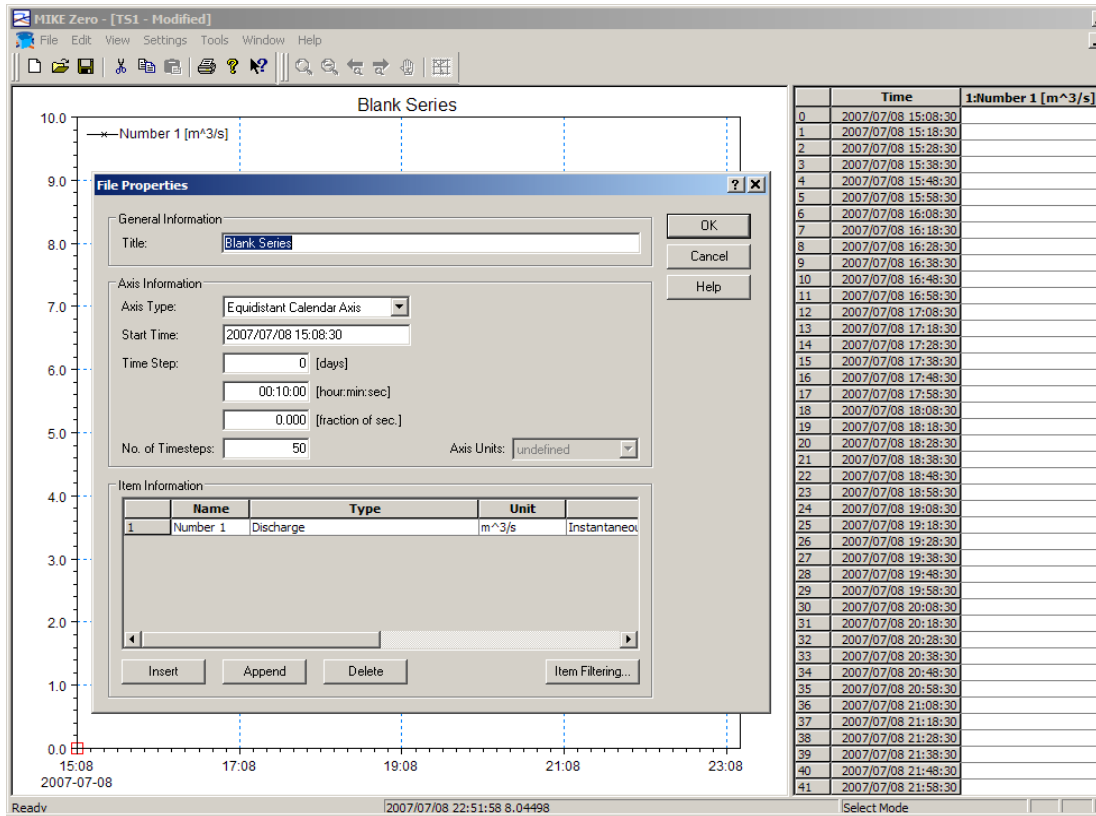
v)   Time Series ready for edit, Right click on graph area to access
        properties of time series.

D2. NETWORK predefined ASCII file

For faster more accurate Network configuration set up a text file with Topo ID,
Branch name, Chainage distance and Coordinates.

```
Net-Q3H005-Q5R001.txt - Notepad
File   Edit   Format   View   Help
Q3H005-Q5R001
Grootvis
0
Coordinates
1          -54400    3551230
**********
Q3H005-Q5R001
Grootvis
1000
Coordinates
1          -54650    3552160
**********
Q3H005-Q5R001
Grootvis
2000
Coordinates
1          -55100    3553000
**********
Q3H005-Q5R001
Grootvis
3000
Coordinates
1          -56000    3552900
**********
Q3H005-Q5R001
Grootvis
4000
Coordinates
1          -56560    3553610
**********
```
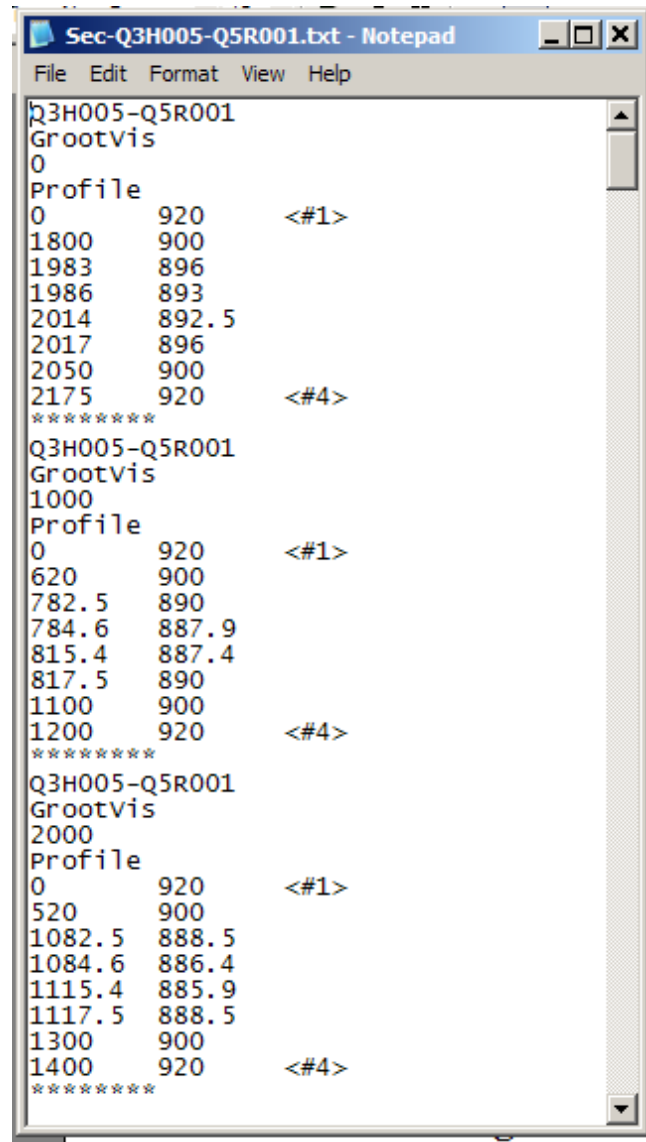
This can be accomplished by Excel or by means of export from GMS system.

The definition format is important and end each entry with "**********"

For compatibility ensure Topo ID and Branch names corresponds to Cross-Sections.

D3. CROSS-SECTION predefined ASCII file

For faster more accurate Cross-Section configuration set up a text file with Topo ID, Branch name, Chainage distance and Profile.

```
Sec-Q3H005-Q5R001.txt - Notepad
File  Edit  Format  View  Help
Q3H005-Q5R001
GrootVis
0
Profile
0          920        <#1>
1800       900
1983       896
1986       893
2014       892.5
2017       896
2050       900
2175       920        <#4>
********
Q3H005-Q5R001
GrootVis
1000
Profile
0          920        <#1>
620        900
782.5      890
784.6      887.9
815.4      887.4
817.5      890
1100       900
1200       920        <#4>
********
Q3H005-Q5R001
GrootVis
2000
Profile
0          920        <#1>
520        900
1082.5     888.5
1084.6     886.4
1115.4     885.9
1117.5     888.5
1300       900
1400       920        <#4>
********
```

This can be accomplished by Excel or by means of export from GMS system.

The definition format is important and end each entry with "**********"

For compatibility ensure Topo ID and Branch names corresponds to Networks.

D4. Starting from MIKE ZERO: Modelling

Open "New file" From list MIKE11
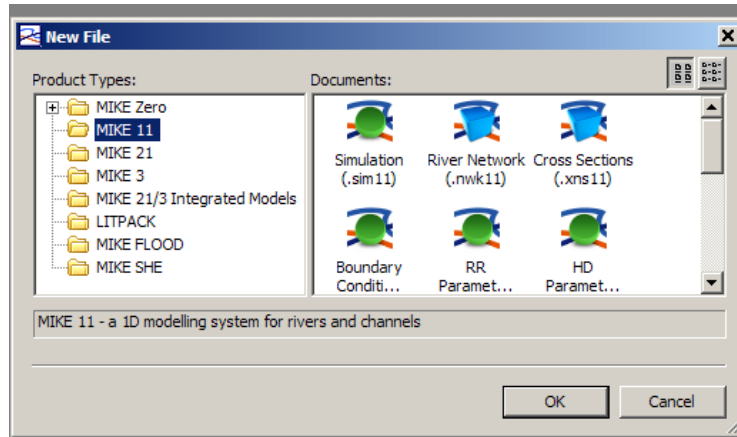
MIKE11 Components:

The following component editors will be discussed:

1	SIMULATION EDITOR	(.Sim11)
2	NETWORK EDITOR	(.Nwk11)
3	CROSS-SECTION EDITOR	(.Xns11)
4	BOUNDARY EDITOR	(.Bnd11)
5	HD Parameter EDITOR	(.Hd11)
6	AD parameter EDITOR	(.Ad11)
7	DA EDITOR	(.Da11)

1 SIMULATION EDITOR
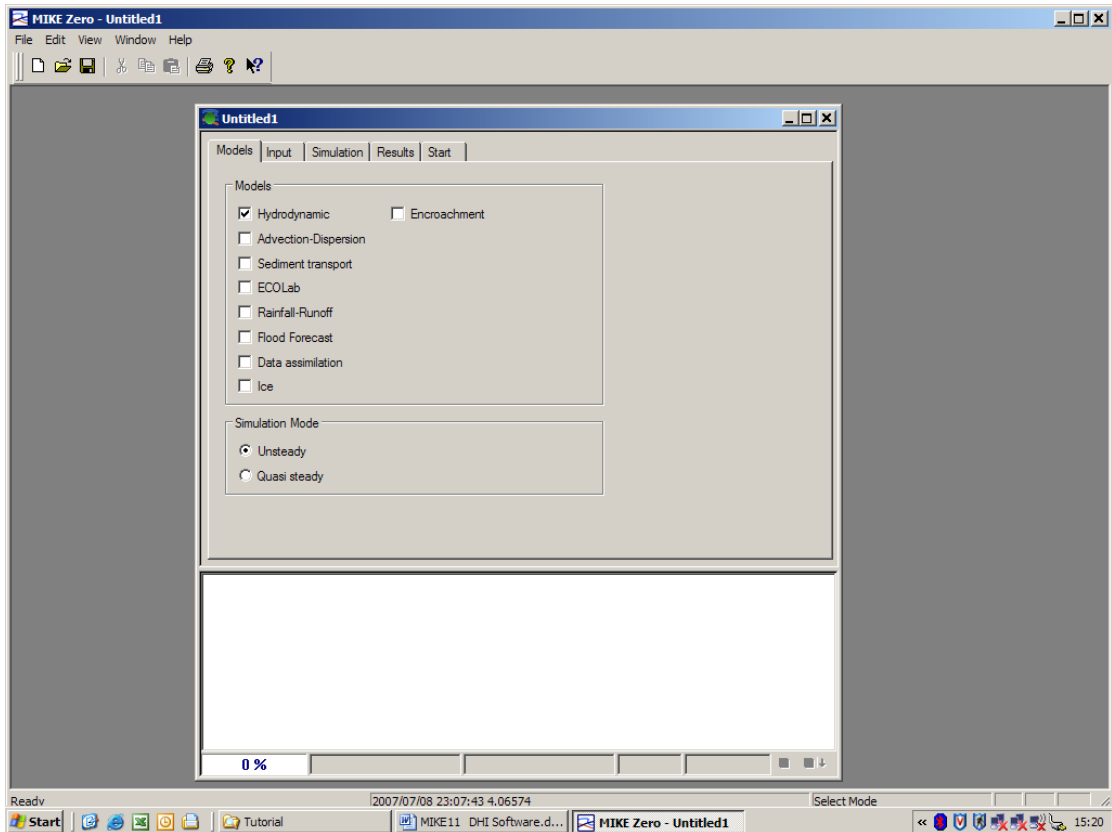
Models:	Checking the models applicable for project.
Input:	Selecting the modelling files for project.
	"Edit" to open and work with model files.
Simulation:	Time step type and unit,
	Simulation period start and end times
	Initial conditions.
Results:	The output Result file name and Location,
	Storing frequency and Unit.
Start:	Validation Status: Green status OK, Red setup error.
	START: click button to start simulation
	Bottom window will display Log messages.
	Status bar: Simulation completion % and Time left.

2 NETWORK EDITOR
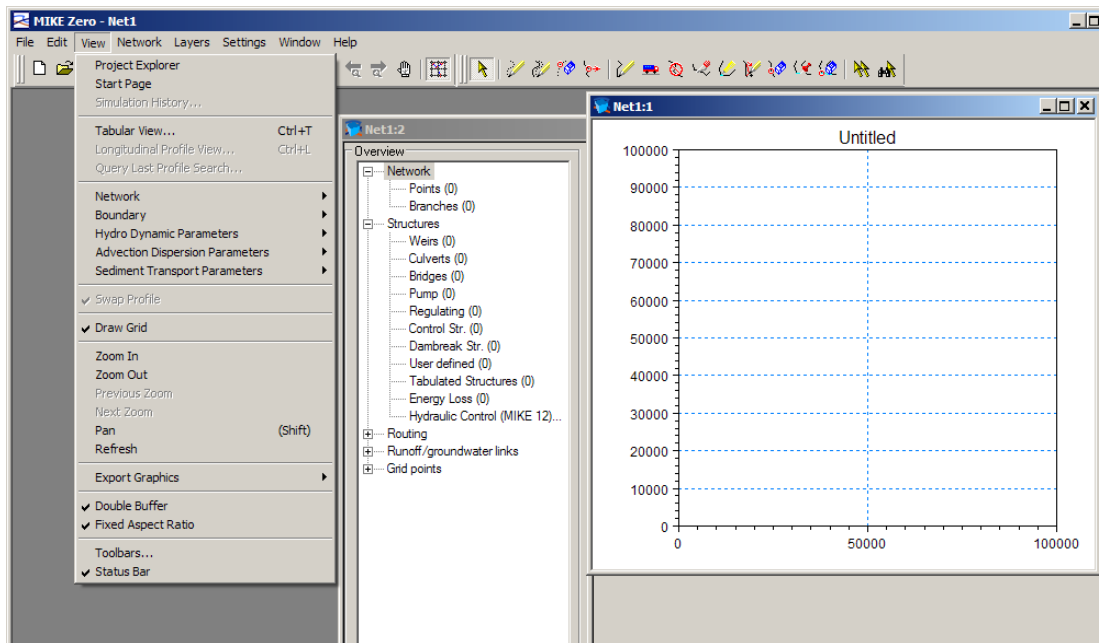
Area Coordinates: Area where project lies in.

View – Tabular View: Window with all Network and tributaries.

    i)   Network: Points and Branches

            Importing Network data for Network Editor

        a)   File – Import – Point and Branch Data from Cross-Section ASCII File.

        b)   Browse and Select ASCII file containing pre-setup data.

    ii)   Structures: Weir, Control Str.

            After base setup is made Structures can be added.

        a)   Weirs most basic, selecting: Location, Attributes, Head Loss factors, Geometry and Calculate Q/h-relations.

        b)   Control Str. (Specialists work): Control structure and rules being pre-defined changes to DT do arise.

              •   Details – Control Definitions – Control Strategy

3 CROSS-SECTION EDITOR
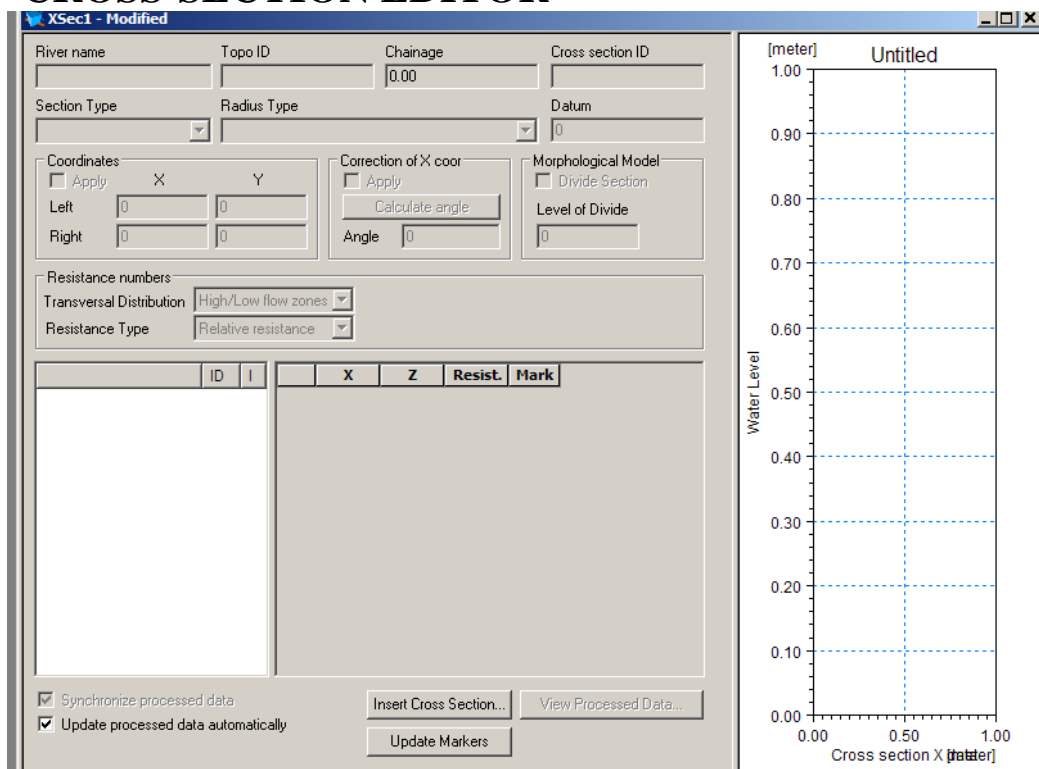
Importing Cross-Sections from pre setup files:
- i) File – Import – Import Raw Data
- ii) Browse and Open ASCII file for Cross-Section Data.

Manual Cross-Sections can be Inserted.
Cross-Section at tributaries can be set: ID, Resistance number and Markers.

4 BOUNDARY EDITOR
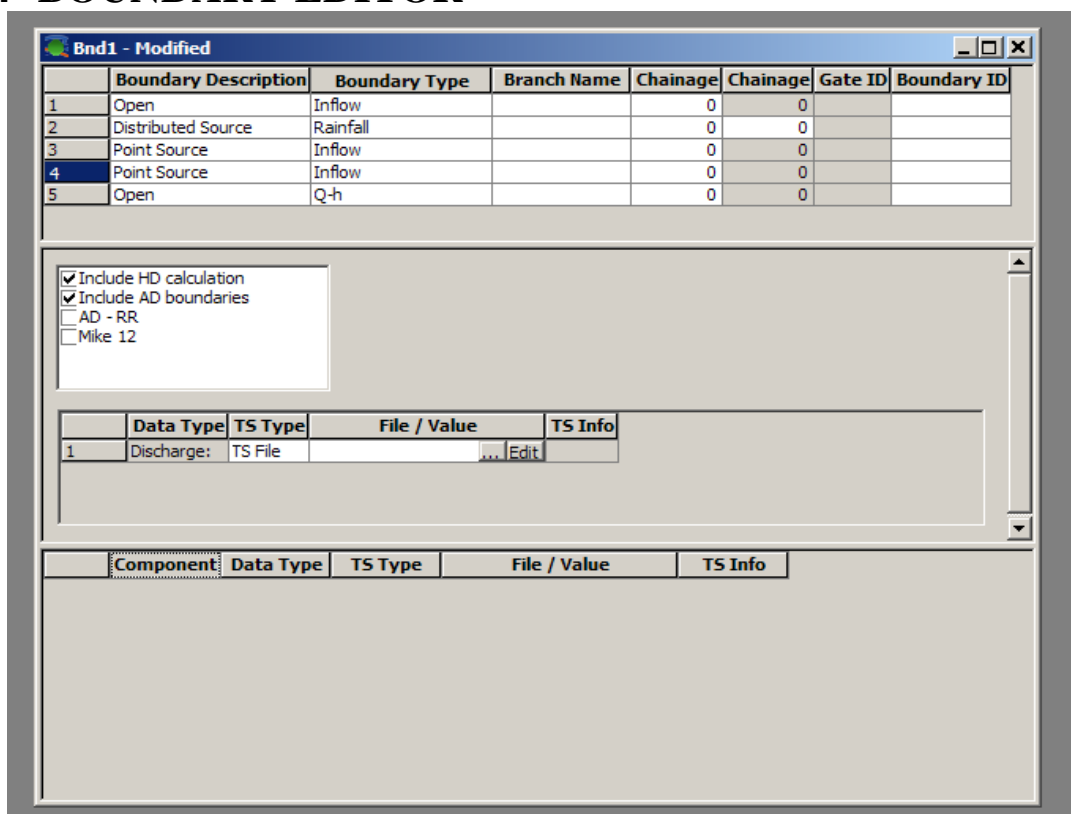
By adding a Boundary, a HD calculation setup is required. By choosing TS Type a Time-Series or a Constant value is connected to the boundary at tributaries.

Open Boundary Type
  i)   Inflow: Start of branch within first upstream cross-section.
  ii)   Q-h: Free Outflow control on branch at last cross-section by   table of Q/h relationship.
  i.   Water Level: Controlling boundary by water level downstream).

Distributed Source Type
  i) Inflow: Flow adding to model over specified branch section.
  ii) Rainfall: Rain water added over specified branch section.
  iii) Evaporation: Water subtraction over specified branch section.

Point Source Type
  i) Inflow: Water added or subtracted at specified chainage.

Tick box "Include AD boundaries":
      AD (Advection-Dispersion) is used in OFS-RT model to model TDS
       (Total Dissolved Salts)

5 (HYDRODYNAMIC) PARAMETER EDITOR

ii)   Initial: Identify Global Values for Water depth and Discharge.
        Local Values for each branch as specified, if needed.

iii)   Bed Resist: Set up an Approach, Formula, Global and Local values.

iv)   Add. Output: Selecting data other than Water level and Discharge
        as output.

v)   Time Series Output:

i)   Generate time series Output data to be used by another simulation.

ii)   Setting output location and file name.

iii)   Identifying items to be placed in Time series.

iv)   Configuring item grid point.

6 (ADVECTION-DISPERSION) PARAMETER EDITOR
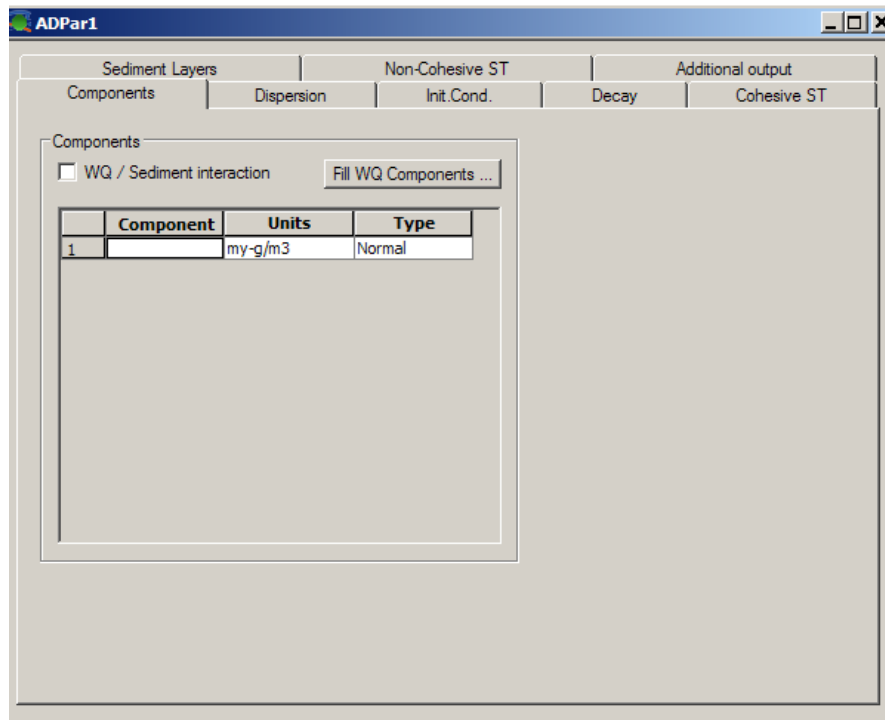
vi)   Components
vii)   Dispersion
viii) Init. Cond.

7 (DATA ASSIMILATION) EDITOR
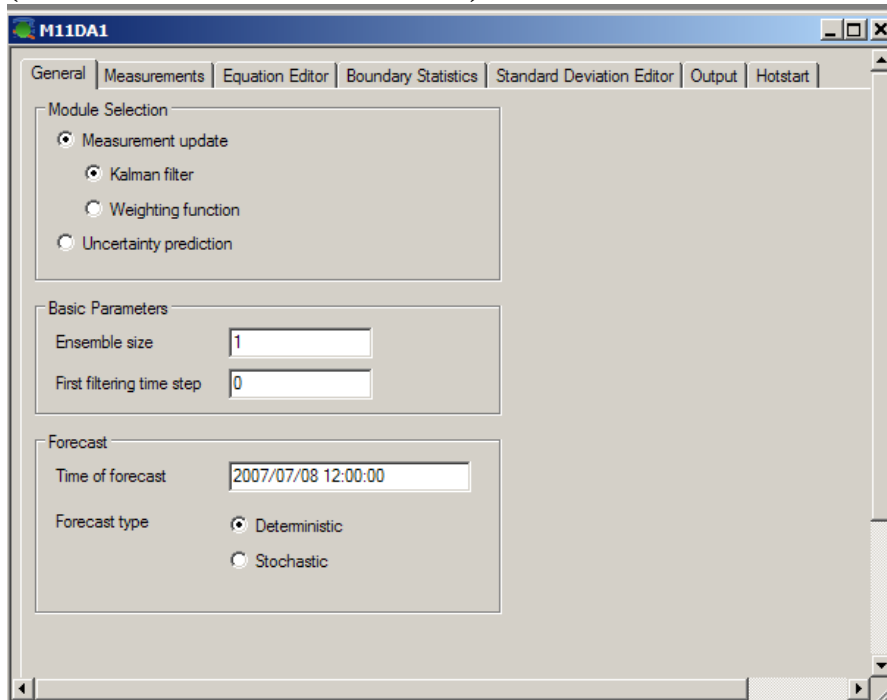
ix) General: Model Selection – Weighting function.
Time of Forecast should be set for every simulation.

x) Measurements: Points on the system over which Data Assimilation will be carried out to start model accurately:

xi)

xii) Measurement location: Branch, Chainage, Variable type and assimilation Time Series file.

xiii) Weight function: Type (Constant or Triangular), Amplitude, Lower and Upper Chainage.

APPENDIX E

FLOODWATCH Quick user guide

Appendix E: FLOODWATCH (Quick user guide)

The FLOODWATCH interface for MIKE11 and AUTOCAL, can be operated by simply following the next steps described in this quick user manual:

1. Starting FLOODWATCH
2. Checking the input data for simulations
3. Model setup
4. Setting up a task
5. Run the 4 hourly interval task
6. Access the output data.
7. Maintenance

For more information and details on FLOODWATCH refer to the:

FLOODWATCH User Guide - Decision support for real-time flood (DHI, 2007).

1. Starting FLOODWATCH

FLOODWATCH runs in an ARCMAP environment. The Icon is displayed in Figure 1.

Figure1   ArcMap FLOODWATCH Icon

FLOODWATCH requires a Login as well as your windows Login information.

Other program Icons that are relevant to the User are displayed in Figure 2:

1.1 FLOODWATCH uses: Windows Tasks Scheduler to load and execute tasks on the computer. For quick viewing and editing, of the time of execution, use the TASK SCHEDULER without having to go through all the ArcMap-editor screens.

1.2 The windows SERVICES in an interface to start & end system operations. This is needed to stop the "DHI.Floodwatch.EventService.exe" when editing the database outside of the normal operations.

1.3 ArcCatalog is one of the editing software modules. (More under Maintenance.)

Figure 2   Useful shortcut Icons for OFS-RT model.

2. Check the input data

Before running the OFS-RT FLOODWATCH model in Real-Time the following requirements should be met:

- The weekly Abstractors' requests must be entered via the Abstractors Pre-Processor.

- Hydras field data received via sms must be checked and exported by Pre-Processor.

- The controlling parameters should be entered with the Abstractors data in the Pre-Processor.

- The DHI dongle must be in place and secured as long as the simulation will be running.

3. MODEL SETUP

Figure 3 shows the OFS-RT setup FLOODWATCH model in the ArcMap editor. From the Drop down menu "Floodwatch", all the options are developed. The Task Editor which will be discussed in section 4, is the most relevant option.
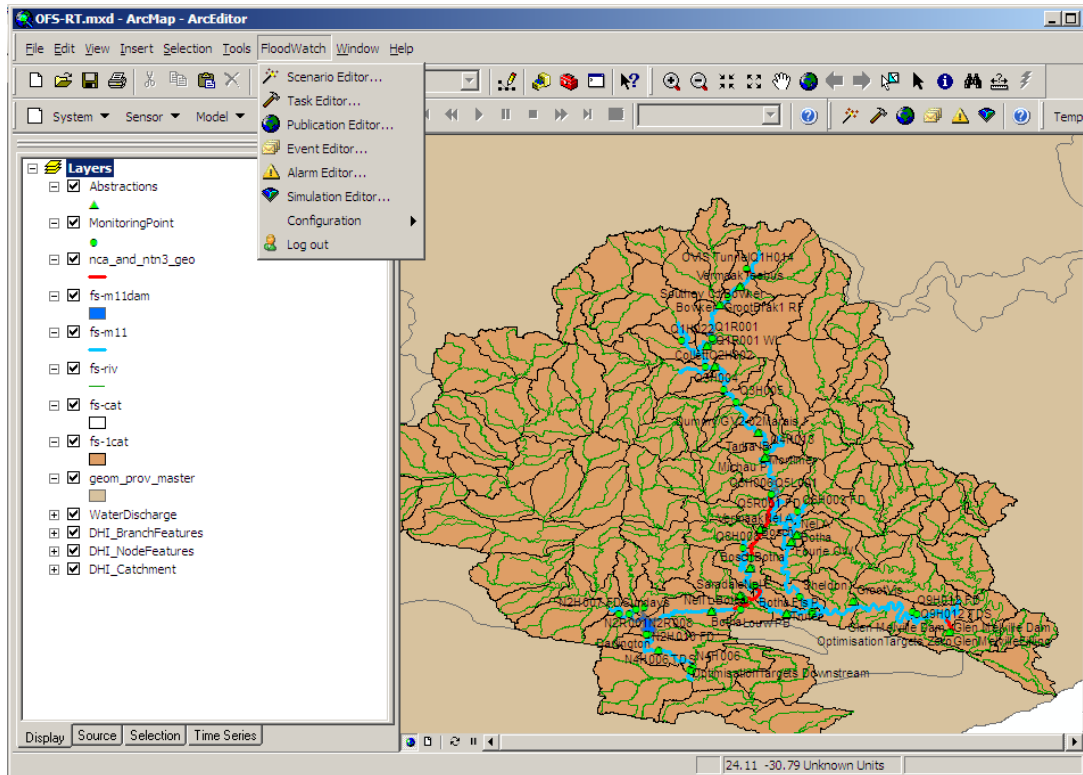
Figure 3   OFS-RT FLOODWATCH in ArcMap editor.

Figure 4 shows the simulation editor, which is a viewer to obtain information on simulations. The editor gives a quick view of simulation information: Start of Simulation(SOS); Time of Forecast(TOF); End of Simulation(EOS). Status: Initialized, InputdataOK; Approved; Time created.

Figure 4   Simulation editor

For each simulation initial conditions are required to start. The setup was built to use a previous simulation output as an Initial condition for a new simulation. The available files for use as Initial conditions are saved on the computer:

C:\FloodWatch\Projects\OFS\Model\OFS-Init

C:\FloodWatch\Projects\OFS\Model\OFS-Init\Time Series\InitialReleases
For FLOODWATCH to access it, it is listed under the tab of Initial conditions, see
Figures 5 and 6.
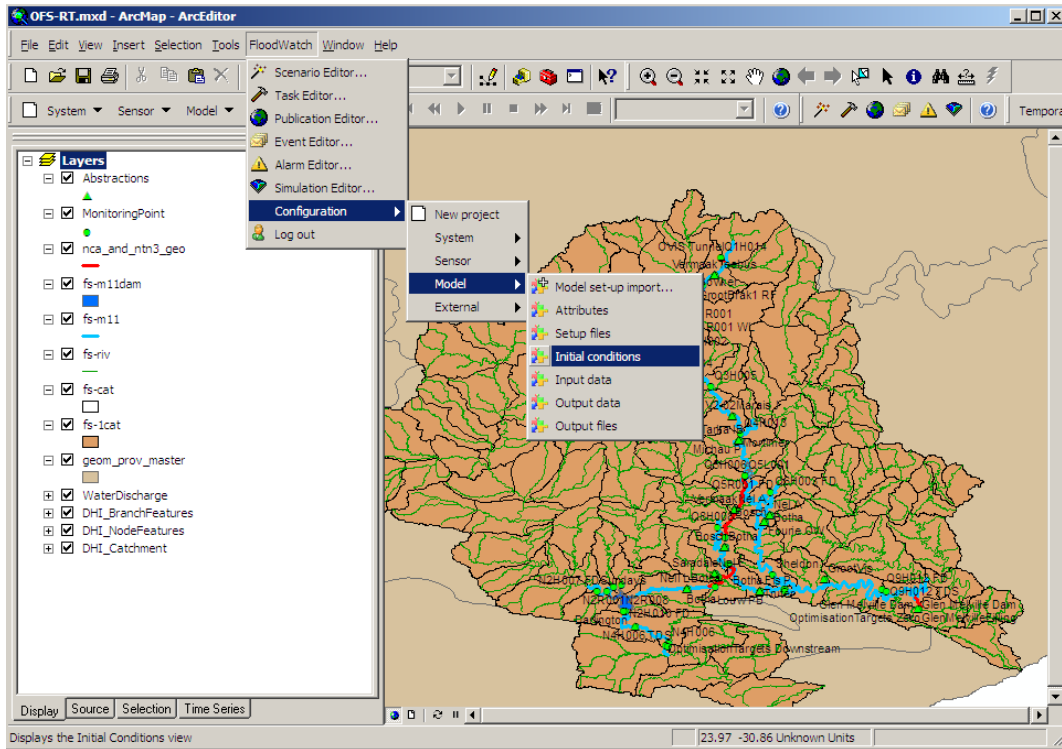
Figure 5   Rooting to: Initial Conditions

The list contains files for the Initial simulation and the optimized simulations. In the
list of available files are default files for both the Initial Simulation and Optimized
simulation. The model uses TOF to look up an appropriate Initial Condition. The
Initial Conditions data are kept in four files that form a package for the simulation. If
it is found that a package is not useable, one would remove a whole package of the
initial condition list and delete the files from the computer location.
To edit the Initial Condition list (Figure 6): Activate the Editor by clicking on the

Select the lines and edit or delete the data. It is important to save the changes and

deactivated the editor by clicking on the and close the editor.

Initial Conditions

Initial Conditions

Model setup: Initial

File location: .\TIME SERIES\InitialReleases\sInitialResults2.dfs0

Source location: .\TIME SERIES\InitialReleases\sInitialResults2.dfs0

Start time: 2005-10-11 00:00:00

End time: 2005-10-15 00:00:00

Default file: ☑

Alternative source: (not selected)

Import File   Export File

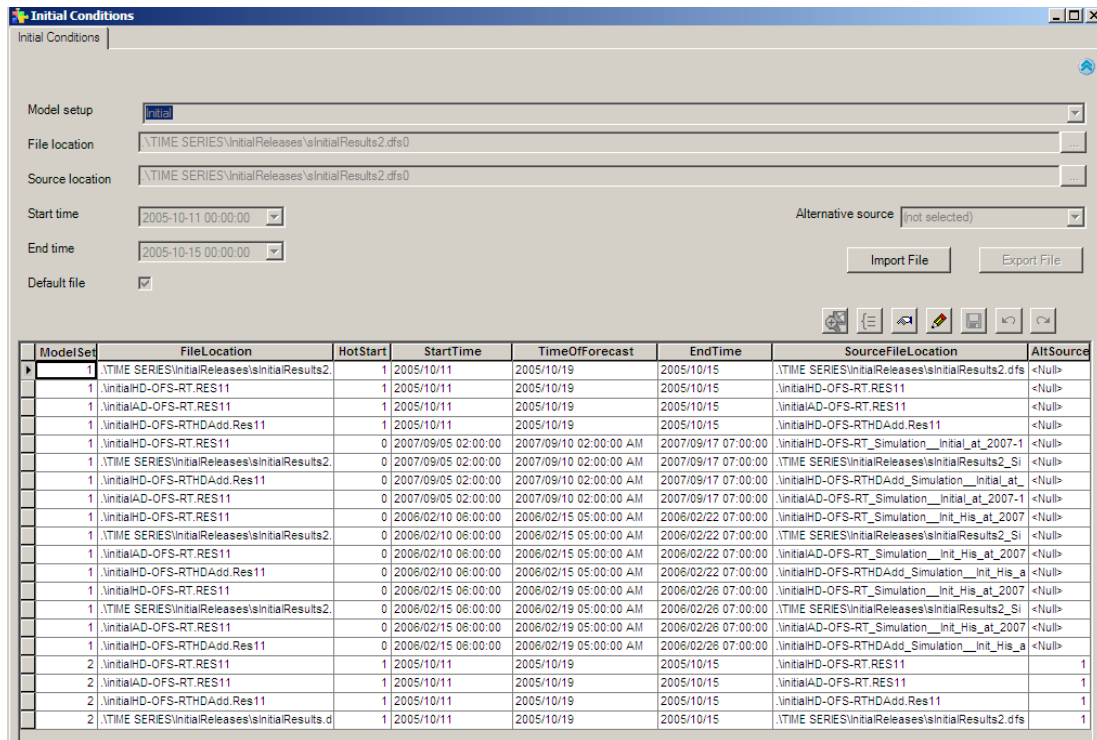| ModelSet	FileLocation	HotStart	StartTime	TimeOfForecast	EndTime	SourceFileLocation	AltSource
1	.\TIME SERIES\InitialReleases\sInitialResults2.	1	2005/10/11	2005/10/19	2005/10/15	.\TIME SERIES\InitialReleases\sInitialResults.dfs	<Null>
1	.\initialHD-OFS-RT.RES11	1	2005/10/11	2005/10/19	2005/10/15	.\initialHD-OFS-RT.RES11	<Null>
1	.\initialAD-OFS-RT.RES11	1	2005/10/11	2005/10/19	2005/10/15	.\initialAD-OFS-RT.RES11	<Null>
1	.\initialHD-OFS-RTHDAdd.Res11	1	2005/10/11	2005/10/19	2005/10/15	.\initialHD-OFS-RTHDAdd.Res11	<Null>
1	.\initialHD-OFS-RT.RES11	0	2007/09/05 02:00:00	2007/09/10 02:00:00 AM	2007/09/17 07:00:00	.\initialHD-OFS-RT_Simulation__Initial_at_2007-1	<Null>
1	.\TIME SERIES\InitialReleases\sInitialResults2.	0	2007/09/05 02:00:00	2007/09/10 02:00:00 AM	2007/09/17 07:00:00	.\TIME SERIES\InitialReleases\sInitialResults2_Si	<Null>
1	.\initialHD-OFS-RTHDAdd.Res11	0	2007/09/05 02:00:00	2007/09/10 02:00:00 AM	2007/09/17 07:00:00	.\initialHD-OFS-RTHDAdd_Simulation__Initial_at_	<Null>
1	.\initialAD-OFS-RT.RES11	0	2007/09/05 02:00:00	2007/09/10 02:00:00 AM	2007/09/17 07:00:00	.\initialAD-OFS-RT_Simulation__Initial_at_2007-1	<Null>
1	.\initialHD-OFS-RT.RES11	0	2006/02/10 06:00:00	2006/02/15 05:00:00 AM	2006/02/22 07:00:00	.\initialHD-OFS-RT_Simulation__Init_His_at_2007	<Null>
1	.\TIME SERIES\InitialReleases\sInitialResults2.	0	2006/02/10 06:00:00	2006/02/15 05:00:00 AM	2006/02/22 07:00:00	.\TIME SERIES\InitialReleases\sInitialResults2_Si	<Null>
1	.\initialAD-OFS-RT.RES11	0	2006/02/10 06:00:00	2006/02/15 05:00:00 AM	2006/02/22 07:00:00	.\initialAD-OFS-RT_Simulation__Init_His_at_2007	<Null>
1	.\initialHD-OFS-RTHDAdd.Res11	0	2006/02/10 06:00:00	2006/02/15 05:00:00 AM	2006/02/22 07:00:00	.\initialHD-OFS-RTHDAdd_Simulation__Init_His_a	<Null>
1	.\initialHD-OFS-RT.RES11	0	2006/02/15 06:00:00	2006/02/19 05:00:00 AM	2006/02/26 07:00:00	.\initialHD-OFS-RT_Simulation__Init_His_at_2007	<Null>
1	.\TIME SERIES\InitialReleases\sInitialResults2.	0	2006/02/15 06:00:00	2006/02/19 05:00:00 AM	2006/02/26 07:00:00	.\TIME SERIES\InitialReleases\sInitialResults2_Si	<Null>
1	.\initialAD-OFS-RT.RES11	0	2006/02/15 06:00:00	2006/02/19 05:00:00 AM	2006/02/26 07:00:00	.\initialAD-OFS-RT_Simulation__Init_His_at_2007	<Null>
1	.\initialHD-OFS-RTHDAdd.Res11	0	2006/02/15 06:00:00	2006/02/19 05:00:00 AM	2006/02/26 07:00:00	.\initialHD-OFS-RTHDAdd_Simulation__Init_His_a	<Null>
2	.\initialHD-OFS-RT.RES11	1	2005/10/11	2005/10/19	2005/10/15	.\initialHD-OFS-RT.RES11	1
2	.\initialAD-OFS-RT.RES11	1	2005/10/11	2005/10/19	2005/10/15	.\initialAD-OFS-RT.RES11	1
2	.\initialHD-OFS-RTHDAdd.Res11	1	2005/10/11	2005/10/19	2005/10/15	.\initialHD-OFS-RTHDAdd.Res11	1
2	.\TIME SERIES\InitialReleases\sInitialResults.d	1	2005/10/11	2005/10/19	2005/10/15	.\TIME SERIES\InitialReleases\sInitialResults2.dfs	1

Figure 6   Initial conditions

4. Setting up a TASK

From the TASK editor, Figure 7, right click and select "Add task".

Other options from this menu are:-Refresh and Reload the editor to display the updated current editor condition.-Delete Task, to remove unwanted tasks from the list. -Start Task, for execution of the tasks, and End Task, to force an ending to the task.-Task History, to view historical messages and locate possible errors.- Properties, to set up and alter task steps for simulations.

FLOODWATCH will prompt the user for Windows login details before task edits can be saved to the project.
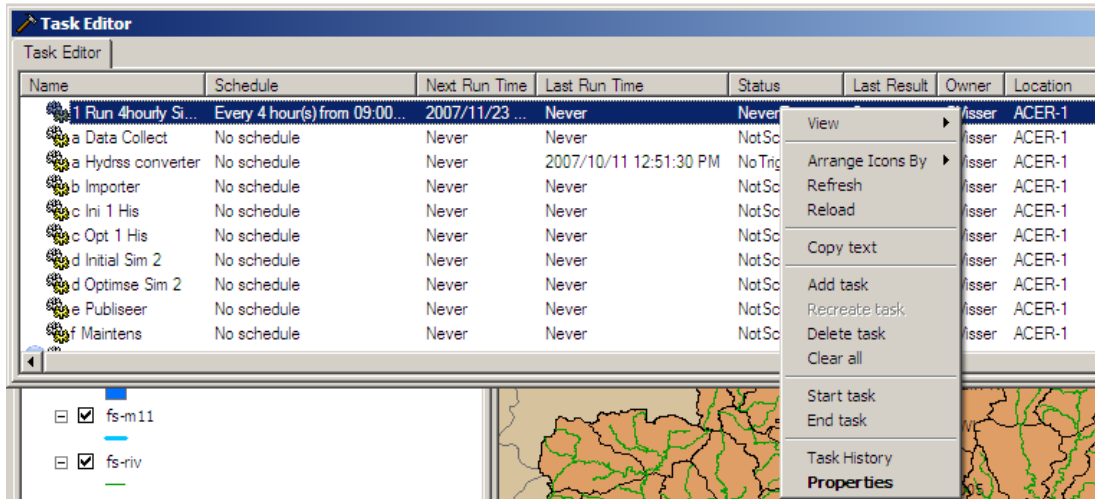
Figure 7   TASK editor

"Add Task" will bring up a window as shown in Figure 8. On the General tab give your new Job an appropriate name and enable it. If the Interactive box is selected the task progress will be visible during execution in a window. Give the task a short description to assist future users. The Job can be scheduled from this window, which is linked to the windows task Scheduler, by clicking "Schedule".
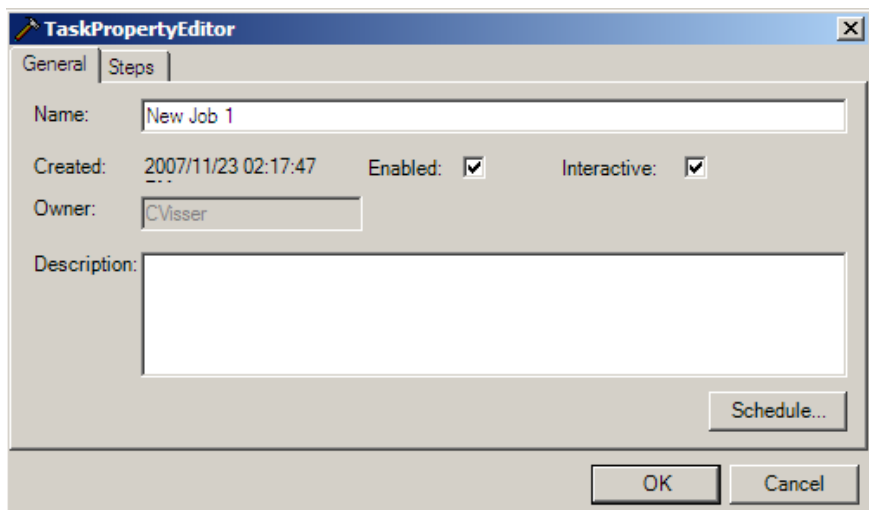
Figure 8   Add task - General

Select the Steps tab: Create a new step or steps for this job. The steps are run in order, from top to bottom, in the window and to change the execution order, move "Step" into the correct slot (Figure 9).

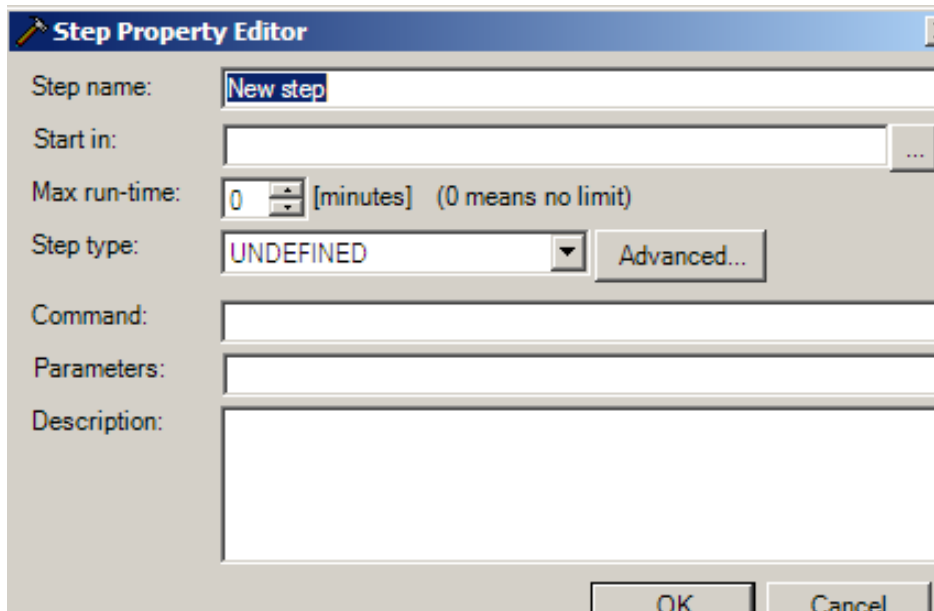Editing the step, opens Step property Editor window (Figure 10).
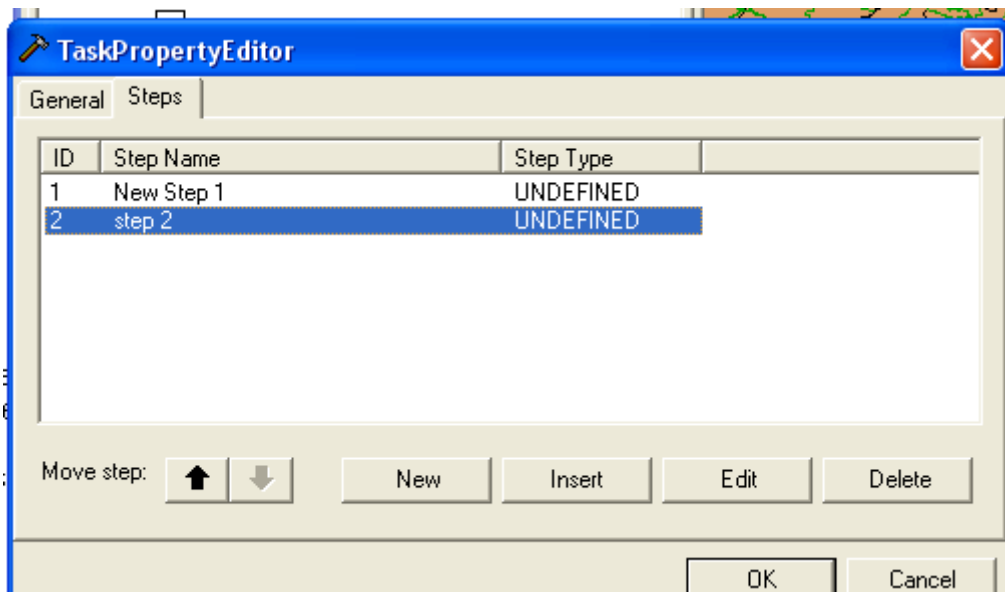
Figure 9   Add task – Steps – New Step

The Step property Editor in Figure 10 set up the step name, Type, Command and Parameters details.

Fill in a description of the step for future users.

From step type, select Simulation and advanced

Figure 10   Step Property Editor

From the Simulation settings, Figure 11:

Scenario Name:From the drop down menu choose the Steps scenario:"Init His" –
Initial simulation on historical data; "Initial" – Initial simulation in real-time; "Opi His" – Optimize simulation on historical data; "Optimize" - Optimize simulation in real-time.

Check the "Approve simulation" box.

"Use manual simulation times" has two options:

a) If not running in Real-Time mode simulation, the user must select the dates and time for the steps simulation.
b) In Real Time mode, FLOODWATCH will use the time of run as TOF, set the SOS four days into the past and set the EOS seven days into the future.

Click on "OK", after input is checked.

After the Simulation setting is complete, FLOODWATCH will autofill the Steps property parameters (Figure 12).
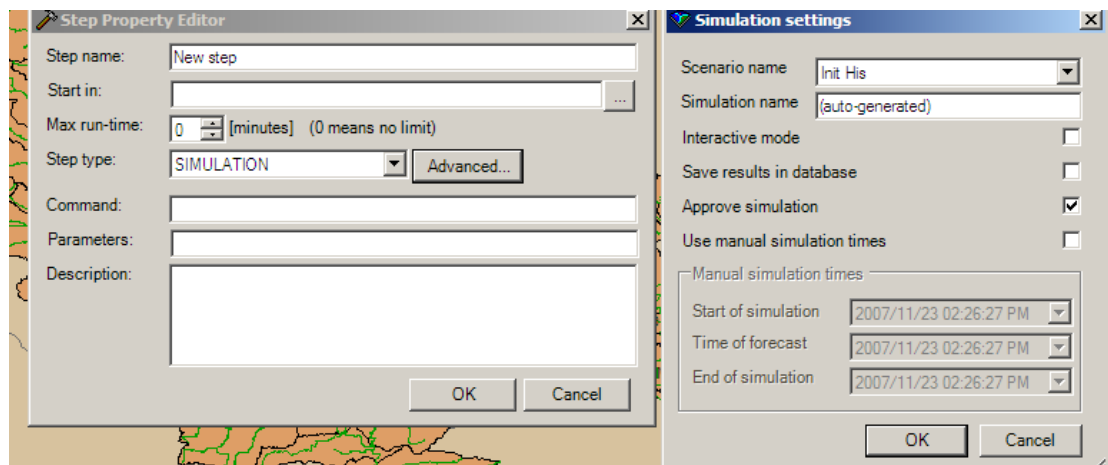
Figure 11   Step type: Select simulation

Figure 12   Step Property Editor, after auto fill of parameters.

After input is checked and approved by the user, click on "OK".
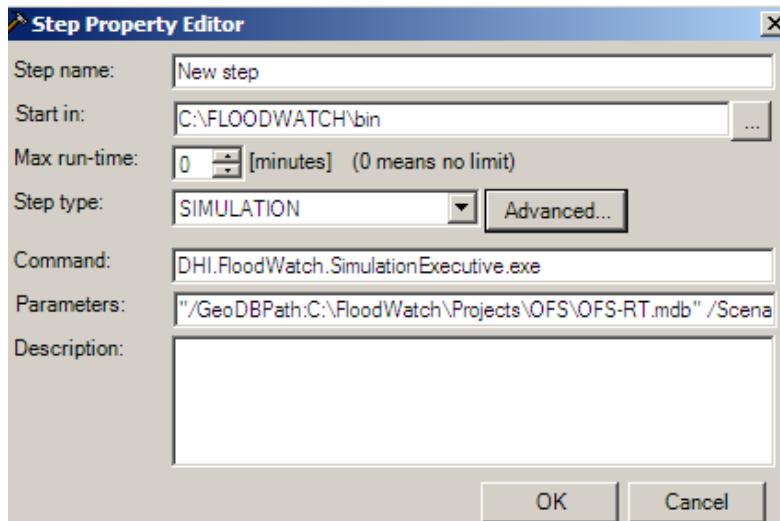
If no more steps are required to be added to the task, click on "OK".

To schedule the task, use the link to "Windows task scheduler" Figure 13.

- For new task or first time scheduled tasks click "new"
- Select a schedule frequency Monthly, Weekly, Daily or under "Advanced" schedule the task in intervals.
- Specify stopping criteria, end date or number runs.
- Give a time at which the task should start tot run.

Figure 13   Windows Task Scheduler

Click on "OK" to save schedule.

Click on "OK" to approve Task.

Right click and select reload to view the new or altered task.

5. Run the 4 hourly interval task.

For running FLOODWATCH in default Real-Time mode:

1. User have checked all input data
2. Select task required to run from Task Editor, by right clicking.
3. Task name: "**2 Run All – 4hours**" Figure 14.
4. Select "Start task"

Alternately the task can be scheduled to run automatic every 4hours.

Figure 14   Task Editor: Run All – 4hours

In the setup of the "**2 Run All – 4hours**" task is all the steps for FLOODWATCH to create and execute a simulation. Figure 15 shows all the task steps:

1. Convert data   Converting HYDRAS data for FLOODWATCH
2. Import data   Import HYDRAS, Abstraction and Control data into FLOODWATCH database
3. Initial Sim   Run Initial Simulation
4. Optimise Sim   Run Optimization Simulation
5. To Web   Convert output to Web base format and post data to Web.

Figure 15   2 Run All – 4hours: Task PropertyEditor

6. FLOODWATCH warnings

FLOODWATCH publishes warnings every 4h on the computer to the user for the following scenarios:

i) High Water Level Warning:The model monitors the observed and forecast period water levels at the four dams (Grassridge, Elsndsdrift, DeMistkraal and Darlington) and compare the level to a target High level near FSL and if exceeded in a run an Alarm will be published and opened on screen for the user to view.

ii) Low Water Level Warning:The model monitors the observed and forecast period water levels at the four dams (Grassridge, Elsndsdrift, DeMistkraal and Darlington) and compare then to a target low level and if under the target level an Alarm will be published and opened on screen for the user to view.

A typical warning view of an Alarm at the high water level warning is shown in Figure 16.
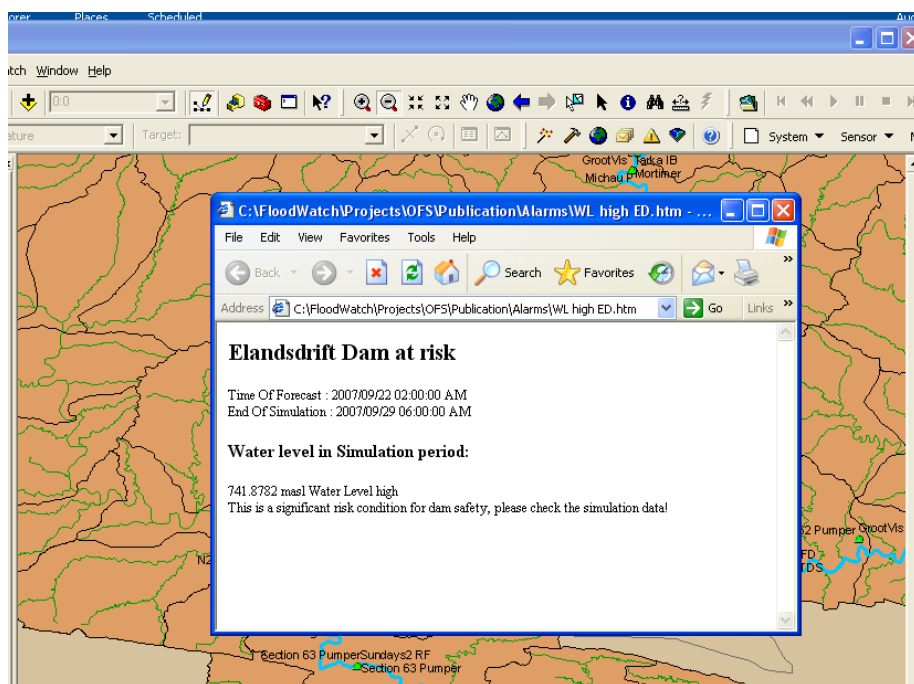
Figure 16: Elandsdrift Dam at risk high water level.

7. Access the output data

After a simulation is completed and approved by FLOODWATCH. FLOODWATCH publishes the data as output to:

C:\FloodWatch\Projects\OFS\Publication\DATA\ OUTPUT-DATA*time stamp*.

This data is accessed by the post processor and generates the web output data which

gets posted on: www.sun.ac.za/ofs-rt

The web pages are saved on the computer:

C:\FloodWatch\Projects\OFS\Publication\web and

C:\FloodWatch\Projects\OFS\Publication\output

From the FLOODWATCH interface the user can access data by right clicking on the

map on the data point to be viewed.

Alternatively, the simulation folder can be accessed and MIKEVIEW can be used

to view the simulation result files:

C:\FloodWatch\Simulations\ Simulation_*** Time stamp ***\MODEL_FILES\

AutoCal-AD-OFS-RT.res11   Output file of TDS data

AutoCal-HD-OFS-RT.res11   Output file of Hydro Dynamic data

In the C:\FloodWatch\Simulations\ Simulation_*** Time stamp

***\MODEL_FILES\ are Log file which can be read for error detection and

troubleshooting:

AutocalRunTime.log

OFS-Autocal_Opt.log

OFS-RT.sim11.apv.log

OFS-RT.Log

Log files can be opened by most text editors.

8. Maintenance

8.1   Scheduled maintenance

With time the Simulations will overfill the computer's hard drive and the

Maintenance task will clean up the old FLOODWATCH simulations and data.

In the Task editor Figure 17 is the "Maintenance" task.

Figure 17   Task Editor – Maintenance

From the step property select Advanced, Figure 18.

For deleting old information the following is checked: Events, Initial Conditions and Simulations.

Under Simulation select the Scenario name of the simulations to be deleted.

In all options supply the number of days to be deleted.

The pre-setup Maintenance task has two steps, one for deleting the old Initial simulations and one for the Optimized simulations.
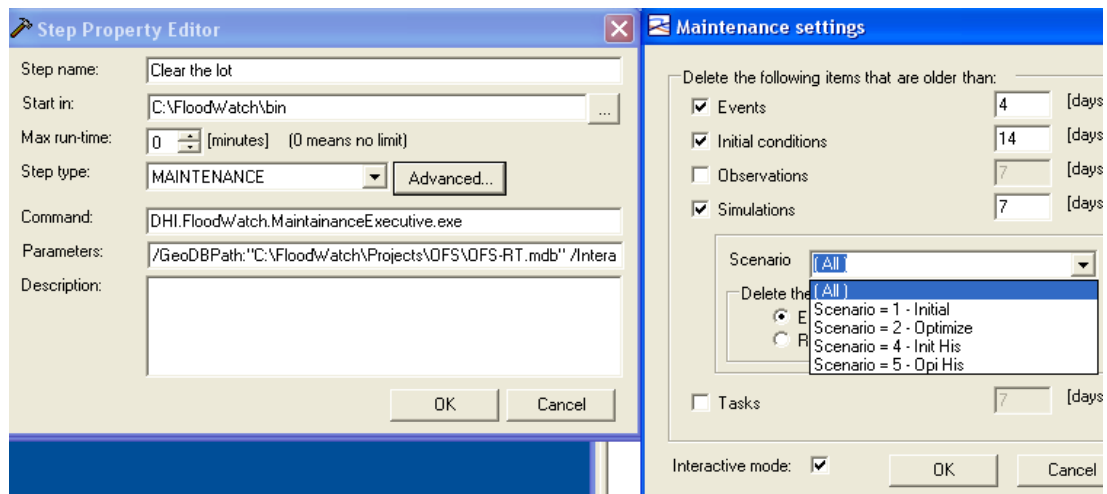
Figure 18   Maintenance: Step Property and Settings

8.2 ArcCatalog

Some essential maintenance on the computer model is required from time to time. Reboot the computer once a week to clear RAM and refresh registries, to enhance general performance.

Run the Disk defragmenter once a month will enhance the hard drive performance.

During the weekly restart of the computer and down time of the system database, the following maintenance must be done:

a) In The ArcMap editor select the Time Series tab
b) On the "OFS-RT | view by: group" right click and select the "Clean up and repair database". This will repair the database and the user might be prompted to approve deletion of duplicate data. See Figure 18.
c) Check that no task is scheduled for OFS-RT setup to run in the next 30 minutes and Close the ArcMap editor.
d) Open the windows SERVICES menu, see Figure 19.
e) Stop the service task: **DHI FloodWatch Event Service**
f) Open the ArcCatalog: browse for the OFS-RT database, see Figure 20
g) Right click on the database and select compress.
h) Close and save all windows.
i) REBOOT the computer
j) Open HYDRAS SMS Receiver, HYDRAS3 Catchment, ArcMap-OFS-RT and schedule task for Real-Time operations.
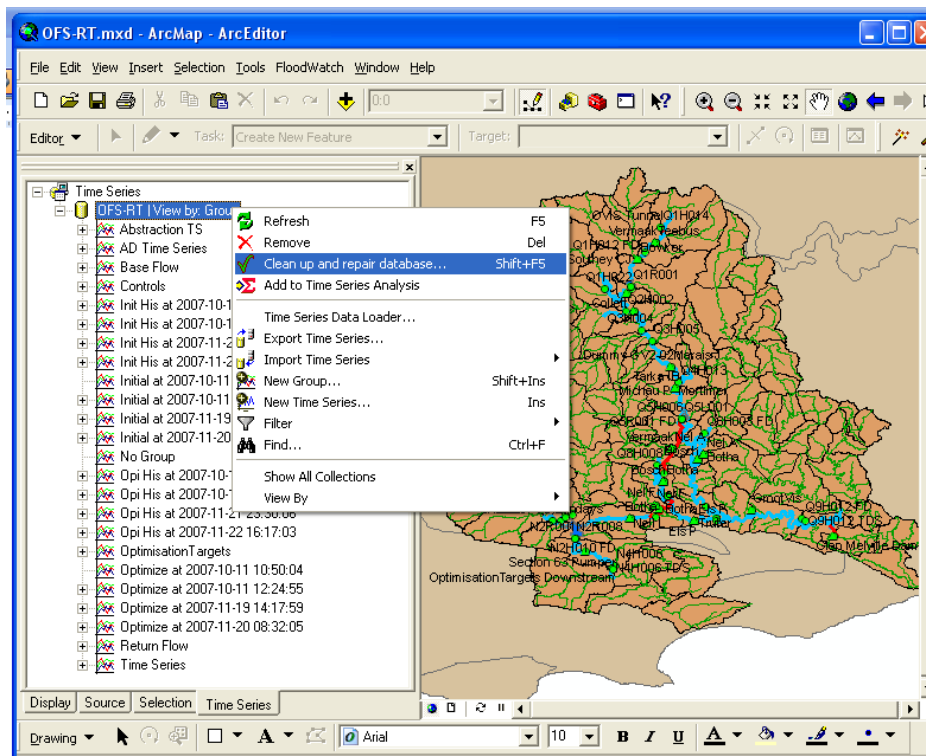
Figure 19 ArcMap: Clean up and Repair
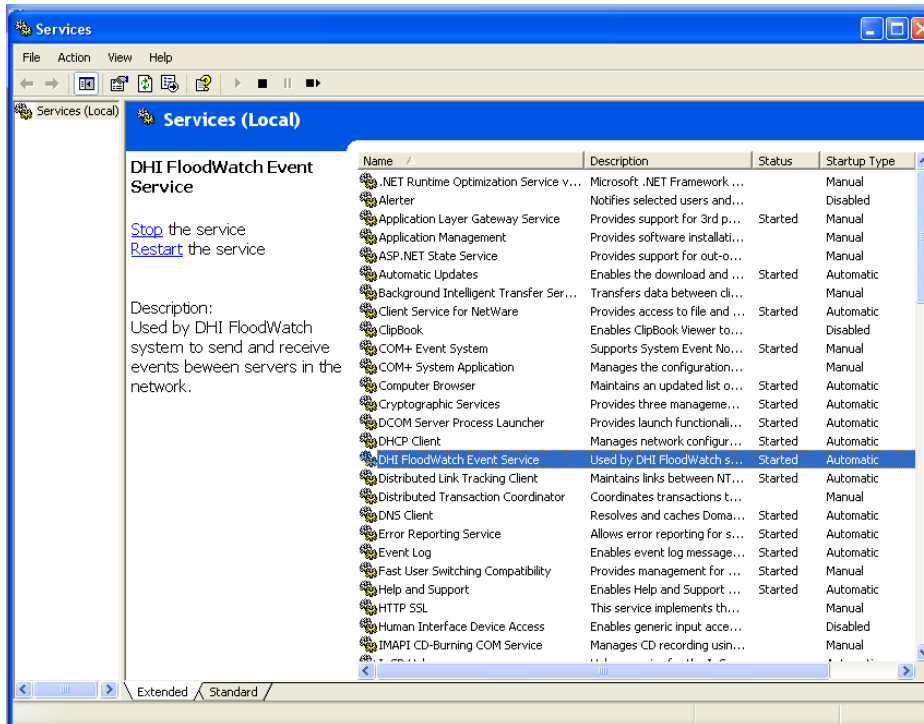
Figure 20 Windows Services
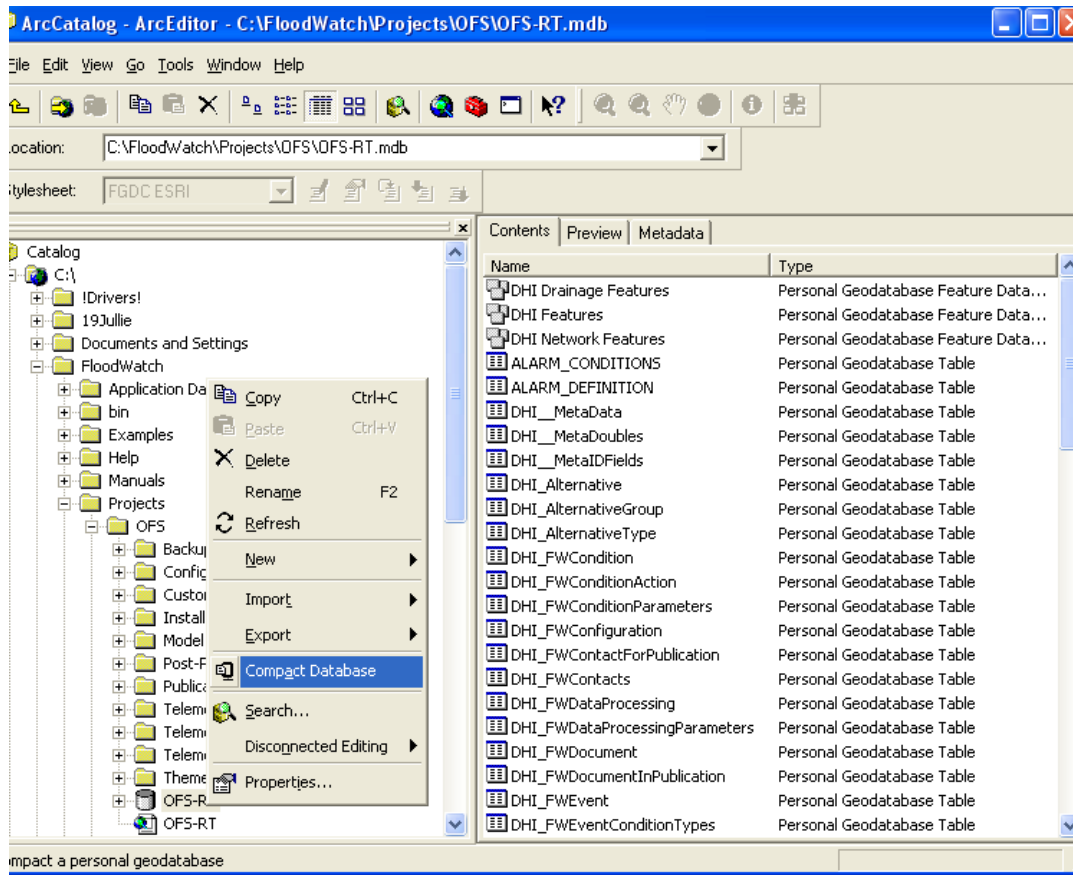
Figure 21 ArcCatalog Editor

The "GHOST" in the computer interferes with files and can corrupt data, this however happens infrequently. The AcrCatalog is one of the tools to open and edit the database. In Figure 21 the OFS-RT database tables are visible and accessible for direct editing.

Prior to directly editing the database close FLOODWATCH - ArcMap and check that no simulations will run during the edit session.

Quick Starting Steps

STEP 1

Start Computer, wait for booting sequins.

Select **OFS-RT** user. (Yellow duck)

(Confirm that NumLock is on.)

Windows Login Password: **1234**

STEP 2

Open OTT Hydras3, by cling on the Icon:

Expand the Left hand column view.

Click on the Menu name: ▪1**/OFS-RT Project**.

Click on the Sub Menu name: **999999999/ >All Stations<**

(This will reveal all the Stations in Hydras3 database for OFS-RT.)

STEP 3

Step 3 is for obtaining the data for the HYDRAS3 database. At least one of the three methods must be used. If not all data can be retrieved by only one method the other can be used to add in (patch) the database.

Step 3a (Dialling for data)

(Follow Hydras3 OTT, Quick User guide, page 16, Dialling for data)

Before a Simulation can be run all the stations must be downloaded to a have complete up to date data set!

Step 3b (only if Modem is connected)

Open OTT SMSReceiver

Confirm that it connected to Modem and start SMS downloading.

Give enough time (±20 min) for GMS system to send data to modem and HYDRAS3 import the data. (This is a good time to make changes, if needed to the Abstractions Pre-Processor.)

Step 3c Internet SMS download

SMS data can be sent to the Operator by the parallel operational Operator over the website.   www.sun.ac.za/OFS-RT

This must be arranged with the parallel operator.

Login on website: Username: **ofs**   Password: **rt**

Click on **System DATA upload** button.

Click on **System SMS data** button

Select the **Open** option.

In the left panal: "**Extract all files**"

Direct by browsing to "**(N:\)ImportedData on "OFS-RT Dell2**"

(Do not brows into subfolders (Done or Error))

. **OK** .

. **Next** .   wait for Extraction to complete.

. **Finish** .   close window and Browsing on **OFS-RT Webpage** can continue.

Force Exporting of HYDRAS3 data will be needed to create text file for FLOODWATCH simulations.

STEP 4

Capturing Abstraction requests or changing controller

parameters in the Pre-Processor.   Use icon on desktop**:**

Follow the Abstractions Pre-Processor (Quick user guide) page 21

Use the buttons on the menu to guide through the Pre-Processor.

<< Step one week back.

>> Step one week forward.

Abstraction   For Irrigators requests, schedule, see page 26 of quick user

guide.

Important when done with the Pre-Processor to click the:

Convert Archive to FLOODWATCH Format   This exports the new and

changes to text files for FLOODWATCH to import and use.

Close the Pre-Processor and its Archive.

STEP 5

Exporting HYDRAS3 data to text files, for FLOODWATCH importing.

- If HYDRAS3 are running in the background and receiving SMS without problems it will be done automatically.

- FORCE Exporting   (If dialling or Internet SMS is used, or Hydras error occurred.)

    Open HYDRAS3.

    Click in menu bar on **EXSTRAS → Multiple Export → Execute**

    Scroll down to **(Quick) Export ALL**

    Selecting the time window of exported data**:**

    Start: (Setting it to -7 days in the past.)

    End: (Setting it to +1 day forward.)

- Checking the output text files:

  Clicking on the "**Exported DATA**" shortcut on the desktop,

     or Brows from **My Computer** → **C:** → **Hydras3** → **Exported Data**.

  Sort by **Size**.

  Open the top (smallest) files and assure that there are at least two (2) lines of data in the text files.

  Editing the data in the of stations data can be done here**:**

  To add in lines in the text files, the correct format is needed! Copy a line from another file and past it in the required file.

  *Check that the Date & time of the edited file is chronologically.

  Very important to confirm in the DATA column, that a good estimated value is entered into the data flied (TDS, WATERLEVEL or DISCHRARGE) depending on the station.

STEP 5

Starting FLOODWATCH by clicking on the Icon:

FLOODWATCH OFS-RT.lnk

LOG IN:

      User Name : **OFS**   Password : **OFS**

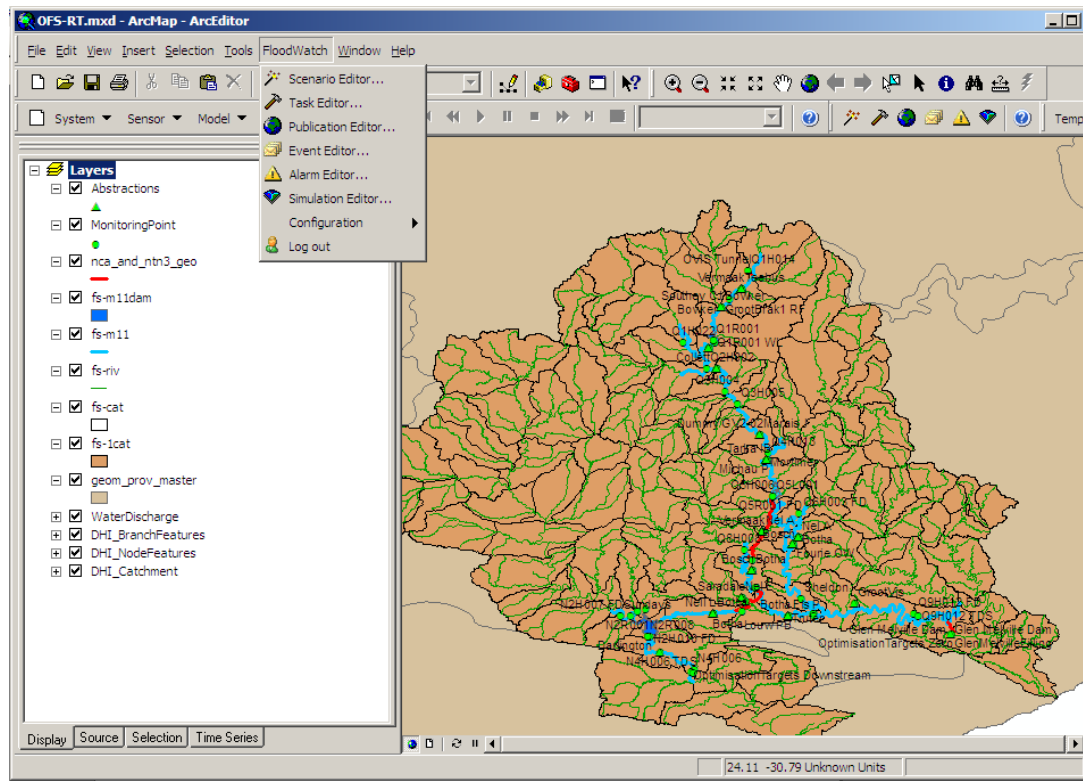In the left panel (bottom) click on **Time Series** and extend the view by click on the

＋**OFS-RT | View by Group**

To refresh the time series files:

Right click on **OFS-RT | View by Group** → select Cleanup and Repair Database.

STEP 6

Start a task

Clicking on Menu toolbar **FLOODWATCH** **Task Editor**

Right Click on the Task **2 Run ALL 4hours**

Select **Start Task** Follow the started task and that it will continue to run

through all the task steps for approximately 4 hours to produce output for web.

STEP 7

Viewing Web output: Newest Simulation is on webpage older simulations in archive.

Open website. www.sun.ac.za/OFS-RT

Login on website: Username: **ofs** Password: **rt**

Or on User computer shortcut to **"OFS-RT WebBlad"**

Brows through Web page to view **Releases, Dam Info, System TDS, Tributaries,**

Latest Simulation Summary and other tabs.

Print the webpage for hard copy reverences.
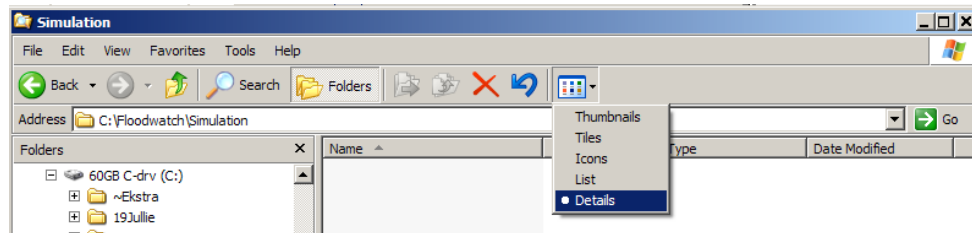
Additional Help:

Scenario 1

View Simulation files and LOG files of simulation:

Open **My Computer** →

C:\FLOODWATCH\SIMULATION "brows for newest time stamp folder"

\Model files

During the simulation seven(7) **Client** folders will be running.

(During the simulation the Log files are being over writing for every run.)

Change the folder view to **Details**.

Select the three Log files:

> OFS-Autocal_Opt.log
>
> OFS-RT.sim11.apv.log
>
> OFS-RT.Log

Look at the size of OFS-RT.Log then it change from 0 KB press **ENTER**

Scroll through the OFS-Autocal_Opt.log to check that it as **OK** all simulations done to point,

OFS-RT.sim11.apv.log scroll to the end and confirm that it has done all the steps and that the enf message refer to Warnings in Log files

OFS-RT.Log that it only contain **Warnings** and no **ERRORS**

These files can be saved to be sent to DATA.zip folder and Internet.

Scenario 2

Simulation Error: Find and delete faulty Simulation and Initial-conditions:

(Also see page 3 in FLOODWATCH Quick user guide)

From the ArcMap OFS-RT → **FLOODWATCH** → **Simulation Editor**

Sort by **Created date**

Search through the list of simulations, to find the simulation "pair" that were not Approved.

(Write down the time and date it was created on.*)

Depending on the error the Initial simulation might be Approved and the Optimise Simulation not, or the Optimise Simulation were not created at all.

Important to select the Initial Simulation and (if created) Optimise Simulation

Right click and select Delete.

Close Editor.

Select from the ArcMap OFS-RT → **FLOODWATCH** → **Configuration** → **Model** → **Initial conditions**. See Quick user guide page 4.

Activate the Editor by clicking on the

Sort the Editor by right clinking on the **Start Time** column and sort.

Expand the **Source File Locations** column by dragging it to the right.

Scroll down and Search in the **Source File Locations** column the *Time and Date of the   . Faulty "unapproved" simulation time and date written down from Simulation Editor above.

The Initial conditions are in x4 lines, select only the set of four files.

Press "**Delete**" on keyboard. Confirm that all four is deleted.

Deactivate the Editor by clicking on the

Then prompt for saving, select **YES**

Close the **Initial conditions** window.

Refresh the time series files**:**

Right click on **OFS-RT | View by Group** → select Cleanup and Repair Database.

<u>Scenario 3</u>

Send additional DATA to Internet:

Open **My Computer** → **C:** → **Oordrag**.

Select and Delete all old files in folder excepted **TransferDATAZIP_na_Acer.bat**
file.

Brows to the location of **files** or **folders** of interest for the transfer.

a) Select the desired **files/folders**,

Right click → **Copy** files

Brows to **My Computer** → **C:\Oordrag\ and PAST files**

or b) Open file and use **Save As** option to save file in: **C:\Oordrag**

Once all wanted files are in: **C:\Oordrag** → Select all these files in the folder.

Right click and **Send to** → **Compressed (Zipped) Folder**

Right click and **Rename** the new folder to **DATA**

Double click on **TransferDATAZIP_na_Acer.bat**

On User computer:

Confirm that internet connection is open.

On the desktop Double click on shortcut: **TransferDATAZipWeb.bat**

or   Brows to **My Computer** → **C:\Oordrag** The data.zip file will be there and
the **TransferDATAZipWeb.bat** can be run from here.

Scenario 4

Retrieve DATA from Internet:

Data can be sent to the Operator by the parallel operational Operator over the website.

www.sun.ac.za/OFS-RT

This must be arranged with the parallel operator.

Login on website: Username: **ofs** Password: **rt**

Click on **System DATA upload** button.

Click on **Data.Zip** button

Select the **Save** option.

Brows to location → **C:\Oordrag** and **Save**. (Continue browsing of the webpage is OK.)

Goto **My Computer** → **C:\Oordrag** The where the data.zip file has been saved.

Double click on **TransferDATAZIP_na_Hoofrekenaar.bat**

Open the **DATA.zip** copy and Past the file/folders where wanted

Scenario 5

Computer Maintenance:

- Clear the Recycle Bin

  Right click on the **Recycle Bin** Icon on Desktop and select **Empty Recycle Bin.**
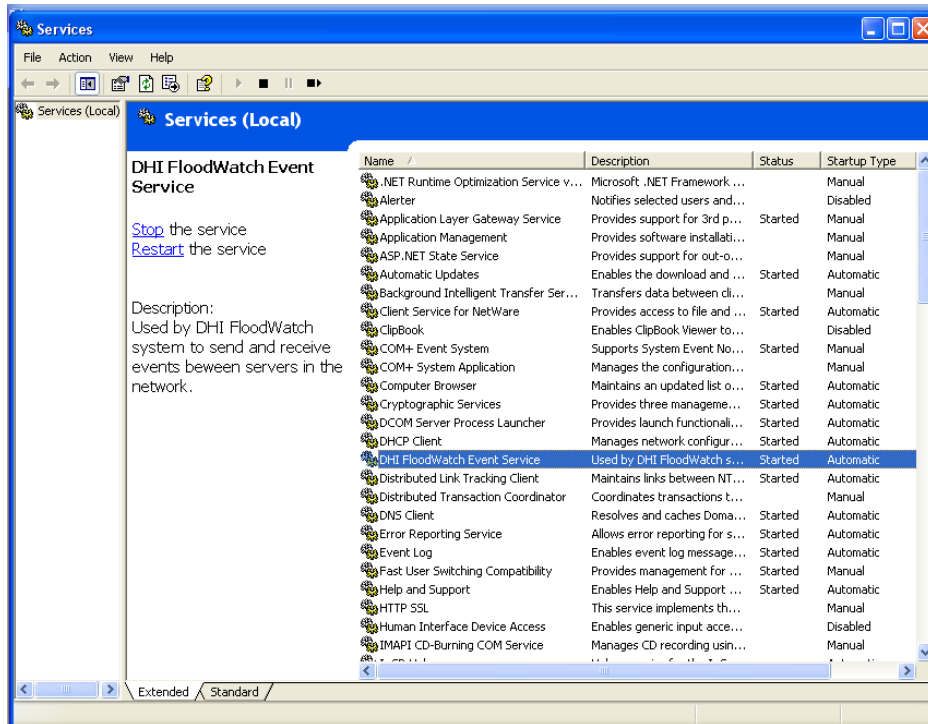
  Then prompt for confirmation to delete all data click **Yes**.

- Compact OFS-RT ArcMap database

  No Simulations must be scheduled or running for extend of Defragging.

  Close all programs

  Open Services: (icon desktop)

Shortcut to services

Scroll and select the **DHI FLOODWATCH Event Service**

Stop the Service by clicking on the Stop in the left panel. Status of service is viewable in Column 3 (Stopped or Started).
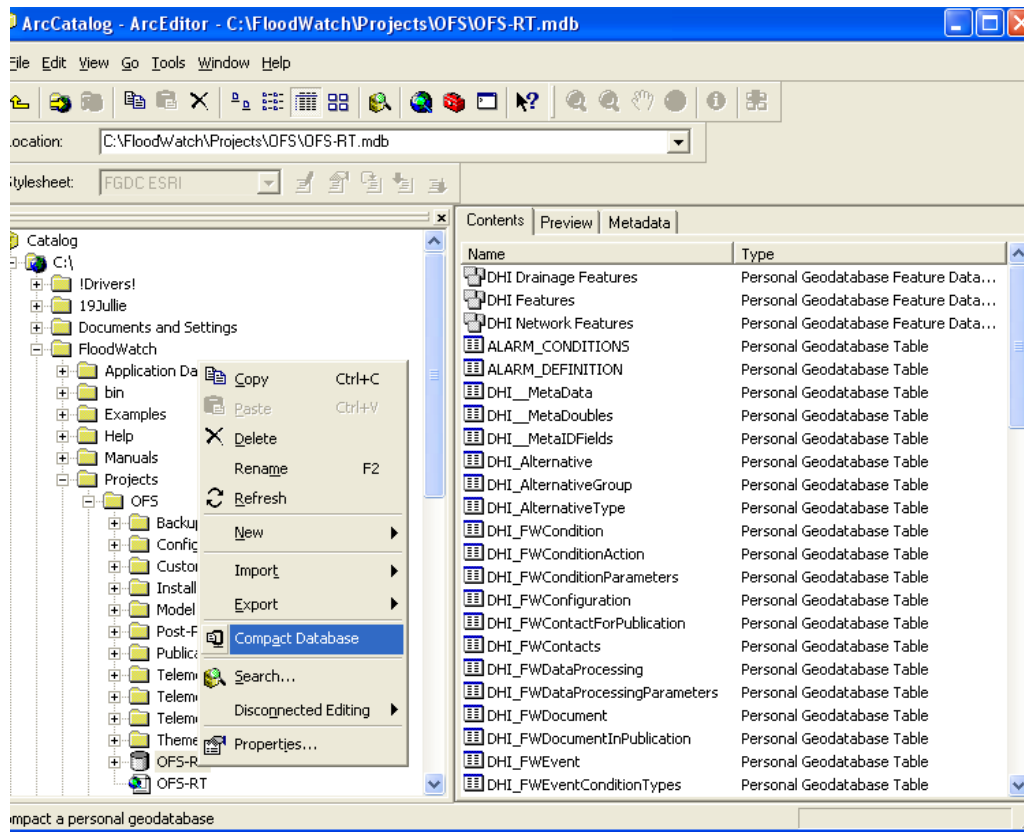
Minimize the Service window.

Open the ArcCatalog from Icon on desktop

ArcCatalog

Brows to the OFS-RT.mdb   The

C:\Floodwatch\Projects\OFS\OFS-RT.mdb

Right click on the Database file and select **Compact Database**

Close ArcCatalog

Open the **Service Window**, Scroll and select the **DHI FLOODWATCH**
Event Service

Start the Service.

Close the **Service Window**

Restart the computer and programs and resume all the tasks.

- Defrag Hard drive

No Simulations must be scheduled or running for extend of Defragging.

Close all programs

From Windows **Start** Menu select:

Programs → Accessories → System Tools → Disk
Defragmenter

Select the Drive to be Defragged **(C:\)** or **(D:\)** and click   Defragment

Wait for the Analyze to complete and then the Defragmenter will start and

take a few hours.

Then done, Close **Disk Defragmenter**.

Restart the computer and programs and resume all the tasks.

Scenario 6

Manual setup and start of Simulation:

Check HYDRAS3 Exported data, refer to step 4.

From the ArcMap OFS-RT → **FLOODWATCH** → **Task Editor**

Select the task which will suite your problem:

a)   **3RunAll** Go through all the importing steps to edit the database.

or b)   **4Run Date&Time** Use the current(previous imported data).

Right click and select **Properties**.

In the task properties window: Select the **Steps** tab

- Select **Initial Sim** and click **Edit** and **Advance**

    (Change the time and dates to needed values, considering the **T**ime **O**f **F**orecast.)

    SOS: [initial TOF] – 4 days

    TOF: [initial TOF, as main reference time and date]

    EOS: [initial TOF] + 7 days and 1 hour

    Click **OK** → **OK**

- Select **Optimise Sim** and click **Edit** and **Advance**

    SOS: [initial TOF]

    TOF: [initial TOF]

    EOS: [initial TOF] + 7 days.

    Click **OK** → **OK**

Close the Properties window.

Right click on the task and select **Start Task**.

Wait for task to start and confirm that all is well.

APPENDIX F

Stepped release post-processor program

Appendix F: Stepped release post-processor program

The post processor takes a release schedule form the FloodWatch model, and imposes the restraints of the release system on it. The new release set points correspond with the old schedule in terms of cumulative water volume. The post processor is implemented over 3 Excel spreadsheets, with a list of methods operating on the sheets. The postprocessor is executed from the FloodWatch model using the Microsoft scripting engine, from a bat file.

The three spreadsheets are:

- **InputData**: Using QueryTable.Refresh Excel function, this page is the input source for the rest of the post processor.
- **ControleSheet:** This page contains parameters controlling the execution of the post processor.
- **FinalRelease**: This page contains the new list of set points for the release system.

The List of methods used in executing the post processor, and their function, are:

5. **FittAll** : executes the post processor on the Excel side
    5.1. **QueryTable.Refresh** : used in a loop to pull the input data into the InputData sheet
    5.2. **SetupOneDam** : used in a loop to setup the input data ready for processing according to the parameters in ControleSheet
    5.3. **SetupOneReleasePoint**: used in a loop to setup the FinalRealse sheet to accept the new set points.
    5.4. **FitOne:** used in a loop to impose one, old release schedule with the release restraints. FitOne works by guessing a valid release schedule, computing its success, over an extremely large number of guesses. The final answer is the release schedule in the large number that works the best.
        5.4.3. **Compute_success_PtoP**: The function that scores each of the guessed release schedules.

5.5. **FillInOneTable:** used in a loop to fill the set points from FitOne into FinalRelease

5.6. **ThisWorkbook.Save:** the Excel workbook is set up such that the new set points are exported as HTML when the workbooks are saved.

APPENDIX G

FLOODWATCH web based model reports

Appendix G: FLOODWATCH web based model reports

The reports can be viewed at the following link:

http://www.sun.ac.za/OFS-RT

The preliminary username is: "OFS"; and the password is: "RT"
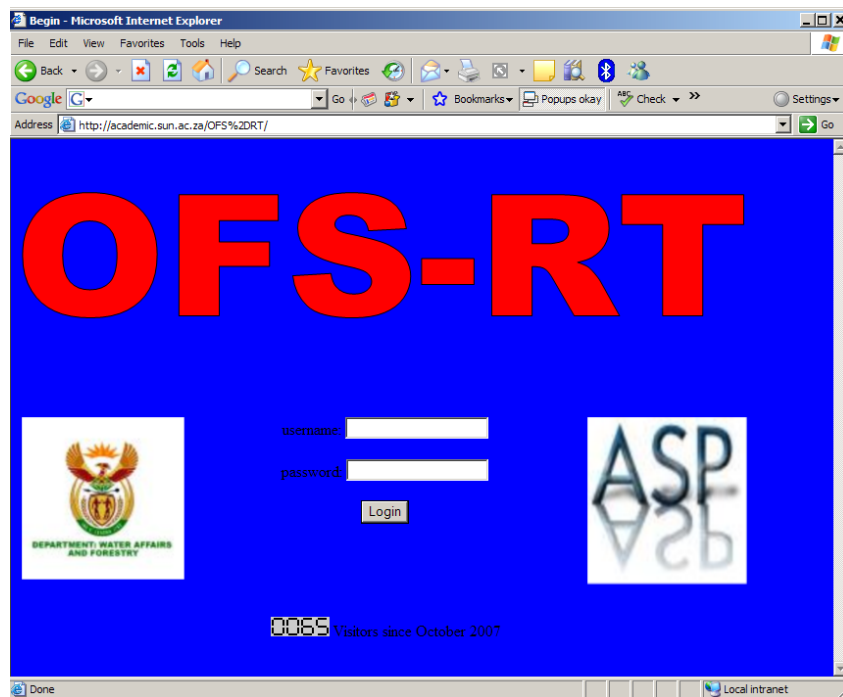
Figure 1   Login page

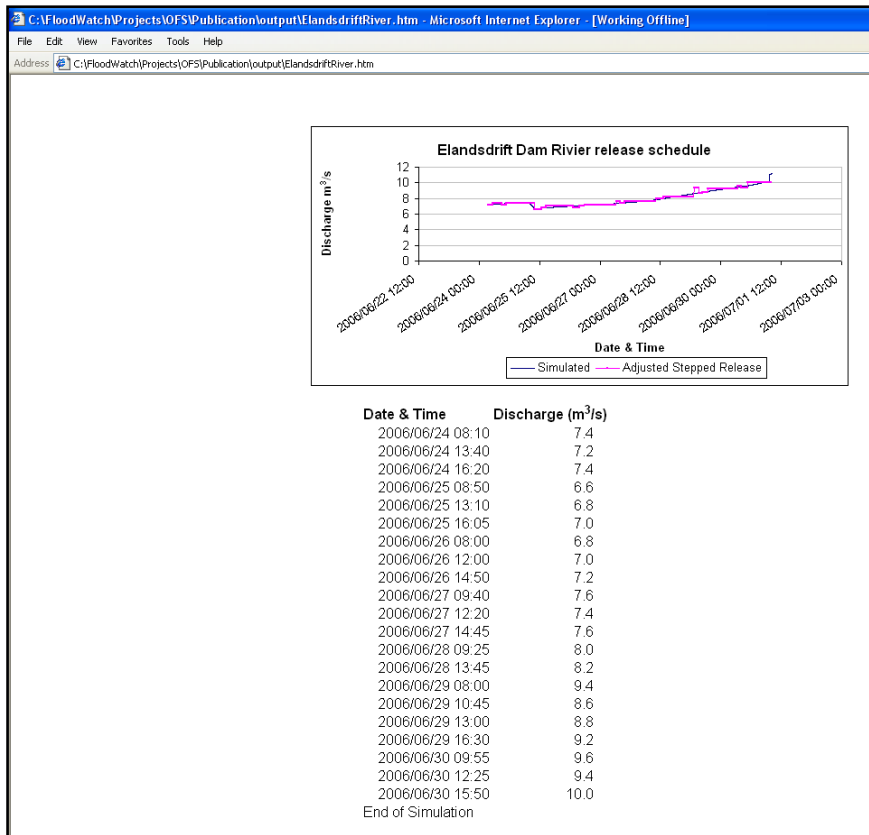**Figure 2   Main menu page**

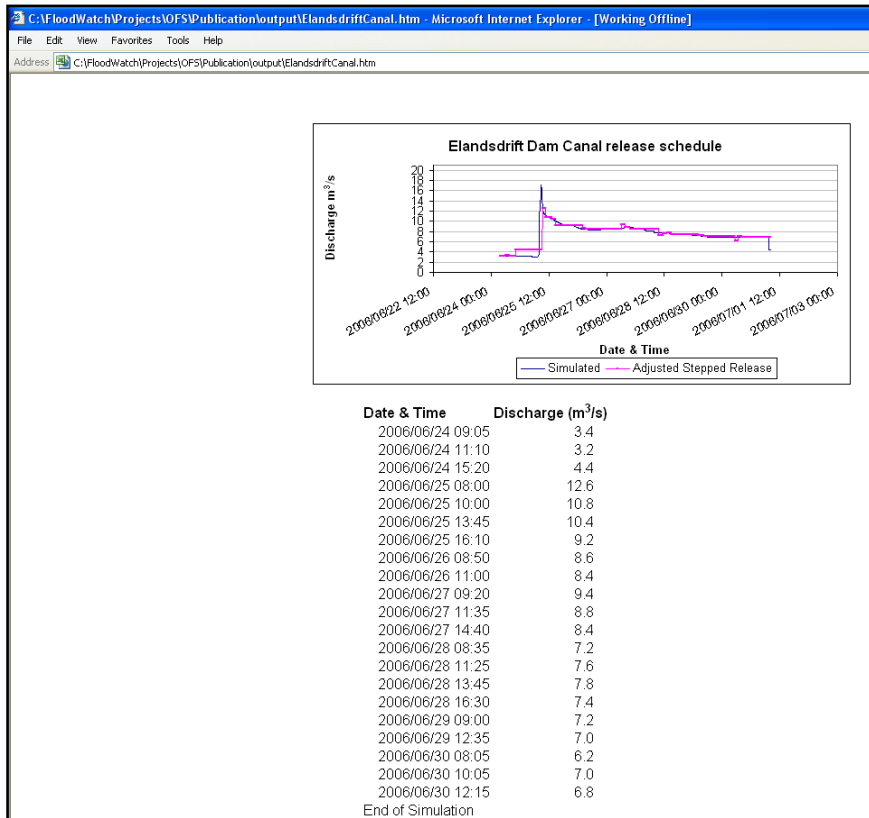**Figure 3   Release Menu**
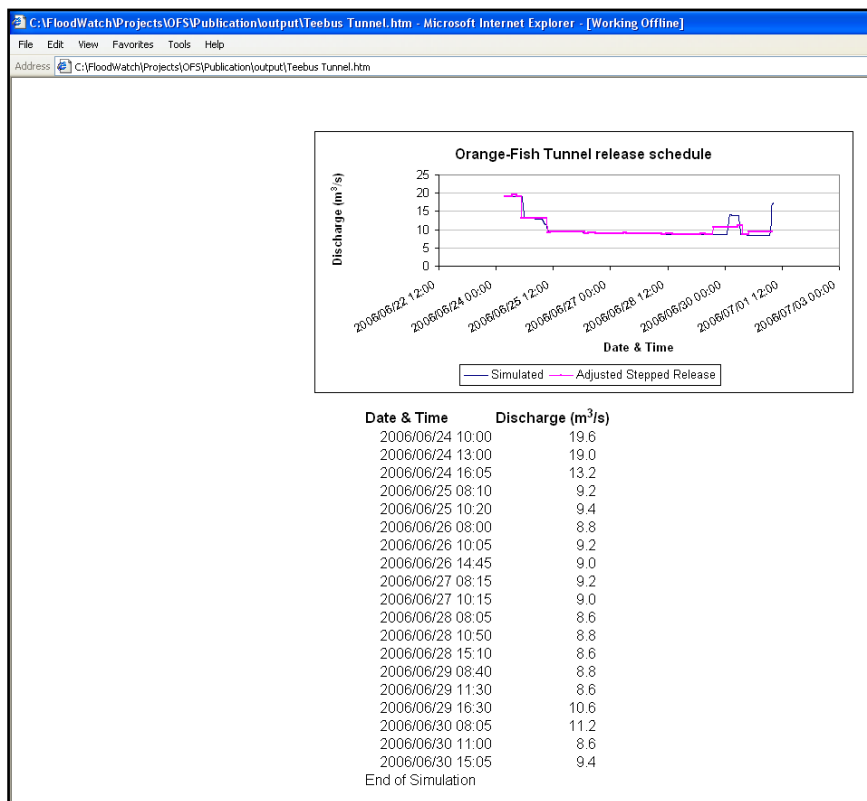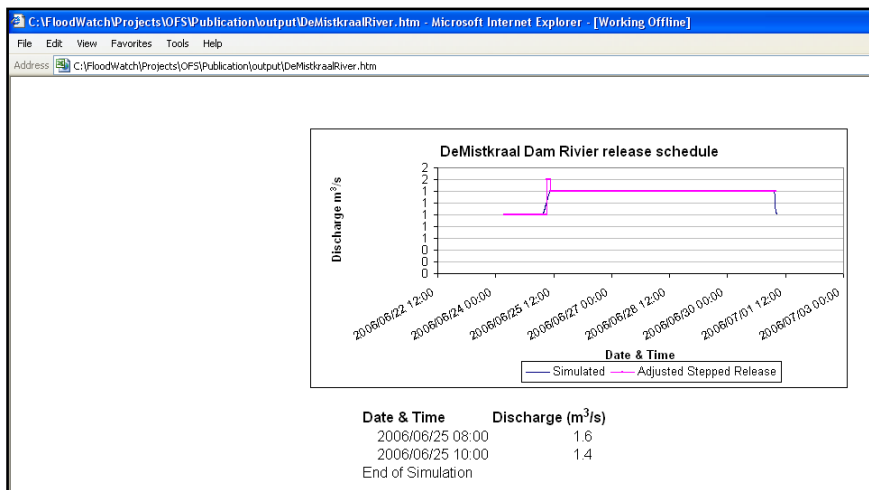

Figure 4   Teebus Tunnel release
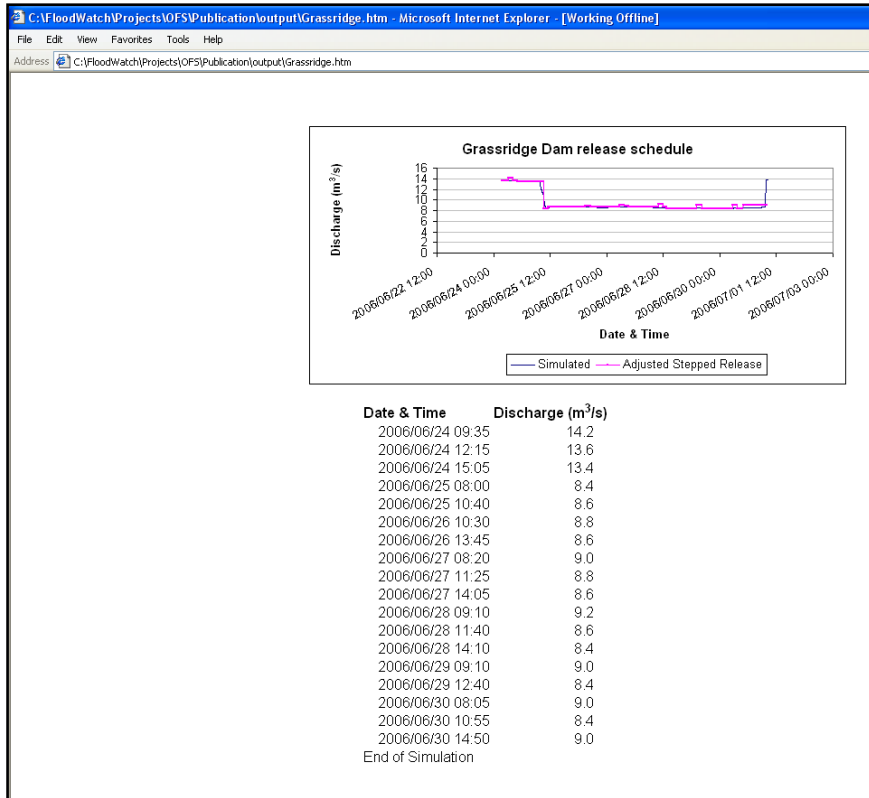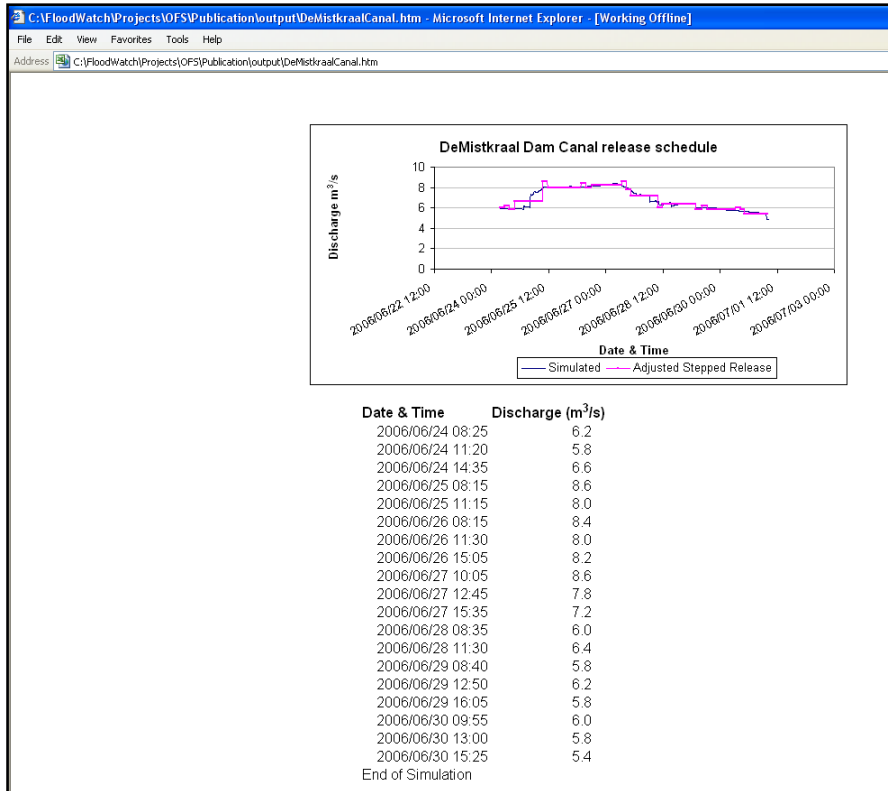
Figure 5   Grassridge Dam River release

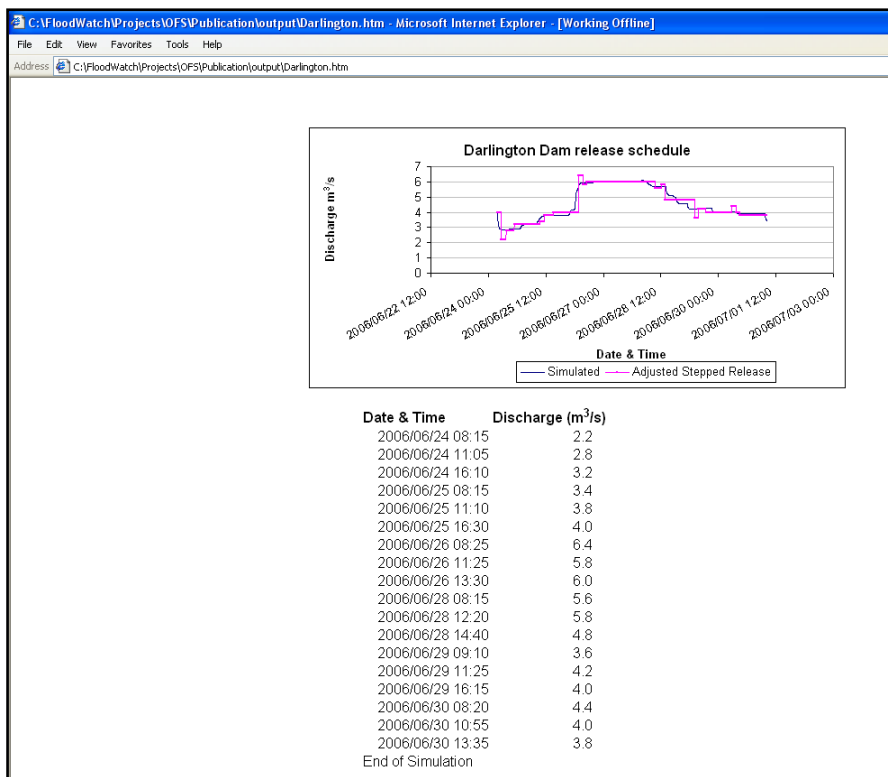**Figure 6   Elandsdrift Dam River release**

Figure 7   Elandsdrift Dam Canal release
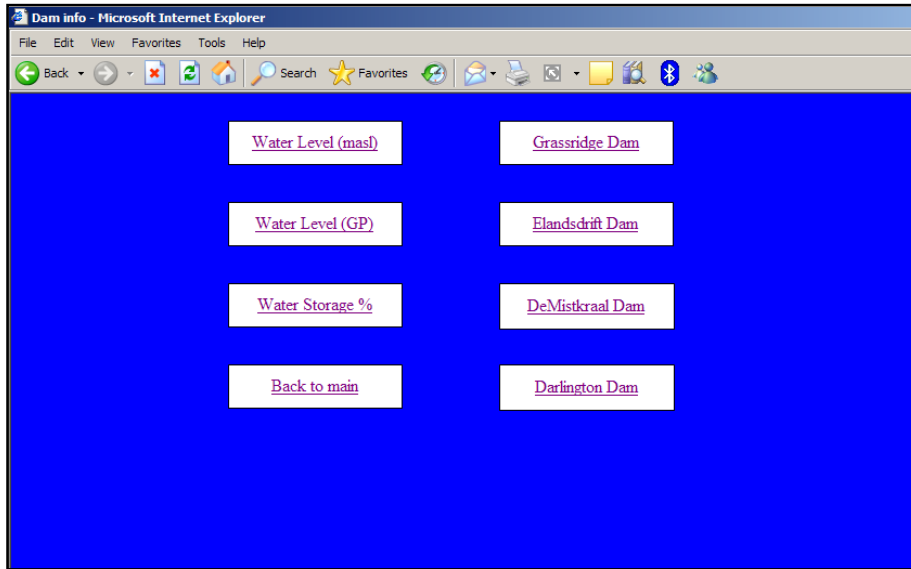

Figure 8   DeMistkraal Dam River release

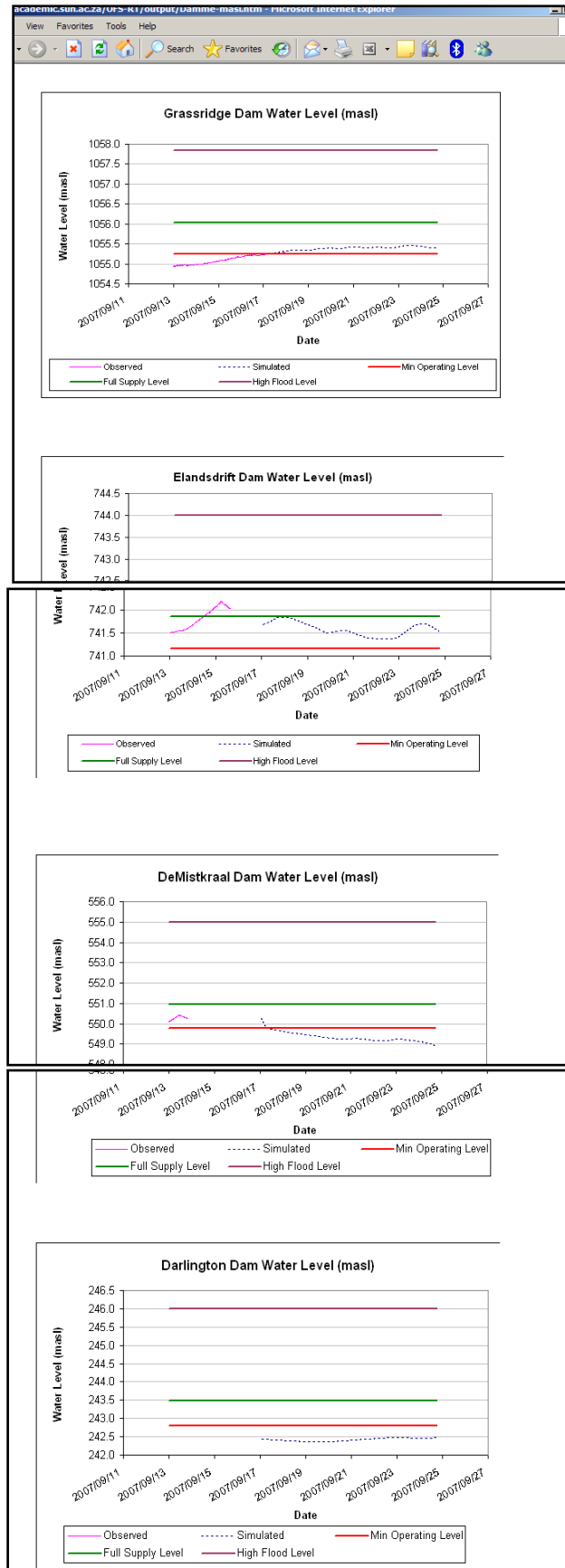**Figure 9   DeMistkraal Dam Canal release**

Figure 10   Darlington Dam River release

==
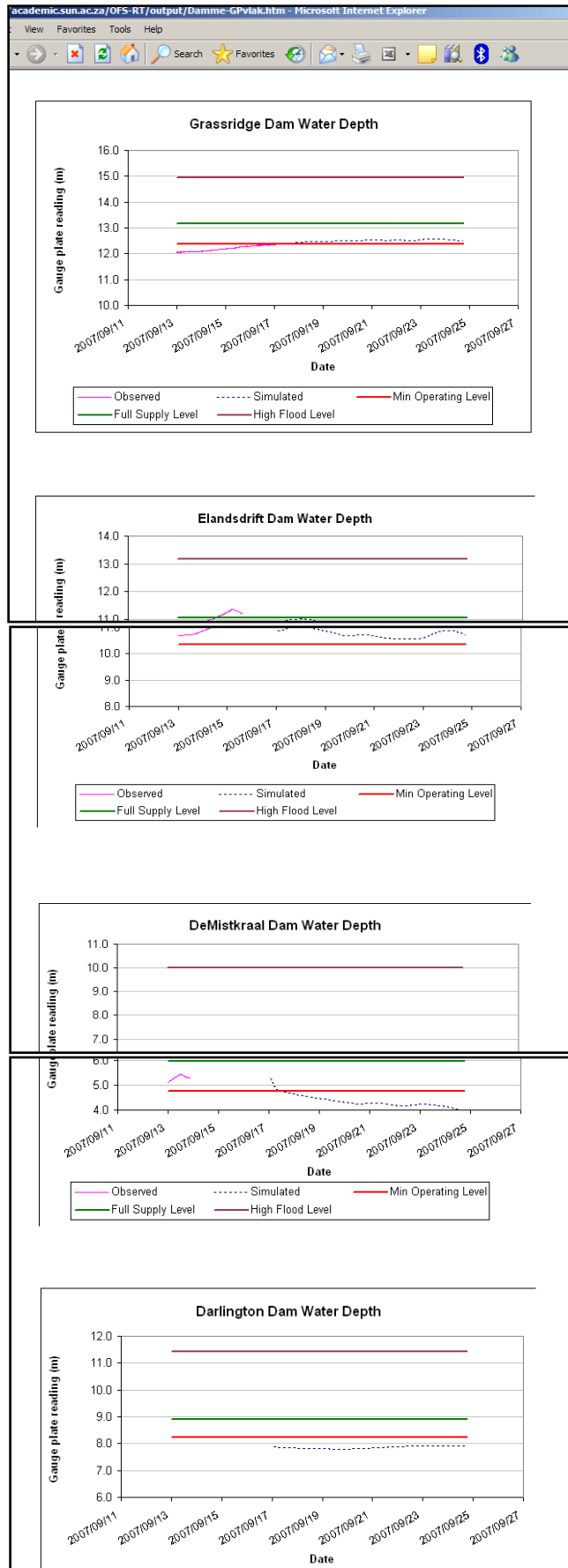

Figure 11   Dam Info menu

Figure 12   Dams Water Levels (masl)

Grassridge Dam Water Depth

Elandsdrift Dam Water Depth

DeMistkraal Dam Water Depth

Darlington Dam Water Depth

Figure 13   Dams Water Levels (m)
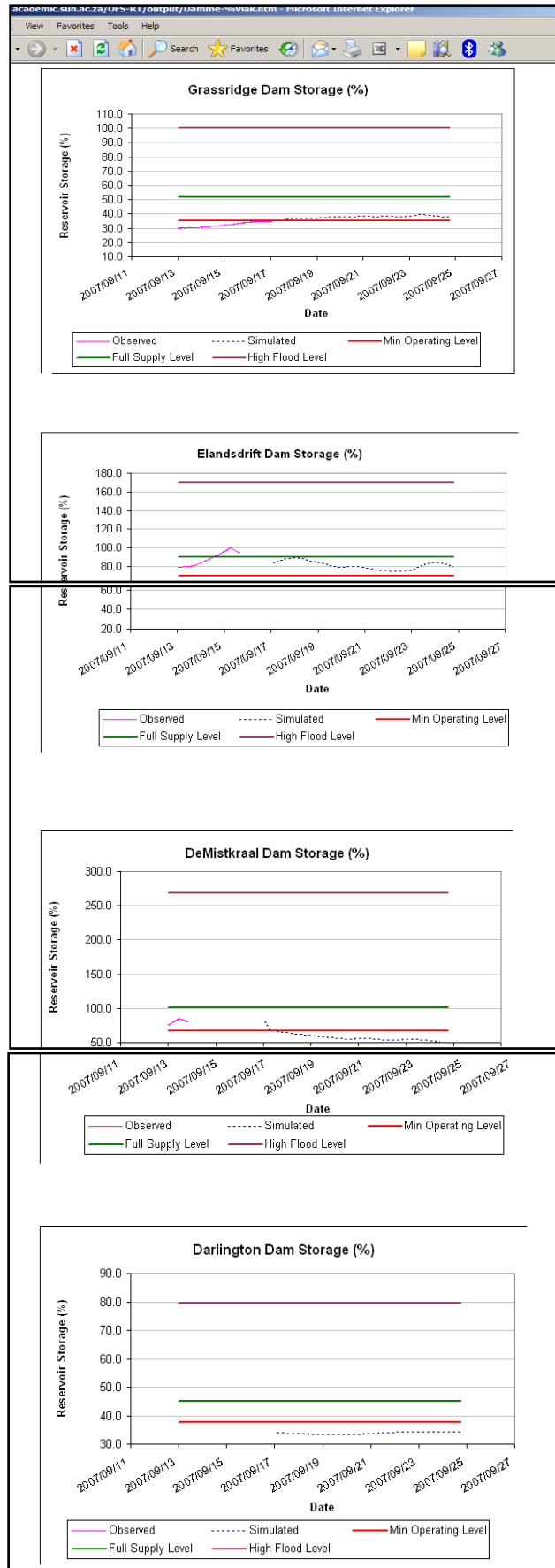
Figure 14   Reservoirs Storage %
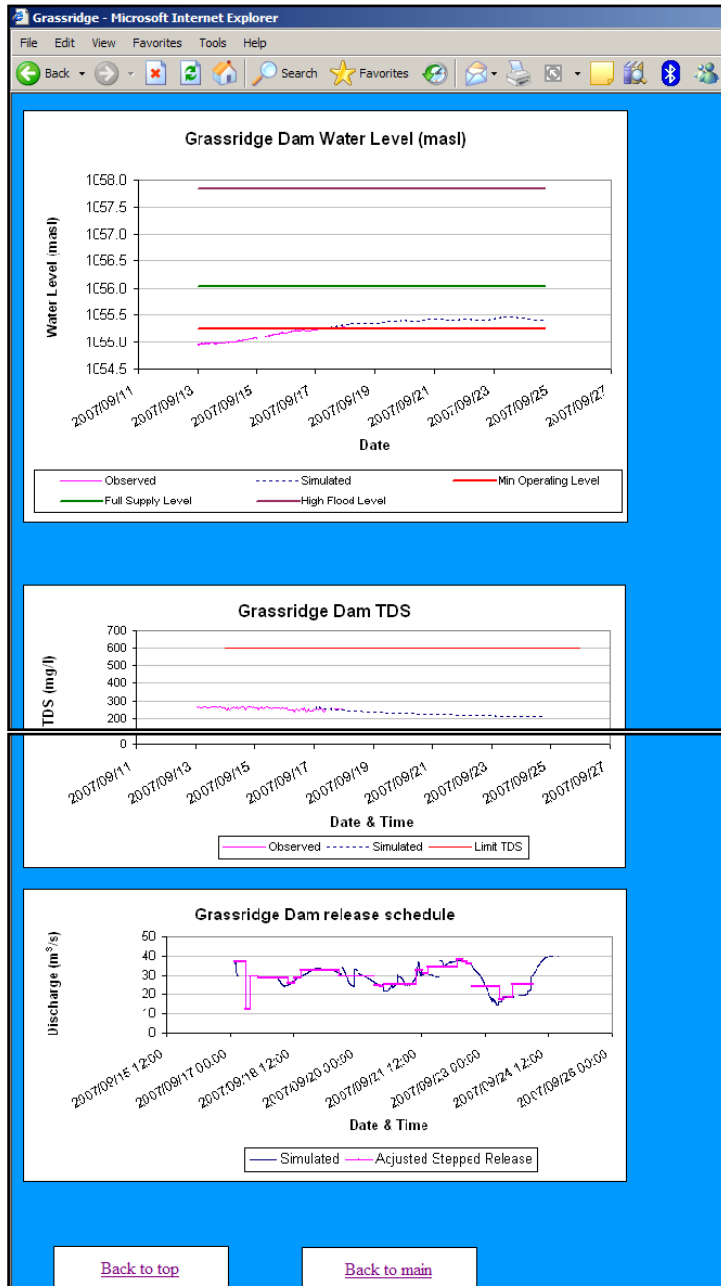
Figure 15   **Dams info: Grassridge Dam**
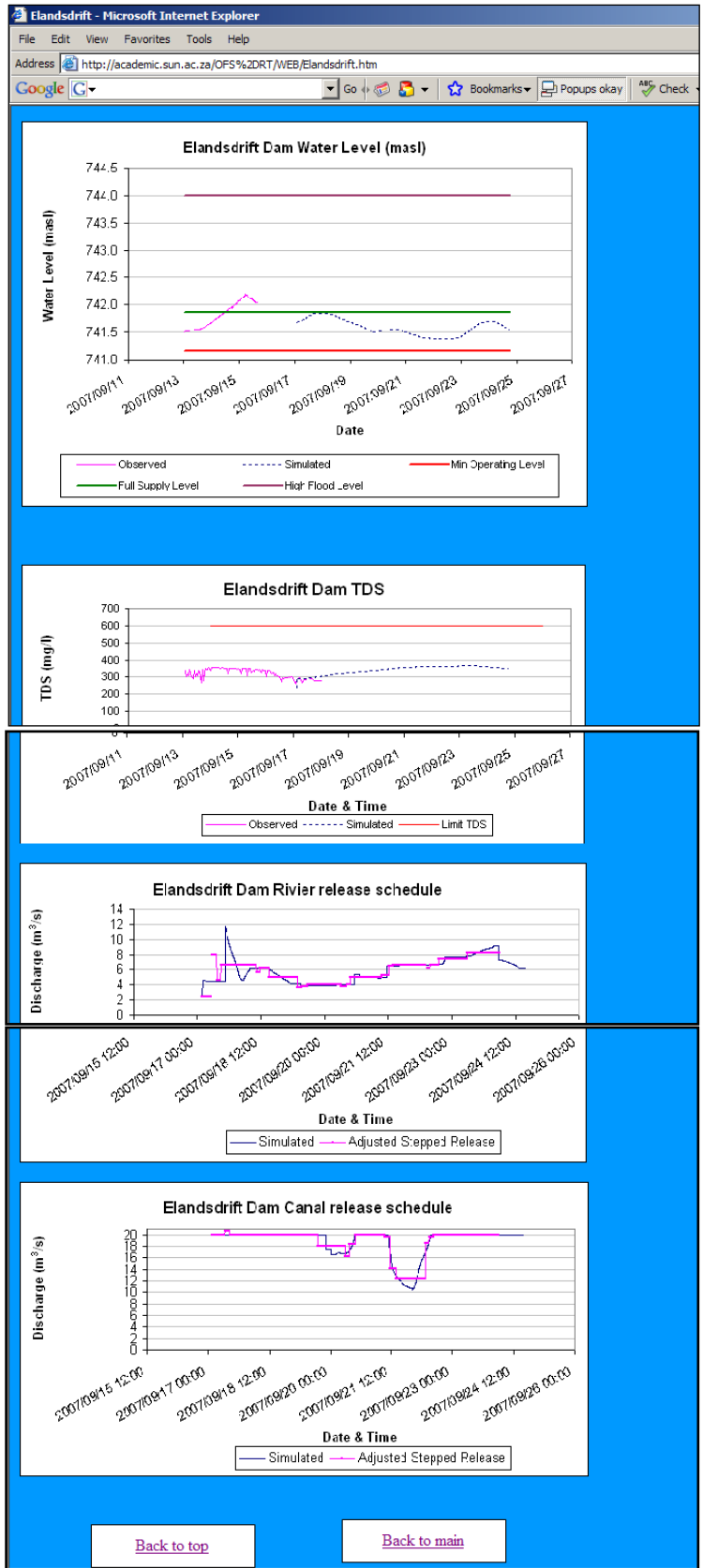
Figure 16   Dams info: Elandsdrift Dam
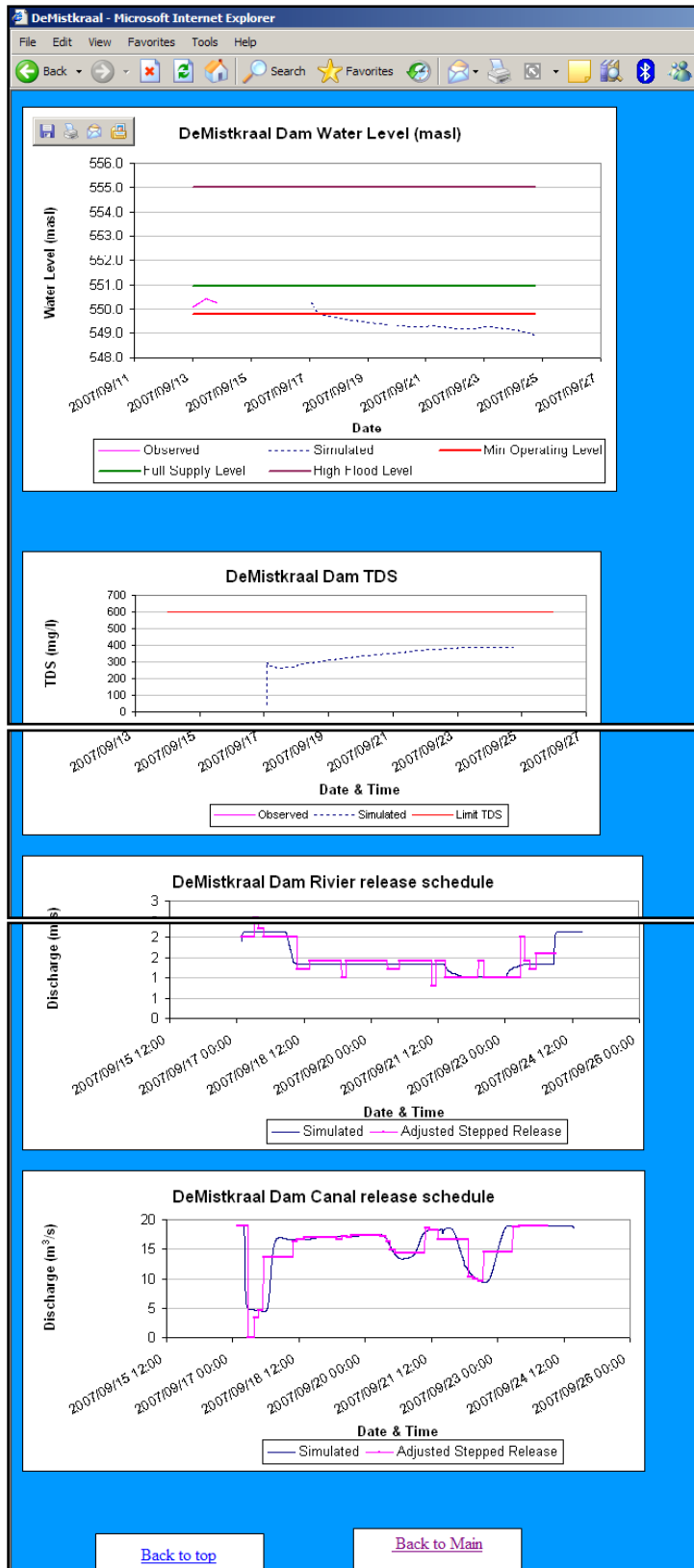
Figure 17   Dams info: DeMistkraal Dam
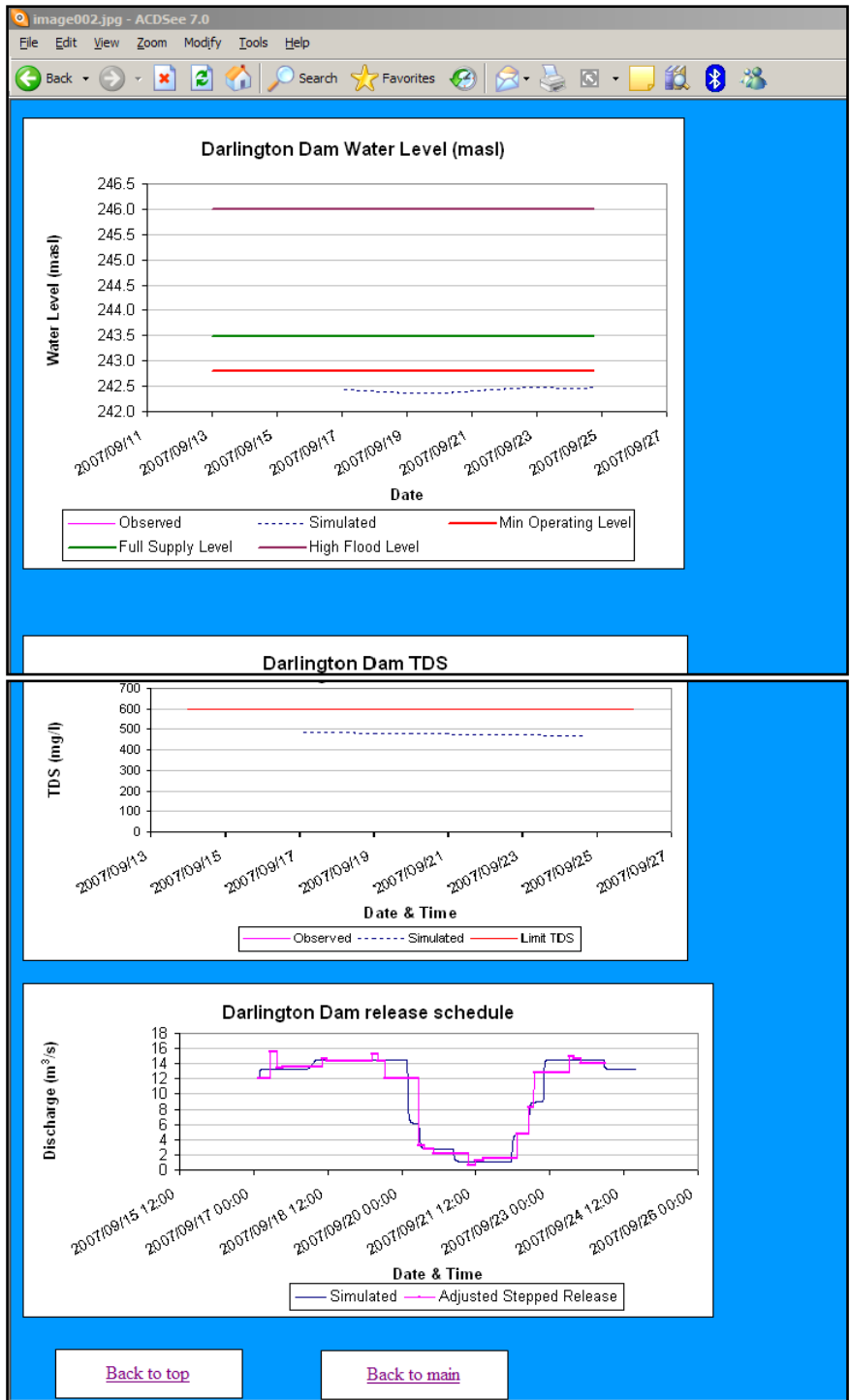
Figure 18   Dams info: Darlington Dam

Figure 19   System TDS

Period Starts at: 2007/09/13 00:06
Observations ends: 2007/09/18 00:00

N2H007 DeDraai Fllow

N2H007 DeDraai TDS

N2H008 Flow

N2H008 TDS

Q2H002 Flow

Q2H002 TDS

Q1H013 Flow

Q1H013 TDS

Q3H004 Flow

Q3H004 TDS

Q4H013 Flow

Q4H013 TDS

Q6H003 Flow

Q6H003 TDS

Q8H008 Flow

Q8H008 TDS

Q7H005 Flow

Q7H005 TDS

N2L009 Flow
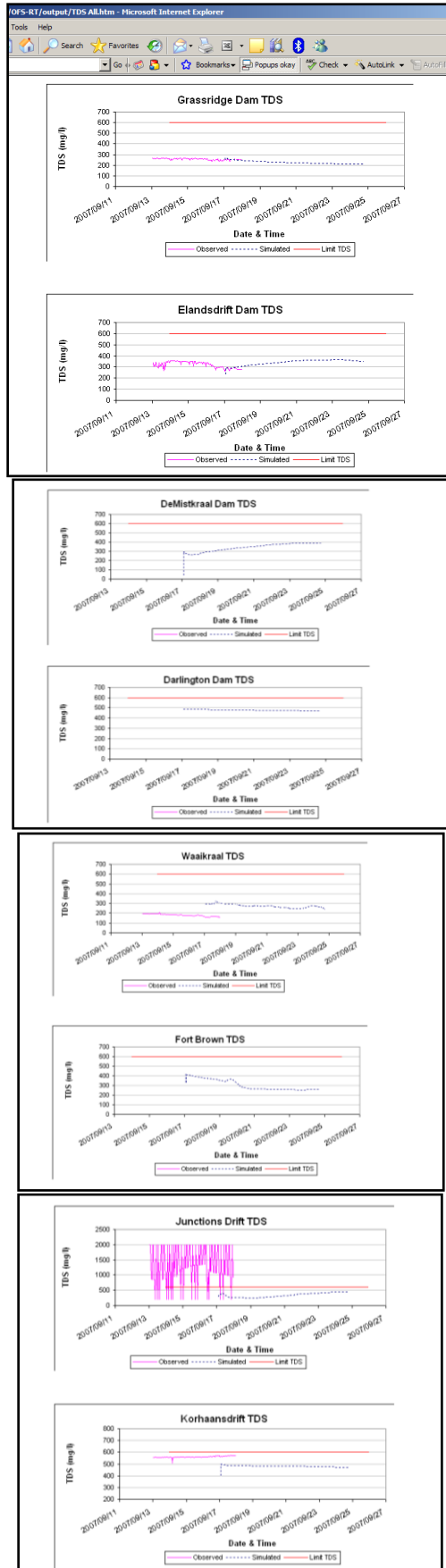
N2L009 TDS
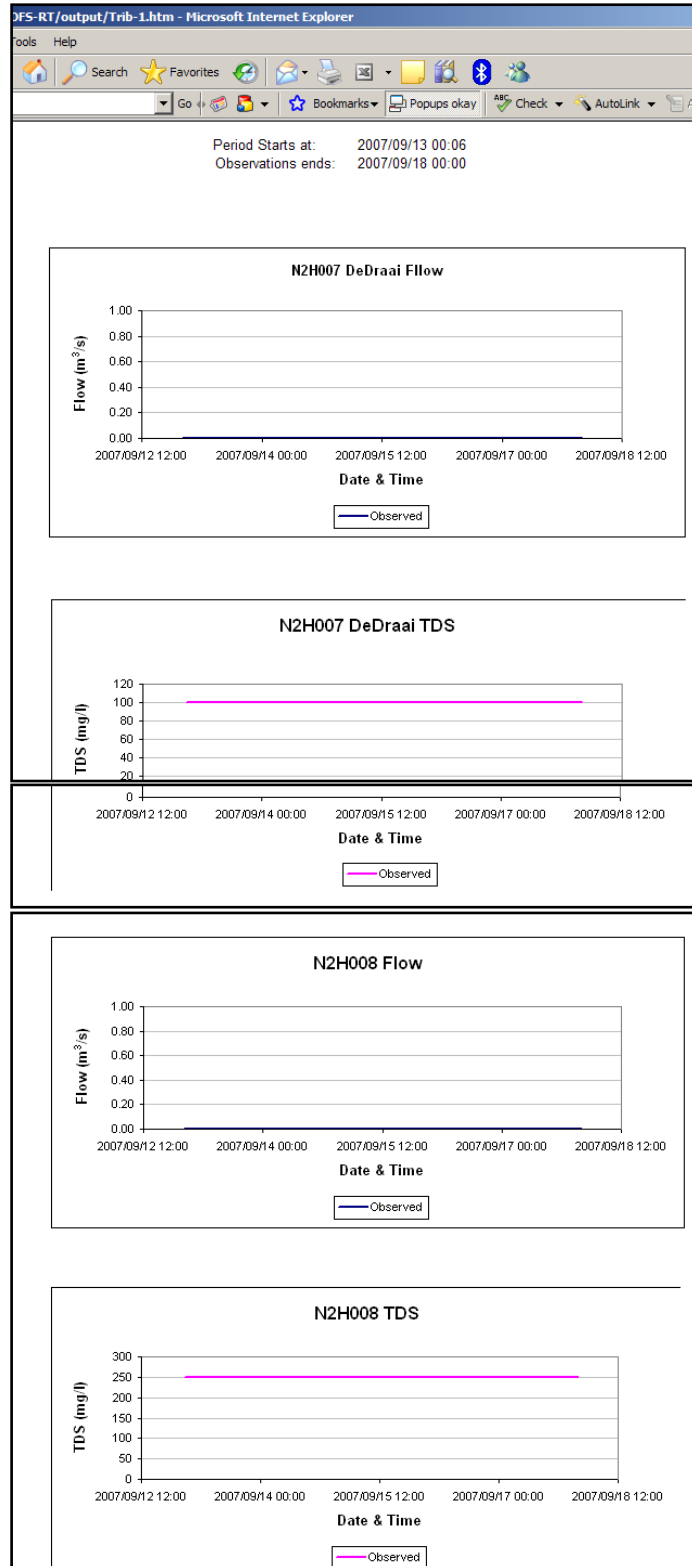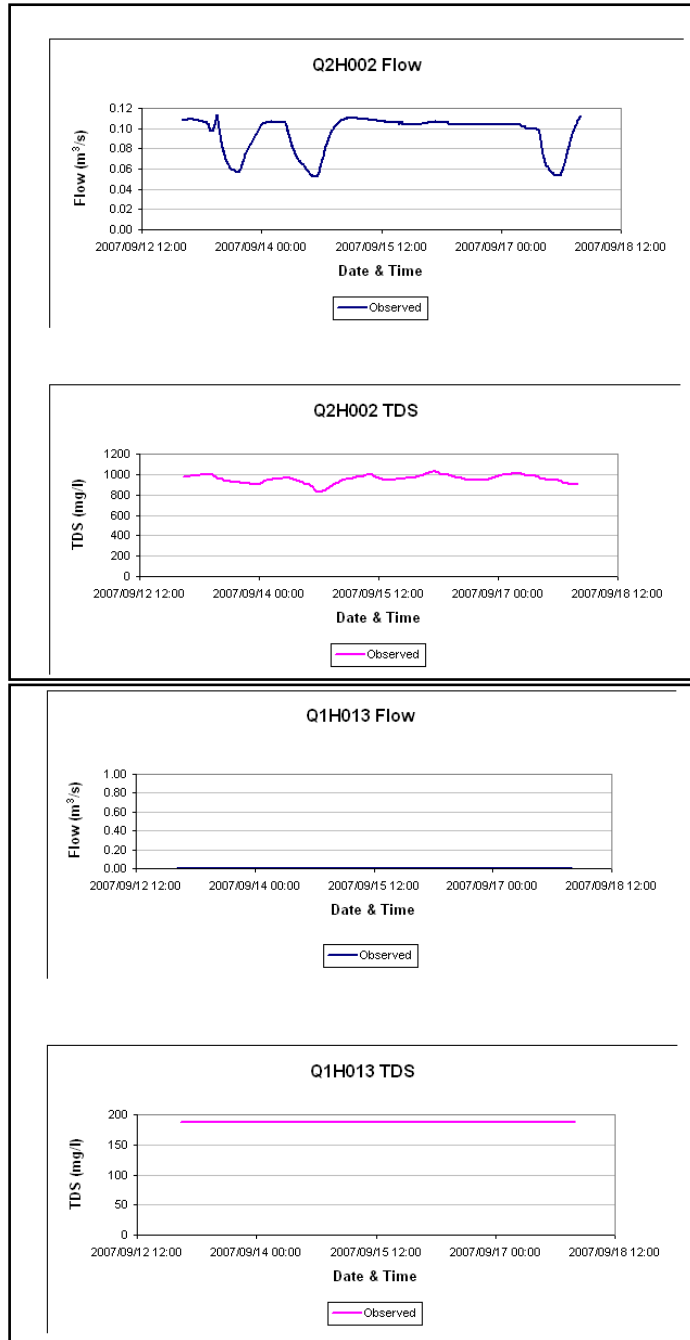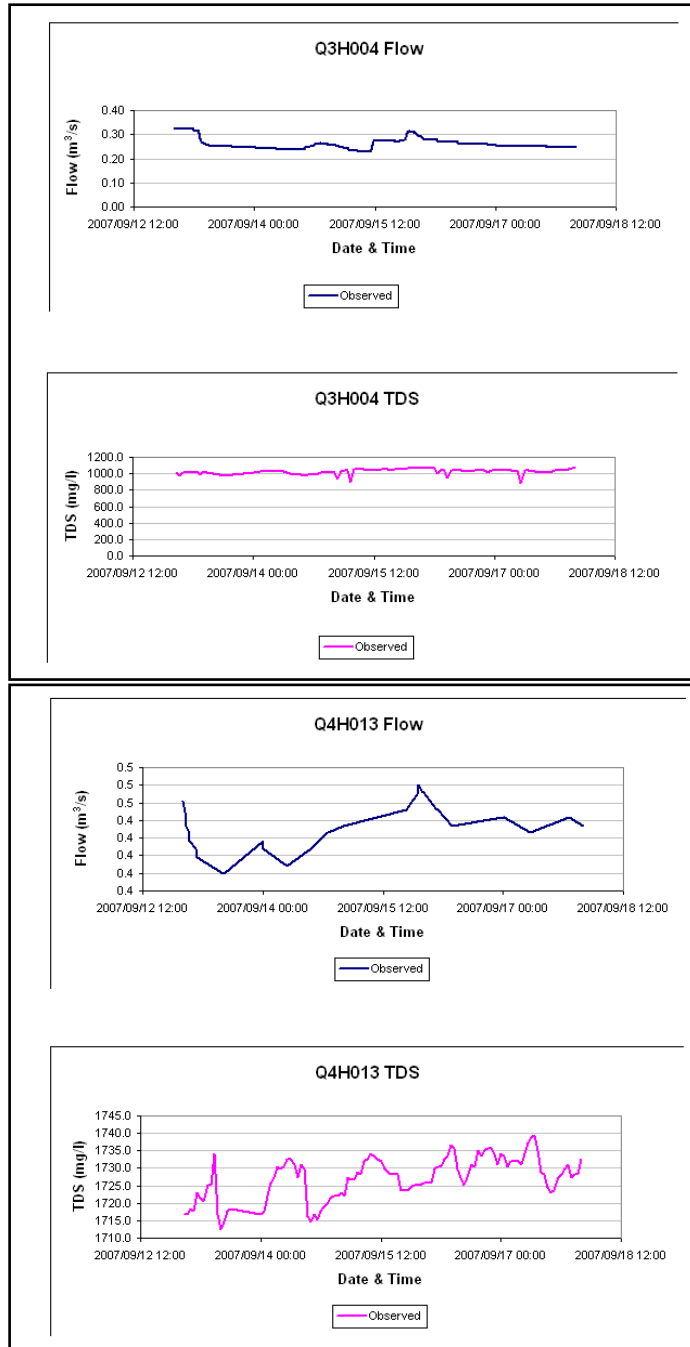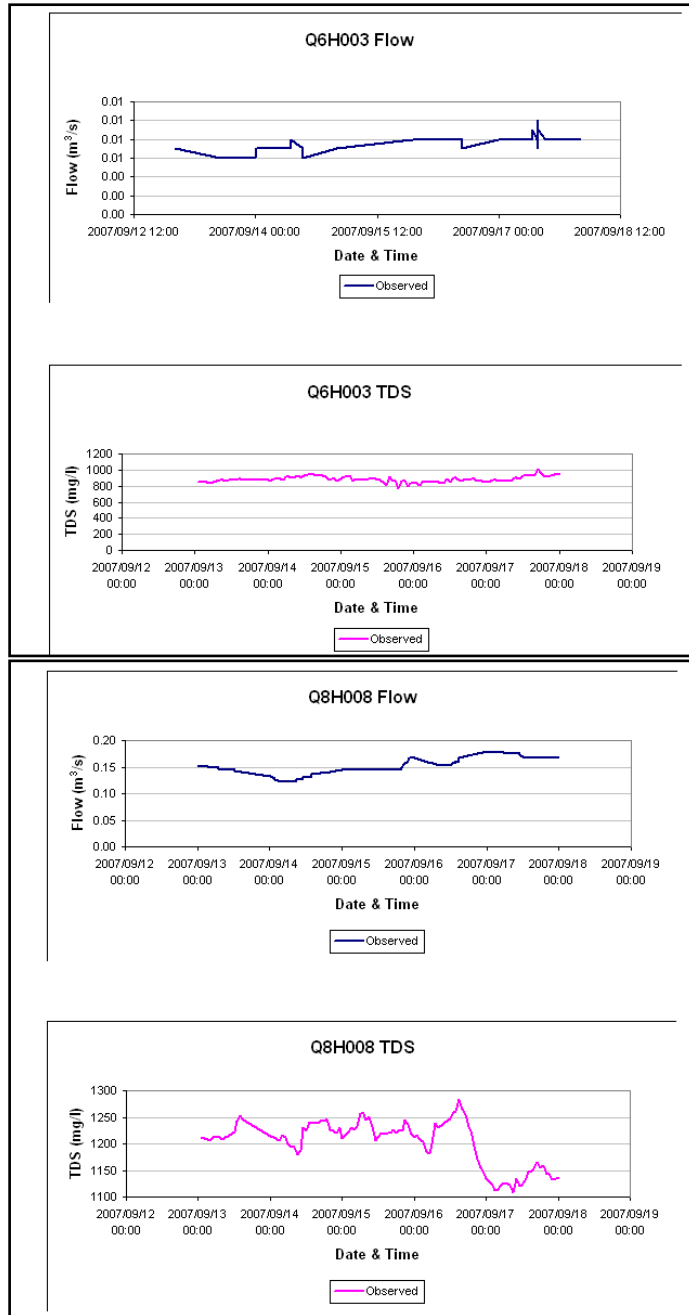
Figure 20   Tributaries

Figure 21   OFS-RT – year summary

Optimization output summary

TOF 2006/03/02 05:00:00 AM
EOS 2006/03/09 07:00:00 AM

Control structure discharge m3/s, river outflow and TDS (mg/l)

Control structure	Q start	Q end	Q min	Q max
Teebus Tunnel	57.4	57.4	9.438295	57.4
Grassridge River	32.05117	50.61371	14.83387	57.25181
Elandsdrift River	884.1232	442.2932	13.01175	910.4184
Elandsdrift Canal	18.33971	18.33971	17.81678	18.33971
DeMistkraal River	905.7662	678.4235	678.4235	1193.169
DeMistkraal Canal	19	19	19	19
Darlington River	5.528243	1079.399	1473.072	5.427997

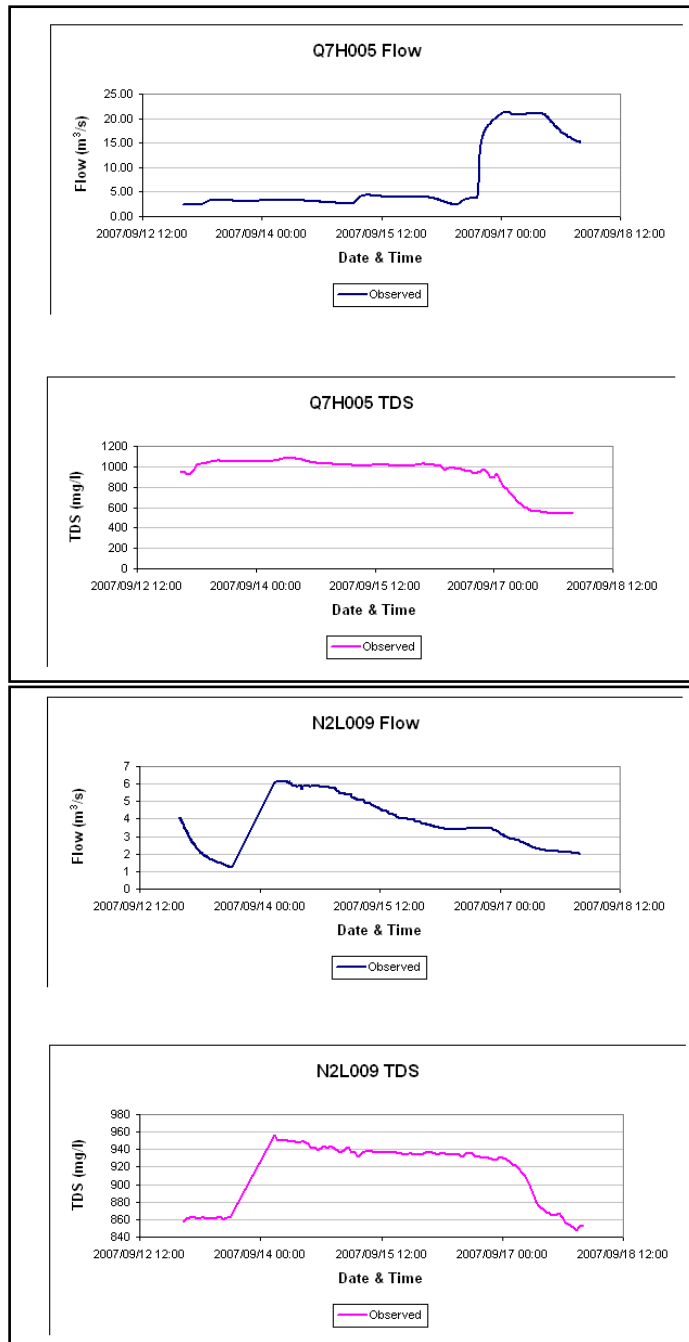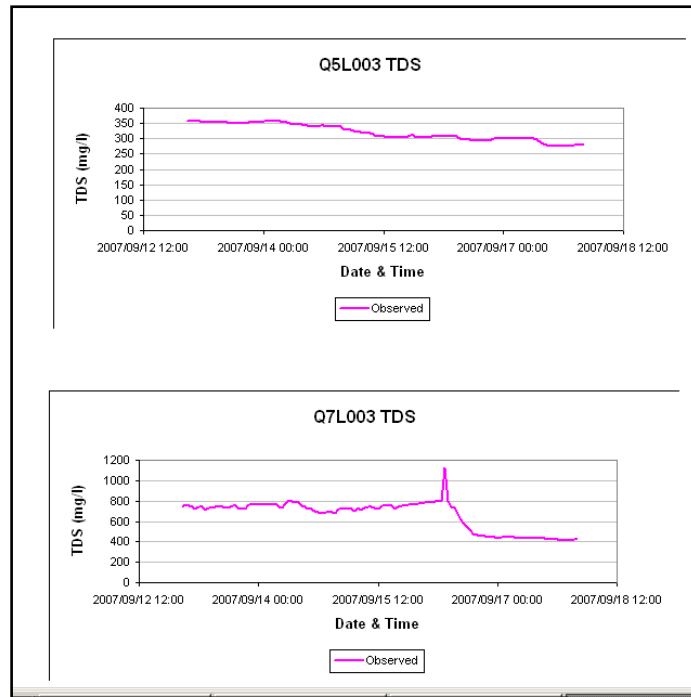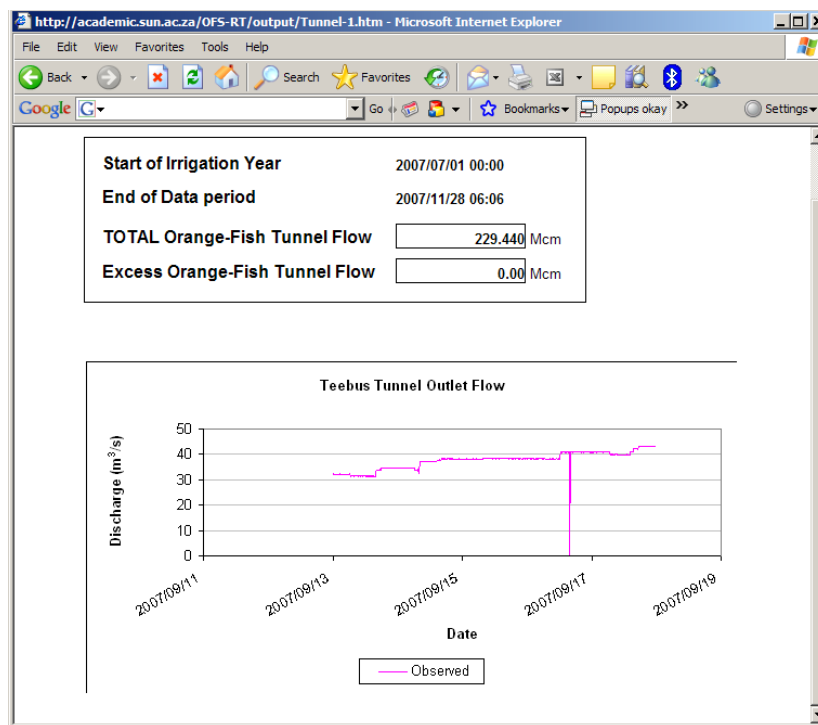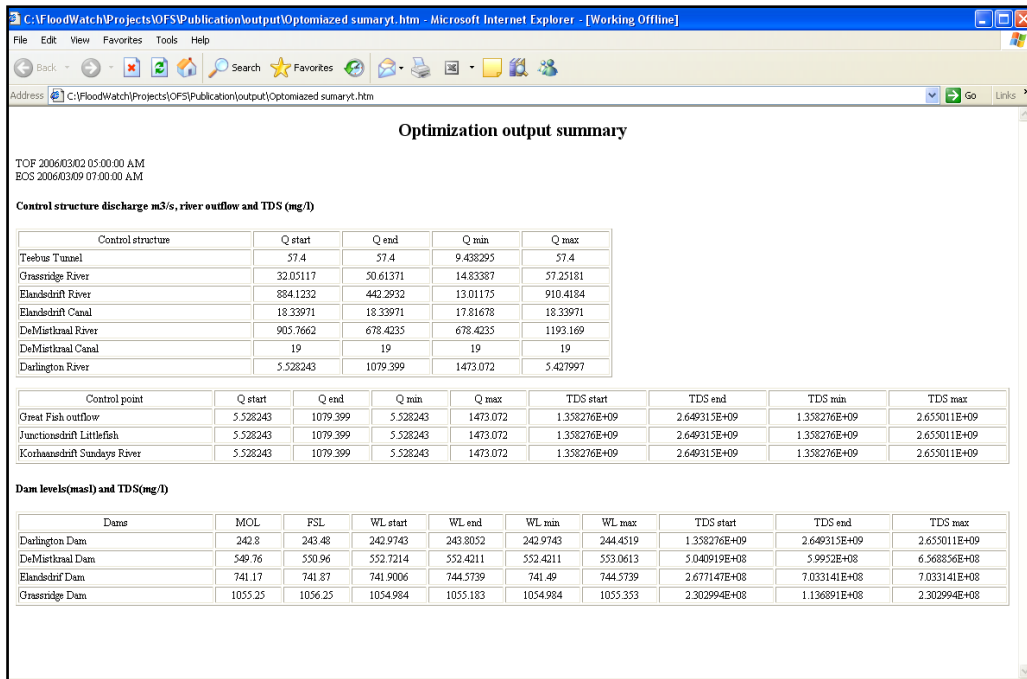| Control point	Q start	Q end	Q min	Q max	TDS start	TDS end	TDS min	TDS max
Great Fish outflow	5.528243	1079.399	5.528243	1473.072	1.358276E+09	2.649315E+09	1.358276E+09	2.655011E+09
Junctionsdrift Littlefish	5.528243	1079.399	5.528243	1473.072	1.358276E+09	2.649315E+09	1.358276E+09	2.655011E+09
Korhaansdrift Sundays River	5.528243	1079.399	5.528243	1473.072	1.358276E+09	2.649315E+09	1.358276E+09	2.655011E+09

Dam levels(masl) and TDS(mg/l)

Dams	MOL	FSL	WL start	WL end	WL min	WL max	TDS start	TDS end	TDS max
Darlington Dam	242.8	243.48	242.9743	243.8052	242.9743	244.4519	1.358276E+09	2.649315E+09	2.655011E+09
DeMistkraal Dam	549.76	550.96	552.7214	552.4211	552.4211	553.0613	5.040919E+08	5.9952E+08	6.568856E+08
Elandsdrif Dam	741.17	741.87	741.9006	744.5739	741.49	744.5739	2.677147E+08	7.033141E+08	7.033141E+08
Grassridge Dam	1055.25	1056.25	1054.984	1055.183	1054.984	1055.353	2.302994E+08	1.136891E+08	2.302994E+08

Figure 22   Simulation summary