Big Cypress Basin Real Time Hydrologic Modeling System

(Contract No. 4600001041)

South Florida Water Management District
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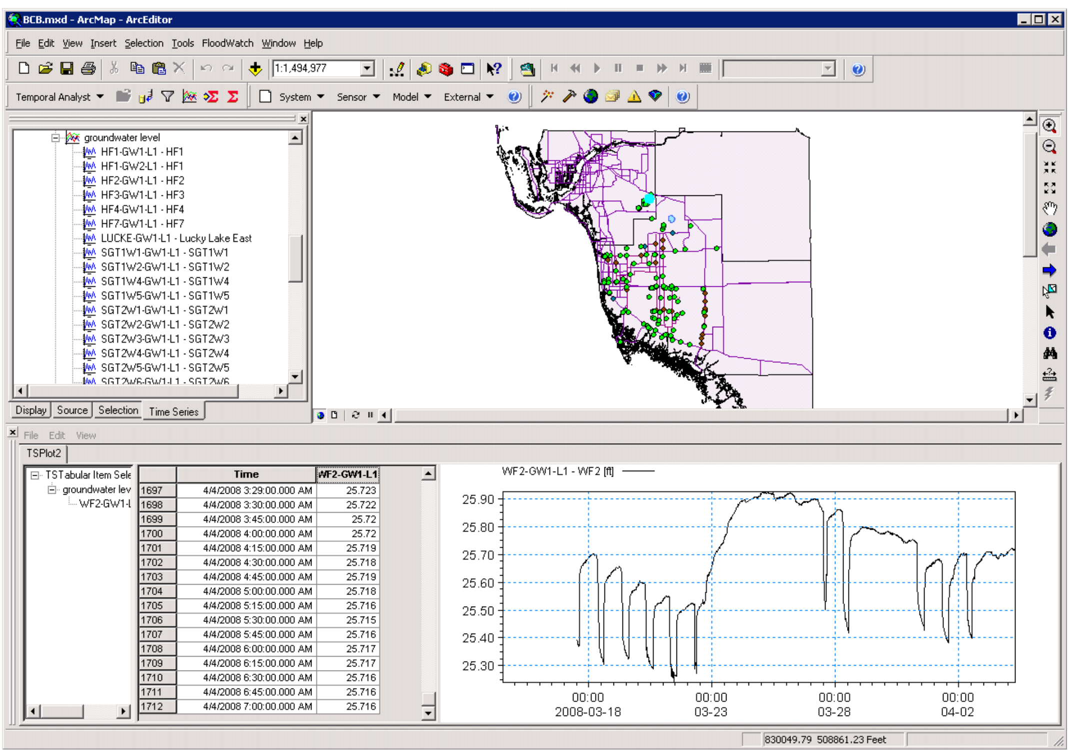
Final Report

December 22, 2008



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APPENDICES

0 EXECUTIVE SUMMARY

This final report describes the successful implementation of the project, “Big Cypress Basin Real Time Hydrologic Modeling System Phase 1 - System Development and Testing”, Contract 4600001041 which was issued by the South Florida Water Management District to DHI Inc., USA. This project has been a collaborative effort between BCB (Ananta Nath, Andy Potts, Max Guerra), HESM (Ken Konyha, Suelynn Dignard, Luis Cadavid, Ke Feng), SCADA and Hydo Data Management (Kenneth Stewart, Chandra Pathak, Miriam Figueroa, Neil Jammula IT (Susan Campbell, Bobby Dorlus, Tracie Streltzer) within the South Florida Water Management District and DHI Group (Michael Butts, Anders Klinting, Preston Manning, Tim Hazlett).

Goals

The major goals were:

- To exploit existing Hydrological and Hydraulic Models, and the real-time telemetric monitoring (SCADA) network to develop a sub-regional real-time modeling and flood forecasting system for the Big Cypress Basin

- To develop a system that will integrate data management, monitoring facilities, forecast models and dissemination methodologies in a single system

These were achieved by implementing and adapting the MIKE FLOODWATCH real time decision support tool and incorporating into this tool the MIKE SHE model developed for the Big Cypress Basin from the Picayune Strand Restoration Project MIKE SHE model.

The system is now fully operational. The system can be accessed using the customized web interface via the South Florida Water Management District Intranet, (to http://bcbmod01p/floodwatch). Advanced users can access the system using the GIS interface for system configuration and maintenance tasks directly on the system server.

The specific objectives were that the Big Cypress Basin Real Time Modeling System should:

- Provide a dynamic linked real-time monitoring system data with hydrologic simulation model and perform real-time modeling

- Allow decision support and scenario analyses

- Allow real-time analysis and optimization of structure operation

- Provide timely flood mapping and web publication

These capabilities have been included in the Big Cypress Basin Real Time Hydrologic Modeling System by developing the system within the framework of the MIKE FLOODWATCH real-time decision support tool. The system consists of an online monitoring component and a real time modeling (forecasting) component. The flow of data and automatic operation of the forecasting system is controlled by the MIKE FLOODWATCH shell. Real-time data is imported from the South Florida Water Management Board SCADA automatically every hour. These data are then published to the flood monitoring web pages. Forecasts are performed automatically, twice daily and the results of forecasts published immediately thereafter.

Benefits

The most important immediate benefits from this system are:

- Operational users and hydrologist now have easy access to all real-time measured data within the Big Cypress Basin.
- There are potentially several direct benefits of this data access including improved structure operation and maintenance and improved real time management of the Big Cypress Basin water resources.
- There is an important added value being derived from using additional use of the real-time data currently being collected within the basin. Indeed, this is the first time in the District that this real-time data is being used together with models.
- Provision of regular hydrologic forecasts

This development represents the state-of-the-art in terms of real time modeling. The most important innovations are

- New way of modeling where the latest information concerning rainfall, water levels within the canals and so on are being used to forecast the future behavior of water within the Big Cypress Basin
- This is a unique forecasting system in the sense that a fully integrated surface water/groundwater model is being applied to real time modeling. This is probably the first of its kind in the US. This type of integrated approach is necessary in the South Florida Water Management District.
- Novel real time updating techniques to improve forecast accuracy have been applied within this project

Recommendations

While successful as a pilot implementation, from our experience gained in implementing the system we have the following key recommendations

1. Providing automatic rainfall forecasting data to the system will provide a substantial improvement in the utility of the system and the accuracy of the forecasts

2. The Big Cypress Basin Real Time modeling system allows the implementation of event-based responses. For example by defining a threshold water level or gate level, the system can be configured to send an e-mail to the gate operator or hydrologist if this threshold is exceeded. Similarly if measured water levels exceed a new forecast can be started. Therefore a key recommendation is to develop a set of thresholds and the corresponding actions and responses that would benefit operational management within the Big Cypress Basin

3. A detailed review of the most critical regulating structures within the BCB model area needs to be carried out. Each structure needs to be represented as accurately as possible including in particular the operating rules governing the independent operation of individual gates within the structure need to be characterized. This will improve the accuracy in forecasting the future behavior of these regulating structures

4. To ensure model accuracy a comparison of the rainfall over the model area captured using the real-time gauges and using the complete rain gage network should be carried out to identify whether the real-time network is representative of the Big Cypress Basin.

5. The new groundwater level real-time data should be used to recalibrate the operational BCB model, with particular emphasis on using this data to reproduce the groundwater dynamics. This should include quality reviews of this new data.

1 INTRODUCTION

This final report describes the implementation of the project, “Big Cypress Basin Real Time Hydrologic Modeling System Phase 1 - System Development and Testing”, Contract 4600001041 which was issued by the South Florida Water Management District to DHI Inc., USA.

The Big Cypress Basin Real Time Hydrologic Modeling System has been implemented using the MIKE FLOODWATCH real-time decision support tool (http://www.dhigroup.com/Software/WaterResources/MIKEFLOODWATCH.aspx) as the overall operational system for managing the data flows, real-time modeling and visualization of monitoring data and forecast results. The modeling is carried out within the MIKE FLOODWATCH system using the integrated MIKE SHE/MIKE 11 hydrologic modeling system, (http://www.dhigroup.com/Software/WaterResources/MIKESHE.aspx).

The objective of this implementation report is to summarize the system, model developments and system configuration implemented specifically for the Big Cypress Basin Real Time Modeling System. The following topics are described:

- Big Cypress Basin Real Time Hydrologic Modeling System Documentation
- How to access the Big Cypress Basin Real Time Hydrologic Modeling System
- MIKE FLOODWATCH real-time flood decision support tool – Summary and key concepts
- Model Setup and Calibration – Model development and performance evaluation giving top level information about the real time model developed for the Big Cypress Basin.
- Forecast Model Setup - Information on the work undertaken to apply the integrated hydrologic model for forecasting purposes including real-time updating (data assimilation) and forecast accuracy
- Configuration of the Online Monitoring component, giving information on the work carried out to register and configure the real-time monitoring data collection and data presentation
- Configuration of the Online Modeling and Forecasting component, giving information on the work carried out to register the hydrologic model, define model scenarios, tasks and publications etc.
- Conclusions and recommendations

2 SUMMARY OF SYSTEM DOCUMENTATION

The System Documentation for this system comprises

1. Implementation of the Big Cypress Basin Real Time Hydrologic Modeling System (this document)
2. MIKE FLOODWATCH – User Guide.
3. Big Cypress Basin Real Time Hydrologic Modeling System - MIKE SHE Modeling Technical Memorandum
4. Big Cypress Basin Real Time Hydrologic Modeling System – Installation Guide

General documentation of the MIKE FLOODWATCH system is provided in the accompanying reference manual "MIKE FLOODWATCH – User Guide" which describes the generic functionality of the MIKE FLOODWATCH system. This user guide integrates the Administrator's Manual, Configurator's Manual and the Operator's Manual described in the original scope. Six copies of this User Guide have been delivered to the South Florida Water Management District.

The MIKE SHE model of the Big Cypress Basin developed for real-time modeling is described this report and in the report "Big Cypress Basin Real Time Hydrologic Modeling System - MIKE SHE Modeling Technical Memorandum". General documentation of the MIKE SHE and MIKE 11 modeling tools is provided in the reference manuals "MIKE SHE – User Guide" and "MIKE 11 – User Guide", already supplied to the District.

The local installation of the MIKE FLOODWATCH tool for the Big Cypress Basin Hydrologic Modeling System is described in the report "Big Cypress Basin Real Time Hydrologic Modeling System – Installation Guide". This document is a short step-by-step guide to installation of the system software. The local configuration is described in chapters 7 & 8 of this report.

3 HOW TO ACCESS THE SYSTEM

3.1 Introduction

The Big Cypress Real Time Hydrologic Modeling System collects and manages the real-time data flows, controls the real-time modeling and visualization of monitoring data and forecast results. Access to the monitoring and forecasting data is provided through either the Web interface or the GIS interface.

Web interface

The **Web interface** provides rapid and direct access to all the real-time monitoring data and forecasting data within the Big Cypress Basin using the South Florida Water Management Intranet. The purpose of this interface is to allow rapid assessments of the situation within the Big Cypress Basin based on the latest real-time data, together with the most recent hydrologic forecasts. The displays within the Web interface provide direct access to all real-time monitoring data with the Big Cypress Basin in the form of structured time series graphs. In a similar manner, the displays show time series graphs for all designated forecast points within the Big Cypress Basin as well as simulated flood maps. For users with access to Google Earth, map-based displays allow efficient navigation and data access over the entire Big Cypress Basin from a single view.

The information is presented in the form of published web pages that are updated as new data becomes available. These web pages have been developed specifically for the Big Cypress Basin Real Time Hydrologic Modeling System. The information contained within these pages is sufficient for the majority of users and end-users. More advanced users can also directly access the system via an interactive Web interface. This interactive user interface not only allows comprehensive access to both the monitoring and forecasting system and data, but also allows users with the proper permissions, to access and control the operational system, generate new alternative forecasts, etc. Access is password controlled to protect the integrity of the operational system.

The **GIS interface** is the main system user interface, for operation, configuration and maintenance. This interface is implemented as an extension to ArcMap. Within this interface geographical information is linked with time series data using the Temporal Analyst tool. The GIS interface, therefore also enables both comprehensive access to time series and map information. The primary application of the GIS interface is to perform system configuration, operation and maintenance operations. Access is password controlled to protect the integrity of the operational system. Access to the system information is structured through a number of editors for specific components of the system. These editors cover the following components.

- Scenarios
- Tasks
- Events

- Publications
- Simulations

The following sections describe how to access the Big Cypress Basin Real Time Hydrologic Modeling System including:

- Accessing the Web interface
- Accessing the GIS interface

3.2 Accessing the Big Cypress Basin Real Time Modeling System through the Web interface

Access to the Big Cypress Basin Web interface is straightforward. Simply direct your browser to http://bcbmod01p/floodwatch - you will see a brief list of content with links to monitoring plots, model results and the interactive web pages, Figure 1. These data are available to any user of the South Florida Water Management District Intranet.

The Big Cypress Basin Real Time Modeling System produces a number of plots of observed data and model results. The system always displays the latest data and model results. These displays are updated immediately after the monitoring data is collected from the SCADA system and when forecasts are carried out. Currently the system is configured to retrieve the latest monitoring data once an hour and to perform forecasts automatically twice a day.

This Web interface also provides access to the comprehensive interactive web interface, "Floodwatch Online". Floodwatch Online provides access to the underlying system and configuration so access is password controlled.

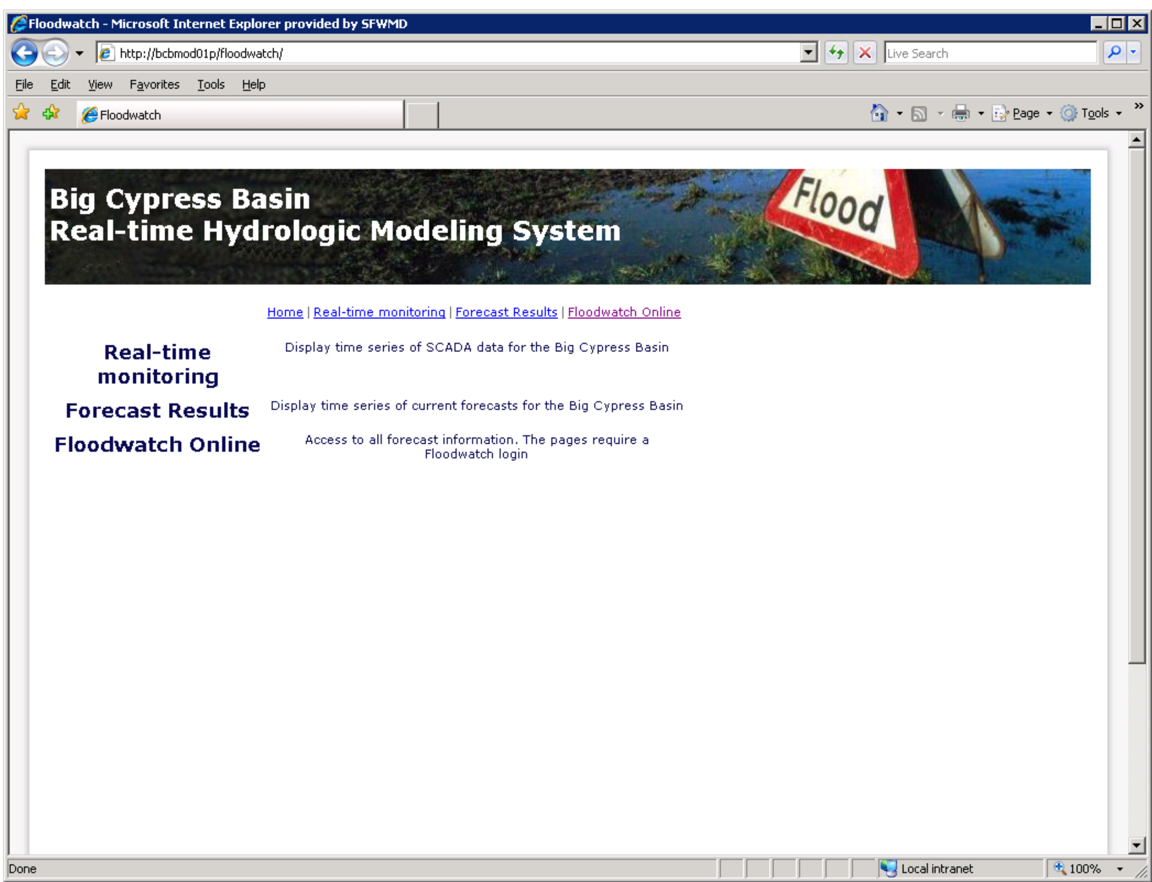


Figure 1 Web access to the Big Cypress Basin Hydrologic Modeling System

3.3 "Static" web pages

The monitoring plots are divided into pages by type of data (rainfall, water level, discharge, groundwater level, bore hole pressure & gates) accessible by clicking on the links on the left.

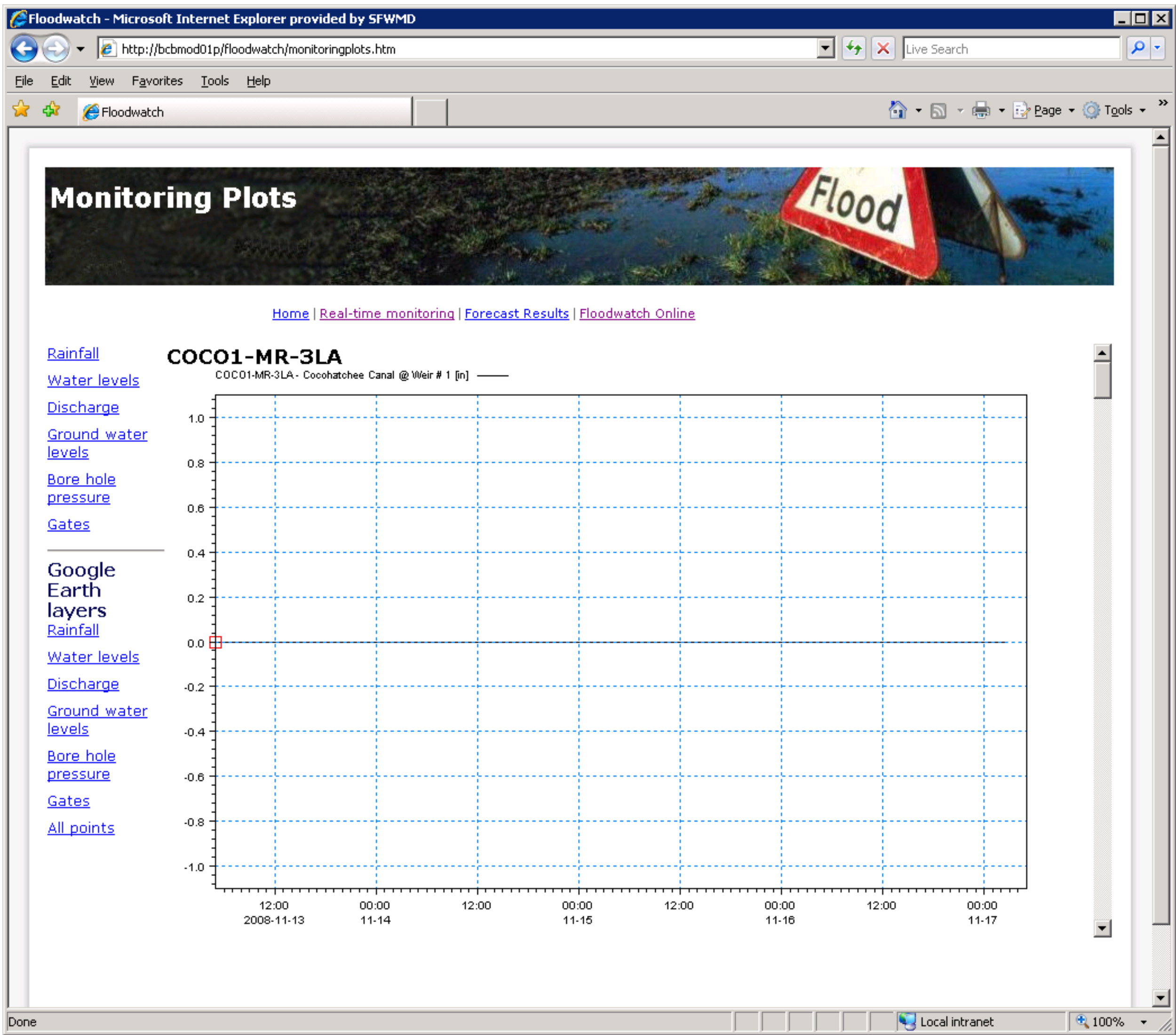


Figure 2 Web displays of real-time monitoring data

The links under Google Earth Layers will open Google Earth (if installed) and display markers for the sensors locations. When clicked, these markers will show a balloon with a miniature version of the time series plot, Figure 2. Click the plot to navigate to the full-size version.

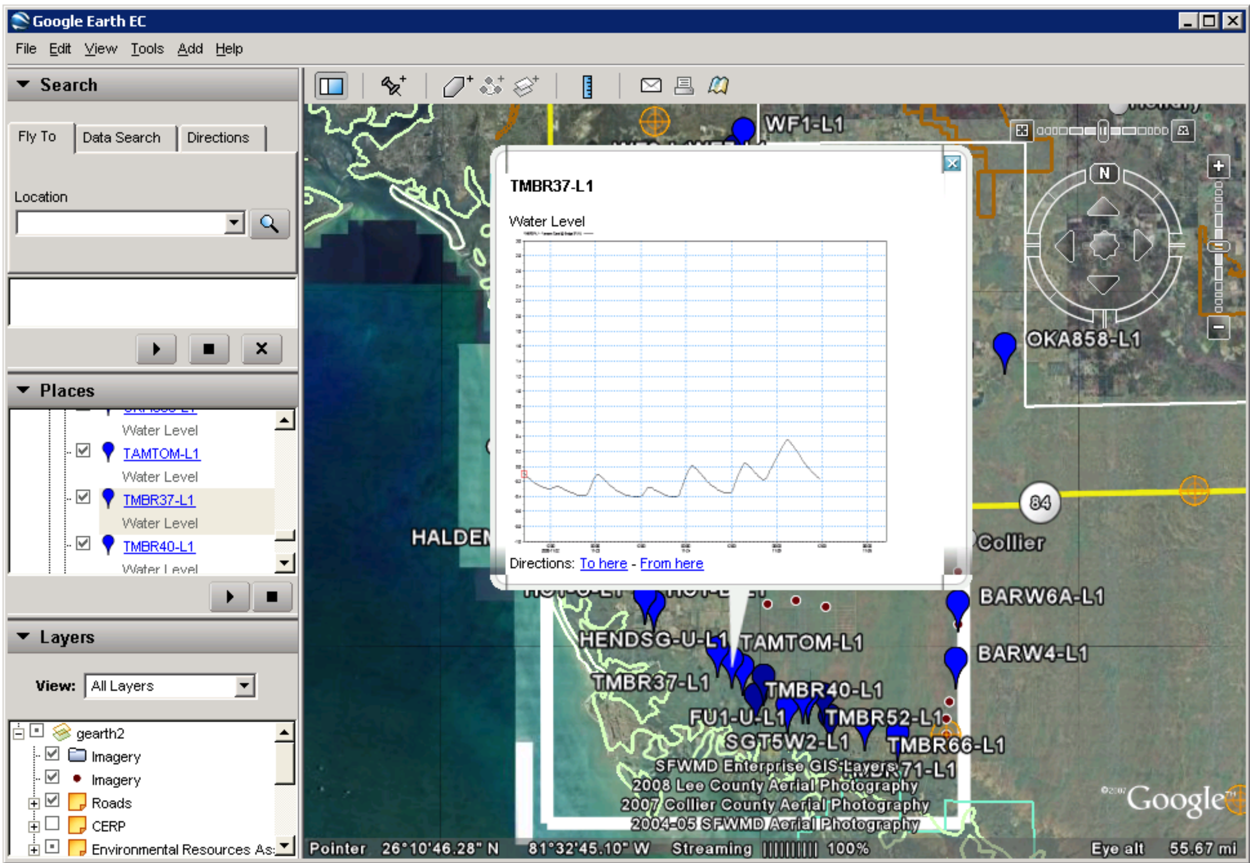


Figure 3 Map-based displays of forecast and monitoring data using Google Earth

The “Forecast results” shows the observed data and model outputs at selected forecasting points from the latest model run with an indication of the Time of Forecast. Google Earth layers are also available for these locations.

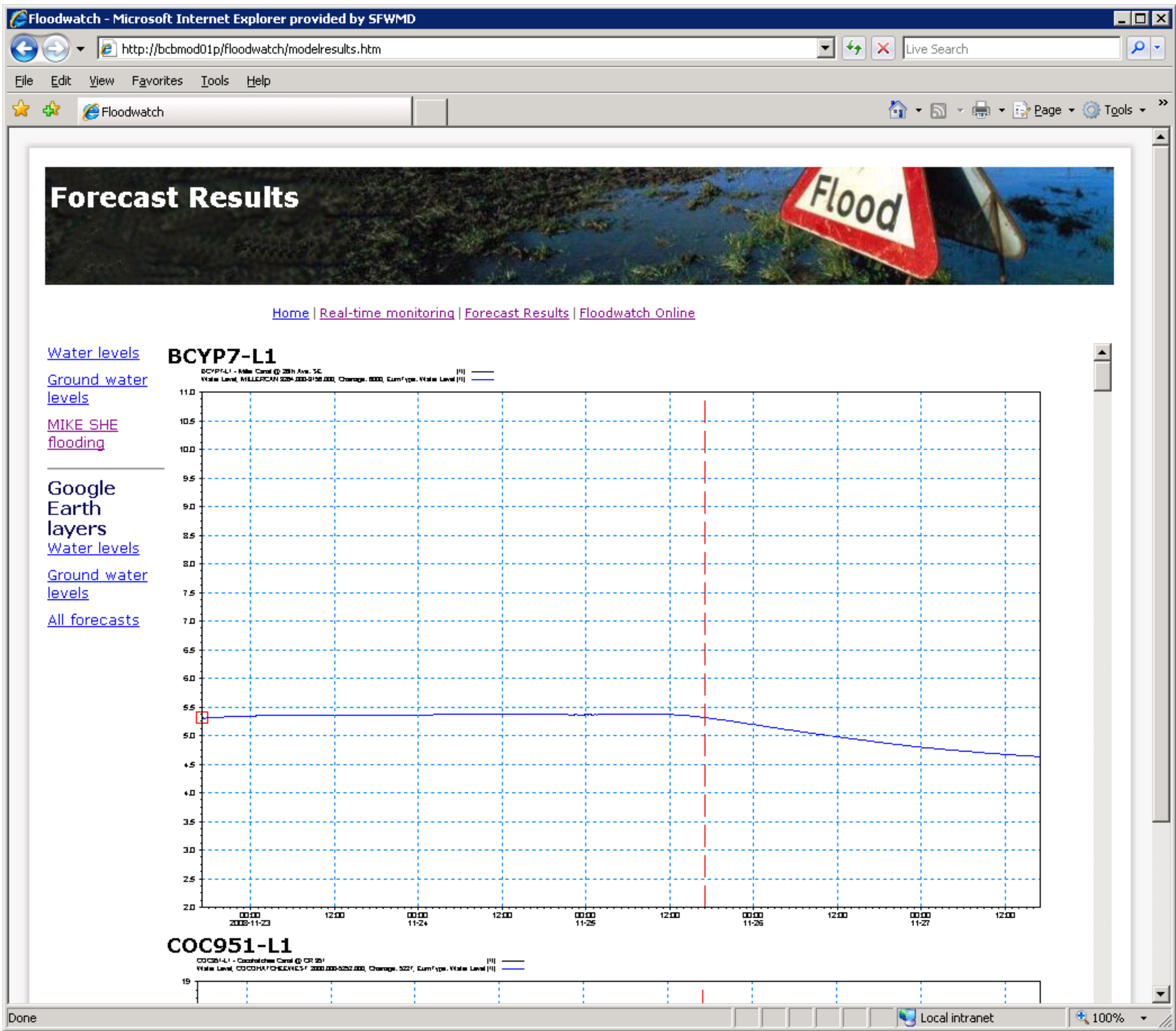


Figure 4 Web displays of forecast data

The Link "MIKE SHE flooding" displays an animation of the MIKE SHE output for overland water depth, Figure 5. The animated map shows both the extent and depth of flooding for a sequence of time steps. The display includes simple controls for the animation.

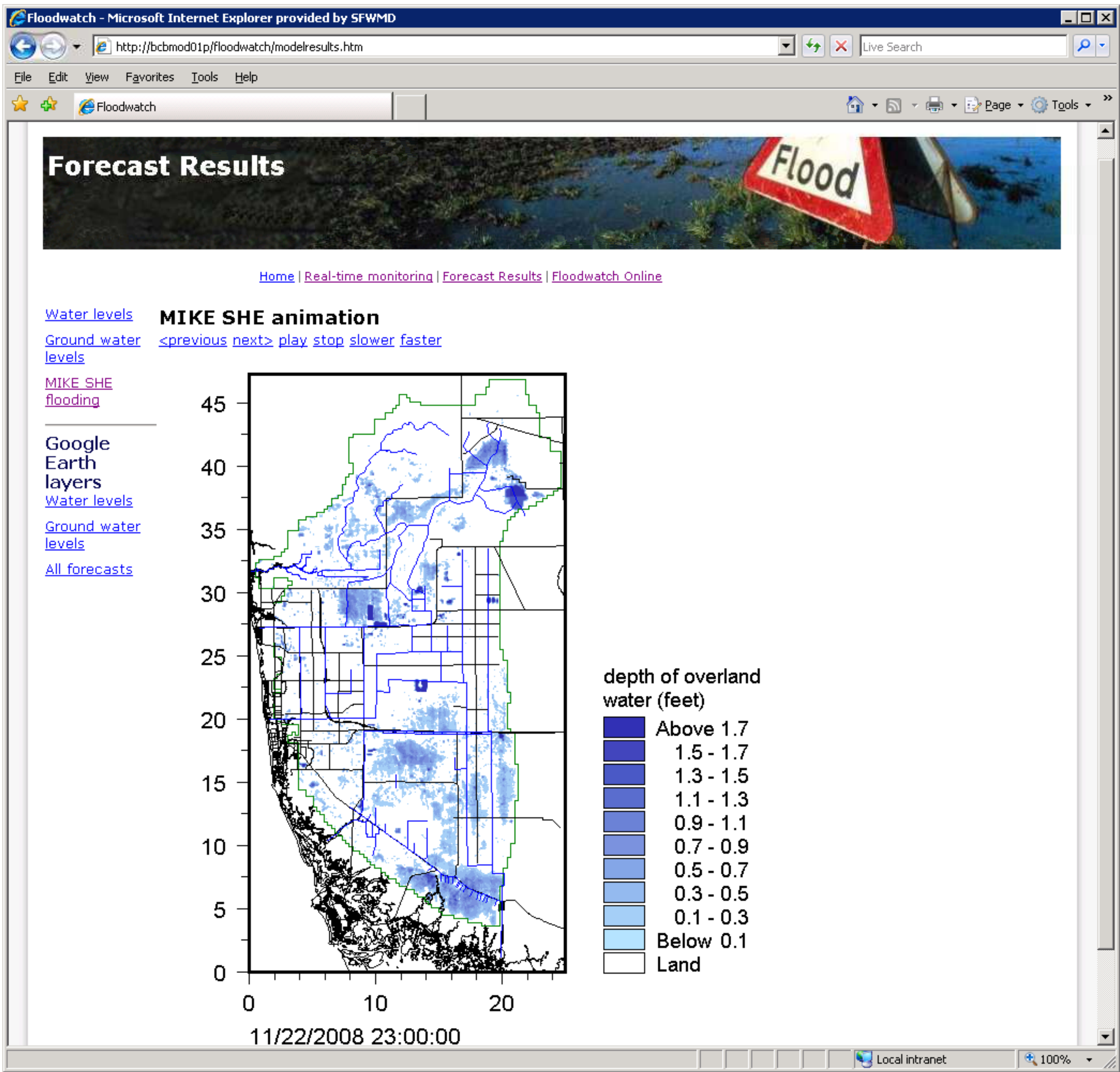


Figure 5 Animated display of flood depth and extent for the Big Cypress Basin

3.4 Interactive Web interface

The interactive web interface not only allows comprehensive access to both the monitoring and forecasting system and data, but also allows users with the proper permissions, to access and control the operational system, generate new alternative forecasts, etc. Access is password controlled to protect the integrity of the operational system.

The interface can be accessed via the “Floodwatch Online” link, Figure 1 , which opens a set of dynamic web pages which allow users to query data (time series, simulation results, events etc) directly from the live database. With proper permissions it is also possible to start (and stop) model runs.

The pages require login, hence a user account must be created by the FLOOD WATCH administrator. Passwords are only created or modified by the administrator via the GIS interface.

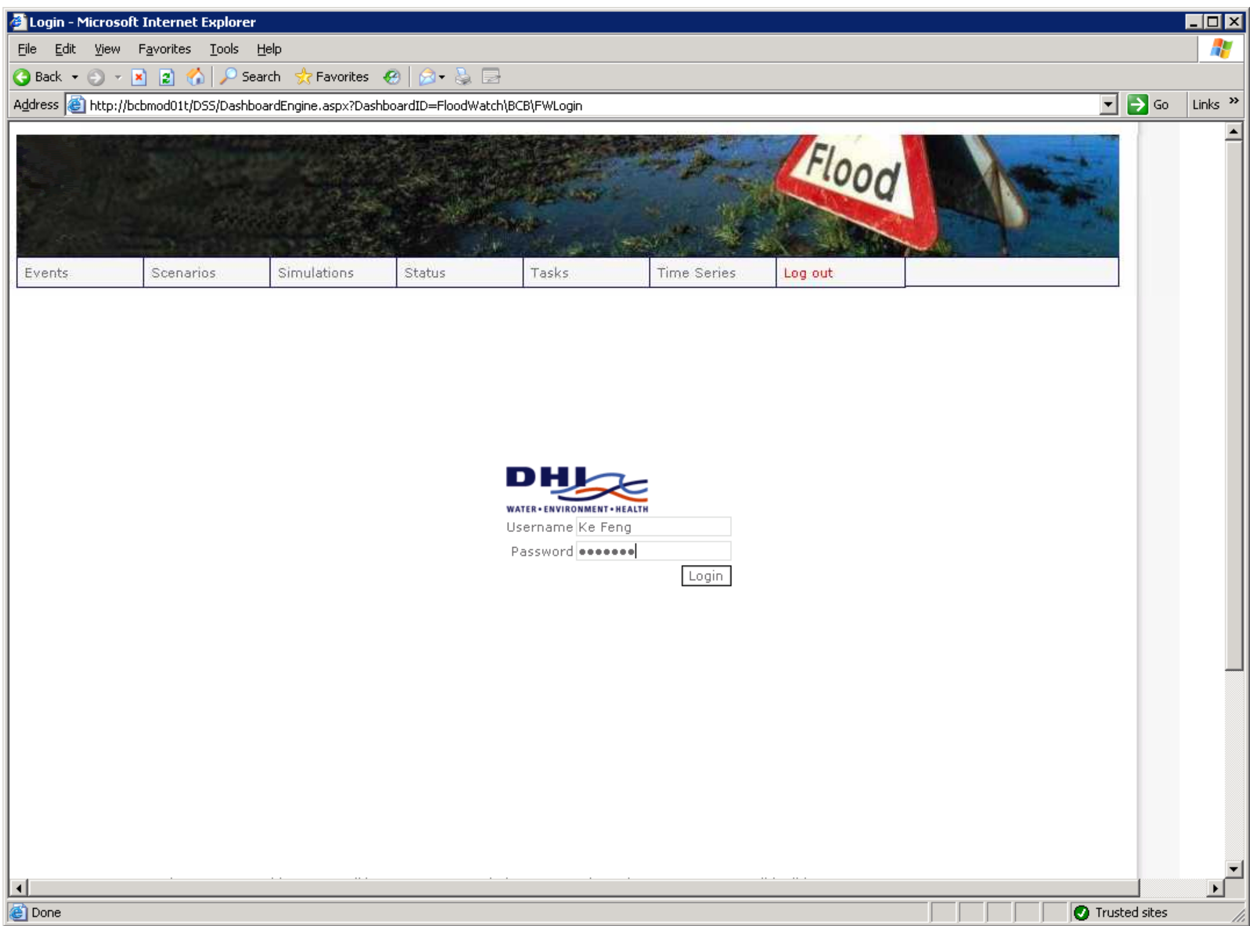


Figure 6 Login display for the dynamic Web interface – FLOODWATCH ONLINE

After login the user is re-directed to the default page, which in this case is the Simulations page where it is possible to inspect details of the Simulations (forecasts) in the database.

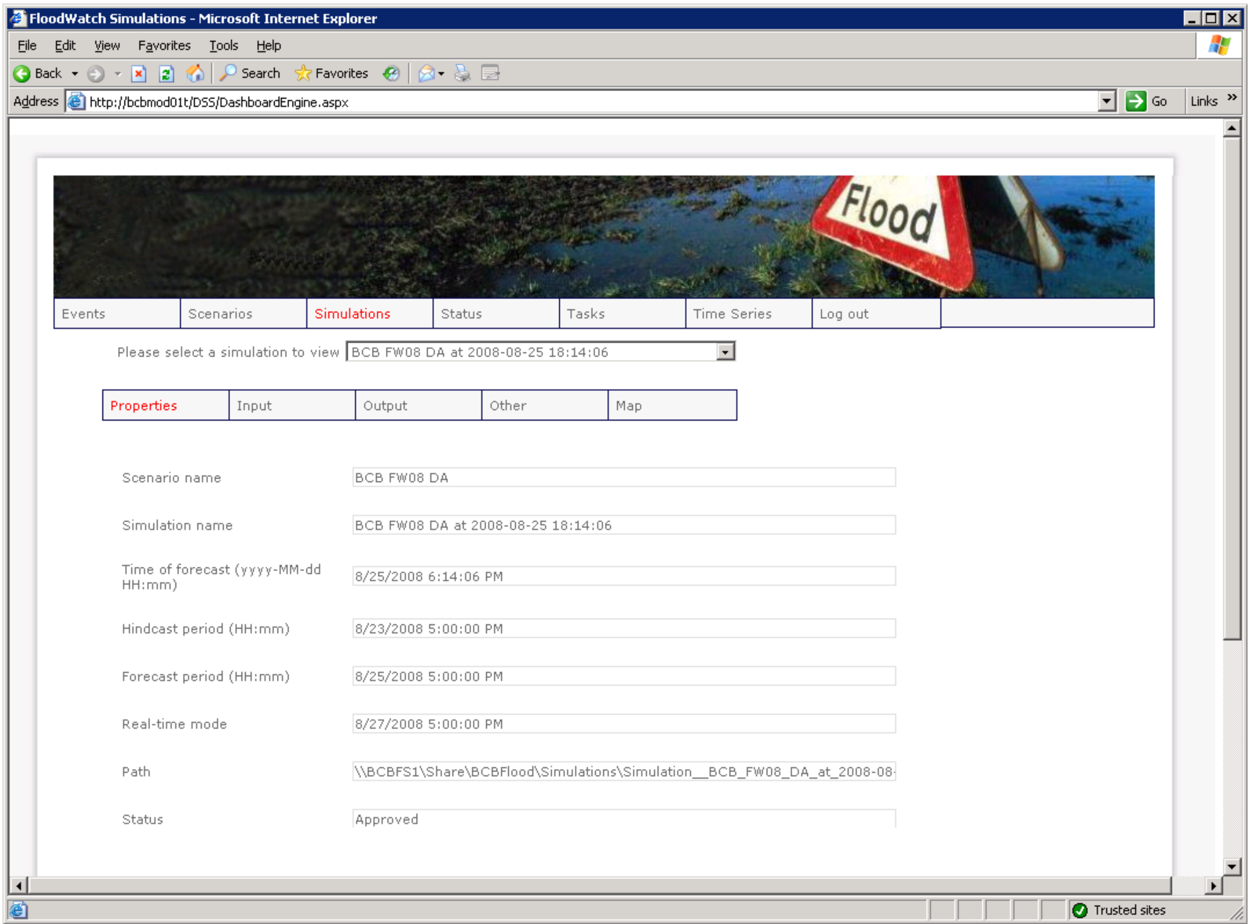


Figure 7 Simulation web page containing details of the forecast simulations made within the Big Cypress Basin

It is then straightforward to navigate around the interactive web interface by selecting the relevant tabs. For example, the Time Series page allows the user to compose plots of multiple time series for a user defined period, Figure 8.

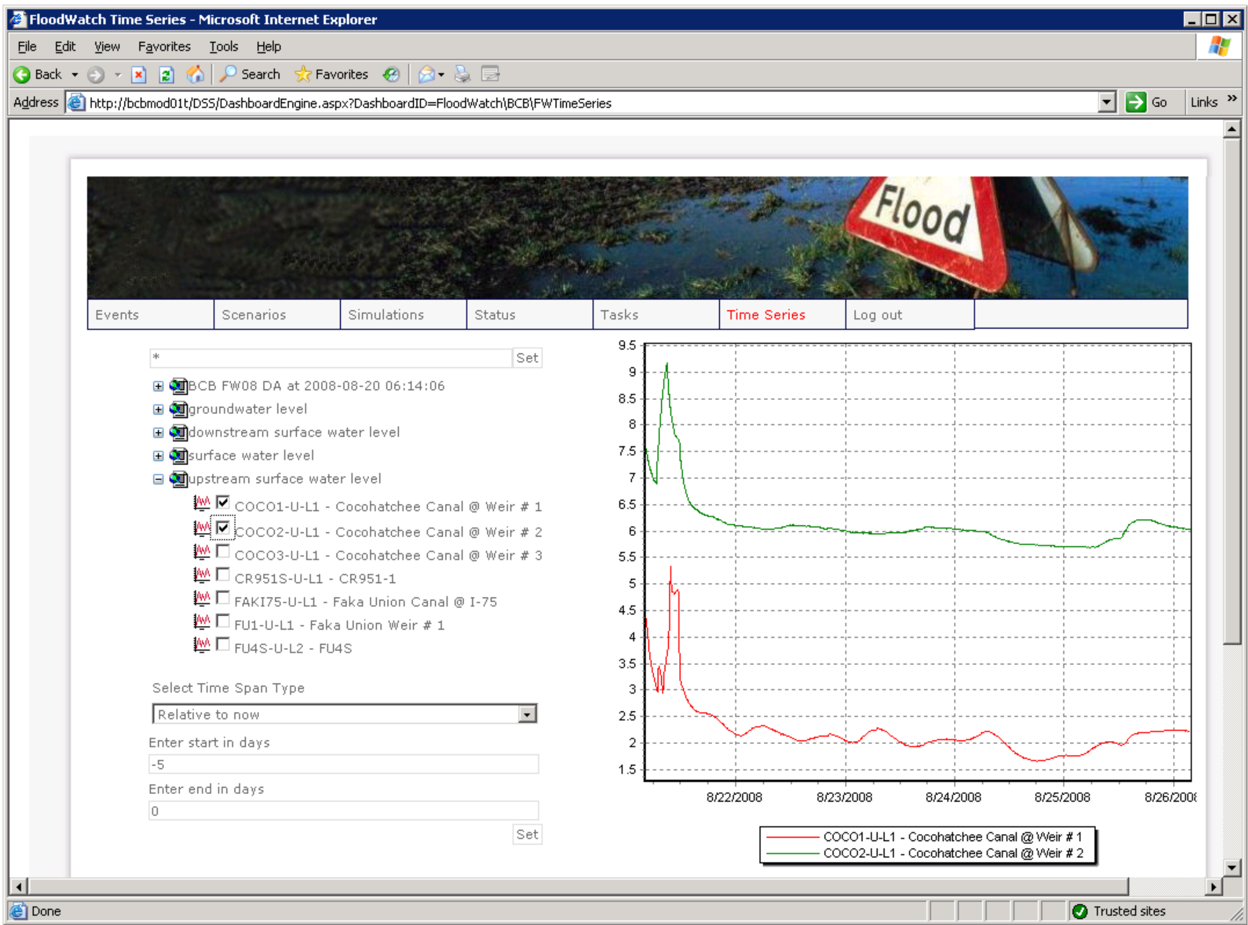


Figure 8 Time series web page allowing multiple plots of forecast time series

A comprehensive description of the interactive Web interface is given in the MIKE FLOODWATCH – User Guide.

3.5 Accessing the GIS interface

The GIS interface provides the most comprehensive complete access to all the Big Cypress Basin Real Time Hydrologic Modeling System. The GIS interface uses ArcMap to present and organise the spatial data. Time series information is linked to the spatial data using DHI's Temporal Analyst tool which is an extension for ArcMap.

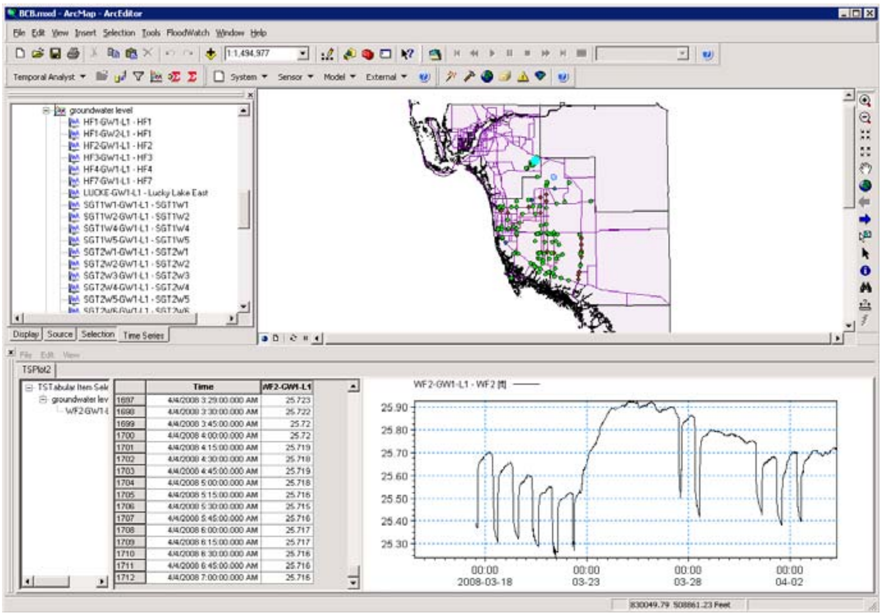


Figure 9 The FLOOD WATCH extension in ArcMap

The GIS application is run only in the BCB Server where FLOOD WATCH is installed. As such the user must log in to the BCBMOD01P machine via Remote Desktop. Only one user at a time should do so.

Once logged in the user can start the ArcMap application from the "BCB Floodwatch" link situated on the desktop. Upon start-up the user is prompted for an username and a password. When logged in the user may use the functionality of the Floodwatch menus and toolbars as well as the Temporal Analyst functionality.

A comprehensive description of the GIS interface and editors is given in the MIKE FLOODWATCH – User Guide.

4 MIKE FLOODWATCH – SUMMARY AND KEY CONCEPTS

The Big Cypress Basin Real Time Hydrologic Modeling System has been developed within the framework of the MIKE FLOODWATCH real-time decision support tool. Real time decision support encompasses the processes of monitoring, real time modeling (forecasting), flood warning and real-time decision-making. Real-time modeling systems, which link weather forecasts, the state of the river catchment, river discharges and water levels, can be used to respond to floods, droughts and other water management events as they occur and to reduce their costs in terms of lives, property and the breakdown of infrastructure as well as protect the quantity and quality of the water supply. To be effective, however, real time modeling systems should provide appropriate decision information in a timely manner to those who need it, where they need it, in a manner that is easy to understand.

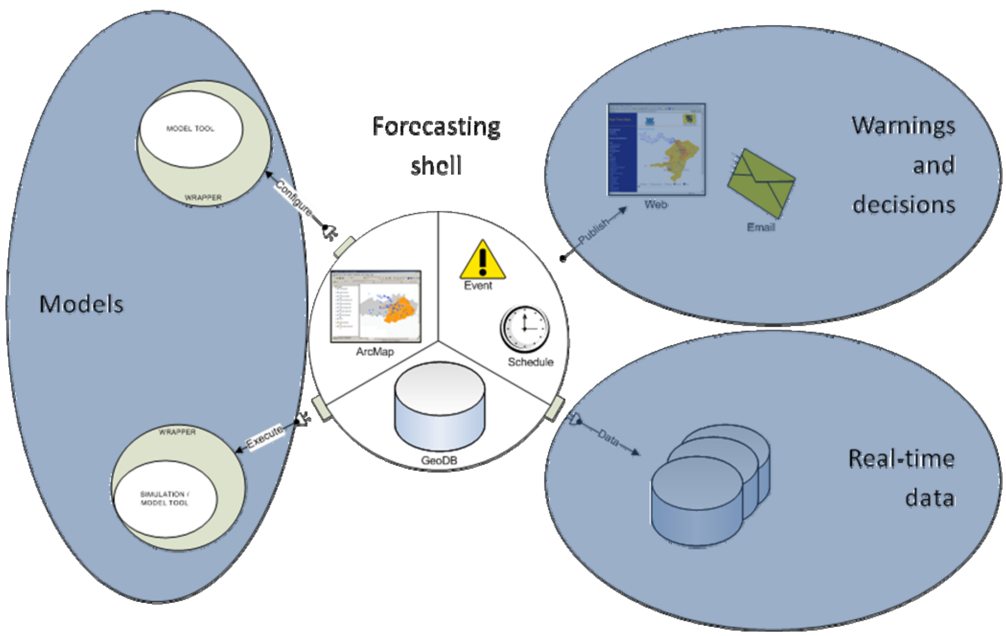


Figure 10 Structure of MIKE FLOODWATCH forecasting framework and interfaces to real-time data, real-time models and the publication/dissemination

The MIKE FLOODWATCH system consists of the hardware and 4 main software components; the Shell controlling the operational and flow of data within the system, the real time data component for data acquisition and processing, the modeling component to manage the real time modeling and the dissemination component for displaying and published real-time data and forecasts, Figure 10.

The main requirements for an effective real time modeling system are

- Rapid access to forecast information in an easily understood form often over wide geographic areas (Real time data and Warning and decision components)

- Rapid forecasts using efficient models and automatic forecast generation (Shell and Models Component)

- Accurate forecasts based on the latest information and real-time updating (Models and Real time data components)

- System reliability in terms of robust data systems, data quality assurance, and fall-back systems, etc. (Shell and hardware)

The system architecture of MIKE FLOODWATCH is provided in two variants; Professional and Enterprise.

MIKE FLOODWATCH PROFESSIONAL

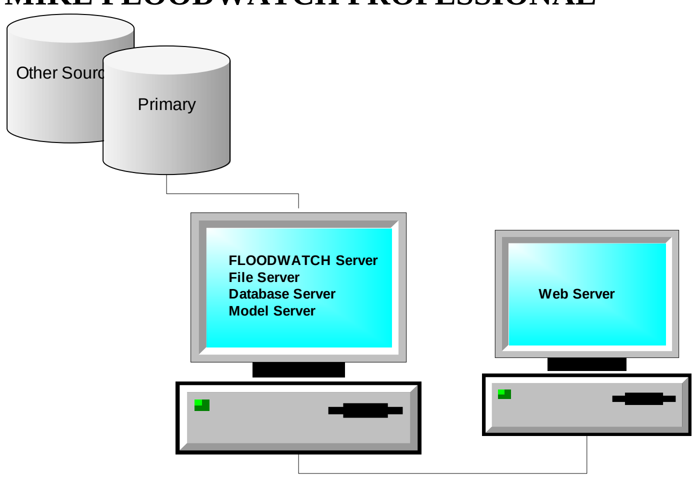


Figure 11 *Architecture of MIKE FLOODWATCH Professional*

For phase 1 of the pilot Big Cypress Basin Real Time Hydrologic Modeling System project, the MIKE FLOODWATCH Professional package has been implemented, Figure 11. This combines the advantage of a low initial investment while providing a dedicated system which meets the needs of the Big Cypress Basin. The web interface provides access to the system for a larger number of external users. The Enterprise version is more suitable for large-scale implementations, Figure 12. The Enterprise version supports multiple servers, multiple clients, integrated data storage options as well as providing a higher level of performance and system redundancy.

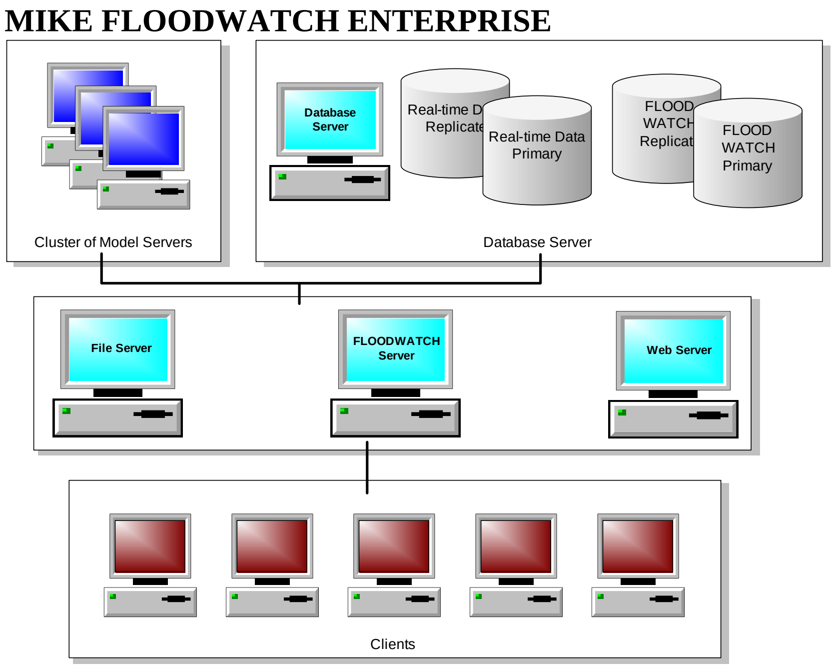


Figure 12 Architecture of MIKE FLOODWATCH Enterprise

Operation and data flows

The acquisition and flow of data and the automatic operation of the forecasting system is controlled by the MIKE FLOODWATCH shell, Figure 10. Real-time data is imported from the South Florida Water Management Board SCADA automatically every hour. These data are then published to the flood monitoring web pages. Forecasts are performed automatically, twice daily and the results of forecasts published immediately thereafter, Figure 13.

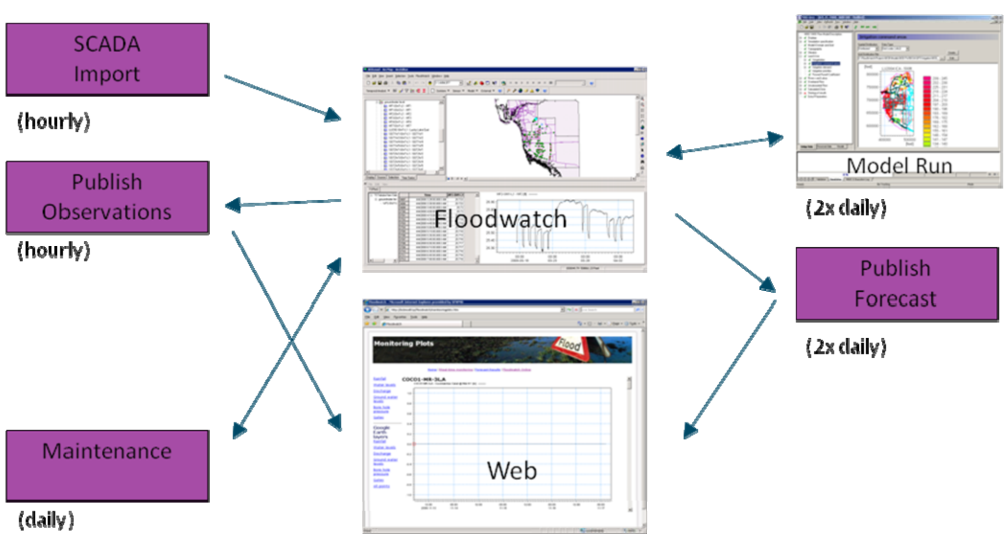


Figure 13 Data flows within the Big Cypress Basin Real Time Hydrologic Modeling System

User Interfaces
The Web and GIS user interfaces provide access to the real-time data and modeling results. These interfaces have already been described in chapter 3.

The data interfaces, control and manage the flow of real-time data. The interfaces can accommodate both point data such as water levels, groundwater levels, rain gages etc and spatially distributed data such as numerical precipitation forecasts and weather radar. In the pilot implementation, only point data sources are being collected within the Big Cypress Basin Real Time Modeling System.

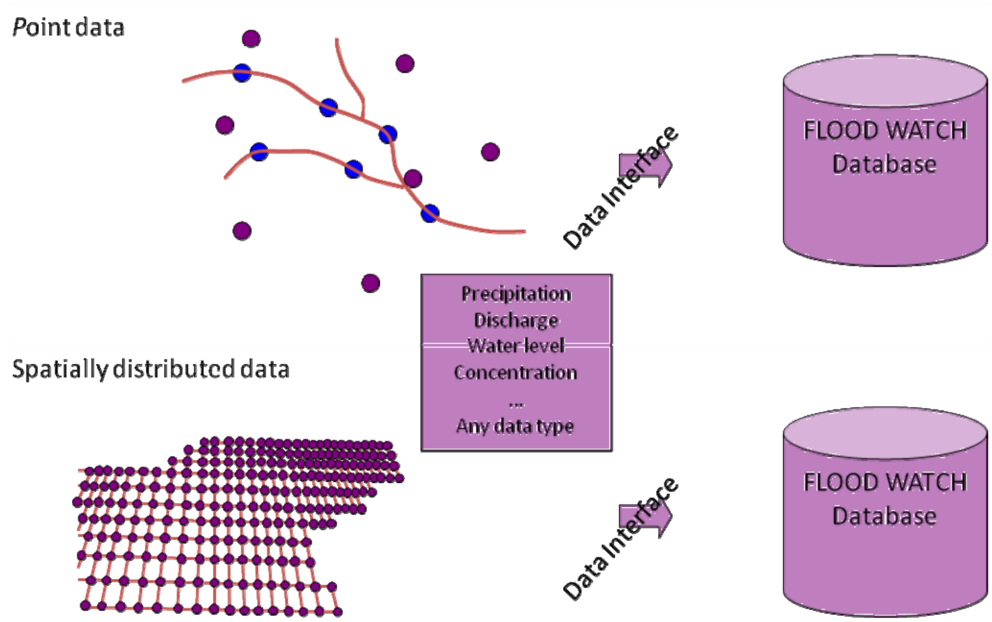


Figure 14 MIKE FLOODWATCH can interface both point data and spatially distributed data.

The data interfaces are developed in two parts

(1) A tailored method, which gets data from external sources

(2) A built-in method, which inserts data into the operational system

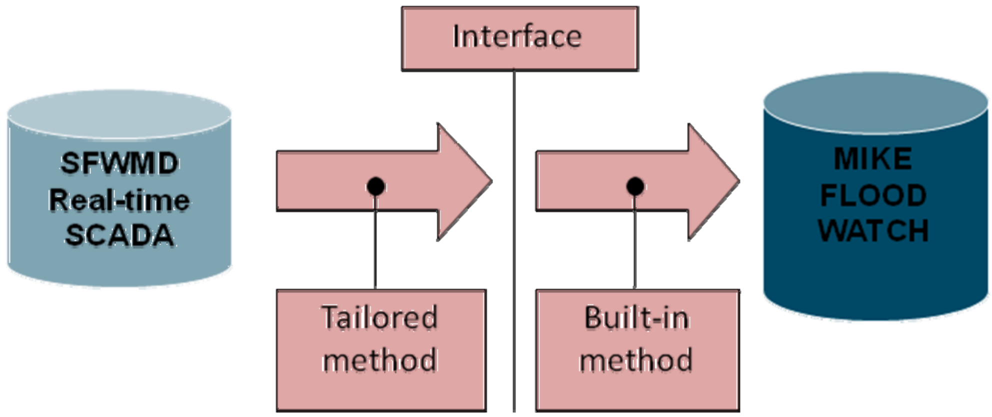


Figure 15 The data interfaces within MIKE FLOODWATCH

The built-in method is a standard method shipped with MIKE FLOOD WATCH The tailored method is developed to a well-defined interface and ensures that data capture can be carried out for different databases and other external data sources. Specific data interfaces for the SFMWD SCADA system have been developed, that interpret the point data and the quality control codes, see chapter 7.2.

Model interfaces

The system provides the capability to run forecasting models provided by DHI Software as well as third party modeling tools. The system can interface a wide range of model types, including hydrologic models, hydraulic and hydrodynamic models, advection-dispersion models, water quality models, forecasting models, error forecast models, optimization methods and others.

Model interfacing is carried out using the concept of a model adapter. The idea of an adapter is that the simulation model for a particular basin can first be developed outside of the real time system. Once the particular model has been developed, calibrated and tested in its own native environment it can ´be linked into the FLOODWATCH system using the model adapter. Two types of model adapters are defined; one for configuring the model within the system and one for running models within the system. The configuration adapter is optional but if available can be used to reduce the effort in incorporating the model with the system. The run-time adapter is required to run a model simulation in real-time and ensures that data is provided to the model in a suitable format, that the model can be run and that forecast data can be extracted from the model

When starting a hydrologic model forecast (simulation), the system

- Creates a new simulation instance (the particular forecast)
- Copies static files to instance directory (directory created for that particular forecast)
- Selects and copies the files containing the initial conditions
- Prepares simulation input time series in interface format

- **Runs the model run-time adapter**
- Imports result time series from interface format

The model run-time adapter

- Saves input time series in native model format
- Sets simulation time parameters describing the start and end of the simulation and time of forecast
- Runs the model engine executable
- Saves selected result time series in interface format

The hydrologic modeling within Big Cypress Basin Real Time Hydrologic Modeling System is carried out using the MIKE SHE integrated surface water- groundwater modeling tool. A model adapter has been developed by DHI for any MIKE SHE model including the Big Cypress Basin model.

5 REAL TIME HYDROLOGIC MODELING

The next two chapters summarize the development and implementation of the MIKE SHE model for the Big Cypress Basin real time model within The Big Cypress Basin Real Time Hydrologic Modeling System.

5.1 Introduction

The Big Cypress Basin Real Time Hydrologic Modeling System consists of two components, a real-time monitoring component and a forecasting component, both implemented within the MIKE FLOODWATCH tool. The real-time monitoring component provides displays of real-time data for the Big Cypress Basin area for rainfall, river and channel water levels, discharge gate levels, and groundwater levels, via links to the SFWMD SCADA system. The forecasting component uses this real-time data together with a hydrologic model of the Big Cypress Basin to forecast the water levels, groundwater levels and flooding within the Basin. The current Big Cypress Basin model (BCB model) within the pilot system was developed from a subset of the Picayune Strand Restoration Project (PSRP) model. The PSRP Strand model was developed and calibrated as a water resources model rather than a real-time forecasting model. As the requirements for an operational forecasting (real time) model are different from a traditional simulation model it is useful to examine these requirements and then to evaluate the performance of the BCB model during a significant flood event.

5.2 Forecasting model requirements

A forecasting model differs from a conventional hydrologic model in four key aspects. The first is the need for rapid results to ensure timely forecasts and the second is that generally fewer data are available in real-time for driving the model. The third is the need to accurately capture the correct initial conditions and finally in order to forecast into the future, forecasts of the future behavior of the model boundary conditions must be made.

Timely forecasts
In order to provide timely forecasts the model results should be made as rapidly as possible, so there is more time to make decisions and take action and also more time to evaluate different forecast scenarios. For this reason the BCB model covers a smaller area than the PSRP model but the model is more detailed because the numerical grid size is reduced from 1500 ft to 500 ft. Other modifications to the model are described in section 5.4.

Real-time data coverage
An operational real time hydrologic model will typically operate on other data sets than conventional models. Conventional hydrologic models are typically calibrated using all the available data including historical rain gage data, groundwater levels, river levels and discharges. The process of collecting, quality controlling and archiving this data is often first complete several weeks after the measurement has been taken. In contrast a forecasting hydrologic model can only use those data that are available in real-time, i.e. accessible within a matter of hours. Therefore there are usually fewer data and sometime different data available for real time modeling than for traditional simulations.

This has two main consequences for real time modeling in the Big Cypress Basin. The first is that the number and distribution of rain gages used for calibrating the hydrologic model are often different from the number and distribution of rain gages used for hydrologic forecasting. Typically, fewer rain gages are available in real-time. This is the case for BCB model. The representativeness of the real time rain gage network and the impact of using fewer rain gages have not been analyzed in this project. The second consequence arises from the fact that the development and calibration of the original PSRP model was carried on daily time step for a period of several years. Daily times steps are clearly too long for real-time modeling where forecasts should be made for the next 48 hours and the real-time data is acquired at 15 minute time steps. The 15 minute data includes phenomena occurring at smaller time scales not represented in the PSRP model.

Initial conditions:
To accurately forecast the future short-term behavior of the river and channel system requires an accurate estimate of the river model initial conditions, i.e. the flows and water levels in the surface network. Similarly, within the more slowly responding groundwater system, seasonal variations in the groundwater levels will affect the basin response to rainfall. In conventional modeling, simulations are carried out of several years and often the results of the first year or two are neglected so that the impact of the initial conditions is minimal. This is not possible in real-time modeling. In the BCB real-time model, an 18 month simulation was first carried out to give the best estimate of initial conditions for June, 2008. Forecasts have been carried out continuously from this point and for each forecast initial conditions for the model run are extracted from the previous forecast. In this manner, the initial conditions are being continually updated.

Measured and forecasted boundary conditions
Conventional hydrologic modeling used to simulate the behavior of a catchment is based on measured boundary conditions. The model boundary conditions include rainfall, potential evapo-transpiration, channel inflows and diversions from outside the model area, internal boundary conditions within the channel controlled by gates and structures and groundwater boundary conditions. Within the BCB model, the surface boundary conditions are either measured directly as is the case for rainfall, structures and channel inflow/diversions or estimated from measurements as is the case for potential evaporation. Groundwater boundary conditions are either defined by (mean) sea level, no flow boundaries corresponding to the limits of the aquifer or derived from large-scale models of the groundwater.

To forecast the future behavior of the Big Cypress Basin it is necessary to be able to forecast these boundary conditions for the next 48 hours or more. Within the pilot model the forecasts are carried out as follows.

Rainfall: Typically quantitative precipitation forecasts are either synoptic forecasts or derived from weather forecast models. At present rainfall forecasts are not provided automatically to the system and zero rainfall is assumed in the forecast period. This is a weakness of the current system and it is strongly recommended that this be addressed in future developments of the system.

Potential evapo-transpiration: While future values of potential evapo-transpiraiton can also be derived from numerical weather models, monthly average estimates of potential evapo-transpiration derived from historical data are used in the BCB model. Experience has shown that these are generally sufficient for short-term forecasting.

River channel: The river boundary conditions in the existing model are catchment inflows at the upstream ends and specified water levels at the downstream ends. The catchment inflows are derived rainfall-runoff processes calculated in MIKE SHE from the rainfall observations and forecasts. The downstream river levels can either be specified as constant values or alternatively can be estimated from astronomical tides, coastal forecasting models or a combination of these. In the current BCB model, the river level boundaries are all tidal so future levels are forecasted using the astronomical tides. However, since only the tidal predictions at Naples are available, these are scaled using a simple linear function, adjusting the amplitude and offset of the signal to match that of historical observations at the river boundaries.

Gates and moveable structures: Generally these are operated according to well-defined rules. These rules are assumed to control the future behavior of these dynamic structures.

Groundwater pumping: As groundwater withdrawals are not available in real-time, estimates of the average monthly withdrawals derived from historical data are applied.

Groundwater boundaries: The future behavior of the groundwater boundary conditions needs to be estimated. Currently the groundwater boundaries for the BCB model are mean sea levels along the coast line which remain fixed with time and monthly values of specified head levels along the northern and eastern boundaries. The time varying heads along the northern groundwater boundary were derived from observed well data. This was not possible along the eastern boundary due to the lack of data, so monthly values were estimated from the PSRP model simulations. Three conditions are worth noting in forecasting the northern and eastern boundaries Firstly the forecasts cover 2-4 days during which groundwater levels will exhibit only small variations however the seasonal variations are important. Secondly, the focus area which is the Golden Gate Estates is quite far from these boundaries. Finally, while these could be estimated by running a regional model this is beyond the scope of this pilot project. Therefore the approach adapted was to use a time varying head boundary condition exhibiting seasonal variations developed for the model cells along the northern and eastern boundaries. This is based on a model time series developed for an entire typical year and is assumed to apply to all subsequent years.

5.3 Picayune Strand Restoration Project (PSRP) Model

The objectives of the Big Cypress Basin Real Time Hydrologic Modeling System include adapting the existing BCB MIKE SHE/MIKE11 model, most recently applied in the Picayune Strand Restoration Project (PSRP), for use in the BCB flood forecasting modeling system. The adaptation of the PSRP MIKE SHE/MIKE11 model involved modifying the model to address local and specific flooding concerns and to reduce computation time. The following section summarizes the modifications made to PSRP model. Several simplifications of the PSRP model were explored in order to determine if some simplifications could be made without affecting accuracy. A more detailed description of the simplifications investigated and the modifications made is given in the report. “Big

Cypress Basin Real Time Hydrologic Modeling System - MIKE SHE Modeling Technical Memorandum".

5.4 Big Cypress Model

The most important modifications made to the PSRP model during this project are summarized below.

- The model area was reduced and the grid resolution 1500 to 500 ft
- Additional structures have been incorporated in the model
- The geometry and operation have been updated in some structures
- The land use description has been updated to reflect 2004 data
- The model input has been modified to use real-time rain gage network
- The leakage has been modified to improve the transient behavior of the groundwater model
- Real-time updating (data assimilation) is implemented to improve forecast accuracy

5.5 Modifications

The first modification was to reduce the size of the model domain in part to focus on the specific area of interest; primarily the Golden Gate Estates and the western portions of Collier County, Florida, west of the Faka Union Cana, Figure 16. Removing the river network along the new eastern boundary involved the introduction of a Q/H boundary to allow drainage out of Lake Trafford via the CK Main Canal. This reduction allowed an increase in grid resolution from 1500 ft in the original PSRP model to 500 ft in the real time model.

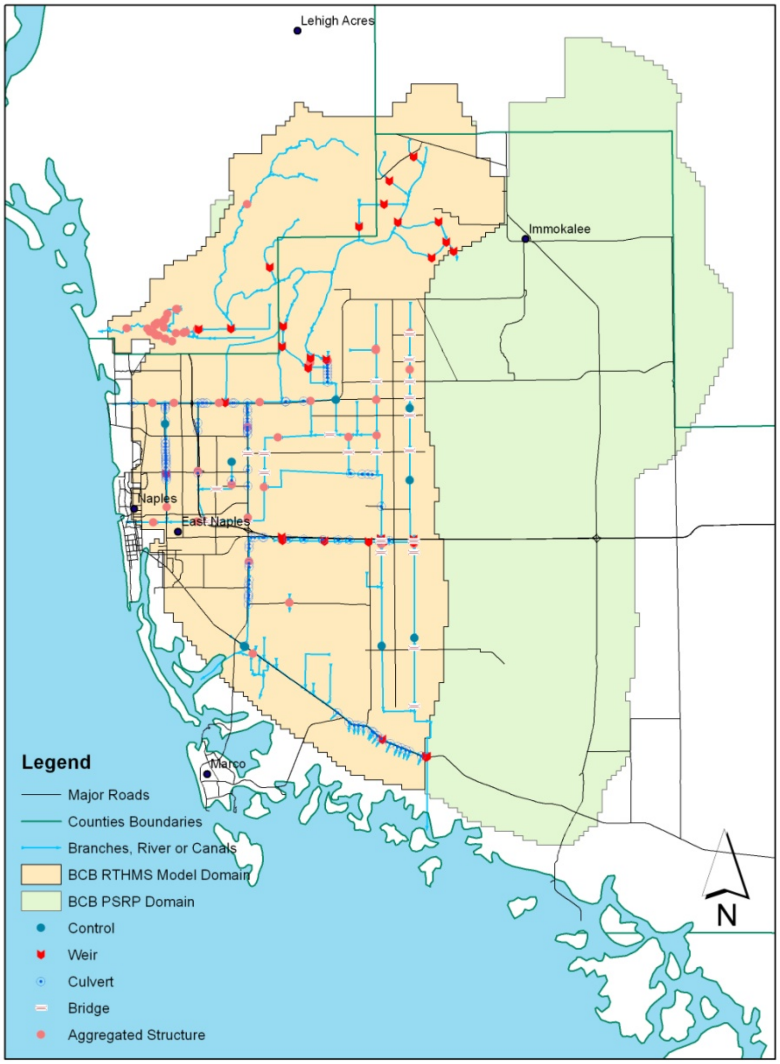


Figure 16 The extent of the model domains for the PSRP model and the BCB real time model

Changes to the description of structures within the river and channel network have been made. Two new structures have been added to the model (CR951-1 and Henderson-2) and modifications to the structure geometry have been made to reflect the current geometry for the Golden Gate Main-1, Golden Gate Main-2, Faka Union-4, Faka Union–5, and Cork-2, structures.

The land use classifications have been updated to reflect the latest available data corresponding to 2004 conditions.

At present, 15 real-time precipitation stations are available. The distribution of rainfall across the basin is determined using Theissen polygons. Historical data from three ET stations are used to estimate long-term monthly averages and these are also distributed using the Theissen polygon approach.

An evaluation of the Tropical Storm Fay was carried out based on the real-time monitoring data captured by the Big Cypress Basin Real Time Modeling System showed rapid transient behavior in the groundwater levels not revealed by the daily data used in the PSRP model. This evaluation is described in chapter 6.5. To better match the rapid groundwater response during Tropical Storm Fay the leakage coefficients for surface water to ground water during flooding.

Finally, in order to improve forecast accuracy, real time updating (data assimilation) using the measured water levels in the river channels has been implemented within the river (MIKE 11) component of the BCB model. The method used and its configuration are described in chapter 6.

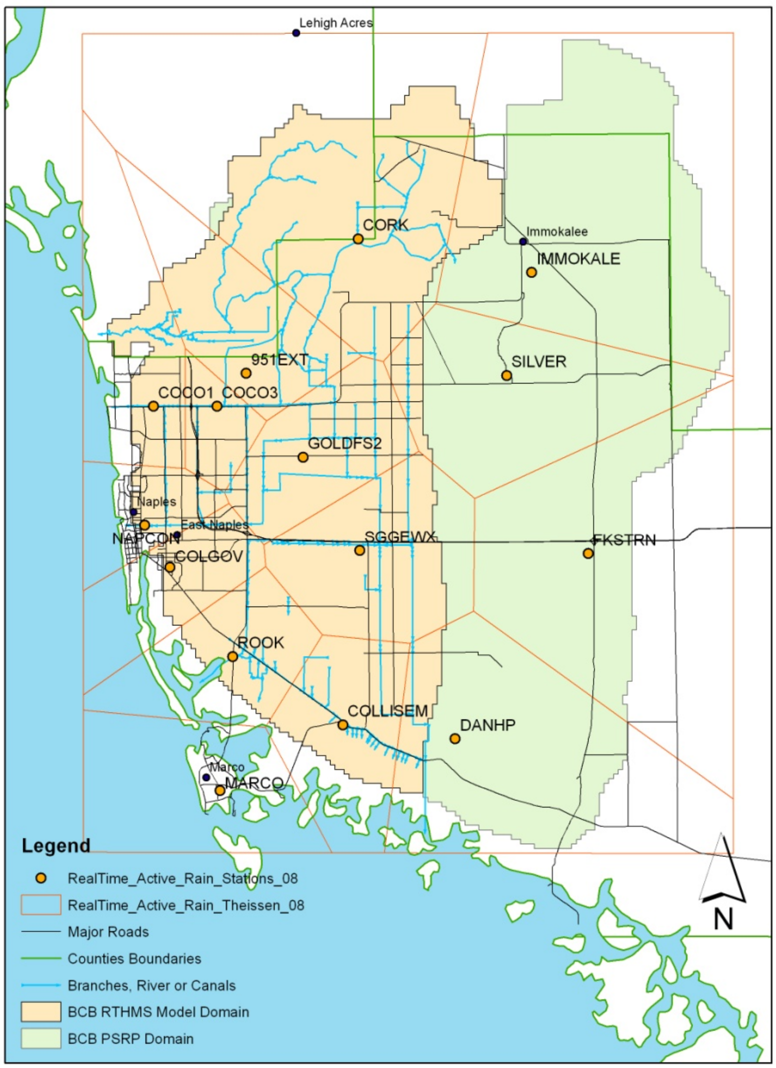


Figure 17 Rain gauges and Theissen Polygon distribution

6 FORECAST MODEL SETUP AND ACCURACY

6.1 Summary

This chapter describes the configuration of the real-time Big Cypress Basin Hydrologic Model for real-time forecasting. The following items are described:

- Development of the MIKE SHE adapter
- Factors affecting forecast accuracy
- Forecast model setup, giving information on the configuration of the Data Assimilation module
- An assessment of forecast accuracy at selected locations during the Tropical Storm Fay, 2008

6.2 MIKE SHE adapter

The MIKE She Adapter for MIKE FLOODWATCH enables configuration and execution of a MIKE SHE model setup in MIKE FLOODWATCH. Like the other model adapters available within MIKE FLOODWATCH, this adapter will parse a model setup and return list of all model setup files, input time series (both point, 1D, 2D and 3D series), initial conditions files, possible output time series and log files.

The MIKE SHE adapter recognizes the use of MIKE 11 for modeling of river and lakes and through call of the MIKE 11 adapter the relevant files for this setup are also located. The combined setup is regarded as a MIKE SHE setup as the model engine uses the SHE-file as the single starting point for the simulation.

During configuration the Adapter creates and adds one file to the setup, “MZAdapterConfig.xml”. This file contains the model setup definitions to be used at runtime by the adapter itself.

6.3 Forecast model accuracy

The accuracy of a hydrologic forecast depends on the following factors. Butts et al. 2002, 2004.

- Accuracy and representativeness of the precipitation forecasts
- Accuracy and representativeness of the precipitation measurements
- Accuracy of boundary forecasts of water level and discharge
- Accuracy of the forecasting model

- The efficiency of the updating or data assimilation methods

- The accuracy of flow and water level observations

Each of these factors are addressed in relation to the Big Cypress Basin model

Accuracy and representativeness of the precipitation forecasts
At present precipitation forecasts are not available in real-time and the future rainfall is set to zero. Forecasts of precipitation 48 or at least hours ahead should improve the forecast accuracy especially if these can be provided at sub-daily time intervals, e.g. 6 hour intervals.

Accuracy and representativeness of the precipitation measurements
As described in chapter 5.4, 15 real-time stations are available to capture the distribution of rainfall over the catchment. At present the ability of this real-time network to represent the rainfall has not been quantified and it is recommended that a comparison of the rainfall over the model area captured using the real-time gauges and using the complete rain gage network should be carried out to identify whether the real-time network is representative of the Big Cypress Basin.

Accuracy of boundary forecasts of water level and discharge
The only boundary forecasts used in the surface water system are downstream channel levels at the coast. These are all tidal, astronomical tide predictions can be used. However, since only the tidal predictions at Naples are available a scaling via a linear function has been applied, adjusting the amplitude and offset of the signal to match that of observations. A qualitative comparison of the results with observations from water levels measured upstream of the coastal boundaries suggest that this is a reasonable approximation.

The groundwater withdrawals are estimated as monthly average values derived from historical data. Provided there are no dramatic changes in volumes withdrawn this can be expected to be an adequate approximation, however these averages should be updated at regular intervals. The groundwater water level boundary forecasts are developed as average monthly values. The accuracy of these estimates is discussed in chapter 5.2 and in the report “Big Cypress Basin Real Time Hydrologic Modeling System - MIKE SHE Modeling Technical Memorandum”. These boundaries are distant from the primary area of interest, the Golden Gate Estates and it is expected that this approach should adequately represent the seasonal variations in groundwater levels affecting flood response.

Accuracy of the forecasting model
The accuracy of a deterministic hydrologic model depends on the accuracy of the data used as model input (boundary conditions – see above) and the data used to calibrate the model (see below). In addition model errors can arise from sub-optimal parameter values or incomplete or biased model structure where the processes within the basin are not properly represented by the model description. In this context, the new groundwater level real-time data should be used to recalibrate the operational BCB model, with particular emphasis on using this data to reproduce the groundwater dynamics. This should include quality reviews of this new data.

The efficiency of the updating or data assimilation methods

The use of real-time observations of flow or water level in the river and channel system to improve forecasts is crucial for obtaining the maximum forecast accuracy. This process known either as updating or data assimilation and is strongly recommended for all forecasting systems, Butts 2002. Updating or data assimilation refers to methods that take into account measurements of water level or discharge in preparing a forecast, adjusting through a feedback process the model to match the observations. Updating is adopted for real-time forecasting to improve the initial state of the system prior to the time of forecast. Furthermore, updating is applied to model correction in the forecast period to account for any inadequacy in the model or in the input data. Updating the forecasts on observed streamflow or water levels provides a practical method of reducing the sensitivity of the flow forecasting model to uncertainties in rainfall data as well as taking advantage of the persistence in hydrologic flows to reduce prediction errors. Within this pilot study a new and efficient updating method will be implemented, (Madsen & Skotner, 2005).

The accuracy of flow and water level observations

Only water level observations (surface water and groundwater) are used within the Big Cypress Basin model and these can be measured with a relatively high precision. The main source of uncertainties is errors in the datum assigned to these measurements.

6.4 Forecast Model Setup

This chapter provides information on the configuration of the real-time updating or data assimilation module. The data assimilation module is based on a new and efficient technique (Madsen & Skotner, 2005) for updating discharges and water level in the river and channel system. A detailed description of this filter-based method is given in the paper by Madsen & Skotner. The method has been implemented with the DA module of the MIKE 11 model.

In broad terms the method first analyzes any deviation between the observed and simulated water levels. In flood forecasting we often apply an error function, which describes a first order autoregessive process.

$$E = A * E(-1) \qquad (1)$$

where the constant A is the correlation coefficient of the errors. This has proven to be a robust error model in many operational forecast models and is also used in the Big Cypress Basin model. The parameter A is either a fixed value or estimated automatically during the forecast. Within the Big Cypress Basin model this coefficient is estimated automatically for each forecast from the deviations between the model and the observations for the 48 hours prior to the time of forecast. This model is then used to forecast the future errors. A filter approach is then used to modify the water levels within the model to match the observations. In all cases a triangular weight distribution is used. The user can modify the length of the channel reach over which this correction is applied by specifying upstream and downstream correction chainages.

The corrections introduced by this method either add water into the reach or extract water from the reach. In this sense this updating method changes the water balance in the system. This is logical as the deviations between the observed and simulated water levels are usually caused by errors in the water balance such as under-estimating or over-estimating the rainfall.

Table 1 The locations within the Big Cypress Basin model used for updating water level

Branch Name	Chainage	Lower Chainage	Upper Chainage	Mike11 File
CocohatcheeWest	*5227*	*4700*	*5300*	*COCOH95_H*
CocohatcheeWest	*8120*	*7600*	*8200*	*COCO3_H*
CocohatcheeWest	*8300*	*8250*	*9000*	*COCO3_T*
CocohatcheeWest	*15071*	*14300*	*15100*	*COCO1_H*
CorkIrrCan1	*3921*	*3821*	*3921*	*CORK*
FakaUnionCan	*10000*	*9600*	*10100*	*FU5_H*
FakaUnionCan	*17580*	*16500*	*17600*	*FU4_H*
FakaUnionCan	*24064*	*24000*	*24200*	*FAKI75*
FakaUnionCan	*45800*	*45700*	*45900*	*FU1_H*
GoldenGateMain	*9334*	*8900*	*9400*	*GOLD_W5_H*
GoldenGateMain	*9534*	*9500*	*10000*	*GOLD_W5_T*
GoldenGateMain	*15675*	*15600*	*15800*	*GOLD_W4*
GoldenGateMain	*34295*	*34200*	*34400*	*GOLD_951*
GoldenGateMain	*38832*	*38200*	*38900*	*GOLD_W2_H*
GoldenGateMain	*39000*	*39000*	*40000*	*GOLD_W2_T*
GoldenGateMain	*42710*	*41900*	*42800*	*GG1_h*
HendersonCr	*3380*	*2900*	*3400*	*HEND84*
HendersonCr	*13500*	*12000*	*13600*	*HENDTAMI_H*
HendersonCr	*13800*	*13700*	*13900*	*HENDTAMI_T*
I-75Can	*6639*	*6000*	*6700*	*D2-8_H*
MillerCan	*6000*	*5900*	*6100*	*BCYPR7*
MillerCan	*9447*	*9400*	*9500*	*MLRI75*
Tamiami1	*9764*	*9700*	*9800*	*TAMIATOM*
Tamiami1	*11050*	*11000*	*11100*	*TAMIBR37*
Tamiami1	*20500*	*20400*	*20600*	*TAMIBR52*

The locations where real time updating (data assimilation) is performed in the real time hydrologic model are listed in Table 1. The list shows data assimilation parameters used in each location. In all cases these correspond to the location of some form of structure. Data assimilation is carried out at all locations where water levels are measured close to a fixed structure. In general, updating at or close to regulating structures should be avoided. However, in the Big Cypress Basin the majority of measured water levels are located close to such structures. In addition, the operation of the gates used in the model only approximately represent the actual operations and it was found that by updating especially upstream of these structures better water level forecasts were obtained. This is discussed in more detail in chapter 6.5. Therefore updating was carried out close to regulating (moveable) structures where these are expected to affect the key forecast locations identified by the Big Cypress Basin staff.

6.5 Tropical Storm Fay 2008

To evaluate the performance of the forecast model during a significant flood event a detailed analysis of the Tropical Storm Fay has been carried out. This section summarizes the main results of this analysis. A complete description of the results of this analysis is given in the report "Big Cypress Basin Real Time Hydrologic Modeling System - MIKE SHE Modeling Technical Memorandum".

Tropical storm Fay, the sixth tropical storm of the 2008 Atlantic hurricane season, made landfall on the Florida Keys late in the afternoon of August 18. The storm failed to reach hurricane levels, remaining a tropical storm but traversed Florida over a period of seven days from August 18-24 and resulted in substantial rainfall across Florida, see Figure 18.

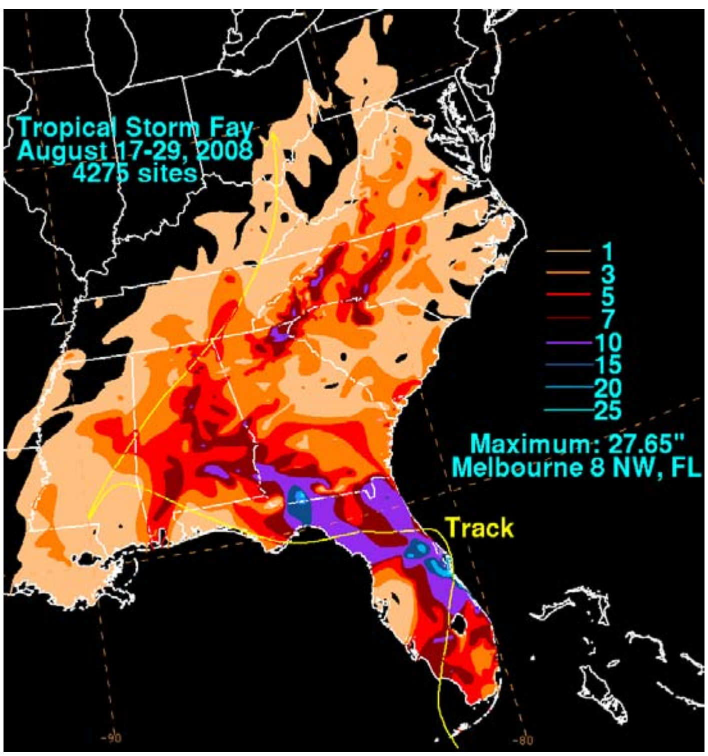


Figure 18 Storm track and total rainfall from Fay over the south east United States

6.6 Rainfall

The rainfall measured in inches during this event for a set of 5 representative gages are shown in Figure 19 - Figure 23. These show that there is substantial rainfall during the 19th but with some variability. For example very little rainfall is measured during that day in the southern part of the model, station DANHP-MR-3LA, while in the north-eastern part of the model at station EXT951-MR-3LA extreme rainfall is observed on the 20th which is not found in other stations shown.

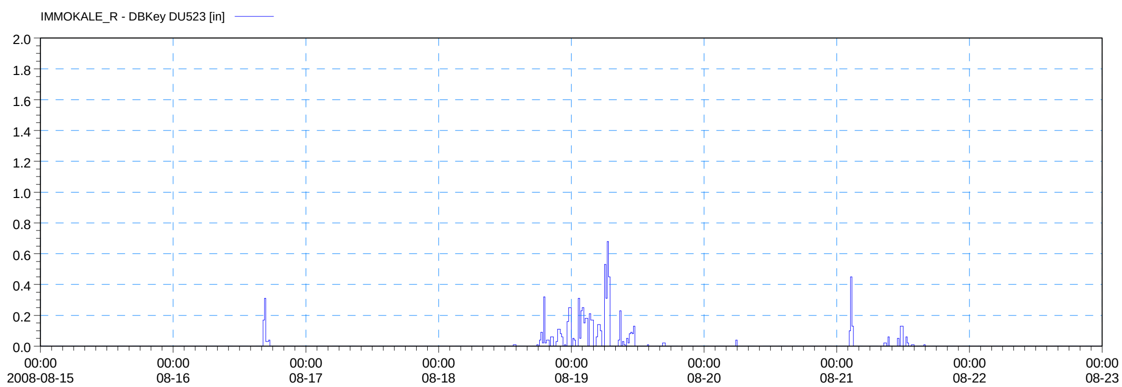


Figure 19 Measured rainfall in mm during tropical storm Fay for station IMMOLF-MR-3LA

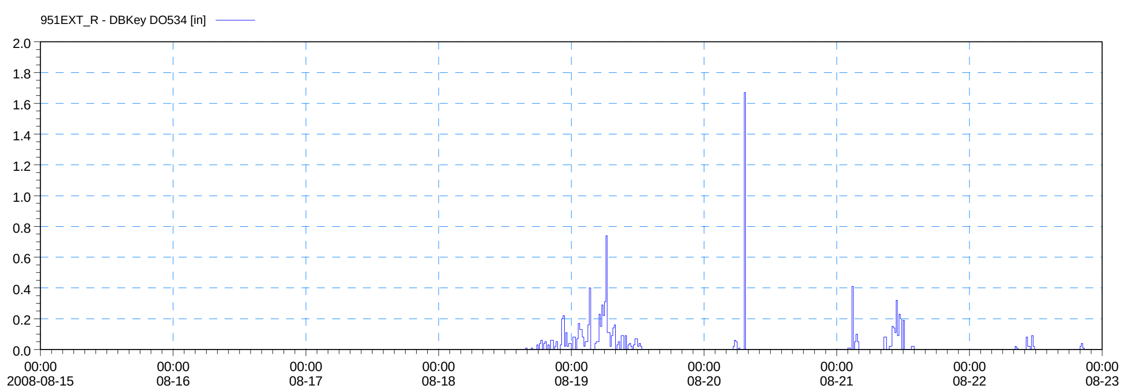


Figure 20 Measured rainfall during tropical storm Fay for station EXT951-MR-3LA

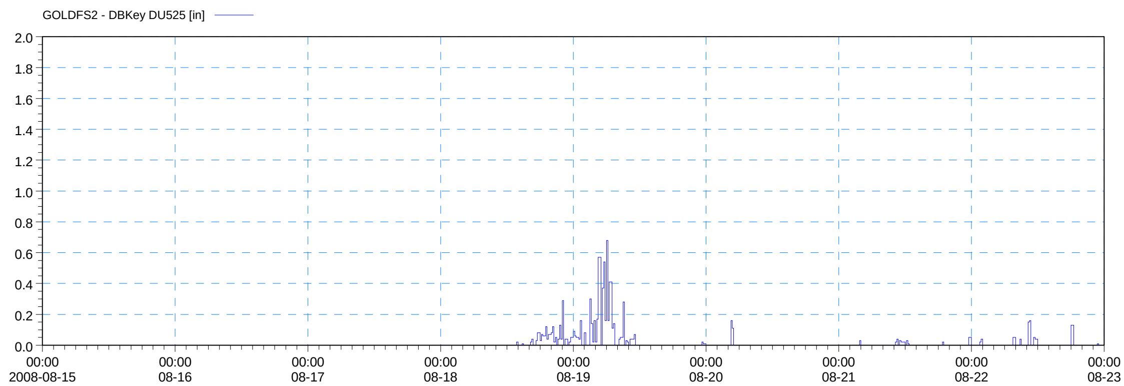


Figure 21 Measured rainfall during tropical storm Fay for station GOLDF2-MR-3LA

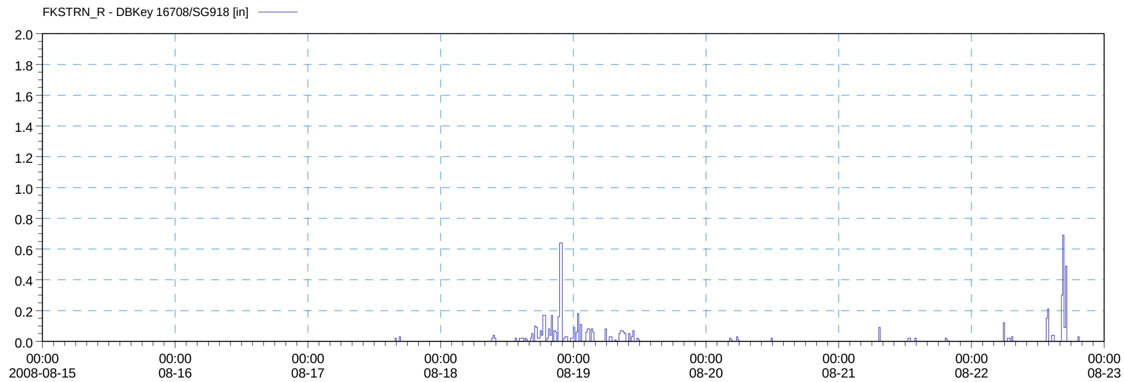


Figure 22 Measured rainfall during tropical storm Fay for station FKSTRN-MR-3LA

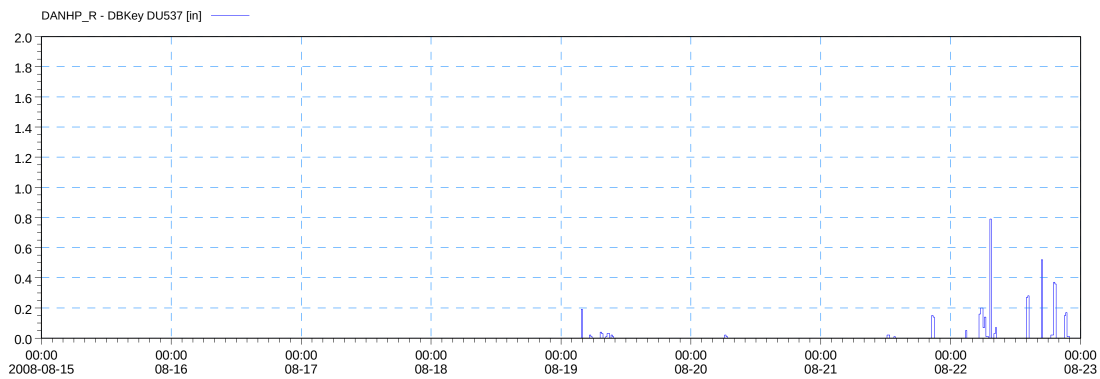


Figure 23 Measured rainfall during tropical storm Fay for station DANHP-MR-3LA

To evaluate the forecast model during Fay a sequence of 4 forecasts is shown in each case. In its' current configuration the BCB system makes water level forecast 48 hours ahead. Each forecast simulation is split into two periods, the hindcast period and the forecast period, see Figure 24. The hindcast period used in the BCB system is 48 hours, and the forecast period is also 48 hours.

During the hindcast period, observations of the actual water levels are used to correct any discrepancies between the water levels simulated by the model in the river and channel system and those that are measured at the same point. This correction is carried out using data assimilation or updating methods. In essence, data assimilation adjusts the level (and volume) of water in the model river system to match the observations. The process of updating or data assimilation used is described in chapter 6.3.

During the forecast period, the future behavior of the water levels is simulated. The start of the forecast period is known as the Time of Forecast (TOF) and obviously, no measurements are available during an actual forecast. However, using historical events such as tropical storm Fay it is possible to evaluate the performance of the forecasting model.

Figure 24 shows the observed water levels for the Golden Gate Tailwater station (GG5) during this event, together with 4 forecasts.

Table 2 Forecasts during tropical storm Fay

	Time of Forecast
Forecast 1	2008-08-18 00:00
Forecast 2	2008-08-19 00:00
Forecast 3	2008-08-19 06:00
Forecast 4	2008-08-18 12:00

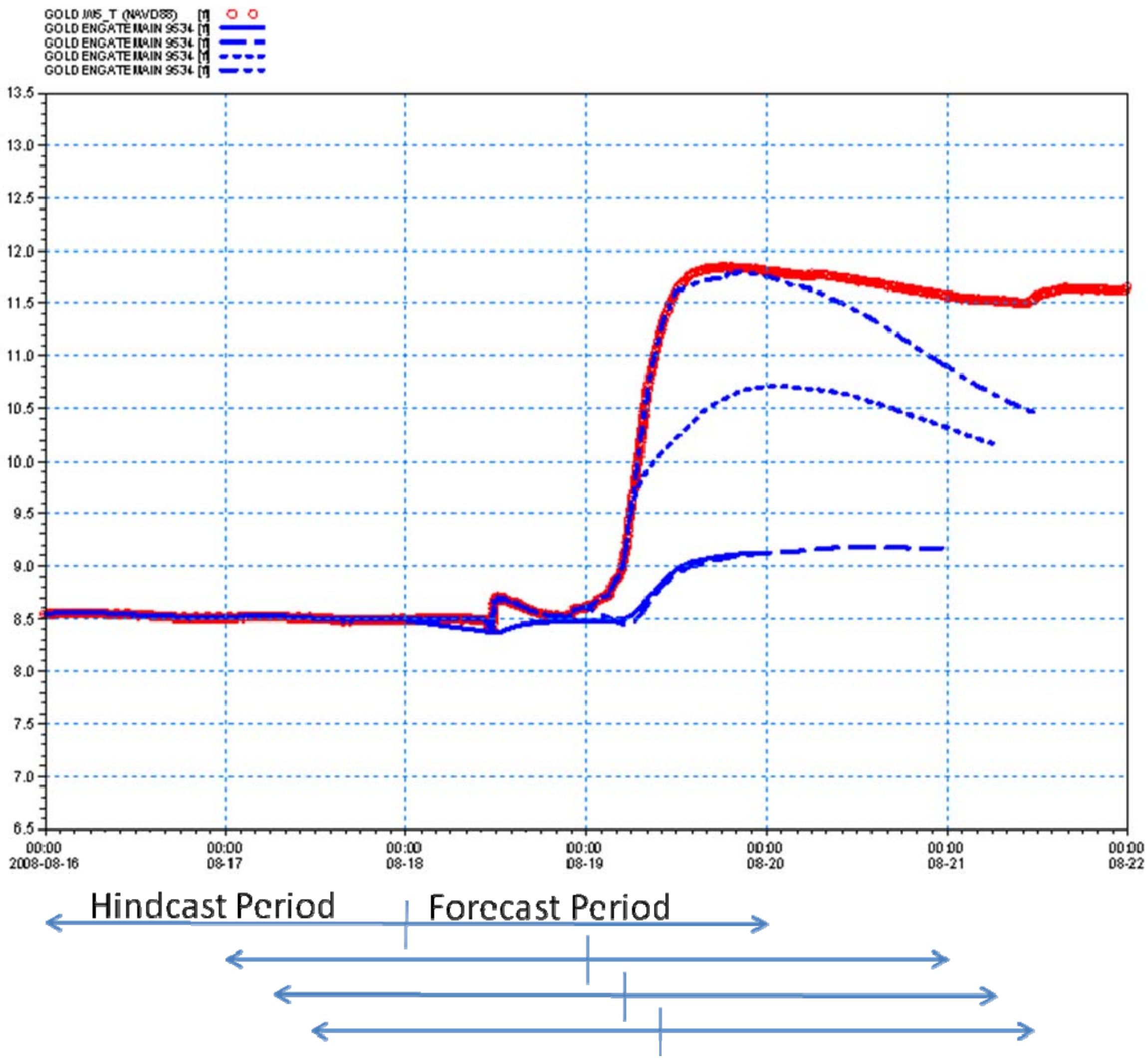


Figure 24 The observed water levels (symbols) and forecasted water levels (lines) for the sequence of 4 forecasts used to evaluate the model during tropical storm Fay.

Forecast 1 is made approximately 36 hours prior to the peak. Forecasts 2, 3 and 4 are made 14, 8 and 2 hours respectively, prior to the peak. In this case, the first two forecasts, 36 and 14 hours ahead of the peak predict a rise in levels but only by approximately a half foot. The actual increase in water level was approximately 3 ft The forecast 8 hours ahead of time show improved accuracy and the forecast just a few hours before the peak captures peak value quite well. This plot indicates reasonable forecasts can be expected around 12-6 hours ahead of the peak. This length of this period however depends on the location of the forecast point in the channel system and the location and distribution of rainfall which will vary from storm to storm.

Surface water gauges

The performance of the forecasting model is illustrated for selected surface water gages. A complete analysis of all gages is given in the report "Two types of forecast locations were identified and shown. Firstly, results are shown where the water levels are measured at locations where there is either no structure or a fixed structure. In all cases the vertical scale is divided into intervals of 0.5 ft. The second set of results is for water levels measured at locations with moveable structures at the same location.

No structures or non moveable structures

The locations of gauging points with either no structures or fixed structures are listed below. For each of these locations the same sequence of forecasts shown in Figure 7 is given. Changes in levels during the hurricane vary from up from 1 ft Faka Union Canal up to 3 ft at Miller Canal.

Table 3 Locations with either fixed structures or no structures where water levels are measured

Abbreviation	*River name*	*Chainage (km)*	*Structure Type*
BCYPR7	Miller Canal	6000	No structure
CORK	Cork Irrigation Canal	3921	No structure
FU1_H	Faka Union Canal	45800	No structure
GOLD951	Golden Gate Main	15675	Bridge upstream
HEND84	Henderson Creek	3380	No structure
TAMIBR37	Tamiami1	11050	No structure
TAMIBR52	Tamiami1	20500	No structure

Overall, a similar pattern in the forecasts is seen. The forecasts improve considerably in accuracy for the short term forecasts, 2 and 8 hours ahead of the peak. There is a slight tendency to underestimate the peaks, which may arise from underestimation of the storm rainfall. However, the peaks are both over- and under-estimated. In the evaluation it is recommended that a comparison of the rainfall over the model area captured using the real-time gauges and using the complete rain gage network should be carried out to identify whether the real-time network is representative of the Big Cypress Basin.

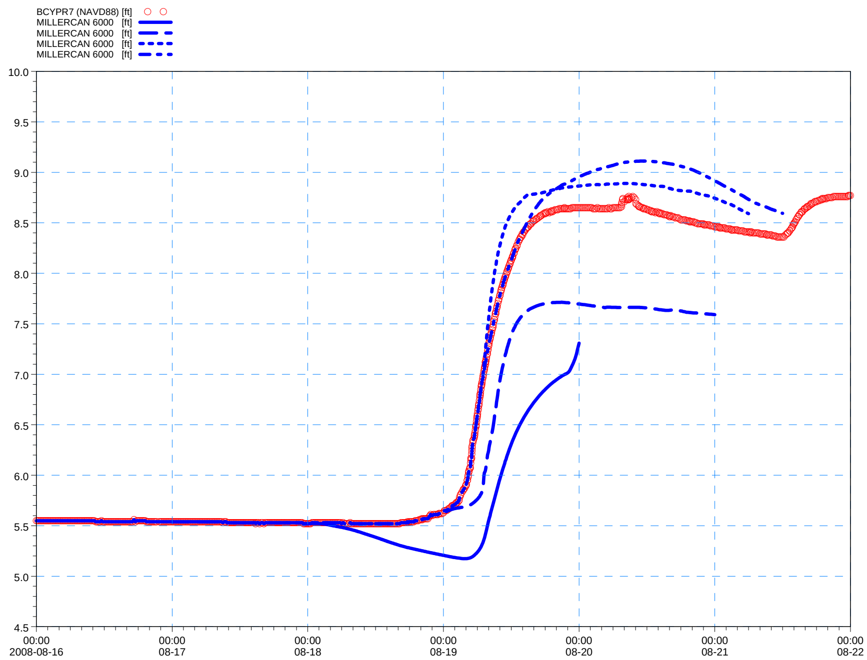


Figure 25 Measured water level (symbols) and forecasted water levels during tropical storm Fay for station Miller Canal

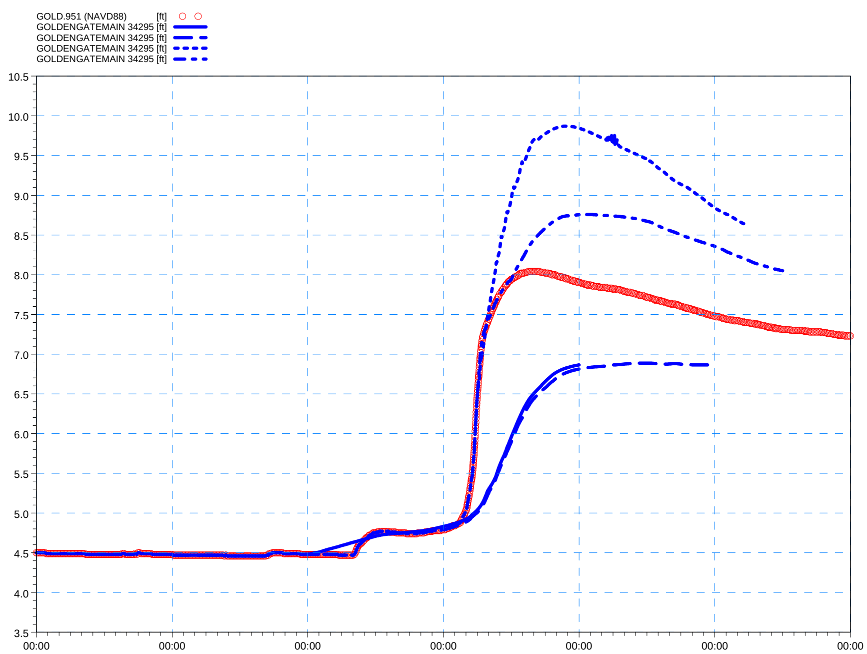


Figure 26 Measured water level (symbols) and forecasted water levels during tropical storm Fay for station Golden Gate Main

Regulating (moveable) structures

Many of the most important forecasting points are at locations where there is also a regulating structure. The locations of gauging points with regulating structures are listed below.

Table 4 Locations with either fixed structures or no structures where water levels are measured

Abbreviation	*River name*	*Chainage (km)*	*Structure Type*
GG5_T	Golden Gate Main	9534	Control structure & weir
GG5_H	Golden Gate Main	9334	Control structure & weir
GG4	Golden Gate Main	29337	Control structure & weir
GG1	Golden Gate Main	42710	Control structure
HC1	Henderson Creek	13500	Control structure
FU4_H	Faka Union	17580	Control structure
FU4_T	Faka Union	17620	Control structure
COCO3_T	Cocohatchee West	8300	Control structure
COCO3_H	Cocohatchee West	8120	Control structure
COCO1_T	Cocohatchee West	15623	Control structure
COCO1_H	Cocohatchee West	15071	Control structure

In reviewing the performance of forecast model for these locations, it appears that the model only approximately captures the behavior at these points. An analysis of why this was the case was carried out. In particular the detailed dynamical behavior of the structure operation is quite complicated in several cases and more dynamic than predicted in the model simulations. Essentially while we are able to match the water levels well in the hindcast period, Figure 27, we are unable to forecast how the control structures will behave in the future, Figure 28.

To match the gate behavior in the forecasts, data assimilation is applied to ensure that the water levels at the gates correspond to the observed levels at the Time of Forecast (TOF). However the forecasted water levels deviate from the observed values after the time of forecast.

The original model concept did not need to represent these dynamics exactly primarily because the model was developed for .water resources rather than short-term water level forecasting. The water levels in the model were conditioned to match measured historical data using only daily water levels. This meant that relatively simple representations of gates could be used whereas for short term forecasting the variations at smaller time steps are needed.

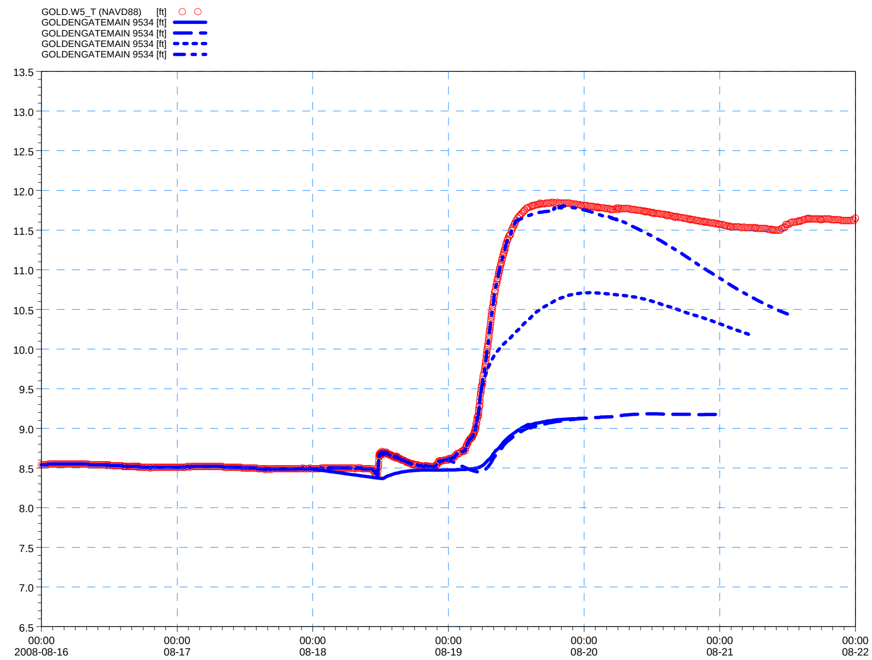


Figure 27 Measured water level (symbols) and forecasted water levels during tropical storm Fay for station Golden Gate Tail Water control structure (GG5_T)

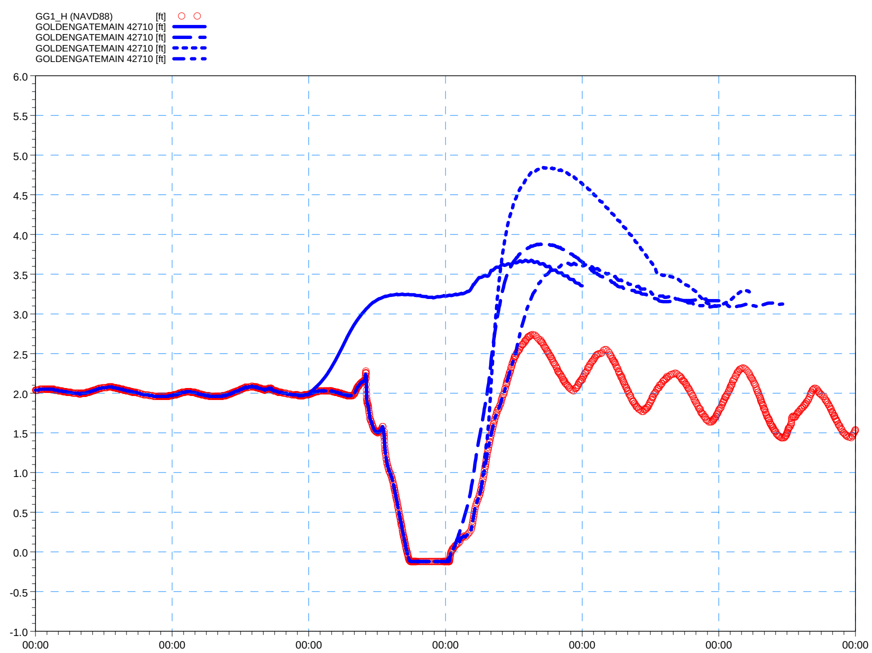


Figure 28 Measured water level (symbols) and forecasted water levels during tropical storm Fay for station Golden Gate 1 control structure (GG1)

It is quite clear from these figures that the water level behavior is strongly controlled by the gate operations and these are very dynamic. In the BCB model developed from the original Picayune Strand model, the gates are operated using historical data of the water levels at the gates. This could be achieved in many cases using a simplified representation of the gates. In effect, the gates were operated in order to match the historical observations. In the evaluation it is recommended that a detailed review of all regulating structures within the BCB model area needs to be carried out. Each structure needs to be represented as accurately as possible including in particular the operating rules governing the independent operation of individual gates within the structure need to be characterized.

Groundwater water levels forecast

Groundwater forecasting is only rarely carried out in operational systems. This is in part because groundwater levels are seldom measured in real-time and in part because changes in groundwater levels can be expected to occur over much longer time scales than changes in the river levels during a storm or flood event. This may not be the case in South Florida because of the close connection between the surface and ground waters in the upper layers.

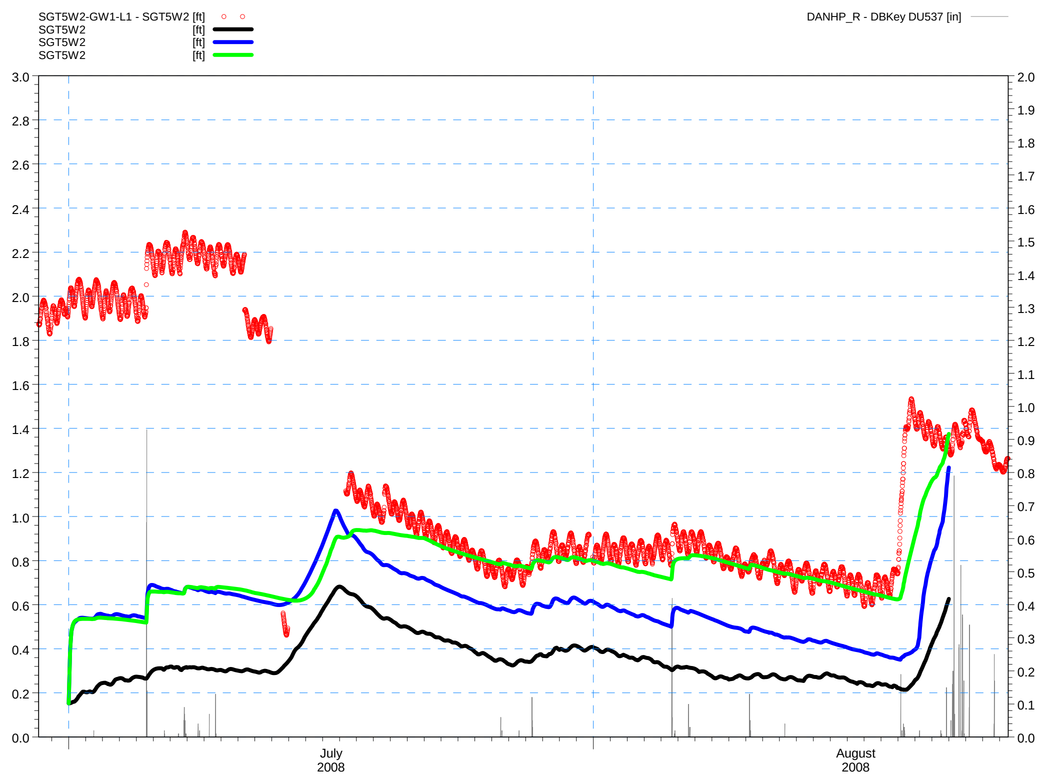


Figure 29 The measured rainfall (grey spikes) and measured groundwater levels (red symbols) during July and August 2008 for the groundwater station SGT5W2. Three simulations are shown. The first (black) curve shows the results from the first BCB model. The second (blue) curve shows the revised BCB model. The third green curve shows the revised model resulting where data assimilation has been used to correct the river levels.

This is highlighted in Figure 29. This figure shows 5 different curves. The gray spikes show the temporal distribution of rainfall during July and August including the period affected by tropical storm Fay for the rain gage closest to this well. The red symbols show the measured groundwater levels. It should be noted that the jumps and variations in early July are not yet fully understood. They probably represent changes in the datum used and therefore only the observations from mid July should be considered.

There are several important features in this plot. Firstly, just comparing the groundwater changes and the rainfall we see a rapid increase in the groundwater levels of about 1 ft over a few hours. Secondly, this rise occurs before the large amount of rainfall measured locally. Nevertheless the timing of this peak is captured reasonably well by the BCB model simulations shown. Three model simulations are shown.

The first (black) curve shows the simulation using the original BCB model implemented in the Big Cypress Basin Real Time Hydrologic Modeling System. Ignoring the first part of July, the model underestimates the groundwater level by one half foot. Model simulations of groundwater levels can be considered acceptable if they within one foot so this is acceptable. Differences between the measured groundwater levels and simulated levels of 1 foot can easily arise as the measurements represent a single point where as the simulated levels are the average over a model grid. The fact that these levels are so close is in fact quite surprising as the real-time groundwater levels collected by the Big Cypress Basin Real Time Hydrologic Modeling System are new wells. Data for these wells were not available when the PSRP model was constructed.

The timing of the rise seems to be correct but the rate of rise predicted by the model is much slower than in reality. In retrospect this might have been expected because the BCB model has been calibrated using daily data and therefore any variations on the sub-daily scale would not be apparent. This indicates that the new real-time data will be a useful source of information about the dynamics of the upper groundwater system in future model studies. In order to address this issue and a revision of the BCB model was carried out increasing the surface leakage factor used. The surface leakage factor controls flows between the flooding on the surface and the groundwater. The (blue curve) results shown in Figure 29 show a positive improvement in the dynamics. As several other factors also affect the groundwater dynamics further work is required to reproduce more accurately the actual dynamics. The current BCB model running operationally in the Big Cypress Basin Real Time Hydrologic Modeling System is this revised BCB model. It is recommended that the new groundwater level real-time data should be used to recalibrate the operational BCB model, with particular emphasis on using this data to reproduce the groundwater dynamics. This should include quality reviews of this new data.

Because of the close connection between the surface water dynamics and the groundwater it was decided to run a final simulation for the whole period using the revised BCB model combined with updating of the water levels in the river system using the observed water level to correct the model river levels. The results of this simulation are shown by the green curve. While it appears that this further improves the simulated groundwater levels this may be coincidental. What is important to note and extremely interesting in terms of understanding the BCB system is that the river levels have a strong influence on the groundwater levels in this case.

The inherent complexity of this system is illustrated in for the nearby groundwater gage SGT5W1. In this case, the groundwater rise coincides with the local rainfall for the earlier rainfall events as well as the heavy rainfall during tropical storm Fay. The revised BCB model appears to capture the groundwater levels quite well and the dynamics. Updating of the river levels in this case also raises the levels but the final levels are now over-estimated. In other parts of the model area further work must be carried to improve model accuracy where the differences in model behavior are significant.

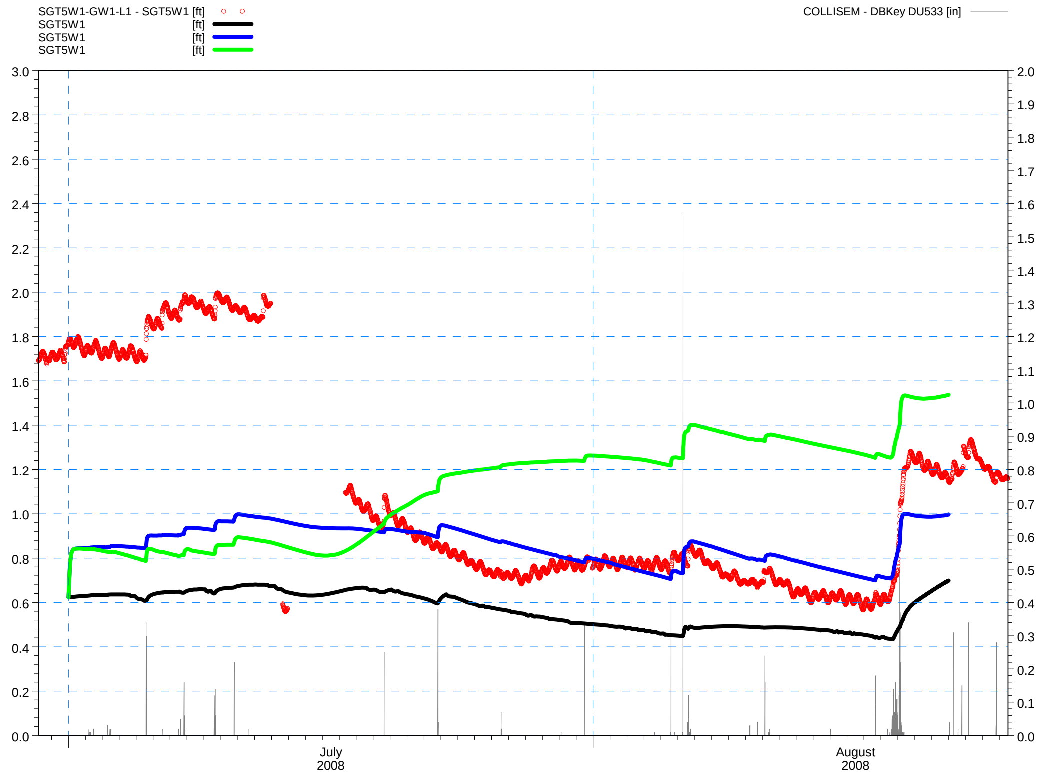


Figure 30 The measured rainfall (grey spikes) and measured groundwater levels (red symbols) during July and August 2008 for the groundwater station SGT5W1. Three simulations are shown. The first (black) curve shows the results from the first BCB model. The second (blue) curve shows the revised BCB model. The third green curve shows the revised model resulting where data assimilation has been used to correct the river levels.

7 SETUP OF THE ON-LINE MONITORING SYSTEM

7.1 Outline

In this chapter, the configuration of the on-line system is described, including

- Interfacing to the SFWMD real-time data
- Sensor definition
- Data QA protocol
- Data handling
- Event definition
- Data presentation

7.2 Interfacing to the SFWMD real-time data

In server BCBMOD01P a SQL Server Express database has been installed for interfacing the TELVENT system data with FLOOD WATCH. Time series data exported from TELVENT to FLOOD WATCH are put into a table, Floodwatch, in the database. FLOOD WATCH picks up the data at regular intervals (currently hourly).

7.2.1 Import.exe

A custom made program, Import.exe, is used to extract the data from the SQL Server table to the FLOOD WATCH database. The program is located in sub-folder Import. When run without command-line arguments a graphical user interface is displayed opening for configuration of the program.

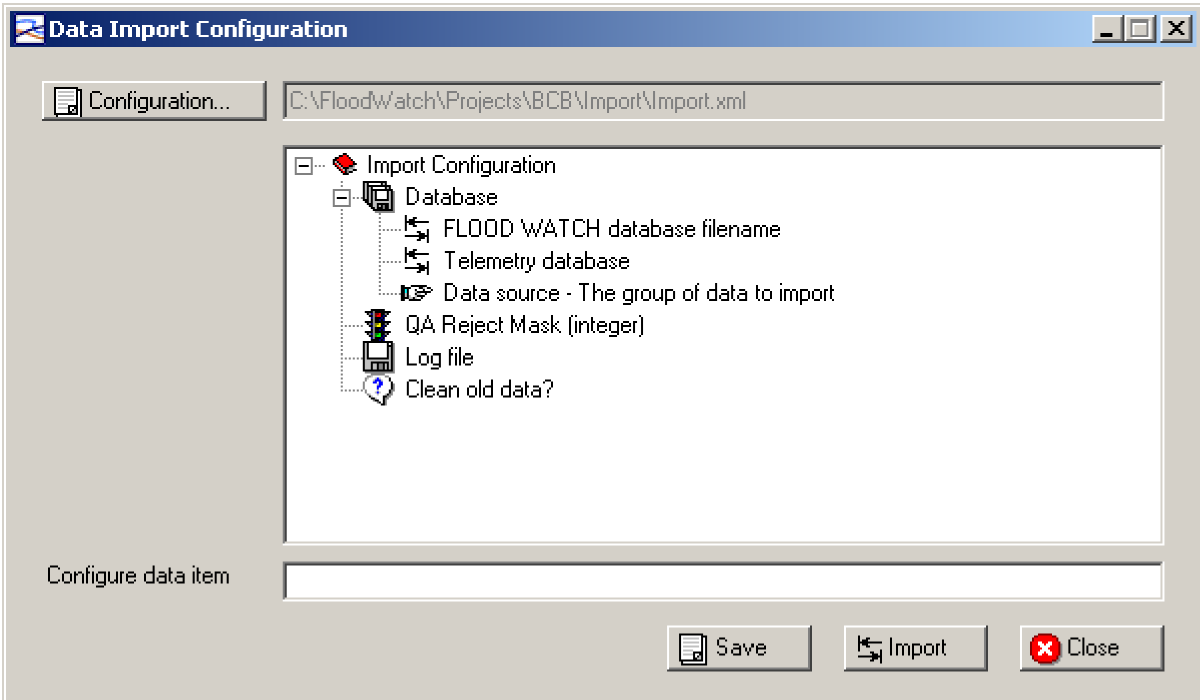


Figure 31 User interface for the customized executable developed to import data from the SFWMD SQL data to the Big Cypress Basin Real Time Modeling system

The configuration file contains information about the specifics of the databases to use and other settings, especially the QA mask to use when verifying the quality of the telemetry data.

The QA mask has been set to a value of 14748 which corresponds to this bit pattern

State	Bit	Description
	1	Restart
	2	Tag
SET	3	Test Mode TAG
SET	4	Offscan
SET	5	Stale Data
	6	Manual Override
	7	Out of Calibration limits
SET	8	Instrument Fail High Alarm
SET	9	HiHi alarm
	10	Hi alarm
	11	Lo alarm
SET	12	LoLo alarm
SET	13	Instrument Fail Low Alarm
SET	14	System record
	15	Historical
	16	Uncertain quality bits
	17	User defined
	18	User defined

19 User defined
20 User defined
21 User defined
22 User defined
23 User defined
24 User defined
25 User defined
26 User defined
27 User defined
28 User defined
29 User defined
30 User defined
31 User defined
32 User defined

Any readings with one or more of these bits set will be discarded.

When run with the name of the configuration file as command-line argument the program will carry out the import according to the settings in the file.

The program retrieves settings from the FLOOD WATCH database about which sensors to look for data for and then builds the SQL query to get available data for each sensor. Readings with bad quality is discarded as are duplicate readings. Other data is inserted into FLOOD WATCH via the standard API, which ensures formatting and processing is carried out. During this process any configured offsets are added to the level data.

The program produces a log-file on the progress, see below.

```
2008-08-26 04:01:03 Starting Import from Datasource Telemetry ...
2008-08-26 04:01:03 Loading data from telemetry database
2008-08-26 04:01:30 connecting to FLOODWATCH database
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/19/2008 5:45:00 AM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/19/2008 7:24:56 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/20/2008 5:34:47 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/21/2008 6:44:48 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/22/2008 11:13:09 AM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/22/2008 12:44:51 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/23/2008 12:34:47 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/23/2008 12:37:28 PM, QualityCode=8208
2008-08-26 04:01:31 Skipped reading - StateID=BARW4-L1, Time + 8/23/2008 2:14:48 PM, QualityCode=8208
2008-08-26 04:01:31 BARW4-L1 - 689 steps between 2008-08-19 03:15:00 and 2008-08-26 03:45:00
2008-08-26 04:01:34 Cleaning of data skipped
2008-08-26 04:01:34 Skipped reading - StateID=BARW6A-L1, Time + 8/19/2008 5:44:48 AM, QualityCode=8208
2008-08-26 04:01:34 Skipped reading - StateID=BARW6A-L1, Time + 8/19/2008 4:59:23 PM, QualityCode=8208
2008-08-26 04:01:34 BARW6A-L1 - 691 steps between 2008-08-19 03:15:00 and 2008-08-26 03:45:00
2008-08-26 04:01:36 Cleaning of data skipped
2008-08-26 04:01:36 BCYP7-L1 - 853 steps between 2008-08-19 03:15:00 and 2008-08-26 03:45:00
```

```
2008-08-26 04:01:37 Cleaning of data skipped
2008-08-26 04:01:37 COC951-L1 - 779 steps between 2008-08-19 03:11:00 and 2008-08-26 03:45:00
```

Following import a separate script is run which simply deletes any readings in the SQL server table with a System time older than 14 days. This effectively means that FLOOD WATCH imports and overwrites 2 weeks readings every hour. This will allow data for a sensor to be added to FLOOD WATCH after a fall-out if it is back online within the 2 weeks period.

All data received by FLOOD WATCH is being stored so far, but automatic maintenance can be configured if it proves necessary to reduce the amount of stored data.

8 SET-UP OF THE ONLINE MODELING AND FORECASTING SYSTEM

8.1 Outline

In this chapter, the configuration of the on-line system is described, including

- Sensor definition
- Registration of models
- Scenario definition for design rainfalls
- Scheduling
- Making a manual forecast
- Publication of results
- Flood mapping

8.2 Sensors and import of data

A sensor in the FLOOD WATCH system represents a time series at a location.

Based upon the information provided in the Excel file “BCB Sites 080804.xls” (and other versions thereof) one sensor has been created for each real-time gauge. The FLOOD WATCH database, BCB.MDB, contains the catalogue of the information whereas the actual time series data is stored in files in sub-folder Telemetry, one file per time series.

The sensors are named by their OASys point id and the time series files are pre-fixed with identifiers indicating data type.

Data Type	pre-fix	example
Discharge	od -	od - GG1-W3-Q.dfs0
Water Level	ow -	ow - BARW4-L1.dfs0
Gate position	og -	og - HC1-G1-L1.dfs0
Bore hole pressure	op -	op - I75MZ-BH1-P.dfs0
Forecast water level	fw -	fw - NOAA Naples Tidal Prediction.dfs0
Evaporation	oe -	oe - BCMAR-MA-8EM.dfs0
Rainfall	or -	or - COCO1-MR-3LA.dfs0

The locations, so-called features, are created in the ArcMap layer MonitoringPoint, based on coordinates provided in above mentioned spreadsheet.

During import all levels (surface water, gate levels and well levels) are datum corrected as the incoming data are in NGVD29 and the model operates in NAVD88. These adjustments are implemented as a linear processing in FLOOD WATCH.

Appendix C lists the created sensors, time series and processing rules.

8.3 Model Registration

Model registration is the process of linking the input and output time series of the model with the sensors in FLOOD WATCH and registering all the files that constitute a model setup.

Once registered the model setup acts as template for actual simulations (model runs) which use copies of the model files together with time series files filled with actual data to make a unique setup to run.

During the model import the input and output time series are identified by the software, but the user must manually link each series with sensors in the database, thus assigning a reference for the model time series to the telemetry/sensor system in FLOOD WATCH.

8.3.1 Model Import

The actual model import is carried out this way:

1. First a complete setup with setup files, inputs, outputs and log files are copied to a sub-folder to the FLOOD WATCH Project directory. In BCB the model files are stored in "Model\BCB FW08 DA".

2. Once the model structure is in place the FLOOD WATCH Model import is started in ArcMap.

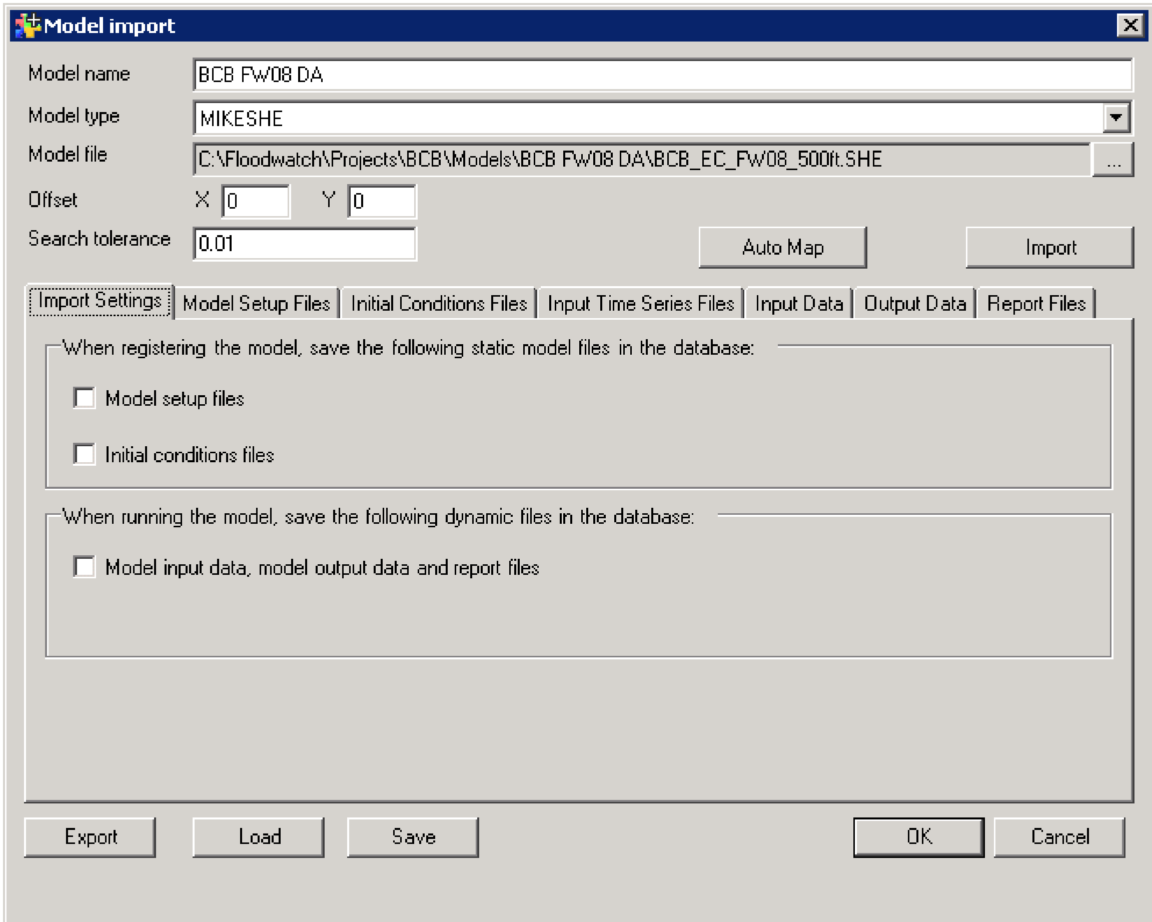


Figure 32Model import editor in the FLOODWATCH GIS interface

The main simulation file is specified and the Import button pressed. This parses the model setup files and returns FLOOD WATCH relevant details.

3. The model setup files are the static files used by the MIKE SHE and MIKE 11 configuration.

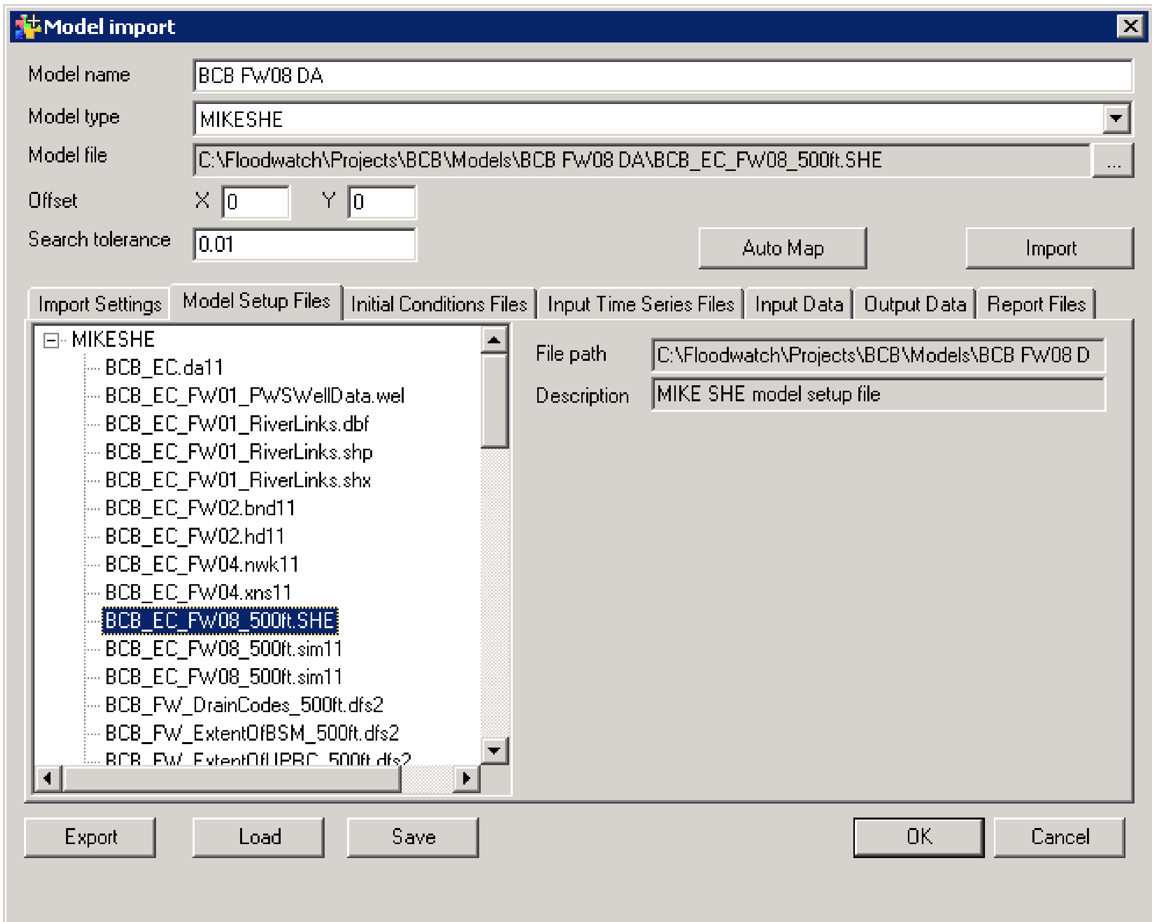


Figure 33 The real time BCB Model set-up files

4. The Initial conditions are the hot start files as they are referenced by MIKE SHE and MIKE 11.

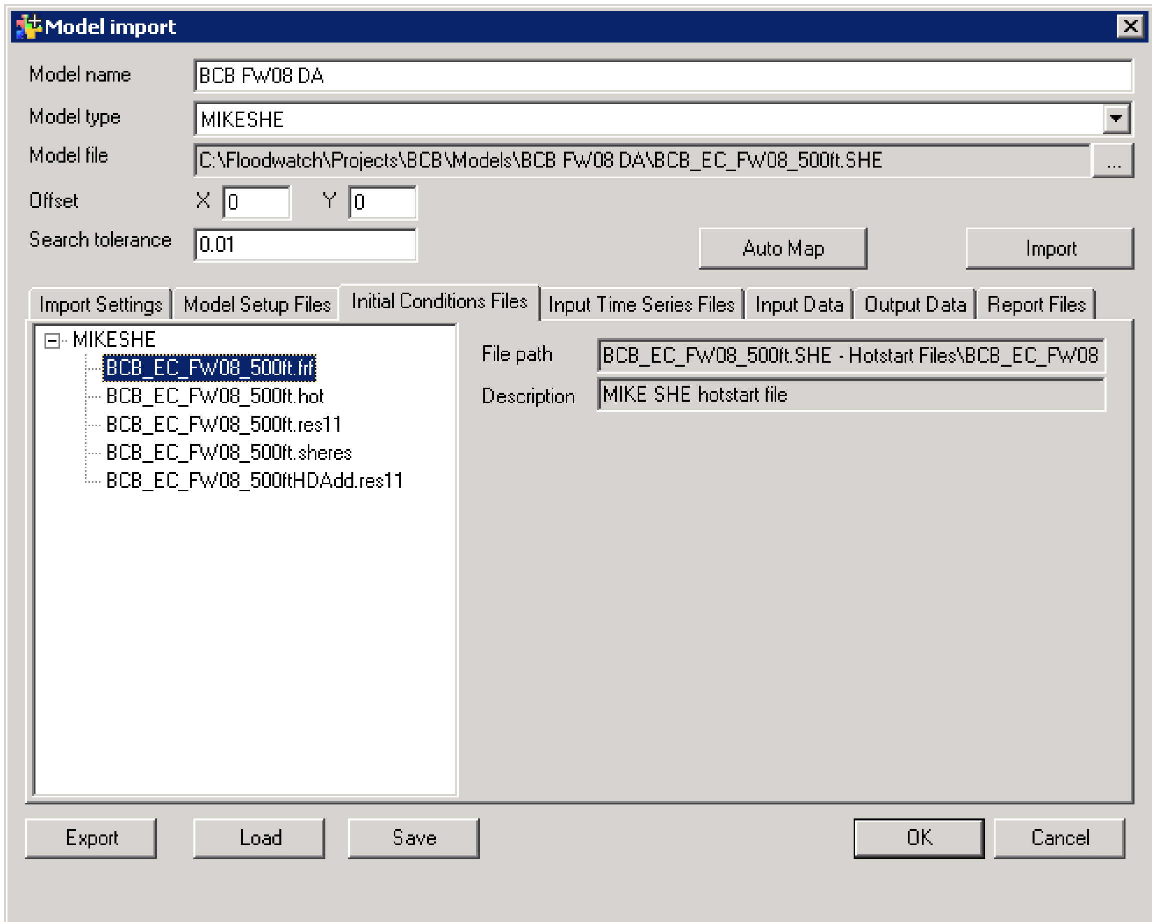


Figure 34 Initial condition files for the real time BCB model

5. The Input Time Series Files are dfs2 files used by the model. In this setup they are static containing input time series extending until 2011. Hence, no special registration is necessary – the files are regarded as static model files (and will be transferred to the list of Model Setup Files once the OK button is pressed).

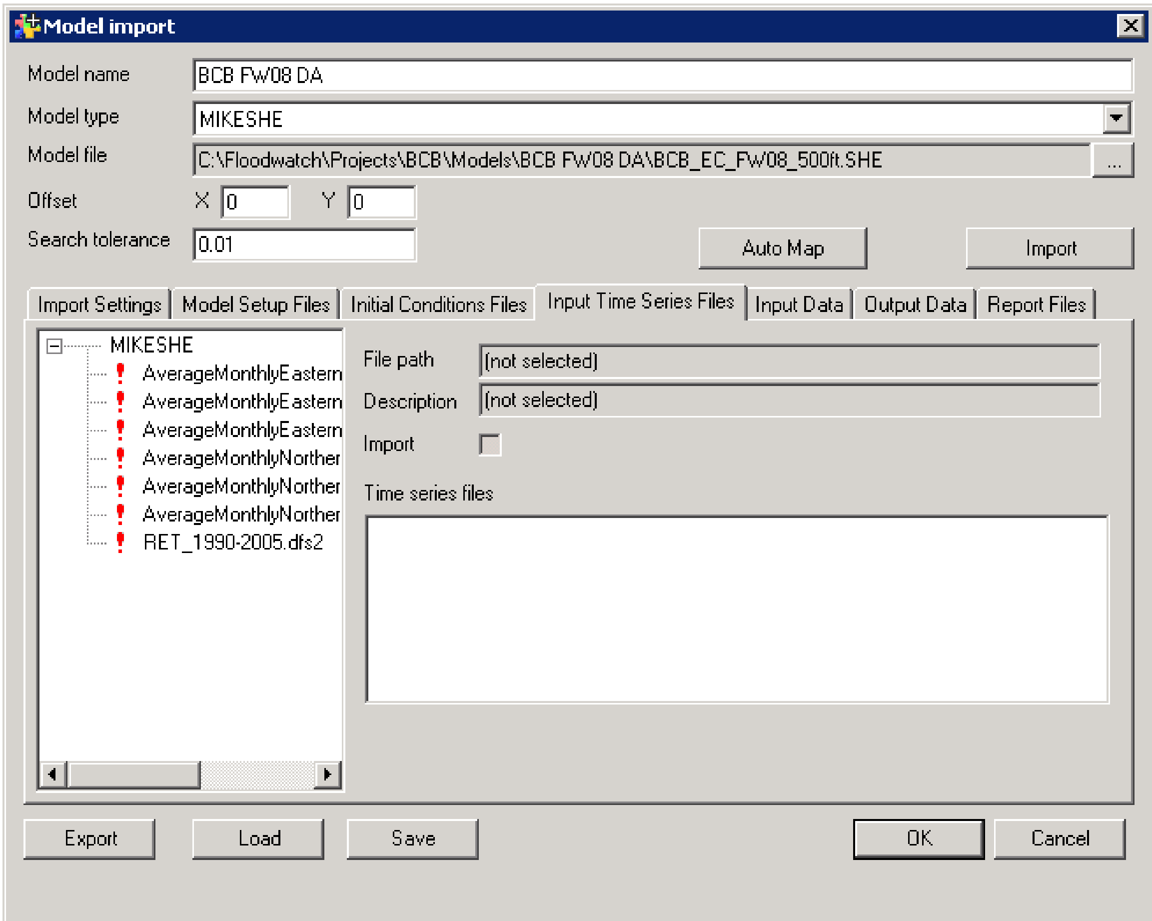


Figure 35 Input time series files for the real time BCB model

6. The Input Data links the point time series (dfs0-files) used by the model to the sensors in FLOOD WATCH. For each of the real-time time series we link the time series in the model to the corresponding FLOOD WATCH sensor.

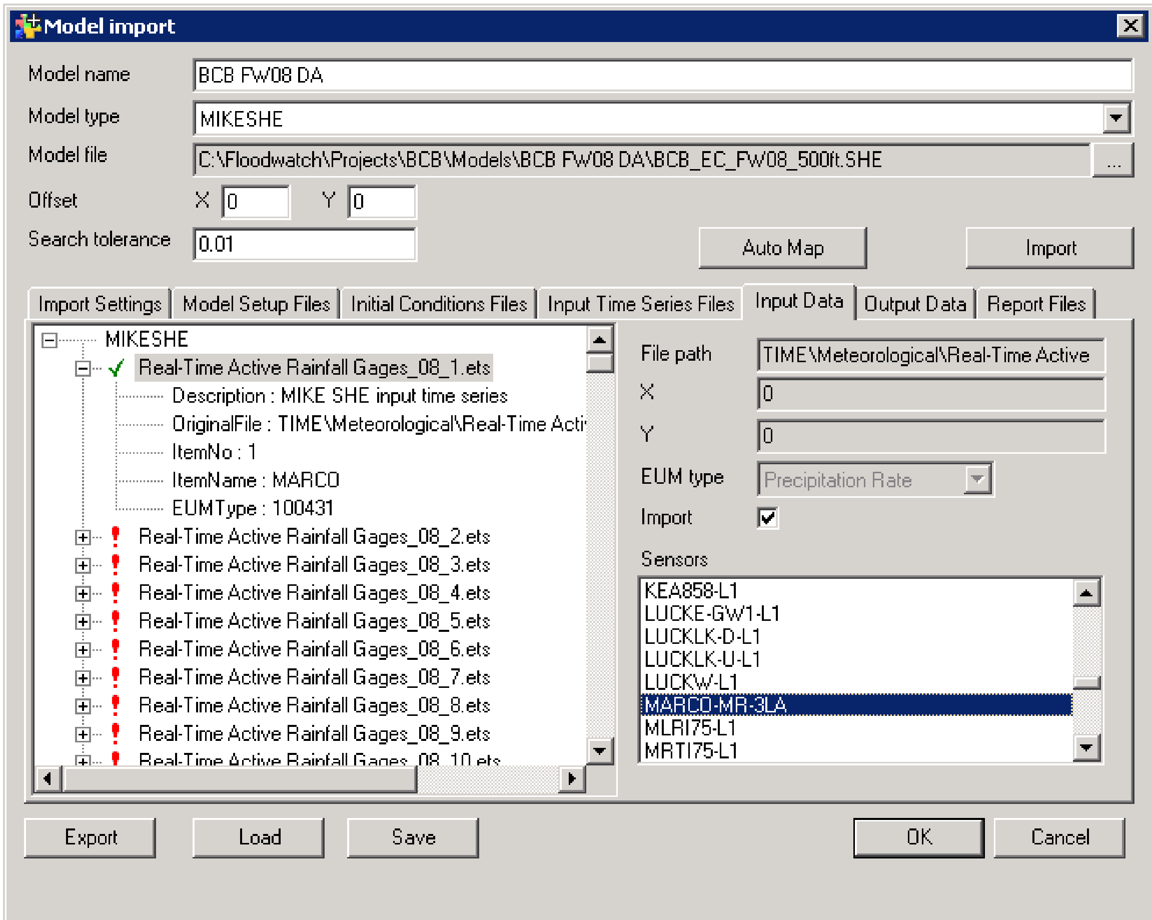
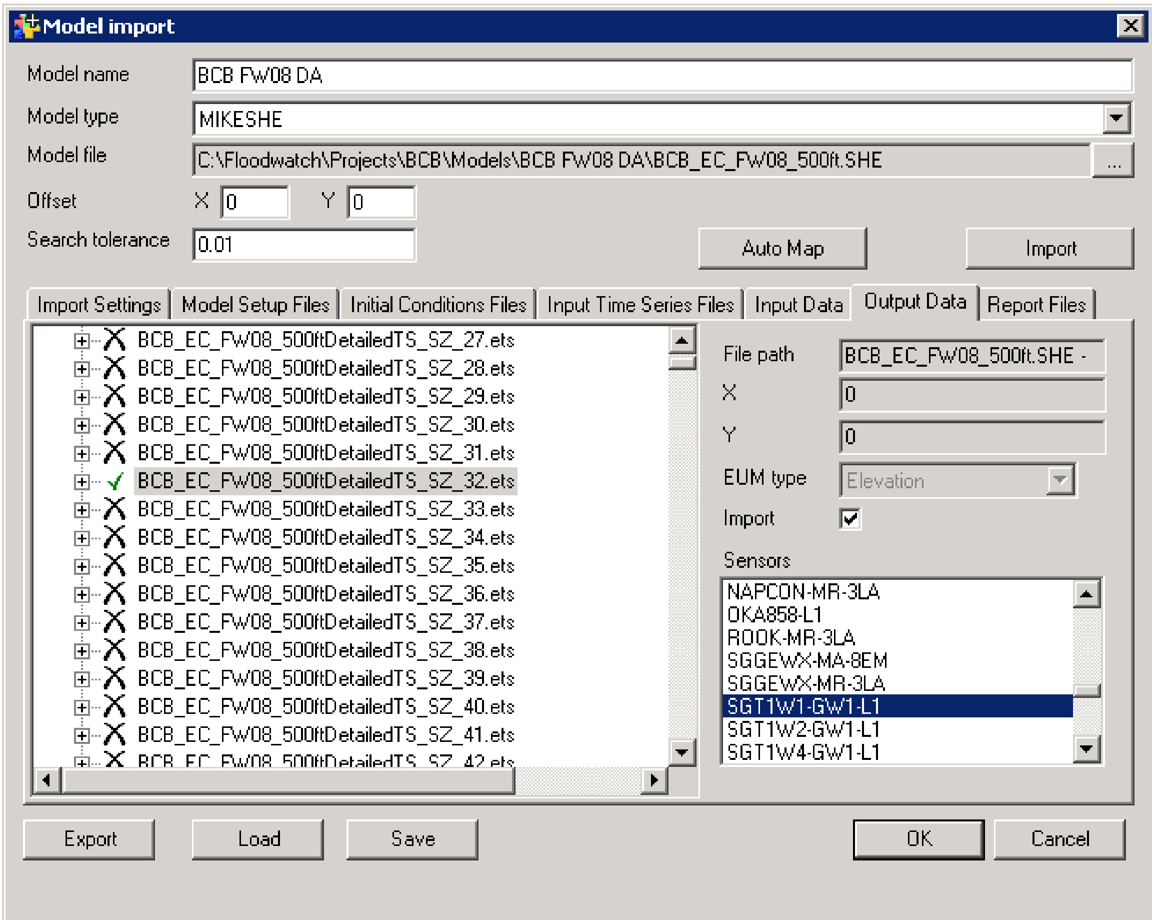


Figure 36 Input data files for the real time BCB model

7. For estimated time series like evaporation and pumps we do nothing. The model files are already filled with time series until 2011 and are regarded as static model files in FLOOD WATCH context (and will be transferred to the list of Model Setup Files once the OK button is pressed).

8. The Output Data list shows all the possible output time series available in the model. For selected forecast points the link between the output time series and the corresponding sensor is made and a tick is set in “import”



9. The Report Files are the possible log files. Two of the files are binary, and not interesting to reister.

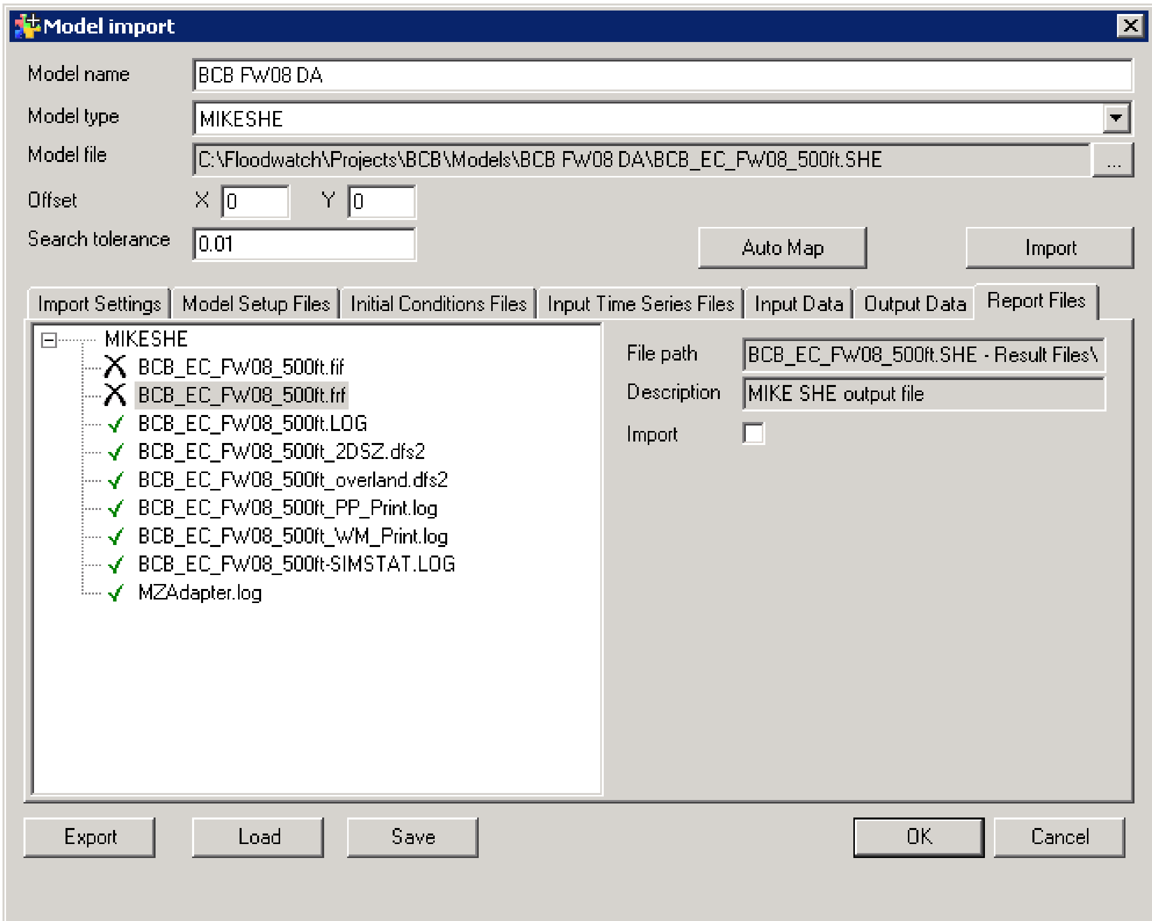


Figure 37 Reports and log files associated with the real time BCB model

When all is registered it is wise to Save the configuration in an XML-file. In case the database update fails, this file can be a starting point for a new attempt.

Pressing OK gives a warning to which it is OK to press Yes.

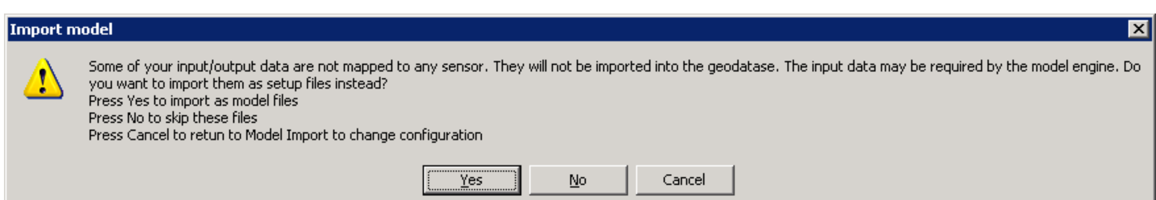


Figure 38 Saving a partial configuration

All the definitions are then inserted into the database. Once complete a couple of manual edits have to be performed in both ArcMap as well as in some of the files in the setup.

a) The initial conditions are registered without dates. Using ArcMap (Floodwatch->Configuration->Model->Initial conditions) these can be entered manually.

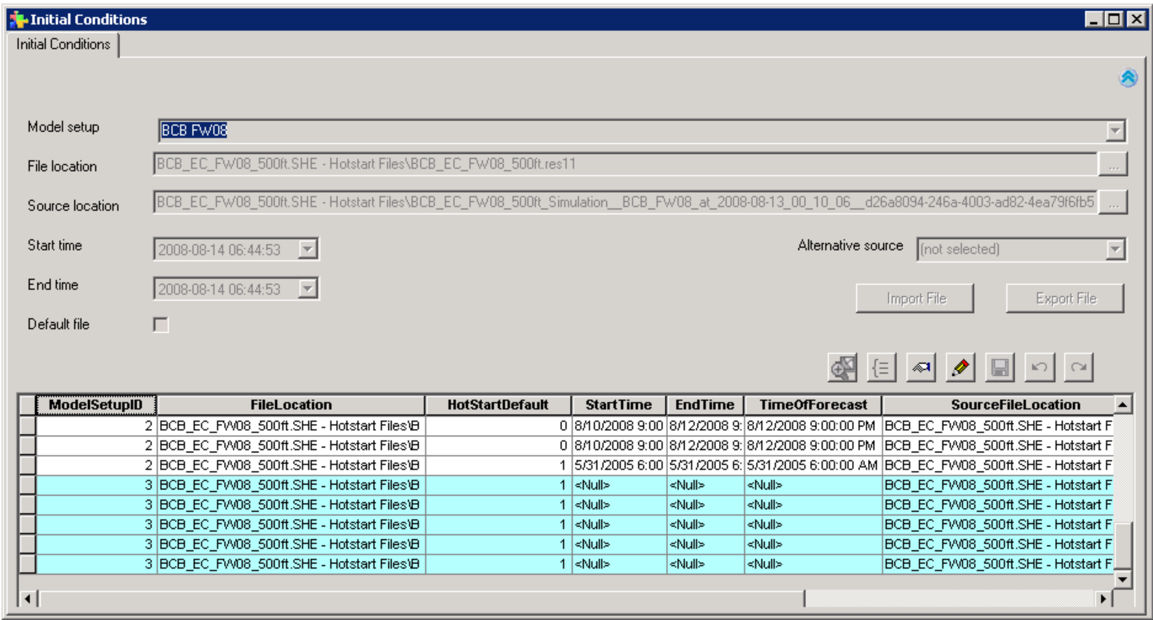


Figure 39 Registering dates for the hotstart files

b) MIKE SHE stores the detailed output in ISO units (e.g. m for levels). In order to convert to US units when extracting the time series we can edit the file MZAdapterConfig.xml which was created during import.

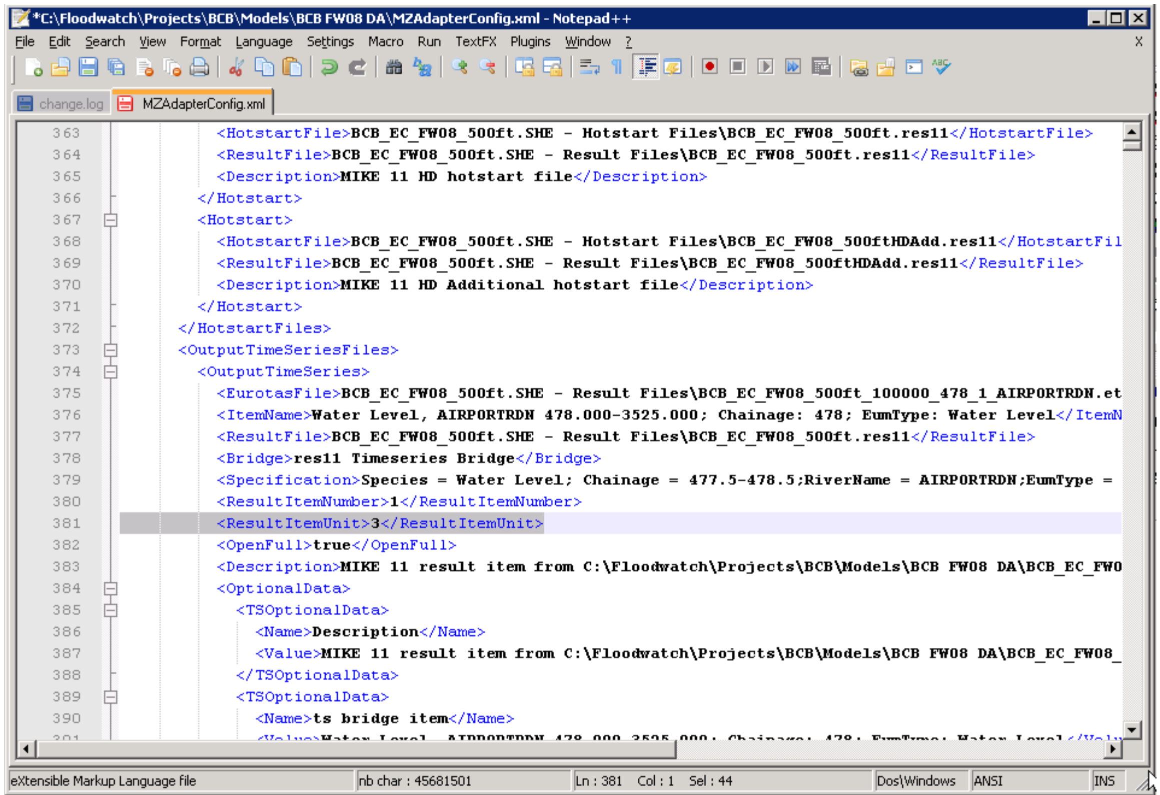


Figure 40 Converting the internal model results from SI units to US units

c) Change

<ResultItemUnit>1</ResultItemUnit>

to

<ResultItemUnit>3</ResultItemUnit>

in the first 1304 OutputTimeSeries items. And also change

<ResultItemUnit>1</ResultItemUnit>

to

<ResultItemUnit>2</ResultItemUnit>

for all the 50 output timeseries referring file

BCB_EC_FW08_500ftDetailedTS_SZ.dfs0

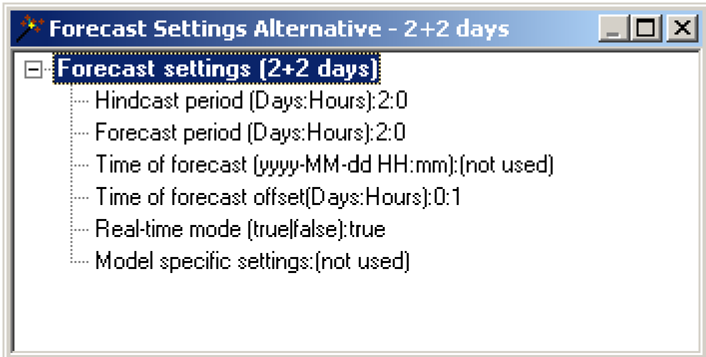
8.3.2 Define Base Scenario

The model is now imported, but not yet ready to be run from within FLOOD WATCH. To run the model we need to define the so-called Scenario, which among other things defines how the real-time input is put together for the actual run.

A scenario consists of a selection of 5 alternatives: one for forecast settings, one for input data, one for input time series files, one for output data and one for report files. Each of the alternative apply actual settings to the previously imported model definitions

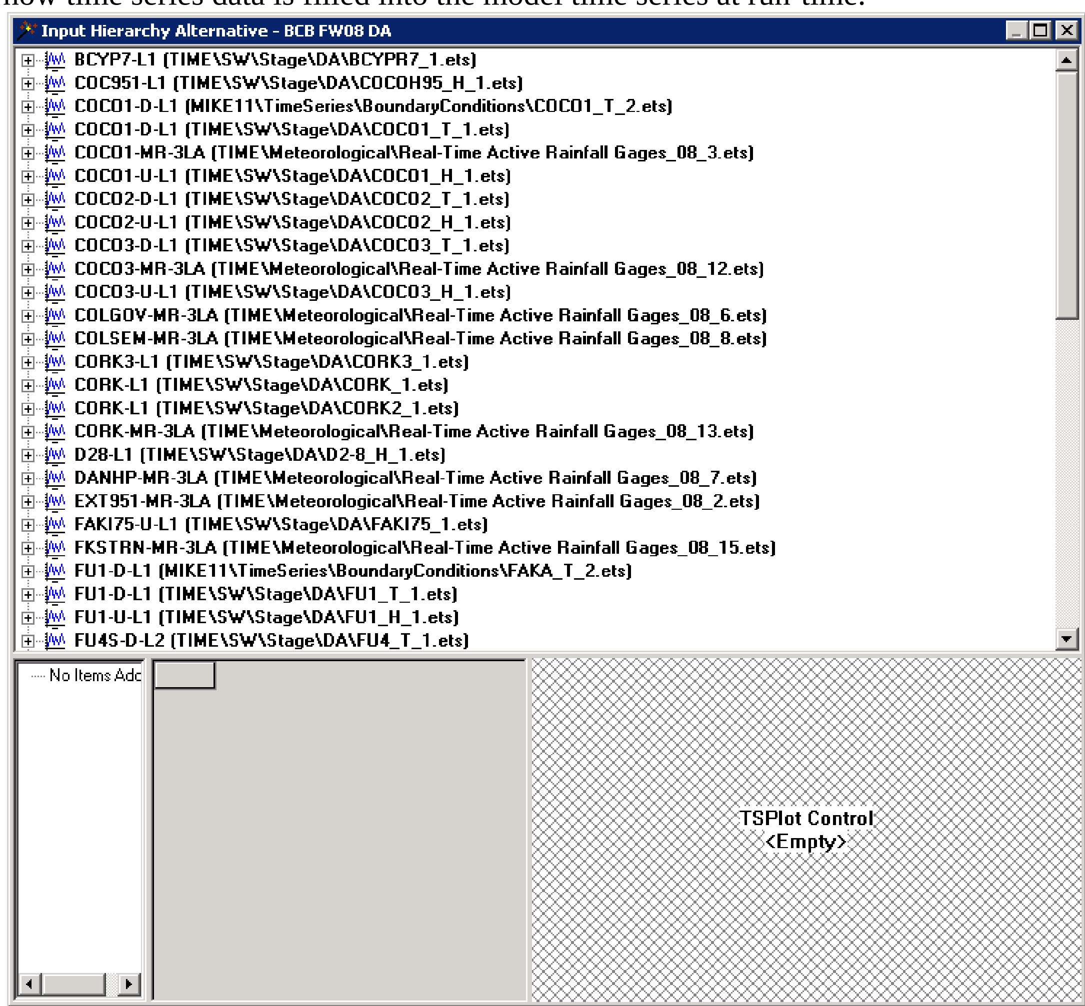
a) Open Scenario Manager from the Floodwatch menu and choose the Alternative tab-page.

b) Specifying the Forecast Settings allows defining the simulation period and how the time of forecast is determined.



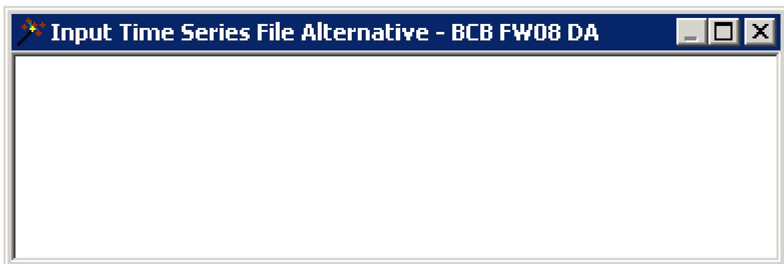
An offset of 1 hour means that the Time Of Forecast is calculated a one hour back from time now of the machine rounded to the previous quarter. The Start Of Simulation in then 2 days prior to Time Of Forecast and End Of Simulation 2 days later.

c) Adding the Input Hierarchy (select the imported model name) gives a rough definition of how time series data is filled into the model time series at run-time.

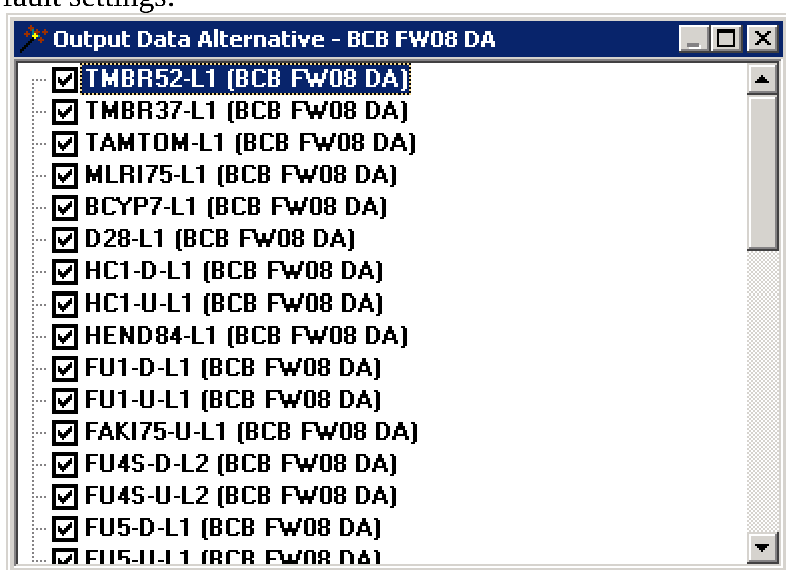


To a start all hierarchies contain one method: Raw data. For the boundary time series and the rainfall time series it is necessary to add definitions to extend the time series beyond observations such that they have data for the entire simulation period. Otherwise the model cannot run.
For rainfall a constant of 0 is added. The level boundaries are all tidal; hence an extension using the astronomical tide predictions can be used. However, since only the tidal predictions at Naples are available a scaling via a linear function has been applied, adjusting the amplitude and offset of the signal to match that of observations.

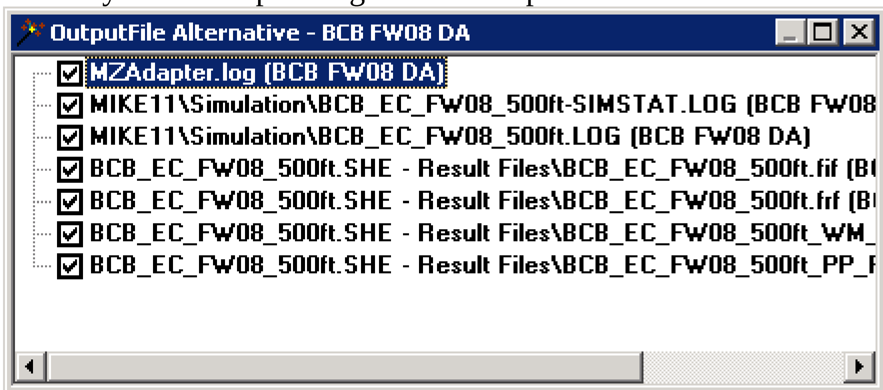
d) The Input Time Series Files alternative is empty as all dfs2-files are treated as static model files.



e) The Output Data alternative lists the defined outputs. We want them all and keep the default settings:



f) Similarly do we keep settings for the Output File alternative



On the Scenarios tab-page a new scenario can now be created by selecting the 5 above alternatives.

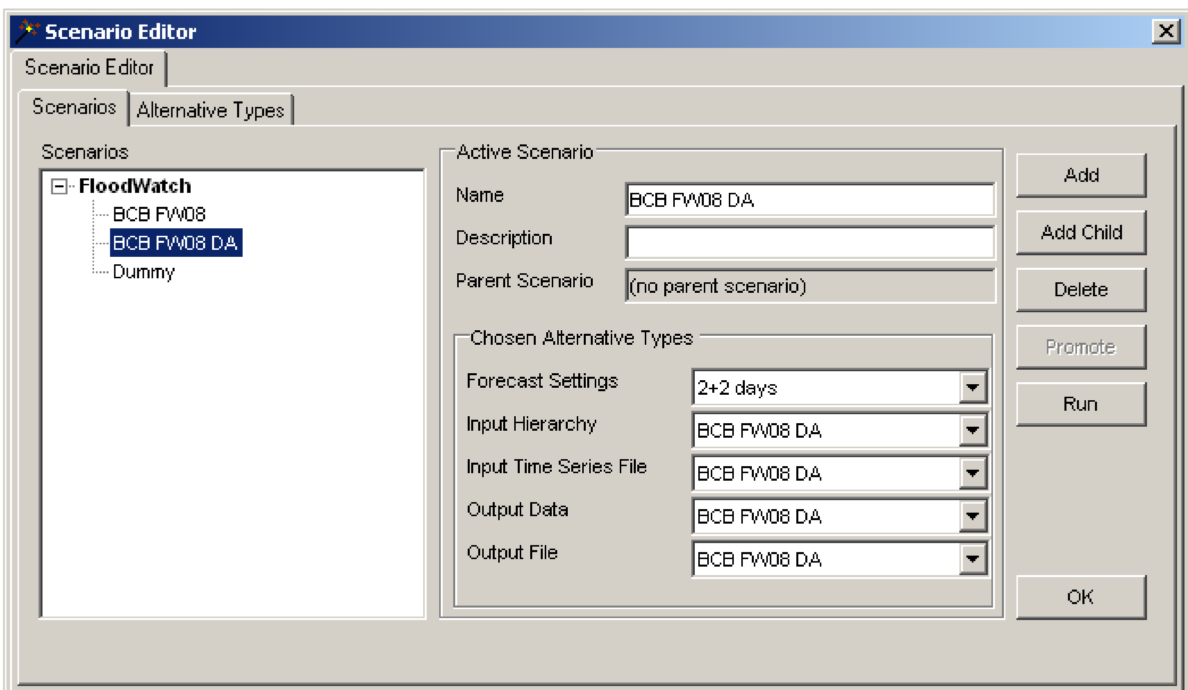
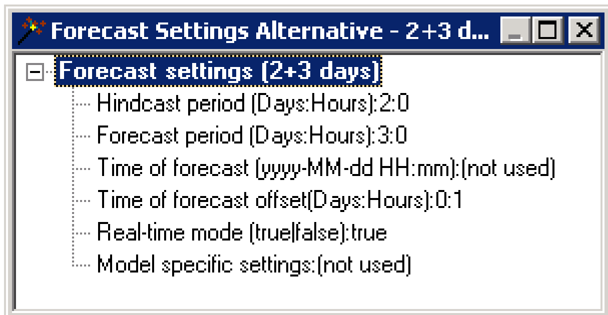


Figure 41 The 5 settings required to define a scenario as shown in the scenario editor

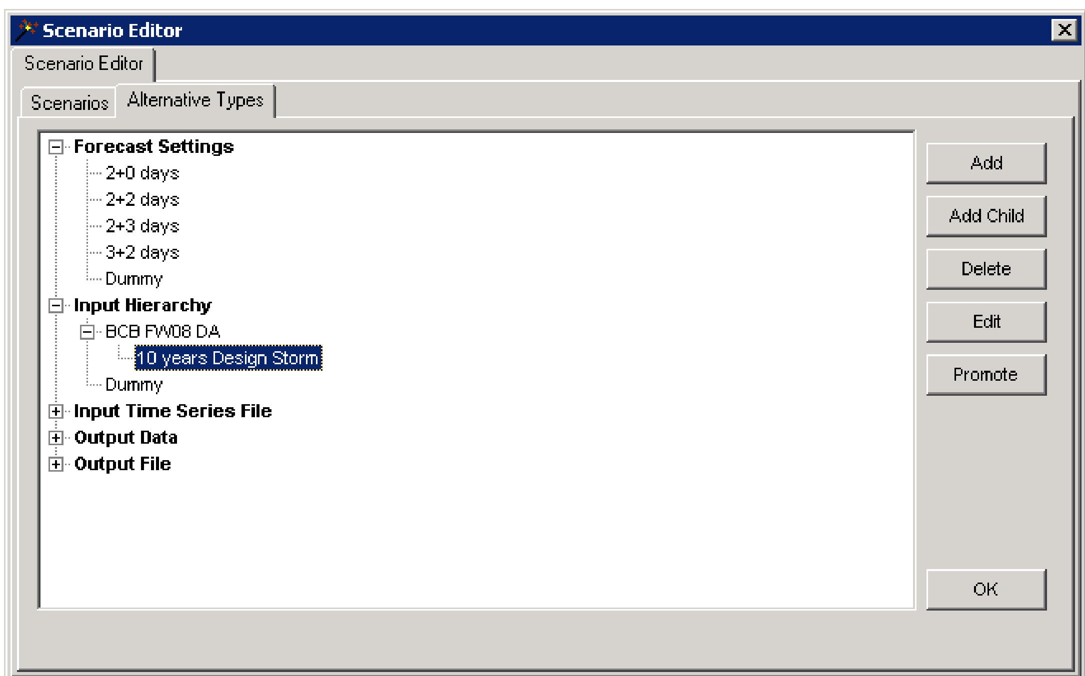
8.3.3 Define Scenario for design Rainfall

For the Design Storms a special hierarchy method has been developed which reads the normalized distribution pattern from a text file and creates a time series from that. A Design Storm Scenario can then be created in a similar fashion as the Base Scenario, only it builds upon the definitions of the Base Scenario and changes only the definitions of the rainfall inputs.

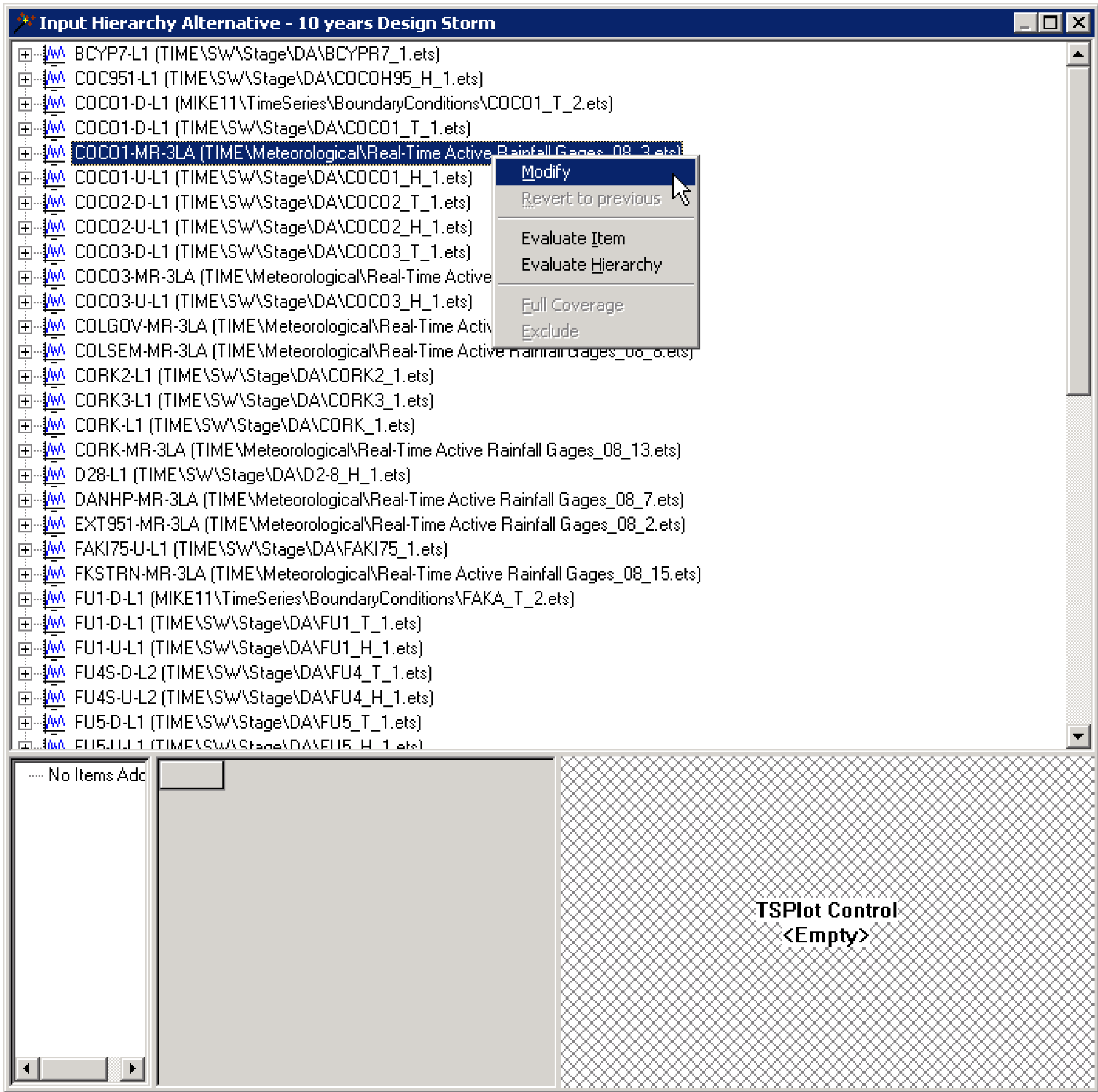
a) The Design Storm is 3 days long; hence we must run the model with 3 days forecast. So first we define a new Forecast Settings Alternative to define this.



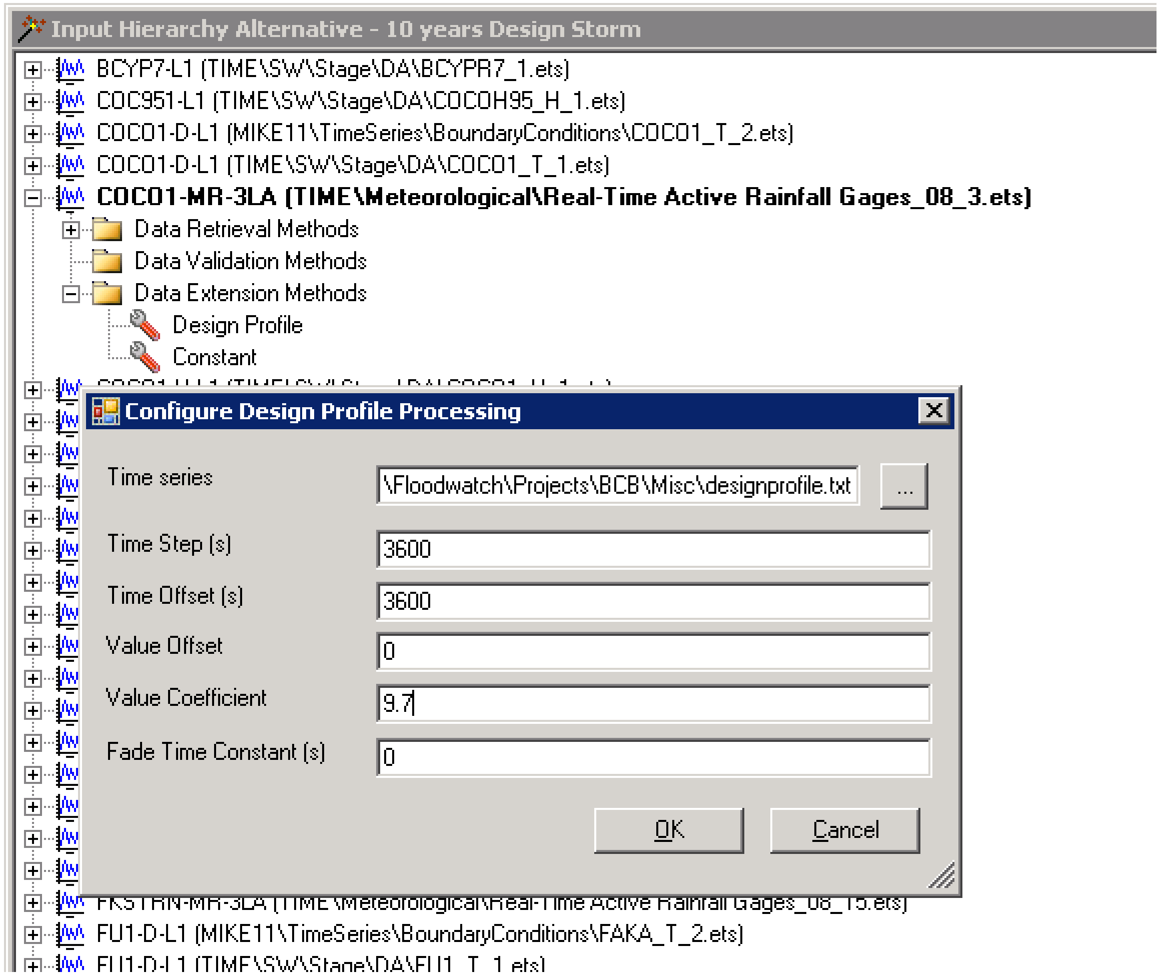
b) Secondly we defined a child hierarchy to the base hierarchy



c) Each of the rainfall time series definitions must then be modified:



Once opened for editing the Constant Data Extension Method is preceded by the new Design Profile method.

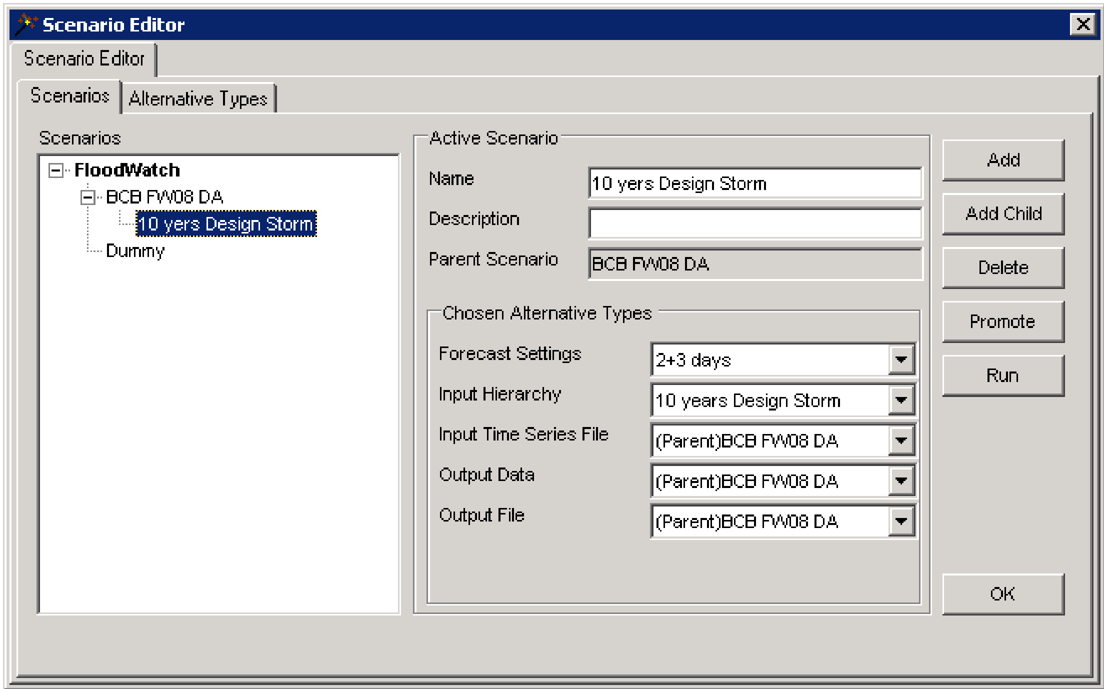


The time series points to a file defining the time steps and the values. The configuration of the parameters then defines the size of each time step (= 3600 secs~1hour), the number of seconds from the end of the observed data to the first profile step (= 0 secs), a value coefficient to multiply all values with (=9.7, which here means the profile renders 9.7 mm rain during the course of the profile), a value offset to be added to all values (=0) an a fade time constant if the profile is to be faded into the observed data over the course of an interval (=0s).

The constant extension method of 0 is kept to ensure the time series (observed data + extension data) covers the full simulation period.

In a similar fashion all the rainfall inputs are configured

d) The newly created alternatives are then combined in a new scenario



The coefficients to use for the different design storms and points are defined like this:

Table 2 Tabulation of the 3-day design storm totals

	3Day-Total Rain in Inches		
Station Name	3-Day 10-Year	3-Day 25-Year	3-Day 100-Year
MARCO	10	12.8	16
951EXT_R	9.1	10.8	13.2
COCO1_R	9.7	11.5	13.9
IMMOKALE_R	7.7	8.7	10.7
GOLDFS2	9.1	10.8	13.6
COLGOV_R	9.8	11.8	15.4
DANHP_R	10	12.2	15.8
COLLISEM	10	12.4	15.8
SILVER	8.1	9.4	11.6
SGGEWX	9.2	11	14.2
NAPCON_R	9.8	11.6	15.6
COCO3_R	9.4	11.2	12.4
CORK_R	8.5	9.6	11.8
ROOK_R	9.8	12.1	15.4
FKSTRN_R	8.5	9.9	13.1

8.4 Scheduling

So far the following schedules have been applied to the automatic runs.

	Task name	Schedule	Steps
1	BCB FW08 DA	Daily at 6:14AM and 6:14PM	1. Run the model 2. Publish results to WWW 3. Make ground water plots and MIKE SHE animation plots to WWW 4. Collect statistics
2	BCB Maintenance	Daily at 9:30PM	1. clean old simulations 2. clean events 3. Clean task history 4. Clean initial conditions 5. Clean temporary files
3	BCB Dummy Model	Daily at 6AM	1. Run Dummy Model
4	BCB Monitoring import and publish	Hourly from 0:45AM every day	1. Import Telemetry 2. Publish plots to www 3. Clean data in SQL server

Task 3 is used to establish an interval for use in the plots of monitoring data (all plots have to relate to a simulation).

8.5 Making a manual forecast

Making a manual forecast is possible from the GIS (ArcMap) interface (requires login to the BCBMOD01P server) or from the interactive Web client (requires FLOOD WATCH Administrator login). The procedure is slightly different, although the same details must be specified.

8.5.1 Manual forecast in GIS (ArcMap) interface

Manual forecasts can be started in ArcMap via either the Scenarios or the Tasks.

Starting a forecast from the Scenarios is done by pressing a button. The user must enter Scenario Editor, select the scenario in question and press the "Run" button. This will create and start a Task which executes the Scenario without approval. Progress can be followed from the Task Editor (task history).

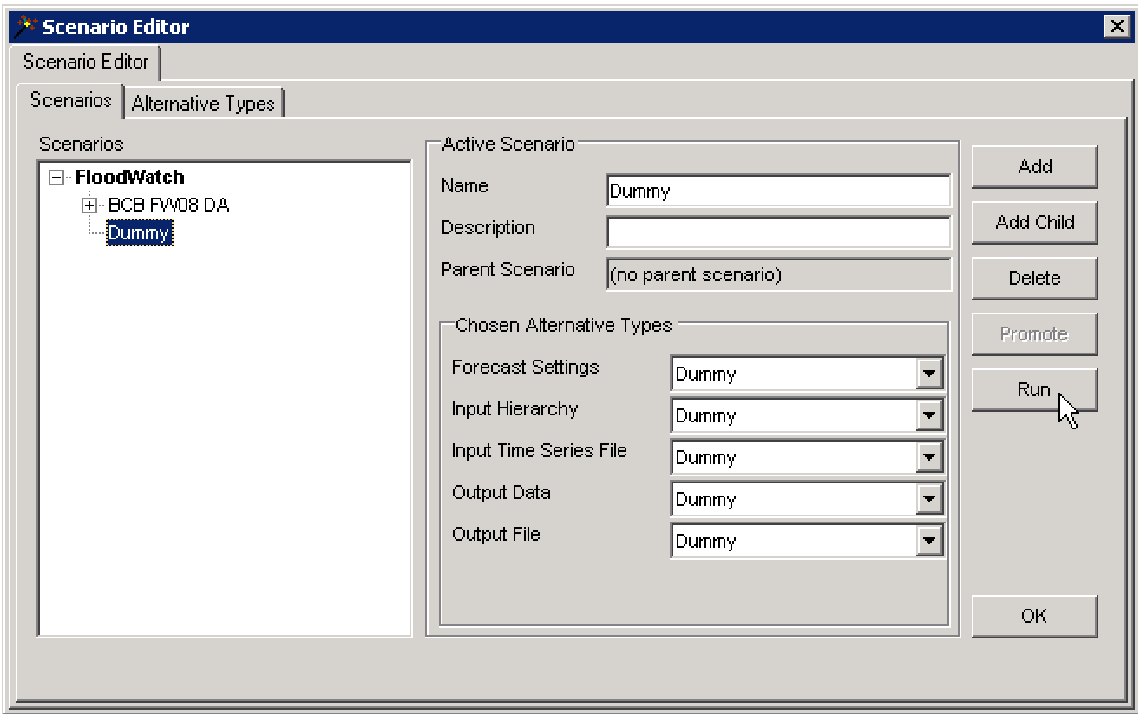


Figure 42 Using the scenario editor to create a manual forecast

The user can also in a straightforward manner run an existing Task which executes a simulation. This is done by entering the TaskEditor, right-clicking the task in question and choosing "Start". This will run the task in the same way as when scheduled, including Approval.

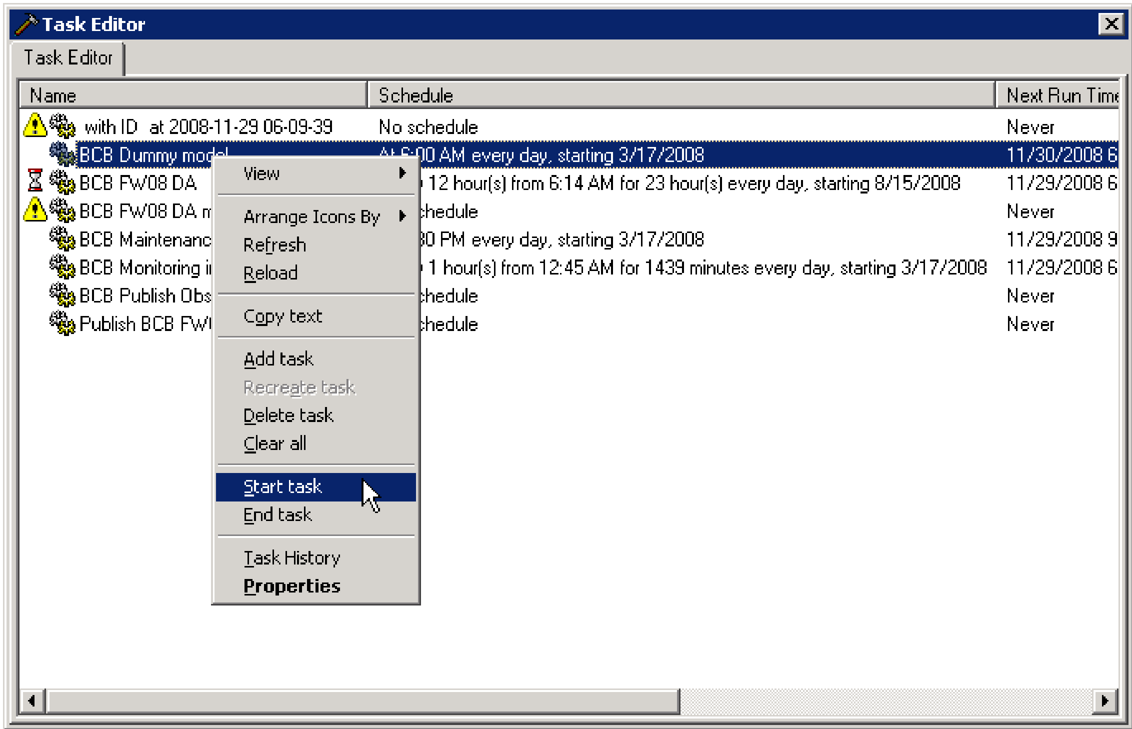


Figure 43   Initiating a manual forecast from the task editor

The user may also define a new task to execute a manual forecast. This is also done in the Task Editor – right click and chose “Add task” – specify the user credentials to create the task and rename the task if appropriate. Add one Task Step and choose the type “SIMULATION”. Press the Advanced button and select the Scenario and specify the other settings. Close all and start the new Task by right-clicking and choosing “Start task”.

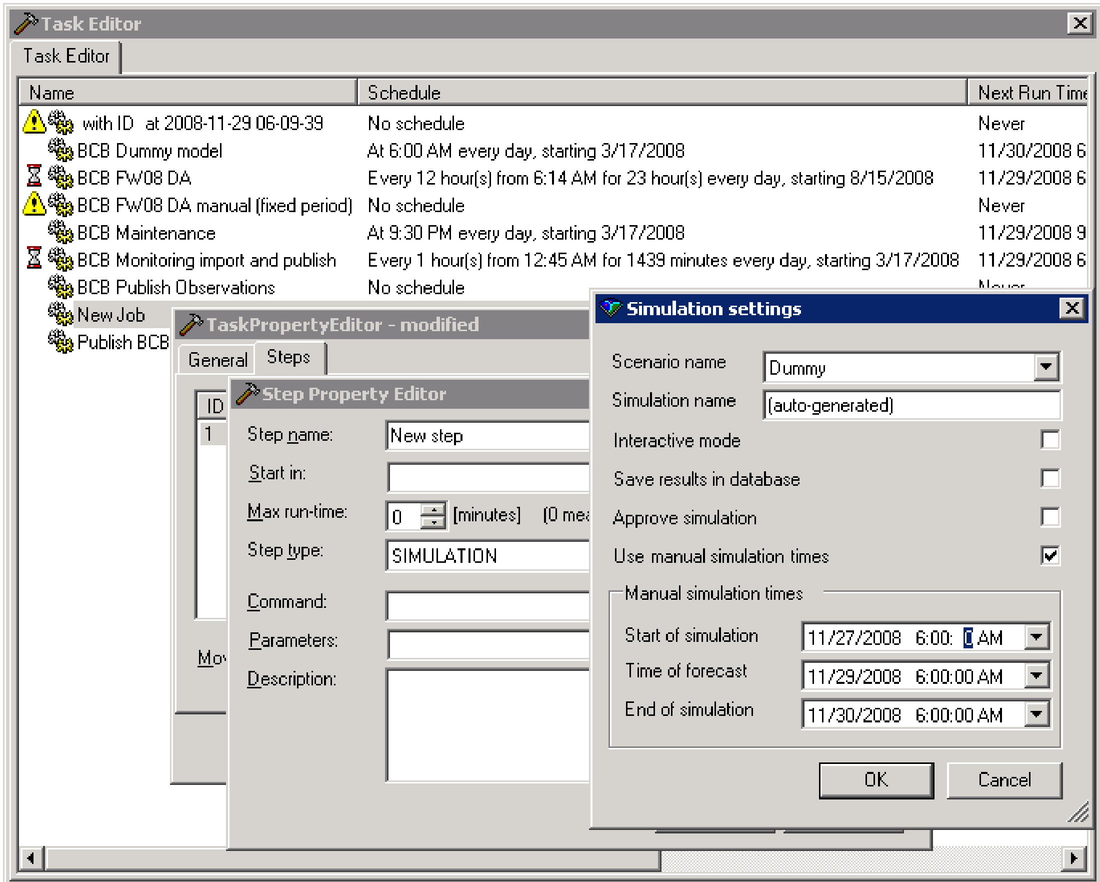


Figure 44 Specifying the manual forecast parameters

8.5.2 Manual forecast via interactive (FLOOD WATCH) Web Interface

A user can either start an already defined job or define a new for a specific scenario. The first option is the simplest.

Starting and existing Task is done from the Tasks display. Clicking the "Start" link will start the Task – unless it is already running, and it will run in the same way as when started by the Task Scheduler.

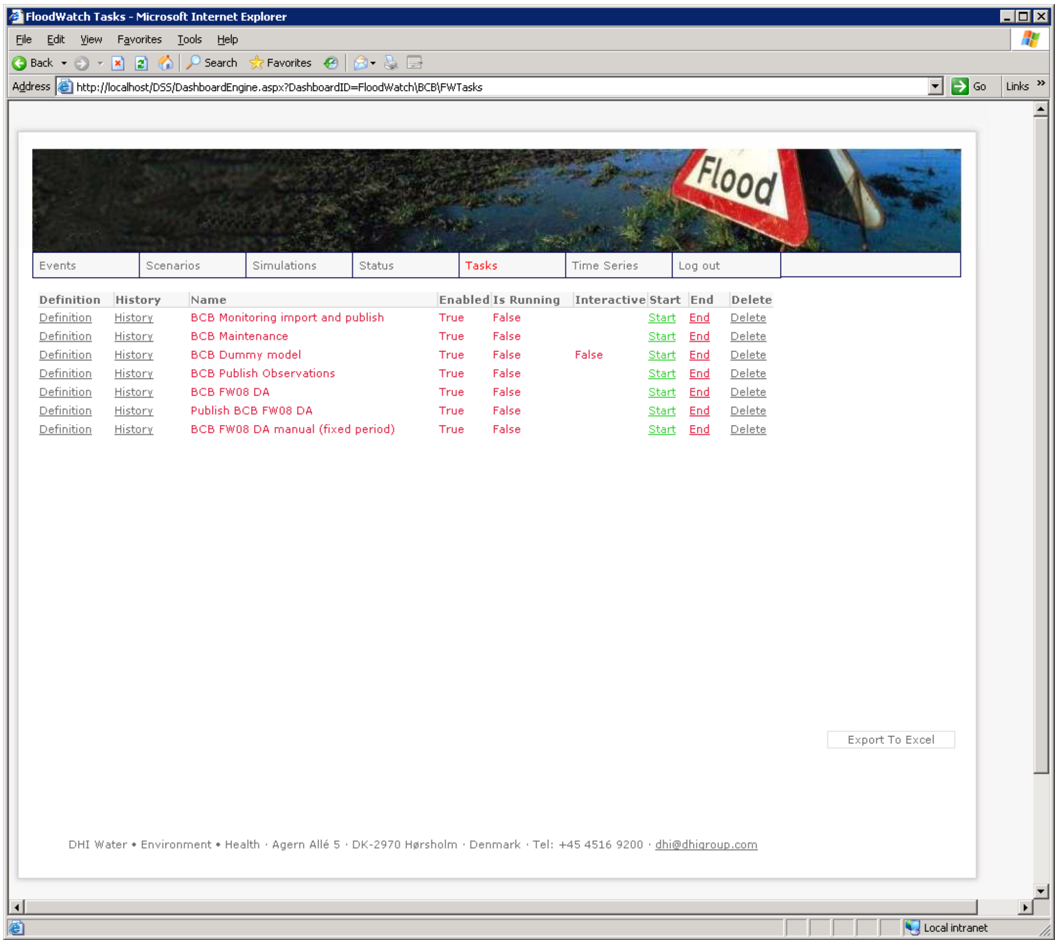


Figure 45 Initiating a manual forecast as an existing task from the Tasks menu

A new Simulation from a scenario can be started from the Scenarios page. By selecting a scenario and defining the simulation period (under Run Scenario) the user can create a temporary task to execute the model. The task requires valid Windows account credentials to run.

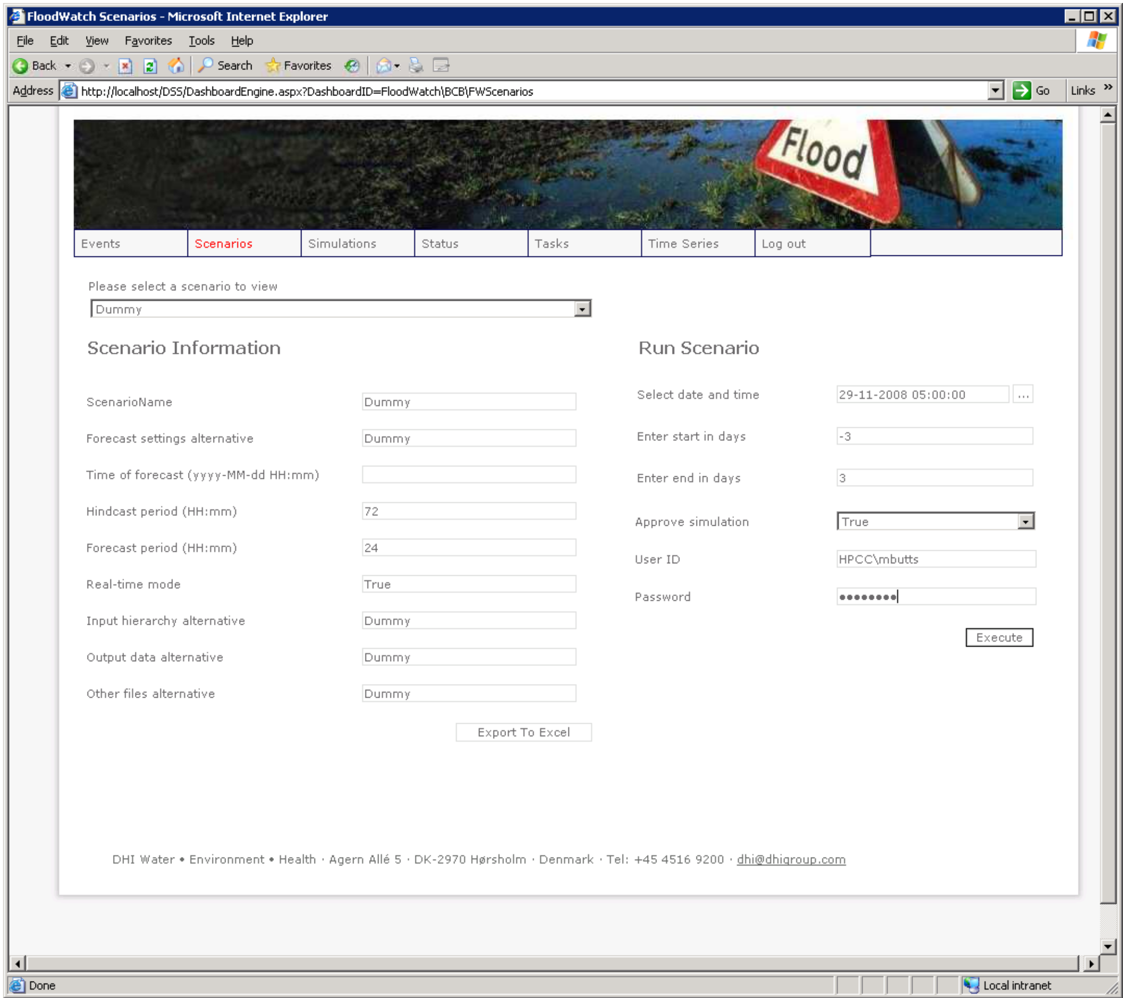


Figure 46 Specifying the forecast parameters for a manual forecast

8.6 Publication of results

FLOOD WATCH produces 2 sets of web-pages following import and model run.

- Monitoring plots

  The monitoring plots are produced following each import (hourly) and consist of plots of the received data for a period of the last 48 hours. With these plots it is quick to check if gages are reporting and data is being received by FLOOD WATCH.

  The monitoring plots are organized by data type, similar to the logical groups defined in ArcMap and used in the database.

- Model results

  The model results are plots of observations together with simulated values for the length of the simulation period, i.e. including forecast. The plots are updated hourly following the import of data, hence until the next model run (next day) the comparison of the forecast with the incoming observations is building up making it possible to do a quick inspection and assess whether the model has the right trend or not.

8.7 Flood mapping

MIKE SHE generates a 2D flood map in the form of a dfs2-file. This file is readily viewable from the FLOOD WATCH Web interface.

The latest MIKE SHE 2D flood maps can be seen as an animation on the Forecast Results www pages, see chapter 3.3.

9 CONCLUSIONS AND RECOMMENDATIONS

The Big Cypress Basin Real Time Modeling System has been successfully developed and all project goals achieved. The system is now fully operational. The system can be accessed using the customized web interface via the South Florida Water Management District Intranet, (to http://bcbmod01p/floodwatch). Advanced users can access the system using the GIS interface for system configuration and maintenance tasks directly on the system server.

The major goals were:

- To exploit existing Hydrological and Hydraulic Models, and the real-time telemetric monitoring (SCADA) network to develop a sub-regional real-time modeling and flood forecasting system for the Big Cypress Basin

- To develop a system that will integrate data management, monitoring facilities, forecast models and dissemination methodologies in a single system

These were achieved by implementing and adapting the MIKE FLOODWATCH real time decision support tool and incorporating into this tool the MIKE SHE model developed for the Big Cypress Basin from the Picayune Strand Restoration Project MIKE SHE model.

The specific objectives were that the Big Cypress Basin Real Time Modeling System should:

- Provide a dynamic linked real-time monitoring system data with hydrologic simulation model and perform real-time modeling

- Allow decision support and scenario analyses

- Allow real-time analysis and optimization of structure operation

- Provide timely flood mapping and web publication

These have all been achieved.

The most important immediate benefits from this system are:

- Operational users and hydrologist now have easy access to all real-time measured data within the Big Cypress Basin.

- There are potentially several direct benefits of this data access including improved structure operation and maintenance and improved real time management of the Big Cypress Basin water resources.

- There is an important added value being derived from using additional use of the real-time data currently being collected within the basin. Indeed, this is the first time in the District that this real-time data is being used together with models.

- Provision of regular hydrologic forecasts

This development represents the state-of-the-art in terms of real time modeling. The most important innovations are

- New way of modeling where the latest information concerning rainfall, water levels within the canals and so on are being used to forecast the future behavior of water within the Big Cypress Basin

- This is a unique forecasting system in the sense that a fully integrated surface water/groundwater model is being applied to real time modeling. This is probably the first of its kind in the US. This type of integrated approach is necessary in the South Florida Water Management District.

- Novel real time updating techniques to improve forecast accuracy have been applied within this project

While successful as a pilot implementation, from our experience gained in implementing the system we have the following key recommendations

1. Providing automatic rainfall forecasting data to the system will provide a substantial improvement in the utility of the system and the accuracy of the forecasts

2. The Big Cypress Basin Real Time modeling system allows the implementation of event-based responses. For example by defining a threshold water level or gate level, the system can be configured to send an e-mail to the gate operator or hydrologist if this threshold is exceeded. Similarly if measured water levels exceed a new forecast can be started. Therefore a key recommendation is to develop a set of thresholds and the corresponding actions and responses that would benefit operational management within the Big Cypress Basin

3. A detailed review of the most critical regulating structures within the BCB model area needs to be carried out. Each structure needs to be represented as accurately as possible including in particular the operating rules governing the independent operation of individual gates within the structure need to be characterized. This will improve the accuracy in forecasting the future behavior of these regulating structures

4. To ensure model accuracy a comparison of the rainfall over the model area captured using the real-time gauges and using the complete rain gage network should be carried out to identify whether the real-time network is representative of the Big Cypress Basin.

5. The new groundwater level real-time data should be used to recalibrate the operational BCB model, with particular emphasis on using this data to reproduce the groundwater dynamics. This should include quality reviews of this new data.

10 REFERENCES

Butts M.B., J Hoest-Madsen and J.C. Refsgaard (2002) Hydrologic Forecasting, Encyclopaedia of Physical Science and Technology 3rd Edition, 2002, Pages 547-566 ISBN: 012227413X

Butts, M. B., J. T. Payne, M. Kristensen and H. Madsen. (2004). An evaluation of the impact of model structure on hydrological modelling uncertainty for streamflow prediction. Journal of Hydrology, Volume 298, Issues 1-4, 1 October 2004, Pages 242-266.

Madsen, H., Skotner, C. (2005). Adaptive state updating in real-time river flow forecasting a combined filtering and error forecasting procedure. *Journal of Hydrology 2005:308.*

A P P E N D I C E S

A P P E N D I X A

Measurement locations for water levels in the Big Cypress Basin Model

This table show the location of all gages within the Big Cypress Basin model where water level is currently measured. Those locations that are being used for real time updating are highlighted in italics and the reach (upper and lower chainage) over which corrections are made is shown and was as the observation file names used.

Branch Name	Chainage	Upper Chainage	Lowerr Chainage	Mike11 File
CocohatcheeWest	*5227*	*4700*	*5300*	*COCOH95_H*
CocohatcheeWest	*8120*	*7600*	*8200*	*COCO3_H*
CocohatcheeWest	*8300*	*8250*	*9000*	*COCO3_T*
CocohatcheeWest	12821			
CocohatcheeWest	13187			
CocohatcheeWest	*15071*	*14300*	*15100*	*COCO1_H*
CocohatcheeWest	15623			
CorkIrrCan1	*3921*	*3821*	*3921*	*CORK*
CorkScrewCan	1174			
CorkScrewCan	6609			
CorkTribCan	0			
FakaUnionCan	*10000*	*9600*	*10100*	*FU5_H*
FakaUnionCan	10800			
FakaUnionCan	*17580*	*16500*	*17600*	*FU4_H*
FakaUnionCan	17620			
FakaUnionCan	*24064*	*24000*	*24200*	*FAKI75*
FakaUnionCan	*45800*	*45700*	*45900*	*FU1_H*
FakaUnionCan	47300			
GoldenGateMain	*9334*	*8900*	*9400*	*GOLD_W5_H*
GoldenGateMain	*9534*	*9500*	*10000*	*GOLD_W5_T*
GoldenGateMain	*15675*	*15600*	*15800*	*GOLD_W4*
GoldenGateMain	29337			
GoldenGateMain	29549			
GoldenGateMain	*34295*	*34200*	*34400*	*GOLD_951*
GoldenGateMain	*38832*	*38200*	*38900*	*GOLD_W2_H*
GoldenGateMain	*39000*	*39000*	*40000*	*GOLD_W2_T*
GoldenGateMain	*42710*	*41900*	*42800*	*GG1_h*
GoldenGateMain	42900			
HendersonCr	*3380*	*2900*	*3400*	*HEND84*
HendersonCr	*13500*	*12000*	*13600*	*HENDTAMI_H*
HendersonCr	*13800*	*13700*	*13900*	*HENDTAMI_T*
I-75Can	*6639*	*6000*	*6700*	*D2-8_H*
MillerCan	*6000*	*5900*	*6100*	*BCYPR7*
MillerCan	*9447*	*9400*	*9500*	*MLRI75*

Tamiami1	*9764*	*9700*	*9800*	*TAMIATOM*
Tamiami1	*11050*	*11000*	*11100*	*TAMIBR37*
Tamiami1	*20500*	*20400*	*20600*	*TAMIBR52*

A P P E N D I X B

Sensors

Sensors and time series

15-min rainfall accumulation

Sensor Name	Time Series Name	File
COCO1-MR-3LA	COCO1-MR-3LA - Cocohatchee Canal @ Weir # 1	or - COCO1-MR-3LA.dfs0
COCO3-MR-3LA	COCO3-MR-3LA - Cocohatchee Canal @ Weir # 3	or - COCO3-MR-3LA.dfs0
COLGOV-MR-3LA	COLGOV-MR-3LA - Collier County Courthouse	or - COLGOV-MR-3LA.dfs0
COLSEM-MR-3LA	COLSEM-MR-3LA - Collier / Seminole State Park	or - COLSEM-MR-3LA.dfs0
CORK-MR-3LA	CORK-MR-3LA - Corkscrew Swamp Sanctuary	or - CORK-MR-3LA.dfs0
DANHP-MR-3LA	DANHP-MR-3LA - Fakahatchee Strand @ Dan House	or - DANHP-MR-3LA.dfs0
EXT951-MR-3LA	EXT951-MR-3LA - CR 951 Extension	or - EXT951-MR-3LA.dfs0
FKSTRN-MR-3LA	FKSTRN-MR-3LA - Fakahatchee Strand North	or - FKSTRN-MR-3LA.dfs0
GOLDF2-MR-3LA	GOLDF2-MR-3LA - Golden Gate Fire Sta. # 2	or - GOLDF2-MR-3LA.dfs0
IMMOLF-MR-3LA	IMMOLF-MR-3LA - Immokalee Landfill	or - IMMOLF-MR-3LA.dfs0
MARCO-MR-3LA	MARCO-MR-3LA - Marco Island Water Plant	or - MARCO-MR-3LA.dfs0
NAPCON-MR-3LA	NAPCON-MR-3LA - The Conservancy	or - NAPCON-MR-3LA.dfs0
ROOK-MR-3LA	ROOK-MR-3LA - Rookery Bay HQ	or - ROOK-MR-3LA.dfs0
SGGEWX-MR-3LA	SGGEWX-MR-3LA - SGGE Weather Station	or - SGGEWX-MR-3LA.dfs0
SILVER-MR-3LA	SILVER-MR-3LA - Silver Strand Grove	or - SILVER-MR-3LA.dfs0

adjustable weir flow

Sensor Name	Time Series Name	File
GG1-W1-Q	GG1-W1-Q - GG Weir # 1	od - GG1-W1-Q.dfs0
GG1-W2-Q	GG1-W2-Q - GG Weir # 1	od - GG1-W2-Q.dfs0
GG1-W3-Q	GG1-W3-Q - GG Weir # 1	od - GG1-W3-Q.dfs0

atmospheric sampling site

Sensor Name	Time Series Name	File
BCMAR-MA-8EM	BCBMR	oe - BCMAR-MA-8EM.dfs0
SGGEWX-MA-8EM	SGGE	oe - SGGEWX-MA-8EM.dfs0
SILVER-MA-8EM	Silver	oe - SILVER-MA-8EM.dfs0

Flow

Sensor Name	Time Series Name	File
GG1-SW-Q1	GG1-SW-Q1 - GG Weir # 1	od - GG1-SW-Q1.dfs0

Gate opening

Sensor Name	Time Series Name	File

COCO1-G1-L1	COCO1-G1-L1 - Cocohatchee Canal @ Weir # 1	og - COCO1-G1-L1.dfs0
COCO1-G2-L1	COCO1-G2-L1 - Cocohatchee Canal @ Weir # 1	og - COCO1-G2-L1.dfs0
COCO2-G1-L1	COCO2-G1-L1 - Cocohatchee Canal @ Weir # 2	og - COCO2-G1-L1.dfs0
COCO2-G2-L1	COCO2-G2-L1 - Cocohatchee Canal @ Weir # 2	og - COCO2-G2-L1.dfs0
COCO3-G1-L1	COCO3-G1-L1 - Cocohatchee Canal @ Weir # 3	og - COCO3-G1-L1.dfs0
COCO3-G2-L1	COCO3-G2-L1 - Cocohatchee Canal @ Weir # 3	og - COCO3-G2-L1.dfs0
FU4S-G1-L2	FU4S-G1-L2 - FU4S	og - FU4S-G1-L2.dfs0
FU4S-G2-L2	FU4S-G2-L2 - FU4S	og - FU4S-G2-L2.dfs0
FU4S-G3-L2	FU4S-G3-L2 - FU4S	og - FU4S-G3-L2.dfs0
FU4S-G4-L2	FU4S-G4-L2 - FU4S	og - FU4S-G4-L2.dfs0
FU4S-G5-L2	FU4S-G5-L2 - FU4S	og - FU4S-G5-L2.dfs0
FU4S-G6-L2	FU4S-G6-L2 - FU4S	og - FU4S-G6-L2.dfs0
FU5-G10-L1	FU5-G10-L1 - Faka Union Weir # 5	og - FU5-G10-L1.dfs0
FU5-G11-L1	FU5-G11-L1 - Faka Union Weir # 5	og - FU5-G11-L1.dfs0
FU5-G12-L1	FU5-G12-L1 - Faka Union Weir # 5	og - FU5-G12-L1.dfs0
FU5-G1-L1	FU5-G1-L1 - Faka Union Weir # 5	og - FU5-G1-L1.dfs0
FU5-G2-L1	FU5-G2-L1 - Faka Union Weir # 5	og - FU5-G2-L1.dfs0
FU5-G3-L1	FU5-G3-L1 - Faka Union Weir # 5	og - FU5-G3-L1.dfs0
FU5-G4-L1	FU5-G4-L1 - Faka Union Weir # 5	og - FU5-G4-L1.dfs0
FU5-G5-L1	FU5-G5-L1 - Faka Union Weir # 5	og - FU5-G5-L1.dfs0
FU5-G6-L1	FU5-G6-L1 - Faka Union Weir # 5	og - FU5-G6-L1.dfs0
FU5-G7-L1	FU5-G7-L1 - Faka Union Weir # 5	og - FU5-G7-L1.dfs0
FU5-G8-L1	FU5-G8-L1 - Faka Union Weir # 5	og - FU5-G8-L1.dfs0
FU5-G9-L1	FU5-G9-L1 - Faka Union Weir # 5	og - FU5-G9-L1.dfs0
HC1-G1-L1	HC1-G1-L1 - Henderson Creek Weir # 1	og - HC1-G1-L1.dfs0
HC1-G2-L1	HC1-G2-L1 - Henderson Creek Weir # 1	og - HC1-G2-L1.dfs0
HENDSG-G1-L1	HENDSG-G1-L1 - Henderson Creek East	og - HENDSG-G1-L1.dfs0

Tidal levels

Adjustable weir crest elevation

Sensor Name	Time Series Name	File	Offset
GG1-W1-L1	GG1-W1-L1 - GG Weir # 1	og - GG1-W1-L1.dfs0	-1.27
GG1-W2-L1	GG1-W2-L1 - GG Weir # 1	og - GG1-W2-L1.dfs0	-1.27
GG1-W3-L1	GG1-W3-L1 - GG Weir # 1	og - GG1-W3-L1.dfs0	-1.27

bore hole (aquifer) pressure

Sensor Name	Time Series Name	File
I75MZ-BH1-P	I75MZ-BH1-P - I75MZ	op - I75MZ-BH1-P.dfs0
I75MZ-BH2-P	I75MZ-BH2-P - I75MZ	op - I75MZ-BH2-P.dfs0

I75MZ-BH3-P	I75MZ-BH3-P - I75MZ	op - I75MZ-BH3-P.dfs0

downstream surface water level

Sensor Name	Time Series Name	File	Offset
I75MZ-BH1-P	I75MZ-BH1-P - I75MZ	op - I75MZ-BH1-P.dfs0	-1.31
I75MZ-BH2-P	I75MZ-BH2-P - I75MZ	op - I75MZ-BH2-P.dfs0	-1.31
I75MZ-BH3-P	I75MZ-BH3-P - I75MZ	op - I75MZ-BH3-P.dfs0	-1.31
COCO1-D-L1	COCO1-D-L1 - Cocohatchee Canal @ Weir # 1	ow - COCO1-D-L1.dfs0	-1.32
COCO2-D-L1	COCO2-D-L1 - Cocohatchee Canal @ Weir # 2	ow - COCO2-D-L1.dfs0	-1.23
COCO3-D-L1	COCO3-D-L1 - Cocohatchee Canal @ Weir # 3	ow - COCO3-D-L1.dfs0	-1.31
CR951S-D-L1	CR951S-D-L1 - CR951-1	ow - CR951S-D-L1.dfs0	-1.32
FU1-D-L1	FU1-D-L1 - Faka Union Weir # 1	ow - FU1-D-L1.dfs0	-1.34
FU4S-D-L2	FU4S-D-L2 - FU4S	ow - FU4S-D-L2.dfs0	-1.33
FU5-D-L1	FU5-D-L1 - Faka Union Weir # 5	ow - FU5-D-L1.dfs0	-1.32
GG1-D-L1	GG1-D-L1 - GG Weir # 1	ow - GG1-D-L1.dfs0	-1.27
GOLDW3-D-L1	GOLDW3-D-L1 - GG Weir # 3	ow - GOLDW3-D-L1.dfs0	-1.32
GOLDW5-D-L1	GOLDW5-D-L1 - GG Weir #5	ow - GOLDW5-D-L1.dfs0	-1.32
GRDN-D-L1	GRDN-D-L1 - Gordon River	ow - GRDN-D-L1.dfs0	-1.27
HALDEM-D-L1	HALDEM-D-L1 - Halderman Creek	ow - HALDEM-D-L1.dfs0	-1.28
HC1-D-L1	HC1-D-L1 - Henderson Creek Weir # 1	ow - HC1-D-L1.dfs0	-1.30
HENDSG-D-L1	HENDSG-D-L1 - Henderson Creek East	ow - HENDSG-D-L1.dfs0	-1.30
I75W1-D-L1	I75W1-D-L1 - I-75 Weir #1	ow - I75W1-D-L1.dfs0	-1.32
LUCKLK-D-L1	LUCKLK-D-L1 - Lucky Lake Weir	ow - LUCKLK-D-L1.dfs0	-1.35
NAP31-D-L1	NAP31-D-L1 - CR 31 South	ow - NAP31-D-L1.dfs0	-1.27
WCOCO-D-L1	WCOCO-D-L1 - West Br. Cocohatchee @ CR 846	ow - WCOCO-D-L1.dfs0	-1.24

groundwater level

Sensor Name	Time Series Name	File	Offset
HF1-GW1-L1	HF1-GW1-L1 - HF1	ow - HF1-GW1-L1.dfs0	-1.29
HF1-GW2-L1	HF1-GW2-L1 - HF1	ow - HF1-GW2-L1.dfs0	-1.29
HF2-GW1-L1	HF2-GW1-L1 - HF2	ow - HF2-GW1-L1.dfs0	-1.29
HF3-GW1-L1	HF3-GW1-L1 - HF3	ow - HF3-GW1-L1.dfs0	-1.30
HF4-GW1-L1	HF4-GW1-L1 - HF4	ow - HF4-GW1-L1.dfs0	-1.30
HF7-GW1-L1	HF7-GW1-L1 - HF7	ow - HF7-GW1-L1.dfs0	-1.29
LUCKE-GW1-L1	LUCKE-GW1-L1 - Lucky Lake East	ow - LUCKE-GW1-L1.dfs0	-1.35
SGT1W1-GW1-L1	SGT1W1-GW1-L1 - SGT1W1	ow - SGT1W1-GW1-L1.dfs0	-1.34
SGT1W2-GW1-L1	SGT1W2-GW1-L1 - SGT1W2	ow - SGT1W2-GW1-L1.dfs0	-1.34
SGT1W4-GW1-L1	SGT1W4-GW1-L1 - SGT1W4	ow - SGT1W4-GW1-L1.dfs0	-1.34
SGT1W5-GW1-L1	SGT1W5-GW1-L1 - SGT1W5	ow - SGT1W5-GW1-L1.dfs0	-1.34

SGT2W1-GW1-L1	SGT2W1-GW1-L1 - SGT2W1	ow - SGT2W1-GW1-L1.dfs0	-1.32
SGT2W2-GW1-L1	SGT2W2-GW1-L1 - SGT2W2	ow - SGT2W2-GW1-L1.dfs0	-1.34
SGT2W3-GW1-L1	SGT2W3-GW1-L1 - SGT2W3	ow - SGT2W3-GW1-L1.dfs0	-1.33
SGT2W4-GW1-L1	SGT2W4-GW1-L1 - SGT2W4	ow - SGT2W4-GW1-L1.dfs0	-1.34
SGT2W5-GW1-L1	SGT2W5-GW1-L1 - SGT2W5	ow - SGT2W5-GW1-L1.dfs0	-1.34
SGT2W6-GW1-L1	SGT2W6-GW1-L1 - SGT2W6	ow - SGT2W6-GW1-L1.dfs0	-1.34
SGT3W1-GW1-L1	SGT3W1-GW1-L1 - SGT3W1	ow - SGT3W1-GW1-L1.dfs0	-1.34
SGT3W2-GW1-L1	SGT3W2-GW1-L1 - SGT3W2	ow - SGT3W2-GW1-L1.dfs0	-1.34
SGT3W3-GW1-L1	SGT3W3-GW1-L1 - SGT3W3	ow - SGT3W3-GW1-L1.dfs0	-1.34
SGT3W4-GW1-L1	SGT3W4-GW1-L1 - SGT3W4	ow - SGT3W4-GW1-L1.dfs0	-1.34
SGT3W5-GW1-L1	SGT3W5-GW1-L1 - SGT3W5	ow - SGT3W5-GW1-L1.dfs0	-1.34
SGT3W6-GW1-L1	SGT3W6-GW1-L1 - SGT3W6	ow - SGT3W6-GW1-L1.dfs0	-1.35
SGT3W7-GW1-L1	SGT3W7-GW1-L1 - SGT3W7	ow - SGT3W7-GW1-L1.dfs0	-1.34
SGT4W1-GW1-L1	SGT4W1-GW1-L1 - SGT4W1	ow - SGT4W1-GW1-L1.dfs0	-1.32
SGT4W2-GW1-L1	SGT4W2-GW1-L1 - SGT4W2	ow - SGT4W2-GW1-L1.dfs0	-1.34
SGT4W3-GW1-L1	SGT4W3-GW1-L1 - SGT4W3	ow - SGT4W3-GW1-L1.dfs0	-1.32
SGT4W4-GW1-L1	SGT4W4-GW1-L1 - SGT4W4	ow - SGT4W4-GW1-L1.dfs0	-1.32
SGT4W5-GW1-L1	SGT4W5-GW1-L1 - SGT4W5	ow - SGT4W5-GW1-L1.dfs0	-1.34
SGT4W6-GW1-L1	SGT4W6-GW1-L1 - SGT4W6	ow - SGT4W6-GW1-L1.dfs0	-1.34
SGT5W1-GW1-L1	SGT5W1-GW1-L1 - SGT5W1	ow - SGT5W1-GW1-L1.dfs0	-1.33
SGT5W2-GW1-L1	SGT5W2-GW1-L1 - SGT5W2	ow - SGT5W2-GW1-L1.dfs0	-1.34
SGT5W3-GW1-L1	SGT5W3-GW1-L1 - SGT5W3	ow - SGT5W3-GW1-L1.dfs0	-1.34
ST1-GW1-L1	ST1-GW1-L1 - ST1	ow - ST1-GW1-L1.dfs0	-1.22
ST2-GW1-L1	ST2-GW1-L1 - ST2	ow - ST2-GW1-L1.dfs0	-1.22
ST3-GW1-L1	ST3-GW1-L1 - ST3	ow - ST3-GW1-L1.dfs0	-1.21
WF1-L1	WF1-L1 - WF1	ow - WF1-L1.dfs0	-1.21
WF2-GW1-L1	WF2-GW1-L1 - WF2	ow - WF2-GW1-L1.dfs0	-1.22
WF3-GW1-L1	WF3-GW1-L1 - WF3	ow - WF3-GW1-L1.dfs0	-1.21
WF4-GW1-L1	WF4-GW1-L1 - WF4	ow - WF4-GW1-L1.dfs0	-1.22
WF5-GW1-L1	WF5-GW1-L1 - WF5	ow - WF5-GW1-L1.dfs0	-1.21
WF6-GW1-L1	WF6-GW1-L1 - WF6	ow - WF6-GW1-L1.dfs0	-1.22
WF7-GW1-L1	WF7-GW1-L1 - WF7	ow - WF7-GW1-L1.dfs0	-1.21
WF7-GW2-L1	WF7-GW2-L1 - WF7	ow - WF7-GW2-L1.dfs0	-1.21

surface water level

Sensor Name	Time Series Name	File	Offset
BARW4-L1	BARW4-L1 - SR29-4	ow - BARW4-L1.dfs0	-1.37
BARW6A-L1	BARW6A-L1 - SR29-6A	ow - BARW6A-L1.dfs0	-1.36
BCYP7-L1	BCYP7-L1 - Miller Canal @ 26th Ave. SE	ow - BCYP7-L1.dfs0	-1.32
COC951-L1	COC951-L1 - Cocohatchee Canal @ CR 951	ow - COC951-L1.dfs0	-1.32
COCOPR-L1	COCOPR-L1 - Palm River @ Palm River Blvd.	ow - COCOPR-L1.dfs0	-1.24
CORK3-L1	CORK3-L1 - Corkscrew Canal @ Cork #3	ow - CORK3-L1.dfs0	-1.32

CORK-L1	CORK-L1 - Corkscrew Swamp Sanctuary	ow - CORK-L1.dfs0	-1.24
D28-L1	D28-L1 - I-75 Weir #2	ow - D28-L1.dfs0	-1.28
ECOCO-L1	ECOCO-L1 - East Br. Cocohatchee @ CR 846	ow - ECOCO-L1.dfs0	-1.24
EXT951-L1	EXT951-L1 - CR 951 Extension	ow - EXT951-L1.dfs0	-1.26
GOL846-L1	GOL846-L1 - Corkscrew Canal @ Cork #1	ow - GOL846-L1.dfs0	-1.31
GOLD4A-L1	GOLD4A-L1 - Cypress Canal @ Weir 4A-1	ow - GOLD4A-L1.dfs0	-1.30
GOLD951-L1	GOLD951-L1 - GG @ CR 951	ow - GOLD951-L1.dfs0	-1.31
GOLDW4-L1	GOLDW4-L1 - GG Weir # 4	ow - GOLDW4-L1.dfs0	-1.32
HEND84-L1	HEND84-L1 - Henderson Creek near SR 84	ow - HEND84-L1.dfs0	-1.31
HF1-L1	HF1-L1 - HF1	ow - HF1-L1.dfs0	-1.29
HF2-L1	HF2-L1 - HF2	ow - HF2-L1.dfs0	-1.29
HF3-L1	HF3-L1 - HF3	ow - HF3-L1.dfs0	-1.30
HF4-L1	HF4-L1 - HF4	ow - HF4-L1.dfs0	-1.30
KEA858-L1	KEA858-L1 - Camp Keais Strand @ CR 858	ow - KEA858-L1.dfs0	-1.32
LUCKW-L1	LUCKW-L1 - Lucky Lake West	ow - LUCKW-L1.dfs0	-1.34
MLRI75-L1	MLRI75-L1 - Miller Canal @ I-75	ow - MLRI75-L1.dfs0	-1.34
MRTI75-L1	MRTI75-L1 - Merritt Canal @ I-75	ow - MRTI75-L1.dfs0	-1.35
OKA858-L1	OKA858-L1 - Okaloacoochee Slough @ SR 858	ow - OKA858-L1.dfs0	-1.34
SGT5W1-L1	SGT5W1-L1 - SGT5W1	ow - SGT5W1-L1.dfs0	-1.33
SGT5W2-L1	SGT5W2-L1 - SGT5W2	ow - SGT5W2-L1.dfs0	-1.34
SGT5W3-L1	SGT5W3-L1 - SGT5W3	ow - SGT5W3-L1.dfs0	-1.34
ST1-L1	ST1-L1 - ST1	ow - ST1-L1.dfs0	-1.22
ST2-L1	ST2-L1 - ST2	ow - ST2-L1.dfs0	-1.22
ST3-L1	ST3-L1 - ST3	ow - ST3-L1.dfs0	-1.21
TAMTOM-L1	TAMTOM-L1 - Tamiami Canal @ Tomato Rd.	ow - TAMTOM-L1.dfs0	-1.32
TMBR37-L1	TMBR37-L1 - Tamiami Canal @ Bridge 37	ow - TMBR37-L1.dfs0	-1.32
TMBR40-L1	TMBR40-L1 - Tamiami Canal @ Bridge 40	ow - TMBR40-L1.dfs0	-1.32
TMBR45-L1	TMBR45-L1 - Tamiami Canal @ Bridge 45	ow - TMBR45-L1.dfs0	-1.33
TMBR52-L1	TMBR52-L1 - Tamiami Canal @ Bridge 52	ow - TMBR52-L1.dfs0	-1.34
TMBR55-L1	TMBR55-L1 - Tamiami Canal @ Bridge 55	ow - TMBR55-L1.dfs0	-1.34
TMBR66-L1	TMBR66-L1 - Tamiami Canal @ Bridge 66	ow - TMBR66-L1.dfs0	-1.36
TMBR71-L1	TMBR71-L1 - Tamiami Canal @ Bridge 71	ow - TMBR71-L1.dfs0	-1.36
WF2-L1	WF2-L1 - WF2	ow - WF2-L1.dfs0	-1.22
WF3-L1	WF3-L1 - WF3	ow - WF3-L1.dfs0	-1.21
WF4-L1	WF4-L1 - WF4	ow - WF4-L1.dfs0	-1.22
WF5-L1	WF5-L1 - WF5	ow - WF5-L1.dfs0	-1.21

WF6-L1	WF6-L1 - WF6	ow - WF6-L1.dfs0	-1.22
WF7-L1	WF7-L1 - WF7	ow - WF7-L1.dfs0	-1.21

Tidal levels

Sensor Name	Time Series Name	File	Offset
fw - Naples Tidal Constituents	fw - Naples Tidal Constituents	fw - Naples Tidal Constitu-ents.dfs0	
fw - NOAA Naples Tidal Pre-diction	fw - NOAA Naples Tidal Pre-diction	fw - NOAA Naples Tidal Pre-diction.dfs0	-2.28

Upstream surface water level

Sensor Name	Time Series Name	File	Offset
COCO1-U-L1	COCO1-U-L1 - Cocohatchee Canal @ Weir # 1	ow - COCO1-U-L1.dfs0	-1.32
COCO2-U-L1	COCO2-U-L1 - Cocohatchee Canal @ Weir # 2	ow - COCO2-U-L1.dfs0	-1.23
COCO3-U-L1	COCO3-U-L1 - Cocohatchee Canal @ Weir # 3	ow - COCO3-U-L1.dfs0	-1.31
CR951S-U-L1	CR951S-U-L1 - CR951-1	ow - CR951S-U-L1.dfs0	-1.32
FAKI75-U-L1	FAKI75-U-L1 - Faka Union Canal @ I-75	ow - FAKI75-U-L1.dfs0	-1.34
FU1-U-L1	FU1-U-L1 - Faka Union Weir # 1	ow - FU1-U-L1.dfs0	-1.34
FU4S-U-L2	FU4S-U-L2 - FU4S	ow - FU4S-U-L2.dfs0	-1.33
FU5-U-L1	FU5-U-L1 - Faka Union Weir # 5	ow - FU5-U-L1.dfs0	-1.32
GG1-U-L1	GG1-U-L1 - GG Weir # 1	ow - GG1-U-L1.dfs0	-1.27
GOLDW1-U-L1	GOLDW1-U-L1 - Golden Gate Canal at CR31	ow - GOLDW1-U-L1.dfs0	-1.27
GOLDW3-U-L1	GOLDW3-U-L1 - GG Weir # 3	ow - GOLDW3-U-L1.dfs0	-1.32
GOLDW5-U-L1	GOLDW5-U-L1 - GG Weir #5	ow - GOLDW5-U-L1.dfs0	-1.32
GRDN-U-L1	GRDN-U-L1 - Gordon River	ow - GRDN-U-L1.dfs0	-1.27
HALDEM-U-L1	HALDEM-U-L1 - Halderman Creek	ow - HALDEM-U-L1.dfs0	-1.28
HC1-U-L1	HC1-U-L1 - Henderson Creek Weir # 1	ow - HC1-U-L1.dfs0	-1.30
HENDSG-U-L1	HENDSG-U-L1 - Henderson Creek East	ow - HENDSG-U-L1.dfs0	-1.30
I75W1-U-L1	I75W1-U-L1 - I-75 Weir #1	ow - I75W1-U-L1.dfs0	-1.32
LUCKLK-U-L1	LUCKLK-U-L1 - Lucky Lake Weir	ow - LUCKLK-U-L1.dfs0	-1.35
NAP31-U-L1	NAP31-U-L1 - CR 31 South	ow - NAP31-U-L1.dfs0	-1.27
WCOCO-U-L1	WCOCO-U-L1 - West Br. Cocohatchee @ CR 846	ow - WCOCO-U-L1.dfs0	-1.24

A P P E N D I X C

Model Output Sensors

Model Output Sensors

The model outputs forecasts in selected surface water level points as well as a number of ground water points.

SensorName	FileLocation
COCO1-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_15623_266_COCOHATCHEEWEST.ets
COCO2-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_13187_258_COCOHATCHEEWEST.ets
COCO3-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_8300_238_COCOHATCHEEWEST.ets
FU1-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_47300_655_FAKAUNIONCAN.ets
FU4S-D-L2	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_17620_607_FAKAUNIONCAN.ets
FU5-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_10800_596_FAKAUNIONCAN.ets
GG1-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_42900_746_GOLDENGATEMAIN.ets
GOLDW3-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_29549_712_GOLDENGATEMAIN.ets
GOLDW5-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_9534_681_GOLDENGATEMAIN.ets
HC1-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_13800_854_HENDERSONCR.ets
BCYP7-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_6000_1105_MILLERCAN.ets
COC951-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_5227_221_COCOHATCHEEWEST.ets
CORK3-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_0_464_CORKTRIBCAN.ets
CORK-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_3921_293_CORKIRRCAN1.ets
D28-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_6639_880_I-75CAN.ets
GOL846-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_6609_393_CORKSCREWCAN.ets
GOLD951-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_34295_720_GOLDENGATEMAIN.ets
GOLDW4-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_15675_688_GOLDENGATEMAIN.ets
HEND84-L1	BCB_EC_FW08_500ft.SHE - Result

SensorName	FileLocation
	Files\BCB_EC_FW08_500ft_100000_3380_817_HENDERSONCR.ets
MLRI75-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_9447_1111_MILLERCAN.ets
TAMTOM-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_9764_1247_TAMIAMI1.ets
TMBR37-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_11050_1248_TAMIAMI1.ets
TMBR52-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_20500_1282_TAMIAMI1.ets
COCO1-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_15071_264_COCOHATCHEEWEST.ets
COCO2-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_12821_256_COCOHATCHEEWEST.ets
COCO3-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_8120_236_COCOHATCHEEWEST.ets
FAKI75-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_24064_618_FAKAUNIONCAN.ets
FU1-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_45800_651_FAKAUNIONCAN.ets
FU4S-U-L2	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_17580_606_FAKAUNIONCAN.ets
FU5-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_10000_595_FAKAUNIONCAN.ets
GG1-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_42710_745_GOLDENGATEMAIN.ets
GOLDW3-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_29337_710_GOLDENGATEMAIN.ets
GOLDW5-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_9334_680_GOLDENGATEMAIN.ets
HC1-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_13500_853_HENDERSONCR.ets
GOLDW2-U-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_38832_733_GOLDENGATEMAIN.ets
GOLDW2-D-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_38918_734_GOLDENGATEMAIN.ets
CORK2-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ft_100000_1174_364_CORKSCREWCAN.ets

SensorName	FileLocation

SensorName	FileLocation
SGT1W1-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_32.ets
SGT1W2-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_33.ets
SGT1W4-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_34.ets
SGT2W1-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_35.ets
SGT2W2-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_36.ets
SGT2W3-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_37.ets
SGT2W4-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_38.ets
SGT3W1-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_39.ets
SGT3W2-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_40.ets
SGT3W3-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_41.ets
SGT3W4-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_42.ets
SGT3W5-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_43.ets
SGT4W1-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_44.ets
SGT4W2-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_45.ets
SGT4W3-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_46.ets
SGT4W4-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_47.ets
SGT4W5-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_48.ets
SGT5W1-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_49.ets
SGT5W2-GW1-L1	BCB_EC_FW08_500ft.SHE - Result Files\BCB_EC_FW08_500ftDetailedTS_SZ_50.ets