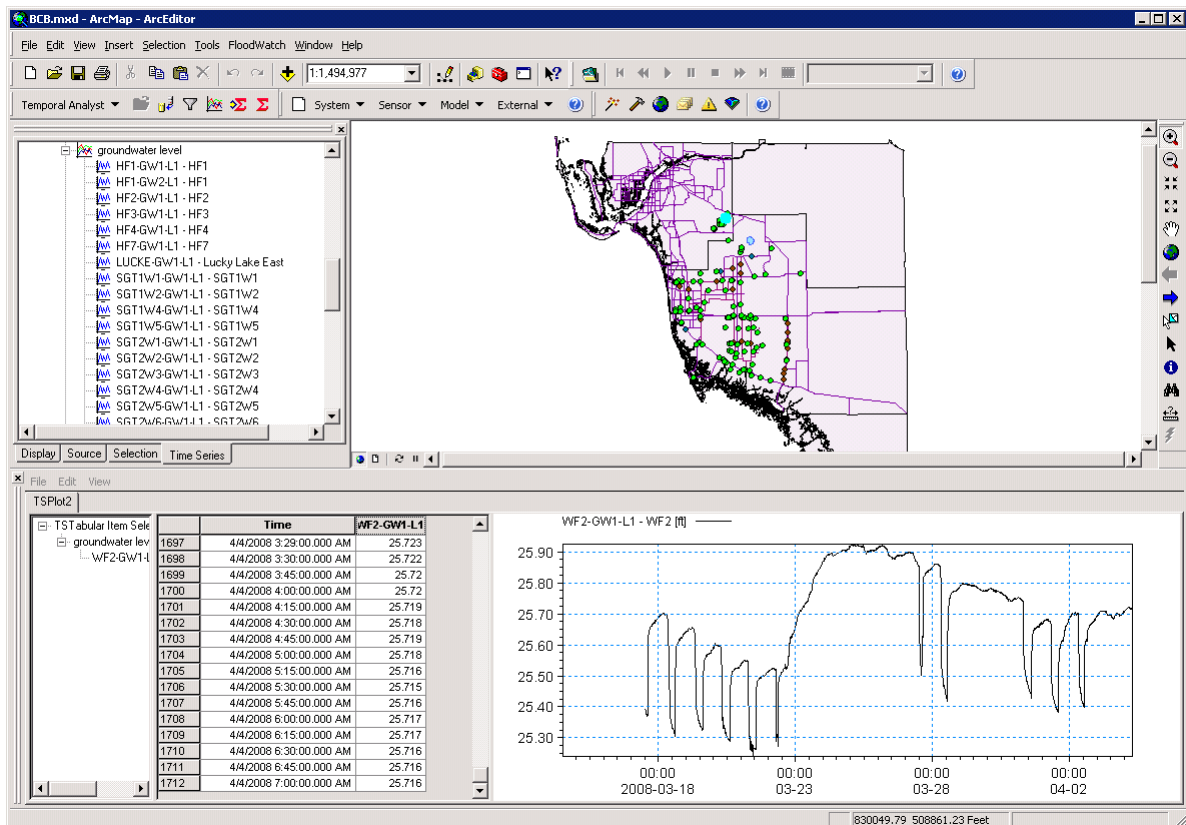


# Big Cypress Basin Real Time Hydrologic Modeling System Improvements (Contract No. 4600001738)



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## **0 EXECUTIVE SUMMARY**

The Big Cypress Basin Real Time Hydrologic Modeling System was successfully implemented in 2008 “Big Cypress Basin Real Time Hydrologic Modeling System Phase 1 - System Development and Testing”, Contract 4600001041. This project was a collaborative effort between BCB, HESM, SCADA and Hydro Data Management within the South Florida Water Management District and DHI.

The second phase of this project, “Big Cypress Basin Real Time Hydrologic Modeling System Improvements“, Contract 4600001738 is focused on improving the current operational system and exploring its applications in the BCB Water Resources Management, to maximize the added value of the existing system. At the end of the first phase a number of recommendations were made to make the system more user-friendly and improve the reliability of the forecasts. These recommendations are reflected in the phase 2 tasks:

- Task 1 BCB Floodwatch System Improvements
- Task 2 Improved Representations of Control Structures
- Task 3 Quantitative Precipitation Forecasts
- Task 4 Training
- Task 5 Final Report

### **Benefits**

The most important immediate benefits from Phase 2 to this system are:

1. Improvements in the information displays to match the needs of the BCB operational staff and make maximum use of the operational data from both the real-time sensors and the forecasting model
2. Detailed and up-to-date representations of the most important control structures in the channel system are now included in the forecasting model and have been shown to improve forecast accuracy
3. Manual precipitation forecasts can now be entered via web displays to allow the user to explore different rainfall scenarios
4. Operational precipitation forecasts from South Florida Water Management District and NOAA are included in the automatic forecast and are expected to improve the hydrologic forecast accuracy

In addition to the deliverables specified in the contract, two additional facilities were developed during this phase at no extra cost.

- a. A web display of the status of the real-time sensors within the Big Cypress basin

- b. A data extraction functionality to simplify data retrieval from the new secondary database provided in Task 1

This report is Task 5 and summarizes the activities carried out in phase 2 into a single report. . The main outcomes of phase 2 are:

### **Task 1: BCB Floodwatch System Improvements**

The following new features have been implemented in the real-time system:

- **Event based Alerts.** The system now issues alerts to whenever pre-defined thresholds are exceeded for at least two hours for selected sensors. These Alerts are issued as e-mails to operational staff that can be read on both personal computers and portable devices (Blackberry)
- **Two Datum Displays.** Displays for operational users of structure levels and water levels are now available relative to either NGVD 29 datum or NAVD 88 datum.
- **Gate Opening Indicator.** Customized displays of operational gate information including gate levels, water levels, status and photographs.
- **Quality Displays.** Improved quality and readability of selected displays
- **Secondary database.** Alternative long-term storage of the BCB monitoring data.

### **Task 2: Improved Representations of Control Structures**

The operation and management of control structures is integral to the management of water resources and particularly important in flood control throughout the BCB. The ability of the RTHMS to accurately represent the geometry and operations of regulating structures is very important for accurate flood forecasts during storm events. The main results of Task 2 are

- Updating of the structures, their geometry and operation to match current conditions
- Develop new representations of structures at key stations to better represent the actual operation. The key stations are
  - • Faka Union Canal: FU4, FU5
  - • Golden Gate: GG5, GG2, GG1
  - • Cocohatchee: COC03, COC02, COC01
  - • Henderson Creek: HC1
- Implement the improved representation in the operational system.

### **Task 3: Quantitative Precipitation Forecasts**

A quantitative precipitation forecast (QPF) is a forecast of the amount of precipitation which will fall during a specific time period. These precipitation amount forecast values can then be used as inputs to hydrologic models for river forecasting purposes. The advantage of using quantitative precipitation forecasts in hydrologic forecasts is that they provide valuable increases in the forecast lead time, the time available to carry out flood protection measures.

The BCB System has now been updated and configured so it uses operational precipitation forecasts in the hydrological forecasts. The system now uses either South Florida Water Management Districts own weather forecasts (which are preferred as they better represent local conditions) or the ALR QPF by the NOAA (considered to be quite reliable by the SFWMDS's own meteorologists) or a combination. In addition, it is now possible for the forecasters using the system to use their own manual precipitation forecasts. These can now be conveniently entered via web displays to allow the user to explore different rainfall scenarios.

### **Task 4: Training**

A tailored training course for BCB was carried out in the Naples office in the period 24-28 August, 2009.

### **Recommendations**

The phase 2 project has highlighted the value of created customized displays for the BCB operational users. From our experience gained in implementing the system we have the following key recommendations

1. The Big Cypress Basin has a large number (46) water control structures for flood protection, water supply and environmental quality management.control. During phase 2 the representations of the important structures have been improved. The next logical step is to allow operational user to evaluate in a convenient way the impacts of multiple gate operations-
2. The performance of the improved system in terms of hydrologic and rainfall forecasting accuracy should be analyzed based on the results of the 2009 wet season to assess the value of the quantitative precipitation forecasts.
3. Further tailoring of the BCB system displays in consultation with the BCB operational staff is desirable to maximize the value of forecast information
4. Consideration should be given to an image or shadow system. There are two main reasons for implementing a shadow system.
  - a. To provide a backup of the main system in the case of system failure

- b. To provide a tool for exploring the effects of different operational measures using copies of the operational system data. Here the purpose is to allow the user to try out different options without interfering directly with the main operational system and for training

Previous recommendations from phase 1 not carried during phase 2:

5. 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.
6. 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 TASK 1 - BCB FLOODWATCH SYSTEM IMPROVEMENTS**

The following system improvements will improve the functionality of the RTHMS with respect to system management and response as well as facilitate the dissemination of accurate information to the public.

- Development of event based alarm level and response protocol and configuration of event response management. The introduction of thresholds will allow the BCB system to be run as an event-based system. This task will improve the model forecasting and corresponding actions and responses that would benefit operational management within the Big Cypress Basin.
- Two Datum Option. The structures and water levels used by the operational staff are based on the datum NGVD 29, however, the MIKESHE output and current plotting are in the NAVD 88 datum. Therefore the monitoring data (such as the water levels, structures and groundwater levels) will be displayed in different datum (both NGVD 29 and NAVD 88) thus reducing the need to convert from NGVD to NAVD within the system.
- Gate Opening Indicator - there are two types of gates in the BCB system, over-flow gate and under-flow gate. In addition to a plot of each structure posted on the website, a customized opening indicator will improve the readability of the structure condition.
- Quality Display – Improvements to clarify the information being displayed will result in higher quality and readability of pertinent information for text, numerical information and mapping displays. The specific changes will be identified jointly by DHI and SFWMD.
- BCB real-time sub database development - to setup and provide longer term storage of the monitoring data, and provide easy access method to the real-time monitoring data being collected by the BCB FLOODWATCH system for BCB staff.

## 1.1 **Two Datum plot**

The FLOOD WATCH built-in plotting functionality displays the data that is stored. Showing data relative to two different datum levels can be achieved either by storing the data twice or by post-processing the data. For the BCB Real-time Hydrologic Modeling System the two datum plots have been implemented as a Visual Basic Script which creates all plots required and performs a datum shift for levels.

The script can produce

- observation plots - for all sensors in the database. For water levels, ground levels and gate levels for two different datum can be viewed.
- model output plots - for all defined outputs for a scenario. The script will for each output plot the simulated values and plot also the available observed values for the same sensor.

For all level plots the default display of levels uses the NGVD 29 datum as this is the datum used by most operational users. The user can then within the same web displays select the alternative NAVD 88 datum displaying levels. For forecasted groundwater levels the script includes the error correction adjustments used to correct the difference between observed and simulated groundwater levels at the time of forecast. This adjusted forecast is shown in red. A Time Of Forecast indicator has been added to the plot.

The script is named **datumplots.vbs** located in folder

D:\Floodwatch\Projects\BCB\Misc\

It can be called by running the either **obsdatumplots.cmd** or **simdatumplots.cmd** batch files to plot observations and simulation results respectively.

The script/command is called with 3 parameters

- Plottype (default = "WL")

The possible values are WL (~water level), GL ( ~gate level), GW (~ground water). This parameter is only relevant if ScenarioID = -1, otherwise the plots are defined by the simulation output.

- ScenarioID (default = -1)

If value is "-1" the plots are all observation plots, otherwise the script will plot simulation outputs

- datum (default = "NAVD88")



Possible values are NAVD88 and NGVD29. The default value is the same as the datum for values in the database, i.e. no datum correction is applied. For NGVD29 datum corrections are listed for each location in the script

The script will output to the location of the webpage plots (D:\floodwatch\projects\bc\www\plots) - replacing any previous instances

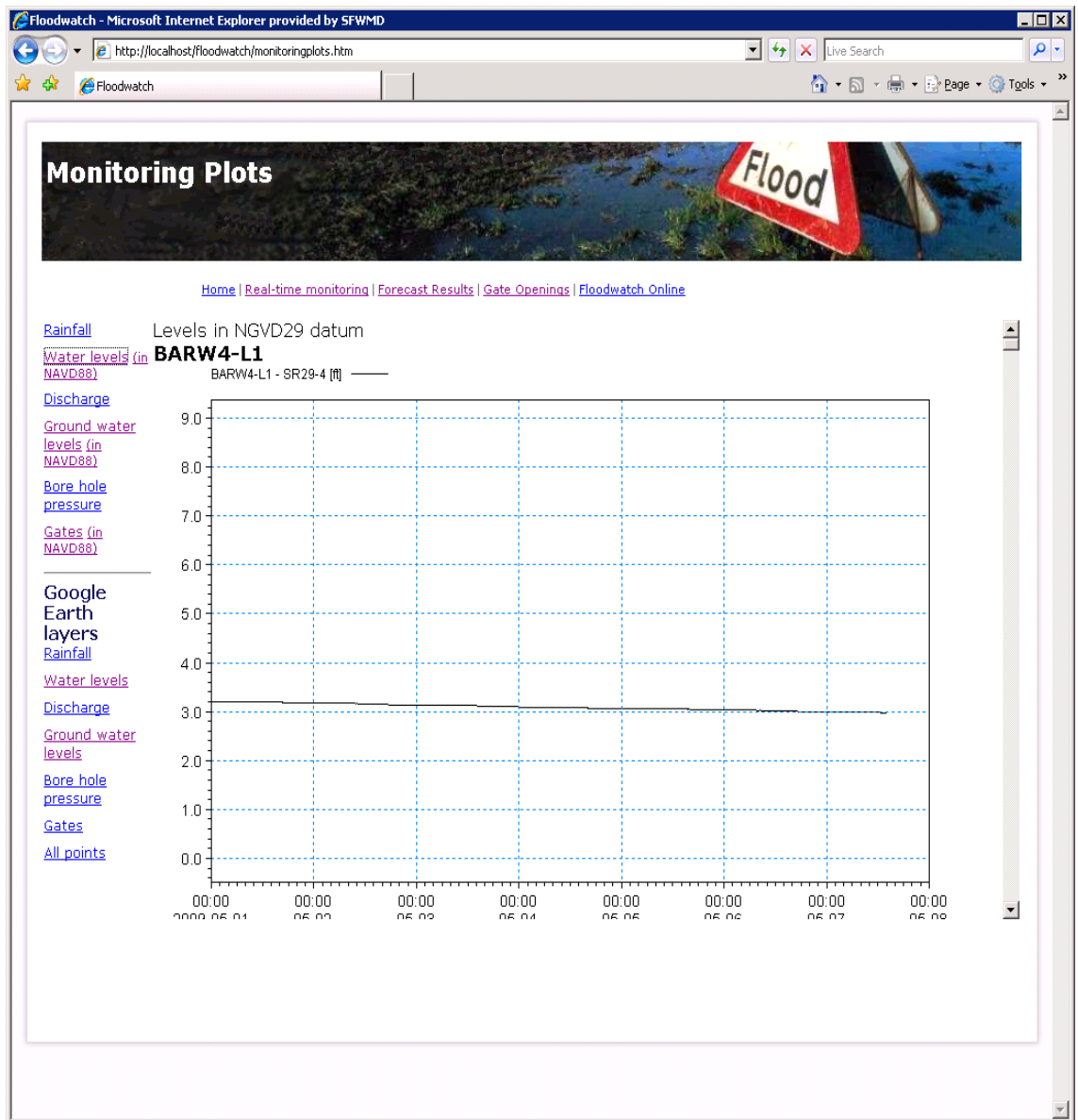


Figure 1-1 The level sites can be viewed using the NGVD 29 datum (default) or the NAVD 88 datum

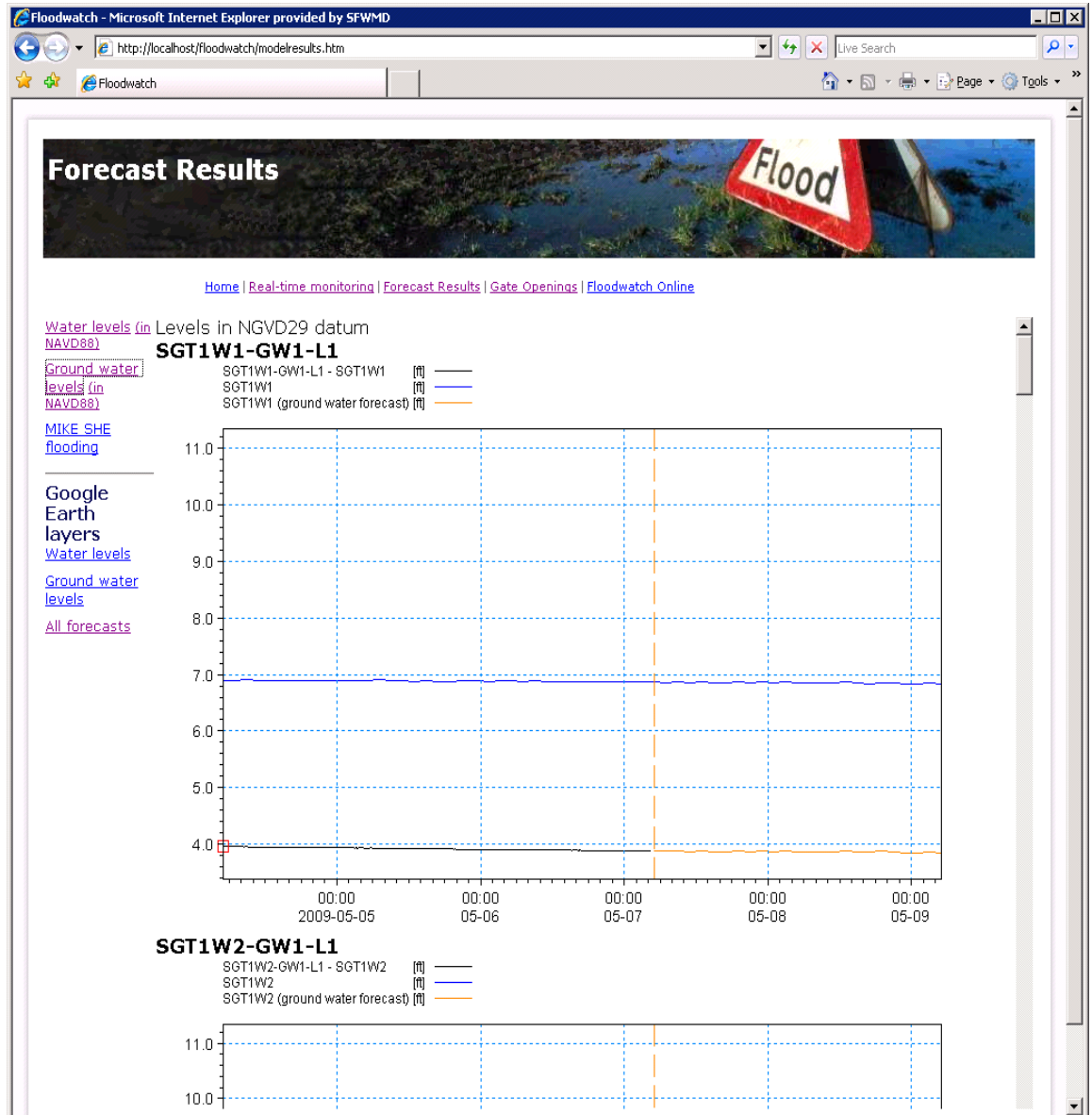


Figure 1-2 Groundwater level forecasts including the error correction forecasts

## 1.2 2D Floodmaps

The 2D animated flood map has been modified to display of flooding maps on top of Google Maps. The page is made by the DHI product Dashboard Manager

After completion of every forecast run the MIKE SHE overland depth DFS2 file is being plotted for each time step into a set of semi-transparent png-files. The png-files are put into the dashboard userfiles folder in

c:\inetpub\wwwroot\dss\userfiles\floodwatch\bcbanimation

The files are unique with respect to time. The dashboard component reads all the files and puts them on top of Google Maps.

The user may zoom and pan the map with the flood maps. Using the slider and animation controls in the page the user can control how the animation works.

The script for creating the png-files is named **make2Dplots.vbs** located in

D:\Floodwatch\Projects\BCB\Misc\

It can be called by running the corresponding **make2Dplots.cmd** batch file

The script uses a utility **dfs2GE.exe** which can be configured to generate images from a dfs2-file and a legend definition. Along with the images the program also produces a kml-file which can be used with Google Earth to animate the images.

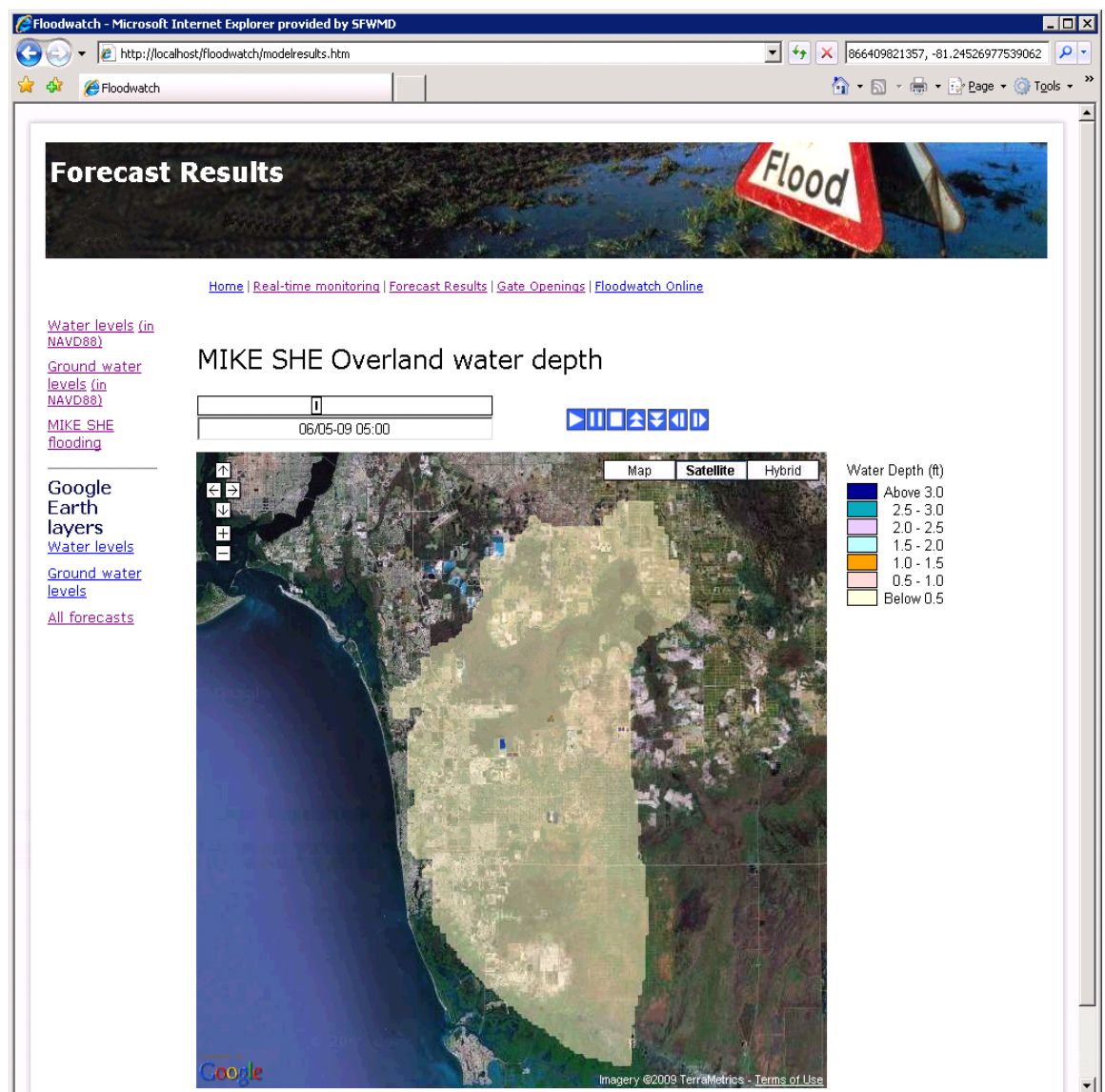


Figure 1-3 MIKE SHE overland water depth animated on Google Maps

The 2D animation is available in the web pages from “MIKE She Flooding” link under “Forecast Results”. The page pre-loads the images and starts an animation. The user can zoom and pan – and control the animation speed, restart and stop via the blue animation controls in the page.

### 1.3 Alerts

An alert is defined as a transgression of a defined alarm level for a successive period of 2 hours.

The requirements for the alert functionality was defined in an email date April 6, 2009 in word document “Threshold\_Warning\_Scenario.doc”:

**The threshold only defines for the wet season (May 1<sup>st</sup> – November 15) at this time.**

**Scenario One:**

If during wet season

FU#5 upstream water level(FU5-U-L1) >= 13.7 ft NGVD for more than 2 hours

**And**

FU#4 upstream water level >= (FU4S-U-L2)12.5 ft NGVD for more than 2 hours

Then send email to the defined group

*The water level in the Faka Union Canal is extremely high, please check operational condition of the gates FU#5 and FU#4.*

**Scenario Two:**

If during wet season

GG#2 upstream water level(GG2-U-L1) >= 6.5 ft NGVD for more than 2 hours

**And**

GG#1 upstream water level (GG1-U-L1)>= 5.2 ft NGVD for more than 2 hours

Then send email to the defined group

*The water level in the Golden Gate Canal is extremely high, please check operational condition of the gates GG#1 and GG#2.*

**Scenario Three:**

If during wet season

water level @ EXT951-L1 >= 14.5 ft NGVD for more than 2 hours

**And**

water level @ COC951-L1 >= 12.25 ft NGVD for more than 2 hours

**And**

Water level @ Cork2-L1 >= 14.0 ft NGVD for more than 2 hours

Then send email to the defined group:

*The water level in the Cocohatchee Canal is extremely high; please check COCO#1, COCO#2 and COCO#3 gates operational condition.*

The requirements for the alert condition evaluation as described above and the need to plot in NVGD29 meant that the standard Floodwatch alarm manager could not be used. Furthermore, a need to view the alarm emails on a portable device (Blackberry) meant that the publications by email generated by the built-in alert functionality in Floodwatch was not suitable.

Therefore a script has been created which:

- Checks if concurrent 2 hours transgressions of values for selected sensors occur.
- emails selected users. The email contains
  - a header indicating the alarm scenario number
  - the body contains the alarm text
  - the body contains a time series plot of the recent (1 week) observations together with a red line indicating the threshold level (both in NGVD29)

The script is named **alert.vbs** and is located in D:\Floodwatch\Projects\BCB\Misc\

It can be called by running the corresponding **alert.cmd** batch file.

It is run following each import of data to Flood watch. This means that the situation is checked every hour and if the conditions exist for several hours the result will be hourly emails with an updated plot of the conditions until the condition is not longer met.

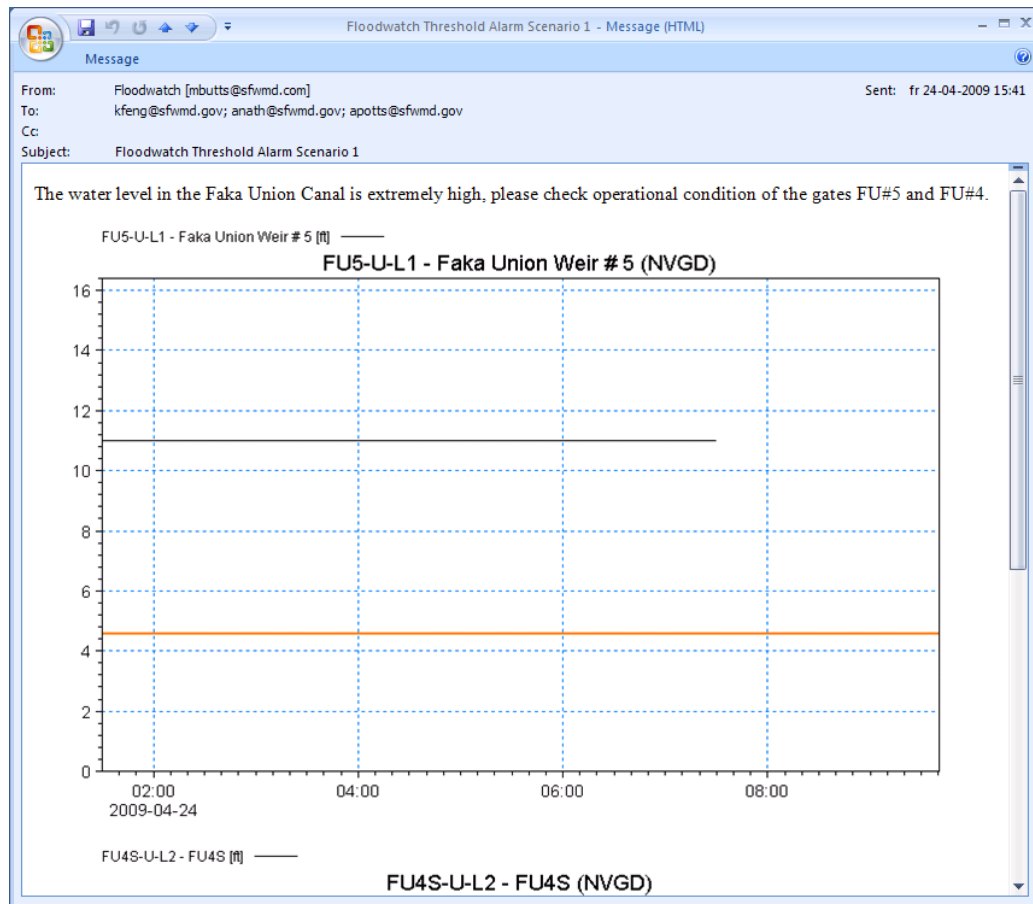


Figure 1-4 Sample alert message in Outlook

## 1.4 Gate Opening Indicators

The Gate Opening Indicators are web pages showing the current state of the gates at various locations. The pages are defined in the Dashboard Manager and are dynamic in the sense that new data is copied to the web server every time data is imported into Floodwatch. This is currently done every hour. The displays reflect the latest observations received in Floodwatch

The gates for which these Gate Opening Indicators are produced were agreed together with SFWMD and are listed below:

- COCO#1
- COCO#2
- COCO#3
- FU#4
- FU#5
- Hend#1 Sluice Gate
- GG#1
- GG#2



Data for the plots are prepared by a Visual Basic Script running just after each import into Floodwatch of observations. As the indicators and levels are required in the NVGD 29 datum the data are adjusted during the copy from the FLOODWATCH telemetry folder into the folder of the Gate Opening Displays.

The script is named **DBMcopyTS.vbs**, is located in sub-folder Misc. It can be called by running the corresponding **DBMcopyTS.cmd** batch file

It copies data covering the last week for the required sensors between the telemetry sub-folder to the dashboard user files folder in

c:\inetpub\wwwroot\dss\userfiles\floodwatch\bcbtelemetry

where the Dashboard page picks it up.

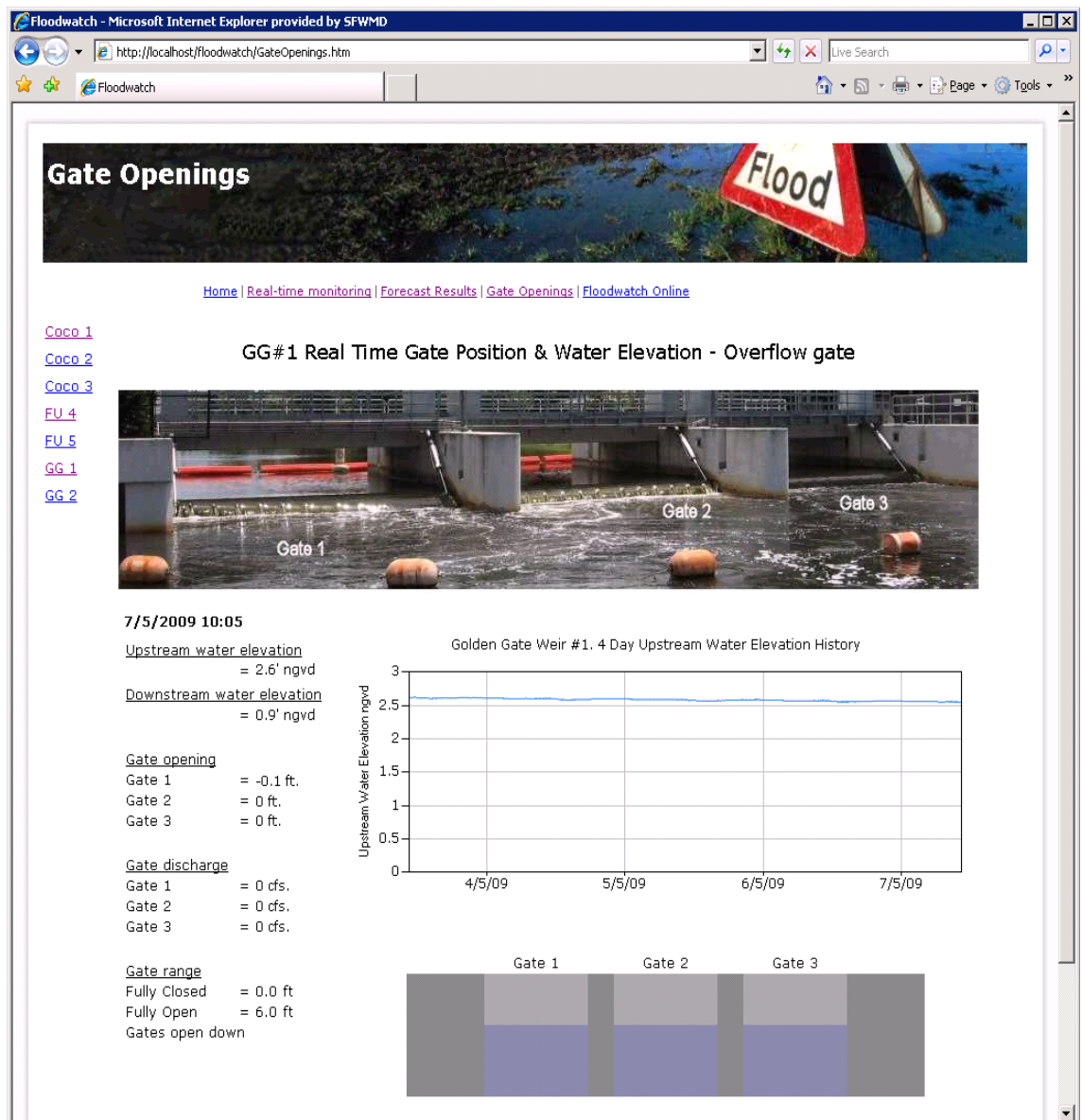


Figure 1-5 Example of the Gate Opening Indicator for GG #1gate.

## 1.5 Database copy

A Visual basic script has been prepared which can - when requested - generate a MS Access database containing all the received time series data.

The script is named CopyTSDatabase.vbs and is located in

D:\Floodwatch\Projects\BCB\Misc\

It can be called by running the corresponding CopyTSDatabase.cmd batch file

The script reads the time series data from the Floodwatch database (BCB.MDB) and creates a new database TSDB.MDB

To extract data from this database the BCB staff should copy the TSDB.MDB file from the sever to the local computer. When opening the database it will automatically display a time series view form, see Figure 1-6 Time series view

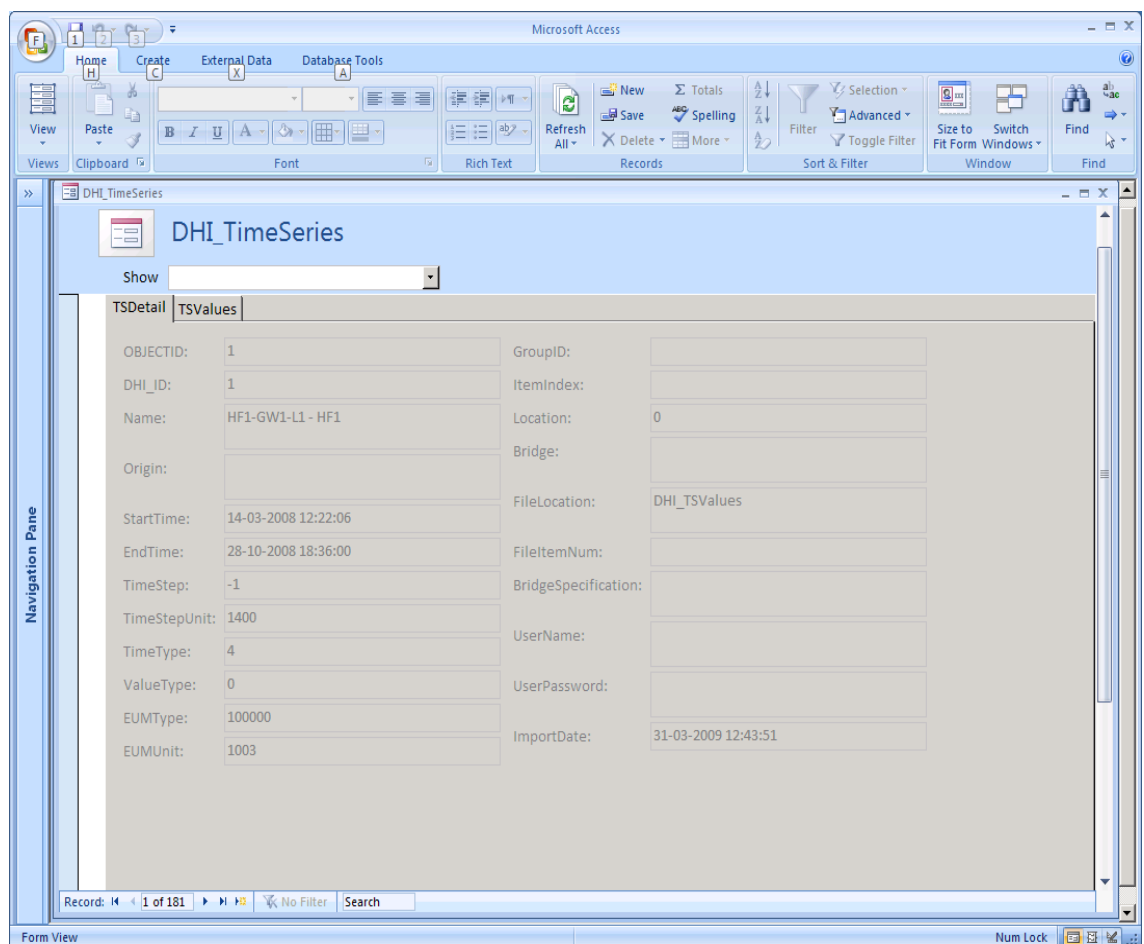


Figure 1-6 Time series view

From the “show” drop down a time series can be selected. It is identified with the OASys identifier.



When selected the details defining the time series are shown at TSDetail tab-page. The actual values are listed in the TSValues tab, see Figure 1-7 Time series values. The data can then be copied to the clipboard for use elsewhere.

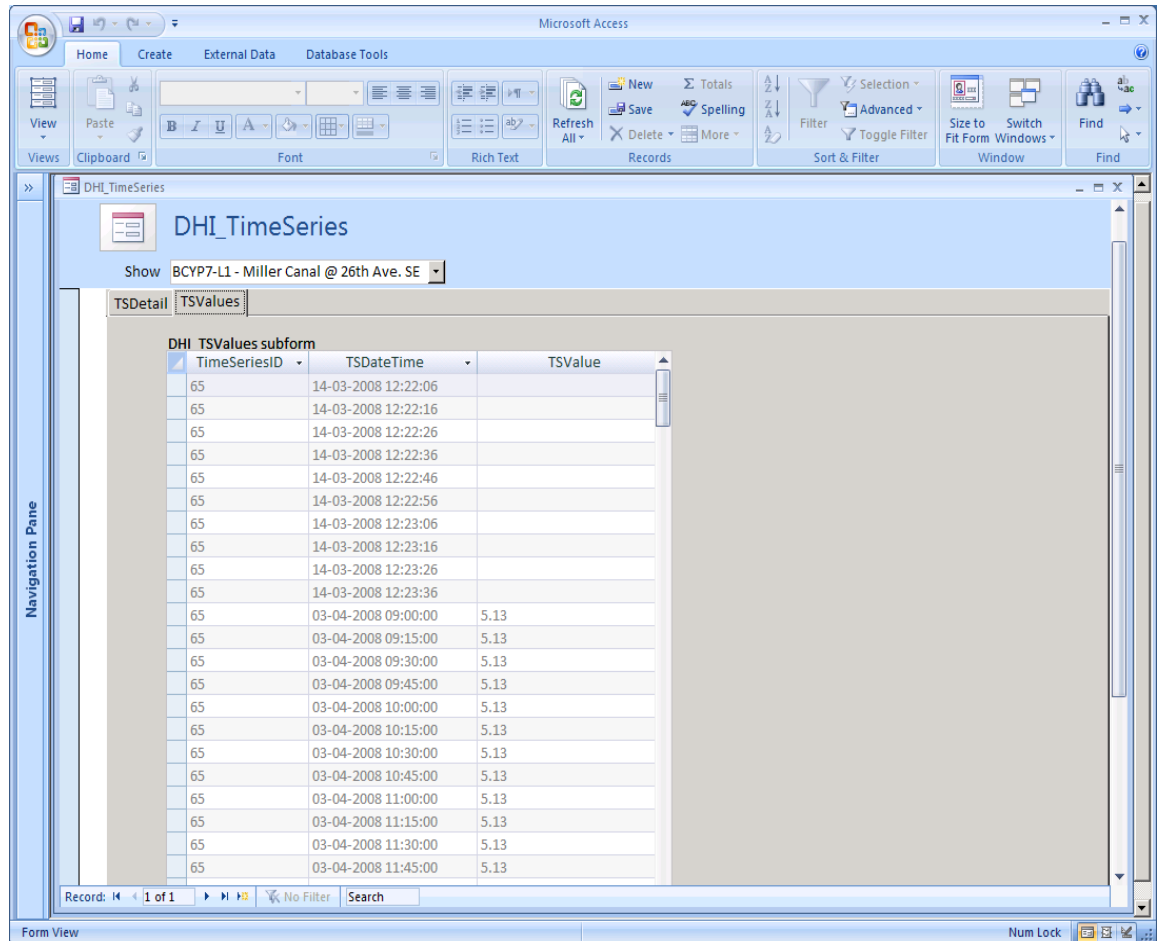


Figure 1-7 Time series values

## **2 TASK 2 - IMPROVED REPRESENTATIONS OF CONTROL STRUCTURES**

The original BCB model was built and calibrated as a regional water resource management tool and required specific modifications to adapt it for flood forecasting. The operation and management of control structures is integral to the management of water resources and particularly important in flood control throughout the BCB. The ability of the RTHMS to accurately represent the geometry and operations of regulating structures is critical for accurate flood forecasts during storm events. During Phase 1, a subset of forecasting points that represent the key forecasting locations were identified by SFWMD and DHI. The key structures corresponding to water level forecasts in the model are:

- Faka Union Canal: FU4, FU5
- Golden Gate: GG5, GG2, GG1
- Cocohatchee: COC03, COC02, COC01
- Henderson Creek: HC1

Reviews of the performance of the BCB forecast indicated that the model only approximately captures the behavior at these points. An analysis of why this was the case was carried out during Phase 1. 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, the model is able to match the water levels well in the hindcast period however; the model is unable to forecast how the control structures will behave in the future. 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. For those structures identified above, DHI will modify the operational strategies to represent the operations as accurately as possible. This will likely involve development of operating rules to govern the independent operation of individual gates within the structures. This presents specific challenges due to the wide range of possible control strategies that could be imposed on an as-needed basis by operation personnel. DHI worked closely with the BCB operational staff to develop strategies that represent theoretical operational strategies that match the actual operations

This section describes the improved representations of the control structures in the BCB model and their implementation.

The MIKE 11 model includes operational structures at 38 different locations. The locations and the structure names are listed in Table 1. With a few exceptions all structures are operated individually in order to maintain the water level upstream of the structures within a certain interval which depends on the season.

Some gates are operated automatically and provide online information on the position of the individual gates. These structures will typically be the more complex to implement. Within the MIKE 11 model, the overall strategy to best represent the real-time gate operation for forecasting is to use the measured gate levels wherever possible to capture the actual operation of individual gates. However in forecasting the behaviour of the gates in the future, these observations are not available and operating rules are implemented that represent the best possible description of the actual operation of the gates under the forecasted conditions.

Both the complex and less complex structures have some common features. The way the operation has been implemented allows for the user to override the rules governing the operation. This override function should however only be used for offline studies or be applied in more advanced online environment such as a DSS. Further, it was found beneficial for the model stability to introduce a requirement that a structure shouldn't open until the head difference across the structure exceeds a certain limit. This rule is also applied to most of the structures.

How the override functionality and the minimum head difference requirement are implemented will be detailed in the section 2.4 describing the time series that are used to communicate different information to the structure operation module of MIKE 11.

In the subsections below, the way in which the operation of the different structures has been implemented will be discussed in detail.

Table 1 Table listing the locations at which operational structures are included in the model.

| Weir Name                         | MIKE 11 Branch Name | MIKE 11 Chainage [ft] |
|-----------------------------------|---------------------|-----------------------|
| Airport Road North                | AirportRdN          | 5626.64042            |
| Airport Road South                | AirportRdS          | 23343.17590           |
| US-41 Weir                        | BelleMeade-7        | 459.31759             |
| Twin Eagles Weir                  | CocohatcheeEast     | 2181.75853            |
| Cocohatchee Canal Weir # 3        | CocohatcheeWest     | 26755.24930           |
| Cocohatchee Canal Weir # 2        | CocohatcheeWest     | 43169.29130           |
| Cocohatchee Canal Weir # 1        | CocohatcheeWest     | 49908.13650           |
| Corkscrew Canal Weir # 2          | CorkScrewCan        | 4101.04987            |
| Corkscrew Canal Weir # 1          | CorkScrewCan        | 21797.90030           |
| Corkscrew Canal Weir # 3          | CorkTribCan         | 328.08399             |
| CR 951 Canal Structure # 2        | CR951               | 10465.87930           |
| CR 951 Canal Structure # 1        | CR951               | 37729.65880           |
| Cypress Canal Weir                | CypressCan          | 22142.38850           |
| Faka Union Weir # 7               | FakaUnionCan        | 10088.58270           |
| Faka Union Weir # 6               | FakaUnionCan        | 21981.62730           |
| Faka Union Weir # 5               | FakaUnionCan        | 34448.81890           |
| Faka Union Weir # 4               | FakaUnionCan        | 57742.78220           |
| Faka Union Weir # 3               | FakaUnionCan        | 79429.13390           |
| Faka Union Weir # 2               | FakaUnionCan        | 109908.13600          |
| Golden Gate Canal Weir # 7        | GoldenGateBr        | 7759.18635            |
| Golden Gate Canal Weir # 6        | GoldenGateMain      | 14563.64830           |
| Golden Gate Canal Weir # 5        | GoldenGateMain      | 30951.44360           |
| Golden Gate Canal Weir # 4        | GoldenGateMain      | 52217.84780           |
| Golden Gate Canal Weir # 3        | GoldenGateMain      | 96377.95280           |
| Golden Gate Canal Weir # 2        | GoldenGateMain      | 127542.65100          |
| Golden Gate Canal Weir # 1        | GoldenGateMain      | 140436.35200          |
| Harvey Canal Weir # 2             | HarveyCan           | 921.91601             |
| Harvey Canal Weir # 1             | HarveyCan           | 8346.45669            |
| Henderson Creek Weir # 2          | HendersonCr         | 17739.50130           |
| Henderson Creek Weir # 1          | HendersonCr         | 45111.54860           |
| I-75 canal weir # 3               | I-75Can             | 10000.00000           |
| I-75 canal weir # 2               | I-75Can             | 22965.87930           |
| I-75 canal weir # 1               | I-75Can             | 39862.20470           |
| Miller Canal Weir # 3             | MillerCan           | 173.88451             |
| Miller Canal Weir # 2             | MillerCan           | 31578.08400           |
| Miller Canal Weir # 1             | MillerCan           | 62335.95800           |
| East Tamiami Weir at Henderson Cr | Tamiami1            | 164.04200             |
| West Tamiami Weir at Henderson Cr | TamiamiWBound       | 5406.82415            |

## 2.1 Online structures

At 9 of the 38 locations the gate positions are logged and are downloaded online. The online gates are: Weirs # 1, 2 and 3 at Cocohatchee Canal, weirs # 1 and 2 at Golden Gate Canal, weirs # 4 and 5 at Faka Union Canal, the sluice gates at weir # 1 at Henderson creek and the gate located at the branch Bellemeade-7.

### 2.1.1 Weirs # 1, 2 and 3 at Cocohatchee Canal and Sluice Gates at Weir # 1 at Henderson Creek

Weirs # 1, 2 and 3 located at the downstream part of Cocohatchee Canal together with the two sluice gates at weir # 1 in Henderson Creek belong to the more complex structures in the model. Not only do they allow for the user to override the rules but they also include direct use of the measured gate levels to control the gates in the model. Furthermore the rules implemented reflect the way the automated gate operation works and ensures continuity in the transition from hindcast to forecast period.

All of the weirs consist of two independently operated sluice gates. In addition to this, the structures in Cocohatchee Canal are equipped with a static weir whereas the weir in Henderson Creek has an additional flap gate. This is however operated manually and independently of the two sluice gates and will thus be described in the section 2.2 dealing with the manually operated gates.

The gate operation implemented for these gates are identical and aims at maintaining the upstream water level within a certain interval. In order to do so they will start to open when the water level reaches the highest allowed water level and will continue to open as long as the water level exceeds this limit. The choice of which gate to open depends on the present position of the gates and for how long they have been closed. The latter condition is introduced to ensure that both gates are kept in operation and do not for example seize up. . The rules for which gate to open are summarized in the decision matrix in Table 2.

Table 2 Decision matrix to be used when deciding which gate to open.

|                                | Gate 2 is closed  | Gate 2 is fully open | Gate 2 is opening | Gate 2 is open but has stopped                          |
|--------------------------------|---|----------------------|-------------------|---|
| Gate 1 is closed               | Open the gate that has been closed for the longest time | Open gate 1          | Open gate 2       | Open gate 1   |
| Gate 1 is fully open           | Open gate 2   |                      | Open gate 2       | Open gate 2   |
| Gate 1 is opening              | Open gate 1   | Open gate 1          |                   | Open gate 1   |
| Gate 1 is open but has stopped | Open gate 2   | Open gate 1          | Open gate 2       | Open the gate that has been closed for the longest time |

When it comes to closing the gates, this is straightforward: If the water level drops below the minimum allowed water level both gates will start closing and continue closing as long as the water level is below the limit.

All structures at Cocohatchee Canal Weir # 1, 2 and 3 at the sluice gates at weir # 1 in Henderson Creek are operated in an identical manner. The rules and the conditions for applying the rules are listed in Table 3.

*Table 3 Table listing the rules needed to control the individual gates at Cocohatchee Canal Weir # 1, 2 and 3 as well as the sluice gates at weir # 1 in Henderson Creek. Also the conditions that must be fulfilled in order to apply any given rule are listed.*

| <b>Rule</b> | <b>Conditions</b>  | <b>Action</b>                     |
|-------------|--|-----------------------------------|
| 1           | Measurements for this gate exist   | Use measured levels for this gate |
| 2           | User overrides and wants this gate closed  | Close this gate                   |
| 3           | User overrides and wants this gate open  | Open this gate                    |
| 4           | Head too small to open   | Close this gate                   |
| 5           | Water level larger than maximum water level<br>and This gate is closed<br>and The other gate is closed<br>and This gate last opened longer time ago than the other gate<br>and Head across gate larger than minimum head for 1 hour  | Open this gate                    |
| 6           | Water level larger than maximum water level<br>and This gate is open<br>and This gate is opening<br>and Head across gate larger than minimum head for 1 hour   | Open this gate                    |
| 7           | Water level larger than maximum water level<br>and The other gate is fully open<br>and Head across gate larger than minimum head for 1 hour  | Open this gate                    |
| 8           | Water level larger than maximum water level<br>and The other gate is open<br>and The other gate has stopped opening<br>and This gate is closed<br>and Head across gate larger than minimum head for 1 hour   | Open this gate                    |
| 9           | Water level larger than maximum water level<br>and The other gate is open<br>and The other gate has stopped opening<br>and This gate is open<br>and This gate has stopped opening<br>and This gate last opened longer time ago than the other gate<br>and Head across gate larger than minimum head for 1 hour | Open this gate                    |
| 10          | Water level lower than minimum water level   | Close this gate                   |
| 11          | If none of the above evaluates to true   | Leave this gate unchanged         |

### **2.1.2 Weirs # 1 and 2 at Golden Gate Canal and Weirs # 4 and 5 at Faka Union Canal**

Weirs # 1 and 2 in the Golden Gate Canal and weirs # 4 and 5 in Faka Union Canal also belong to the more complex structures in the model. As with the weirs # 1, 2 and 3 at Cocohatchee Canal they allow for the user to override the rules but they also include direct use of the measured gate positions to control the structures in the model. This can be viewed as a model boundary condition or a type of assimilation of the gate levels. Furthermore the rules implemented reflect the way the automated gate operation works and ensures continuity in the transition from hindcast to forecast period.

The four weirs are not identical when it comes to the types of gates: Weir # 1 has three individually operated gated spillways whereas weir # 2 is equipped with three individually operated Obermeyer gates. Weir # 4 and 5 in Faka Union has 6 and 12 sluice gates, respectively.

However, the operation implemented for the weirs are identical. The method adopted is described below but the basically the gates are opened or closed a certain amount whenever the water level induces a gate movement. The gate is typically opened or closed 1.5 ft. This is true for the gates at Golden Gate Canal whereas the gates at Faka Union Canal only opens or closes 1.0 ft.

As with the other gates the purpose is to maintain the upstream water level within a certain interval. In order to do so a gate will be opened 1.5 feet when the water level reaches the highest allowed water level. For the next 15 minutes after operation of the gate no gate movement will take place. This ensures that the gate will not open excessively in situations with only a minor exceedance of the maximum water level. If the maximum water level is still exceeded after the 15 minutes one of the gates will open 1.5 ft. more. Which gate to open depends on the position of the gates and for how long they have been closed: If all the gates are at the same level the gate that started opening the longest time ago will be the next to open. If all the gates started opening at the same time last time they opened, gate number 1 is taken. If the gates are not at the same position the gate being the least open will be the one that opens. If more than one gate is in this position the gate with the lowest number will be the next to open. Closing of the gates is straightforward: If the water level gets below minimum water level all the gates will close 1.5 ft. After doing so no gate movement will take place for the next 15 minutes. If the water level is still below minimum water level after the 15 minutes the gate will close an additional 1.5 ft.

The rules for when to operate a gate and the associated conditions are summarized in Table 4.

Table 4 Table listing the rules that govern the operation of the gates at weir # 1 and 2 at Golden Gate Canal and at weir # 4 and 5 in Faka Union.

| Rule | Conditions   | Action                            |
|------|--|-----------------------------------|
| 1    | Measurements for this gate exist   | Use measured levels for this gate |
| 2    | User overrides and wants this gate closed  | Close this gate                   |
| 3    | User overrides and wants this gate open  | Open this gate                    |
| 4    | Head too small to open   | Close this gate                   |
| 5    | Less than 15 minutes since gate was operated   | Leave this gate unchanged         |
| 6    | Water level larger than maximum water level<br>and All three gates at the same level<br>and This gate has lowest number among gates that opened longest time ago<br>and Head across gate larger than minimum head for 1 hour | Open this gate by 1.5/1.0 ft      |
| 7    | Water level larger than maximum water level<br>and This gate has lowest number among gates with the smallest discharge<br>and Head across gate larger than minimum head for 1 hour   | Open this gate by 1.5/1.0 ft      |
| 8    | Water level lower than minimum water level   | Close this gate by 1.5/1.0 ft     |
| 9    | If none of the above evaluates to true   | Leave this gate unchanged         |

### 2.1.3 The gate at Bellemeade-7

This gate is implemented in MIKE11 using measured gate levels when these are available. Since no information was available for the operation of the gate the last measured gate position is applied during the whole forecast period. In addition to this the user can override this rule and either close the gate or open the gate.

Table 5 Table listing the rules implemented for the gate at Bellemeade-7.

| Rule | Conditions                                | Action                            |
|------|---|-----------------------------------|
| 1    | Measurements for this gate exist          | Use measured levels for this gate |
| 2    | User overrides and wants this gate closed | Close this gate                   |
| 3    | User overrides and wants this gate open   | Open this gate                    |
| 4    | If none of the above evaluates to true    | Leave this gate unchanged         |

## 2.2 Manually operated gates

The major part of the manually operated gates is implemented in MIKE 11 using the same rules of operation. These gates consist of one or two individual gates. They can be either sluice gates or overflow gates. As with the online gates the purpose is to maintain the upstream water level within a certain interval. However, there are no general rules that can be applied when implementing the gate operation in MIKE 11. For this reason it has been necessary to make some assumptions. The gates can be opened during working hours only. By default this is chosen to be between 10 o'clock and 14 o'clock. This interval is configurable. How to change this will be described in details in section 3. Fur-



ther, it is assumed that only one gate will be opened at a time and that at least 12 hours must pass after operation of a gate before a new gate operation can take place. Table 6 lists the structures for which these standard rules of manual operation apply. For the structures consisting of a single gate the rules of operation is summarized in Table 7.

*Table 6 Table listing the structures at which the standardized rule for manual operation applies*

| <b>Weir Name</b>                  | <b>Number of gates</b> |
|-----------------------------------|------------------------|
| Corkscrew Canal Weir # 1          | Two gates              |
| Corkscrew Canal Weir # 2          | Two gates              |
| Corkscrew Canal Weir # 3          | One gate               |
| CR 951 Canal Structure # 1        | Two gates              |
| CR 951 Canal Structure # 2        | Two gates              |
| Cypress Canal Weir                | Two gates              |
| East Tamiami Weir at Henderson Cr | One gate               |
| Faka Union Weir # 3               | Two gates              |
| Faka Union Weir # 6               | Two gates              |
| Faka Union Weir # 7               | One gate               |
| Golden Gate Canal Weir # 3        | Two gates              |
| Golden Gate Canal Weir # 4        | Two gates              |
| Golden Gate Canal Weir # 5        | Two gates              |
| Golden Gate Canal Weir # 6        | One gate               |
| Golden Gate Canal Weir # 7        | One gate               |
| Henderson Creek Weir # 1          | One gate               |
| Henderson Creek Weir # 2          | Two gates              |
| I-75 canal weir # 1               | One gate               |
| I-75 canal weir # 2               | Two gates              |
| I-75 canal weir # 3               | Two gates              |
| Miller Canal Weir # 2             | Two gates              |
| Miller Canal Weir # 3             | Two gates              |
| Twin Eagles Weir                  | Two gates              |
| West Tamiami Weir at Henderson Cr | One gate               |

For the structures consisting of a single gate the rules of operation are summarized in Table 7.

Table 7 Table listing the rules applied for controlling a single manually operated gate.

| Rule | Conditions  | Action                    |
|------|---|---------------------------|
| 1    | User overrides and wants this gate closed   | Close this gate           |
| 2    | User overrides and wants this gate open   | Open this gate            |
| 3    | Head too small to open  | Close this gate           |
| 4    | Less than 12 hours since gate was operated  | Leave this gate unchanged |
| 5    | Manual operation is possible<br>and Water level larger than maximum water level<br>and Head across gate larger than minimum head for 1 hour | Open this gate            |
| 6    | Manual operation is possible<br>and Water level lower than minimum water level  | Close this gate           |
| 8    | If none of the above evaluates to true  | Leave this gate unchanged |

For the structures with two gates the rules listed in Table 7 applies to the first gate. For the second gate the rules must be extended in order to ensure that only one gate will be opened at a time. These modified rules are listed in Table 8.

Table 8 Table listing the rules applied to the second gate of the manually operated structures.

| Rule | Conditions  | Action                    |
|------|---|---------------------------|
| 1    | User overrides and wants this gate closed   | Close this gate           |
| 2    | User overrides and wants this gate open   | Open this gate            |
| 3    | Head too small to open  | Close this gate           |
| 4    | Less than 12 hours since gate was operated  | Leave this gate unchanged |
| 5    | Manual operation is possible<br>and first gate is open<br>and first gate has been open for at least 12 hours<br>and Water level larger than maximum water level<br>and Head across gate larger than minimum head for 1 hour | Open this gate            |
| 6    | Manual operation is possible<br>and Water level lower than minimum water level  | Close this gate           |
| 8    | If none of the above evaluates to true  | Leave this gate unchanged |

For the structures at weir # 1 at Mille Canal and weir # 2 at Faka Union Canal no attempt has been made to detail and refine the rules of operation. This is due to the fact that these two structures will soon be removed.

For weir # 1 and 2 in Harvey Canal the rules used are quite straightforward: They will be closed during the dry season and open during the wet season. How information on which season prevails is conveyed to MIKE11 is described in section 3.

For the gates located at Airport Canal North and Airport Road South the rules applied says that the gate will open when a certain maximum water level is exceeded. In contrast to most of the other gates no minimum water levels are defined for these gates. Instead they will close as soon as the water level drops below the maximum water level.

## **2.3 Pumps**

At three locations pumps have been installed: At the structure at Airport Road South, at CR951 canal structure # 1 and at I-75 canal weir #2. These structures are used during the dry season only in order to store excess water when available. None of the pumps can be operated between 6 and 9 o'clock and between 18 and 21 o'clock due to an agreement with the power supplier.

Pumping from The Golden Gate Canal to the Airport Road Canal will start in situations where the water level in Golden Gate is above 3.23 ft NAVD88 and the water level in Airport Road Canal falls below 5.73 ft NAVD88. Pumping ceases when the water level in Airport Road Canal reaches 7.02 ft NAVD88.

Pumping from The Golden Gate Canal to the CR951 Canal will start in situations where the water level in Golden Gate is above 4.23 ft NAVD88 and the water level in CR951 Canal falls below 6.73 ft NAVD88. Pumping ceases when the water level in CR951 Canal reaches 7.13 ft NAVD88.

The pump in I-75 canal will be operated when the water is not spilled at the structure at Golden Gate Weir # 2 and the water level in I-75 drops below 5.74 ft. NAVD88. Pumping stops when the water level in I-75 reaches 6.74 ft. NAVD.

## **2.4 Configuring the Structure Operation**

The way the structures have been implemented in MIKE 11 makes it possible for the user to configure parts of the operation. The maximum and minimum water levels are stored in time series taking into account the seasonal variation. Table 9 lists the minimum and maximum water levels for both the wet and dry season. The time series are stored in a separate subfolder to the MIKE 11 model named 'TargetWaterLevels'. The file names start with either 'MaximumWaterLevel' or 'MinimumWaterLevel' followed by the structure name which is followed by the string '-(NAVD88) indicating the datum used, e.g. the maximum water level for the weir # 1 at Golden Gate Canal would be named 'MaximumWaterLevelAirportRoadCanalNorth-(NAVD88).dfs0'.

The override options in which the user can specify that a gate must be either open or closed are also implemented using time series. For each of the individual gate having this option a time series is stored in a subfolder named 'OverRides'. It works in this way: If the user specifies 2 in the relevant file the structure will be closed. If a number 1 is specified the structure will be open. If no override is requested the value to specify is 0.

Table 9 Table listing the control water levels for the different structures

| Weir Name                              | Wet Season                      |                                 | Dry Season                      |                                 |
|--|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
|  | Max. Water level in feet NAVD88 | Min. Water Level in feet NAVD88 | Max. Water level in feet NAVD88 | Min. Water Level in feet NAVD88 |
| Airport Road North                     | 6.26                            | -                               | 7.26                            | -                               |
| Airport Road South                     | 6.23                            | -                               | 7.23                            | -                               |
| Cocohatchee Canal Weir # 1             | 5.47                            | 2.77                            | 5.47                            | 3.97                            |
| Cocohatchee Canal Weir # 2             | 8.97                            | 6.77                            | 8.97                            | 7.47                            |
| Cocohatchee Canal Weir # 3             | 10.27                           | 8.77                            | 10.57                           | 9.57                            |
| Corkscrew Canal Weir # 1               | 9.74                            | 7.74                            | 11.24                           | 10.24                           |
| Corkscrew Canal Weir # 2               | 10.25                           | 8.75                            | 11.25                           | 10.25                           |
| Corkscrew Canal Weir # 3               | 11.26                           | 9.76                            | 12.26                           | 11.26                           |
| CR 951 Canal Structure # 1             | 6.73                            | 5.73                            | 7.73                            | 6.73                            |
| CR 951 Canal Structure # 2             | 10.73                           | 8.73                            | 11.23                           | 9.23                            |
| Cypress Canal Weir                     | 8.75                            | 8.25                            | 9.25                            | 8.50                            |
| East Tamiami Weir at Henderson Creek   | 3.70                            | 2.70                            | 4.70                            | 4.20                            |
| Faka Union Weir # 2                    | 4.88                            | 3.88                            | 4.88                            | 4.38                            |
| Faka Union Weir # 3                    | 5.39                            | 4.89                            | 5.89                            | 5.14                            |
| Faka Union Weir # 4                    | 10.70                           | 9.70                            | 10.70                           | 9.70                            |
| Faka Union Weir # 5                    | 12.22                           | 11.22                           | 13.22                           | 12.22                           |
| Faka Union Weir # 6                    | 13.73                           | 13.23                           | 14.23                           | 13.48                           |
| Faka Union Weir # 7                    | 15.44                           | 14.44                           | 15.94                           | 15.44                           |
| Golden Gate Canal Weir # 1             | 2.73                            | 1.23                            | 3.73                            | 2.23                            |
| Golden Gate Canal Weir # 2             | 4.73                            | 3.73                            | 5.23                            | 4.48                            |
| Golden Gate Canal Weir # 3             | 6.73                            | 6.23                            | 7.23                            | 6.48                            |
| Golden Gate Canal Weir # 4             | 8.73                            | 8.23                            | 9.23                            | 8.48                            |
| Golden Gate Canal Weir # 5             | 9.73                            | 9.23                            | 10.23                           | 9.48                            |
| Golden Gate Canal Weir # 6             | 14.53                           | 13.53                           | 15.03                           | 14.53                           |
| Golden Gate Canal Weir # 7             | 12.63                           | 12.13                           | 13.13                           | 12.38                           |
| Harvey Canal Weir # 1                  | -                               | -                               | -                               | -                               |
| Harvey Canal Weir # 2                  | -                               | -                               | -                               | -                               |
| Henderson Creek Weir # 1, Sluice Gates | 4.20                            | 2.70                            | 5.20                            | 4.20                            |
| Henderson Creek Weir # 1, Flap Gate    | 4.45                            | 4.20                            | 4.45                            | 4.20                            |
| Henderson Creek Weir # 2               | 8.70                            | 6.70                            | 9.70                            | 8.20                            |
| I-75 canal weir # 1                    | 5.43                            | 4.93                            | 5.93                            | 5.18                            |
| I-75 canal weir # 2                    | 7.24                            | 6.74                            | 7.74                            | 6.99                            |
| I-75 canal weir # 3                    | 8.74                            | 7.74                            | 9.74                            | 8.24                            |
| Miller Canal Weir # 1                  | 3.70                            | 2.70                            | 3.70                            | 3.20                            |
| Miller Canal Weir # 2                  | 5.40                            | 4.90                            | 5.90                            | 5.15                            |
| Miller Canal Weir # 3                  | 9.20                            | 8.20                            | 9.20                            | 8.70                            |
| Twin Eagles Weir                       | 11.25                           | 9.75                            | 12.25                           | 11.25                           |
| US-41 Weir                             | -                               | -                               | -                               | -                               |
| West Tamiami Weir at Henderson Creek   | 3.20                            | 2.15                            | 3.70                            | 3.20                            |

The way the season is defined is by using the time series named 'SeasonDefinition.dfs0'. This file will hold 0 for the dry season and a 1 for the wet season.

The minimum head needed before a gate can open is specified in the file named 'MinimumHeadBeforeOpeningOfGates.dfs0'.

The numbers of hours that must pass before manually gates can be operated again are specified in the file named 'MinimumHoursBetweenManualOpeningOfGates.dfs0'.

The earliest time of the day manually gates can be operated are specified in the file named 'StartTimeForManualOperation.dfs0'. The latest time of the day the can be operated are specified in the file 'EndTimeForManualOperation.dfs0'.

## **2.5 *Initial assessment of improved representations on forecast accuracy***

To exemplify the impact of the improvements made in phase 2 on the forecast accuracy a simple comparison of the phase 1 and phase 2 models was performed. The results shown here should be regarded as an initial assessment and only represent a single forecast. Nevertheless the results show a very convincing improvement in the model performance, i.e. forecast accuracy.

To results presented compare the phase 1 forecast (black line) and the phase 2 forecast (blue line), which includes both the new structure operations and the rainfall forecasts, for a number of key sites. The forecasts were made on Friday 26<sup>th</sup> June, 2009 and the observations shown as red symbols and were obtained from the subsequent real-time data collected the real time SCADA system. Some data was not available at FU4 at the time the forecasts were made. The improvements are entirely due to the improved representation of the gate operations in this case.

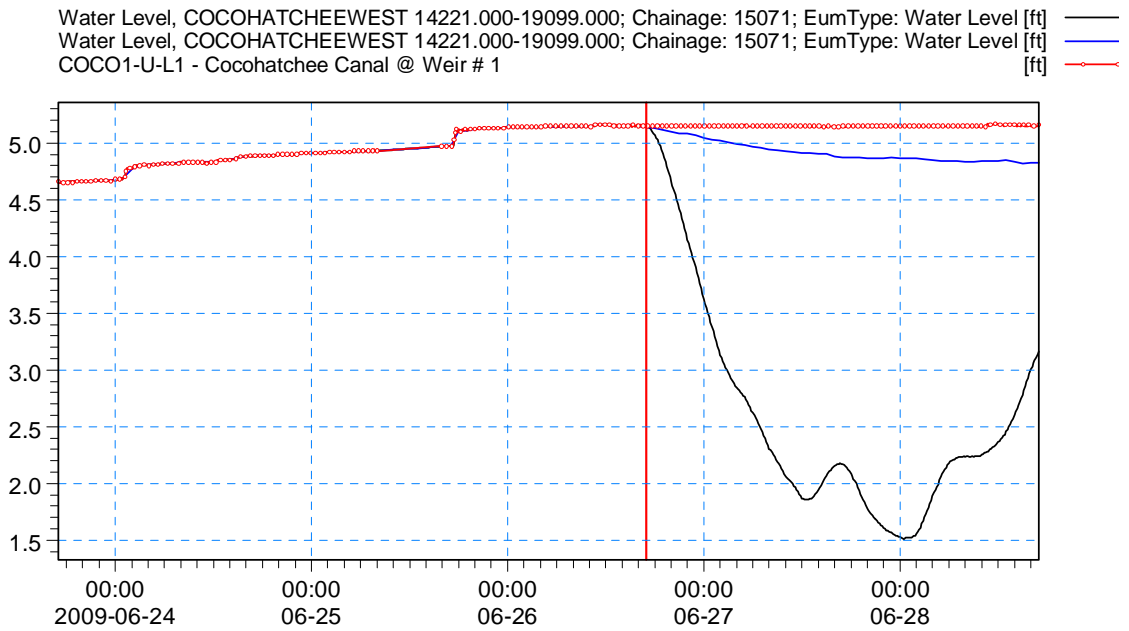


Figure 2-1 Comparison of the water levels at COCO1 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

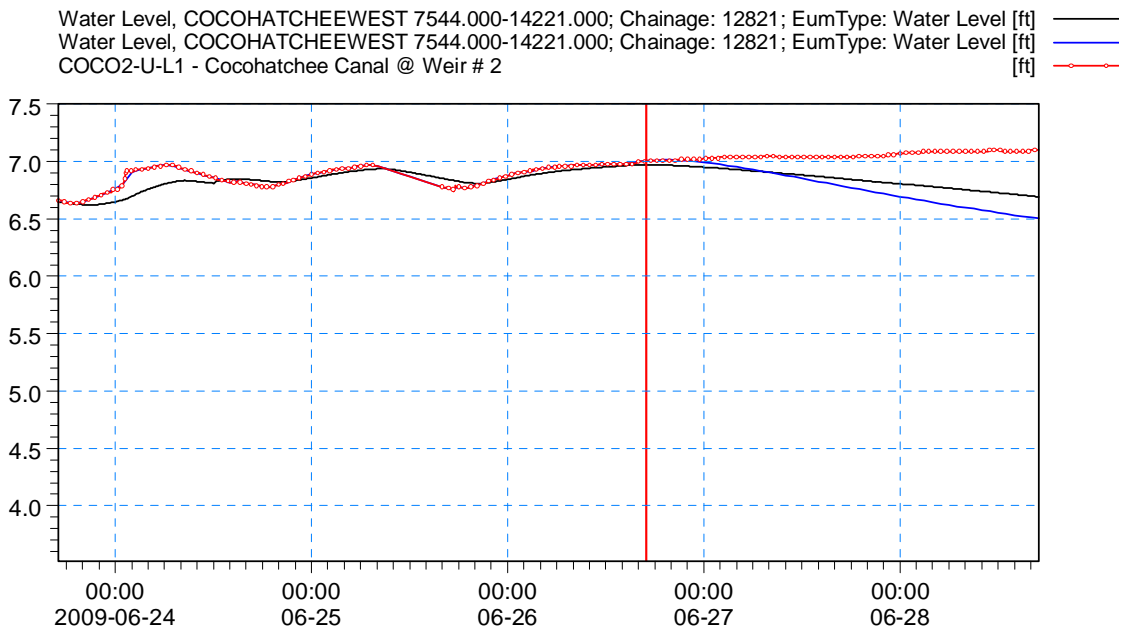


Figure 2-2 Comparison of the water levels at COCO2 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

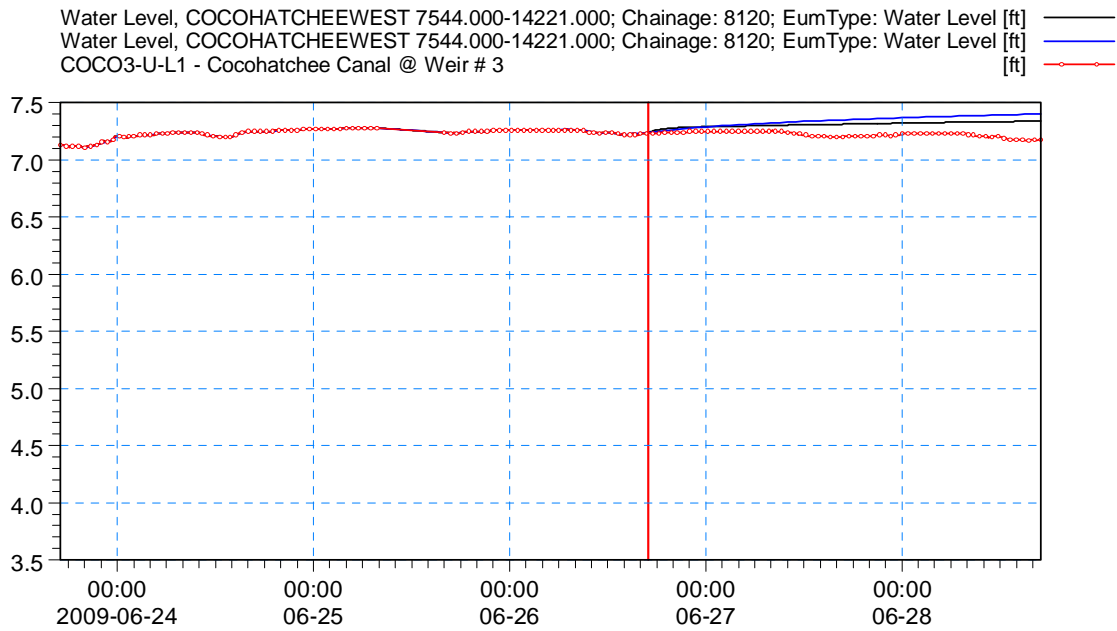


Figure 2-3 Comparison of the water levels at COCO3 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

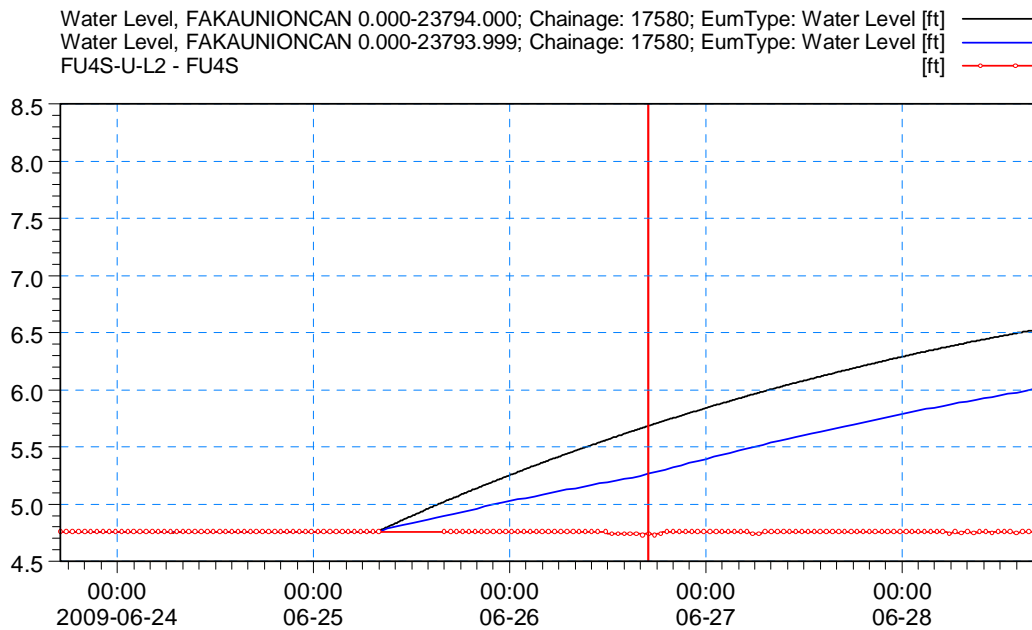


Figure 2-4 Comparison of the water levels at Faka Union 4 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

Water Level, FAKAUNIONCAN 0.000-23794.000; Chainage: 10000; EumType: Water Level [ft] —  
 Water Level, FAKAUNIONCAN 0.000-23793.999; Chainage: 10000; EumType: Water Level [ft] —  
 FU5-U-L1 - Faka Union Weir # 5 [ft] —

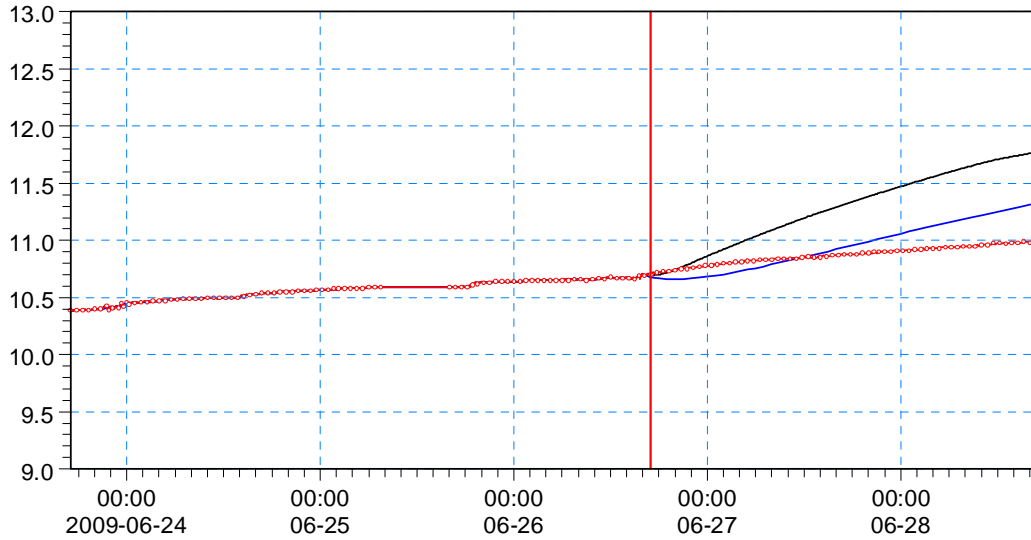


Figure 2-5 Comparison of the water levels at Faka Union 5 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

Water Level, GOLDENGATEMAIN 41874.000-45728.000; Chainage: 42710; EumType: Water Level [ft]  
 Water Level, GOLDENGATEMAIN\_DS29337 41874.000-45728.000; Chainage: 42710; EumType: Water Level [ft]  
 GG1-U-L1 - GG Weir # 1 [ft]

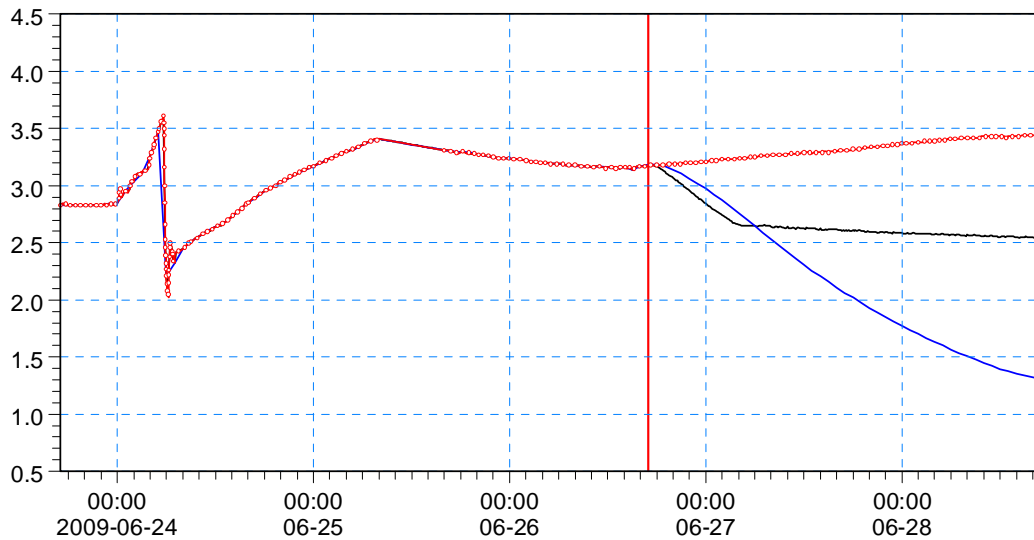


Figure 2-6 Comparison of the water levels at GOLDEN GATE 1 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)



Water Level, GOLDENGATEMAIN 38103.000-41874.000; Chainage: 38832; EumType: Water Level [ft]  
 Water Level, GOLDENGATEMAIN\_DS29337 38103.000-41874.000; Chainage: 38832; EumType: Water Level [ft]  
 GG2-U-L1 - GG Weir # 2 [ft]

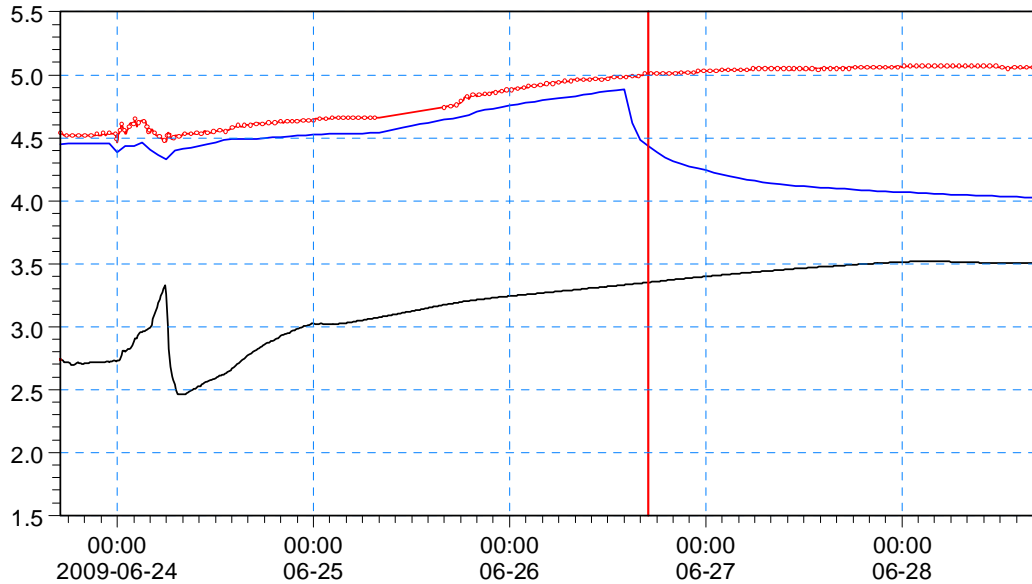


Figure 2-7 Comparison of the water levels at GOLDEN GATE 2 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

**GG5 – upstream**

Water Level, GOLDENGATEMAIN 4526.000-12886.000; Chainage: 9334; EumType: Water Level [ft] ———  
 Water Level, GOLDENGATEMAIN 4526.000-12886.000; Chainage: 8500; EumType: Water Level [ft] ———  
 GOLDW5-U-L1 - GG Weir #5 [ft] ———

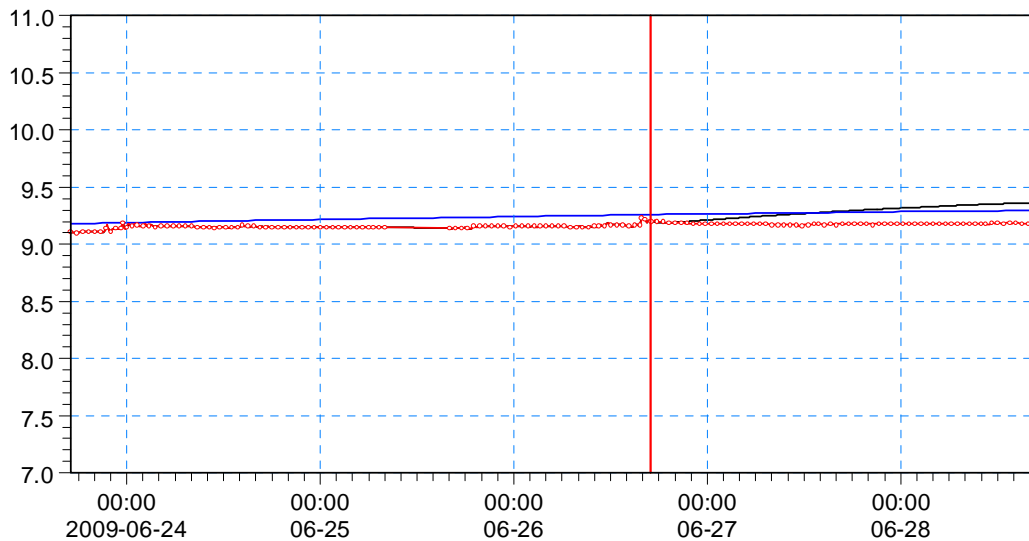


Figure 2-8 Comparison of the water levels at GOLDEN GATE 5 upstream (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

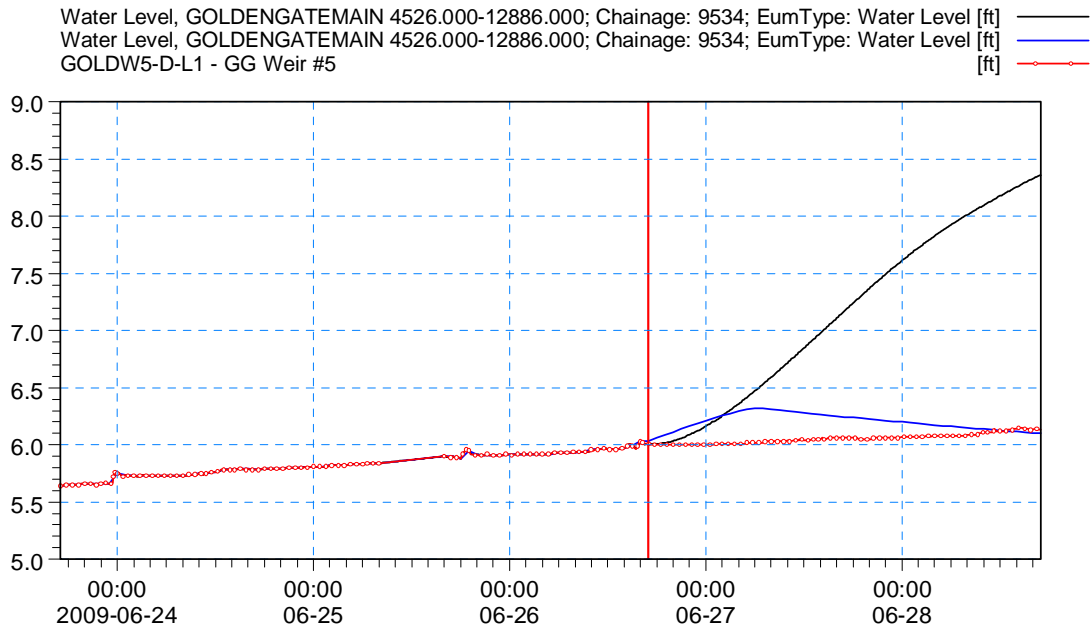


Figure 2-9 Comparison of the water levels at GOLDEN GATE 5 downstream (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

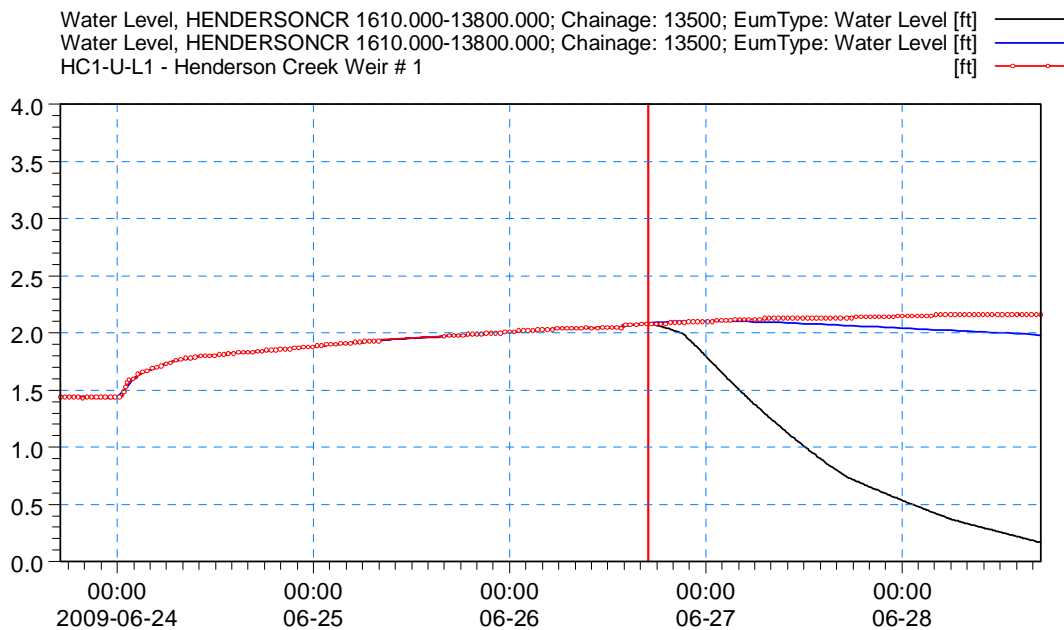


Figure 2-10 Comparison of the water levels at HENDERSON CREEK 1 (red symbols) with the phase 1 model (black) and the phase 2 model (blue)

### **3 TASK 3 - QUANTITATIVE PRECIPITATION FORECASTS (QPF'S)**

The purpose of this task is to develop jointly with SFWMD, interfaces to quantitative precipitation forecasts derived from numerical weather models, preferably. South Florida Water Management Districts own weather forecasts The BCB system will be updated and configured to acquire these forecasts, process and display them and to include them in the automatic and manual forecasts.

The main activities carried out were

- Review of existing sources of Quantitative Precipitation forecasts
- Selection of QPF's to be used in the operational system.
- Implementation of the QPF data acquisition and data hierarchy

A quantitative precipitation forecast (QPF) is a forecast of the amount of precipitation which will fall during a specific time period. These precipitation amount forecast values can then be used as inputs to hydrologic models for river forecasting purposes. The advantage of using quantitative precipitation forecasts in hydrologic forecasts is that they provide valuable increases in the forecast lead time, the time available to carry out flood protection measures.

Quantitative precipitation forecasts can be derived from statistical forecasting models, weather radar, synoptic forecasts, satellite-based remote sensing or numerical weather forecasting (meteorological) models.

Many of the radar-based methods are based on advective schemes that assume the rainfall storm pattern remains constant and moves at a constant velocity. Rainfall forecasts of this type are variously referred to as advection or feature tracing, precipitation projection or nowcasting and are used in several countries, notably the United Kingdom, Japan and the United States. Experience indicates that for short lead times, the radar-based approaches provide acceptable accuracy but accuracy decreases for larger lead times (1.5-3 hours).

Increasing use is being made of numerical weather forecasting models in both weather and flood forecasting as these can extend the forecast lead time considerably. However there is an upper limit to the lead time over which weather systems can be predicted deterministically because of the turbulent and chaotic nature of meteorological flows. Numerical weather prediction models are usually meso-scale models which represent the storm process on a 10-50 km grid

#### **3.1 Requirements for the BCB system**

The key requirements for the QPF's in the BCB realtime modeling system are; first that the forecasts provide sufficient lead time to be useful for flood protection, structure operation and other real time operations. Second the forecasts must be sufficiently reliable

that they provide real added value to the quality of the hydrologic forecasts. Third the results should be available in a digital form that can be read automatically by the real time system preferably without user intervention.

Analysis of the Tropical Storm Fay indicated that responses to heavy rainfall occur within 12-24 hours. To provide effective forecasts of the channel system 48 hours ahead then rainfall forecasts for the next 24-36 hours would provide valuable improvements in forecast accuracy. To achieve these lead times, quantitative precipitation forecasts derived from numerical weather forecasts are the most appropriate.

From discussions with the South Florida Water Management Districts own meteorologists, two candidates were identified as being the most reliable as the basis for operational hydrologic forecasting. These are referred to here as SFWMD QPF and the ALR QPF.

### **3.1.1 SFWMD QPF**

The SFWMD QPF is the forecast produced by the SFWMD's own meteorologists. It is considered the most reliable as it takes advantage of the meteorologists' local knowledge of the climate and current meteorological conditions and is based on information from a number of different sources.

The forecasts are regional scale where the Florida region is divided into a number of sub-areas. Table 1 shows an example of these forecasts in text format. The Big Cypress basin is covered by the forecast for the "BCP" area.

The forecasts are performed once a day. The forecasts start at 7AM the day of the forecast and give estimates of 24 hour accumulated rainfall for the periods 0-24, 24-48, and 48-72 hours ahead. These forecasts are typically available from 10AM each day.

Table 1 Example of the SFWMD QPF

| 10:40AM Saturday, June 27, 2009 (eps) |      |      |      |      |
|---------------------------------------|------|------|------|------|
| BASIN                                 | SAT  | MAX  | SUN  | MON  |
| UK                                    | 0.50 | 2"   | 0.35 | 0.50 |
| LK                                    | 0.35 | 1.5" | 0.25 | 0.35 |
| LO                                    | 0.25 | 1.5" | 0.20 | 0.25 |
| EAAE                                  | 0.18 | 1"   | 0.10 | 0.15 |
| EAAW                                  | 0.12 | 1"   | 0.10 | 0.10 |
| WCAs                                  | 0.18 | 1"   | 0.10 | 0.20 |
| WCA3                                  | 0.10 | 1"   | 0.05 | 0.10 |
| MSL                                   | 0.33 | 2"   | 0.25 | 0.40 |
| PB                                    | 0.25 | 1.5" | 0.18 | 0.30 |
| BROW                                  | 0.18 | 1.5" | 0.10 | 0.25 |
| DADE                                  | 0.12 | 1"   | 0.05 | 0.12 |
| ECAL                                  | 0.18 | 1"   | 0.15 | 0.25 |
| BCP                                   | 0.08 | 1"   | 0.10 | 0.10 |
| SWC                                   | 0.12 | 1"   | 0.20 | 0.20 |
| DIST                                  | 0.22 | -    | 0.17 | 0.24 |

Further details and updates available at  
<http://my.sfwmd.gov/sfwmd/common/images/weather/qpf.html>  
 and  
<http://my.sfwmd.gov/sfwmd/common/images/weather/forecast.html>  
 and  
<http://my.sfwmd.gov/sfwmd/common/images/weather/forecast.txt>

The advantages of the SFWMD QPF are that it is reliable and gives forecasts up to 3 days ahead. The main disadvantages are that it is relatively large scale and the resolution in time is 24 hours.

Further details and graphics of these forecasts can be found below:

<http://my.sfwmd.gov/sfwmd/common/images/weather/qpf.html>  
 and  
<http://my.sfwmd.gov/sfwmd/common/images/weather/forecast.html>  
 and  
<http://my.sfwmd.gov/sfwmd/common/images/weather/forecast.txt>

### 3.1.2 ALR QPF

The ALR QPF is the forecast produced by the NOAA (see - <http://www.srh.noaa.gov/alr/qpfpage.html>). It is considered to be quite reliable by the SFWMDS's own meteorologists.

The forecasts are regional scale where the Florida region is divided into a number of sub-areas. Table 2 shows an example of these forecasts in text format. The Big Cypress basin is covered by the forecast for the "SFWMD10" area.

The forecasts are performed once a day. The forecast starts at midnight GMT the day of the forecast, equivalent of 7 PM the previous day EST (GMT-5) and gives estimates of

6 hour accumulated rainfall for the periods 0-6, 6-12, 12-18, and 18-24 hours ahead. These forecasts are typically available from mid day GMT each day.

Table 2 Example of the ALR QPF (lines with "<..>" indicate cut out sections)

```

000
FSUS42 KALR 021215
QPSALR
.BR ALR 0602 Z DH12/DC200906021215
.B1 /DRH+6/PPQFL
.B2 /DRH+12/PPQFL
.B3 /DRH+18/PPQFL
.B4 /DRH+24/PPQFL
:
:       Quantitative Precipitation Forecast
:
:       6-hr      6-hr      6-hr      6-hr
:       pcpn      pcpn      pcpn      pcpn
:
:   HSA BIRMINGHAM
AKLA1    0.00 / 0.00 / 0.00 / 0.00 : 0.00  ARKADELPHIA
ARKA1    0.00 / 0.00 / 0.00 / 0.00 : 0.00  LEWIS SMITH DAM
<..>
:   HSA MIAMI
KISF1    0.02 / 0.15 / 0.00 / 0.00 : 0.17  KISSIMMEE R - S65
<..>
SFWMD9   0.10 / 0.37 / 0.00 / 0.00 : 0.47  CALOOSAHATCHEE
SFWMD10  0.14 / 0.18 / 0.01 / 0.00 : 0.33  SOUTHWEST COAST
SFWMD11  0.21 / 0.28 / 0.00 / 0.00 : 0.49  BIG CYPRESS
<..>

```

The main advantage of the ALR QPF is that it gives 6 hour forecasts over the next 24 hours. The main disadvantages are that it is relatively large scale and forecasts are only given for the next 24 hours.

The forecasts are available via the link;

<http://www.srh.noaa.gov/data/ALR/QPSALR>

### 3.2 Implementation of the QPF data hierarchy

For the BCB real-time modeling system there are 4 possible precipitation forecasts that can be used for automatic forecasting. They are

1. User-defined QPF
2. ALR QPF
3. SFWMD QPF
4. Zero Rainfall QPF

### **3.2.1 Zero rainfall QPF**

Starting with the last option first. The Zero rainfall QPF, as the name indicates, assumes that there is no rainfall falling in the forecast period. This was implemented in phase 1. Where the forecast time is less than or equal to the time from peak rainfall to peak runoff (catchment response time) then forecasting without rainfall forecasts or assuming the forecast is for zero rainfall will provide accurate forecasts. Analysis of the Tropical Storm Fay indicated that responses to heavy rainfall occur within 12-24 hours. To provide effective forecasts of the channel system 48 hours ahead then rainfall forecasts for the next 24-36 hours would provide valuable improvements in forecast accuracy. This forecast is used for automatic forecasts when no other forecasts are available.

### **3.2.2 SFWMD & ALR QPF**

The SFWMD QPF and ALR QPF are described in the previous section.

### **3.2.3 User-defined QPF**

It is possible with the BCB real-time system to run or re-run hydrologic forecasts using the manual forecast functionality within MIKE FLOODWATCH. Figure 1 shows the menu where the user can create manual forecasts using the MIKE FLOODWATCH Web Interface. Figure 2 shows the corresponding menu for the GIS interface. In both cases the user selects the pre-defined scenario defining the sources of input for the model run, specifies the simulation period and runs the mode. In the web interface the specification of the Time Of Forecast, hindcast period and forecast period together with the windows credentials for the job is done prior to pressing “Run”. In the GIS interface these properties are prompted for by pop-ups.

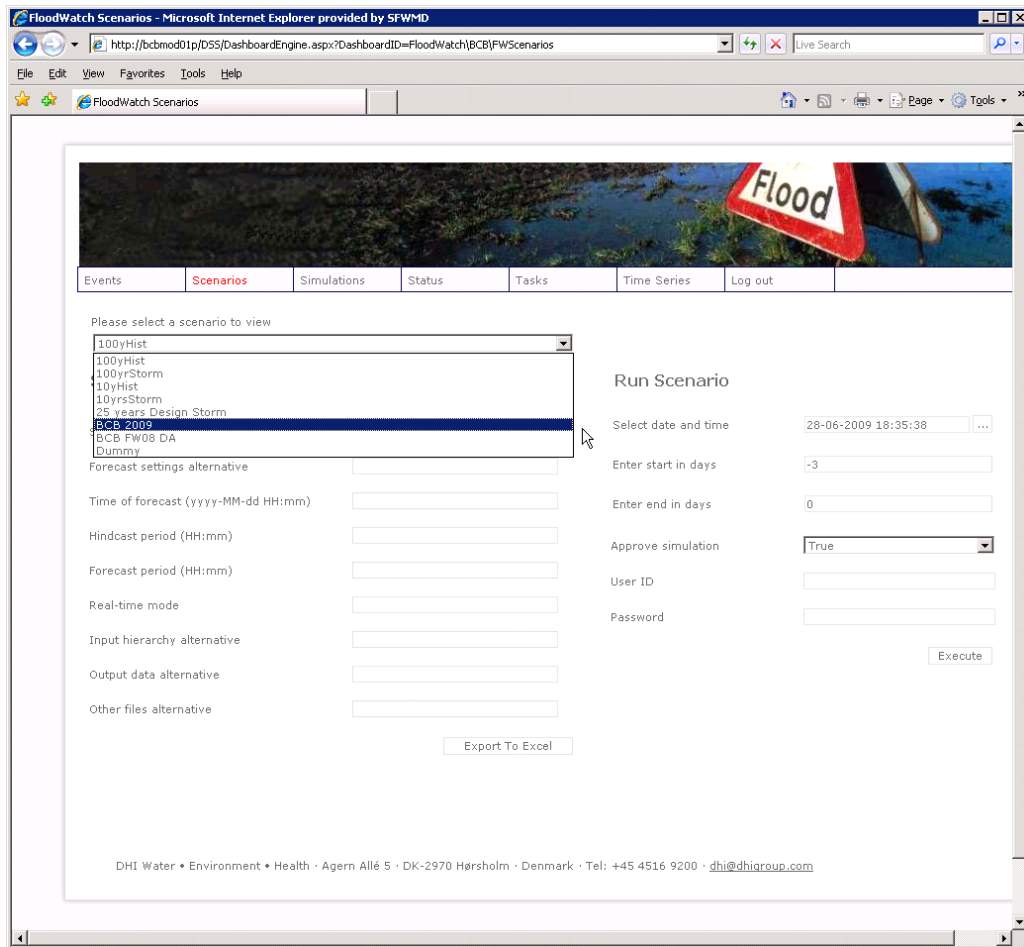


Figure 3-1 Manual forecasts via the Web Interface

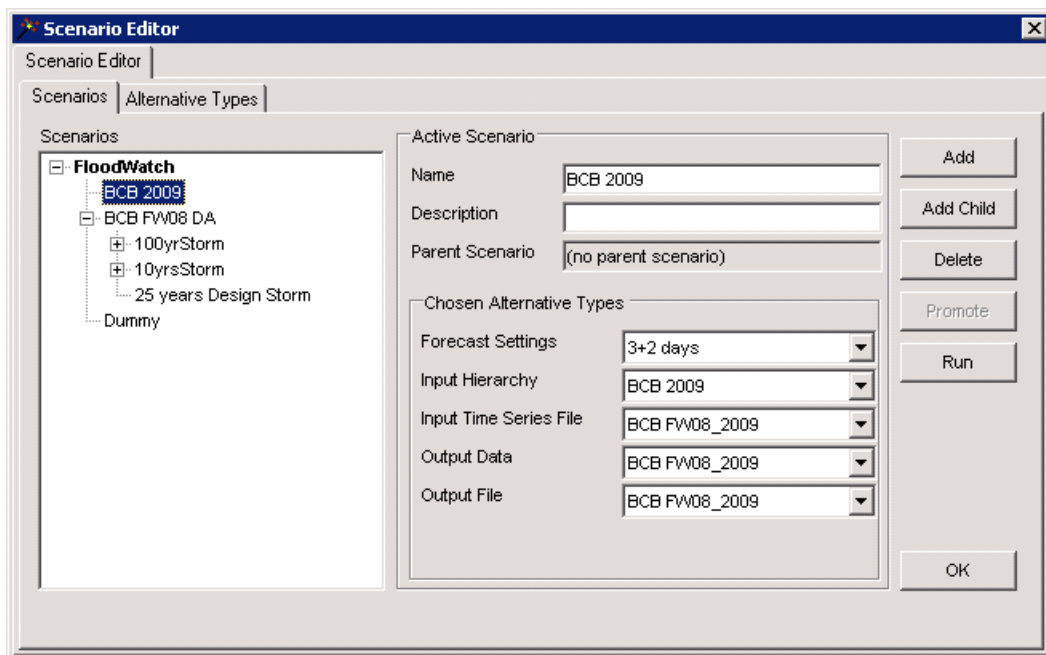


Figure 3-2 Manual forecasts via the GIS interface



After discussion with the SFWMD staff, it was agreed to implement via the external web pages a facility to allow SFWMD operational staff to provide a user-defined QPF that would be used by the automatic forecast.

The basic operation for automatic forecasts will therefore be that if a user-defined QPF has been provided prior to the automatic hydrologic forecast this will override other QPF's and is used at the QPF for the automatic forecasts. The implementation of this user-defined QPF uses the concept of a data hierarchy.

### **3.2.4 The MIKE FLOODWATCH Data Hierarchy**

Time series data collected in real time is often unreliable. Faults in external systems, sensors, outstations, transmission systems or the telemetry server can result in either data failing to reach a forecasting system or the transmission of erroneous values. Many of the input time series used in a forecast model are boundary conditions e.g. rainfall or downstream tidal levels which act as forcing terms controlling the dynamics of flow within the model. If this boundary data is unavailable, alternative data sources or estimates should be provided in order for the model to run successfully. If the boundary condition data is erroneous, then at best the accuracy of the forecast will decrease, however in extreme circumstances the model may fail to run.

The concept of a data hierarchy is designed to overcome the problems caused by failure of time series in all but the most extreme circumstances. It controls the flow of time series data into a model by means of a pre-configured hierarchy. This hierarchy is used by the system to select or derive the most appropriate time series to represent a boundary condition from the available data.

The data hierarchy operates only once a forecast has been started. At this time the forecast system shell retrieves the available data from the forecasting databases and begins preparing the time series data to be used in that forecast. The data hierarchy consists of an ordered sequence of alternative input time series and a set of operations that can be performed on this data called Data Methods.

In its simplest form the data hierarchy starts by evaluating the time series at the top of the hierarchy. If the first time series is not available or incomplete then the next source is evaluated. If the second source is unavailable or incomplete then the next source is evaluated until either a complete time series is obtained or every time series in the hierarchy proves unsuitable.

An example of how the Data Hierarchy operates is shown in Figure 3. In this case, the hierarchy consists three time series measuring the position of a gate. At the top of the hierarchy is the primary instrument. In the middle is the secondary (or back-up) instrument. The last series is a default gate position. In this case the hierarchy has been configured so that if data is unavailable or incomplete for the first source in the hierarchy then the second source is evaluated. If data from this source is unavailable or incomplete then the last source is evaluated. The last source is defined so that the forecast can be run. In this case shown in Figure 3 the data from the first two members of the hierarchy are incomplete and therefore the last time series, the default gate position is used.

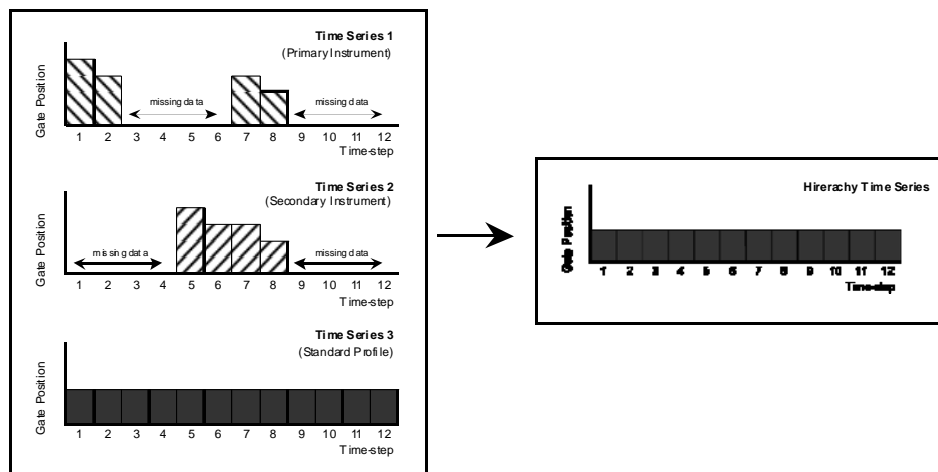


Figure 3-3 Simplified example of the use of the Data Hierarchy

A complete description of the data hierarchy concept and methods is given in chapter 3 of the MIKE FLOODWATCH User Guide.

### 3.2.5 The QPF data hierarchy.

For the automatic forecasts in the BCB real time system, the following hierarchy has been implemented for the precipitation forecasts.

1. User-defined QPF
2. ALR QPF
3. SFWMD QPF
4. Zero Rainfall QPF

Thus if the user-defined QPF has been specified then this is used. If this is not available then the ALR QPF is used to the extent it is available. The SFWMD QPF is then used to extend the forecast. Finally the forecast is extended with a zero rainfall. Thus, the hierarchy attempts to create a QPF using the combination of the high temporal resolution of the ALR QPF and the longer extent of the SFWMD QPF. To ensure a full forecast period is available in all circumstances, a fall-back of zero rainfall is specified. The User-defined QPF allows the user to override the automatic forecasts.

## 3.3 Implementation of the QPF data acquisition

Three sensors have been prepared in FLOOD WATCH to store the 3 QPFs: manual, ALR and SFWMD. The time series of the sensors can be located in the FLOOD WATCH time series tree under Forecast Rainfall group, see Figure 4.

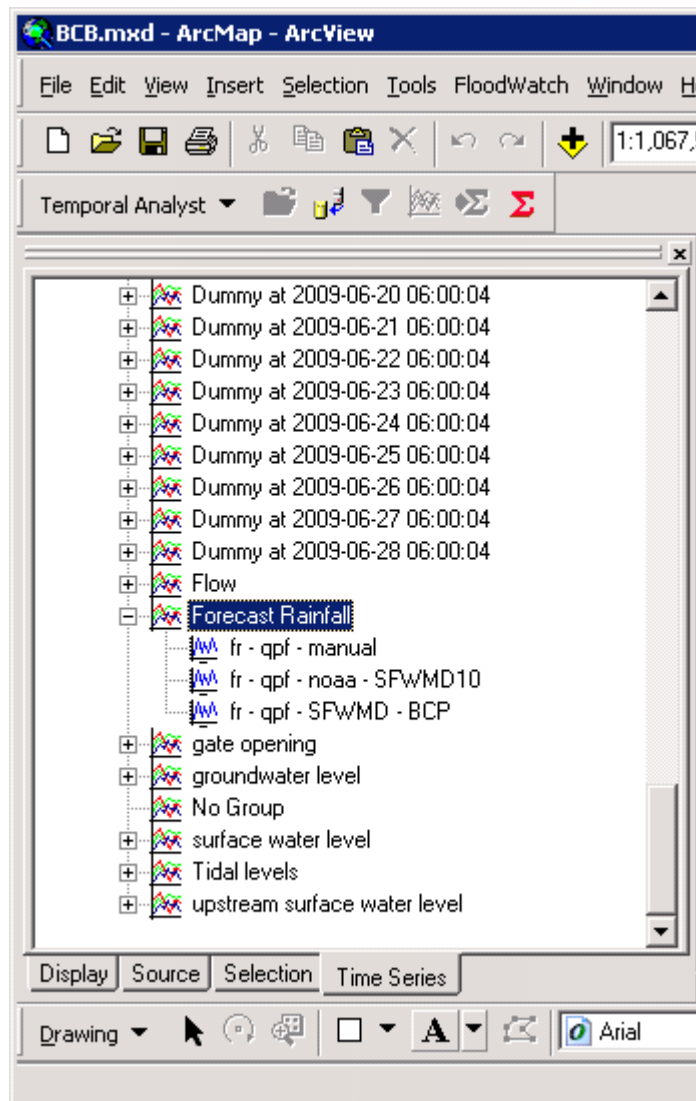


Figure 3-4 QPF sensors

The sensors are:

- fr – qpf – manual
- fr – qpf – noaa - SFWMD10
- fr – qpf – SFWMD - BCP

As part of the hourly import of telemetry data a new script, ImportWebQPF.vbs, is called. It will import data for each of the 3 sources – overriding any overlapping data already in the source. Hence, each time series will build up a record of forecasts – and the last part stretching into the future being the last forecast read.

The script reads the pages of the web, decodes the numbers and transforms them into a time series, before inserting them into the FLOOD WATCH database. In order to match

the 15 minute intervals of the observed rainfall the 6 hourly value and 24 hourly values are divided into 15 minute equivalents.

### 3.3.1 Implementation of the User-defined QPF

User-defined QPF can be entered via a web-page. The address is

<http://bcbmod01p/floodwatch/qpf.asp>

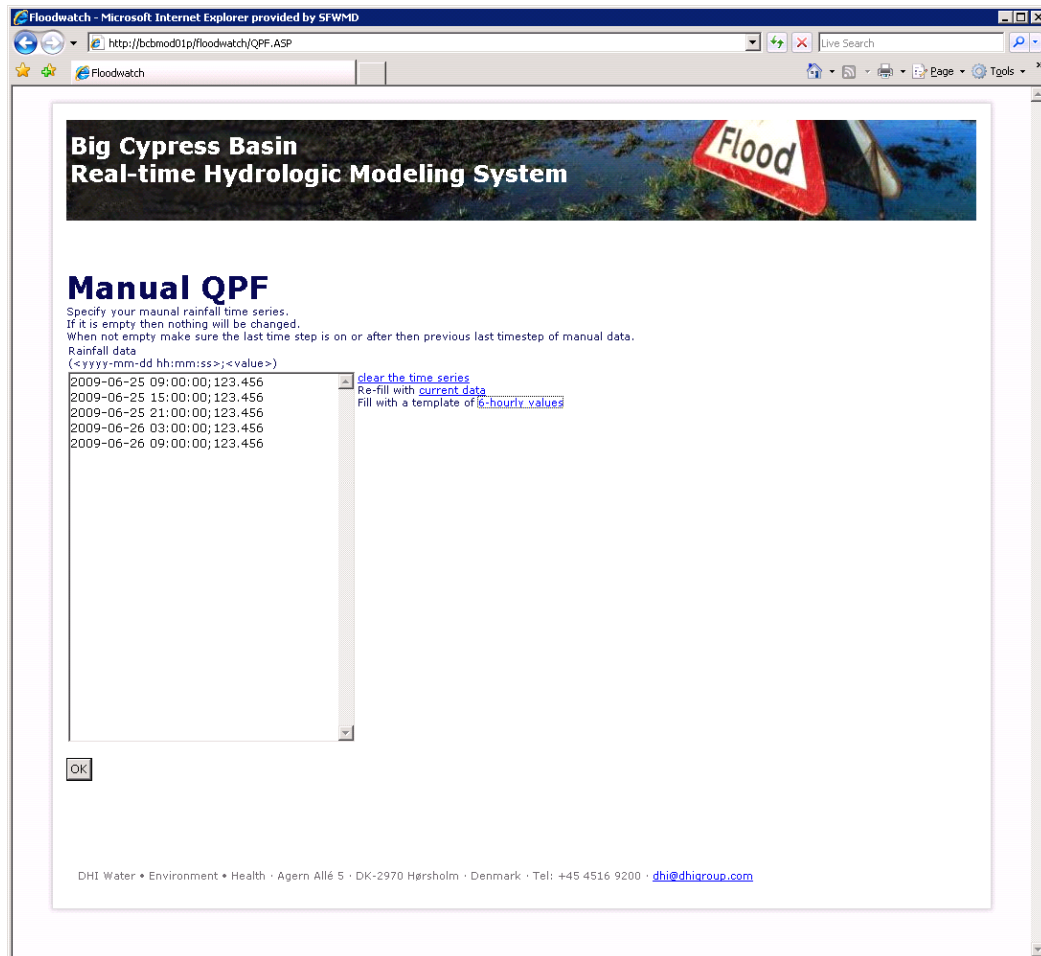


Figure 3-5 User-defined QPF entry

When the page is opened it will display the last User-defined QPF time series entered by the page. The user can delete it, alter it, or enter a new time series. By pressing OK, the content of the text box is validated and if acceptable, the time series is written to a text file on disk on the server. The validation shall ensure each record conforms to the format

yyyy-mm-dd hh:mm:ss;<value>

where the first part is the date and time and the <value> is a number representing the precipitation since the time step before. Each entered time must be after the previous. The size of the time steps is free, but it is suggested to use 15 minutes intervals to make the time series fit the observed values.

The created file is read by the import script and inserted into the database and will continue to be until it is emptied or replaced by a new time series.