

REPUBLIC OF YEMEN
MINISTRY OF AGRICULTURE AND IRRIGATION

IRRIGATION IMPROVEMENT PROJECT

(IDA Credit No. 3412 – YEM)

Main Technical Assistance Package for IIP

Spate Management Model User's Guide

Revision 1.0

December 2004

 **ARCADIS** EUROCONSULT

IN ASSOCIATION WITH

 **Halcrow**



YEMENI ENGINEERING GROUP

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p Note Most of the screen captures shown in this Guide are taken from a computer running Microsoft Windows XP. If you are using a different version of Windows, the screens may look slightly different from those shown.

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1. INTRODUCTION

1.1 Model Use

The Spate Management Model (SMM) was developed for the purpose of simulating spate irrigation practices in the flood wadis of Yemen, with emphasis on Wadi Tuban and Wadi Zabid. The model can be used as an aid to decision making in the improved operation and management procedures planned for the wadis. It could also be used to explore the scope for changes to water allocation procedures in order to achieve better water management.

The SMM can simulate the passage and distribution of floodwater in wadi plains starting from the head of the wadi down to the command areas. Flow distribution at the diversion structures and canal offtakes is based on user-defined water rights, canal/offtake capacities, and the crop water requirements of the command areas or spate irrigation practices. Bed losses from the wadi and canal network and the field application losses are taken into consideration.

The output from the SMM includes the volumes of water diverted to each command area, the quantities of water still due to each crop in each command area, the quantity of water that has been used to meet crop water requirements and that that has been lost, the volume of spate water that has not been diverted to command areas, and the volume of excess flow that may either go the wadi drainage area (e.g. the sea) or replenish the groundwater. The direct output from the SMM is in tabular and report formats. In addition, the model can export selected output data to the ArcView GIS for graphical presentation.

There are two basic uses for the model:

1. As a planning tool: in which case the SMM will be used to advise on the most appropriate operation and water distribution in the wadi over a future period of time, typically one year or more.
2. As an in-season operation tool: in which case the SMM could be given the quantities of water the command areas have received, allowing the outstanding requirements to be estimated, perhaps on flood by flood basis.

1.2 Model Concept and Calculation Methods

1.2.1 Flood Flow Distribution in Water Network

A run of the SMM is likely to simulate the occurrence of a flood or a series of floods at the top-end of the modelled wadi delta (e.g. at the gauging station). Flood hydrographs are defined in the model as date & time-discharge relationships. The user defines the time periods of simulation runs (start and end dates).

The SMM simulates the passage of the given flood flows down the wadi and canal network, deducting seepage losses from the flow as it proceeds (other losses such as evaporation losses from the network water surface are ignored). At bifurcation junctions, available flow is distributed among downstream branches according to user-defined criteria, their carrying capacities, and the crop water requirements of the command areas or spate irrigation practices.

1.2.2 Water Allocation to Command Areas

The floodwater distributed to the wadi and canal network is allocated to the command areas according to their irrigation water requirements and irrigation priorities. The irrigation water requirements of the command areas are calculated according to one of the following user-selectable criteria:

1. Fixed gross application depth per crop (spate): this irrigation method mimics farmer practice in spate irrigation by which a user-defined fixed depth of water is applied to each crop type, provided that water is available to the command area.

The target depth of application is applied irrespective to soil moisture conditions on the day(s) of application. The field application efficiency is not accounted for in this case because it is usually included in the defined fixed application depth. In fact, the calculation procedure in this case is reversed such that the actual application efficiency is calculated as the ratio of the volume of spate water stored in the root zone to replenish soil moisture deficit on the day of application to the total volume applied.

On the other hand, rainfall, if any, is deducted from the required application depth on the assumption that even if the farmers apply fixed water depths, they are likely to reduce the depth of application when it rains.

When possible, SMM will apply the total required depth of water in the first spate application to the command area. If no sufficient water is available in the first irrigation, additional applications will be allocated to the command area until the required depth has been applied (depending on water availability and water rights). When a crop has been fully irrigated with the required depth of water, it is not irrigated again before a certain number of user-defined days elapses (to prevent repetitive irrigation of upstream command areas).

2. Actual crop water requirements: the depth of water to be applied in any irrigation is calculated based on the soil moisture deficit on the day of application after deducting the rainfall, if any, and allowing for the average field application efficiency.

1.2.3 Crop Water Use and Production

The actual volumes of water allocated to each command area are used to maintain a soil moisture balance for each crop in each command area. The soil moisture balance is used to calculate actual crop water consumption, rainfall water-use efficiency and to estimate potential crop yield. In the soil moisture balance calculations, rainwater takes precedence over irrigation water in replenishing soil moisture deficit. Accordingly, rainwater is assumed to be fully stored in the soil profile until the soil moisture deficit is fully replenished, i.e. no rainfall is lost until the soil profile has been filled with water.

1.3 Model Capabilities and Limitations

- The size of the network that can be simulated (i.e. number of network reaches and command areas) is theoretically limited by available computer memory. However, the simulation runs of very large networks are very likely to take long hours. The selection of the details that should be included in the modelled network should therefore be carefully

made such that very lengthy simulations are avoided while at the mean time the results are not affected by omissions in the simulated model. (For example, the prepared example of Wadi Zabid included the network of the wadi delta down to the secondary canal level. The command areas served by lower-level canals were lumped with the areas served by the secondary canals.)

- The simulated network may have loops, however water is always assumed to flow from the upstream to the downstream end of each network reach (i.e. no negative flows).
- The simulated network may have only one source of surface (flood) water.
- SMM cannot automatically simulate the contribution of groundwater to crop water requirements. However, the user may feed the model with such contributions such that it can take them into consideration in related calculations (e.g. estimation of crop yield).
- Each command area can have up to a maximum of four crops in its cropping pattern.

1.4 Structure of the Guide

The basics of database principles and management are outlined in Section 2 with an overview of some of the main features of the SMM. The following sections then describe the different functions of the SMM, given in the same order that is likely to be followed when using the model. Input data manipulation; e.g. data entry, importing, checking, and printing; is discussed in Section 3. Section 4 then discusses how the SMM can be used to make simulation runs, and finally the means of reviewing simulation results are described in Section 5.

1.5 Recommended Steps for Using the Model

The following is a list of the steps that may be followed when using the SMM to build a new simulation model, run simulations and then review the results. For more details on each step, refer to the respective section of this Guide whose number is given next to each step.

Using GIS:

- Prepare the layout of the water network and command areas of the system to be modelled. Enter all the data required for each reach and command area into the GIS. Refer to Appendix I

Using SMM:

- Input required data: 3.2
 - § Enter/edit monthly ETo data. 3.2.1
 - § Enter/edit crop data 3.2.2
 - § Enter/edit cropping pattern data 3.2.3
 - § Enter/edit soil data 3.2.4
 - § Enter/import/edit rainfall data 3.2.5 / 3.4
 - § Enter/import/edit inflow data 3.2.6 / 3.4

§ Enter/edit bed losses data	3.2.7
§ Enter/edit water rights data	3.2.8
§ Import network data from the GIS into SMM.	3.2.9
§ Enter/edit network additional data.	3.2.9
§ Import command area data from the GIS into SMM.	3.2.10
§ Enter/edit command area additional data.	3.2.10
• Check all input data.	3.3
• Run simulation.	4
• Review simulation results.	5

2. DATABASE PRINCIPLES

2.1 File Management

The SMM was developed as a Microsoft Access application. Accordingly, the model's input and output data as well as its code that does the manipulation of the data and all sorts of calculations are all stored inside one Microsoft Access database file. To run SMM, you must have Microsoft Access installed on your computer. (For information on how to install and run SMM, please refer to the "ReadMe.txt" file on the SMM disc.)

When you run the SMM and make any changes to the data, the changes are saved immediately inside the database file. In addition, Microsoft Access does not have the option to automatically backup the database when it is modified. Consequently, due care must be taken before making any changes to the SMM data.

It is therefore good practice to make a new copy of the model's database file (.mde) before making significant changes to the data. To do so, start Windows Explorer and locate the existing model file (say SMM_Run1.mde), make a copy of the file under a new name (e.g. SMM_Run2.mde) and use that new copy to make the data changes.

As you make changes to the data and make some simulation runs, you may notice that the model's file is growing large. To compact the file and hence possibly make its size smaller, enable the auto-compact SMM option as follows:

- Start SMM. A welcome window appears on the screen for a few seconds, after which SMM main menu appears (Figure 1).
- From SMM main menu, click on "Database Management". The database management window appears on the screen.
- Enable the "Auto-compact the database when the application is closed" option and then close the database management window.
- Exit SMM. As SMM closes, it will compact the database possibly making the file size smaller.

N Tip The auto-compact option may slow down SMM shutdown process. It is advisable to keep this option disabled and enable it only when required.

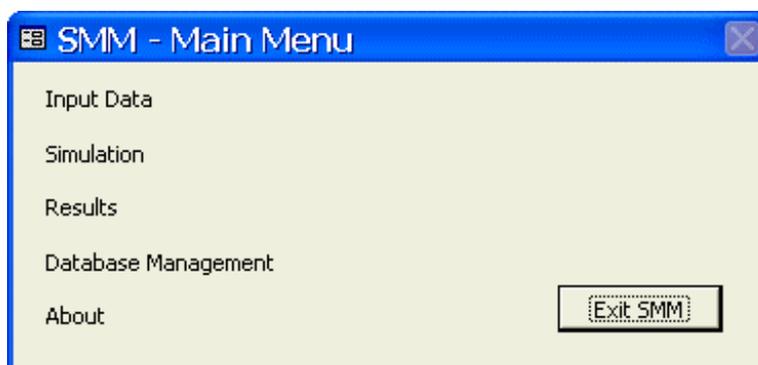


Figure 1 SMM main menu

2.2 Navigating Through SMM Windows

SMM main menu (Figure 1) should appear on the screen shortly after the model starts. As its name implies, this window is central to the operation of SMM and is used to navigate to other windows. When you activate another window from SMM main menu, e.g. input data window (Figure 4), the main menu disappears from the screen and the other window appears instead. To close that other window and return to SMM main menu, click on the close button [X] on the top-right corner of the window (Figure 2).

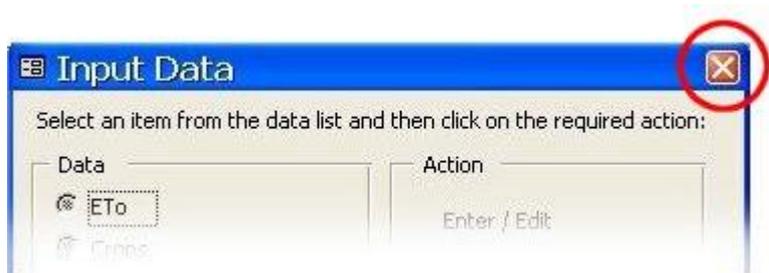


Figure 2 Click on close button to return to SMM main menu

2.3 Data Entry Hints

Some data entry windows in SMM are provided with hints that either help you enter the correct data or generally facilitate data entry. Figure 3 shows an example of the data entry hints in the simulation window (detailed description of the simulation window is available later in Section 4). As you move the cursor to enter the “Last Date” of the simulation run, a hint is shown at the left-lower corner of the SMM main window (status bar) giving a brief description of the required data. Additionally, if you keep the mouse pointer over the data entry box for a few seconds, a floating message is shown giving a hint that can facilitate data entry.

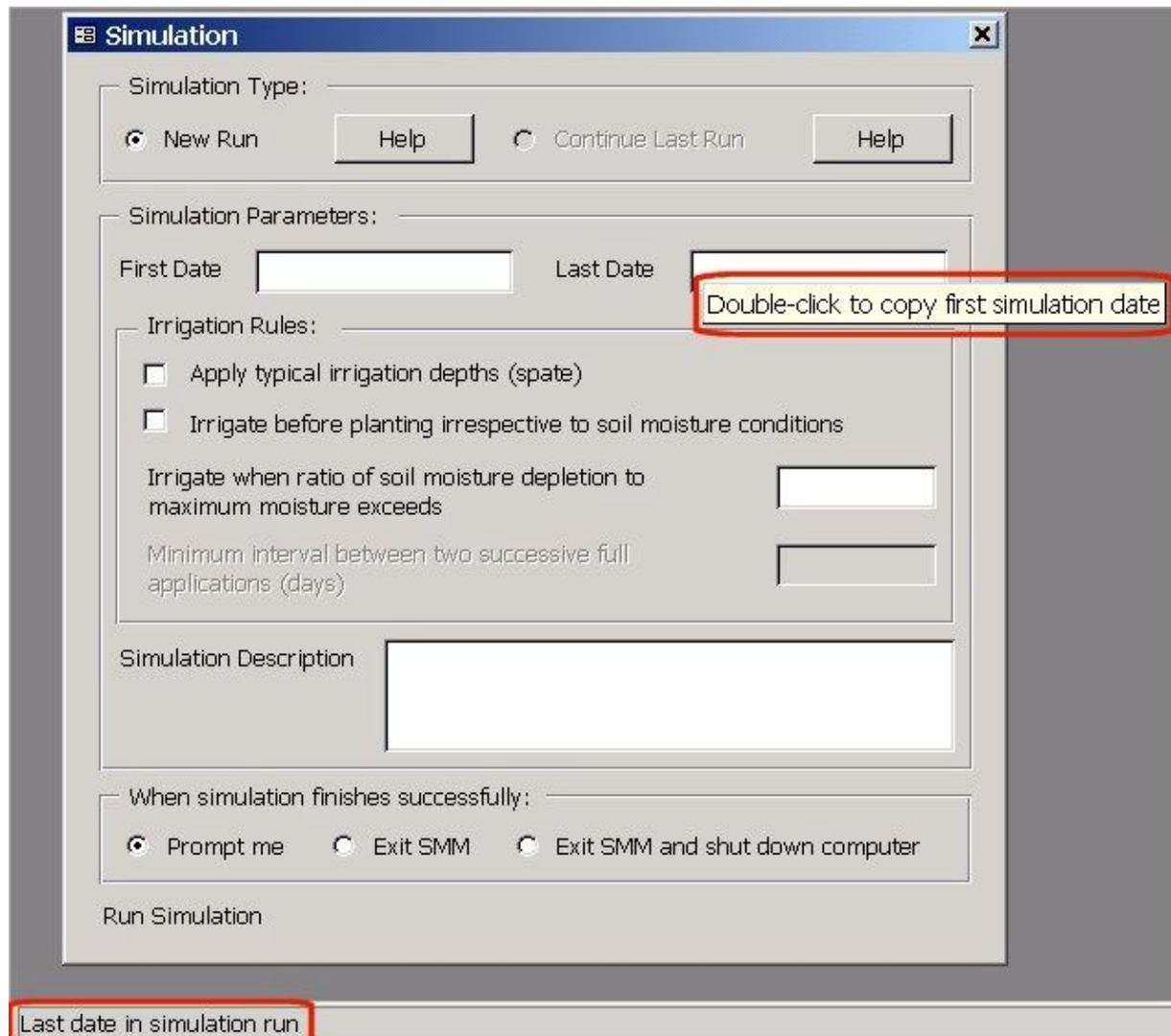


Figure 3 Data entry hints

3. INPUT DATA

The manipulation of the SMM input data is achieved via the input-data manipulation window (Figure 4). To open this window:

- Start SMM.
- From SMM main menu, click on “Input Data”. The input-data manipulation window appears on the screen.

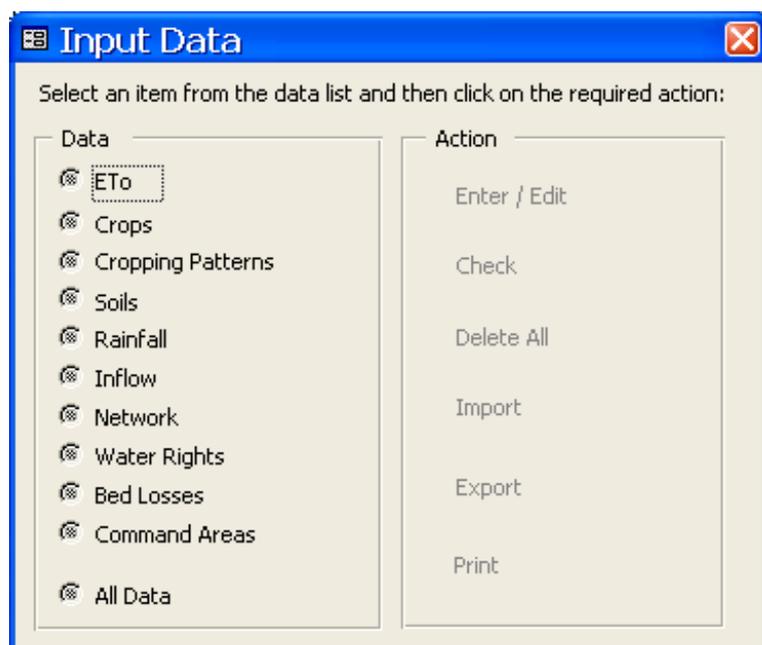


Figure 4 Input-data manipulation window

3.1 Data Requirements

The following is a list of the input data required for the SMM:

- § Total monthly reference evapotranspiration (ETo) data.
- § Crop data (name, maximum root depth, yield response factor, planting months, growing period, typical spate application depth & monthly crop coefficients Kc).
- § Cropping pattern data (up to four crops for each command area).
- § Soil data (soil type & water-holding capacity).
- § Average daily rainfall data over project area.
- § Inflow data (base flow & flood hydrographs).
- § Water network data (reach capacities, lengths, water allocation priorities & water shares).
- § Water rights for the canals and the direct offtakes from the wadis.
- § Average bed losses from wadi and canal reaches.
- § Command area data (total cultivable areas, maximum diversion capacities, typical irrigation efficiencies, water allocation priorities, cropping patterns & soil types).

Details of each data item are given in the following sections.

3.2 Entering/Editing Input Data

SMM has various data entry windows for entering/editing the different input data items. To open the data entry window for any data item:

- Open the input-data manipulation window (refer to Section 3).
- Select one of the data items and then click on “Enter / Edit” to open its data entry window.

3.2.1 Monthly ETo Data

The SMM requires total monthly reference evapotranspiration data (ET_o) for the calculation of crop water requirements. Figure 5 shows the ET_o data entry window. The window contains a whole year’s ET_o data record. Each data record must have the data of a unique year. On the other hand, only one data record may have average ET_o data, which should be designated by entering the year as zero.

Figure 5 ET_o data entry window

When SMM runs a simulation, it looks for ET_o data for the exact year(s) of the simulation. If no ET_o data for the simulation year(s) is found, SMM uses the ET_o data for year zero as typical values. If neither data record is found, the SMM gives an error message and stops the simulation.

3.2.2 Crop Data

Figure 6 shows the crop data entry window. Each crop should have the following data items:

- Crop ID: the crop ID is assigned automatically by the SMM and cannot be modified by the user.
- Root Depth (m): the maximum rooting depth of the crop.

- Yield Response Factor (Ky): this factor is used to estimate the potential reduction in crop yield if it is not given its full water requirements over its growing season. (For more information on this factor refer to FAO 56¹).
- First Planting Month: the earliest planting month of the crop (enter the month number from 1 to 12).
- Last Planting Month: the latest planting month of the crop (enter the month number from 1 to 12).
- Growing Period (days): the length of the active growing period of the crop (during which the crop requires water for growing).
- Harvesting Period (days): the length of the last growing period of the crop (during which the crop does not require water for ripening).
- Typical Application Depth (m): the gross typical depth of water that is applied to this type of crop in the normal spate irrigation practice.

Field	Value	Monthly Kc values:
Crop ID	(AutoNumber)	Kc1
Crop Name		Kc2
Description		Kc3
Root Depth (m)		Kc4
Yield Response Factor (Ky)		Kc5
First Planting Month		Kc6
Last Planting Month		Kc7
Growing Period (days)		Kc8
Harvesting Period (days)		Kc9
Typical Application Depth (m)		Kc10
		Kc11
		Kc12

Record: 5 of 5

Figure 6 Crop data entry window

- Monthly Kc values: Up to 12 monthly average Kc values for the crop. The first Kc value (Kc1) is the value for the first planting month (**not for January**). (For more information on crop Kc values refer to FAO 56).

¹ FAO, 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome.

N Tip For perennial crops, enter the lengths of the growing and harvesting periods such that their sum does not exceed 365 days.

3.2.3 Cropping Pattern Data

The cropping pattern data is used to define the schedule of crops grown in each command area. Figure 7 shows the cropping pattern data entry window:

- The cropping pattern ID is assigned automatically by the SMM and cannot be modified by the user.
- Each cropping pattern can contain up to a maximum of four crops.
- Each crop in the cropping pattern is defined by its name, as entered in the crop data, and the percentage of the area it occupies to the total command area.

The screenshot shows a software window titled "Cropping Pattern Data" with a close button in the top right corner. Below the title bar, it says "* All Data *". The main area contains a form with the following fields:

- ID: (AutoNumber)
- Description: [Text input field]
- Crop 1: [Dropdown menu]
- Crop 1 Percent: [Text input field]
- Crop 2: [Dropdown menu]
- Crop 2 Percent: [Text input field]
- Crop 3: [Dropdown menu]
- Crop 3 Percent: [Text input field]
- Crop 4: [Dropdown menu]
- Crop 4 Percent: [Text input field]

At the bottom of the window, there is a record navigation bar showing "Record: 5 of 5" with navigation icons for first, previous, next, and last records.

Figure 7 Cropping pattern data entry window

- p Notes**
- Always enter all crop data using the crop data entry window before entering the cropping pattern data such that you can select crop names from the list of entered crops.
 - When entering crop percentages, enter the figures as percentages not as fractions (e.g. enter 75 not 0.75 for 75%).

**Tips**

- If a command area grows more than four crops, divide it in the model into two or more areas, create two or more cropping patterns depending on the number of crops grown, and assign them to those areas.
- If some command areas are left fallow, this can be simulated in the SMM by defining a “fallow” cropping pattern, i.e. a cropping pattern that contains no crops (Figure 8), and assigning it to those command areas.

Figure 8 Fallow cropping pattern

3.2.4 Soil Data

The soil data is used to define the characteristics of the soils in each command area that impact water availability to plants. The following data items are required for each soil type (Figure 9):

- Soil ID: the soil ID is assigned automatically by the SMM and cannot be modified by the user.
- Soil Type: the classification of the soil (e.g. silt, loam, etc.).
- Water-Holding Capacity (mm/m): the water holding capacity per unit depth of the soil profile can be worked out as:

$$\text{WHC} = (\text{FC} - \text{WP}) * 10$$

where: WHC = Water-holding capacity per unit depth of the soil profile (mm/m)
 FC = Field capacity moisture content by volume
 WP = Wilting point moisture content by volume

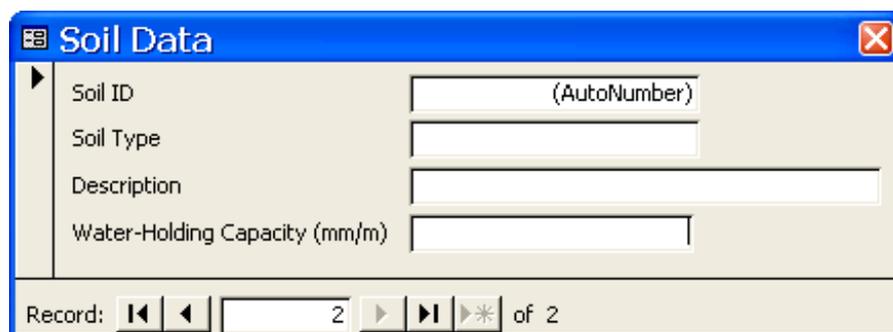


Figure 9 Soil data entry window

3.2.5 Rainfall Data

The SMM requires daily rainfall data. Figure 10 shows the rainfall data entry window with some sample data. Data from more than one rainfall gauging station can be entered. Those stations should be located within the modelled wadi delta, not in the catchment area.

Station ID	Station Name	Date	Rain
89	ALJIRBAH	20/01/2003	0.5
89	ALJIRBAH	21/01/2003	0.8
89	ALJIRBAH	28/01/2003	1.6
89	ALJIRBAH	15/04/2003	2.2
89	ALJIRBAH	19/04/2003	1
89	ALJIRBAH	07/06/2003	0.1
89	ALJIRBAH	08/06/2003	0.2
89	ALJIRBAH	30/06/2003	1.3
89	ALJIRBAH	13/07/2003	3
89	ALJIRBAH	17/07/2003	6.1
89	ALJIRBAH	19/07/2003	0.5
89	ALJIRBAH	20/07/2003	0.3
89	ALJIRBAH	21/07/2003	2.8
89	ALJIRBAH	24/07/2003	0.1
89	ALJIRBAH	28/07/2003	29.3
89	ALJIRBAH	05/08/2003	1.4
89	ALJIRBAH	06/08/2003	0.5
89	ALJIRBAH	07/08/2003	21.3
89	ALJIRBAH	14/08/2003	2.2
89	ALJIRBAH	16/08/2003	0.1

Figure 10 Rainfall data entry window

3.2.6 Inflow Data

The inflow data is used to define the flood flow available to the modelled wadi. The inflow data can either be historical or synthetically generated using models such as FloodSim². Figure 11 shows the inflow data entry window with some sample data:

Date	TimeID	Flood Q	Base Q
01/01/2003	0	0.0	0.3
01/02/2003	0	0.0	0.7
01/03/2003	0	0.0	0.7
11/04/2003	13	3.3	1.1
11/04/2003	14	6.5	1.1
11/04/2003	15	10.5	1.1
11/04/2003	16	14.2	1.1
11/04/2003	17	14.4	1.1
11/04/2003	18	14.5	1.1
11/04/2003	19	13.6	1.1
11/04/2003	20	12.8	1.1
11/04/2003	21	12.1	1.1
11/04/2003	22	11.4	1.1
11/04/2003	23	10.8	1.1
11/04/2003	24	10.2	1.1
11/04/2003	25	9.6	1.1
11/04/2003	26	9.1	1.1
11/04/2003	27	8.6	1.1
11/04/2003	28	8.1	1.1
11/04/2003	29	7.7	1.1
11/04/2003	30	7.3	1.1
11/04/2003	31	6.9	1.1

Figure 11 Inflow data entry window

- **TimeID:** Inflow data can be entered on a 15-minute basis, i.e. up to 96 readings per day. Those readings are assigned time IDs from 0 to 95, with time ID 0 representing midnight (12:00 am) and time ID 95 representing 11:45 pm.

p Note When the inflow data is imported from FloodSim output files, the SMM works out the time IDs automatically.

² Working Paper 25, November 2003. Hydrological Analysis (Final Report). Main Technical Assistance Package for Yemen Irrigation Improvement Project, Arcadis Euroconsult and Associates.

- Each inflow reading should be divided into flood discharge (Flood Q) and base discharge (Base Q).

3.2.7 Bed Losses Data

The bed losses data allows for the simulation of seepage and other bed losses that take place as floodwater travels down wadi and canal reaches. The typical formula adopted in the SMM for estimating bed losses is written as:

$$\text{Bed losses (cumecs/km)} = A Q^N$$

where: Q = flow in the reach (cumecs)

A & N = regression constants

The bed losses data entry window (Figure 12) allows for entering values for the regression constants of the above bed losses formula for two types of reaches only, namely “Wadi” and “Canal”. Thus, only one bed losses formula is used to estimate the losses from all wadi-type reaches in the model (wadi, obar & ogma) and another formula is used to estimate the losses from all canal-type reaches (main, secondary, tertiary, etc.).

The Cut-off Q in the bed losses data entry window can be used to set the minimum flow below which all water is assumed to be lost. Consequently, the bed losses formulas are applied only when the flow exceeds the cut-off discharge, otherwise all the flow is assumed to be bed losses.

* All Data *	
Type	Wadi
Bed losses (cumecs/km) = A Q ^N	
A	0.0478
N	0.78
Cut-off Q (cumecs)	2 (All flow will be lost)
Record: 2 of 2	

Figure 12 Bed losses data entry window

3.2.8 Water Rights Data

The water rights data describe the conditions that govern when a canal or a wadi reach in the water network can or cannot take water. The SMM allows the water rights of every canal or wadi reach in the water network to be defined based on two criteria: calendar dates and/or water availability (see water rights data entry window in Figure 13). When setting the water rights based on calendar dates, up to 12 time periods can be defined for each reach during which the reach can take water. Setting the water rights based on water availability is

achieved by setting the threshold flow above which the reach can take water. Setting both criteria superimposes both of them at the same time, i.e. a reach can take water only if the simulation date and time are within one of the water allocation time periods and the flow available at the head of the reach is not less than the threshold flow for water allocation.

The screenshot shows a software window titled "Water Rights Data" with a close button in the top right corner. Below the title bar, there is a text label "* All Data *". The main area contains a form with the following fields:

- ID:** A text box containing "(AutoNumber)".
- Description:** A large empty text box.
- Allocate water if available discharge >=:** A text box followed by "(cumeecs)".
- Allocate water during the following periods only:** A section containing a table with 12 rows and 2 columns. The columns are labeled "From" and "To". The rows are labeled "Period #1:" through "Period #12:". Each cell in the table is empty.

At the bottom of the window, there is a record navigation bar with the text "Record: 11 of 11" and several navigation icons.

Figure 13 Water rights data entry window

When defining the water right periods, the following should be taken into consideration:

- You can enter the dates as dd-mm (day-month) only without years. In fact during simulations, the SMM applies the given periods to any simulation year.
- Each period is defined by a starting date (From) to an ending date (To). The ending date should always be later than the starting date. Consequently, you may need to divide a period which spans over two years as demonstrated by the following example:

Suppose that some canals have the right to take water from 1 September to 15 March. To define this water allocation period in the SMM, break it into two consecutive periods as follows:

- Period #1: from 1 September to 31 December
- Period #2: from 1 January to 15 March.

-
- N Tip** If some reaches can take water at any time of the year, you can simulate this in the SMM as follows:
- Go to a new record in the water rights data entry window.
 - Enter a meaningful description, e.g. “Any time”.
 - Define period #1 from 1 Jan to 31 Dec.
 - Leave the discharge blank.
 - Go to the network data and assign the ID of the created water right to the target reaches.
-

3.2.9 Network Data

The SMM uses the network data to “know” the series of water courses (reaches) that connect together to convey floodwater from its catchment area to the various command areas in the wadi delta. The water network of a typical spate irrigation scheme comprises two main types of reaches: wadi-type reaches and canal reaches. Wadi-type reaches can be further sub classified as wadi reaches (the main wadi and its sub-branches), obars and ogmas. Canal reaches can be main, secondary and tertiary canals.

a) Data entry steps

The network data preparation and entry into SMM is carried out in the following main steps:

- First, digitise the water network in the GIS and then check it for consistency and errors using DC Water Design extension (refer to Appendix I for more details).
- Second, enter the following attribute data in the GIS for the digitised network features (reaches):
 - DC_ID: a unique identification code to be given to every reach in the network. It is usually assigned automatically by DC Water, however you may want to change it as may be required.

-
- N Tip** If you change the DC_ID of the network reaches, you may want to copy that field to another one in case DC Water overwrites the changes you made to DC_ID.
-

- Name: the true name of the network reach (e.g. Wadi Zabid, etc.).
- Type: must be one of the following types: wadi, ogma, oqma, obar or canal.
- Length: the length of each network reach in meters (can be calculated using ArcView).
- MaxQ: the maximum flow capacity of the reach (cumecs). Enter 0 for no restriction.
- WatPriority and WatShare: are the reach water priority and shares respectively (see Section “Understanding water allocation priorities and shares” below for more details).

- Third, import the network data into the SMM (refer to Section 3.4 for more details):
 - From SMM main menu, click on “Input Data”. The input-data manipulation window appears on the screen.
 - Select “Network” and then click on “Import”.
 - Select “OK” in the prompt to confirm data importing.
 - The file selection window appears to let you select the file from which data is to be imported (Figure 17). Change the file type at the bottom of the window to “dBase Tables (*.dbf)” and then browse to the location where the network data file exists. The file name should be “*network_theme_name.dbf*” where “*network_theme_name*” should be replaced with the name of the network theme in the GIS. Select the file name from the list and then click on “Open”.

p Note Do not import network data from the GIS into SMM while its attributes table is joined with output table from SMM. Remove any joins before importing the data (refer to Section 5.2.2 for more details).

- Finally, enter additional network data directly into SMM through the network data entry window (Figure 14).

Figure 14 Network additional data entry window

- Reach Code: the identification code (DC_ID) given to the network reach in the GIS (cannot be changed from SMM).
- Water Rights ID: select the ID of the water rights that apply to the reach (if the water rights data has already been entered).
- Has Inflow: select if the reach is the most upstream reach in the network (only one reach in the whole network should have this setting).

N Tips • You may want to enter the water rights data first before entering the additional network data such that you can select the water rights ID for

each network reach from the list.

- After importing the basic network data from the GIS and entering the additional data as described above, you should check the network data in SMM (refer to Section 3.3). If errors are found in the basic data, those errors can only be corrected in the GIS. The corrected data should then be imported again in SMM. Note however that if the identification codes (DC_ID) of the network reaches are not changed during the corrections, you will not have to re-enter the additional network data again in SMM because it will retain that data from the last entry.

b) Understanding water allocation priorities and shares

It is very important that one understands how SMM uses water allocation priorities and water shares to distribute water among network reaches. SMM uses this information to distribute the water available at junctions to the downstream reaches, thus water allocation priorities and water shares are only required for reaches downstream from junctions. To demonstrate how water allocation priorities and water shares affect water allocation to network reaches, the small network shown opposite is used. The network consists of a main reach carrying discharge (Q) and bifurcates at junction (J) into three reaches R1, R2 & R3. Three examples are discussed:

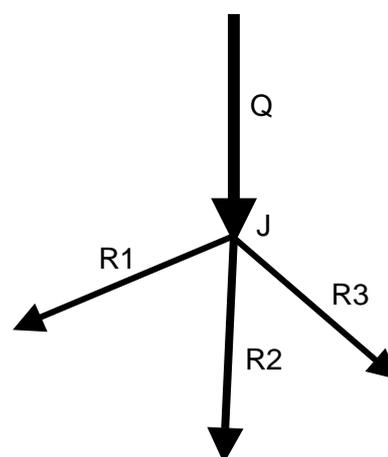


Table 1 Example 1 for reach water allocation

Reach	Water Allocation Priority [§]	Junction Water Share (%) [§]	Simulation Process Order [‡]	Allocated Q [‡]
R1	1	50%	1	50% total Q
R2	2	25%	2	50% remaining Q
R3	3	25%	3	100% remaining Q

[§] To be given by the user.

[‡] As simulated by SMM.

In the first example (Table 1) we assume that the user has defined the water allocation priorities and water shares for all three reaches. When SMM allocates the discharge (Q) at junction (J), it starts with reach (R1) because it is given the highest priority (1). And because reach (R1) is given 50% share of the total junction water, SMM allocates to the reach a maximum discharge of 50% Q. However, depending on the carrying capacity of reach (R1) and the actual demands of its command areas, it may actually take less than 50% Q.

After allocating water to reach (R1), SMM allocates water to the second highest priority reach, which is reach (R2) in this example (priority 2). Reach (R2) is given a maximum share of 25% of total junction water. However, because water has already been allocated to reach

(R1) and the remaining water should be distributed between reaches R2 & R3 only, SMM recalculates the share of reach (R2) as 50% of remaining junction Q.

After allocating water to reach (R2), there is only one reach remaining, R3 and is allocated all remaining Q taking into consideration its carrying capacity and the actual demands of its command areas.

Table 2 Example 2 for reach water allocation

Reach	Water Allocation Priority [§]	Junction Water Share (%) [§]	Simulation Process Order [‡]	Allocated Q [‡]
R1	1		1	100% total Q
R2	2		2	100% remaining Q
R3	3		3	100% remaining Q

[§] To be given by the user.

[‡] As simulated by SMM.

In the second example (Table 2) we assume that the user has defined the water allocation priorities for all three reaches but not the water shares. According to the given water allocation priorities, SMM allocates water to reach (R1) first then to reach (R2) and finally to reach (R3) (refer to the previous example). However, because no water shares are given, SMM starts by allocating a maximum discharge of 100% total junction Q to reach (R1). Depending on the carrying capacity of reach (R1) and the actual demands of its command areas, it may actually take less than 100% Q. After allocating water to reach (R1), SMM allocates water to reach (R2) by giving it a maximum discharge of 100% remaining junction Q, and so on with reach (R3).

Table 3 Example 3 for reach water allocation

Reach	Water Allocation Priority [§]	Junction Water Share (%) [§]	Simulation Process Order [‡]	Allocated Q [‡]
R1		50%	Not defined	Not defined
R2		25%	Not defined	Not defined
R3		25%	Not defined	Not defined

[§] To be given by the user.

[‡] As simulated by SMM.

In the third example (Table 3) we assume that the user has defined the water shares for all three reaches but not the water allocation priorities. Because the water allocation priorities are not defined, the order in which SMM will allocate water to the three reaches cannot be known and may vary from a simulation run to another. Accordingly the discharges allocated to the reaches may also vary.

p Note In example 3, if by chance SMM allocates water to reach (R1) first, then to R2 and then to R3; the discharges allocated to the reaches will be similar to those in example 1.

3.2.10 Command Area Data

The basic definition of a command area in the SMM is that it is a piece of agricultural land in the simulated project that takes water from one network reach only and has the same water right and allocation priority. Accordingly, if some farmer fields irrigate from one another (field to field irrigation), those can be grouped together as just one command area in the SMM. In the case of modernised spate irrigation schemes it is envisaged that a command area in the SMM will be the area managed by a water user group (WUG). However, the user may wish to simulate more than one WUG as just one command area in the SMM. This will be possible provided that the WUGs in any command area take water from the same canal reach and have the same water rights and allocation priority. The actual definition of command areas in the simulated models is therefore up to the user to decide, provided that the above conditions are met.

a) Data Entry Steps

Similar to the network data, the command area data preparation and entry into SMM is carried out in the following main steps:

- First, digitise the command areas in the GIS.
- Second, enter the following attribute data in the GIS for the digitised command areas:
 - DC_ID: a unique identification code to be given to every command area.
 - Description: optional name or description of the command area.
 - FeedCode: the identification code (DC_ID) given to the network reach that directly feeds the command area with irrigation water.
 - NetArea: the net cultivable area (ha).
 - MaxQ: the maximum diversion capacity of the command area (cumecs).
 - IrrEff: the average efficiency of surface irrigation in the command area (enter the figures as percentages not as fractions, e.g. enter 60 for 60% efficiency).
 - IrrPriority: the priority of allocating water to the command area. This is only important if more than one command area take water from the same network reach. The area given the highest priority (1) will be allocated water first until its full requirements are met, and then the area of the second highest priority (2) will be allocated water, and so on.
- Third, import the command area data into the SMM (refer to Section 3.4 for more details):
 - From SMM main menu, click on “Input Data”. The input-data manipulation window appears on the screen.
 - Select “Command Areas” and then click on “Import”.
 - Select “OK” in the prompt to confirm data importing.

- The file selection window appears to let you select the file from which data is to be imported (Figure 17). Change the file type at the bottom of the window to “dBase Tables (*.dbf)” and then browse to the location where the command area data file exists. The file name should be “*command_area_theme_name.dbf*” where “*command_area_theme_name*” should be replaced with the name of the command areas theme in the GIS. Select the file name from the list and then click on “Open”.

Note Do not import command area data from the GIS into SMM while its attributes table is joined with output table from SMM. Remove any joins before importing the data (refer to Section 5.2.2 for more details).

- Finally, enter additional command area data directly into SMM through the command area data entry window (Figure 15).

Figure 15 Command areas additional data entry window

- Area Code: the identification code (DC_ID) given to the command area in the GIS (cannot be changed from SMM).
- Rainfall Station ID: select ID of the rainfall station that is representative to the rainfall in this command area (if the rainfall data has already been entered).
- Cropping Pattern: select ID of the cropping pattern that is grown in the command area (if the cropping pattern data has already been entered).
- Soil Type: select the type of the soil of the command area (if the soil data has already been entered).
- Crop Already Planted: select for the crops that have already been planted in the field, e.g. if you are carrying out a mid-season simulation and therefore

you cannot leave SMM to decide which crops should be planted based on water availability.

- Last Application Date: enter the date of the last actual irrigation application that has been given to the crop (if any).
- Total Application Depth: the total actual depth of irrigation water that has been applied to the crop till the “Last Application Date”. This can either be spate or groundwater irrigation.

**Tips**

- You may want to enter the rainfall, cropping pattern and soil data first before entering the additional command area data such that you can select the rainfall and cropping pattern IDs as well as the soil type for each command area from the lists.
- After importing the basic command area data from the GIS and entering the additional data as described above, you should check the command area data in SMM (refer to Section 3.3). If errors are found in the basic data, those errors can only be corrected in the GIS. The corrected data should then be imported again in SMM. Note however that if the identification codes (DC_ID) of the command areas are not changed during the corrections, you will not have to re-enter the additional command area data again in SMM because it will retain that data from the last entry.

3.3 Checking Input Data

As you enter or edit input data via data entry windows, SMM checks for data errors and prompts you for erroneous data. However, some further checks are sometimes required to ensure the integrity of all input data after data entry/editing is complete. To check any data item:

- Open the input-data manipulation window (refer to Section 3).
- Select the data item to be checked and then click on “Check”.

SMM checks the data. If no errors are found, SMM prompts the user accordingly. Otherwise, a message is shown describing the data error and the respective data entry window appears on the screen showing **only** the data records that have the error in order to enable the user to take due action (Figure 16).

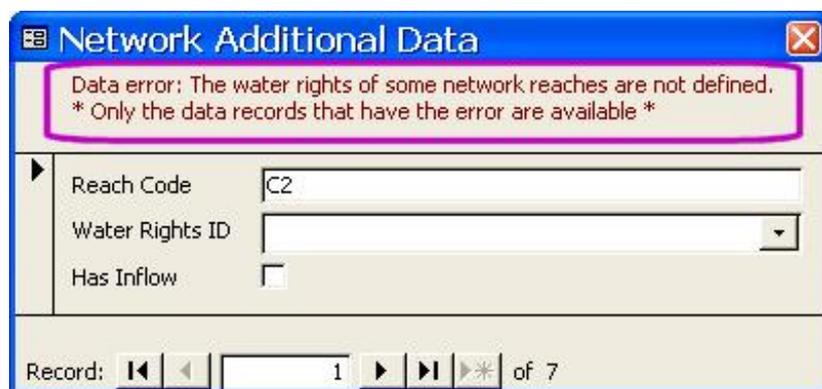


Figure 16 Data entry window showing erroneous data records only

- N Tips**
- You can check all input data for errors at once by selecting “All Data” and then clicking on “Check” in the input-data manipulation window (Figure 4). Nonetheless, SMM will automatically check all input data before any simulation run.
 - If errors are found in the basic network or command area data, those errors can only be corrected in the GIS (SMM will prompt you so). Make the necessary corrections in the GIS and then import the corrected data into SMM and check it again until no errors are found.

3.4 Importing Input Data

SMM provides the facility of importing some input data items from external sources. The input data items that can be imported are the rainfall, inflow, network and command area data. To import any data item:

- Open the input-data manipulation window (refer to Section 3).
- Select the data item to be imported and then click on “Import”.

- p Notes**
- The “Import” command in the input-data manipulation window will be disabled (dimmed out) if the selected data item cannot be imported (e.g. ETo data).
 - The SMM data structure may be changed from version to another. Do not try to import and export data between different versions of the model.
 - When importing data from a source file to a target file, the data in the source file remains intact.
 - Data importing might fail due to one or more of the following reasons:
 - The source database file is password protected (remove the protection before importing the data).
 - You are importing data from a dBase file (.DBF) whose name is

not in the old DOS 8.3 format (make a copy of the file, rename it and then import the data from that copy).

a) Importing Rainfall Data

You can import rainfall data into the current SMM database file from other SMM database files. For instance, you may have some rainfall data already entered into SMM_Run1.mde database file and you want to import this same data into SMM_Run2.mde. The procedure is as follows:

- Start SMM_Run2.mde.
- From SMM main menu, click on "Input Data". The input-data manipulation window appears on the screen.
- Select "Rainfall" and then click on "Import".
- Select "OK" in the prompt to confirm data importing.
- The file selection window appears to let you select the file from which data is to be imported (Figure 17). Browse to the location where the source file exists (SMM_Run1.mde in this example), select the file name from the list and then click on "Open".
- SMM imports the rainfall data from SMM_Run1.mde into SMM_Run2.mde.

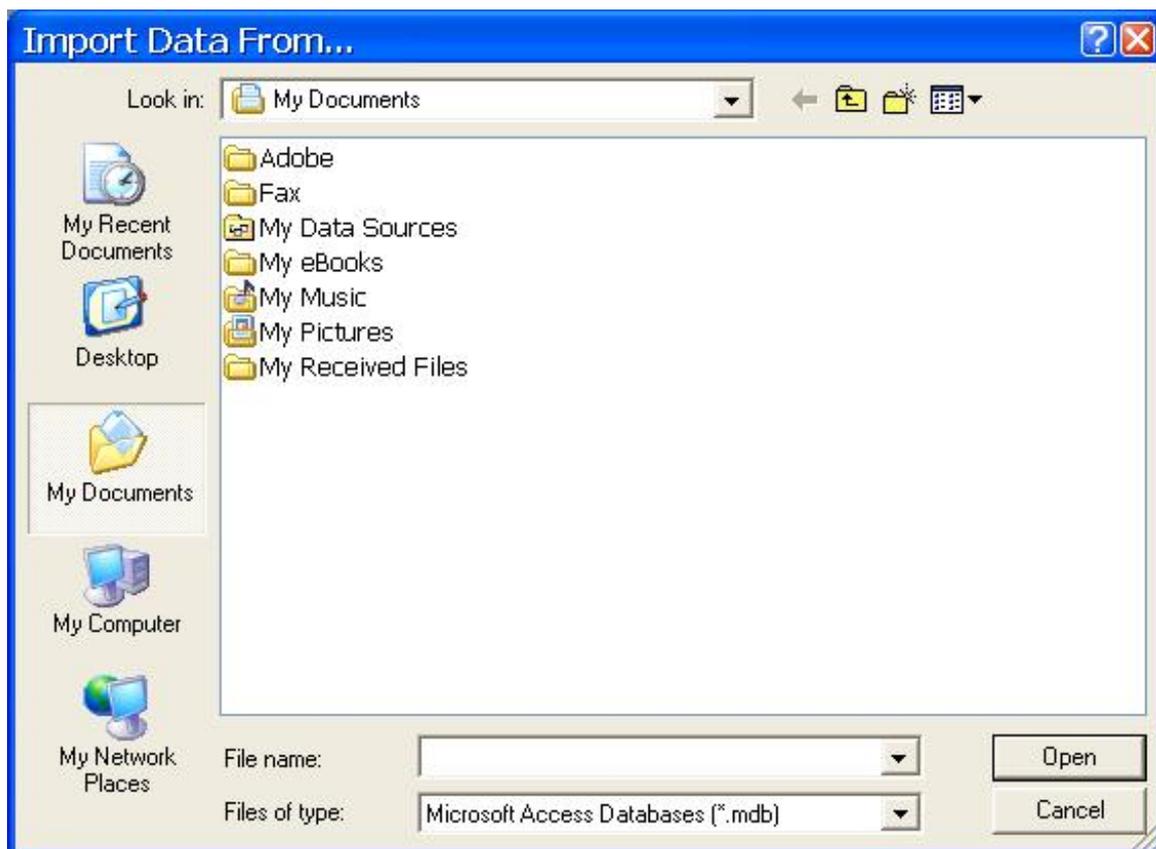


Figure 17 Import data source file selection window

p Note The imported data overwrites existing data of the same type. In the case of importing rainfall and/or inflow data, any existing data records that have the same year as the imported data are overwritten by the imported data. Using the previous example for demonstration, if SMM_Run2.mde contains rainfall data for 6 months in year 2003 and SMM_Run1.mde contains rainfall data for 2 months only in year 2003. When the rainfall data is imported from SMM_Run1.mde into SMM_Run2.mde, the whole 6 months of rainfall data in SMM_Run2.mde are deleted and replaced with the imported 2 months of rainfall data from SMM_Run1.mde (i.e. there will be some data loss in this case).

b) Importing Inflow Data

Importing inflow data is very similar to importing rainfall data, with the only difference being that SMM can import inflow data from SMM database files as well as from FloodSim output files.

p Note To import inflow data from FloodSim output files, two source files must exist in the same folder, namely x-baseflow.dat & x-hydrograph.dat where x is the code given in FloodSim to the run whose output data is to be imported. **When you are prompted by SMM to select the source file, you must select the x-hydrograph.dat not the x-baseflow.dat in the file selection window.**

3.5 Exporting Input Data

SMM provides the facility to export input data to external sources, namely Microsoft Access database files (.MDB or .MDE) and dBase IV database files (.DBF):

- When exporting data to a dBase file (.DBF) that already exists, any data in that file is overwritten by the exported data.
- When exporting data to an Access database file (.MDB or .MDE), the file must already exist. The exported data tables will overwrite existing tables of the same name in the target file.

To export any data item:

- Open the input-data manipulation window (refer to Section 3).
- Select the data item to be exported and then click on "Export".

p Note To export all input data at once, select “All Data” in the input-data manipulation window and then click on “Export”. In this case the data can be exported to Access database files (.MDB or .MDE) only.

3.6 Deleting Input Data

To delete all input data of some type:

- Open the input-data manipulation window (refer to Section 3).
- Select the data item whose data is to be deleted and then click on “Delete All”.

p Notes

- To delete all input data at once, select “All Data” in the input-data manipulation window and then click on “Delete All”. In this case all the simulation results will be deleted as well.
- Once data is deleted, it cannot be undeleted again. Please be sure to make a backup copy of the database file before deleting important data.

3.7 Printing Input Data

You can make hard copies of the input data by printing the data to a printer as follows:

- Open the input-data manipulation window (refer to Section 3).
- Select the data item whose data is to be printed and then click on “Print”.
- The data print preview window appears on the screen. Right-click on that window and select “Print...” to print the page(s) to the Windows default printer.

p Note To print all input data at once, select “All Data” in the input-data manipulation window and then click on “Print”. Note that in this case the print preview window will not appear on the screen and the data will be printed directly to the printer.

4. RUNNING SIMULATIONS

When all relevant input data has been entered into SMM and checked for no errors, the model should be able to do simulation runs. The simulation options and parameters are set in the simulation window (Figure 18). To open the simulation window:

- From SMM main menu, click on “Simulation”. The simulation window appears on the screen.

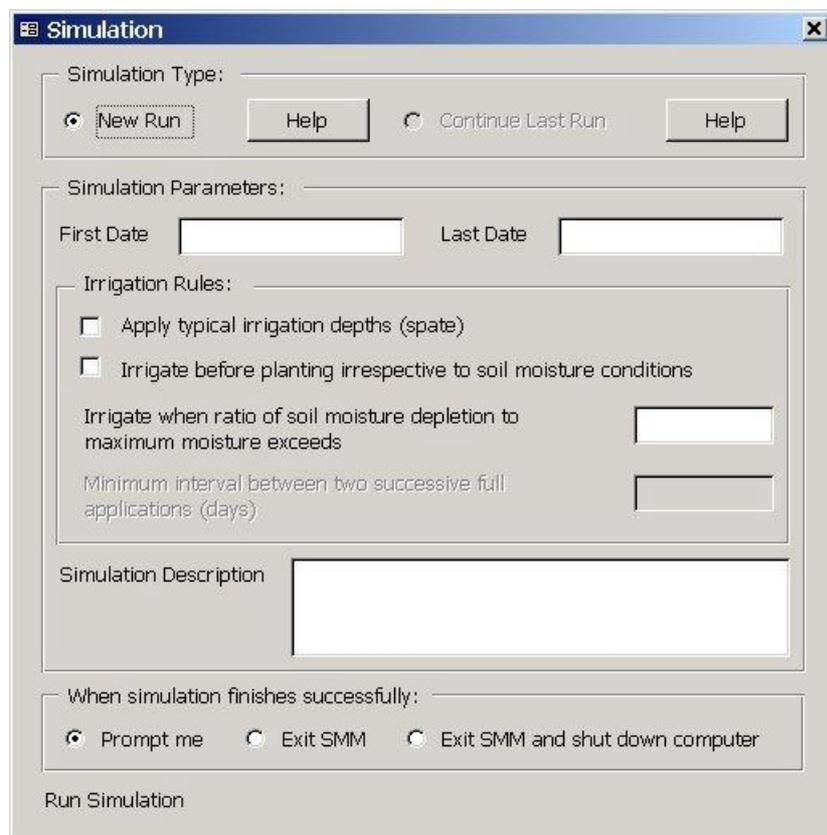


Figure 18 Simulation window

4.1 Simulation Type

The simulation type defines whether SMM should start a new simulation run or whether it should continue the last successful run:

- **New Run:**

Deletes all the results from previous simulation runs (if any) from the current database and starts a fresh run. Use this option if you have made significant changes to the input data after the last run such that combining the new results with the previous results will not be logical.

- **Continue Last Run:**

Starts a simulation run that builds on the results from the last successful run. Use this option if you have not made significant changes to the input data after the last run such that combining the new results with the previous results will be logical.

p Note This option will be disabled (dimmed out) if there are no results from previous simulation run(s) in the database.

4.2 Simulation Parameters

- First Date: the first date in the simulation run (note that this parameter will be disabled when you select “Continue Last Run” in the simulation type).
 - Last Date: the last date in the simulation run.
 - Irrigation Rules:
 - Apply typical irrigation depths (spate): when this option is selected (checked), SMM applies fixed irrigation depths to the crops, provided that water is available, irrespective to the crop water requirements or the soil moisture conditions. This setting therefore mimics farmer practice with spate irrigation. When this option is not selected (unchecked), water is applied to the crops according to their crop water requirements and soil moisture conditions (optimal irrigation).
-

p Note The fixed irrigation depth to be applied to each crop type in spate irrigation is entered with the crop data (refer to Section 3.2.2).

- Irrigate before planting irrespective to soil moisture conditions: when this option is selected (checked), SMM always pre-irrigates before crop planting to replenish soil moisture to field capacity, provided that water is available. When this option is not selected (unchecked), SMM pre-irrigates before crop planting only if required (according to soil moisture conditions).
-

p Note This option is available only when the first option is not selected (unchecked – optimal irrigation). When the first option is selected (spate), SMM will always pre-irrigate before crop planting.

- Irrigate when ratio of soil moisture depletion to maximum moisture exceeds: the threshold soil moisture depletion ratio at which SMM irrigates the crops provided that water is available. The valid range for this ratio is greater than 0 to less than or equal to 1, with the larger ratios putting the crops under higher stress.
-

p Note This option is available only when the first option is not selected (unchecked – optimal irrigation).

- Minimum interval between two successive full applications (days): this parameter enables the user to define the minimum frequency of spate irrigation. The value of the parameter should be the minimum interval before any command area can be spate irrigated again after the last full irrigation. Setting this parameter prevents repeated

irrigation of upstream command areas when they have the water right and water is available.

p Note This option is available only when the first option is selected (checked – spate irrigation).

- **Simulation Description:** a description of the simulation that can be used to record the purpose of the simulation or the scenario being tested.

4.3 Post Simulation Action

SMM provides three actions to take when the simulation run finishes successfully:

- **Prompt me:** SMM will show a message indicating that the run has finished successfully.
- **Exit SMM:** SMM will automatically shut down itself.
- **Exit SMM and shut down computer:** SMM will automatically shut down itself and the computer. This action is particularly useful if you want to make long simulation runs (a one year simulation run of a medium-size network is likely to take several hours). In such cases, you can run SMM unattended, say at night, and choose this action such that SMM shuts down itself and the computer when the run is finished.

p Notes

- If an error occurs during the simulation, SMM will show a message of the error and will not take any of the above actions.
- If you are running SMM on a computer running Windows NT/2000/XP, SMM may not be able to shut down the computer if you do not have the privileges to do so. Consult your system administrator on this matter.
- Do not enable the “Auto-compact the database when the application is closed” option (refer to Section 2.1) if you plan to use the “Exit SMM and shut down computer” action.

- **Run Simulation:** click on “Run Simulation” to start the simulation run. The progress of the run will be shown at the bottom of the simulation window. Press Esc at any time to stop the run. Note however that simulation runs can only be stopped at the ends of simulation days.

N Tip Make sure that you have enough space on the hard disk where the SMM file to run the simulation is located. A one-year simulation of a medium-size network may require 500 MB or more of disk space for result storage.

5. SIMULATION RESULTS

After a simulation run has been completed successfully, the results of the run can be reviewed either from within the SMM or using GIS.

5.1 Reviewing Simulation Results Using SMM

The simulation results can be reviewed in SMM via the results window (Figure 19). To open the results window:

- From SMM main menu, click on “Results”. The results window appears on the screen.

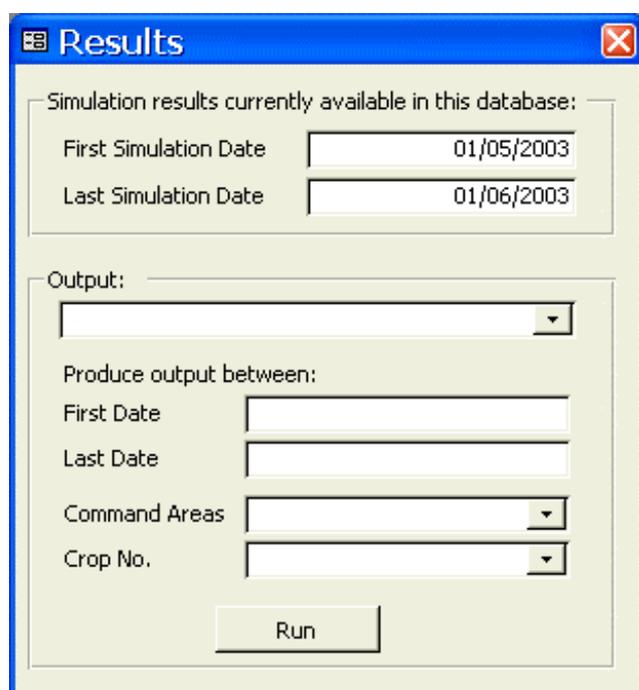


Figure 19 Results window

The top half of the window gives the first and last simulation dates for the period for which results are available. The bottom half of the window lists all possible outputs. To see a particular output:

- Select the required output from the list.
- Enter the first and last dates for the simulation period for which the output is required (or leave them blank to see the results for the whole period simulated).
- Select the command area and crop number as applicable.
- Click on “Run”.
- A preview of the results is shown on the screen. To make a print out of the results, right-click on the results preview window and choose “Print...” from the pop-up menu and then follow the remaining instructions.

-
- p Notes**
- The preparation of some results require lengthy calculations, so it could take a few seconds after clicking on the “Run” button before the results actually appear on the screen.
 - If you open the results window when no simulation results are available in the database, SMM will prompt you accordingly and the output options will be disabled.
-

5.1.1 Simulation Parameters

This output produces a list of the simulation parameters that were used in making the last simulation run.

5.1.2 Project Water Resources Summary

This output produces a summary of the water resources availability and use for the whole simulated scheme:

- Inflow: the total volume of surface water (usually flood water) that was available to the simulated scheme during the output period.
- Diverted Water: the total volume of water diverted to the command areas within the simulated scheme during the output period. These volumes are the gross volumes at the heads of the command areas. (Percentage = diverted water / inflow).
- Percolation from Command Areas: the total volume of field losses from the command areas out of their diverted water. (Percentage = percolation from command areas / diverted water).
- Network Seepage Losses: the total volume of seepage losses from the simulated network during the output period. (Percentage = seepage / inflow)
- Outflow: the total volume of surface water that was neither diverted to the command areas nor lost to seepage (outflow = inflow – diverted water – network seepage losses). Consequently, this water may flow to the scheme drainage area (e.g. to the sea at the tail end of the wadi) and/or replenish the groundwater. (Percentage = outflow / inflow).
- Rainfall: the total volume of rainfall over the actually cultivated area (not over the whole cultivable area).
- Rainfall Losses: the volume of rainfall water that was not beneficially used to meet crop water requirements in the actually cultivated area. (Percentage = rainfall losses / rainfall).
- Rainfall to Inflow Percentage: percentage of total volume of rainfall to total volume of inflow from surface water resources.

5.1.3 Project Production Summary

This output produces a summary of the crop production results for the whole simulated scheme:

- Total Cultivable Area (ha): the total net area of all the command areas in the scheme.
- Total Crop Area (ha): the sum of cultivated crop areas all over the scheme during the output period.
- Cropping Intensity (%): the percentage of the total crop area to the total cultivable area.
- Total Crop Water Requirements (m^3): the total volume of crop water requirements for all the cultivated crops during the output period.
- Actual Crop Evapotranspiration (m^3): the total actual crop evapotranspiration for all the cultivated crops during the output period.
- Gross Irrigation Application (m^3): the total volume of irrigation water applied to all the cultivated areas during the output period.
- Applied/Requirements (%): the percentage of the total volume of applied irrigation water to the total volume of crop water requirements during the output period.
- ETa/CWR (%): the percentage of the total actual crop evapotranspiration to the total crop water requirements during the output period.
- Average Application Rate (m^3/ha): the total volume of applied irrigation water divided by the sum of cultivated crop areas all over the scheme during the output period.
- Average Application Efficiency (%): the weighted average field application efficiency scheme wide during the output period.
- Average Potential Yield (%): the weighted average potential yield for all the cultivated crops during the output period.
- Outstanding Irrigation Volume (m^3): the outstanding volume of irrigation water requirements for all the crops still growing in the scheme after the end of the output period allowing for the field application efficiencies of the different command areas in which they are grown (as given in the command area input data).

5.1.4 Command Area Results Summary

This output produces summary results for each command area within the simulated scheme:

- Command Area Code: the identification code (DC_ID) given to the command area.
- Net Area (ha): the total net area of the command area.
- Total Crop Area (ha): the sum of cultivated crop areas in the command area during the output period.
- Cropping Intensity (%): the percentage of the total crop area to the total net area.
- Total Crop Water Requirements (m^3): the total volume of crop water requirements for all the crops cultivated in the command area during the output period.
- Actual Crop Evapotranspiration (m^3): the total actual crop evapotranspiration for all the crops cultivated in the command area during the output period.
- Gross Irrigation Application (m^3): the total volume of irrigation water applied to all the crops cultivated in the command area during the output period.

- ETa/CWR (%): the percentage of the total actual crop evapotranspiration to the total crop water requirements during the output period.
- Applied/Requirements (%): the percentage of the total volume of applied irrigation water to the total volume of crop water requirements during the output period.
- Average Application Rate (m³/ha): the total volume of applied irrigation water divided by the sum of cultivated crop areas in the command area during the output period.
- Average Application Efficiency (%): the weighted average field application efficiency for all the crops in the command area during the output period.
- Average Potential Yield (%): the weighted average potential yield for all the crops cultivated in the command area during the output period.
- Outstanding Irrigation Volume (m³): the outstanding volume of irrigation water requirements for all the crops still growing in the command area after the end of the output period allowing for the field application efficiency (as given in the command area input data).

p Note Only the command areas that had some crops grown during the output period are included in the output list. Command areas that had no crops grown during the output period are not included.

5.1.5 Crop Results Summary

This output produces summary results for each crop grown within the simulated scheme:

- Crop Name: the name of the crop.
- Crop Area (ha): the total area cultivated with the crop in the whole scheme during the output period.
- Total Crop Water Requirements (m³): the total volume of crop water requirements for the whole area cultivated with the crop in the whole scheme during the output period.
- Actual Crop Evapotranspiration (m³): the total actual crop evapotranspiration for the whole area cultivated with the crop in the whole scheme during the output period.
- Gross Irrigation Application (m³): the total volume of irrigation water applied to the whole area cultivated with the crop in the whole scheme during the output period.
- ETa/CWR (%): the percentage of the total actual crop evapotranspiration to the total crop water requirements during the output period.
- Applied/Requirements (%): the percentage of the total volume of applied irrigation water to the total volume of crop water requirements during the output period.
- Average Application Rate (m³/ha): the total volume of applied irrigation water divided by the total cultivated crop area during the output period.
- Average Application Efficiency (%): the weighted average field application efficiency for all the areas cultivated with the crop in the whole scheme during the output period.

- Average Potential Yield (%): the weighted average potential yield for the crop in the whole scheme during the output period.
- Outstanding Irrigation Volume (m³): the outstanding volume of irrigation water requirements for all the areas in the scheme in which the crop will be still growing after the end of the output period allowing for the field application efficiency (as given in the command area input data).

p Note Only the crops grown during the output period are included in the output list. Crops that were not grown during the output period are not included.

5.1.6 Command Area Crops

This output produces summary results for each crop in each command area within the simulated scheme:

- Command Area Code: the identification code (DC_ID) given to the command area.
- Plant Number: the number of the plantation of the same crop during the simulated period, so when it is the first time the crop is planted the number will be 1, and when it is the second time the number will be 2, etc.
- Crop Name: the name of the crop.
- Crop Area (ha): the area cultivated with the crop.
- First Date: the first date the crop water present during the output period.
- First Growing Day: the number of days between the reported "First Date" and the first date the crop was actually cultivated.
- Last Date: the last date the crop was present during the output period.
- Last Growing Day: the number of days between the reported "Last Date" and the first date the crop was actually cultivated.
- Rainfall (mm): the total depth of rainfall over the crop area during the output period. (Will be blank if there was no rainfall during the output period.)
- Crop Water Req. (mm): the total crop water requirements for the crop (ET_c) during the output period.
- Actual Crop ET (mm): the total actual crop evapotranspiration during the output period.
- App. Depth (mm): the total actual depth of irrigation water applied to the crop area during the output period.
- Applied/Requirements (%): the percentage of the total actual applied water to the total crop water requirements during the output period.
- ET_a/CWR (%): the percentage of the total actual crop evapotranspiration to the total crop water requirements during the output period.

- Rainfall Efficiency (%): the average fraction of the rainfall that was used beneficially to meet the crop water requirements during the output period. (Will be blank if there was no rainfall during the output period.)
- Application Efficiency (%): the actual average field application efficiency during the output period.
- Potential Yield (%): the potential crop yield based on the ratio of the actual to the required crop evapotranspiration during the output period.
- Outstanding CWR (mm): the outstanding crop water requirements for the period after the output period till the end of the crop's growing season.
- Outstanding Vol. (m³): the outstanding volume of irrigation water requirements calculated from the outstanding CWR for the area of the crop and allowing for the field application efficiency (as given in the command area input data).

p Note Only the command areas that had some crops grown during the output period are included in the output list. Command areas that had no crops grown during the output period are not included.

5.1.7 Crop Water Chart

This output produces a chart showing the soil moisture conditions of a selected command area and crop during the output period.

5.1.8 Reach Discharge Summary

This output produces a summary of the flows in all the reaches of the simulated network over the whole simulated period:

- Reach Code: the identification code (DC_ID) given to the reach.
- Maximum Net Discharge (m³/s): the maximum net discharge in the reach (i.e. after deducting seepage losses) during the output period.
- Net Water Volume (m³): the total volume of net reach flow (i.e. after deducting seepage losses) during the output period.
- Seepage Losses (m³): the total volume of seepage losses from the reach during the output period.

5.1.9 Reach Day Summary

This output produces a summary of the flows in all the reaches of the simulated network during one selected day one:

- Reach Code: the identification code (DC_ID) given to the reach.
- Max. Avail. Q (m³/s): the maximum discharge that was available to the reach during the output day.

- Max. Gross Q (m^3/s): the maximum gross discharge in the reach (i.e. before deducting seepage losses) during the output day.
- Max. Seepage (m^3/s): the maximum seepage losses from the reach during the output day.
- Req. Water Volume (m^3): the total volume of irrigation water required for all the command areas feeding directly from the reach during the output day.
- Actual Water Volume (m^3): the total volume of irrigation water actually allocated to all the command areas feeding directly from the reach during the output day.

5.1.10 Reach Discharge Chart

This output produces a chart showing the actual net discharge and bed losses for a selected network reach during the output period.

5.1.11 Reach Discharge Chart (with available Q)

This output produces a chart showing the actual net discharge and bed losses for a selected network reach in addition to the discharge that was available to the reach (flow arriving at the head of the reach) during the output period. This chart may be useful in finding out why a certain reach was allocated say very little flow by comparing available discharge to actual discharge.

5.1.12 Delete All Simulation Results

This option deletes all the simulation results from the model's database. SMM will give a warning message before actually deleting the data.



Note Deleted data cannot be undeleted again. Please take due care before deleting any data. If in doubt, make a backup copy of the model before deleting any data (refer to Section 2.1 for information on how to make backup copies of the model).

5.2 Reviewing Simulation Results Using GIS

The output of the simulation results produced by SMM is mainly in tabular and chart formats. For spatial presentation of the results, the use of a GIS is important. This section describes how this may be achieved using the ArcView 3.x GIS.



- Notes**
- This section assumes that the user is familiar with the use of the ArcView GIS software.
 - Reviewing SMM simulation results can also be done using the ArcGIS 8.x software. Due care should be taken though not to save any of the model
-

themes using this version of the software because they will not be readable again by ArcView 3.x.

The main steps for reviewing the simulation results in the GIS are as follows:

- Close the SMM model whose results you would like to review in the GIS.
- Open the ArcView project that contains the modelled network and command areas.
- From ArcView connect to the SMM database and import the output table that contains the results to be reviewed.
- Join the SMM output table with the proper attributes table in ArcView and view the results.

The details of some of these steps are given below.

5.2.1 Importing SMM Output Data into ArcView

In ArcView:

- Click on the “project window” to activate the project-related menu commands.
- Select “SQL Connect” from the “Project” menu. The SQL Connect window is shown.
- For “Connection” select “MS Access Database” and then click on “Connect” to browse to and select the SMM database file that contains the required results (you may need to change the “List of File Types” to “All Files” to be able to see the SMM database files).
- If the connection is successful, the “Tables” list will show a list of all the tables in the SMM database. Double-click on the name of the SMM table that contains the required results (refer to Table 4) after which the “Columns” list will show the names of the fields in the table. Double click on “<All Columns>”.
- Give a name for the “Output Table” (say “SMM1”) and then click on “Query”. If the query is successful, a table of the given name (“SMM1”) should be added to the tables in the ArcView project.
- Close the SQL Connect window.

Table 4 SMM result tables

SMM table name	Results in table*	Join with attributes table
_ReachSum	Reach Discharge Summary	Network
_ReachQ	Reach Day Summary	Network
_Commands	Command Area Results Summary	Command areas
_CommandCrops	Command Area Crops	Command areas

* For more details on these results, refer to Section 5.1.

p Note If you save the ArcView project after importing SMM output data, each time you open that project again, ArcView will prompt you to select the SMM database.

5.2.2 Joining Imported SMM Table with Attributes Table in ArcView

After successfully importing any SMM output table into ArcView, you must join that table with the appropriate attributes table before you can review the results.

In ArcView:

- Open the SMM output table that was imported in ArcView (e.g. “SMM1”).
- Open the appropriate attributes table (refer to Table 4).
- Click on the name of the “DC_ID” column in the SMM output table (the column name should appear sunken).
- Click on the name of the “DC_ID” column in the attributes table (the column name should appear sunken).
- From the “Table” menu select “Join”, or click the “Join” button on the toolbar.
- The SMM output table will be closed and the attributes table will grow larger showing the joined columns from the output table.

p Notes

- You can only join two tables together.
- To remove a join, open the joined table and then select “Remove All Joins” from the “Table” menu.
- Do not import network or command area data from the GIS into SMM while the attributes tables are joined with output tables from SMM. Remove any joins before importing data.

APPENDICES

Appendix I. USING ARCVIEW AND DC WATER TO PREPARE NETWORK AND COMMAND AREA DATA FOR SMM

This section briefly outlines the steps that should be followed for preparing the network and command area schematics and basic data to be used in SMM using the ArcView 3.x GIS.

p Note This section assumes that the user is familiar with the ArcView 3.x GIS software and the DC Water Design extension. For more information, refer to the ArcView Help and the DC Water Design Manual.

- Start ArcView and create a new project.
- Make sure that the DC Water Design extension is installed on your system. Load the extension in the project.

p Notes

- You can install the DC Water Design extension from its installation package that is supplied on the SMM disc.
- The DC Water Design extension can only be used with ArcView 3.x, but not with ArcView 8.x or higher.

- In any “view” in the created project, create at least four “themes” for the water network, junctions, inflow and command areas. The theme types should be “line”, “point”, “point” and “polygon” respectively.

N Tip Avoid using long file names for the theme files (e.g. you may save them under the names “network”, “junctions”, “inflow” and “commands”) as using long file names may cause problems on some systems when importing the data into SMM.

- Click on the “Epanet Themes” button on the toolbar to open “Epanet Themes” dialog and assign the first three themes to the DC Water types “pipes”, “junctions” and “reservoirs” respectively.
- Add the following fields to the themes’ attribute tables before digitising any feature or using any other DC Water command:

Theme	Field name	Field type	Field width	Field decimals
Water network	DC_ID	String	12	N/A
	Node1	String	12	N/A
	Node2	String	12	N/A
	Name	String	50	N/A
	Type	String	12	N/A
	Code	String	32	N/A
	MaxQ	Number	16	4

Theme	Field name	Field type	Field width	Field decimals
	WatPriority	Number	4	0
	WatShare	Number	3	0
Command areas	DC_ID	String	12	N/A
	Description	String	50	N/A
	FeedCode	String	12	N/A
	NetArea	Number	16	2
	MaxQ	Number	16	4
	IrrEff	Number	3	0
	IrrPriority	Number	4	0

- p Notes**
- Field names are not case sensitive, e.g. DC_ID is perfectly equal to dc_id.
 - When creating some of the above fields in ArcView 3.x, it will prompt you that the field name is too long and that it will shorten it and use the long name as an alias. You should accept this.

- After making sure that all the above fields have been created successfully, use DC Water to create any missing fields (select “Create Missing Fields” from the “DC Water Design” menu).
- Digitise the water network first (i.e. wadi, oqma, canal reaches, etc.) using the special buttons added by the DC Water extension (note that network reaches are designated “pipes” in DC Water). Make sure to digitise the network reaches in the normal direction of the flow. When you digitise a reach, DC Water will add the appropriate junctions at the ends of the reach. The first reach you digitise will therefore have two junctions added to both ends. All subsequent reaches should have one or no junctions added as they should be connected to the ends of other reaches (when you digitise a reach that should be connected to other reaches that have already been digitised and DC Water informs you that it is going to add more than one junction with that new reach, do not accept this because this will mean that the new reach will not be connected to others).
- After digitising the water network, digitise one “reservoir” node at the head of the wadi (e.g. at the location of Kolah gauging station in case of Wadi Zabid network).
- Finally, digitise the command areas. They are not mapped to any of the DC Water types so they should be digitised using the standard ArcView digitising tools (you can digitise them as rectangles, circles, polygons, etc).
- After digitising all the network components, make sure to check the model using DC Water for duplicate IDs, network connectivity, etc (use DC Water menu commands “Check Epanet Model” and “Make Epanet Model”).
- Enter the basic network and command area data in the GIS (refer to Sections 3.2.9 and 3.2.10 respectively for more details).
- When all is okay, save the ArcView project and then close ArcView. Run SMM and import the network and command area data (refer to Sections 3.2.9 and 3.2.10 respectively for more details).

Appendix II. WADI ZABID EXAMPLE

II.1 Model Description

A model for Wadi Zabid has been prepared as an example for demonstration purposes. The model covers the delta of Wadi Zabid downstream from Kolah gauging station. It comprises the main Zabid wadi and its branches (Wadi Nassery and Wadi Ain), the main oqmas, and the canal network down to the secondary level. The total command area for each canal is modelled by three command areas representing the head, middle and tail areas. The modelled command areas of the secondary canals include the areas irrigated from lower-level canals (since those canals are not included in the modelled network). Schematic layouts of the modelled network and command areas of Wadi Zabid are shown in Figure II.

The average monthly reference evapotranspiration (ET_o) data was taken from the Consultant’s Working Paper 1¹. The daily rainfall data for the year 1970 was used in the model as it represents a year with average rainfall. The inflow data (wadi flood hydrographs) was generated using the FloodSim model. The cropping patterns used in the model were based on those in the Consultant’s Working Paper 1. Two cropping patterns were used for the whole wadi area, one for Group 1 canals and the second for Groups 2 & 3 canals. Crop data was taken from FAO CropWat data files.

Canal capacities and water rights were based on the information collected by the Consultant’s water management engineers. Bed losses from the wadi and canals were taken from Lawrence & Hinton, 1986². The maximum diversion capacities for the command areas were calculated by assuming that the outlets deliver a water duty of 60 l/s/ha, i.e.:

$$\text{Max Q for command areas (m}^3\text{/s)} = \text{area (ha)} * 60 \text{ (l/s/ha)} / 1000$$

p Note A soft printout of the input data for Wadi Zabid SMM model is available on the SMM disc.

II.2 Simulation Runs

Four simulation runs were carried out using the prepared Wadi Zabid model for the following scenarios:

Run01	<ul style="list-style-type: none"> Fixed inflow of 100 m³/s. Spate irrigation.
Run02	<ul style="list-style-type: none"> Fixed inflow of 100 m³/s. Optimal irrigation.

¹ Working Paper 1, August 2002. Water Management in Wadi Tuban & Wadi Zabid. Main Technical Assistance Package for Yemen Irrigation Improvement Project, Arcadis Euroconsult and Associates.

² Lawrence P. & Hinton R., 1986. Wadi Zabid Diversion Structures – Field Performance Measures. Report No. OD 73. Hydraulics Research, Wallingford, UK.

Run03	<ul style="list-style-type: none"> • Inflow data as generated by FloodSim run ZD208. • Spate irrigation.
Run04	<ul style="list-style-type: none"> • Inflow data as generated by FloodSim run ZD208. • Optimal irrigation.

p Note The output of FloodSim run ZD208 is available on the SMM disc.

The first two runs simulate a theoretical situation of a constant inflow into the Wadi. In fact the main purpose of these two runs was to test the functionality of the SMM itself. The last two runs, on the other hand, use inflow hydrographs that were generated by the FloodSim model (Figure I) and therefore simulate more realistic situations in terms of availability of surface water resources. The purpose of these two runs was to assess the impact of two water management options on resource use and project production. Discussion of selected results from the last two runs is presented below.

The simulation period for all the runs was one year from 1/1/2003 till 31/12/2003.

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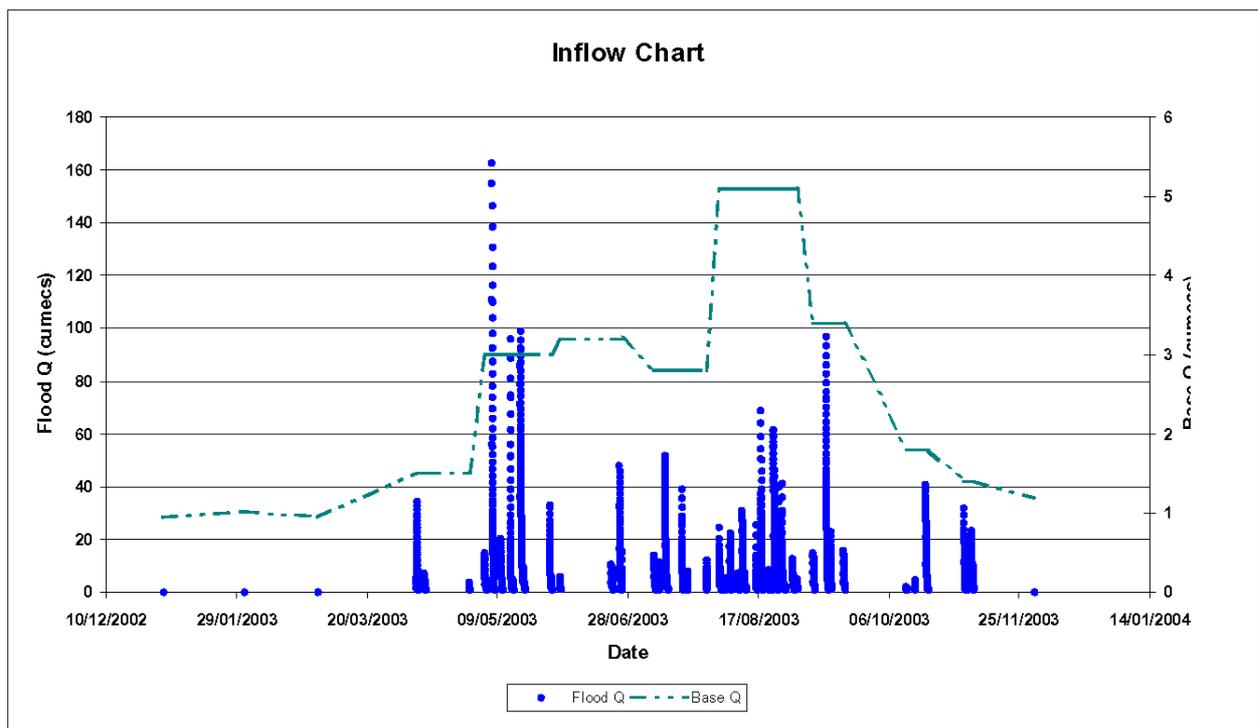


Figure I Flood hydrographs produced by FloodSim run ZD208

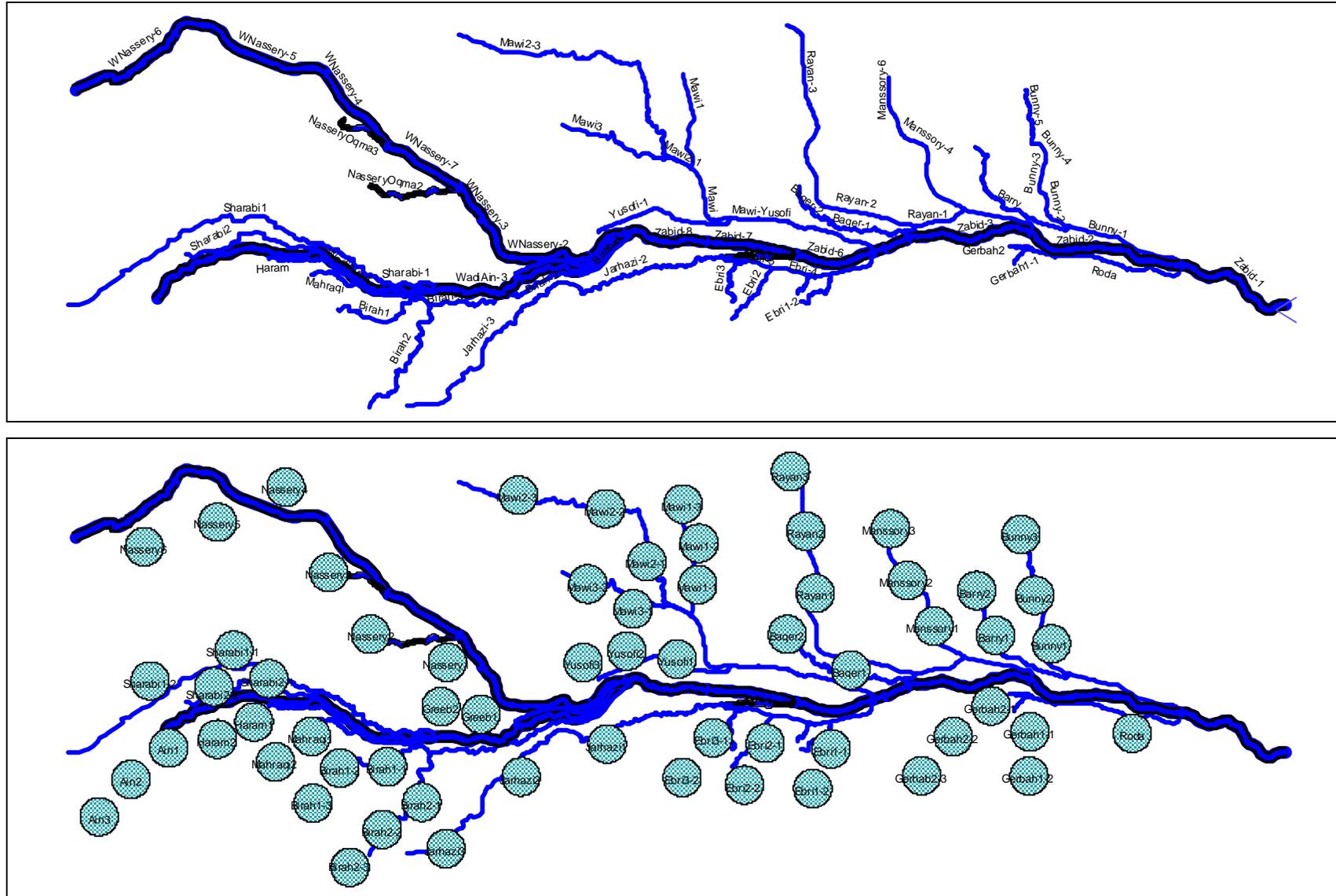


Figure II Schematic layouts of the water network and command areas used in Wadi Zabid SMM model

II.3 Results Discussion

This section discusses the results obtained from simulation runs 03 and 04. As explained above the two runs are identical except that run03 simulates spate irrigation (i.e. each crop is irrigated with a given fixed depth of water irrespective to soil moisture conditions) whereas run04 simulates optimal irrigation (i.e. crops are irrigated according to their actual needs and soil moisture conditions). The discussion makes comparisons between similar outputs from both runs in order to highlight the differences between the results.

p Note Soft printouts of the results of simulation runs 03 & 04 are available on the SMM disc.

II.3.1 Water Resources Summary

The summaries of project water resources use show significant differences between runs 03 & 04. The total surface water inflow was the same in the two runs, which ensures the fact that the same inflow hydrographs were used in both runs. On the other hand, the volume of water diverted to the command areas was significantly larger in case of run03. This does not necessarily imply that the use of water resources was more efficient in run03 than in run04. The percentage of percolation from the command areas was a lot higher in run03, which shows that too much water was applied to the command areas, as it is usually the case with spate irrigation.

It should also be noted that the outflow was larger in run04 than in run03. This again does not necessarily indicate lower efficiency of the use of water resources in this run. In fact run04 had more outflow because simply less water was applied to the command areas than in run03. In addition, the outflow is not necessarily lost water as it can be used to replenish the groundwater for example.

II.3.2 Project Production Summary

The project production summary complements the overall picture of the use of resource drawn earlier by the water resources summary results. The total crop area, and hence cropping intensity, in run04 was about 3.6 times that in run03. This typically leads to higher crop water requirements in run04. Actual water application was only 69% of the requirements in run04 compared to 562% in run03. The average application rate was 3539 m³/ha in run04 while it was excessively high at 28189 m³/ha in run03. This was also translated into higher average application efficiency in run04 than in run03.

Accordingly, both the water resources summary and production summary results for runs 03 & 04 clearly show that run04 was much more efficient in terms of water and land resource utilisation.

II.3.3 Command Area Results Summary

The command area summary results are better reviewed using the GIS such that the spatial variation in the results can be easily seen. Referring to Figure III and Figure IV, most of the command areas had cropping intensities in the range of 30 to 40%. Typically, the cropping intensity decreased from head to tail. Out of the 64 command areas in the model, 46 did not have any crop grown in run03 compared to 15 in run04.

II.3.4 Crop Water Charts

The command area crop results and the crop water charts provide detailed information for each crop in each command area. If command area “Bunny1” is taken as an example, we find that three crops were grown in this area in both run03 and run04 (see tabular output for this command area in the result print outs below). The crop water charts show some interesting results. In run03 (Figure VI), sorghum was irrigated very frequently, as it may happen in spate irrigation when water is available. This led to very high water content in the soil for most of the growing season (note that the soil moisture deficit was nearly zero most of the time, Figure VI). Consequently, crop growth was not affected by any water shortage and potential yield was estimated as 100% (note that the actual crop evapotranspiration line lies on top of the crop water requirements line all the time).

In run04 (Figure VII), sorghum still had sufficient water supply and did not suffer from any water shortage, thus no reduction in yield. However, in this simulation the crop was irrigated only five times during its growth period, thus far less irrigation water was used to grow the same crop and produce the same potential yield compared to run03.

Cotton was irrigated only once at the beginning of the growing season in run03 (Figure VIII). This single spate irrigation was sufficient to fully replenish the soil moisture and keep the crop growing throughout the whole season without needing further irrigation and without any impact on yield.

In run04, on the other hand, the situation was slightly different. Cotton was again irrigated only once at the beginning of the growing season (Figure IX). However, another irrigation was required near the end of November (note that the soil moisture deficit reached the maximum available moisture at that time). But because at that time Bunny had no right to take water the crop could not be given the required irrigation and hence suffered from some water shortage.

II.3.5 Reach Discharge Summary

Figure V depicts the maximum discharges in the different reaches of Wadi Zabid water network for runs 03 & 04. The maximum discharges in the reaches are governed by reach capacities and flood water availability. Nonetheless, it is important to notice that the general trend in both figures is that water availability decreases from head to tail (from right to left in case of Wadi Zabid network). More important is the fact that more reaches had no water at all (shown in red) in run03 than in run04, which reflects water distribution equity in the two cases.

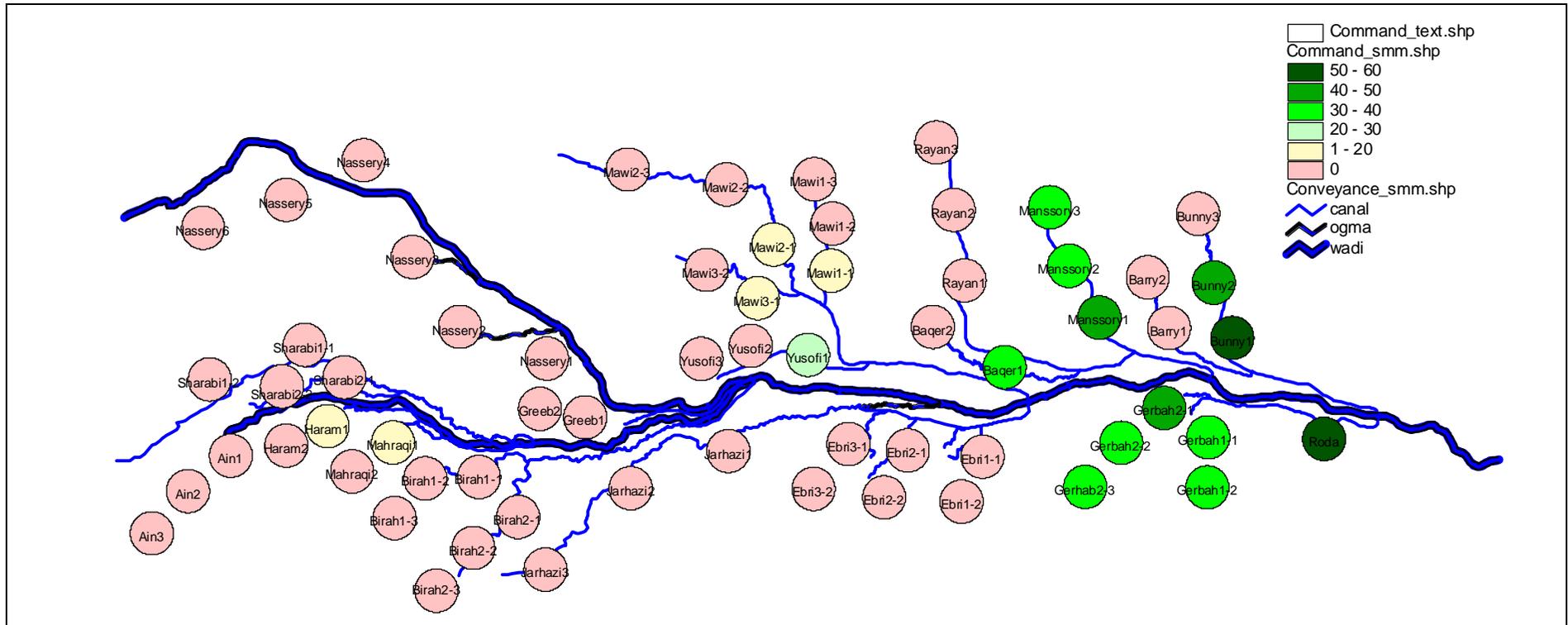


Figure III Wadi Zabid command area cropping intensities (Run03)

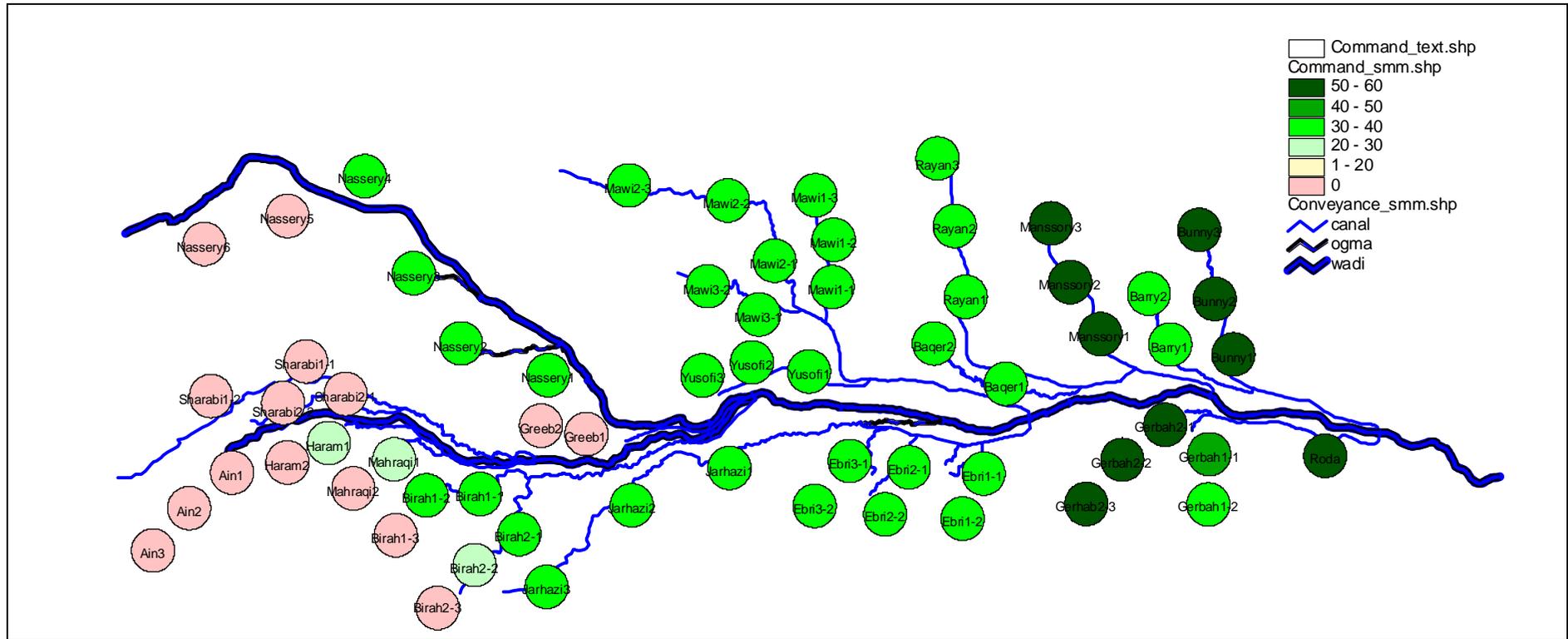


Figure IV Wadi Zabid command area cropping intensities (Run04)

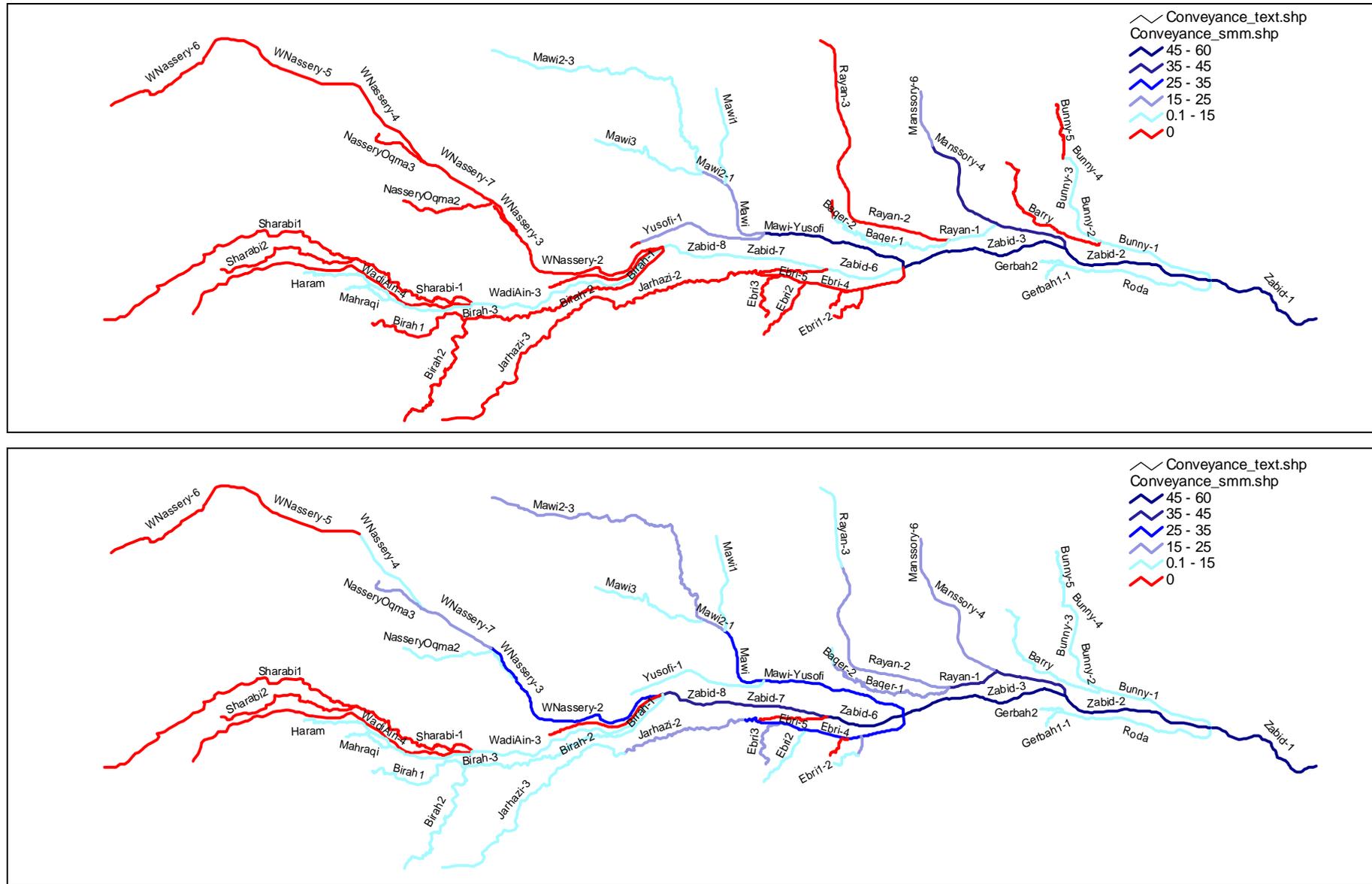


Figure V Maximum flows in the reaches of Wadi Zabid water network (top: Run03, bottom: Run04)

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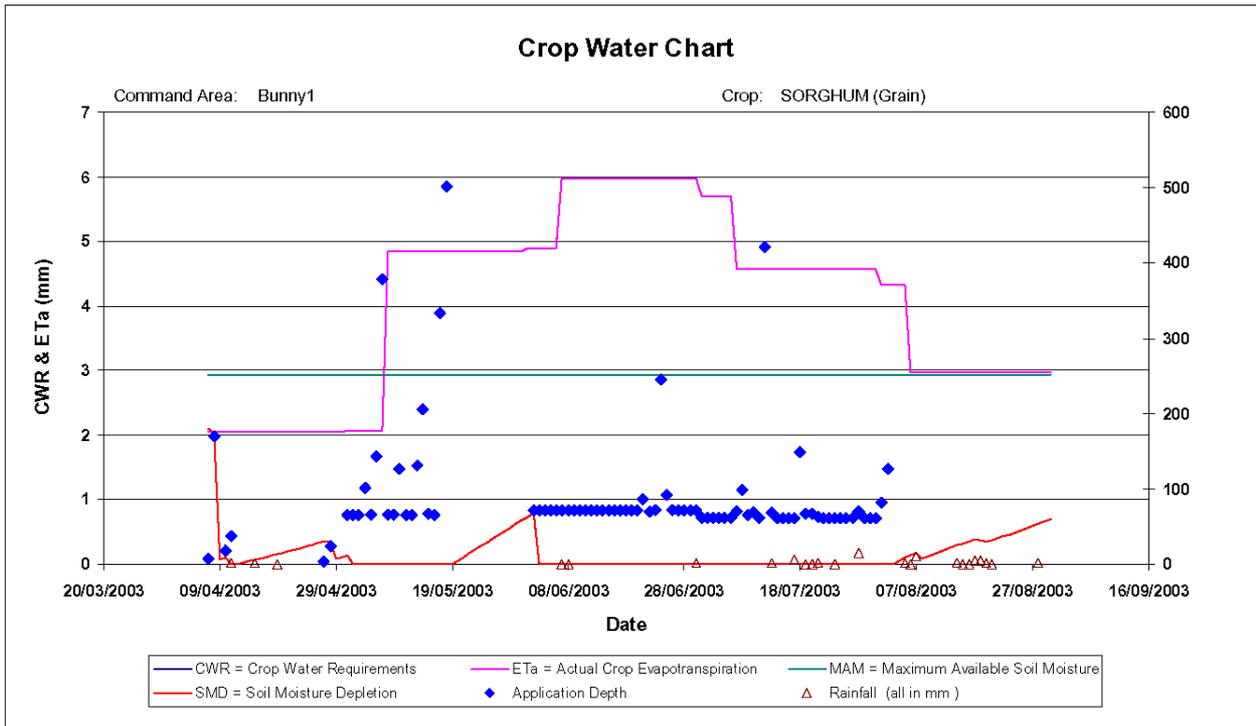


Figure VI Crop water chart for sorghum (Run03)

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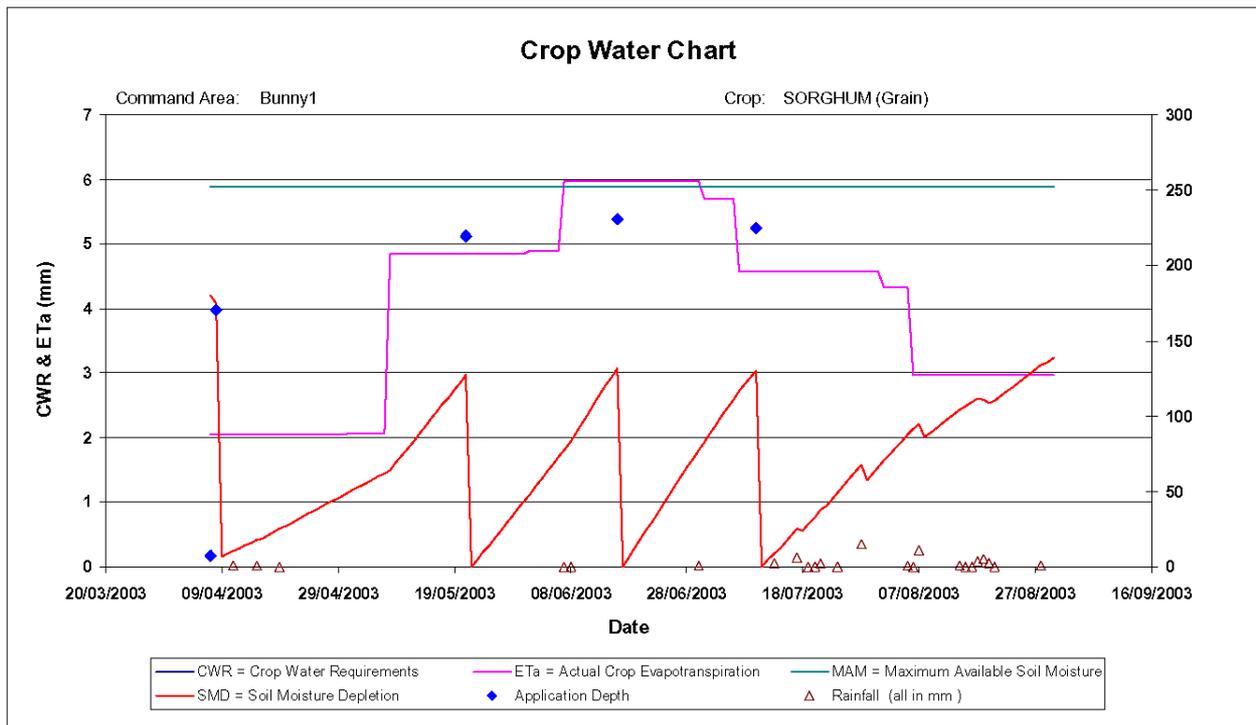


Figure VII Crop water chart for sorghum (Run04)

Spate Management Model Version 1.0

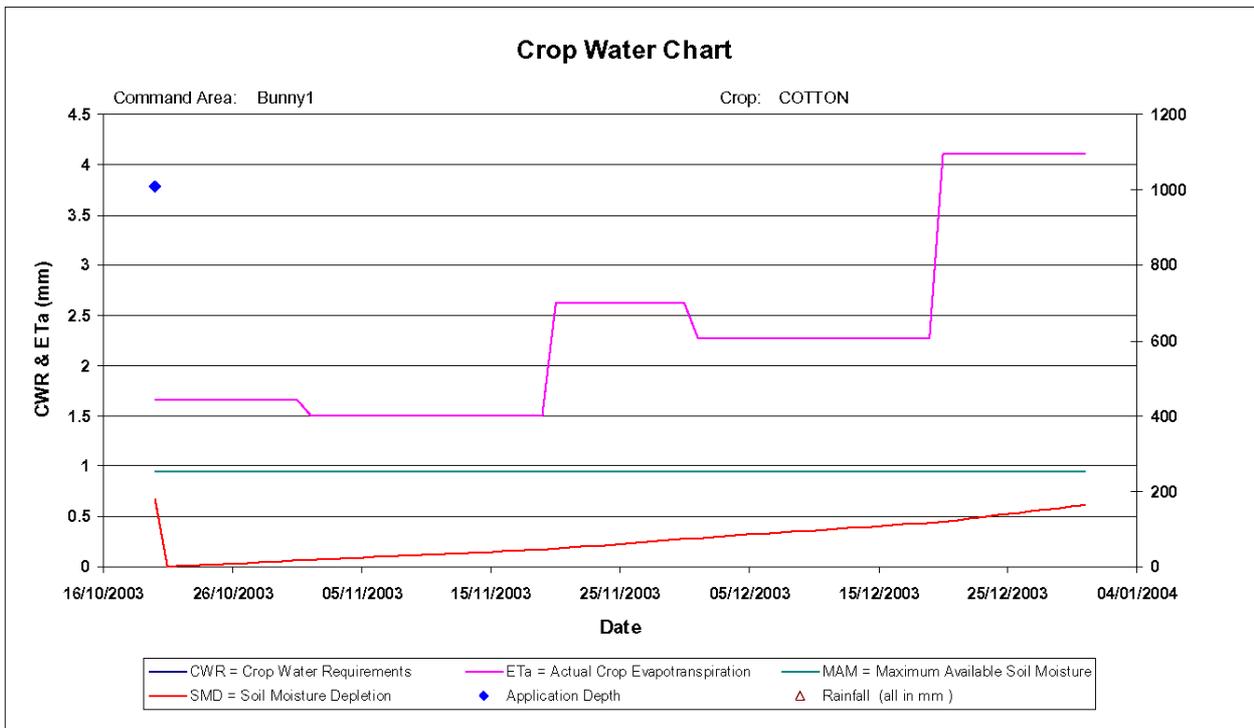


Figure VIII Crop water chart for cotton (Run03)

Spate Management Model Version 1.0

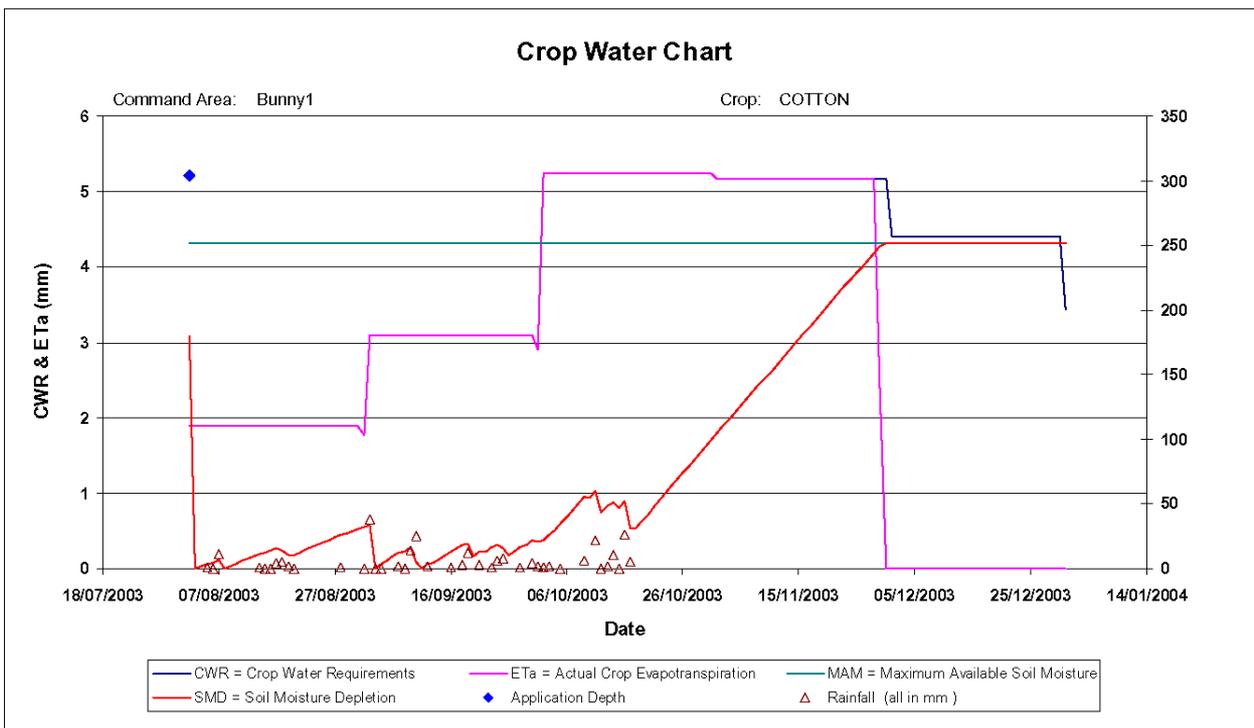


Figure IX Crop water chart for cotton (Run04)