
A Guide to Aquator

3 Groups

Version 4.2

Oxford Scientific Software Ltd.



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Groups

Groups And How To Add Members

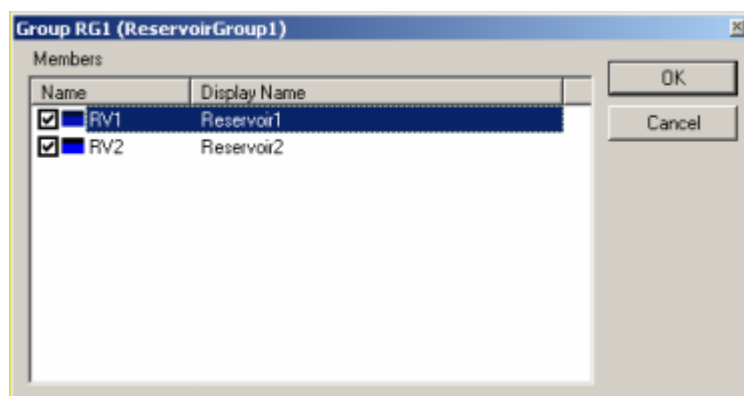
Groups can contain one or more Aquator Components. In practice there should be at least two Components to give the Group a sensible meaning.

Only certain types of Components can be included in each type of Group. For example it is not possible to include a gauging station Component in a Reservoir Group. One Group cannot be a member of another Group. However individual Components may be in more than one Group.

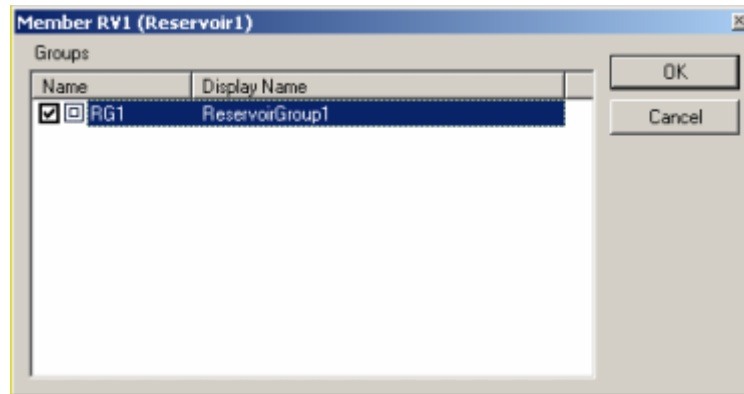
Groups are similar to Components in that they can (optionally) have *Properties, Parameters, States, Variables, Sequences* and *Constraints*.

Components may be added to or removed from a Groups by one of the following methods:

1. Right click with the mouse on the Group and select the menu item *Members...* All Components that can be included in the Group are listed. Check those which are to be included



2. Right click with the mouse on the Component and select the menu item *Groups....* All Groups that this Component can be a member of are listed. Check the appropriate box(es)



Groups can be of the following types:



-  Abstraction Group
-  Demand Saving Group
-  Reservoir Group
-  Tariff Group

Abstraction Group



An Abstraction Group allows *Constraints* to be attached to more than one Component. For example it is possible to include two or more *Groundwater* Components into an Abstraction Group and attach an *Annual Licence* constraint to the Group. This *Annual Licence* is then utilised by all members of the Group (*see Chapter on Constraints*).

Types of Components that can be put into an Abstraction Group include:

-  Groundwater
-  Abstraction

Properties

A Group only has one set of properties. Properties do not change during a model run.

Group	Name
Component	Display Name
	Draw order
Options	Show name
Schematic	Left
	Top
	Width
	Height
	Name X
	Name Y
Draw	Angle
	Shape
	Line attributes
Shell	Fill attributes
	Caption
	Path
Info	Arguments
	Identifier
	Grid reference
	GIS reference
	Cross reference
	Owner
	Location
	Manager
Other	

Parameters

A Group can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
Options	Enabled
	Events on
	Trace on

Group	Name
	Trace flags
Control flow	Type
	Value
Resource State	Use Yesterdays Value

States

A Group can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Group.

Variables

A Group can have more than one set of variables. Variables are possible daily outputs from the Group and may be turned on and off.

Group	Name
Abstraction	Amount
	Maximum available
	Control flow
Operation	Resource state
	Status level

Sequences

A Group can have more than one set of sequences. Sequences are a requirement, sometimes optional, of the Group for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

Name	Time series	Profile
Control flow	Optional	Optional

Control flow

Control flow on any day supplied as a sequence. See the description of *Resource state* below.

Constraints

This Group can have constraints attached.

Members

This Group can include Groundwater and Abstraction Components.

Interfaces

An interface defines a fixed set of instructions to which the Group responds. During this response by the Group, it is possible for the VBA programmer to modify this response to customise the way model operates.

Name
IBaseObject
IComponent
IAbstractionGroup
ISymbol
ILicence

Resource State

An abstraction group determines its resource state from the control flow. If the *Control flow.Type* specifies the sequence to be used then the value is taken from the time series, if specified, otherwise from the profile. If the value is missing then the control flow is set to zero.

Otherwise the *Control flow.Value* parameter is used if the Control flow.Type specifies the parameter is to be used, else the control flow is zero.

If the control flow is zero then the resource state is invalid. Effectively this means an infinite resource state and implies that all available water can be used on pass 4 (excess pass).

Otherwise the value of *Operation.Resource state* equals the amount available divided by the control flow value. Effectively the abstraction group can be "drawn down" on pass 4 until an amount equal to the control flow is left. This amount can be used on pass 5 if necessary.

Status level

This Group type always reports an end of day status level of *OK* (*Operation.status level* = 0) unless changed by the VBA programmer.

Demand Saving Group



Demand saving is triggered when a component reaches a critical condition. This is normally a Reservoir's storage dropping below one of its demand saving control curves. When demand saving is in force, demands at Demand Centres is reduced.

With no Demand Saving Groups

If no demand saving groups are included in a model, demand saving is model wide. Any Reservoir that is set up to trigger demand saving triggers the same demand saving for all Demand Centres in the model.

A Reservoir triggers demand saving when its parameter *Operation.Demand saving* is set to *True* and has *Level 1 – n control curves* defined.

A Demand Centre reduces its demands by the currently demand saving amount when its parameter *General.Apply demand saving* is set to *True*.

With Demand Saving Groups

Models of larger regions might wish to have a different Reservoir or Reservoirs triggering demand saving on only the local Demand Centres. And in that zone different demand saving percentages might apply that are specific to that zone only. There might be a number of such zones in the model as a whole.

A demand saving group allows Reservoirs and Demand Centres to be grouped together to implement demand saving separately from other parts of the model.

Setting up Demand Saving Groups

Both Reservoirs and Demand centres can be members of a demand saving group. They can be added to or removed from a Demand Saving Group by the methods described above in *Groups And How To Add Members*.

Alternatively, and more easily, they may be setup using the menu item "Setup – Demand Saving Groups..." which allows model wide configuration of demand saving. As an example consider a

model that has four Reservoirs (RV1 - 4), seven Demand Centres (DC1 - 7) and two Demand Saving Groups (DG1 & DG2). The form for defining the model's Demand Saving Groups is initially as follows:

		Model	DG1	DG2
Set Demand Saving Level	RV1	X		
	RV2	X		
	RV3	X		
	RV4	X		
Apply Demand Saving Factor	DC1	X		
	DC2	X		
	DC3	X		
	DC4	X		
	DC5	X		
	DC6	X		
	DC7	X		

which shows that all the Reservoirs are contributing to the model wide demand saving and all the Demand centres are taking their demand saving from the Model. The two demand saving groups are effectively not being used. If the following is required:

1. Model demand saving to be controlled by RV1 and affect DC2 and DC6 only
2. DG1 to be controlled by RV1 and RV2 (i.e. taking the higher of the two demand saving level reported by the reservoirs each day). DG1 to affect DC1, DC3 and DC6
3. DG2 to be controlled by RV3 and RV4 and to affect DC4, DC5, DC6 and DC7

DC6, being both in the Model and two Demand Saving Groups, will, on any one day, take the maximum of the three demand saving factor it receives. In this complex example the Demand Saving Group setup form would be as shown below:

		Model	DG1	DG2
Set Demand Saving Level	RV1	X	X	
	RV2		X	
	RV3			X
	RV4			X
Apply Demand Saving Factor	DC1		X	
	DC2	X		
	DC3		X	
	DC4			X
	DC5			X
	DC6	X	X	X
	DC7			X

a more realistic scenario would be the following where the two Demand Saving Groups control separate groups of Demand Centres and are themselves controlled by two reservoirs each:

		Model	DG1	DG2
Set Demand Saving Level	RV1		X	
	RV2		X	
	RV3			X
	RV4			X
Apply Demand Saving Factor	DC1		X	
	DC2		X	
	DC3		X	
	DC4		X	
	DC5			X
	DC6			X
	DC7			X

Setting up a Demand Saving Group is similar to setting up demand saving on the Model. There are the same Parameters, States, Sequences and Variables on a Demand Saving Group as on the Model. Please refer to the “Demand Saving” section of “How it all works” in the Chapter 1 “Aqator”.

Demand saving hold

To constrain the demand saving level from changing too rapidly demand saving hold may be enforced. Essentially this puts a value greater than one on the minimum number of days that must elapse after a requested change in demand saving level before the demand saving level that is enforced is changed.

This is controlled by the *Demand saving hold (DSH).Method* state value that can take one of three enumerated values.

None No demand saving hold and the demand saving level may change as frequently as every day.

Simple period A single period is specified in days, which applies to all levels and to both increases and decreases in demand saving. The period is specified by the *Simple DSH.Delay/hold period* state value and the number of days so far at the current demand saving level by the *Simple DSH.Day in period* state value.

Multi-level delays Before a higher demand saving level is reached that level must have been requested for at least *D* days, where *D* is given by one of five state values *Multi-level DSH: 1.Delay* to *Multi-level DSH: 5.Delay*, one for each level. Similarly the demand saving level cannot decrease until at least *H* days that this level have passed, where *H* is given by one of five state values *Multi-level DSH: 1.Hold* to *Multi-level DSH: 5.Hold*, one for each level. Finally, the five state values *Multi-level DSH: 1.Days* to *Multi-level DSH: 5.Days*, one for each level, record how many days have passed at each level respectively.

Properties

A Group only has one set of properties. Properties do not change during a model run.

Group	Name
Component	Display Name
	Draw order
Options	Show name
Schematic	Left
	Top
	Width
	Height
	Name X
	Name Y
Draw	Angle
	Line attributes
	Fill attributes 1
Shell	Fill attributes 2
	Caption
	Path
	Arguments

Group	Name
Info	Identifier
	Grid reference
	GIS reference
	Cross reference
	Owner
	Location
	Manager
	Other

Parameters

A Group can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
Options	Enabled
	Events on
	Trace on
	Trace flags
Demand saving	On
	Level 1
	Level 2
	Level 3
	Level 4
	Level 5
	Source

States

A Group can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start. States are described at the end of this Chapter.

Group	Name
Demand saving hold (DSH)	Method
	Start level
Simple DSH	Day in period
	Delay/hold period

Group	Name
Multi-level DSH: 1	Days
	Delay
	Hold
Multi-level DSH: 2	Days
	Delay
	Hold
Multi-level DSH: 3	Days
	Delay
	Hold
Multi-level DSH: 4	Days
	Delay
	Hold
Multi-level DSH: 5	Days
	Delay
	Hold

Variables

A Group can have more than one set of variables. Variables are possible daily outputs from the Group and may be turned on and off.

Group	Name
Demand saving	Level
	Percent
Operation	Status level

Sequences

A Group can have more than one set of sequences. Sequences are a requirement, sometimes optional, of the Group for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

Name	Time series	Profile
Demand saving level	Optional	Not used
Demand saving factor	Optional	Not used
Demand saving factor – level 1	Not used	Optional

Name	Time series	Profile
Demand saving factor – level 2	Not used	Optional
Demand saving factor – level 3	Not used	Optional
Demand saving factor – level 4	Not used	Optional
Demand saving factor – level 5	Not used	Optional

Demand saving factor

The sequence of Demand saving factors (between 0 and 1) that determine the Demand saving imposed daily during a model run.

Demand saving factor - level 1

This sequence determines the demand saving factor if the demand saving level is 1.

Demand saving factor - level 2

This sequence determines the demand saving factor if the demand saving level is 2.

Demand saving factor - level 3

This sequence determines the demand saving factor if the demand saving level is 3.

Demand saving factor - level 4

This sequence determines the demand saving factor if the demand saving level is 4.

Demand saving factor - level 5

This sequence determines the demand saving factor if the demand saving level is 5.

Demand saving level

The *sequence* of *Demand saving levels* that determine the Demand saving level imposed daily during a model run.

Reservoir Group



A Reservoir Group is based on an *Abstraction Group* and contains all its functionality. The Abstraction Group functionality

means that you can attach a constraint such as an *Annual Licence* to a Group of Reservoirs (see *Chapter on Constraints*).

In addition it contains facilities for the operation of a Group of Reservoirs as a whole. The Group maximum storage is the sum of the maximum storage of the individual Reservoirs; the Group observed storage is the sum of the individual Reservoirs' observed storage and the Group calculated storage is the sum of the current storage in each of the individual Reservoirs.

An *Aquator Control Curve* can be attached to the Group so that the Group's resource state may be determined. This is then used to determine water availability during model execution in the same way as for an individual Reservoir. Aquator control curves can be attached to the Group and any Group members. The *resource state* of any Reservoir in the Group is the minimum of its own resource state and that of the Group.

A Reservoir Group can instigate *Demand saving* in the same way as a individual Reservoir. As a consequence Demand saving Control Curves, named *Level n control curve* can be attached to a Reservoir Group. Demand saving control curves can be assigned to both individual Reservoirs and the Reservoir Group.

Types of Components that can be put into an Abstraction Group include:

 Reservoir

Properties

A Group only has one set of properties. Properties do not change during a model run.

Group	Name
Component	Display Name
	Draw order
Options	Show name
Schematic	Left
	Top
	Width
	Height
	Name X
	Name Y
Draw	Angle
	Shape
	Line attributes

Group	Name
	Fill attributes
Shell	Caption
	Path
	Arguments
Info	Identifier
	Grid reference
	GIS reference
	Cross reference
	Owner
	Location
	Manager
Other	

Parameters

A Group can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
Options	Enabled
	Events on
	Trace on
	Trace flags
Operation	Demand saving
Fail	At dead water level
	At emergency storage level
	At demand saving level
Resource State	Use Yesterdays Value
Storage	Failure Margin

States

A Group can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Group.

Variables

A Group can have more than one set of variables. Variables are possible daily outputs from the Group and may be turned on and off.

Group	Name
Storage	Calculated
	Calculated (%)
	Observed
	Observed (%)
	Control
	Control (%)
	Emergency
	Emergency (%)
	Dead water
	Dead water (%)
Demand saving	Threshold 1
	Threshold 1 (%)
	Threshold 2
	Threshold 2 (%)
	Threshold 3
	Threshold 3 (%)
	Threshold 4
	Threshold 4 (%)
	Threshold 5
	Threshold 5 (%)
Operation	Failure Amount
	Resource state
	Status level

Sequences

A Group can have more than one set of sequences. Sequences are a requirement, sometimes optional, of the Group for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

Name	Time series	Profile
------	-------------	---------

Name	Time series	Profile
Control curve	Optional	Optional
Level 1 control curve	Not used	Optional
Level 2 control curve	Not used	Optional
Level 3 control curve	Not used	Optional
Level 4 control curve	Not used	Optional
Level 5 control curve	Not used	Optional

Control curve

Aquator Control Curve for the Reservoir. If the storage on any day is above this curve, there is an excess of water available from this source and this water is more likely to be used to meet demand,

Level *n* control curve

The Reservoir control curve below which demand saving level *n* is reported by the Reservoir. Level 1 is a less severe condition than Level 2; consequently, the *Level 1 curve* should be above the *Level 2 curve* and the *Level 2 curve* above the *Level 3 curve* etc.

Constraints

This Group can have constraints attached.

Members

This Group include Reservoir Components.

Interfaces

An interface defines a fixed set of instructions to which the Group responds. During this response by the Group, it is possible for the VBA programmer to modify this response to customise the way model operates.

Name
IReservoirGroup
IBaseObject
IComponent
ISymbol
ILicence

Resource State

If the Reservoir Group has the control curve sequence defined, the value of *Operation.Resource state* is calculated as:

$$= \frac{\text{(Current group storage – minimum group storage)}}{\text{(Control curve storage – minimum group storage)}}$$

If there is no control curve the Resource State is set to 1.0 if the current storage is above the minimum storage; otherwise it is set to zero.

The state of constraints attached to the Reservoir Group also determine its resource state. The value of Resource State reported in the variable is the minimum of all the resource states of its constraints and the Reservoir Group itself.

Status level

This Group type reports an end of day status level of *OK* (*Operation.status level* = 0) unless:



- The parameter *Fail.At dead water level* is set to *True* and the end of day storage is at or below the dead water level. Or:
- The parameter *Fail.At emergency storage level* is set to *True* and the end of day storage is at or below the emergency storage level. Or:
- The parameter *Fail.At demand saving level* is set to a value other than *None* and the end of day storage is less than demand saving control line specified.

Tariff Group



Tariff Groups are used to perform detailed calculations of the cost of electricity consumption and/or the income from electricity generation. From these calculations, for example, different pumping regimes that balance cost against risk in different ways can be examined.

Types of Components that can be put into a Tariff Group include:

-  Pump Station
-  Hydrogenerator

Of these the Pump Station uses electricity and hence is a cost, while the hydrogenerator generates electricity and hence provides income.

The operation of a tariff group is straightforward in principle:

- at the start of the day it sets the maximum flow to be passed by each member and, optionally, the expected cost or income per MI of each member
- at the end of the day it calculates the cost of or income from each member

Note especially that apart from setting the maximum flow and possibly the cost or income per MI, the group has no effect on the movement of water during the day.

The maximum flow to be passed by each member is calculated from lookup tables, to be described, and from the state of one or more Reservoirs. Thus at least one Reservoir must be associated with each Tariff Group. Tariff Groups have no direct effect on Reservoirs, they simply examine the storage at the start of the day.

The intention is that a Tariff Group will operate in such a way as to minimize cost and/or maximize income, while ensuring that the probability that Reservoirs are not refilled adequately each year is held to an acceptable level.

The parameters associated with a Tariff Group and its members are described next, including a more detailed explanation of how the Tariff Group performs its calculations.

Group parameter: electricity price data

A Tariff Group works with one or more electricity tariffs. The number of tariffs is chosen before members are added to the group and cannot be changed afterwards unless all members are removed. Each tariff consists of a monthly profile of price per kWh and a monthly profile of hours availability per day.

Tariffs are numbered 1, 2, ... and should be in time order, the first starting at midnight, the second following the first, etc. The total hours of availability per day should be 24.

In principle daily profiles could be used but the custom setup dialog, to be described later, can edit monthly profiles only.

Because the data for each tariff is held in two profiles it is easy to set up more than one tariff group. Simply choose the same profiles for each tariff in each group.

Group parameter: storage zone data

The capacity of the Reservoir associated with the Tariff Group (or the total capacity of all Reservoirs, if more than one) is divided

into zones. The number of zones is chosen when the Tariff Group is added to the project and cannot be changed afterwards.

The Zone Table is an array-type parameter of percentage storages in ascending order. Each element of the array provides the percentage storage at the lower limit, or bottom, of the zone i.e. element 1 of the array should be 0% for the first zone (zone 1). The second element of the array provides the lower storage limit for zone 2 and implicitly the upper storage limit for zone 1. The last element should be the lower storage limit of the topmost zone, which has an implicit upper limit of 100%.

Each day this table and the ratio of actual reservoir storage to capacity, expressed as a percentage, are used to determine the zone. The zone number (1, 2...) is then used as an index into another table, described next.

Member data: maximum flow rates

Each member of a Tariff Group has an associated parameter which determines the maximum flow rate each day. This parameter is a 3-dimensional array of values indexed as follows:

- index 1: zone number (1 to max number of zones)
- index 2: tariff number (1 to max number of tariffs)
- index 3: month number (1 to 12)

At the start of the day, given the current storage zone and the month, the maximum flow rates *in MI/d for each tariff* are determined from this table. Given the hours each tariff is available during the day, the maximum water in MI that can be moved during each tariff's period of availability is determined. And finally the sum over all tariffs of these amounts provides the maximum flow to be passed by the member for the day.

Note that when plotting the various flow rates calculated by the Tariff Group and its members it is easy to be misled when comparing the actual daily flow of a Tariff Group member with the flows allowed for each tariff. The actual daily flow is, conceptually, spread over 24 hours, while the flows allowed for each tariff can only occur during the hours each tariff is available. But all these flows are measured and plotted in MI/d and hence there is scope for confusion.

The contents of this 3D array are crucial to proper operation of a Tariff Group. The key to understanding what "proper operation" means is to realise that these values are balancing the desire to minimize cost with the requirement to refill the reservoir(s) adequately each year. Therefore it is highly likely that the data entered into this 3D array will be determined experimentally from the statistics generated from a large number of model runs using all available historic data.

Given that the maximum flow rates are determined by examining the reservoir storage each day it is also important to realise that the maximum flow rate for each member set by the Tariff Group each day is expected to be the actual flow passed by the member by the end of the day. The only factor that should affect this should be the actual flow rate available at the supply or supplies.

Therefore each Tariff Group will almost certainly require a small amount of custom VBA code which provides the Tariff Group with the actual flow rate available at the supply or supplies (see Setting the flow available from the supply each day).

Member data: rating curve

Each member of a Tariff Group has an associated parameter which determines the power used or generated by a given flow. This parameter is a 2D array where the first column provides the power in kW and the second column the corresponding flow rate in MI/d.

Some Pump Stations and Hydrogenerators can only operate at fixed flow rates, indicated by the state of another parameter. In this case there must be exactly one point on the rating curve for each allowed flow rate. The Tariff Group will then ensure that only these flow rates are used. This implies that every MI/d value in the 3D array of maximum flow rates *must* also be a point on the rating curve.

Conversely a Pump Station or Hydrogenerator that can operate with variable instantaneous flow rates may have any form of rating curve.

Note especially that in both cases the first point on the rating curve (lowest flow rate) is taken as the minimum flow rate at which operation can be achieved. If for example low river flows so constrain a Pump Station that this lower limit cannot be reached then the maximum flow rate for the day is set to zero.

Calculation sequence

This check list summarises the operation of a tariff group. For simplicity we assume one tariff group associated with one reservoir and with several Pump Station members.

At the start of each day:

1. determine the zone from the reservoir storage
2. from the zone, the date, and the 3D array of maximum flow rates, determine for each Pump Station the desired maximum flow rate in MI/d for each tariff
3. generate the *SetDesiredFlows* event for each Pump Station member, passing the values found in step 2; this

allows custom VBA code to accumulate the total desired flow for each tariff

4. generate the *GetMaxFlowRates* event for each Pump Station member; custom VBA code should be supplied by the user to handle this event and return the actual instantaneous flow rate in MI/d available for this member for each tariff, this is typically the available flow at the Abstraction which supplies the Pump Station (see Setting the flow available from the supply each day)
5. if this Pump Station can only operate at fixed pumping speeds then reduce each available instantaneous flow rate to the highest point on the rating curve below or equal to the value returned by the event handler; if below the first point then substitute zero
6. if the resulting actual available flow rate for each tariff is less than the flow rate determined in step 2 for each tariff then substitute the actual available flow rate
7. set the maximum flow rate for the pump station for the day to the sum over all tariffs of the flow rate found for each tariff in steps 2-6
8. recall that this maximum flow rate is now expected to be the actual flow rate at the end of the day; therefore it is possible to calculate the anticipated cost per MI; optionally, set the Pump Station's cost per MI to this value

During the day water is now moved as normal. The maximum flow rate set in step 7 may affect water movement. Otherwise, unless the cost per MI was set at step 8, the Tariff Group has no effect on water movement. But if the cost per MI was set at step 8, then this may affect route ordering in pass 4 when Aquator attempts to minimize cost of operation.

At the end of the day

1. retrieve the actual flow for each Pump Station and verify that this equals the maximum flow set in step 7; if not equal then an entry will be made in the log at the end of the run; this is a sign that the model is not properly set up or perhaps that the VBA code described in step 4 is not returning the correct values
2. using each tariff in turn, in ascending cost order, calculate the cost of operation for each Pump Station
3. generate the *CheckMaxFlowRates* event to allow VBA code to back-check its earlier calculations
4. accumulate the total daily cost for all Pump Stations in the group, and the total cost for the whole run

At the end of the run

5. enter into the run log the details of any errors detected during the run; it is important to check for these log entries because a Tariff Group makes detailed checks during a run that it and its members are operating correctly and that all the parameter data is valid

Calculating the flow available from the supply

Proper operation of a Tariff Group will typically require some custom code to calculate the maximum instantaneous flow rates available for each Tariff Group member for each tariff, as described in the next section (Setting the flow available from the supply each day). Here we describe why VBA custom code is required and the problems that need to be addressed if the calculations are to be consistent with the real world.

The key issue is that a Tariff Group is required to perform detailed sub-daily calculations but Aquator is a daily timestep simulation. Therefore it is impossible for Aquator and the Tariff Group component to completely determine how the system can operate at sub-daily timesteps.

A simple example would be a Pump Station drawing water from a river Abstraction but operating for one tariff period of 12 hours per day only. This Pump Station cannot remove more than one-half the flow in the river each day. Hence custom code is required to specify a maximum instantaneous flow rate equal to the river flow during this one tariff period and zero for the rest of the time.

Furthermore there will typically be other Pump Stations pumping water from other Abstractions on *same* river. The effect of these must be allowed for but this may require a complex algorithm.

If for example water is drawn for only one hour a day from two Abstractions which in the real world are several hours river-flow-time apart then it may be perfectly possible for both to abstract at a high rate at the same time without affecting each other.

But two Abstractions only one hour apart, each abstracting at the same time of day for several hours, will affect each other and this must be allowed for in the *GetMaxFlowRates* event handler.

Setting the flow available from the supply each day

Proper operation of a Tariff Group will usually require some custom code to handle the *GetMaxFlowRates* events generated by the Tariff Group component. This event is fired once per member per day and the custom event handler should return a value that represents the absolute maximum instantaneous flow rate in Ml/d that is available for each tariff for the member in question.

Here is a simple example of using the available flow in a river at abstraction points but see the previous section Calculating the

flow available from the supply for details of the real-world considerations that might need to be taken into account:

```
Option Explicit
Private m_objAbstraction1 As AQTComponents.Abstraction
Private m_objAbstraction2 As AQTComponents.Abstraction

Private Sub TariffGroup_BeforeInitialize( _
    ByVal StartDate As Date, _
    ByVal Steps As Long)
    Set m_objAbstraction1 = Model.Components.Item("AB1")
    Set m_objAbstraction2 = Model.Components.Item("AB2")
End Sub

Private Sub TariffGroup_AfterTerminate()
    Set m_objAbstraction1 = Nothing
    Set m_objAbstraction2 = Nothing
End Sub

Private Sub TariffGroup_GetMaxFlowRate( _
    ByVal MemberName As String, _
    ByVal NumTariffs As Long, _
    MaxFlowRates() As Single)

    Dim nTariff As Long
    Dim fFlowRate As Single

    If Name = "PU1" Then
        fFlowRate = m_objAbstraction1.V_UpstreamFlow
    ElseIf Name = "PU2" Then
        fFlowRate = m_objAbstraction2.V_UpstreamFlow
    Else
        Debug.Assert False
    End If
    For nTariff = 1 To NumTariffs
        MaxFlowRates(nTariff) = fFlowRate
    Next nTariff
End Sub
```

To create this event handler, right-click on the Tariff Group symbol on the schematic and choose *Customize* from the popup menu. In the VBA window that appears choose *TariffGroup* from the left-hand dropdown list at the top of the edit window, then choose the names of the above event handler routines (*BeforeInitialize*, *AfterTerminate*, and *GetMaxFlowRates*) from the right-hand dropdown list.

The code example above demonstrates a couple of techniques useful for high performance:

- instead of searching the project for the required component every day (*Model.Components.Item("AB1")*), a reference to this object is stored in a module-level

variable (*m_objAbstraction1*) once only, at the start of the model run; for this to work, first select the VBA menu item Tools...References and tick Aquator components, so that VBA understands an *AQTComponents.Abstraction* object; it is good practice to discard the reference (*Set m_objAbstraction1 = Nothing*) at the end of the run

- now, instead of searching for the required variable each day (*Variables("Flow.Upstream").Value*), a direct reference (*m_objAbstraction1.V_UpstreamFlow*) can be used

This style of accessing variables is not only much faster than *Model.Components("AB1").Variables("Flow.Upstream").Value* but it is also clearer and less error prone. The same technique can be applied to parameters, states, and sequences.

Properties

A Group only has one set of properties. Properties do not change during a model run.

Group	Name
Component	Display Name
	Draw order
Options	Show name
Schematic	Left
	Top
	Width
	Height
	Name X
	Name Y
Draw	Angle
	Shape
	Line attributes
Tariff group	Fill attributes
	Number of tariffs
	Number of zones
	Members
Plot maxima	Reservoirs
	Hours per day
Shell	Price
	Caption

Group	Name
	Path
	Arguments
Info	Identifier
	Grid reference
	GIS reference
	Cross reference
	Owner
	Location
	Manager
Other	

Parameters

A Group can have more than one set of parameters. Parameters do not change during a model run.

Group	Name
Options	Enabled
	Events on
	Trace on
	Trace flags
Zone	Table
<PU1>	Rating curve
	Fixed flow rates
	Set price per MI

States

A Group can have more than one set of states. The value of a state variable may be different at the end of a model run to its value at the start.

There are no states for this type of Group.

Variables

A Group can have more than one set of variables. Variables are possible daily outputs from the Group and may be turned on and off.

Group	Name
-------	------

Group	Name
Tariff group	Total flow
	Total cost
	Total income
	Net cost
	Net income
Storage	Percent
	Zone
Operation	Status level
<PU1>	Max flow rate from supply
	Cost
	Cost @ tariff N
	Income
	Income @ tariff N
	Flow
	Max flow
	Flow @ tariff N
	Max flow rate @ tariff N
	Hours flow @ tariff N
	Supply limited

Sequences

A Group can have more than one set of sequences. Sequences are a requirement, sometimes optional, of the Group for daily values of data. These data are supplied by a time series (potentially a different value every day) or a profile (series repeating annually).

Name	Time series	Profile
Hours per day tariff N	Not used	Required
Price per kWh tariff N	Not used	Required

Hours per day tariff N

Number of hours per day that tariff N (N=1, 2...) is available. Must be a monthly profile. There are as many of these sequences as there are tariffs.

Price per kWh tariff N

Cost of or income from electricity used or generated for tariff N (N=1, 2...). There are as many of these sequences as there are tariffs.

Constraints

This Group cannot have constraints attached.

Members

This Group can include Groundwater and Hydrogenerator Components.

Interfaces

An interface defines a fixed set of instructions to which the Group responds. During this response by the Group, it is possible for the VBA programmer to modify this response to customise the way model operates.

Name
IBaseObject
IComponent
ITariffGroup
ISymbol

Status level

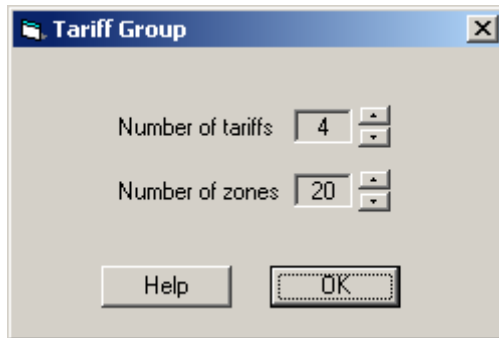
This Group type reports an end of day status level of *OK* (*Operation.status level* = 0) unless one of the numerous data consistency checks fails. In this case consult the model run log for a description of any failures or errors detected.

Tariff Group Initialization Dialog



This dialog is used to initialize a Tariff Group. Tariff Groups are used to perform detailed calculations of the cost of electricity consumption and/or the income from electricity generation.

To show this dialog right-click on the Tariff Group symbol on the schematic and select *Initialize* from the popup menu. This menu item will be disabled if the Tariff Group already has members because you cannot alter the number of tariffs or the number of zones after members have been added to the group.



Set the number of tariffs and the number of reservoir storage zones by clicking on the up-down arrow controls, then click OK.

Tariff Group Setup Dialog

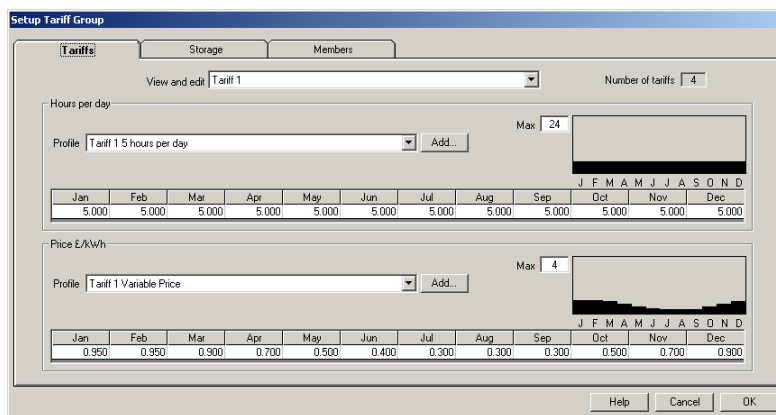


This dialog is used to set up a Tariff Group. Tariff Groups are used to perform detailed calculations of the cost of electricity consumption and/or the income from electricity generation.

To show this dialog right-click on the Tariff Group symbol on the schematic and select *Setup* from the popup menu. This menu item will be disabled if the Tariff Group has not been initialized. Select *Initialize* from the popup menu and enter the number of tariffs and number of reservoir storage zones. The *Setup* menu item will then be enabled.

The Tariff Group Setup Dialog has three tabs, described next.

Tariff Group Setup Dialog Tab 1: Tariffs



Select in turn each tariff from the dropdown list *View and edit* at the top. For each tariff

- if necessary, click on the *Add* buttons to create new *Hours per day* and *Price per kWh* profiles in the database (these **must** be monthly profiles)
- from the dropdown lists labelled *Profile*, choose an *Hours per day* and *Price per kWh* profile for each tariff
- if necessary, click in any white grid cell to edit one or more monthly values; press *Enter* to move to the next cell; press *Esc* to exit edit mode; buttons labelled *Save Changes* and *Cancel Changes* will appear and all other controls will be disabled; you **must** click on one of these buttons to save or discard any changes before proceeding further
- a thumbnail plot of each profile appears to the right; enter values in the *Max* labels to set the upper limit to the plots **and** the upper limit to any acceptable value entered whilst manually editing

Note especially that unlike all other data presented on this form, profile data is saved immediately. Clicking *Cancel* will **not** discard any newly created profiles or any edited profile values.

Tariff Group Setup Dialog Tab 2: Storage

Setup Tariff Group

Tariffs Storage Members

Reservoirs associated with the tariff

Name	DisplayName
<input checked="" type="checkbox"/> RV1	Reservoir1
<input type="checkbox"/> RV2	Reservoir2
<input checked="" type="checkbox"/> RV3	Reservoir3

Number of zones: 20

Make All Zones Same Size

Zone	% full
20	95.0
19	90.0
18	85.0
17	80.0
16	75.0
15	70.0
14	65.0
13	60.0
12	55.0
11	50.0
10	45.0
9	40.0
8	35.0
7	30.0
6	25.0
5	20.0

Percent values refer to bottom of zone. Top zone top value is implicitly 100%

Help Cancel OK

Reservoir storage associated with the tariff group is selected and storage zones are created on this tab

Check (tick) one or more reservoirs to be associated with the tariff group. The total capacity of all reservoirs selected is divided into storage zones.

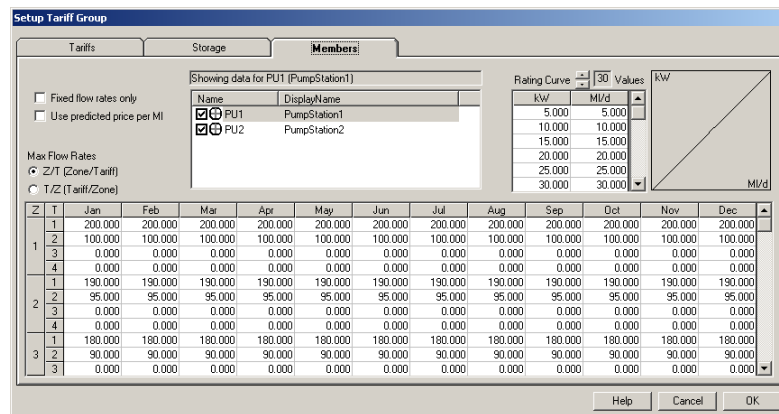
Enter the storage **at the bottom of the zone** as a percentage of capacity into the *Zone/% full* table in one of the following ways:

- click in a cell and enter values manually; press *Enter* to move to the next cell; press *Esc* to exit edit mode

- right-click on any cell and choose *Paste* to paste values into the table e.g. copied from a column of figures in a spreadsheet; as much data will be pasted as possible i.e. until the end of the grid or the end of the data held in the system clipboard
- drag any point (the filled circles) in the thumbnail plot of the storage zone table on the right

Note that this table is presented in reverse order to the underlying array-type parameter. Also that the last value in the table (first value in the array) should normally be 0% and that the value 100% should **not** appear in the table since 100% is implicitly the upper level of the topmost storage zone.

Tariff Group Setup Dialog Tab 3: Members



Here the members of the Tariff Group are selected and the parameter data required for each member is entered.

Check (tick) each component in the list at the top which is to be a member of the group. Conversely, uncheck any component to be removed from the group.

Select each member in turn by clicking on the name of the member in the list so that it is highlighted and the name appears in the label *Showing data for...* label above. Enter the required data for the selected member as follows:

- tick or untick the *Fixed flow rates only* check box; if ticked then the only instantaneous flow rates supported by the member are those explicitly entered into the second column of the *Rating Curve* grid; if unticked then values in the *Rating Curve* may be interpolated
- tick or untick the *Use predicted price per MI* check box; if ticked then the price per MI predicted from the tariff and flow rate tables is used as the *Cost.Cost per MI* or *Income.Income per MI* for the pump station or

hydrogenerator respectively; setting this predicted value at the start of the day may affect route cost and hence route ordering; conversely, if unticked, the component's fixed parameter value is used for route ordering

- enter the values for the maximum flow rates as a function of zone, tariff, and month, into the large grid at the bottom; you can enter data manually by left-clicking in any cell (press *Enter* to move to the next cell and *Esc* to terminate editing), or right-click in any cell and select *Paste* from the popup menu; this pastes any rectangular array of data on the system clipboard into the grid on a best-effort basis, but in particular will work as expected if a rectangular array of data is copied into the clipboard from a spreadsheet first; click on the *Zone/Tariff* and *Tariff/Zone* option buttons to alter how the data is ordered in the grid; see *Member data: maximum flow rates*.
- alter the number of values in the *Rating Curve* grid by clicking on the up-down arrow control at top-right, to the left of the *Values* label
- enter the rating curve values into the *Rating Curve* grid either manually (left-click on a cell, use *Enter* to move to the next cell and *Esc* to exit edit mode), or right-click and choose *Paste* to paste one or two columns of data held on the system clipboard into the grid on a best-effort basis; see *Member data: rating curve*.

Note that no changes are made to the project unless and until *OK* is clicked.

It is expected that some effort will be required to enter all the required data so as to ensure proper operation of the Tariff Group component. During the validation process it is very important to monitor any messages in the model run log from the Tariff Group that may indicate improper operation due to inconsistent data.

Properties

A *Property* is a value for a Group which has no hydrological significance. For example, the co-ordinates of a Group on the schematic and the colours used to render the Group's icon.

Component.Display name

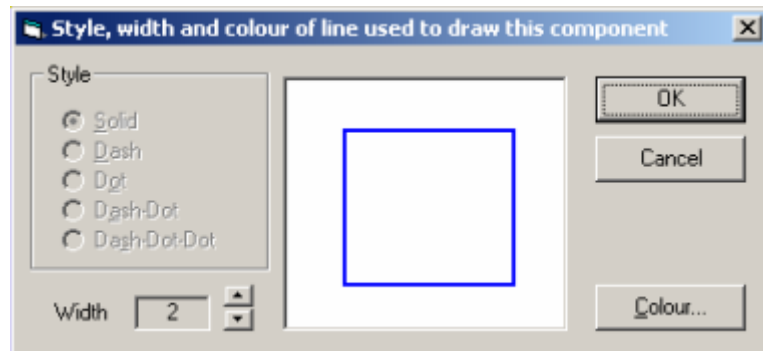
The name that appears on the schematic and other output. This name may be changed.

Component.Draw order

Reserved for future use.

Draw.Line attributes]

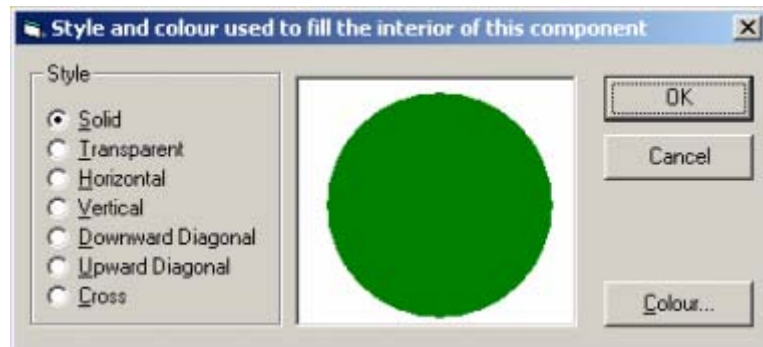
[*Line attributes*] may be replaced with a more specific name such as *Draw.Reach attributes*. The line drawing is defined by selecting this property and clicking on the [...] button. The following dialog box is displayed;



Note that, in common with many other Windows applications, it is not possible to specify a *Style* other than solid with a line *Width* greater than 1.

Draw.[Fill attributes]

[*Fill attributes*] may be replaced with a more specific name such as *Draw.Fill attributes 2*. The fill attributes are defined by selecting this property and clicking on the [...] button. The following dialog box is displayed:



Draw.Font

Any Windows screen font available on the system. A standard font selection dialogue box is displayed to enable font selection.

Draw.Shape

Shape the object is to take. For example, rectangular or circular.

Draw.Text

Any single line text string.

Info.Identifier, Info.Grid Reference, Info.GIS Reference, Info.Cross Reference, Info.Owner, Info.Location, Info.Manager, Info.Other,

Each of these properties is a single line of text that can be used for additional description of the component. The text could be for internal use for annotating a component. Alternatively it could be used by external applications using Aquator automation interface. An example would be a GIS package retrieving GIS co-ordinates from the *Info.GIS Reference* property.

Options.Show name

If set to *True*, the name is shown on the schematic. This option must also be set to *True* to enable numerical animation of the Component during a model run.

Plot maxima.Hours per day

Used inside the *Tariff Group Setup Dialog* to (a) fix the upper limit of the thumbnail plots of the *Hours per day* profiles, and (b) as an upper limit to valid data when editing these profiles.

Plot maxima.Price

Used inside the *Tariff Group Setup Dialog* to (a) fix the upper limit of the thumbnail plots of the *Price* profiles, and (b) as an upper limit to valid data when editing these profiles.

Schematic.Left, Schematic.Top, Schematic.Width and Schematic.Height

The position (*Left, Top*), relative to the Top Left Hand corner, and size (*Width, Height*) of the Group on the schematic.

Schematic.Name X, Schematic.Name Y, and Schematic.Name Angle

The position of the Group name (*Name X, Name Y*), relative to the position of the Group.

Name Angle is reserved for future use.

Shell.Caption, Shell.Path, and Shell.Arguments

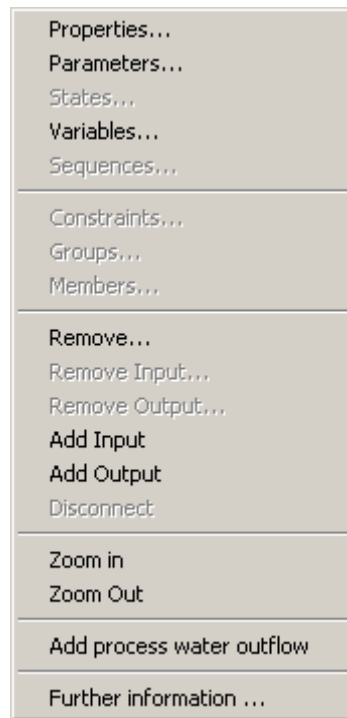
These three properties allow each Aquator Group to be linked to an external application.

For example, it would be possible to link a Water Treatment Works to the appropriate record in an Access database.

The second application is invoked by clicking the right mouse on the schematic, and selecting the appropriate item from the pop-up menu.

If *Shell.Caption* and *Shell.Path* are non blank, an item is appended to the pop-menu item for that Group.

For example if *Shell.Caption* = "Further information...", the pop-up menu might look like:



Shell.Path must be set to the name of the application that is to be started. For example:

C:\Program Files\Microsoft Office\Office\MSACCESS.EXE

Shell.Arguments is optionally set to command line arguments of the second application. Continuing the example of the Access database, this might be the name of the database to open and name of macro to run after the database is loaded:

"C:\Aquator\Database\Aquator.mdb" /X WTW4

Tariff group.Members

This non-editable property shows the concatenated names of tariff group members. To change group membership do one of the following

- use the *Tariff Group Setup Dialog* (preferred method); right-click on the tariff group symbol on the schematic and choose the *Setup* popup menu item, then choose the *Members* tab on the dialog which appears
- right-click on the tariff group symbol on the schematic and choose the *Members* popup menu item
- right-click on any pump station or hydrogenerator symbol on the schematic and choose the *Groups* popup menu item.

Tariff group.Number of tariffs

This non-editable property shows the number of tariffs associated with the group which was specified when the group was created.

Tariff group.Number of zones

This non-editable property shows the number of zones associated with the group which was specified when the group was created.

Tariff group.Reservoirs

This non-editable property shows the concatenated names of reservoirs used by the tariff group. To set or change which reservoirs are used, right-click on the tariff group symbol on the schematic and choose the *Setup* popup menu item, then choose the *Reservoirs* tab on the dialog which appears

Parameters

A *Parameter* is a value for a Group which affects its behaviour during a model run, but which typically does not change during a run, and often is not changed between runs. For example: the stage-area-volume curves of a Reservoir Group would not normally be altered frequently.

Control flow.Value

The value of the parameter that is used when the *Control flow.Type* parameter is set to *Parameter value*.

Control flow.Type

The control flow is used to determine the group's resource state which in turn controls how much excess water (water that can be supplied on pass 4) is available. This parameter provides alternative methods of assessing the control flow.

- **None** – Resource state is invalid, effectively infinite, which implies that all available water can be supplied on pass 4.
- **Parameter value** – Resource state determined as the ratio of maximum available supply divided by a fixed parameter value (*Control Flow.Value*).
- **Sequence value** – Resource state determined as the ratio of maximum available supply divided by a value taken from the sequence *Control flow*.

The effect of the control flow is that on pass 4 (excess water pass) the abstraction group can be "drawn down" to leave an amount equal to the control flow, which is then available for pass 5 if required.

Demand saving.Level 1

This is the percentage reduction in demand at demand saving level 1. The daily demand saving level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.Level 2

This is the *difference* between the reduction in demand at demand saving level 2 and at demand saving level 1, expressed as a percentage of the unreduced demand. The daily demand saving level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.Level 3

This is the *difference* between the reduction in demand at demand saving level 3 and at demand saving level 2, expressed as a percentage of the unreduced demand. The daily demand saving level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.Level 4

This is the *difference* between the reduction in demand at demand saving level 4 and at demand saving level 3, expressed as a percentage of the unreduced demand. The daily demand saving

level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.Level 5

This is the *difference* between the reduction in demand at demand saving level 5 and at demand saving level 4, expressed as a percentage of the unreduced demand. The daily demand saving level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.On

This is the percentage reduction in demand at demand saving level 1. The daily demand saving level is set by the greatest demand saving level requested by any component subject to a minimum period at which the demand saving level is held constant.

Demand saving.Source

This determines the source of the *Demand Saving* imposed during the model run. Possible choices are:

1. **Component level:** The maximum of the Demand saving levels imposed by all components.
2. **Sequence level:** the Demand saving level taken from a *Time series* or *Profile*.
3. **Sequence factor:** the multiplying factor by which Demand is scaled, taken from a *Time Series* or *Profile*.

Fail.At dead water level

Report an end of day failure if the Reservoir storage is below the dead water level.

Fail.At demand saving level

Report an end of day failure if the Reservoir storage is at or below the demand saving level specified by this parameter.

Fail.At emergency storage level

Report an end of day failure if the Reservoir storage is below the emergency storage level.

Options.Animate on

Set to True if the Component is to provide day by day animation as the model runs. An example of this a Reservoir which can

show its current storage state each day by graphically on the schematic.

Model execution time is increased when this option is on.

Operation.Demand saving

If set to *True* this Group will communicate its demand saving level with Aquator.

Options.Enabled

When enabled the Group operates normally. Setting this option to *False* effectively removed the Group from the system during model execution. It is recommended that if one or more Groups are disabled, the model log is inspected to check the water balance.

Options.Events on

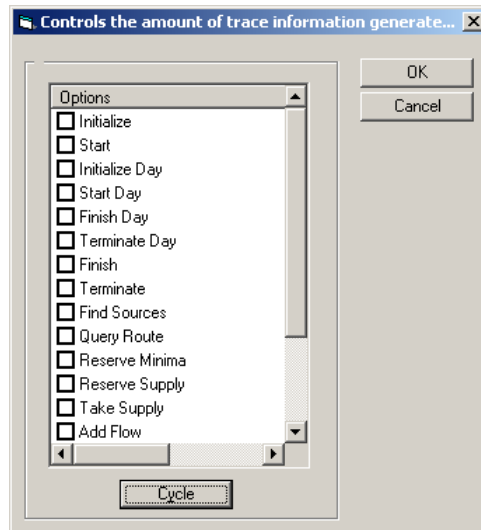
When set to *True* any Visual Basic (VBA) code attached to the Group will be executed. If you have no VBA code then it is a good idea to set this option to *False* as this will improve model performance.

Options.Trace on

When set to *True*, Group events are logged in the *Trace log*. This is useful when debugging a system to ensure it is behaving as required. It is more efficient in terms of model execution time to have this option set to *False*

Options.Trace flags

This option allows the trapping of specific events during a model run on a Group by Group basis. The following dialog box is displayed to allow the events to be specified:



<PU1>.Fixed flow rates

The parameter group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

If True this parameter specifies that the pump station or hydrogenerator can operate only at flow rates specified by the <PU1>.Rating curve parameter. If False then any flow rate at or above the first point on the <PU1>.Rating curve parameter is valid.

<PU1>.Max flow rates

The parameter group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

This parameter is a 3D array indexed like (zone, tariff, month). Each element of the array specifies the maximum flow for a given storage zone (1 to maximum number of zones), tariff (1 to total number of tariffs), and month (1 to 12).

Use the *Tariff Group Setup Dialog* to edit these values; right-click on the tariff group symbol on the schematic and choose the *Setup* popup menu item, then choose the *Members* tab on the dialog which appears.

<PU1>.Rating curve

The parameter group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

This array parameter consists of power (kW) values in the first column and flow (M/d) in the second column, in ascending order. This parameter is used to convert a flow rate to the power required (pump stations) or generated (hydrogenerators). If the <PU1>.Fixed flow rates parameter is True then only the values in the array are valid operating points. If False then interpolation in the table is allowed.

<PU1>.Set price per MI

The parameter group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

If this parameter takes the value True then at the start of each day the tariff group sets the unit price of water (price per MI) expected for the pump station or hydrogenerator. This can alter the route ordering when water is moved on pass 4 when Aquator attempts to minimise cost of operation.

If this parameter is False then the unit cost of water for the pump station or hydrogenerator remains set to its own parameter value. This may well be the preferred setting when conducting large numbers of runs to study pumping costs, else changes in route order may make it more difficult to interpret results.

Resource.State.Use Yesterdays Value

This parameter controls whether the Abstraction Group emulates the behaviour of earlier (2.X) versions of Aquator, whereby the Resource State for any day is not updated until the next day. All new projects should always have this parameter set False. When projects created by earlier versions are loaded this parameter is set to True and you may wish to evaluate any changes that result from setting it to False.

Storage.Failure Margin

The tolerance on detecting and reporting a failure when the reservoir storage drop to emergency and/or dead water level. Rounding error might leave the storage fractionally above one of these key levels and therefore not result in a failure being reported. For example if dead storage was 1000 MI, and this parameter set to 0.01 MI, failure would be reported at 1000.01 MI or less. (This parameter can also take negative values.)

Zone.Table

The zone table of a tariff group is a table of reservoir storages expressed as a percentage, in ascending order. Each value represents the start (lower limit) of a storage zone. The first value should be 0% for zone 1. The value 100% should *not* be present, it is implicitly the upper limit for the top storage zone.

States

A value for a Group which affects its behaviour during a model run, and which typically does change during the run, and often is changed between runs. For example: the initial storage of a Reservoir Group on the first day of the run would typically vary from run to run.

Demand saving hold (DSH).Method

This enumerated state value can take the one of the values: *None*, *Simple period*, or *Multi-level delays*. See *Demand saving hold*.

Simple DSH.Delay/hold period

If *Demand saving hold (DSH).Method* is *Simple period* then this is the minimum number of days that must elapse between changes in demand saving level.

Simple DSH.Day in period

If *Demand saving hold (DSH).Method* is *Simple period* then this is the number of days into the holding period at the start of the

model run. This enables restarting on any day and getting the same results.

Demand saving hold.Start level

If *Demand saving hold (DSH).Method* is *Simple period* or *Multi-level delays* then this is the demand saving level at the start of the model run. This enables restarting on any day and getting the same results.

Multi-level DSH: [1-5].Delay

If *Demand saving hold (DSH).Method* is *Multi-level delays* then this is the delay in days that must elapse before the increase to the corresponding demand saving level is allowed. See *Demand saving hold*.

Multi-level DSH: [1-5].Hold

If *Demand saving hold (DSH).Method* is *Multi-level delays* then this is the hold period in days that must elapse before the corresponding demand saving level can be decreased. See *Demand saving hold*.

Multi-level DSH: [1-5].Days

If *Demand saving hold (DSH).Method* is *Multi-level delays* then this is the time in days spent so far at each demand saving level. See *Demand saving hold*.

Variables

A value for a Group which is computed daily during a model run. This can include both predicted and observed values i.e. a sequence of observed storage linked to a Reservoir Group can be captured in a variable so that both observed and calculated storage can be plotted on the same chart.

Abstraction.Amount

Daily supply from abstraction group.

Abstraction.Control flow

The control flow used to calculate the *resource state*.

Abstraction.Maximum available

Maximum available from abstraction group each day ignoring constraints.

Demand saving.Level

The daily value of the demand saving level, an integer between zero (no demand saving) and five (maximum demand saving).

Demand saving.Percent

The daily value of the demand saving as a percentage of total demand in the absence of any demand saving.

Demand savings.Threshold (n) & Demand savings.Threshold (n) (%)

The demand saving control curve sequence for Level *n* in MI or as % full.

Operation.Demand saving level

The daily value of demand saving level reported by this Group.

Operation.Failure amount

This provides the actual amount by which the failure criterion was not met. If more than one failure criterion is enabled, this figure contains the maximum of all failure amount on any one day.

Operation.Resource state

The state of the resource at the Group at the beginning of the day (i.e. before any water has been taken). A resource state of 1 is *normal*; values greater than 1 indicate the resource is in a better than normal state. A resource state less than 1 indicates the resource is in a worse state than normal. If the resource state is greater than 1, the Group is then able to supply water on Pass 4 (i.e. when least cost water is being sought).

Operation.Status level

The status level reported by this Component at the end of the day. Status level can be one of the following:

Level	Description
0	OK
1	Warning
2	Failure
3	Error

<PU1>.Cost

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

The cost of operation of this component, calculated from the actual flow and the price and availability of the various electricity tariffs.

<PU1>.Cost @ tariff N

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group. The 'N' suffix takes the values 1,2... up to the number of tariffs.

The cost of operation of this component while passing water during the period for which tariff N was available..

<PU1>.Flow

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

The actual flow passed by this component by the end of the day, averaged over 24 hours and expressed in Ml/d. If the tariff group and its members are operating correctly then this should equal the maximum flow that was calculated at the start of the day and held in the <PU1>.Max flow variable.

<PU1>.Flow @ tariff N

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group. The 'N' suffix takes the values 1,2... up to the number of tariffs.

The flow passed during the period of tariff N.

<PU1>.Hours flow @ tariff N

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group. The 'N' suffix takes the values 1,2... up to the number of tariffs.

The number of hours tariff N was available.

<PU1>.Income

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

The income from operation of this component, calculated from the actual flow and the price and availability of the various electricity tariffs.

<PU1>.Income @ tariff N

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group. The 'N' suffix takes the values 1,2... up to the number of tariffs.

The income from operation of this component while passing water during the period for which tariff N was available.

<PU1>.Max flow

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

The maximum flow that was calculated for this member by the tariff group at the start of the day, averaged over 24 hours and expressed in MI/d. If the tariff group and its members are operating correctly then this should equal the actual flow at the end of the day held in the <PU1>.Flow variable.

<PU1>.Max flow rate @ tariff N

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group. The 'N' suffix takes the values 1,2... up to the number of tariffs.

The maximum flow rate during the period of availability of tariff N.

<PU1>. Max flow rate from supply

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

This variable holds a value corresponding to the absolute upper limit to the flow in MI/d that can be supplied to this component. Typically this must have been a value calculated by custom VBA code in response to the *GetMaxFlowRate* event.

<PU1>.Supply limited

The variable group name <PU1> is a placeholder for the name of each pump station or hydrogenerator in the tariff group.

This 32 bit integral variable signals whether supply limitations were detected. A value of zero indicates that all requested maximum flows were achievable and were not supply-limited. Otherwise if bit N is 1 (N=0,1,2...) it signals that the maximum desired instantaneous flow rates specified in the maximum flow rates 3D table were limited during tariff N+1. Thus a value of 1 indicates that tariff 1 flows were limited, 2 that tariff 2 flows were limited, 3 that both tariff 1 and tariff 2 flows were limited, and so on.

Storage.Calculated & Storage.Calculated (%)

Reservoir storage calculated by the model as storage in MI or as % full.

Storage.Control & Storage.Control (%)

The Aquator Reservoir control curve sequence in MI or as % full.

Storage.Dead water & Storage.Dead water (%)

The Reservoir dead water storage line in MI or as % full.

Storage.Emergency & Storage.Emergency (%)

The Reservoir emergency storage line in MI or as % full.

Storage.Flood & Storage.Flood (%)

The Reservoir flood drawdown control curve sequence in MI or as % full.

Storage.Hydropower & Storage.Hydropower (%)

The Reservoir hydropower control curve sequence in MI or as % full.

Storage.Irrigation & Storage.Irrigation (%)

The Aquator irrigation control curve sequence in MI or as % full.

Storage.Observed & Storage.Observed (%)

The observed (measured) Reservoir storage sequence in MI or as % full.

Storage.Percent

The state of the reservoirs associated with a tariff group at the start of each day, expressed as a percentage of capacity.

Storage.Zone

The reservoir zone for the day. This is an index 1, 2... up to the maximum number of zones, calculated from the *Storage.Percent* variable and the *Zone.Table* parameter.

Tariff group.Net cost

The difference between the *Tariff group.Total cost* and *Tariff group.Total income* variables. Will be negative if income exceeds cost.

Tariff group.Net income

The difference between the *Tariff group.Total income* and *Tariff group.Total cost* variables. Will be negative if cost exceeds income.

Tariff group.Total cost

Sum of costs calculated from tariff data for all members of the tariff group. Does not allow for any income from any members of the group that generate income.

Tariff group.Total flow

Sum of flows passed by all members of the tariff group.

Tariff group.Total income

Sum of income calculated from tariff data for all members of the tariff group. Does not allow for the cost of any members of the group that incur cost rather than generate income.

Sequences

A sequence is a requirement for daily data during a model run. Sequential data must be supplied to a Group in order for the Group to operate correctly. For example, a Reservoir Group requires a rainfall sequence to compute water added by precipitation each day.

The type of sequence available is particular to each Group.