A Guide to Aquator

6 Analyzers

Version 4.2

Oxford Scientific Software Ltd.

Contents

Analyzers

What is an Analyzer?

An Analyzer is an Aquator add-on which applies a specific analysis technique to an existing project.

An example is an Analyzer which carries out several runs of a model, each run with gradually increasing *Demand Centre* demands to determine the level of demand that causes the system to fail.

Optionally Analyzers can have *Properties, Parameters, States, Variables* and *Sequences*. These are added to the project's properties, parameters, states, variables and sequences collections, but may only be visible on the Analyzer's own setup form.

Additional Analyzers may be added to Aquator by third parties to undertake new types of analysis.

Standard Analyzers

Aquator Analyzers are:

Deployable Output – English & Welsh method

Deployable Output – Scottish method

Risk analysis

River flow analysis (flow duration & low flow frequency)

Deployable Output – English and Welsh method

The purpose of this *Analyzer* is to determine the yield or *deployable output* (DO) of a water resources system using the method used in England and Wales. The method involves setting a minimum and maximum overall demand in a resource zone and increasing the demand incrementally until failure is encountered. The DO of the system is defined as the overall demand that is one increment below the demand causing a failure.

This analyser allows the demand increment to be specified as well as the range of demands to be studied. Using the run dates already specified for the model, there is one model run for each overall demand, starting with the minimum demand.

Demand centres that are to have their demands scaled during the analysis are be specified. These demands are then scaled, keeping the same relative demand between individual demand centres so that the total is equal to that overall total for a particular model run. Specifying demand centres in this way allows for other demand centres to have their demand held constant for each of the model runs. These demand centres may be present in the model to represent other uses such as power stations or demands outside the resource zone.

Two methods of finding the deployable output are provided:

1. **Binary chop**. This method executes the model run with minimum demands first, followed by the run with maximum demands. If the first run does not fail and the last run does fail, the next model run is mid way between the minimum and maximum. If this third run fails, the second half of the demand range is eliminated from the analysis as it cannot contain the solution. If the third run does not fail, the solution must be in the upper range of demands. By applying this technique a solution is found faster on average than by the step by step method. However the binary chop has been known to find an incorrect solution under unusual circumstances when demand saving measures are in place. Here increasing the demand from a failed demand, can invoke more severe or lengthy demand saving, so that at the next demand increment there is no failure. The binary chop technique can find this higher demand and report it as the Deployable Output.

2. **Step by step**. This method executes the model run with minimum demands first, followed by successive runs with

demands increased by the demand increment. The analysis is complete when failure occurs and the deployable output is the overall demand of the penultimate run.

Setting failure conditions - English and Welsh Method

Failures are defined at the component level. For example a demand centre has a parameter *Fail.If demand not met*. Setting this to True causes a failure when supply does not meet demand on any day and this will be detected by this analysis module. Similarly a reservoir has many possible ways of failing (e.g. empty or compensation flow not met) and these are defined in the reservoir's parameters. Reservoir groups can also trigger a failure in a number of ways. A river abstraction can also trigger a failure if a prescribed flow is not met.

In addition it is possible to trigger or remove failures using VBA on any component in the *AfterTerminateDay* event by setting the Status parameter. Trigger a failure by the following:

Status = aqtStatusFailure

Force a failure not to be counted by:

Status = aqtStatusOK

Thus there is a large degree of flexibility in defining what does and what does not constitute a failure.

In addition failure can (optionally) be triggered by exceeding a number of demand saving events. Demand saving events are triggered on days when the demand saving level is higher than it was yesterday. For example a Level 1 demand saving event is triggered when there were no demand restrictions (savings) yesterday, but a Level 1 state exists today. The number of such events that are allowed for the duration of the whole run can be specified. If more events than allowed are triggered, the analyser treats this as a failure. The analysis uses the Model state value "Demand saving hold.Start level" as the demand saving level on the day before the run start date, so this should be set to the correct value to avoid possibly triggering a spurious event on day one. Demand saving level is taken from the model's overall demand saving variable. On any day this is the maximum of demand saving levels throughout the project including any demand saving groups.

Applying the analysis – English and Welsh Method

Unless there is a good reason to the contrary, the analysis is best undertaken on the longest possible simulation period. The run simulation period is defined in Aquator under menu **Setup -> Model…**, **States** tab.

If you have more than one demand centre, set up each of their parameters *General.Demand* and *General.Demand factor* to be in the correct ratio between demand centres. (The ratio between demands at demand centres is preserved for each model run undertaken during the analysis as the system wide, Overall demand is increased.) If you have full Demand sequence specified for any demand centre, this is ignored for this analysis and the *General.Demand* and *General.Demand factor* parameters used instead.

Decide on your failure criteria and set the appropriate parameters in the model components that can cause a failure. See *Setting failure conditions* for further information.

Select the **Tools -> Analyze** menu item and then **Deployable Output – English and Welsh Method**. The following form is displayed which controls the analysis:

In the above form the *Run Duration* frame shows the length of the model run period. This is defined by the project *Run start date* and *Run finish date* – see above.

The Demand centre frame is used to define which demand centres are to be included in the run by run demand scaling process.

The analysis technique should be chosen as required. The section *Deployable Output – English and Welsh method* describes the advantages of each method.

The Demand Range frame allows the overall system demand specified for each model run. The DC Parameter *Total* value displayed on the form is the total of all demand centre demands as defined in their parameters and is for information only. The *Minimum Demand* is overall demand for the first model run.

Subsequent model run uses an overall demand which is the *Minimum Demand* plus a number of *Demand Steps*. The *Max number of runs* value shows how many model runs will take place as the *Minimum Demand* is incremented to the *Maximum Demand*. In practice fewer runs might take place.

The Demand saving trigger frame configures the analyser to optionally trigger a failure when more than a specified number of demand saving events at a particular demand saving level are detected. The *Enable demand saving triggers* check box determines whether or not this method of triggering a failure is to be used. The *Max Level n events* text boxes allow the maximum permitted number of events at each demand saving level to be specified. An event in this context is defined as day on which the demand saving level has increased from its value yesterday. (Note that the effects of hunting (oscillations) in demand saving level can be mitigated by the model wide state values in the *Demand saving hold* group.)

The *Close form on completion* check box in the Options frame determines whether the above form is closed automatically once the analysis is complete.

Having set up the analysis parameters, the analysis is carried out by clicking on the *Execute* command button. The form then changes to run mode:

In the above form the *Analysis progress* frame shows how the analysis is progressing and its estimated completion time.

The grid in the *Results* frame has one cell for each overall demand and year. It is possible to scroll through this grid as the analysis proceeds to study the result. Each time the model starts a new year and the Auto scroll check box is ticked, the cell in the

grid relating to the current demand and year is made visible. The Copy command button:

copies the current content of the grid into the clipboard in a format suitable for pasting into Excel.

The *Abort* command button may be used to abort the analysis at any stage.

After the analysis is completed, the most relevant result set will be displayed in the project tree view. If the deployable output has been found, this will be the model run relating to the DO. If a solution has not been found, a result set if left so that it might be studied to determine a more suitable set of parameters.

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

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

Group	Name
EnglishDO	Description
	Min demand
	Max demand
	Demand increment
	Analysis method
	Enable demand saving triggers
	Max demand saving trigger events
	Exit on completion

States

An Analyzer 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 Analyzer.

Variables

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

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer 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).

There are no sequences for this type of Analyzer.

Deployable Output – Scottish Method

 Deployable Output – Scottish method

The purpose of this Analyzer is to determine the yield or deployable output of a water resources system. The methodology has been determined by Scottish Water in cooperation with the Scottish Environment Protection Agency (SEPA)

The analysis involves the following steps:

1. Run the model multiple times. Each model run has an incrementally increased Overall demand.

2. For each "Overall demand", the number of Failure years is counted for the **N** years of the analysis period. A year is deemed as a "Failure year" if there is at least one failure reported by the model during the year. What constitutes a failure is model dependent, but would typically include supply not meeting demand and a reservoir reaching emergency or dead storage.

3. If the Failure years series for each increase in demand, is not contiguous, the method attempts to find the missing values by sub-dividing the demand step. For example an Overall demand of 200 Ml/d might produce 2 Failure years and the next Overall demand of 205 Ml/d then produce 4 failure years. The demand range 200-205 Ml/d is then sub-divided to find the demand that produces 3 failure years.

4. If the same number of Failure years is produced by more than one Overall demand, the higher demands are ignored. For example an Overall demands of 210 Ml/d and 215 Ml/d might both produce 5 Failure years. In this

case the 215 Ml/d demand is ignored and 5 Failure years associated with and Overall demands of 210 Ml/d.

5. The resulting two column series then comprises an increasing number of Failure years paired with increasing Overall demand.

6. The Return period of the number of Failure years is then calculated based on the total record length, **N**.

7. Overall demand is then plotted against Return period of each number of Failure years assuming a General Extreme value (GEV) distribution.

8. Interpolation of this GEV plot enables the failure demand at any intermediate return period to be estimated. Higher demands cause failure at lower return periods.

It can be seen that the method is fixed in terms of the analysis technique, but open to flexibility by the choice of definition of failure and return period. For example the Deployable Output of a system might be defined as follows: *The lowest overall demand that causes failure at a one in fifty year return period.*

The statistical calculations are based on the method described in the *Low Flow Studies Report*, **_Institute of Hydrology_**, *January 1980, Report Number 1 (page 10)* and outlined here:

The *exceedance* probability of an event, $P_{(i)}$, is calculated as:

$$P_{(i)} = (i - 0.44) / (N + 0.12)$$

where:

i = rank (range: 1 to N)

N = length of simulation (years)

The return period, $T_{(i)}$, can be derived from the *exceedance* probability:

$$T_{(i)} = (1 - P_{(i)})^{-1}$$

In this analysis we are interested in the probability of <u>not</u> getting a failure with a particular level of demand so the two formulae above combine and simplify to give:

$$T_{(i)} = (N + 0.12) / (i - 0.44)$$

The x axis (return period) is of type General extreme value (GEV). $T_{(i)}$ is converted to plotting position, $X_{(i)}$, using:

$$X_{(i)} = [1 - exp\ (-kz_{(i)})] / k$$

where:

$$z_{(i)} = -\ln [-\ln \{ (T_{(i)} - 1) / T_{(i)} \}]$$

The Weibull Distribution

The *Low Flow Studies Report* recommends the use of the *Weibull* form of the GEV (k = 0.25) to determine plotting position, $W_{(i)}$:

$$W_{(i)} = [1 - exp (-0.25 * z_{(i)})] / 0.25$$

This analysis module allows uses a value of k = 0.25 by default, but this may be changed to any value in the range –0.25 to +0.25 (excluding zero) to permit experimentation with different forms of the GEV.

Setting Failure Conditions - Scottish method

What constitutes a failure is defined at the component level. For example a demand centre has a parameter *Fail.If demand not met*. Setting this to *True* causes a *failure* when supply does not meet demand on any day and this will be detected by this analysis module. Similarly a reservoir has many possible ways of failing (e.g. empty or compensation flow not met) and these are defined in the reservoir's parameters. Reservoir groups can also trigger a failure in a number of ways. A river abstraction can also trigger a failure if a prescribed flow is not met.

In addition it is possible to trigger or remove failures using VBA on any component in the *AfterTerminateDay* event by setting the *Status* parameter. Trigger a failure by the following:

Status = aqtStatusFailure

Force a failure not to be counted by:

Status = aqtStatusOK

There is therefore a large degree of flexibility in defining what and what does not constitute a failure.

If more than one component reports a failure on any one day, this is treated as a single failure in the annual count of number of days failure. It is therefore not possible to have more than 366 days failure in any year. (For example a demand centre might report a failure because demand was not met and reservoir report a failure because it was empty all on the same day – but this is counted as one day's failure).

Applying the Analysis - Scottish method

1. The analysis may be controlled in one of two ways. Firstly the "Full analysis" simply uses the start and end dates of the model as currently set up, a start month, and three other parameters that control the range of *Overall demand* to be investigated. The second method is "Excel control" that utilises an Excel spreadsheet that defines the dates of the model run, the set of *Overall demands* and whether or not the model is to be run for a particular *Overall demand* and year.

2. Unless there is a good reason to the contrary, the analysis is best undertaken on the longest possible simulation period. (The longer the simulation period, the

higher the return period the analysis estimates and the greater the accuracy for lower return periods. For example a simulation period of 10 years has a maximum 18 year return period event, whereas a simulation period of 75 years provides an estimate of the 134 year return period event.) The run simulation period is defined in Aquator under *Setup* menu, menu item *Model…*, *States* tab.

3. If the model has more than one demand centre, set up each of their parameters *General.Demand* and *General.Demand factor* to be in the correct ratio between demand centres. (The ratio between demands at demand centres is preserved for each model run undertaken during the analysis as the system wide, *Overall demand* is increased.) If there is full *Demand sequence* specified for any demand centre, this is ignored for this analysis and the *General.Demand* and *General.Demand factor* parameters used instead.

4. Decide on the *failure* criteria and set the appropriate parameters in the model components that can cause a failure. See *Setting failure conditions* for further information.

5. Select the *Tools* menu, *Analyze* menu item and then *Deployable Output – Scottish Method*. The following form is displayed which controls the analysis:

1. In the above form the *Common control* frame allows the reporting return period to be specified. These should be

entered as a comma separated string in order of lowest to highest. Once the basic analysis has been completed it is possible to get the analyser to run the model for one or more of the return period demands. This is achieved by adding an asterisk (*) to each of the required return periods. The following illustrates how a model run is executed automatically by the analyser for 1 in 40 year return period demand once the main analysis is complete:

Return periods 10, 20, 30, 40*, 50 ,60, 70 ,80, 90, 100

2. The *Step reduction factor* is used when a certain number of failure years is missing. For example if the *Step reduction factor* is 5, an *Overall demand* of 200 Ml/d produces 2 *Failure years* and the next *Overall demand* of 205 Ml/d might then produce 4 failure years. The demand range 200-205 Ml/d is then sub-divided by this parameter (5) to search for the demand that produces 3 failure years. *Overall demands* of 201, 202, 203 and 204 are the investigated. If the missing *Failures years* is still not found the range is sub divide further by the same factor provided the step is not less than the *Minimum step size* parameter.

3. The Demand centre frame is used to define which demand centres are to be included in the run by run demand scaling process.

4. If the *Full analysis* tab is selected the parameters on this tab are used to control the analysis (rather than the Excel spreadsheet).

   The *Run Duration* frame shows the length of the model run period. This is defined by the current project *Run start date* and *Run finish date*.

   The *Analysis Period* frame determines the analysis period. The analysis period is always less than or equal to the model run period. The analysis period starts on the first day of the month specified in the *Start Month* drop down list box and extends for as many complete years from that date as possible. This *Start Month* parameter therefore allows for the definition of a water year that is different to a calendar year (e.g. 1st October to 30th September). There must be at least 3 complete years for the analysis to proceed.

5. The *Demand Range* frame allows the overall system demand specified for each model run. The *DC Parameter Total* value displayed on the form is the total of all

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demand centre demands as defined in their parameters and is for information only. The *Minimum Demand* is overall demand for the first model run. The second model run uses an overall demand which is the *Minimum Demand* plus the *Demand Step*. Successive model runs have their overall demand increased by the *Demand Step* until the *Maximum Demand* parameter is reached. These values of overall demand are distributed amongst individual demand centres as described in 3 above. The *Number of Runs* value shows how many model run will take place between as the *Minimum Demand* is incremented to the *Maximum Demand*.

6. If the *Excel control* tab is selected, steps 7 and 8 above are replaced with control information supplied in an Excel spreadsheet:
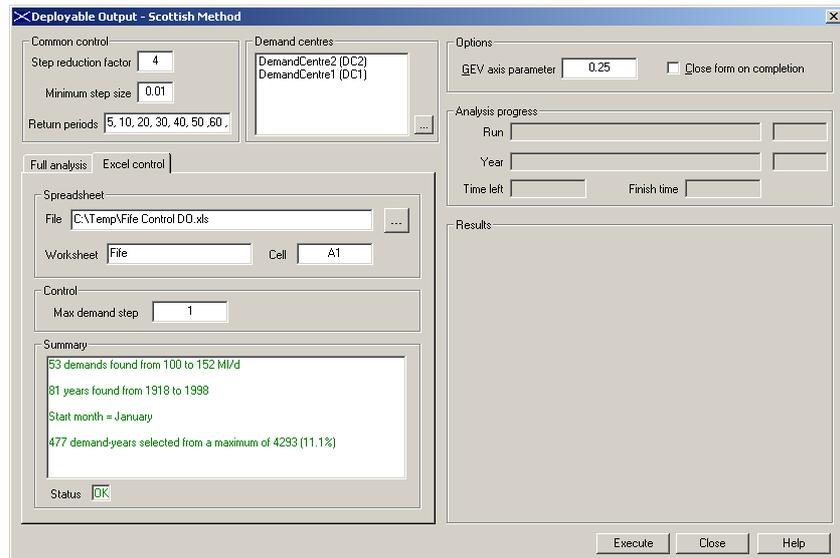
1. The *Spreadsheet* frame allows the name and location of the control spreadsheet to be specified along with the *Worksheet* and location *Cell* in that worksheet of the control data.

2. The *Control* frame contains the single text box *Max demand step*. This allows fewer demands (and hence potential model runs) to be defined in the control spreadsheet. This parameter comes into play after the model runs defined by the spreadsheet have taken place, along with any sub-division of demands required by the *Step reduction factor*. If the number of failures at one

demand is larger than the number of failures at the next lowest demand and the increase in demand is larger than the parameter set here (*Max demand step*), this demand range is split by the analyzer to produce additional demands increasing by no more than this parameter value. The effect of this is to obtain a more accurate estimate of the demand causing each failure. This parameter sets the upper bound for the accuracy of results.

3. The *Summary* frame shows a summary of the control data as a check the information is correct. Error messages (such as failure to find the file) are also displayed here.

4. The format of the control data in the spreadsheet is best described using an example:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	AQT control	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325
2	1-Jan-1955															X	X
3	1-Jan-1956													X	X	X	X
4	1-Jan-1957													X	X	X	X
5	1-Jan-1958																
6	1-Jan-1959																
7	1-Jan-1960																
8	1-Jan-1961																
9	1-Jan-1962																
10	1-Jan-1963												X	X	X	X	X
11	1-Jan-1964									X	X	X	X	X	X	X	X
12	1-Jan-1965									X	X	X	X	X	X	X	X
13	1-Jan-1966																
14	1-Jan-1967																
15	1-Jan-1968																
16	1-Jan-1969																
17	1-Jan-1970																
18	1-Jan-1971																
19	1-Jan-1972																X
20	1-Jan-1973																X
21	1-Jan-1974															X	X
22	1-Jan-1975	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
23	1-Jan-1976	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24	1-Jan-1977																
25	1-Jan-1978																
26	1-Jan-1979																
27	1-Jan-1980																
28	1-Jan-1981																
29	1-Jan-1982																
30	1-Jan-1983																
31	1-Jan-1984																
32	1-Jan-1985																
33	1-Jan-1986																
34	1-Jan-1987																
35	1-Jan-1988																
36	1-Jan-1989													X	X	X	X
37	1-Jan-1990											X	X	X	X	X	X
38	1-Jan-1991											X	X	X	X	X	X
39	1-Jan-1992																
40	1-Jan-1993																
41	1-Jan-1994																
42	1-Jan-1995																
43	1-Jan-1996											X	X	X	X	X	X
44	1-Jan-1997											X	X	X	X	X	X
45	1-Jan-1998																
46	1-Jan-1999																
47	1-Jan-2000																
48	1-Jan-2001																
49	1-Jan-2002																
50	1-Jan-2003																
51	1-Jan-2004																
52	1-Jan-2005																
53	1-Jan-2006																

1. The top left corner of the control data must contain the text "AQT control". The location of this cell is supplied as the *Cell* in the worksheet (step 10 above).

2. There is one column for each *Overall demand* and one row for each analysis year. The *Overall demands* (in Ml/d) must increase left to right, but there no requirement that

the step size should be equal. The analysis year should be a valid first of month date. The month determines the month the analysis starts. Analysis years must be in chronological order and start on the first day of the same month as the first year.

3. The cells contained by the *Overall demands* row and analysis years column, determine which years are to be included in the analysis for each *Overall demand*. If a cell is empty or contains the numeric value 0 (zero), the model is not run for that *Overall demand* and year. Any other cell content results in that year being included in the analysis.

4. The same initial state values are used when executing each partial model run for each *Overall demand*.

5. It is important to have sufficient "warm up" years before a critical year so that the model will have stabilised enough to yield a reasonable representation of those years run in the *Full analysis* mode.

6. The *Options* frame allows the GEV parameter for the results plot to be specified. This should be set to 0.25 for a *Weibull Distribution* (see above) but must be in the range –0.25 to +0.25 (excluding zero). The *Close form on completion* check box determines whether the above form is closed automatically once the analysis is complete.

7. Having set up the analysis parameters, the analysis is carried out by clicking on the *Execute* command button. The form then changes to run mode:
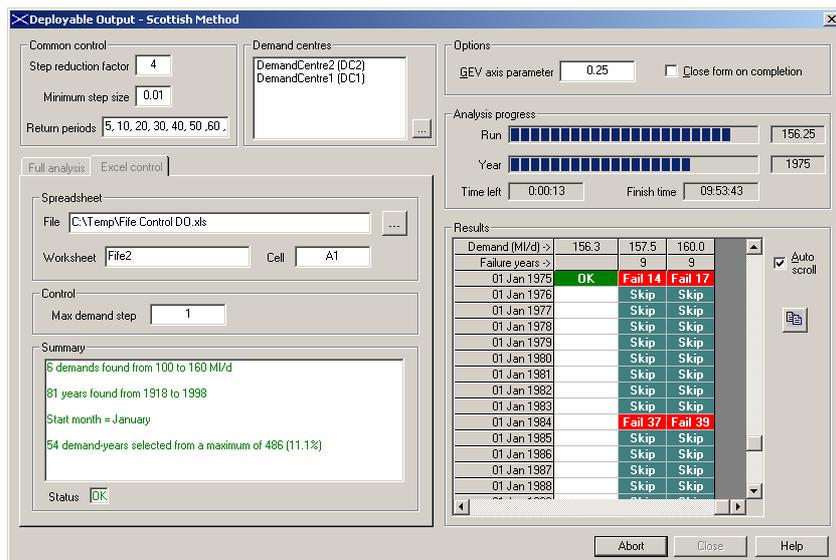
1. In the above form the *Analysis Progress* frame shows how the analysis is progressing and its estimated completion time. The number after 'Fail' in a cell gives the number of day's failure for that year and demand. The number of runs and estimated time can increase during an analysis as more *Overall demands* are added to locate a particular number of *Failure years*.

2. The grid in the *Results* frame has one cell for each *Overall demand* and year. Values in these cells show the status of that year as either "OK" if no failures were reported, "Fail" if one or more failures were detected or "Skip" if the year was skipped in the analysis. "Skip" will only be appear when running in *Excel control* mode. It is possible to scroll through this grid as the analysis proceeds to study the result. Each time the model starts a new year and the *Auto scroll* check box is ticked, the cell in the grid relating to the current demand and year is made visible. The *Copy* command button, copies the current content of the grid into the clipboard in a format suitable for pasting into Excel.

3. The 'Abort' command button may be used to abort the analysis at any stage.

4. After the analysis is completed, the results are displayed under the *Deployable output* node in the *project tree view*. An example is given below:

```
==================================
Deployable Output - Scottish Method
==================================

Model:                     Scottish DO test
Analysis date & time:      26/07/2007 14:17:39
Period:                    1955 to 2006
Start month:               Jan
Years:                     52
Min possible return period: 3.84 years (*)
Max possible return period: 93.07 years (#)


* = Reduce by increasing the maximum demand (to increase the number of failures years above the current 14)
# = Increase by increasing the record length (to more than the current 52 years)


Analysis results
================

Number of failures    Demand (Ml/d)    Return period (years)    Plotting position
------------------    -------------    ---------------------    -----------------
1                     255.             93.07                    2.71044
2                     306.25           33.41                    2.32993
3                     310.             20.36                    2.10508
4                     320.             14.64                    1.93705
5                     321.25           11.43                    1.7997
6                     323.75           9.37                     1.68184
7                     325.             7.95                     1.57755
8                     326.25           6.89                     1.48328
9                     330.             6.09                     1.39672
10                    335.             5.45                     1.31628
11                    340.             4.94                     1.24079
12                    341.25           4.51                     1.16941
13                    345.             4.15                     1.10145
14                    350.             3.84                     1.03639


Interpolated return periods
===========================

Return period (years)    Fail demand (Ml/d)
---------------------    ------------------
3                        Not enough failures to estimate this return period
5                        339.337
10                       322.918
20                       310.516
30                       307.022
40                       296.216
50                       284.426
60                       275.294
70                       267.904
80                       261.737
90                       256.471
100                      Record length too short (56 years record required)
150                      Record length too short (84 years record required)
200                      Record length too short (112 years record required)
```

1. "Analysis result" are the results of the calculations described above. "Interpolated return periods" give the *Overall demands* at the specified return periods.

2. Graphical results are also displayed as illustrated below showing the failure demand for the range of return periods. For example a demand of approximately 310 Ml/d would cause failure once every twenty years.

Deployable Output - Scottish Method
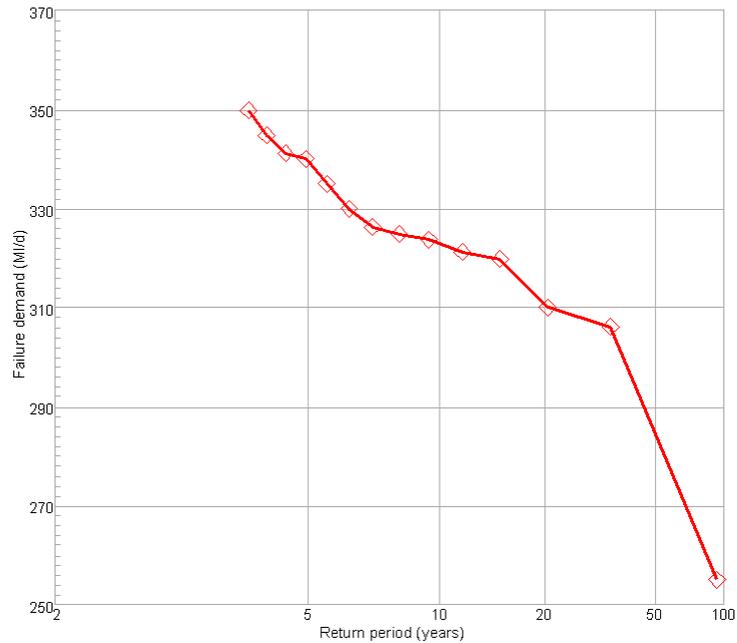
3. A text log listing the failures for each demand is produced. Each line in the log represents one failure day. The first component that reports a failure is the one listed. In other words if more than one component reports a failure on any one day, only one component is entered into this log.

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

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

Group	Name

Group	Name
ScottishDO	Start month
	Min demand
	Max demand
	Demand increment
	GEV parameter
	Exit on completion
	Demand increment reduction
	Minimum demand increment
	Return periods
	Analysis type
	Control spreadsheet
	Control worksheet
	Control cell
	Maximum yield step

States

An Analyzer 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 Analyzer.

Variables

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

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer 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).

There are no sequences for this type of Analyzer.

Risk analysis

Risk analysis .

The purpose of this analyzer is to assist with the operation of water resource systems over the year ahead by calculating two types of risk:

1. Risk of each level of demand restriction lasting a number of days in the year ahead

2. Risk of reservoir storage being below a certain level on any day in the year ahead.

The first type of risk can be applied to both the model wide demand restrictions and to demand restrictions generated by demand restriction groups. An example of the graphical output produced by this part of the analysis is shown below. There is one line for each level of demand restriction that gives the level of risk (y axis) of that demand restriction level lasting a number of days (x axis) in the year ahead.

Risk of demand restrictions - Upland system (Model)
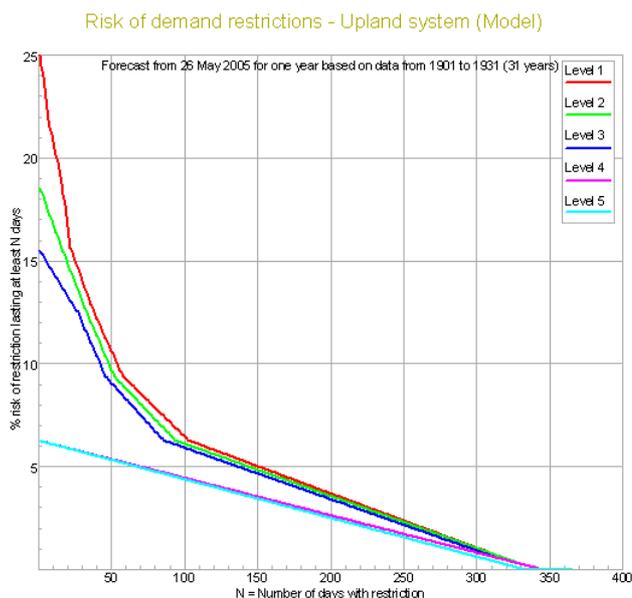
The second type of risk can be applied to individual reservoirs or reservoir groups. The following chart, produced by this analyzer, shows the graphical output for the analysis applied to a reservoir group. For any date up to a year ahead (x axis), the risk of reservoir storage being at or below a certain level (y axis) is calculated. Reservoir storage can be presented in mega-litres or as percent full:

Storage risk - Main reservoir (RV1)
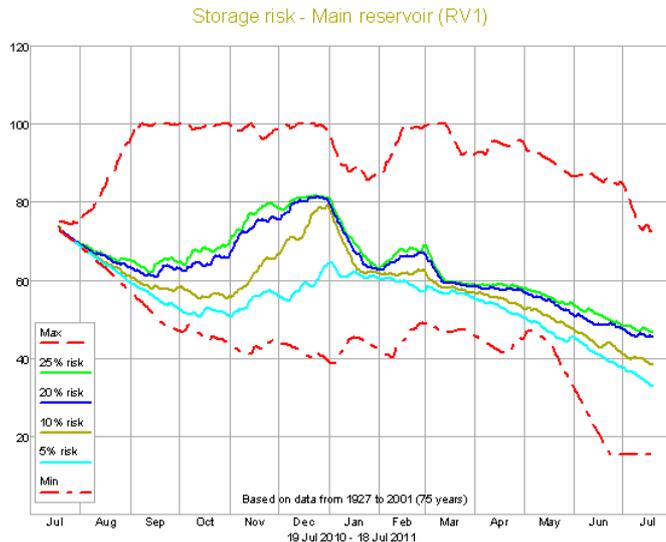
One run of the analyzer can generate results for any number of objects for both types of risk.

The analyzer uses a state set chosen by the user to represent current conditions (i.e. level in each reservoir, amount of licence left and catchment state if using a catchment model). This same state set is then used as the starting condition for a number of models run. Let this number of models be "N". Each of the "N" model runs is one year in length and uses a different year of historic data. Each run will therefore use "N" sets of rainfall, evaporation and flow data. Thus from the same staring condition a "N" equally likely sets of demand restrictions and reservoir storages are generated. From these data captured during the "N" model runs it is possible to generate the two charts shown above:

Demand restriction risk calculation

1. For each year the number of days at each demand restriction level is calculated. Higher levels of demand restriction are considered to have triggered lower levels as well. For example a day with a Level 4 restriction would not only count towards the number of days in that year that had a Level 4 restriction but also to the totals for Level 3, Level 2 and Level 1 as well. There are therefore "N" values of number of days for each Level.

2. For each level of demand restriction the number of days at that level within a year are sorted (ranked) into ascending order (1 > N).

3. An array of "N" risk values "R" are calculated based on the rank position "n":
R(N - n + 1) = (100 * n) / (N + 1)

4. For each number of days from 1 to 365/366 linear interpolation is used on the data from 2 & 3 above to get the risk of that number of day's demand restriction occurring at each Level.

5. Risk is plotted against number of days that the restriction is likely to last.

Storage risk calculation

1. For each of the 365/366 days of the "N" model runs reservoir storage is captured. There is therefore "N" possible values of storage on Day 1 and "N" possible values on Day 2 etc.

2. An array of "N" risk values "R" are calculated based on the rank position "n":
R(n) = (100 * n) / (N + 1)

3. For each day, the "N" storage values are sorted into ascending order.

4. For each day linear interpolation/extrapolation is used on 2 & 3 above to obtain the storage associated with each of user chosen risk values.

5. For any date up to a year ahead the risk of reservoir storage being at or below a certain level plotted for each user chosen risk. The maximum modelled storage on any day (Max risk) and the minimum modelled storage (Min risk) is also plotted. Note that if "N" is small extrapolation will produce estimates of user chosen risk that are outside the modelled range (Max risk & Min risk).

Setting up a state set

During the analysis, each 365/366 day run of the model starts using the same state set. Typically this state set would represent the state of the system today. It is probably bets to create a new state set for this purpose. Having done this individual state values can be changed by selecting the appropriate component and changing setting the states to today's values. For example, the current storage would be set for each reservoir:

Group	Name	Units	Value	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	
Storage	Abs. start value	MI	1458																Close
	Rel. start value	%	90.0																Help
Demand saving leve	Yesterday		0																

RV2 (Upstream) States (Default Set) — User-defined group "Group k"
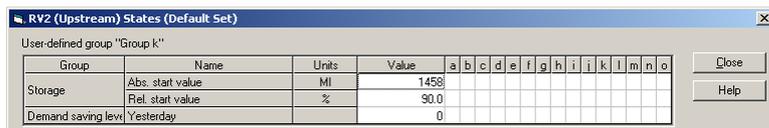
If there are many state values to set for this type of run, it would be advisable to use Aquator's "User defined" edit group facility to

set up a single form for editing the state values. The following example allows two reservoir storages and an annual licence states to be edited in one operation:
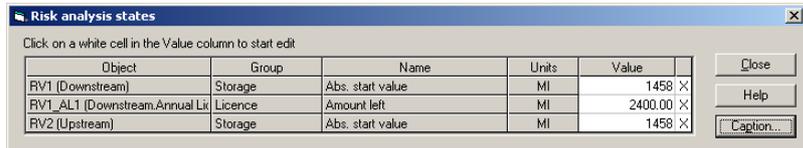
The analyzer form

On selecting this analyzer the following form is displayed:
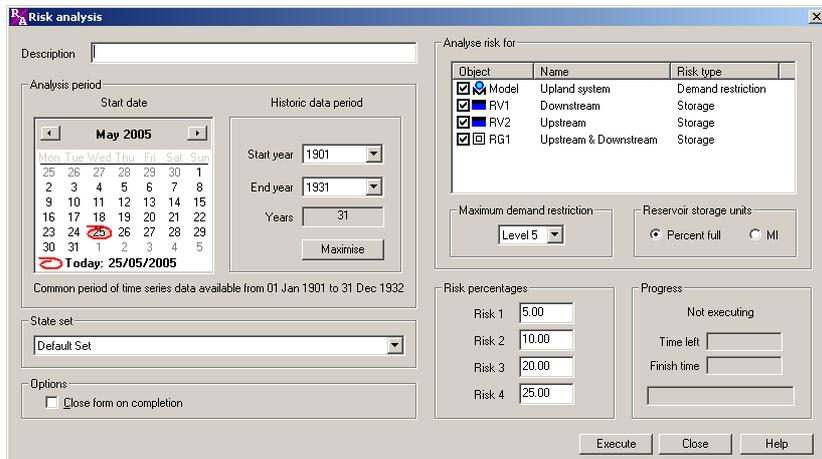
The start date of the "N" model runs is specified on the calendar. The default value for this is today's date. There is no restriction on the start date.

The period of historic data that is to be used in the analysis is specified in terms of a start year and an end year. Normally the maximum number of years possible would be used as more years give a the better estimate of risk.

The "Start year" and "End year" drop down list boxes are filled with years that have time series data available. The analyzer automatically scans the model looking for time series data assigned to the model and all components, checking each time series start and end date. Using the start date currently set on the calendar only complete years are allowed. For example if the start date was set to 25 May 2005, and a time series had start and end dates of 1 April 1920 and 31 March 2005, the first year of data would be 1920 and the last year would be 2003. It is the maximum of all time series start years and minimum of all end years that are used to fill the drop down list boxes.

The selection of the state set to be used in the analysis is made in the lower left drop down list box.

The list box on the right hand side of the form shows all objects that can be included in the analysis. Check those objects that need to be included.

By default the analysis of demand restrictions reports on all five Levels of demand restriction.. In models where less than five Levels are required, this can be specified in the "Maximum demand restriction" list.

Finally the levels of risk in the storage analysis can be specified in the four text boxes in the "Risk percentages" group.

The analyzer results

Examples of the graphical output produced by this analyzer are given above for both types of analysis. In addition tabular data use to plot the charts appears in the results node so that numeric values can be exported from Aquator if required. An example of this for risk of demand restriction is shown below:

Days	Level 1 Risk (%)	Level 2 Risk (%)	Level 3 Risk (%)	Level 4 Risk (%)	Level 5 Risk (%)
1	25.00	18.55	15.51	6.23	6.23
2	24.48	18.36	15.39	6.21	6.21
3	23.96	18.16	15.28	6.20	6.19
4	23.44	17.97	15.16	6.18	6.17
5	22.92	17.77	15.05	6.16	6.16
6	22.40	17.58	14.93	6.14	6.14
7	21.88	17.38	14.81	6.12	6.12
8	21.53	17.19	14.70	6.10	6.10
9	21.18	16.99	14.58	6.09	6.08
10	20.83	16.80	14.47	6.07	6.06
11	20.49	16.60	14.35	6.05	6.04
12	20.14	16.41	14.24	6.03	6.02
13	19.79	16.21	14.12	6.01	6.01
14	19.44	16.02	14.00	6.00	5.99
15	19.10	15.82	13.89	5.98	5.97
16	18.75	15.63	13.77	5.96	5.95

An example of storage risk tabular output follows:

Date	Min % full	5% risk % full	10% risk % full	20% risk % full	25% risk % full	Max % full
19 Jul 2010	73.79	73.79	73.81	73.83	73.84	75.32
20 Jul 2010	72.58	72.61	72.63	72.66	72.70	74.91
21 Jul 2010	72.25	72.26	72.29	72.33	72.38	74.78
22 Jul 2010	71.90	71.93	71.98	72.02	72.07	74.88
23 Jul 2010	71.53	71.59	71.66	71.72	71.80	74.64
24 Jul 2010	71.18	71.27	71.35	71.44	71.48	74.46
25 Jul 2010	70.84	70.94	71.00	71.13	71.20	74.15
26 Jul 2010	70.52	70.61	70.67	70.82	70.93	74.43
27 Jul 2010	70.16	70.27	70.35	70.51	70.63	74.75
28 Jul 2010	69.92	69.95	70.06	70.20	70.30	75.07
29 Jul 2010	69.58	69.63	69.73	69.93	70.05	74.74
30 Jul 2010	69.21	69.30	69.41	69.66	69.76	74.56
31 Jul 2010	68.87	68.98	69.13	69.41	69.67	74.45
01 Aug 2010	68.54	68.66	68.84	69.09	69.43	74.87
02 Aug 2010	68.18	68.30	68.50	68.85	69.20	76.03
03 Aug 2010	67.83	67.94	68.26	68.79	68.99	76.77
04 Aug 2010	67.54	67.59	67.94	68.58	68.73	77.10
05 Aug 2010	67.21	67.27	67.61	68.26	68.62	77.14
06 Aug 2010	66.84	67.00	67.27	67.97	68.39	77.77
07 Aug 2010	66.46	66.80	66.98	67.68	68.18	78.10
08 Aug 2010	66.08	66.60	66.72	67.34	67.93	78.31
09 Aug 2010	65.70	66.27	66.45	67.05	67.62	78.40
10 Aug 2010	65.33	65.94	66.25	66.78	67.34	79.57
11 Aug 2010	64.96	65.64	66.13	66.84	67.10	80.73
12 Aug 2010	64.61	65.31	65.80	66.79	67.08	81.30
13 Aug 2010	64.27	64.97	65.47	66.56	67.25	81.75
14 Aug 2010	63.94	64.64	65.22	66.42	66.97	82.46

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

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

Group	Name
Risk Analysis	Description
	End year
	Exit on completion
	Last state set
	Maximum demand saving level
	Object list
	Reservoir units as Ml
	Risk percentages
	Start date

Group	Name
	Start year

States

An Analyzer 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 Analyzer.

Variables

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

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer 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).

There are no sequences for this type of Analyzer.

River flow analysis

  River flow analysis (flow duration & low flow frequency)

This analyzer carries out standard hydrological analysis techniques on flow series. Two techniques are supported – Flow Duration analysis and Low Flow Frequency analysis.

Flow frequency analysis has similar applications to flow duration analysis. They both help quantify the low flow regime of a river. However, because the frequency is expressed in terms of return period in years in the flow frequency technique, it is more suitable for describing rare events with return periods of 10 to 25 years. Consequently, it is important to note that the 90% exceedance probability on the flow duration curve is a more common event than the 90% exceedance probability (10 year return period) on the flow frequency curve.

In Aquator, both techniques can operate on time series data stored on the database and/or model run results.

In addition both techniques also support the analysis of more than one series at a time. For example it is possible to produce a single

chart showing two or more flow duration curves for modelled flow generated from a number of model runs.

Results can be presented in a choice of units including Ml/d, m^3s^{-1} and non dimensional forms.

On selecting this analyzer the following form is displayed:

The selection of time series data to be included in the analysis is common for both the flow duration and low flow frequency techniques. At least one time series must be chosen for analysis on the "Time series" tab before either analysis can proceed.

Any flow series stored on the database can be included by checking the appropriate series in the upper right list box. Model run results can also be included by firstly selecting the correct model run from the drop down list and then checking the appropriate result variable in the lower right list box.

The following form shows three series selected, two from time series stored on the database (in blue) and one result series (in green).

Having selected the data for analysis, proceed to the required analysis method by selecting the appropriate tab – "Flow duration" or "Low flow frequency".

Flow duration analysis

Flow duration analysis gives the percentage of time a particular flow value is equalled or exceeded. For example a 95 percentile flow of 12.45 m^3s^{-1}, means that for 95% of the time the flow is at or above 12.45 m^3s^{-1} (often called Q_{95}).

There are number of options that can be set for the analysis which control the calculations and the form of output. The following form shows the "Flow duration" tab where these parameters are located:
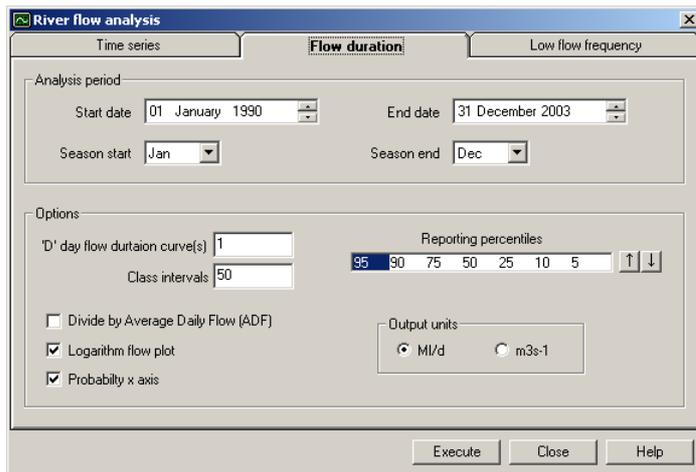
Analysis period

It is here that the period over which data are to be analysed is chosen. If no data exists on a particular day it is counted as a 'missing' value. Data could be missing from a time series stored on the database (as Aquator supports missing values) or, in the case of a model run result, the dates of the model run may not fully cover the analysis period chosen.

A seasonal flow duration analysis may be carried out by specifying start and end month to the season. Seasons can span the end of a calendar year by setting the start month of the season to a later month than the end month of the season (e.g. Oct – Mar covers the six months Oct, Nov, Dec, Jan, Feb & Mar).

Options

The analysis may be carried out on single daily values if 'D' day flow duration curve is set to 1. Alternatively this parameter can be set to values greater than 1 up to a maximum of 180. In this case successive, overlapping, periods of 'D' days are used in the analysis. For example if set to 5, the mean flow over days 1-5 is taken as the first time period; the mean flow over days 2-6 is taken as the second time period.

Concurrent analysis of the selected series for multiple "D" day intervals is possible by setting a number of values for this parameter using a comma as a separator. For example the 1 day, 10 day and 30 day flow durations curves may be calculated in one execution and results plotted on a single graph by setting this parameter to 1,10,30.

The number of class intervals is used during the calculations to categorise the flows. If set to 50, for example, the range of flows encountered (maximum – minimum) is divided by 50 and the number of flows in each interval counted. Class intervals are created on a logarithmic scale to help produce a more even distribution of flows in each interval. Setting the number of class intervals too small will reduce the accuracy of the analysis; setting it too large may result in less smooth flow duration curves.

The analysis calculates and reports the average daily flow (ADF) of the whole period of the analysis, taking into account any seasonal settings. The ADF may be used to standardise the analysis and produce the flow duration curves in non dimensional form. If this is required, check the 'Divide by average daily flow (ADF)' option.

The flow duration curve produced by the analysis has a probability x axis as the default as this tends to produce straighter flow duration curves. If the 'Probability x axis' check box is un-ticked, this produces plots with a linear x axis. Flow is shown on the y axis and can be linear or logarithmic. Check the 'Logarithm flow' option to produce a logarithmic plot. Many river flow sequences

plot better (i.e. a straighter line) using the logarithm of flows. This is because log flows tend to be normally distributed.

The five reporting percentiles may be changed using the 'Reporting percentiles' control. An example of this would be if the 98 percentile flow was required rather than the 95 percentile flow.

Finally the results can be presented in either Ml/d, m^3s^{-1}.

Analysis results

The analysis produces three types of output. The first is the flow duration table where each reporting percentile is shown for each series:

```
                        Flow duration table
                        -------------------

       Start date:  1 Jan 1970                 Time interval (days) = 1
       End date:   31 Dec 1984                 Intervals in period  = 5479

Series    1: Station 1
Series    2: Station 2

                        Series 1    Series 2
Intervals with data        5309        5110
Intervals missing           170         369

Average daily flow        0.634       0.389

 95 percentile (Q95)      0.007       0.013
 90 percentile (Q90)      0.011       0.022
 75 percentile (Q75)      0.019       0.041
 50 percentile (Q50)      0.057       0.082
 25 percentile (Q25)      0.204       0.260
 10 percentile (Q10)      1.041       0.870
  5 percentile (Q5)       2.941       1.616

    Average daily flow units:  Ml/d
    Percentile units:          Ml/d
```

The second form of output is the class interval data:

Interval	Class (Ml/d)	% in class	Class (Ml/d)	% in class
1	0.0000	100.0	0.0000	100.0
2	0.0001	99.5	0.0001	99.9
3	0.0002	99.5	0.0002	99.9
4	0.0002	99.5	0.0002	99.9
5	0.0003	99.5	0.0003	99.9
6	0.0004	99.5	0.0004	99.9
7	0.0005	99.5	0.0005	99.9
8	0.0006	99.5	0.0006	99.9
9	0.0008	99.5	0.0008	99.9
10	0.0011	99.5	0.0011	99.9
40	3.3306	4.4	2.6854	2.6
41	4.3499	3.4	3.4880	1.7
42	5.6813	2.7	4.5305	1.1
43	7.4200	2.1	5.8845	0.6
44	9.6910	1.3	7.6432	0.4
45	12.6570	0.9	9.9275	0.3
46	16.5308	0.5	12.8945	0.2
47	21.5901	0.3	16.7482	0.1
48	28.1979	0.2	21.7537	0.1
49	36.8281	0.1	28.2551	0.1
50	48.0995	0.0	36.6997	0.0

The third form output is a table of the all interpolated percentiles between 2 and 98%:

Percentile	Kinkell Bridge recorded flows (1 day)	Old Flows - Kinkell plus compen 0.3 (1 day)
2	8428.382	8745.592
3	7333.260	7531.870
4	6710.806	6946.965
5	6228.291	6400.494
6	5816.045	5994.000
7	5483.329	5721.435
8	5184.359	5451.487
9	4982.574	5193.364
10	4788.983	4935.240
11	4611.982	4749.312
12	4456.932	4564.049
13	4301.882	4381.130
14	4162.564	4205.141
15	4033.300	4029.152
16	3904.037	3871.080
17	3781.900	3721.959
18	3665.755	3572.839
19	3549.610	3448.105

The fourth form output is the flow duration curve:

Flow Duration Curve
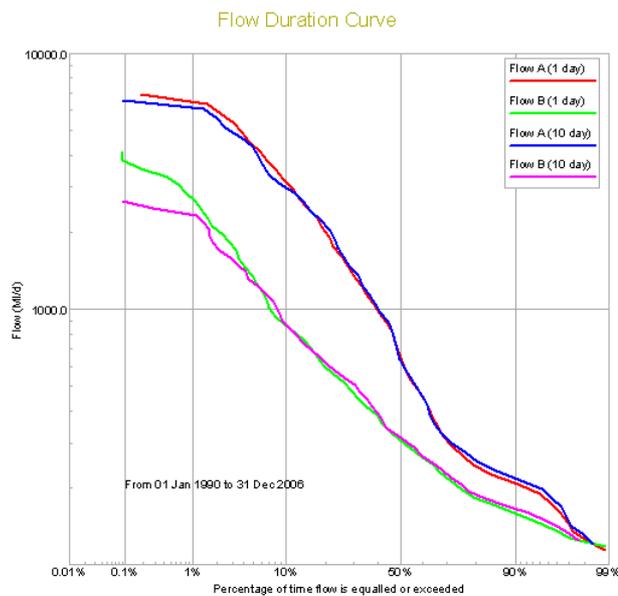
Low flow frequency analysis

Low flow frequency analysis provides the return period of low flow events. For example the one in ten year return period, 1 day, low flow might be estimated at 23.44 m^3s^{-1}. This means that on average, the minimum daily flow in a each year, is at or below 23.44 m^3s^{-1} once every ten years.

There are number of options that can be set for the analysis which control the calculations and the form of the output. The following
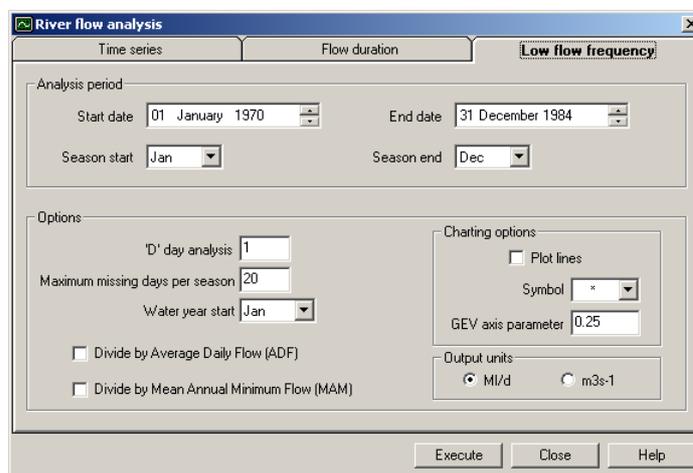
form shows the "Flow duration" tab where these parameters are located:

Analysis period

It is here that the period over which data are to be analysed is chosen. If no data exists on a particular day it is counted as a 'missing' value. Data could be missing from a time series stored on the database (as Aquator supports missing values) or, in the case of a model run result, the dates of the model run may not fully cover the analysis period chosen.

A seasonal low flow frequency analysis may be carried out by specifying start and end month to the season. Seasons can span the end of a calendar year by setting the start month of the season to a later month than the end month of the season (e.g. Oct – Mar covers the six months Oct, Nov, Dec, Jan, Feb & Mar).

Options

The analysis may be carried out on single daily values if 'D' day analysis is set to 1. Alternatively this parameter can be set to values greater than 1 up to a maximum of 180. In this case successive, overlapping, periods of 'D' days are used in the analysis. For example if set to 5, the mean flow over days 1-5 is taken as the first time period; the mean flow over days 2-6 is taken as the second time period.

The analysis looks at water years starting with the month specified in the 'Water year start' drop down list. Within each water year, data are used only from within the defined season. The year is discarded from the analysis if there are too many missing daily values in the season. This limit is set by the 'maximum missing days per season' parameter.

It is the minimum of the 'D' day flows that are found each season that are taken forward in the analysis. These minima may be converted to m^3s^{-1} or a non dimensional form by dividing by either:

- The Average Daily Flow (ADF) calculated from within the season

- The mean of the annual minima, Mean Annual Minimum (MAM)

The 'Charting options' parameters allow the format of the graphical output to be changed. Either or both lines and points may be drawn and the form of the x axis (GEV) changed. This should be set to 0.25 for a Weibull Distribution but must be in the range –0.25 to +0.25. (see below)

Method

The statistical calculations are based on the method described in the *Low Flow Studies Report*, **_Institute of Hydrology_**, *January 1980, Report Number 1 (page 10)* and outlined here:

The *exceedance* probability of any of the annual minima, $P_{(i)}$, is calculated as:

$$P_{(i)} = (i – 0.44) / (N + 0.12)$$

where:

i = rank (range: 1 to N)

N = number of years

The return period, $T_{(i)}$, can be derived from the *exceedance* probability:

$$T_{(i)} = (1 - P_{(i)})^{-1}$$

The x axis (return period) is of type General extreme value (GEV). $T_{(i)}$ is converted to plotting position, $X_{(i)}$, using:

$$X_{(i)} = [1 – exp (-kz_{(i)})] / k$$

where:

$$z_{(i)} = - ln [-ln \{ (T_{(i)} – 1) / T_{(i)} \}]$$

The Weibull distribution

The *Low Flow Studies Report* recommends the use of the *Weibull* form of the GEV (k = 0.25) to determine plotting position, $W_{(i)}$:

$$W_{(i)} = [1 – exp (-0.25 * z_{(i)})] / 0.25$$

This analysis module uses a value of k = 0.25 by default, but this may be changed to any value in the range –0.25 to +0.25 to permit experimentation with different forms of the GEV (see above).

Analysis results

The analysis produces two types of output. The first is a table giving the low flows ranked and return periods assigned. There is one such table for each series analysed:

```
                    Low Flow Frequency Analysis
                    ---------------------------

         Series:      Station 1

         Start date:  1 Jan 1970            Time interval (days) = 1
         End date:    31 Dec 1984           Water year start     = Jan

                    Seasonal analysis between Jan and Apr

         Water                                              Exceedance
         Year     Start Date     Rank      Flow    Return period   Probability
         ----     ----------     ----      ----    -------------   -----------

         1975    17 Apr 1975      1        0.027        1.0           0.040
         1977    21 Apr 1977      2        0.019        1.1           0.110
         1971    16 Apr 1971      3        0.017        1.2           0.181
         1976     9 Jan 1976      4        0.015        1.3           0.252
         1983     6 Feb 1983      5        0.013        1.5           0.323
         1972     9 Jan 1972      6        0.013        1.6           0.394
         1978     1 Jan 1978      7        0.013        1.9           0.465
         1973     1 Jan 1973      8        0.011        2.2           0.535
         1982     6 Jan 1982      9        0.010        2.5           0.606
         1974     1 Jan 1974     10        0.009        3.1           0.677
         1981    15 Jan 1981     11        0.006        4.0           0.748
         1979    19 Jan 1979     12        0.002        5.5           0.819
         1984     8 Jan 1984     13        0.001        9.1           0.890
         1980     2 Jan 1980     14        0.000       25.2           0.960
         1970                         Insufficient data


         Flows in Ml/d

         On average the minimum starts 30 days from start of water year

         Average Daily Flow (ADF)      = 1.068 Ml/d
         Mean Annual Minimum Flow (MAM) = 0.011 Ml/d
```
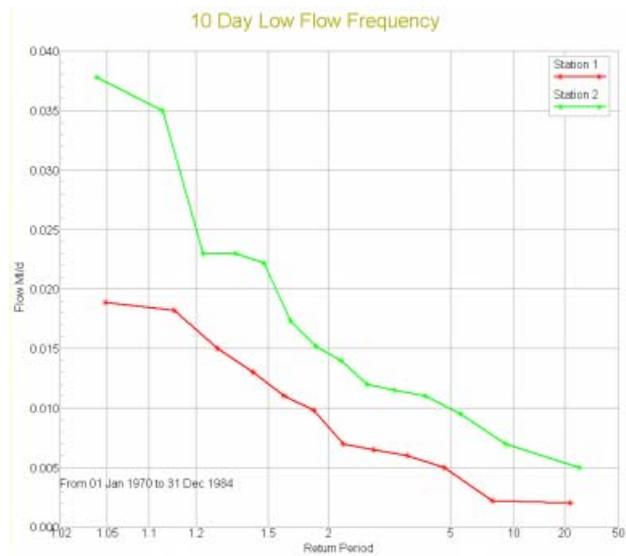
The second type of output is the low flow frequency plot:

10 Day Low Flow Frequency

Properties

An Analyzer only has one set of properties. Properties do not change during a model run.

There are no properties for this type of Analyzer.

Parameters

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

Group	Name
River Flow Analysis FDC	Start date
	End date
	Season start month
	Season end month
	"D" day FDC
	Divide by ADF
	Percentiles
	Output units
	Plot log flows
	Classes
River Flow Analysis LFF	Start date
	End date
	Season start month

Group	Name
	Season end month
	Water year start month
	"D" day period
	Max days missing
	Divide by ADF
	Divide by MAM
	Output units
	GEV axis parameter
	Plot lines
	Plot symbol

States

An Analyzer 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 Analyzer.

Variables

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

There are no variables for this type of Analyzer.

Sequences

An Analyzer can have more than one set of sequences. Sequences are a requirement, some times optional, of the Analyzer 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).

There are no sequences for this type of Analyzer.

Properties

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

Parameters

A *Parameter* is a value for an Analyzer 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 would not normally be altered frequently.

EnglishDO.Analysis method

Technique to be used to estimate the deployable output – Binary chop (numeric value = 1) or Step by step increase (numeric value = 2). See *Analysis definition*.

EnglishDO.Demand increment

The amount by which overall demand is increased for successive model runs. See *Applying the analysis*.

EnglishDO.Description

A user supplied line of descriptive text that describes the analysis.

EnglishDO.Enable demand saving triggers

Boolean value (True/False) that determines whether or not failure can be triggered by exceeding the number of demand saving events allowed at each demand saving level.

EnglishDO.Exit on completion

Whether or not the form which controls the analysis is to be left visible after the analysis is complete. See *Applying the analysis*.

EnglishDO.Max demand

The maximum overall demand to apply to chosen demand centres. See *Applying the analysis*.

EnglishDO.Max demand saving trigger events Level 'n'

The maximum number of demand saving events allowed before a failure is triggered at each of the five demand saving levels.

EnglishDO.Min demand

The overall demand to apply to chosen demand centres for the first model run in the analysis. See *Applying the analysis*.

Risk Analysis.Description

A description of the analysis.

Risk Analysis.End year

End year of historic data to be used in the analysis.

Risk Analysis.Exit on completion

If checked, the analysis form is closed automatically when the analysis has finished executing. If not checked, the form remains.

Risk Analysis.Last state set

State set to be used in the analysis.

Risk Analysis.Maximum demand saving level

The maximum demand saving level to report on.

Risk Analysis.Object list

A list of objects that are to take place in the analysis. This might be the Model and/or reservoirs and/or reservoir groups.

Risk Analysis.Reservoir units as Ml

If set to "True" reservoir storage is presented in mega-litres. If set to "False" reservoir storage as presented in percent full.

Risk Analysis.Risk percentages

An array type parameter that defines the level of risk to be studied in the storage analysis.

Risk Analysis.Start date

Start date of the analysis.

Risk Analysis.Start year

Start year of historic data to be used in the analysis.

River Flow Analysis FDC.Classes

The number of classes or intervals that the flow duration analysis should use. The maximum flow minus the minimum flow over the analysis period give the upper limit of the biggest class and lower limits of the smallest class. Classes are calculated on the logarithms of flows.

River Flow Analysis FDC."D" day FDC

Number of days flow to average to provide one value for analysis. The minimum value is 1 and maximum is 180. For example if "D" is set to 5, the first flow value used in the analysis is the average flow over days 1, 2, 3, 4 & 5; the second flow value is the average flow over days 2, 3, 4, 5 & 6.

Concurrent analysis of the selected series for multiple "D" day intervals is possible by setting a number of values for this parameter using a comma as a separator. For example the 1 day, 10 day and 30 day flow durations curves may be calculated in one execution and results plotted on a single graph by setting this parameter to 1,10,30.

River Flow Analysis FDC.Divide by ADF

Present results in non dimensional form by dividing by the Average Daily Flow (ADF) as calculated within the defined season.

River Flow Analysis FDC.End date

End date for abstracting data for the flow duration analysis.

River Flow Analysis FDC.Output units

Results can be presented in either Ml/d, m^3s^{-1}.

River Flow Analysis FDC.Percentiles

The seven percentiles reported in the results. These are initially 95, 90, 75, 50, 25, 10 and 5.

River Flow Analysis FDC.Plot log flows

Set to True to plot the y axis as logarithms of flow. Typically the logarithms of river flows tend to be normally distributed. Therefore setting this parameter to True should produce plots with straighter lines.

River Flow Analysis FDC. Plot probability x axis

Set to True to use a normal probability x axis or False to use a linear x axis. Typically the logarithms of river flows tend to be normally distributed. Therefore setting this parameter to True should produce plots with straighter lines.

River Flow Analysis FDC.Season end month

See start month above.

River Flow Analysis FDC.Season start month

Start month for a seasonal analysis. Season can be whole year by making start month the month after the end month (e.g. Start = Jan; End = Dec). Seasons can span end of year by making end month earlier than start month (e.g. season Nov, Dec, Jan , Feb, Mar is set by Start = Nov; End = Mar).

River Flow Analysis FDC.Start date

Start date for abstracting data for the flow duration analysis.

River Flow Analysis LFF."D" day period

Number of days flow to average to provide one value as a candidate for the minimum in a year. For example if "D" is set to 5, the first flow value used in the analysis is the average flow over days 1, 2, 3, 4 & 5; the second flow value is the average flow over days 2, 3, 4, 5 & 6.

River Flow Analysis LFF.Divide by ADF

Present results in non dimensional form by dividing by the Average Daily Flow (ADF) as calculated within the defined season.

River Flow Analysis LFF.Divide by MAM

Present results in non dimensional form by dividing by the Mean Annual Minimum (MAM).

River Flow Analysis LFF.End date

End date for abstracting data for the low flow frequency analysis.

River Flow Analysis LFF.GEV axis parameter

The General Extreme Value parameter (range -0.25 to +0.25). This affects the position of each return period on the x axis. Set to 0.25 for the Weibull distribution

River Flow Analysis LFF.Max days missing

The maximum number of days that are allowed to be missing within the season before the year is excluded from the analysis.

River Flow Analysis LFF.Output units

Results can be presented in either Ml/d, m^3s^{-1}.

River Flow Analysis LFF.Plot lines

Set to true to draw lines between the annual minima points on the chart..

River Flow Analysis LFF.Plot symbol

Select the type of symbol to use when plotting the annual minima. Can be none.

River Flow Analysis LFF.Start date

Start date for abstracting data for the low flow frequency analysis.

River Flow Analysis LFF.Season end month

See start month above.

River Flow Analysis LFF.Season start month

Start month for a seasonal analysis. Season can be whole year by making start month the month after the end month (e.g. Start = Jan; End = Dec). Seasons can span end of year by making end month earlier than start month (e.g. season Nov, Dec, Jan , Feb, Mar is set by Start = Nov; End = Mar).

River Flow Analysis LFF.Water year start month

The analysis can use water years starting in any calendar month.

ScottishDO.Analysis type

Can be either "Full analysis" or "Excel control" (stored as values 1 and 2 respectively). See *Method and applying the analysis*.

ScottishDO.Control cell

The name of the cell in the Excel control spreadsheet that has the run control information (e.g. "A1"). See *Method and applying the analysis*.

ScottishDO.Control spreadsheet

The name and location of the Excel control spreadsheet (e.g. "C:\ScottishDO.xls"). See *Method and applying the analysis*.

ScottishDO.Control worksheet

The name of the worksheet in the Excel control spreadsheet that has the run control information (e.g. "Sheet1"). See *Method and applying the analysis*.

ScottishDO.Demand increment

The amount by which overall demand is increased for succesive model runs. See *Method and applying the analysis*.

ScottishDO.Demand increment reduction

The current demand step is divided by this number to allow additional model runs at intermediate Overall demands in an attempt to find a missing number of Failure years. See *Method and applying the analysis*.

ScottishDO.Exit on completion

If checked, the analysis form is closed automatically when the analysis has finished executing. If not checked, the form remains to view the intermediate results on the grid or so that another analysis can be undertaken. The final analysis results are shown on the tree view in the project window.

ScottishDO.GEV parameter

The General Extreme Value distribution parameter. Set to 0.25 for a *Weibull Distribution*. See *Method and applying the analysis.*

ScottishDO.Max demand

The maximum overall system demand for any model run in the analysis. See See *Method and applying the analysis.*

ScottishDO.Max yield step

The maximum step up in demand for an increase in number of failures (for use with spreadsheet). See *Method and applying the analysis.*

ScottishDO.Min demand

The overall system demand for the first model run in the analysis. See *Method and applying the analysis.*

ScottishDO.Minimum demand increment

When the current demand step is divided by parameter "ScottishDO.Demand increment reduction" to allow additional model runs at intermediate Overall demands in an attempt to find a missing number of Failure years, this parameter specifies the minimum step size before the attempt is aborted. See *Method and applying the analysis.*

ScottishDO.Return periods

Required return period entered as a comma separated string (e.g. "5, 10, 20, 50, 100"). See *Method and applying the analysis.*

ScottishDO.Start month

The start month for the water year to be used in the analysis. See *Method and applying the analysis.*

States

A *State* is a value for an Analyzer 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 on the first day of the run would typically vary from run to run.

Variables

A *Variable* is a value 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 Component can be captured in a variable so that both observed and calculated storage can be plotted on the same chart.

Sequences

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