Southern Africa FRIEND Phase II

ARIDA

Assessment of the Regional Impact of Drought in Africa

Operation Manual

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Contents

1   Introduction

The ARIDA software is a tool for drought monitoring and assessment based on DFID-funded research conducted by the Centre for Ecology and Hydrology into methods of analysing steam-flow data for these purposes.

The tools presented in this software package provide useful techniques for application in Southern Africa, and, given analysis of appropriate regional data, for application in other parts of the world. It will provide water managers in particular with a useful addition to their analysis tools. The potential to be linked to real-time data from the SADC-HYCOS project means that the software will become increasingly useful as greater volumes of flow data from benchmark stations become available.

This manual describes the research involved and the application of the methods used and includes a step-by-step guide to using the software.

2   Background

Drought is perhaps the most complex and least understood of natural hazards. The devastating impacts of drought in several regions have received much attention, most notably the large-scale famines leading to high death rates which have occurred in Central and Eastern Africa on a number of occasions since the 1970s. Droughts in Southern Africa have received less world-wide media attention despite their devastating environmental, sociological, financial and political implications. Such droughts are continuing to affect greater numbers of people, particularly the poor population who have traditionally had lower levels of reliability of access to fresh water supplies. The need to urgently address this water resources problem is accentuated by the water scarce situation that is developing in the region with increasing levels of population, higher levels of urbanisation, and possible climate change. Although there has been some progress in improving the ability of societies to mitigate the impacts of drought in the short term and reduce vulnerability in the longer term, it still appears that responses, both at the national and international levels, are often woefully inadequate.

The ARIDA project arose from the need for more practical tools for assessing the impacts of drought on water resources. The project has concentrated on stream-flow droughts, as these are key indicators of drought in water resources systems. The objectives were to provide improved capabilities for effective assessment of stream-flow droughts in Southern Africa, and to develop tools and software that can be used to analyse historic and monitor current droughts. An additional objective was to ensure that the methods are appropriate to the particular hydrological characteristics of the Southern African region.

2.1   ARIDA research

Detailed analyses of drought characteristics were conducted on data from fifteen flow gauging stations, selected to represent the variety of geomorphological conditions, catchment sizes, climates and hydrological regimes found across the Southern African region.   The majority of the data were taken from the Southern Africa FRIEND database (Flow Regimes from International Experimental and Network Data). The stations were also selected to have the longest records possible to give larger data sets, with the minimum of artificial modification to flow regimes, so that the techniques of analysis could be widely applied.

Under the ongoing SADC (Southern African Development Community) HYCOS (Hydrological Cycle Observing System) project, flow data are available in near real-time at linked databases in each SADC country. The SADC-HYCOS project is part of a WMO initiative to improve hydrometric networks in several regions around the world. The tools and methods developed in the ARIDA study, and disseminated throughout the SADC region, can be linked to the same databases, thereby benefiting from the rapid availability of stream-flow data to give more reliable and readily available drought information. In this way, they can provide useful techniques for application in Southern Africa, particularly by water resources planners and hydrologists needing to plan for periods of water shortage. The ability to plan for periods of drought should assist water resources managers to decide which demand

management techniques to apply, and when to apply them, to ensure that water supply is more reliable and fewer people are subjected to water shortages.

With water scarcity becoming an increasing problem throughout the world and not just in the SADC region, techniques and tools which can assist water resources managers to plan ahead for drought situations will be invaluable. The complexities of drought behaviour in different environments, the varying availability of data, and the different end-user requirements mean that no single approach to the assessment of stream-flow droughts is satisfactory across the whole Southern African region. Because of this, a variety of methods were considered for the analysis of historic droughts; they are not all applicable everywhere, but they are all incorporated into the software and by using a combination of approaches a satisfactory analysis can be carried out across the whole region.

2.2   Drought analysis methods

Five methods for analysis and assessment of drought are included in the software. Below is a short summary of each. Section 4 of this manual explains these methods in detail.

Low flow frequency analysis. Stream-flow droughts are characterised in terms of the annual minimum discharge averaged over a range of durations. A probability distribution is then fitted to the annual minima, from which the estimated return period of a drought event can be extracted.

Run-sum analysis. Stream-flow droughts are defined when the flow in a river falls below a pre-determined threshold, such as the flow that is exceeded for 70% of the time (the Q70 flow value). For the analysis of short, or within-year, droughts daily flow data are used. Suitable threshold values should be user-determined, dependent on the type of flow regime; for example, a different threshold is required for ephemeral rivers (having a large proportion of zero flows) from rivers where the flow is more reliably high throughout the year. Methods for removing a number of complicating factors (such as small peaks of flow serving to split an otherwise continuous drought event, whilst not contributing any remedial effect) in the definition of drought periods have been determined (*e.g.* the moving average technique). Statistical analyses of the drought duration data derived from the run-sum method are carried out using a partial duration series approach. For the analysis of long, or multi-year, droughts annual flow data are used and the threshold is defined as the mean flow, since it standardises the severities of high and low flows, and gives more emphasis to the extremes of the distribution, both key considerations in drought analyses.

Accumulated runoff analysis

This method is useful in it provides a good, clear visual impression of the flow events in the context of the behaviour of previous years. It compares the cumulative flow up to a particular day of interest with the cumulative flow on the same day of the year from the historic data set.

Monthly bulletin output analysis.

This method ranks the present flow situation with respect to the historic flow record, and presents this information graphically so that the severity of the present situation can easily be viewed against the situation in any previous *X*-year period.

2.3   Application to different river regimes

Low flow frequency analysis has been found to have limitations, particularly in the more arid parts of the Southern African region. The accumulated runoff and bulletin output methods provide limited information on statistical drought properties though can be used to provide a good contextual picture of drought severity through a drought period. Overall, the two run-sum analysis approaches – using daily data for short droughts and using annual data for multi-year droughts – give the broadest picture of different types of drought (having different levels of human impact) and provide perhaps the most useful picture of drought from stream-flow data. The ability to use a range of different thresholds means that the method can be applied over the whole range of flow regimes found in the region, although the threshold must be selected by an experienced water resources manager to have significance for the water resources system in question. No single threshold can be recommended here since a particular level of drought will have a different significance for different applications.

3 Technical overview

3.1 Database

HYDATA is used as the principle national hydrological archive in most of the SADC countries and was installed in all of the countries as part of the SADC-HYCOS project for storing the real-time data. ARIDA has been designed to link directly to HYDATA databases of version 4.1 or later.

3.1.1 Data

All of the methods in ARIDA use daily flow data. Any stage data must be converted to daily flow data using an appropriate rating equation or table before the methods can be used.

3.2 Installation

The software has been designed to minimise run-time changes to the system files and registry of the computer onto which it is installed. However during installation, as for any piece of software, it is necessary to install the most recent versions of any system files. All of these files will be back compatible and will therefore not affect the ability of the computer to run software previously installed. If there *are* any concerns over the changes made to system files during installation, these should be taken up with the Centre for Ecology and Hydrology. The Centre for Ecology and Hydrology does not take responsibility for any problems occurring due to the installation or use of this software.

3.2.1 Hardware

It is recommended that the ARIDA software is used on PC's with a minimum specification of P100MHz, 32MB RAM running Windows 95 or later and with a screen size of 16 inches. Roughly 3 MB of hard disk space will be needed. Use on machines below this standard will impair performance. The software can be used across a Windows network and also on a networked PC.

3.2.2 Setting up the ARIDA software

The following is a brief guide to installing ARIDA on your computer. For a more detailed set of instructions, or if any problems arise during installation, please see the document 'Installation Notes.doc' provided on the CD.

- Insert the ARIDA CD into your CD drive.

- Run the setup program by either:

  1. Opening Windows Explorer and double-clicking the item **'Setup.exe'** from the list of files in the directory **'ARIDA'** on the CD drive.
  2. Running the setup.exe program through the **'Start' | 'Run…'** command line.

The setup program will ask you to choose a suitable directory for the application. Select the directory in which HYDATA is installed (usually 'C:\Program

Files\Institute of Hydrology\HYDATA 4.2.'). The program will install the ARIDA software to this folder.

The setup program will ask under which 'Start' menu item you wish to store the application. Leave this as 'IH Software'.

The setup program will then install the necessary programs and may ask you to restart the computer at the end of the installation.
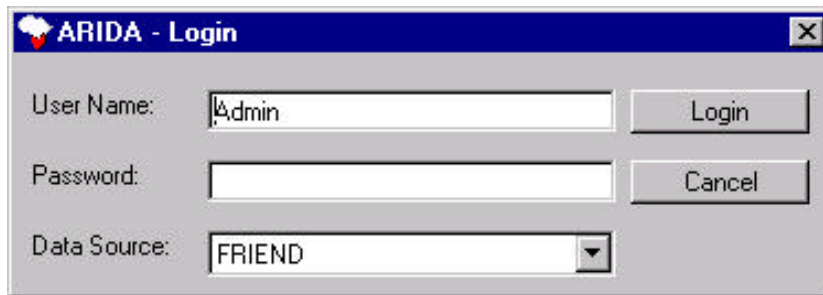
If any problems occur in the installation, please refer to the document 'Installation notes.doc' stored on the CD.

4   Getting started

To run the ARIDA software go to **'Start'|'Programs'|'IH software'|'ARIDA'** or double click the ARIDA icon on the desktop or in the directory where the software was installed (usually 'C:\Program Files\Institute of Hydrology\HYDATA 4.2.').

4.1   Login

This will open the ARIDA login screen below. Select the HYDATA database from the 'Data Source' list and login using the normal HYDATA username and password.

Login screen

When run with larger databases the ARIDA software will take longer to start-up. On login, the main form should appear with the ARIDA splash screen and a progress-bar at the bottom.

4.2   Summary of options available in ARIDA

The main form allows the user to access the functionality of the software through a number of menu options. These are summarised below:

File
Print and printer setup and exit options.

Edit
'Copy' option for copying forms to the Windows clipboard and then to other documents (e.g. MS Word).

Reports
Access to the reports generated by ARIDA. A 'report wizard' for designing reports on any station using a number of the available methods. A number of pre-designed reports are also available.

Low flow & drought analysis
This option allows the user to select a drought analysis method and then to select a station to which to apply the method. The appropriateness of the method for the river regime can be examined and the parameters altered. Parameters for each station and method can be saved for future use. Graphs and tables of results can be printed for each station individually and tailored for use in reports.

Advanced

Default parameters and graph settings for each ARIDA method are saved and applied to any station where these settings have not been individually saved. These can be altered through a number of forms accessible through the 'Advanced' menu. Methods for 'patching' periods of missing data are also available.
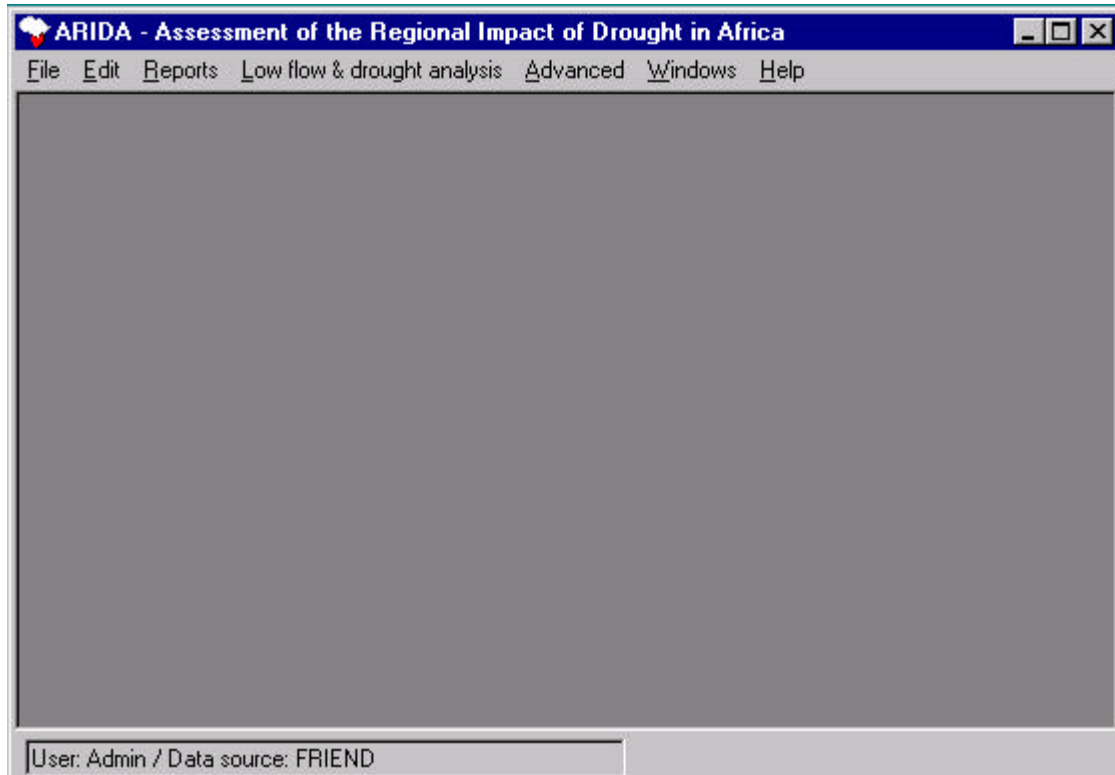
Main form

Windows

Lists the windows opened and allows them to be selected or closed.

Help

Information about the ARIDA software and an online version of this manual is available.

5   Low flow & drought analysis

All of the drought analysis and assessment methods used in the ARIDA software can be accessed through the 'Low flow & drought analysis' option on the main form.

5.1   General use

In general each of these methods has a number of variable parameters to be input by the user. The method can then be run and a table and graph of results is produced for examination. The parameter setting, table and graph forms are easily accessible to allow the user to make adjustments to the parameters, run the method and quickly see the effects of these adjustments on the results.

Single graphs and tables can be printed using the buttons on the forms.

Once appropriate parameters and/or graph settings for a station have been found they can be saved and used in reports to override the more general default settings.

It is thought that the user would initially make a detailed assessment of each method at each station at which drought assessment is required and save the settings for this station. It would then be simple to quickly produce graphs, tables and reports when new data is entered and the current drought period needs assessing.

5.1.1   'Current' date

Many of the methods have a 'current date' parameter. This allows the current drought to be seen in the context of historical droughts at the station. By default the 'current date' is the last date for which data is available at the station because real-time data is often not available. The 'current date' can also be changed to see how any drought would have been assessed at the time (although the full record of data would, of course, not have been available). It is hoped that this flexibility will not cause confusion but will allow the user greater insight into the use of the software.

5.1.2   Using the low flow & drought analysis forms

Each method displays a windows form with a number of tabs across the top. These tabs are used to access the parameters, tables and graphs of results. Clicking on the tabs will allow the user to switch back-and-forth quickly between each. The forms should be automatically sized to fit the screen and can be resized, to a certain extent, to suit the user. On some computers opening multiple forms at the same time may slow the computer down, sometimes significantly. For this reason it is recommended that only one form is opened at any time when running ARIDA on slower computers.

5.1.3   Copying and printing tables and graphs

Each table and graph has buttons to allow the user to print and copy the graph or table to the clipboard. Tables will be printed as simple text files as seen on the screen – any edits made to the text on the screen will be printed or copied to the clipboard. Once copied, tables can be pasted from the clipboard into standard Windows documents

such as Word or Excel. Before copying or printing graphs the user should resize the form to create the best aspect ratio as this will be reflected in the resulting graph.

5.1.4 Changing graph settings

The appearance of any graph can be changed by altering the x- and y-axes, titles, setting logarithmic axes, showing legends, etc. To do this click on the graph area of any graph to show the relevant graph options form. Alter the settings and click **'OK'** to apply the changes to the graph. Click **'Cancel'** to discard changes. To save graph settings for future use at a station, open the graph options form and click **'Save'**.

5.1.5 Saving parameters and graph settings

Wherever parameters can be altered for a method there is a button that allows the user to save these for future use. When the software is first used the method parameters and graph settings that appear for each station are the defaults (see 'Changing default settings' section 7.2 for details). After saving parameters, each time the method and station are selected the form will appear displaying the saved parameters.

These saved parameters can then be used when producing reports (see section 6).

5.2   Low flow frequency analysis

5.2.1   Background to low flow frequency analysis

The low flow frequency analysis method creates flow frequency plots of the annual minima. Data are averaged over one or more D-day periods before the minima are found. These minima are ranked from highest to lowest and assigned exceedance probabilities using the Gringorten formula for probability of the i-th ranked event of N, considered suitable for a range of distributions:

$$P_i = (i\text{-}0.44) / (N\text{+}0.12)$$

In order to represent this graphically a plotting position, W_i, for each point was assigned using the Weibull formula:

$$W_i = 4[1\text{-}\{\text{-}\ln(P_i)\}^{0.25}]$$

The data is plotted as flow or percentage of mean flow against plotting position and a return period axis added by calculating a range of return periods, T_i, using:

$$T_i = 1/(1\text{-}P_i) \quad = (1\text{-}\exp[\text{-}\{1\text{-}W_i/4\}^4])^{\text{-}1}$$

A probability distribution, selected by the user, is fitted to the data and plotted on the graph. This is performed by the following process:

  i.   Probability weighted sample L-Moments are calculated from the data ranked from lowest to highest.
 ii.   The sample L-Moments are used to estimate the parameters of the (non-exceedance) probability distribution.
iii.   The probabilities of flows across the range of the graph are calculated using the distribution and the estimated parameters. The probabilities are then converted to exceedance probabilities and the plotting positions found using the Weibull formula above.

This flow frequency plot gives the user a graphical representation of the range of the annual minima, and a distribution from which to estimate the return period of future annual minima. The correlation coefficient of the distribution with the data is provided to guide the user on the accuracy of such estimations.

The method gives no indication of the duration or severity (cumulative deficit of water volume) of a drought, just the minimum flow each year.

Much discussion has been made of fitting probability distributions to annual minima sequences containing zero flow years. Strictly speaking, this method is not appropriate for such sequences. The method in ARIDA fits the distribution to the data including the zero flow years. This means that any distribution with more than a small percentage of zero years will not be valid. This will be evident from the graph.

This approach does not require complete years of data to produce flow frequency curves, however ARIDA allows a user defined tolerance in the number of days or periods to be set for excluding years with missing data. Obviously data missing from

the dry period of a year is likely to affect the annual minimum found whereas missing data from periods of high flow should not affect results.

ARIDA also allows the user to select the D-day period duration, the period over which the flow is averaged before the annual minimum is found, from 1, 7, 10, 30, 60 and 180 days.

5.2.2   Using low flow frequency analysis

From the main form select **'Low flow & drought analysis'|'Low flow frequency analysis'**.

This will open the form below:

Low flow frequency analysis time series selection form

▪ Select the station and time series of interest from the list. Clicking on the list's column headers will sort the entries by station number, station name or time series name.

▪ Select the start and end years using the drop down boxes.

▪ Click **'OK'** to open the **'Low flow analysis form'** or cancel to quit.

5.2.3   Low flow frequency analysis form

The low flow frequency analysis form consists of a tabbed dialog box allowing access to three panels showing method settings, a table of annual minima and a low flow frequency graph.

To close the form at any time click on the [X] button in the top right-hand corner.

5.2.3.1   Settings panel

The first panel allows the user to change the analysis parameters and to re-run the analysis.


Low flow frequency analysis settings form

- **Total missing days permitted in year** – allows the user flexibility in using or rejecting years without full datasets. Decisions on whether to use years with missing data should be made by hydrologists considering whether the data is missing from high or low periods and whether D-day smoothing (see below) or patching the data (see section 7.1) would avoid statistical irregularities.

- **Consecutive missing days permitted in year** - allows the user to decide the extent to which years with missing data spread throughout the year missing data spread throughout the year should be included or excluded.

- **D-day periods** - the D-days at which the data is to be smoothed before annual minima are calculated can be selected by the user by highlighting D-day periods in the list of available periods on the right and clicking on the arrows ('<', '>') to add or remove D-days from the list, on the left, of those selected. It is possible to plot more than one D-day sequence on one graph. Smoothing can produce a more useful plot by reflecting the longer-term low flow within each year.

- **Distribution to fit to** - allows a distribution to be chosen. The distributions available are Exponential, Log-Normal, GEV (General Extreme Value) and Pareto.

To save changes in the settings click '**Save station settings**'. These changes will be reflected in reports on this station. To run the analysis click '**Run analysis**' move to the other low flow frequency analysis form panels to view the results.

5.2.3.2   Annual minimum flow table panel

The second tab gives access to a panel showing the annual minimum flows. These are printed as a report, which also lists the settings, made on the settings panel. The table of flows can be ordered by year or by minimum or mean flow for any of the D-day periods.
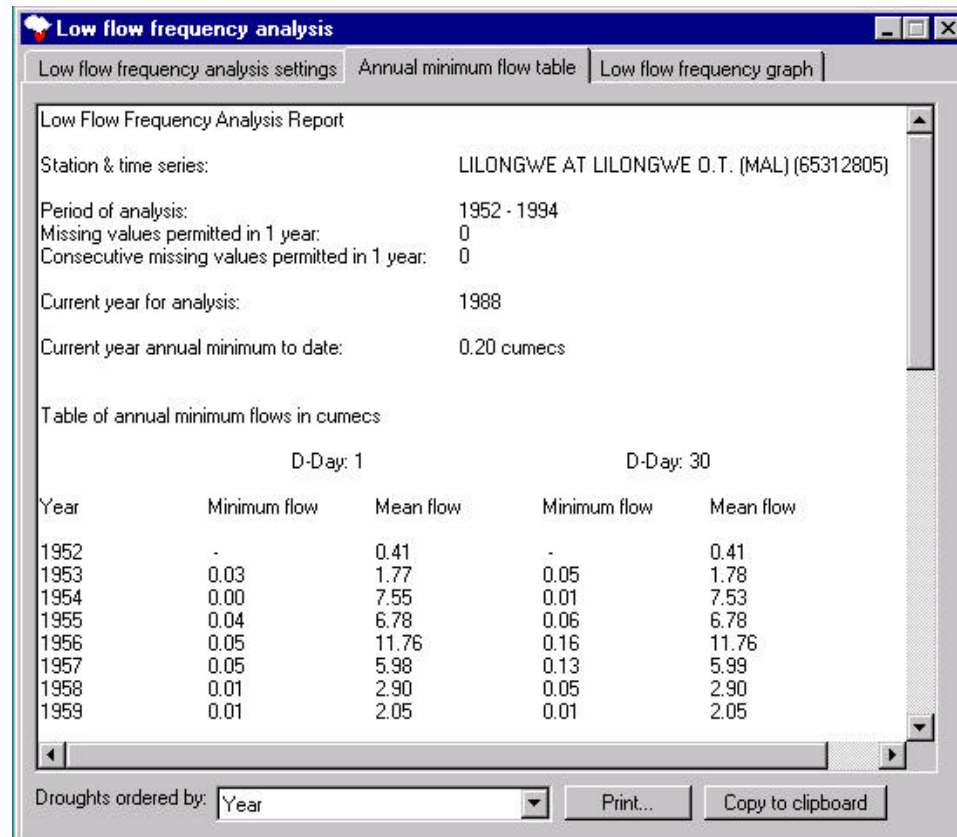

Annual minimum flow table panel

Data can easily be copied and pasted into a spreadsheet for further analysis or printed to any windows-connected printer using the 'Copy to clipboard' and 'Print' buttons at the bottom of the panel.

5.2.3.3   Low flow frequency graph panel

The third tab reveals the low flow frequency graph created with the sequences in the table. The steps involved in creating the graph are listed above in section 5.2.1.
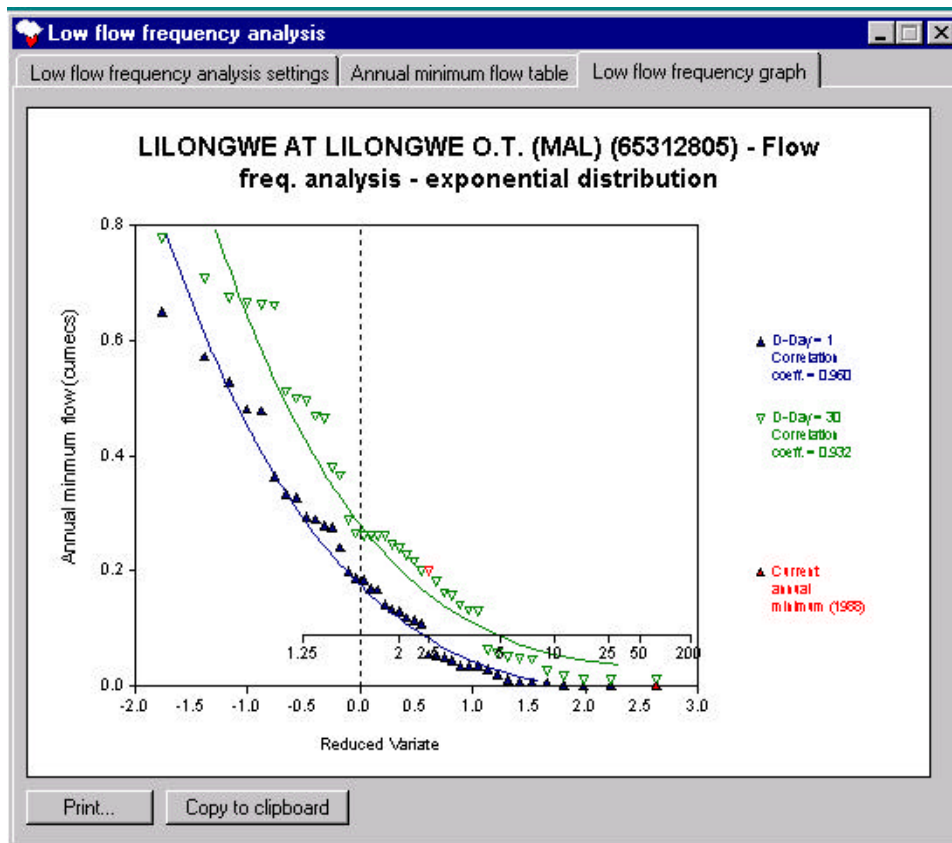
Low flow frequency graph panel

Clicking on the graph reveals the low flow frequency graph options form through which the graph appearance can be altered.

5.3   Run-sum analysis - short drought events

5.3.1   *Background to run-sum analysis*

Run-sum analysis provides the broadest summary of drought events indicating durations, deficits and severity. This method involves selecting a threshold flow to define drought events. Periods of flow below this threshold are found for the length of the record.

The threshold or truncation level is often set as a percentage of the mean flow, but it is normally up to experience and application to determine a suitable level. ARIDA offers different methods for defining the truncation level whilst simultaneously displaying the flow hydrograph thus enabling the level to be set by eye.

Dependent droughts

Often a large drought event may be interrupted by one or more small events which lie above the defined threshold. The large event is broken into several smaller droughts when common sense might say they should be considered as a single drought. These are called 'dependent droughts' and can be pooled to recreate the single large event.

Several methods are available to do this:

- **Inter-event time** – a time, in days, is specified and any drought broken by a period of flow threshold exceedance of less than this time is considered as a single drought.
- **Inter-event time and deficit-excess comparison** – as well as taking into account inter-event time mentioned above, the volume of flow above the threshold occurring between the two dependent droughts is compared to the cumulative deficit volume of the first. If the ratio of the two is less than a specified ratio, the droughts are considered one. In the case of multiple dependent drought events the comparison can be between the volume above the threshold and either the cumulative deficit volumes across preceding dependent events (sum of deficits) or the cumulative deficit less the intervening excess volumes (deficit – excess).
- **Moving average** – averages the flows over a set period, smoothing the hydrograph resulting in small peaks above the threshold being removed.
- **Sequential peak** – inter-event time but compares drought events occurring on either side of the peak.

Small droughts

Small droughts, where the flow drops below the threshold for a very short time or the drop only creates a small deficit volume, are not necessarily a good indicator of river drought, and make the run-sum analysis method very sensitive to small changes in the threshold flow. A method is available for removing these by comparing each drought's duration and cumulative deficit with the mean of all droughts in the record. If either falls below a set ratio in this respect, it is rejected as a small drought.

Applying these methods gives a partial duration series for three drought statistics:

1. Drought duration in days
2. Drought severity – cumulative drought deficit (Ml)
3. Drought magnitude – severity / duration (Ml/day)

These droughts are listed in a table and can be plotted as a drought frequency plot using the following steps:

i. Take the appropriate drought statistics and rank in ascending order.
ii. Calculate exceedance probabilities, F_i, from the Gringorten formula as for low flow frequency plots.
iii. Calculate reduced variates $(-\log(1-F_i))$
iv. Return period is calculated using $T_i = 1 / [? (1-F_i)]$ where ? is the average number of droughts per year.
v. Reduced variate is plotted against the drought statistic and a distribution is fitted to the data and plotted by calculating the distribution probability and reduced variate across the range of the drought statistic as for low flow frequency plots.

5.3.2   *Using run-sum analysis for short drought events*

Select '**Low flow & drought analysis**'|'**Run-sum analysis - short drought events**' from the menu option on the main form to open the run-sum analysis time series selection form. This is similar to the form for selecting time series for low flow analysis.

Scroll through the list and select a station/time-series on which to perform the run-sum analysis. Select start and end dates for the data analysis, clicking in the '**?**' button will reveal a calendar. Click '**Select all**' to set the range to include all available data.

Click '**OK**' to open the run-sum analysis form or **'Cancel'** to quit.

5.3.3   *Run-sum analysis – short drought events form*

The run-sum analysis short drought events form consists of four panels opened by clicking on the appropriate tab at the top of the form.

5.3.3.1   *Run-sum analysis settings panel*

The first panel allows the method's settings to be altered.

Run-sum analysis settings panel

▪ Select a **Truncation method** and **Truncation level** from the lists:
   - Truncate at percentage of mean flow, selected from a list
   - Truncate at number of standard deviations from the mean, selected from a list
   - Truncate at flow duration exceedance percentile, selected from a list
   - Truncate at absolute flow, entered in cumecs
   Truncation levels can be seen using the truncation hydrograph, see section 5.3.3.2.

▪ Select a **Dependent drought method** for pooling dependent droughts, see section 5.3.1 for more details, from the following options:
   - No method
   - Inter-event time only
   - Inter event time and deficit-excess comparison
   - Moving average
   - Sequential peak
   Set the options as appropriate

▪ Select a **Small drought method**, see section 5.3.1, as required and adjust the settings.

▪ Select a **Distribution to fit** to the data from the list:
   - Generalized Pareto
   - Log Normal
   - Generalised Extreme Value (GEV)
   - Exponential

▪ Select a **Current date** on which to assess the drought conditions

Click **'Save settings'** to store the new settings for future use and for reports.

Click **'Perform run-sum analysis'** to run the analysis with the new settings. Note: if the settings are changed without clicking this button, the drought table and drought frequency graph will not be updated.

5.3.3.2   Truncation level hydrograph panel

Truncation level defines the level at which a drought event occurs. In ARIDA this can be set interactively with the flow hydrograph to observe the changes in truncation level.

Click the **'Truncation level hydrograph'** tab to show the truncation hydrograph panel:
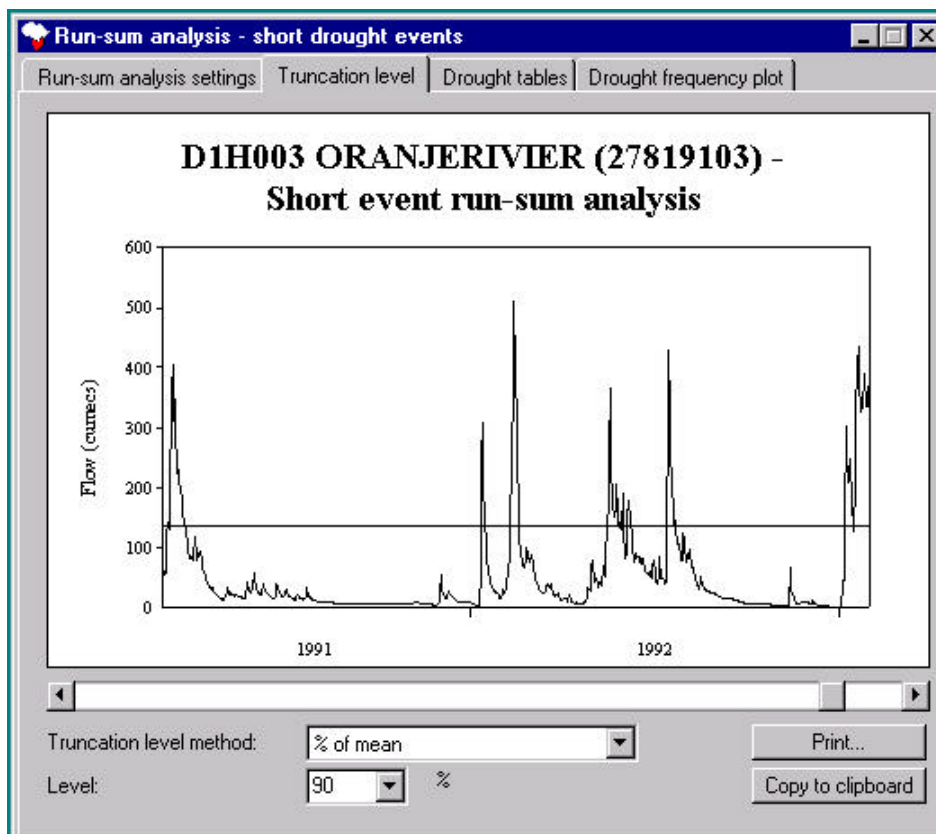
*Truncation level hydrograph panel*

- Select the truncation method and level using the drop down boxes as on the settings panel. Changes will automatically be updated on the hydrograph and the setting panel.

- Scroll left to right using the scrollbar at the bottom of the panel, observing the areas defined as drought periods by the truncation level.

- Select a truncation level appropriate for the station.

Changes to the graph's appearance can be made by clicking on the graph to reveal the **'Run-sum analysis graph options'** form. Click '**OK**' to apply the graph settings changes. Clicking '**Save'** will save the graph settings at this station for future use. Click '**Cancel'** to cancel any changes.

Return to the 'Run-sum analysis settings' panel to re-run the analysis with the new settings.

5.3.3.3   Drought table panel

After performing the run-sum analysis click the **'Drought table'** panel tab to view the results.
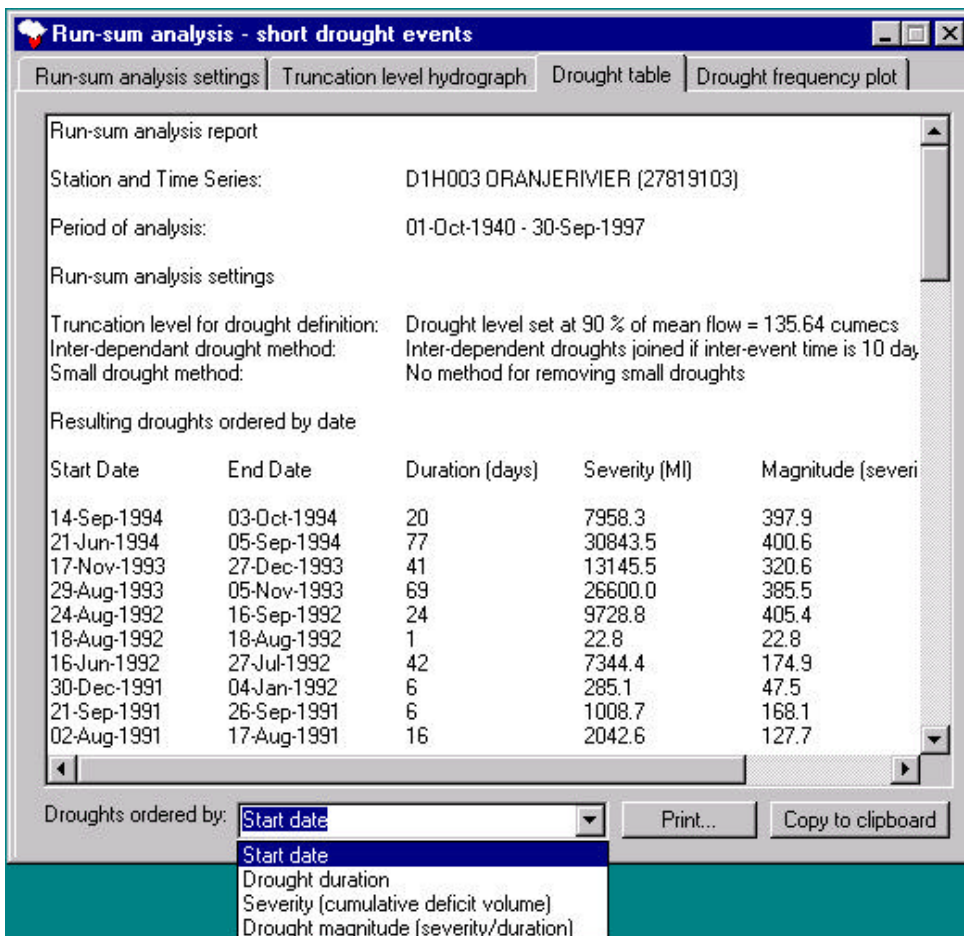

Drought table panel

Analysis settings and resulting droughts are listed in a report, droughts can be ordered chronologically or by drought duration, severity or magnitude.

This report can be copied or printed using the buttons at the bottom of the screen.

5.3.3.4   Drought frequency plot panel

Click the **'Drought frequency plot'** tab at the top of the form to show the drought frequency plot of the results.
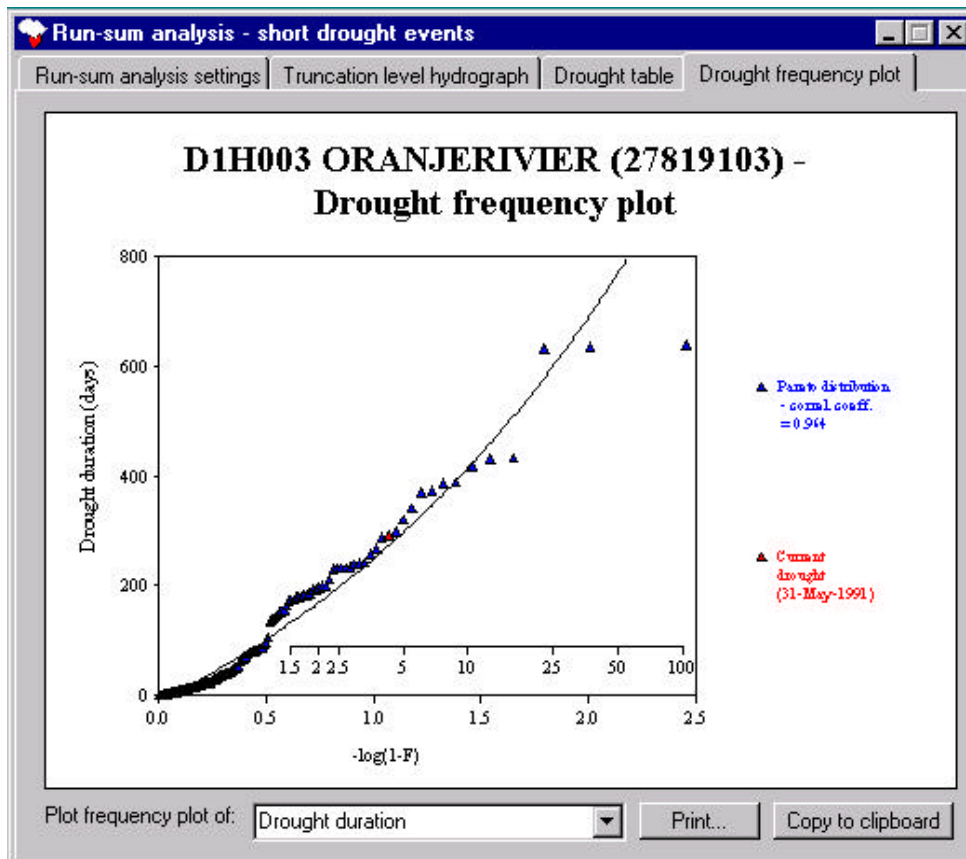
Drought frequency plot panel

The drought statistic plotted can be changed by selecting the required statistic in the drop-down list at the bottom of the panel.

The graph can be printed or copied to the clipboard using the appropriate buttons.

5.4 Run-sum analysis - multi-year drought events

5.4.1 Background to multi-year run-sum analysis

Multi-year run-sum analysis uses daily flow data to calculate total annual runoff (in mm) using the value for catchment area taken from the database. The deviation of annual runoff from the mean and the cumulative deviation from the mean are plotted on a graph against time.

This is a useful method for observing the long-term changes in flow and longer term drought events at a station.

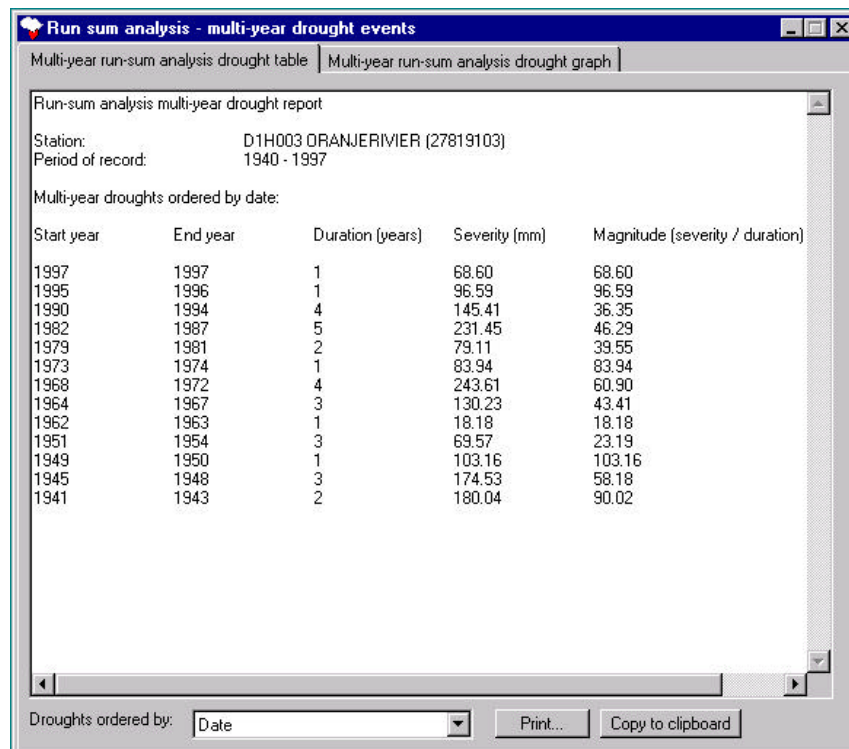### 5.4.2 Using run-sum analysis – multi-year drought events

Select **'Low flow & drought analysis'|'Run-sum analysis - multi-year drought events'** from the menu options on the main form to show the time series selection form.

Select the time series of interest from the list box. Click '**OK**' to run the analysis or '**Cancel**' to quit.

5.4.3 'Run-sum analysis –multi-year drought events' form

The run-sum analysis – multi-year drought events form contains two panels accessed by clicking on the tabs at the top of the form.

5.4.3.1 Multi-year run-sum analysis drought table panel

Run-sum analysis multi-year drought report

Station: D1H003 ORANJERIVIER (27819103)
Period of record: 1940 - 1997

Multi-year droughts ordered by date:

Start year	End year	Duration (years)	Severity (mm)	Magnitude (severity / duration)
1997	1997	1	68.60	68.60
1995	1996	1	96.59	96.59
1990	1994	4	145.41	36.35
1982	1987	5	231.45	46.29
1979	1981	2	79.11	39.55
1973	1974	1	83.94	83.94
1968	1972	4	243.61	60.90
1964	1967	3	130.23	43.41
1962	1963	1	18.18	18.18
1951	1954	3	69.57	23.19
1949	1950	1	103.16	103.16
1945	1948	3	174.53	58.18
1941	1943	2	180.04	90.02

Droughts ordered by: Date | Print... | Copy to clipboard

Run-sum analysis – multi-year drought events panel

This panel contains a list of the multi-year 'droughts' resulting from the method – these are periods where for one or more years, the total annual runoff dropped below the mean annual accumulated runoff.

Droughts can be ordered by date, duration, severity or magnitude.

5.4.3.2   Multi-year run-sum analysis drought graph panel

This panel shows a graph showing the deviation of annual accumulated runoff from the mean against time, highlighting drought years, where the accumulated runoff fell below the mean, in red and non-drought years in black. A line of cumulative deviance from the mean is plotted in blue against the right graph-axis.
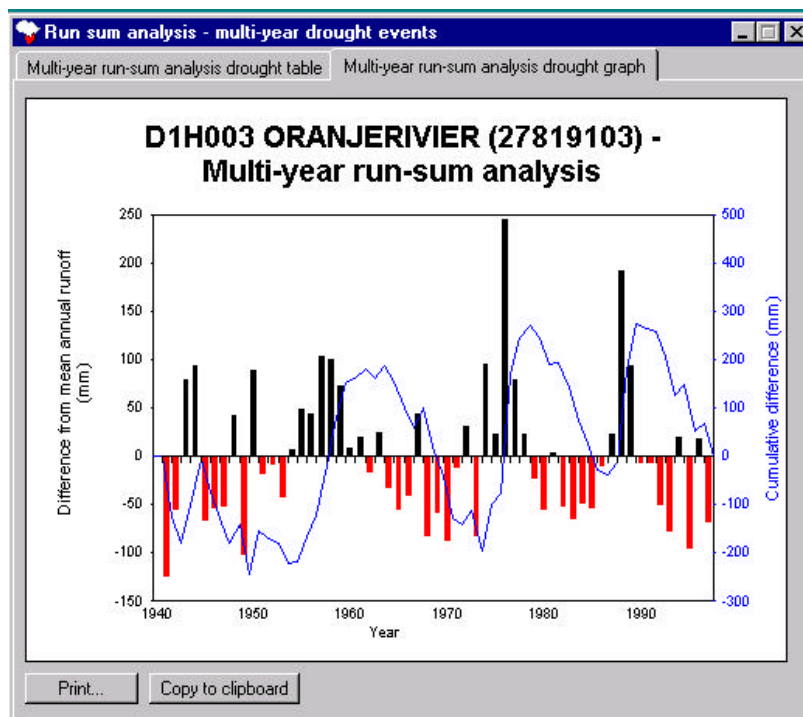
Multi-year run-sum analysis drought graph panel

The appearance of the graph can be altered by clicking on the graph and changing the settings on the graph options form. Saved changes will be stored for future use.

5.5   Accumlated runoff analysis

5.5.1   Background to accumlated runoff analysis

Accumulated runoff analysis uses daily flow data to calculate daily runoff (mm). For each day of each hydrological year the accumulated runoff (total from the first day of the year to the day in question) is determined. For each day (1 to 365 – extra days on leap-years are added to the previous day) the accumulated runoff from every year is ranked and given an exceedance probability. This is then an estimate of the probability of the accumulated runoff exceeding that flow on this day in any year.

Plots are drawn showing contours of constant percentile across the hydrological year. This illustrates the variability of the total runoff between years. The 'current' year can be set and plotted against these contours so that the change in the runoff relative to all previous years can be observed. As a drought progresses the change in the percentile of total runoff exceeded can be used as an indicator of the changing status of the drought.

As the method looks only at accumulated runoff, directly related to the accumulated flow, this method may be particularly useful when looking at rivers important to reservoir recharge.

5.5.2   Using accumulated runoff analysis

Select **'Low flow & drought analysis'**|**'Accumulated runoff analysis'** to show the time series selection form. Select a time series and start and end dates for the analysis and click **'OK'** to run the analysis or **'Cancel'** to quit.

5.5.3   Accumulated runoff analysis form

The accumulated runoff analysis form consists of three panels accessed through the tabs at the top of the form.

5.5.3.1   Accumulated runoff settings panel

The first panel allows the user to alter the settings for the method.
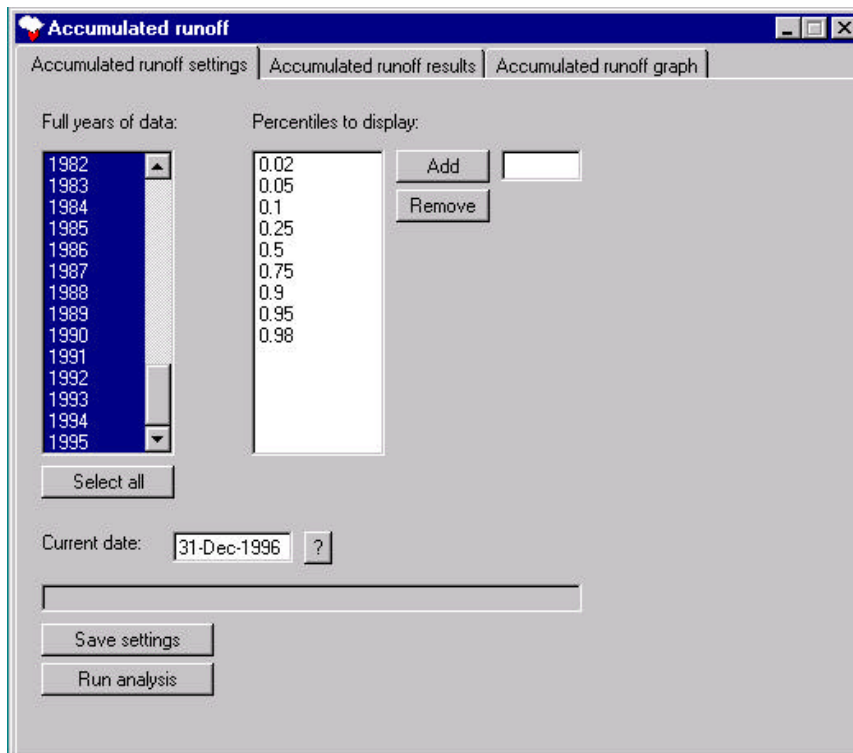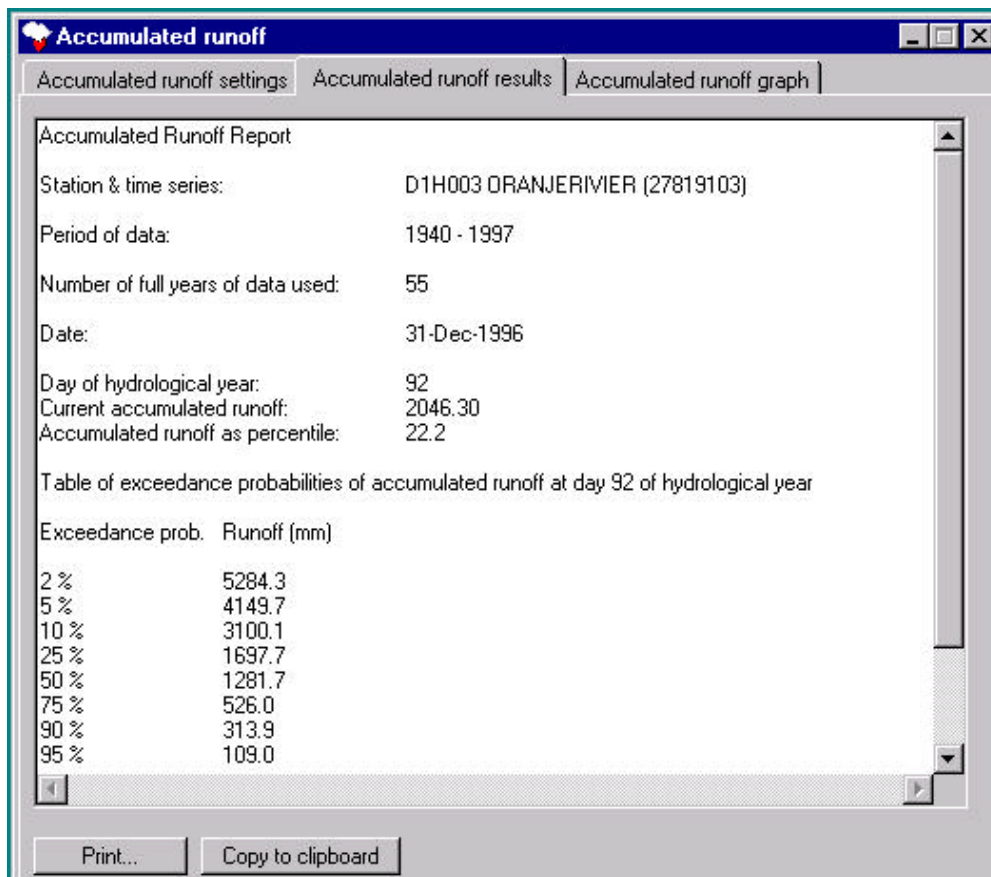
Accumulated runoff settings panel

- **Full years of data** – The method works using full years of data only. A list of full years in the period selected is shown and years where data is known to be poor can be removed. Highlighted years will be used in the analysis. Hold down the **'Ctrl'** button and click on a year to add and remove highlighting. Click **'Select all'** to select all available years. At least five years of data are required though more are needed for a meaningful graph.

- **Percentiles to display** – the graph can be modified by selecting the percentiles to 'contour' across the hydrological year. Enter a new percentile in the box and click '**Add**' to add to the list. Remove a percentile by highlighting it in the list and clicking '**Remove**'. At least three percentiles are required. To examine the runoff from low-flows in more detail, add extra percentiles at high percentiles. Note: Displaying extreme percentile contours may be impossible if there are insufficient years for calculating the flow at these percentiles. For example, ten years of data will only allow percentiles from 9.1% to 91% (as the exceedance probability, P_i, for the i-th event is given by $P_i = i / (N + 1)$ where N is the total number of events).

- **Current date** – Any date can be selected and the runoff in the year up to the date can be monitored.

Click **'Save settings'** to save these settings for future use

After settings have been changed, the user must click **'Run analysis'** before the table and graph will be updated with the new results.

*5.5.3.2   Accumulated runoff results panel*

This panel shows a report of the accumulated runoff results. This report focuses on the current date selected on the settings panel and shows the exceedance percentile relating to that day's runoff as well as the runoff at all of the selected percentiles and the maximum and minimum percentiles reached during the hydrological year.

Accumulated runoff results panel

5.5.3.3   Accumulated runoff graph panel

This panel shows the accumulated runoff graph. Selected percentiles are shown across the whole year and the current year to-date can be seen as a thicker line cutting the percentile contours.
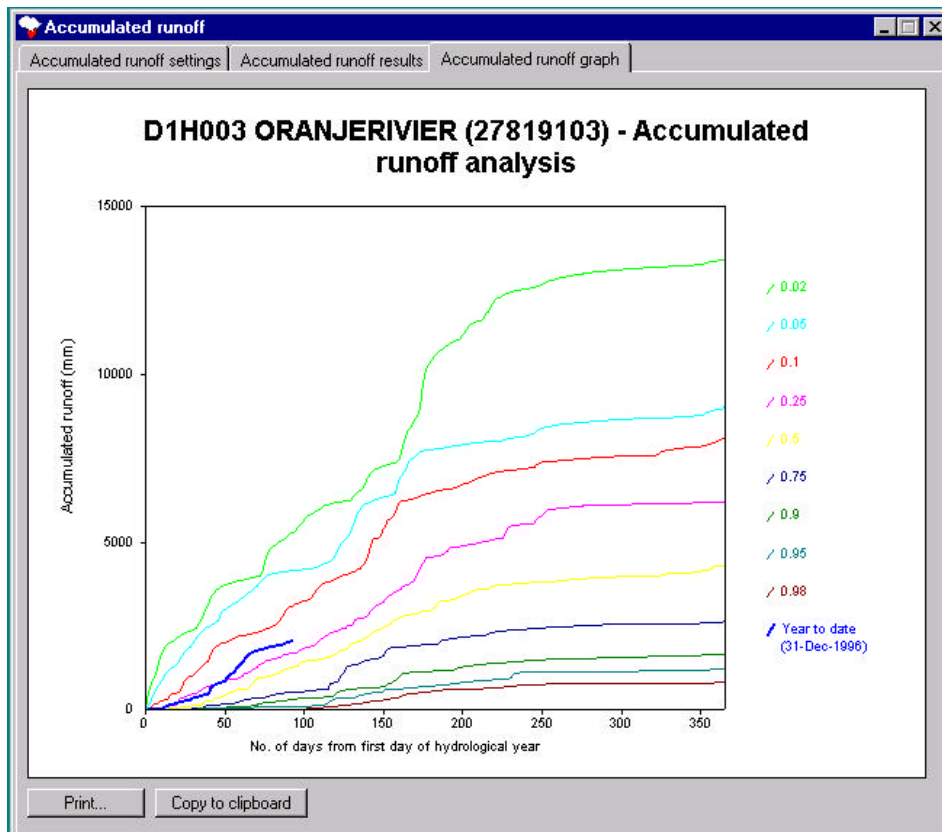
Accumulated runoff graph panel

Click on the graph area to access the graph options form.

Click '**OK**' to apply the changes to the graph. Click '**Save**' to apply the changes to report. Click '**Cancel**' to close the form and discard the changes.

5.6   Monthly flow bulletins

5.6.1   Background to monthly flow bulletins

This method calculates mean monthly flows from daily flow data. Each month's flow is plotted against time, as a standard hydrograph, along with the long-term mean for each month and the maximum and minimum monthly flow recorded. The display can be thought of as similar to the 'Validation plot' in HYDATA.

Monthly flows can be seen in the context of the long-term flow records for that station and can be a valuable standardised report on flows smoothed by monthly averaging.

5.6.2   Using monthly flow bulletins in ARIDA

Select **'Low flow & drought analysis'|'Monthly flow bulletins'** from the menu options on the main form to show the monthly flow bulletin time series selection form. Select a station and time series from the list and the range of data for which the extremes should be calculated. Click **'OK'** to run the analysis.

5.6.3   Monthly flow bulletin form

The monthly flow bulletin form is divided into two panels accessed using the tabs at the top of the form. There are no settings for this method.

5.6.3.1   Monthly flow bulletin table panel

Monthly flows for the whole record are analysed and displayed in a report. Results can be ordered by year, month, absolute flow and difference from long-term monthly mean, maximum and minimum by selecting the appropriate item in the dropdown list at the bottom of the panel. Results can be ordered by two variables by selecting the appropriate list items in reverse order. For example, to order the results primarily by month and then by flow within each month, first order by flow and then order by month.
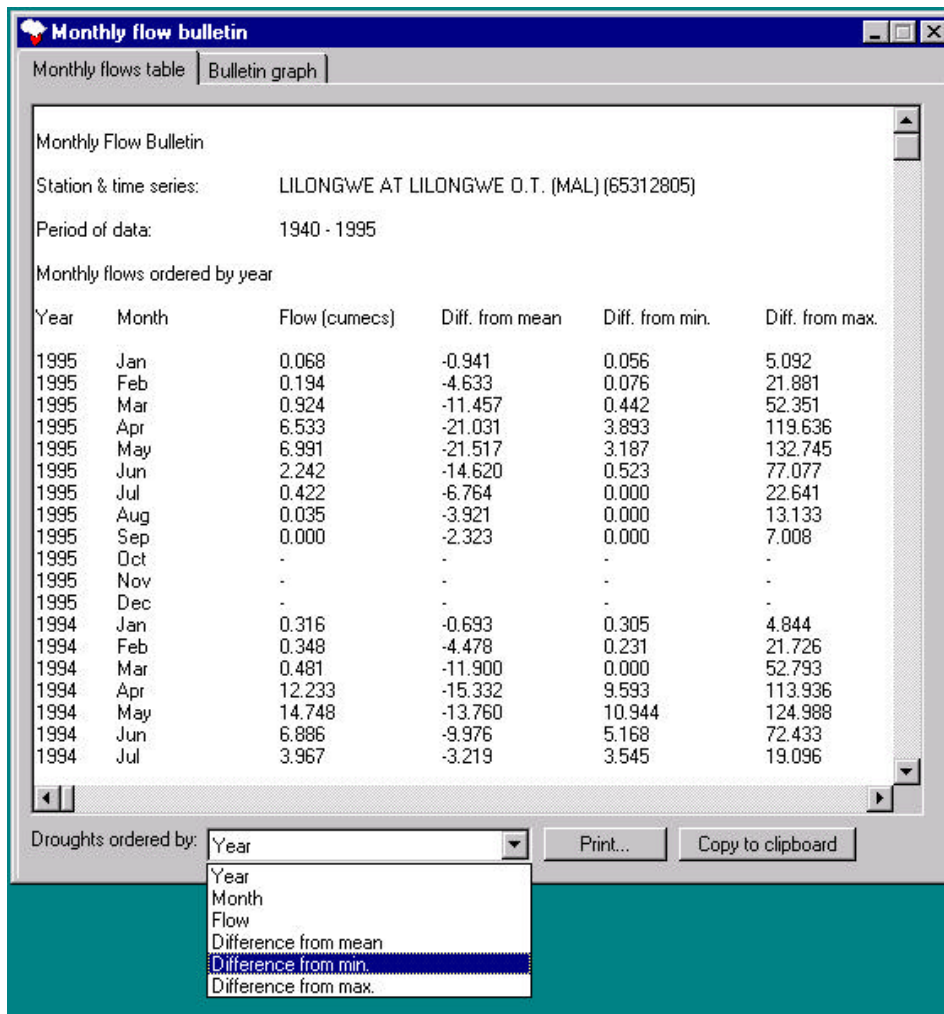
Monthly flows table panel

Results can be copied to the clipboard using the button at the bottom of the form and pasted into a spreadsheet for further analysis.

5.6.3.2 Bulletin graph panel

This panel shows the graph described above. To alter the graph appearance, for example, to change the years shown, click on the graph area to show the graph options form and adjust the options. Click **'OK'** to apply ay changes. Click **'Save'** to save any changes for future use. Click **'Cancel'** to discard changes.
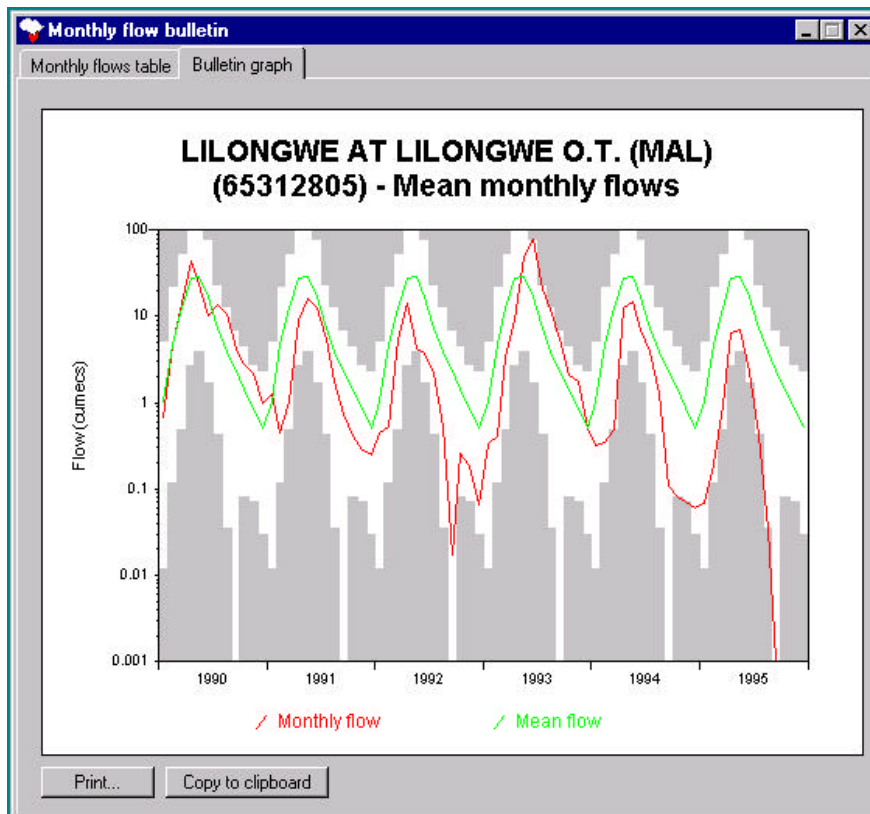
Bulletin graph panel

6   Station reports

This section outlines how to access data through the pre-defined reports and covers use of the advanced report settings.

The **'Station reports'** menu provides quick and efficient way to view the data. Each option contains a pre-set layout of graphs available for the low flow and drought analysis methods described. For each report type, any number of stations can be selected and plotted together thus enabling comparisons to be made, for example between similar catchments, river regimes etc.

6.1   Predefined reports

The first stage in creating a report is selection of the type of report.

There are six pre-defined reports available:

1. **Full report**

    The full report displays all the available report types together in a pre-defined layout. This is a useful summary of the methods used and enables quick comparisons to be made of the methods and data.

    Displays monthly flow bulletin graph, accumulated runoff analysis graph, run-sum analysis truncation hydrograph and drought frequency plot, multi-year run-sum analysis graph and low flow frequency plot.

2. **Low flow frequency report**

    Used for multi-station reports of low flow frequency plots.

3. **Truncation hydrograph report**

    Used for multi-station reports showing hydrographs with run-sum analysis defined truncation levels.

4. **Run-sum analysis drought frequency report**

    Used for multi-station reports showing drought frequency plots with pre-defined default truncation levels and fitted distributions.

5. **Run-sum analysis - multi-year drought event report**

    Creates report with graphs of drought periods over a number of years for multiple stations by displaying a running and cumulative difference from mean annual runoff.
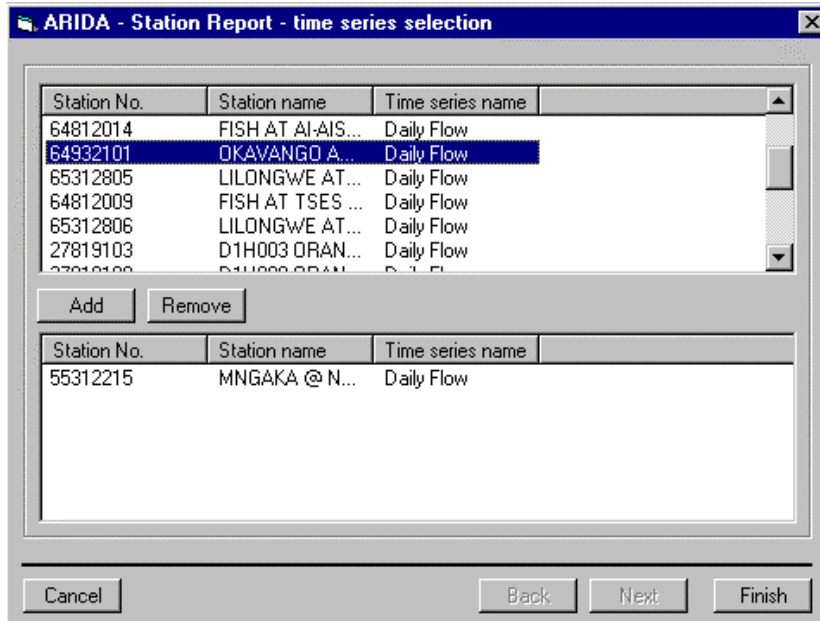
6. **Accumulated runoff report**

    Used for multi-station reports of accumulated runoff analysis graphs.

7. **Bulletin report**

Displays a graph of mean monthly flow for selected period. Used for multi-station reports of the monthly flow bulletin method.

6.1.1 Accessing station reports

For each approach, when a report type is chosen a dialogue box will appear as below:

Time series selection box

The stations visible in the lower box are those for which reports will be generated.

▪ Select the required stations by scrolling through the list, highlight a station/time series and click '**Add**'. To remove a time series from the lower box, highlight the time series and click '**Remove**'.

▪ To generate the report click '**Finish**'.

A report of the selected type will be printed to the screen with showing graphs and tables produced with the methods selected for each time series selected.

The graph and table details, such as titles, x- and y-axis scales, etc., can be changed for graphs in two ways:

i.   Changing the settings for the method (run-sum, low-flow frequency, etc.) in 'Default Settings' will apply changes to all graphs – see section 7.2.

ii.   Changing the settings for the method when looking at a particular station and time series will apply the changes only to graphs/tables for this station and time series.

Both of these methods of altering graph and table appearances are explored later in this manual.

6.2 Creating customised reports using the Report Wizard

This section describes how the Report Wizard can be used to create customised reports.

The Report Wizard will generate reports by guiding the user through a series of forms allowing decisions to be made regarding content and layout. At any point it is possible to go back to the previous form to make changes. Having created a report, the Report Wizard can be used to edit or simply to reproduce and print the report.

6.2.1 Creating a report

▪ Select **'Station reports'|'Report wizard'** to show the report wizard form.

6.2.1.1   Report Wizard form

Report wizard form

▪ Select '**New report**' to define a new report, or select a report name from the drop down list to view a report previously created. Previously created reports can be deleted by selecting the name in the list and clicking the '**Delete report'** button.

▪ Click '**Next**' to change the report layout and contents or '**Finish**' to view an existing report without changing it.

6.2.1.2   Time series selection form

The next form allows the user to select time series to include in the report.

- Select the stations to be included in the report, by highlighting the time series and clicking '**Add**' or '**Remove**'; the stations in the lower box are those to be included.

- Click '**Next**' to proceed to the **'Report items settings'** form.

6.2.1.3   Report item settings form

This form selects which features are to be displayed and how.
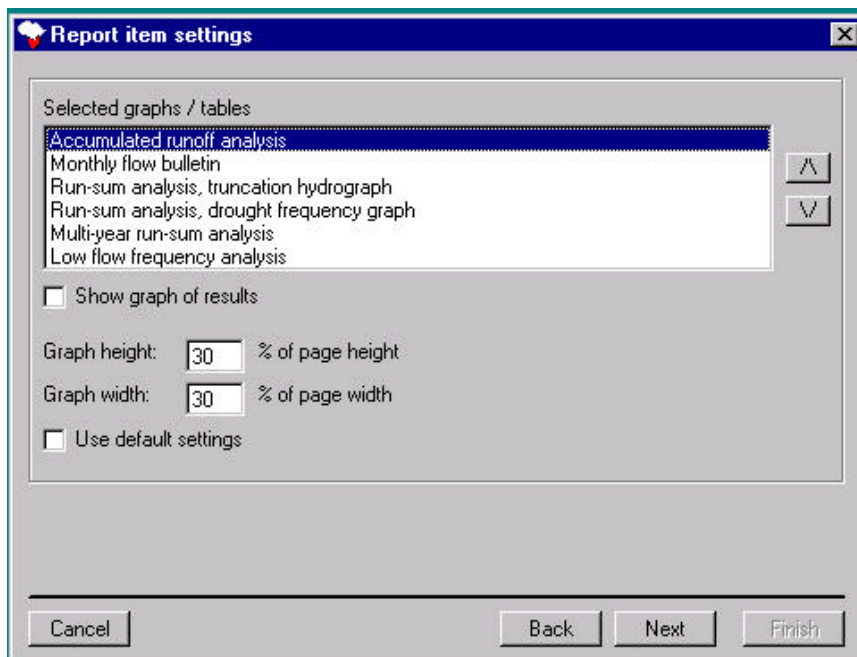
Report items settings form

The top section **'Selected graphs'** lists the methods available.

- Select a method by highlighting and checking the box **'Show graph of results**' which appears beneath the box. To change the order in which these will appear in the final report, highlight a method and click the up and down arrows to the right of this box.

- The Graph height and width options are set as a percentage of page height and width with suggested heights and widths being between 30 and 95%.

- Check '**Use default settings**' to use the default settings otherwise individual time series settings will be used.

- Click '**Next**' to proceed to the Report layout form.

- Click '**Back**' to go back to the Time series selection form.

- Click '**Cancel**' to close the report wizard and returns to the main form.

6.2.1.4   Report layout form

This form sets the page appearance, e.g. margins, headers and footers etc.

Report layout form options:

The **Margins** section sets the invisible border between the edge of the page and the text area:

▪ Enter a value typically 0-1% of the page dimensions for top, bottom, left and right margins.

In the **Header, footer and titles** section:

▪ To display the title of the report assign a height in the '**Header height**' box. Suggested header text height is 3-5%. Enter the title of the report in the '**Header text**' box

▪ To display the report title on every page check **'Show header on every page?'** .

▪ To display the page numbers assign a height in the '**Footer height'** box. Suggested height is 1%.

▪ Check **'Number pages?'** to apply page numbers.

When plotting more than one time series it may be useful to display the time series titles before each group of charts/tables.

▪ Set the text height by entering a value in the '**Time series title height'** box. Suggested height is 2%.

▪ Check '**Show title before every time series**' to display the time series title.

Report layout form

- Click '**Next**' to proceed to the 'Save report template' form.

- Click '**Back**' to return to 'Report item settings' form.

- Click '**Cancel**' to close the report wizard.

6.2.1.5   Save report template form

- Enter a name for the new report.

- Click '**Finish**' to produce the report.

7 Advanced options

7.1 Patching

Missing data is a problem when performing any type of analysis of historical data when fitting distributions and simply in terms of getting meaningful results.

The patching option gives one method for filling in periods of missing data, particularly when the missing periods are too long to be filled meaningfully by interpolation.

A 'Destination' station and time series is selected. This is the time series that has missing data to be filled. One, two or three 'Source' time series are selected to be used for patching the destination time series.

Monthly flow duration curves are calculated for each time series.

A day of missing data is in-filled by taking the flow at the source stations on this day and finding the flow duration curve percentiles at this flow. The flow at the destination station is found from the destination station flow duration curve at the same percentile and an unweighted mean of the three results from each source station is taken.

This method of infilling data is based on the assumption that there is a similarity between the flow duration curves for each station and that they are free from large artificial influences or at least similarly affected by them. Results will obviously be better for stations affected by the same events and for time series that are not dominated by 'flashy' events.

7.1.1 Using the patching option

Select **'Advanced'|'Patch time series data'**.

- Select the 'destination' station/time series to be patched.
- Select up to 3 'source' time series with which to patch the data by holding down the 'Ctrl' key whilst clicking the stations in the list.

These are the stations ARIDA will use to predict the missing flows and should ideally be stations that nearby and experience the same events as well as being free from artificial influences.

Click **'Patch data'** to show a new window displaying the flow hydrograph containing the time-series to be patched (black) and the predicated data (red). Use the scroll bar to locate the period of missing data.
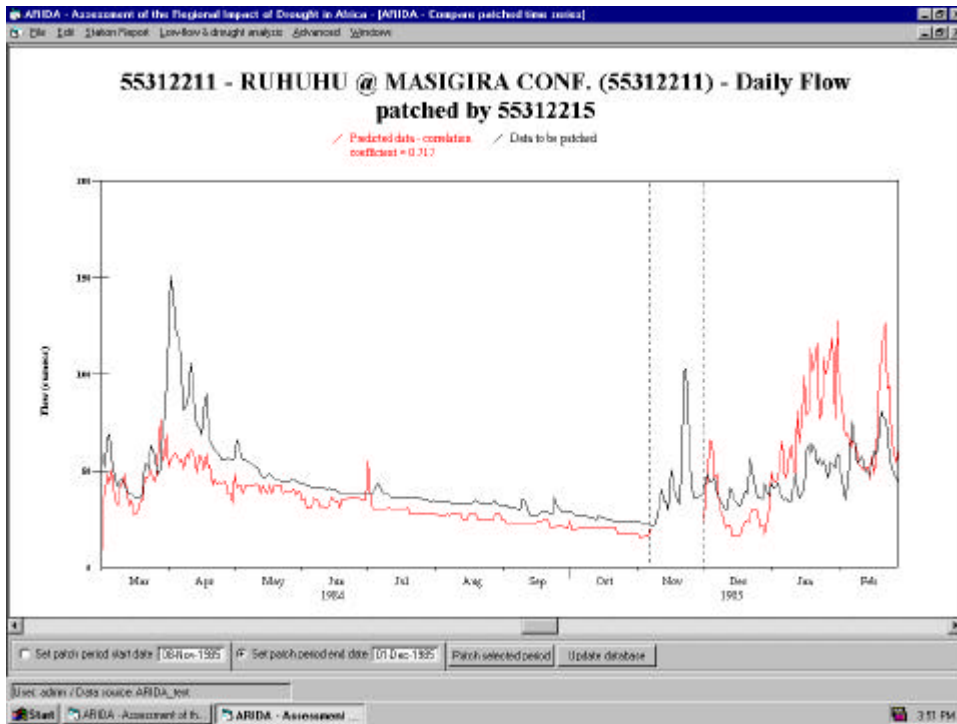
Compare patched time series form

To set the start and end dates of the patching period:

▪ Check the **'Set patch period start date'** and click on the relevant position on the hydrograph. A vertical dashed line will appear and the exact date will be entered in the box.

▪ Select the end date in the same way.

▪ Right click on the graph to show the graph options form.

▪ Click '**Patch data**' to add the predicted data to the destination times series. The following 'patching options' form will appear:

Patching options form

– Select a **Flag for patched data**' from the drop down box. This flag will appear in the new or modified time series when viewed in HYDATA.

– Enter a comment in the '**Comment for patched data**' box if necessary, by clicking and overwriting the existing text.

- Click '**OK**' to accept and return to the hydrograph.

- Click '**Cancel**' to close form and return to the previous form.

▪ Select '**Update database**' to save the changes to the database. The following form will appear:

Update database form

This form gives the choice of either saving the predicted data straight into the destination time series or to save changes to a new time series. Saving the data as a new time series will avoid confusion as to which data is real and which is simulated.

- Click '**OK**' to update the database.

- Click '**Cancel**' to return to the previous form with out saving changes.

7.2   Default settings

The default settings determine the parameters used in analysis methods and the overall appearance, i.e. of axes, titles, etc., of the graphs for all time series selected. This enables the graphs and tables to be plotted in a consistent format for comparisons to be made.

The default settings forms allow access to the background settings for all methods and are similar to the settings and graph options forms for the methods as selected from the 'Low flow & drought analysis' menu.

Select **'Advanced'|'Default settings'** and a method from the list.

The exact form will vary from method to method but in general it is possible to set defaults for most parameters and graph settings.

The options found in the default settings forms are covered in more detail in the Low flow & drought analysis section (section 5) under each method heading.

Once changes have been made, click '**Save**' to apply the new settings or '**Cancel**' to discard the changes. Saved changes will now be applied as default settings for all methods unless specific changes have been made to a station and saved.

Note: Changes that are saved in the 'Low Flow & Drought Analysis' section will apply to the particular time series and override any default settings when viewing reports for the selected time series.

7.3   Reset settings

If any settings have been changed, selecting **'Reset settings'** will return all the settings to original values, and any changes that have been made and saved (either in default settings or to individual time series) will be lost as will any custom reports.