

rap

river analysis package



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USER GUIDE

River Analysis Package - Users Guide

Prepared by
Nick Marsh

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River analysis Package

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1 Introduction

The River Analysis Package (RAP) is a toolbox of quantitative techniques for Environmental Flow management. RAP has several modules to help river managers, scientists and consultants to tackle a range of river management projects. RAP is primarily targeted at the allocation of environmental flows, however future modules will be useful for other forms of river restoration such as predicting channel geometry for re-engineered channels and understanding relationships between flow, hydraulics and biota. RAP B.1.0.0 has been released with two operational modules.

1.1 Hydraulic Analysis (HA)

The Hydraulic Analysis (HA) module has been based on the Flow Events Method (Stewardson and Gippel, 2003) of allocating environmental flows. The HA module allows users to construct a one dimensional hydraulic model of a river reach and to determine ecologically relevant flow thresholds based on hydraulic parameters such as water depth and velocity. HA allows the creation of a time series of potentially ecologically relevant hydraulic data for subsequent analysis in TSA and comparison with biological data or alternative flow regimes.

1.2 Time Series Analysis (TSA)

The Time Series Analysis (TSA) module of the River Analysis Package (RAP) has been developed to produce a graphical user interface that allows users to interactively investigate time series data. TSA is designed for use as an interpretive tool. TSA input must be daily time series data, it is designed for stream flow data but can equally be used for hydraulic time series data or meteorological data. The algorithms underlying TSA are used by the Rules Based Models (RBM) module and Quantitative Models (QM) module of RAP to predict biological responses to alternate flow scenarios.

1.3 The user guide

The RAP Users Guide can be printed or viewed as a single PDF document for those users who like to read a report from cover to cover. The RAP Users Guide is also the basis for the online Help featured in RAP, all the content of this document can be found in the RAP Help menu.

1.4 River Analysis Package

1.4.1 Overview

RAP can be used for many purposes depending on the demands of the user, here are some suggestions;

- Hydrologists,

Interactively compare pre- and post-regulation flow regimes, or compare flow regimes of different streams, to aid in the development of flow allocation strategies.

- Civil engineers,

Use a partial duration series to calculate discharge for design floods less than 10yr ARI.

- Stream managers,

Assess the likely habitat limitations imposed by hydrologic regime, rapidly produce summary reports for other users.

- Freshwater Ecologists,

Quantify the flow regime by calculating flow metrics for statistical comparison with temporally and spatially variant biological data to provide a clearer understanding of the association between hydrology and aquatic habitat.

- Fluvial Geomorphologists,

Create a one dimensional hydraulic model of a river reach and calculate a time series of geomorphically relevant hydraulic parameters (e.g. threshold of bed sediment transport).

Hydraulic Analysis (HA) Module

HA uses a one-dimensional hydraulic model to calculate potentially ecologically relevant hydraulic metrics and to visualise the depth of flow at different cross-sections.

Time Series Analysis (TSA) module

TSA uses daily time series data (e.g. flow data) to generate summary statistics or plots of changes in statistics through time. TSA is used for comparing alternate flow regimes, identifying changes in a flow regime through time and for generating flow statistics that can be used to predict the likely biological response to flow change.

1.4.2 Features

Hydraulic Analysis (HA)

HA allows the importation of HECRAS (US Army Corp of Engineers- USACE) cross-section data, as well as user input cross-section data to create a 1-D hydraulic model of a river reach. The FldWav (pronounced "Flood Wave") (USA National Weather Service) 1-D hydraulic model is used to calculate a hydraulic parameters in the reach for multiple alternative discharges, the hydraulic parameters are presented as a rating curve for each the hydraulic parameters versus discharge. If a time series of discharge is provided this can be converted to a time series of hydraulic parameters that can be subsequently analysed in TSA. The hydraulic parameters calculated by HA are:

- Surface width
- Wetted Perimeter

- Cross-sectional area
- Local depth
- Thalweg Depth
- Lateral gradient
- Volumetric flow per width
- Bulk (Mean) flow velocity
- Hydraulic Radius
- Froude Number
- Aspect ratio

Time Series Analysis (TSA)

TSA calculates time series metrics for post processing in other statistical packages as well as providing a graphical display of how alternative metrics change through time.

TSA calculates the following time series metrics:

- General statistics, Mean, median, Q90, Q10, Skew, coefficient of variation
- High flow spell analysis
- Low flow spell analysis
- Colwell's statistics
- Rates of rise and fall
- Base flow analysis
- Partial series flood frequency
- Annual series flood frequency
- TSA has the following graphical interface features:
- Display input data
- Display graphical interpretation of time series metrics (based on annual, seasonal, monthly basis)
- Flow duration curves (whole period, annual, seasonal, monthly)
- Flood Frequency curves (partial and annual series)
- Baseflow component of flow

1.4.3 Audience

RAP is intended for scientists in the field of environmental flows, hydrology and hydraulics field. It is also intended that RAP will be used by government agencies, environmental and engineering consultants, water managers and as a communication tool for community consultation. RAP is also used in undergraduate engineering and science teaching.

1.5 Data requirements

1.5.1 Input data

Time Series Analysis (TSA)

TSA allows simple drag-and-drop of common formats of daily streamflow data;

- Comma delimited (.csv) with the first column a daily time step date and subsequent column(s) as data.
- IQQM:- standard output format from the Integrated Quality, Quantity Model produced by the New South Wales Department of Land and water Conservation.

Time Series Data

The basic time unit of TSA is daily, however it is anticipated that sub-daily, monthly, seasonal and annual time series data will also be handled by TSA.

Time series data must be gap free, that is, there must be no empty cells if viewed in a spreadsheet. Users should ensure that any gaps in the input data are filled with -9999. For the Beta release of RAP, even -9999 values can create difficulty for some calculations, hence it is best to only load complete time series data with no missing data or null values (-9999).

Visualisation

TSA provides an input screen to allow users to zoom in and out and pan through the time series data for a quick visual overview of the data.

Output from TSA is presented in visual summaries for easy interpretation

Time period for analysis

TSA can handle any length of input data from 1 day to 1000 years. Some functions are not available for very short records.

Time period for summary computation

The analysis of the input time series can, for most metrics, be undertaken for the whole period, years, up to six user-defined seasons, and months.

Measures of central tendency

TSA provides both mean and median measures of central tendency for any statistic where multiple outputs are produced. The measures of central tendency are Mean and median, and the measures of variation around these are coefficient of variation (CV) which is the standard deviation/mean, and the Variability which is a range defined by percentiles (e.g. Q10-Q90) divided by the median.

Hydraulic Analysis (HA)

HA uses channel cross-sectional data in order to create a one-dimensional hydraulic model. The cross-sectional data can be entered directly into HA, or by copying and pasting cells from a spreadsheet application or by importing data hydraulic model already setup in HECRAS (US Army Corp Engineers). In order to run the 1-D hydraulic model, Channel roughness factors must be assigned for each cross-section. The channel roughness (Manning's n) can be varied according to discharge, or set as a constant value for all discharges.

In order to create an output time series of a hydraulic parameter (e.g. average depth), you must load time series flow data and combine it with a rating curve of the hydraulic parameter. That is, combine daily discharge with a rating curve of average depth versus discharge to create a time series of daily depth. The newly created time series file can be saved or exporting to TSA for analysis.

1.5.2 Output data

Hydraulic Analysis (HA)

The main output from the hydraulic analysis module are time series of hydraulic parameters. These can be saved as comma delimited files.

Time Series Analysis (TSA)

As well as a visual output, TSA provides tabulated numeric output that can be simple saved as a comma delimited file for input into other post processing statistical packages.

1.6 Product components

The River Analysis Package (B1.0.0) contains the Time Series Analysis Module and Hydraulic Analysis Module. It is intended that future Versions of RAP will also include a module for the prediction of biological response to flow change (Rules Based module and Quantitative Models Module) as well as a module to allow the prediction of regional channel morphology characteristics.

1.7 References and training

RAP is a product developed jointly by the CRC for Catchment Hydrology (CRCCH) and CRC for Freshwater Ecology (CRCFE). Each module of RAP has a different development team, as such each module should be referenced separately.

The Hydraulic Analysis module can be referenced as:

Stewardson M, and Marsh (2004) Hydraulic Analysis Module: River Analysis Package. Cooperative Research Centre for Catchment Hydrology, Monash University, Melbourne Australia.

The Time Series Analysis module can be referenced as:

Marsh N. (2004) Time Series Analysis Module: River Analysis Package, Cooperative Research Centre for Catchment Hydrology, Monash University, Melbourne Australia.

As part of the product delivery, the CRCCH runs training workshops. Details of workshops are posted on the Toolkit web site (www.toolkit.net.au) in the news and events sections. References for relevant conference papers and journal articles are also available at the Toolkit web site, in the RAP member's area. A discussion forum for RAP users is available in the RAP members area, feel free to view recent discussion topics and ask questions of the RAP development team and other RAP users.

2 Installation

2.1 Technical specifications

Minimum Requirements	
Processor	133-megahertz (MHz) Intel Pentium-class processor
Operating System	<p>RAP is supported on the following platforms: Microsoft Windows® Server 2003* (.NET Framework 1.1 is installed as part of the operating system) Windows XP Professional* Windows XP Home Edition Windows 2000* Windows Millennium Edition (Windows Me) Windows 98 Microsoft Windows NT® 4.0 Service Pack 6a</p> <p>RAP cannot be installed on 64-bit computers</p>
Memory	128 megabytes (MB) of RAM, 256 MB recommended
Hard Disk	10 MB of hard disk space required
Display	1024 x 768 or higher-resolution display with 256 colours
Input Device	Microsoft mouse or compatible pointing device
Other	<p>Microsoft Internet Explorer 5.01 or later is required. The .net framework 1.1 redistributable or later is required.</p>

Table 1 System requirements

The person installing the software must have local administrator access on the computer. Ideally, you should also have the relevant permissions to install and uninstall software.

Note	If you are using a networked computer, then inform your system administrator BEFORE applying any service packs or updates, as there may be other applications on your computer that could be affected by these updates.
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2.2 Distribution media

RAP is distributed via the Toolkit web site and can be downloaded by:

- 1 Going to the Toolkit web site (www.toolkit.net.au)
- 2 Registering as a toolkit user
- 3 Once a registered toolkit user, then going to the users download area and selecting RAP.
- 4 Press the Submit button to commence the download

2.3 Licence agreement

Acceptance of the licence agreement is part of the installation procedure. You must acknowledge that you have read, understood and agree to be bound by RAP software licence agreement to be able to proceed with the installation. The licence agreement can be viewed when using RAP by selecting **Help > About** and selecting the Licence agreement button.

2.4 Folders

The RAP installer creates a data directory that contains:

- 1 The RAP software (default path c:\Program Files\Toolkit\RAP)
- 2 Documentation (this User Guide, default path c:\Program Files\Toolkit\RAP\documentation)
- 3 Sample data (default path c:\Program Files\Toolkit\RAP\Sampledata)

2.5 Installation

2.5.1 Framework Installation

The .NET Framework is a component of the Microsoft Windows® operating system used to build and run Windows-based applications. RAP is built using the .NET Framework and consequently requires that the .NET Framework redistributable be installed prior to running. The .NET Framework Redistributable will install the .NET Framework onto your machine and is downloadable from www.msdn.microsoft.com/netframework/downloads/redist.aspx.

You can check to see if you already have the .NET Framework installed by clicking Start on your Windows desktop, selecting **Settings > Control Panel**, and then double-clicking the Add or Remove Programs icon. When that window appears, scroll through the list of applications. If you see Microsoft .NET Framework 1.1 listed, the latest version is already installed and you do not need to install it again.

2.5.2 Stand-alone PC

After downloading the software to a local directory, double clicking RAPsetup.exe will initiate an install wizard which leads you through the install procedure. Once again, you must indicate that you have read, understood and agree to be bound by RAP licence agreement. There are two decisions to be made during the installation, the name of the install directory

(default is C:\Program Files\toolkit\RAP), and if the user wishes to also load sample data (default is yes)

Potential Problems If your computer doesn't have enough space to install the data, the install procedure will give you an out of disk space message. Select Cancel to exit the installation procedure. You will need to find a larger disk drive.

If the .NET framework is not installed on your machine, the install procedure will give you a warning message. Select cancel the installation procedure. You will need to install the .NET redistributable software .

2.6 User Interface

RAP uses standard Microsoft Windows® windows. The features in the window are the:

- Title bar that includes the Toolkit icon followed by the product name and a version number.
- The standard windows minimise, maximise/restore and close icons.




Optional top level menu.



Figure 2-1: Example of RAP window

To minimise or maximise a window or restore it to its previous size

Click the appropriate button in the upper-right corner of the window:

- Click  to minimise the window to a taskbar button. To restore the minimised window to its previous size, click its taskbar button.
- Click  to maximise the window so it covers the full screen.
- After maximising a window, click  to restore the window to its previous size.

Note You can also double-click the window's title bar to maximize it or restore it to its previous size.

You can click on the Toolkit icon on the left of the title bar or right click on the title bar to display a menu to restore, move, size, minimise, maximise or close the window.

The title line contains the name of the software followed by a version number. The version number is in three parts; x.y.z where:

x Major Version indicator (integer starting at 1)

y Minor Version indicator (integer starting at 0; may go to any number but rest on a major version change)

z Bug fix indicator (integer starting at 0; may go to any number but reset to zero on a minor or major version change.

The suffix b may be added to a version number to denote that the software is a beta release.

2.6.1 Start Menu icons

The start menu icon is the standard Toolkit triple-drop icon with the acronym RAP underneath.

2.6.2 Screens or dialogs

When a module of RAP is selected, the module screen appears, with a tree view to the left of screen and a context sensitive menu at the top of the screen for navigation. Users can make selections of RAP options via the right side of the screen. These user options can be saved or loaded via the file menu.

2.6.3 Mouse & keyboard controls

You can navigate around RAP pages using the TAB button, or the mouse.

2.6.4 Manual configuration

Advanced user options are available for the Time Series analysis module. Advanced user options allows the units (e.g. m3/s, MI/d) to be set, the analysis period and the method of analysis.

2.7 Uninstalling RAP

To uninstall RAP go to **Start > Control Panel > Add Remove Programs**. Select RAP, select uninstall. RAP will be removed from your system.

3 Using RAP

3.1 Getting started

To run the River Analysis Package click on the RAP icon on the desktop or select **Start > Programs > Toolkit > River Analysis Package**.

The RAP introduction splash screen will appear for approximately 5 seconds or until a mouse button or key is pressed. The RAP menu will then appear. In the centre of the screen are a selection of the available modules within RAP. If the mouse is moved over a module button, a brief description on the module appears to the right. Select a module by single clicking on the appropriate button.

Each module of RAP has a menu across the top of the largest window. This menu is context sensitive in that it changes depending on which module you currently have active. You can have both TSA and HA modules open at the same time, however whichever window 'has focus' will determine the menu on the largest window. The window with the bold banner has focus.

As well as the context sensitive menu at the top of the main window, each RAP module has a tree-view to the left side of the screen to help navigate around the software. The tree-view is a replication of the menu, however you can have several nodes of the tree open at once for easy navigation (Figure 3) where as the menu automatically hides the lower-level items once it has lost focus.

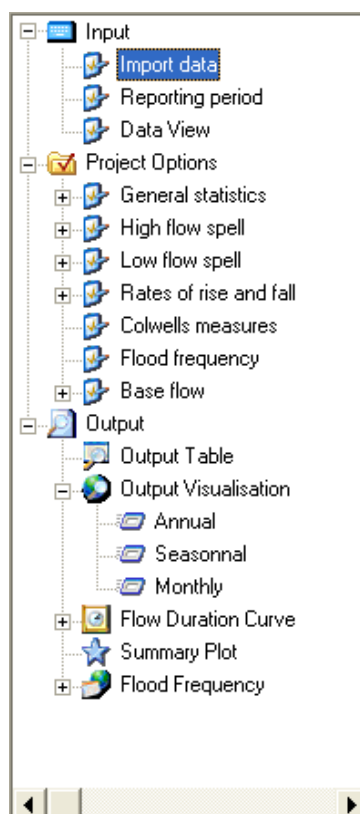


Figure 3-2: Tree view for easy navigation

3.2 How to Run HA (quickstart).

For a quick introduction to running the Hydraulic Analysis module, follow these steps (more information in subsequent sections);

- 1 Open RAP
- 2 Select Hydraulic Analysis
- 3 Select **Input > Section data** on the left tree view
- 4 To load a river network, go to **File > Open > Survey Data**, then navigate to some sample data (try c:\program files\toolkit\RAP\Sample data) open the .go1 file by double clicking with the mouse (left button).
- 5 Got to **Hydraulic Model > Hydraulic Model run** on the tree view, Hit the "Run FldWav" button to run the hydraulic model.
- 6 Explore the output by looking at the **Output > Water Levels**, **Output > Rule Library**, or **Output > Rating Curves** screens.
- 7 You can convert the hydraulic data to a time series of hydraulic data, go to the **Output > Export** screen. Drag a time series file to the "Input Discharge Time Series" box (try c:\program files\toolkit\RAP\Sample data). Select a hydraulic parameter, and either save the time series or send it to the Time Series Analysis package.

3.3 How to run TSA (quickstart)

For a quick introduction to analysing some time series data, follow these steps (more information in subsequent sections);

- 1 Open RAP
- 2 Select TSA
- 3 Select **Input > Import data** on the left tree view
- 4 Open windows explorer and navigate to some sample data (try c:\program files\toolkit\RAP\Sample data) grab the .csv file by selecting with the mouse (left button).
- 5 Drag and drop the file onto the plot area of the input scree. That is keep the left mouse button depressed while dragging the file to the plot area of the input screen in TSA, release the mouse button.
- 6 Select **Project Options > General statistics** in the tree view
- 7 Click some boxes to select statistics to calculate.
- 8 Click the run button (below the tree view)
- 9 The output data table should be displayed
- 10 Graphical output can be viewed by navigating via the output tree view node.

4 Hydraulic Analysis Module

The Hydraulic Analysis Module is started by selecting the button at the start up screen or going to **File > New > Hydraulic Analysis**. There is not restriction on the number of Hydraulic Analysis sessions open at any one time.

4.1 Input Section Data

To construct a hydraulic model, you first need to enter channel survey data. Survey data consists of cross-sectional stream surveys, all recorded against the same horizontal datum. You can import section data that has been saved from HECRAS, or enter it directly into HA. To load a file from HECRAS, go to **File > Import > Survey data** and select the HECRAS .go file.

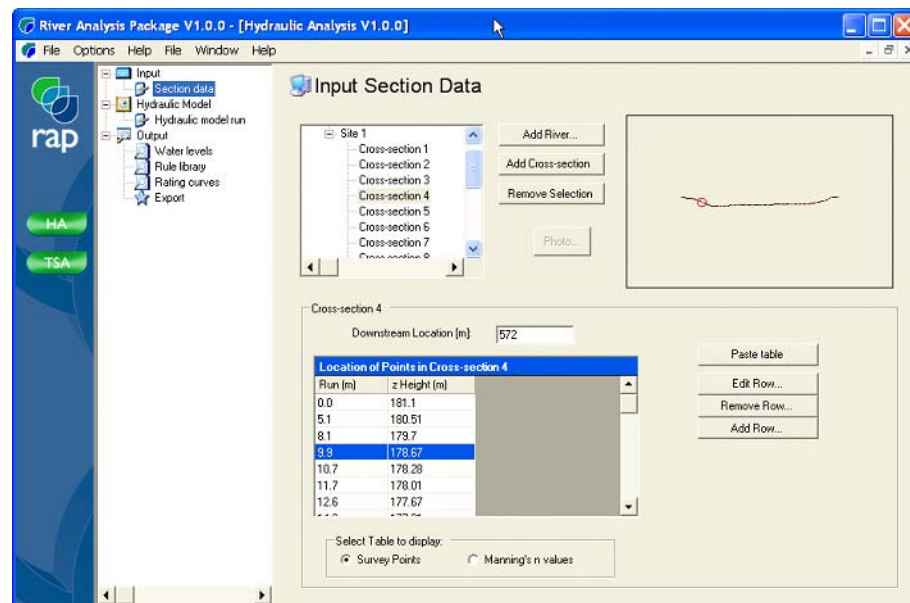


Figure 4-3: Input section data screen

To enter data manually, first enter the river (select the Add River button) and name it accordingly. Select the river which you have just added and click the radio button to state

whether Manning's n values should be based on discharge or river height (default is Discharge). You can also specify the number of water surface elevations used as input to the hydraulic model.

Select the Add Cross-section button to add a cross-section. Enter the longitudinal distance (Downstream Location) for the cross-section (this is usually the number of metres upstream from the mouth or confluence). To add cross-section survey data, select a row in the Location of Points table, select Edit Row, and enter the distance across the channel (Run) and the height for each point. Continue to do this for all points in the cross-section by selecting the Add Row button for each new set of cross-section points. Alternatively if your data is in a spreadsheet, simply copy it from the spreadsheet, click the Location of Points table and select the Past Table button.

As you enter cross-section points you will notice the cross-section appearing in the top right hand side of the screen, this helps you avoid data entry errors. As you step through the points in the table, a red circle will follow your position in the plot of the cross-section to help navigate your position in the cross-section.

To construct a hydraulic model you also need to enter the channel roughness for each cross-section. Select the Manning's n values button near the bottom of the display to switch to a table of Manning's n values. Manning's n can be specified as constant for all discharges, or can be varied according to discharge. At least one Manning's n value must be specified for each cross-section, the default setting is 0.04.

4.2 Hydraulic model

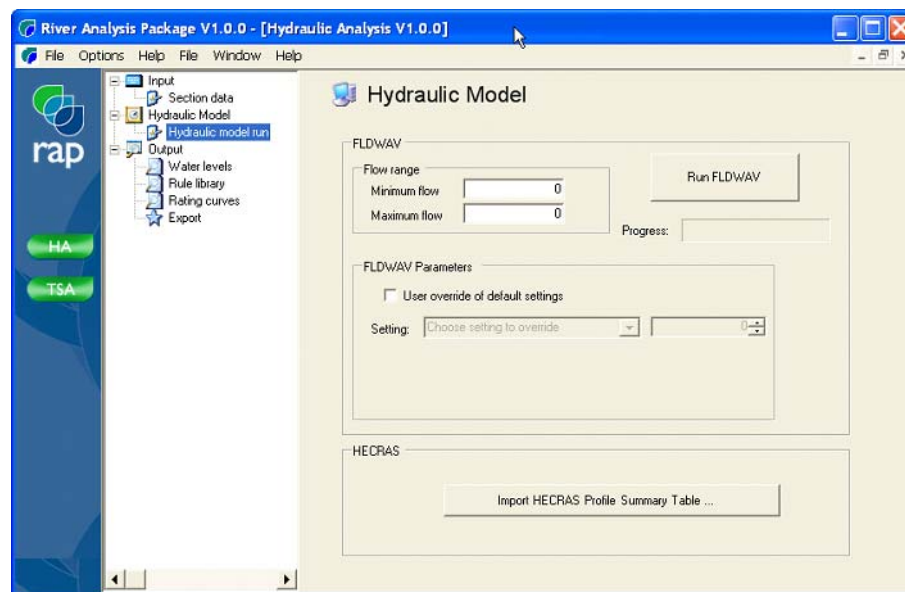


Figure 4-4: Hydraulic model Run Screen

Once all the channel cross-section data has been entered, you can run the hydraulic model by entering the minimum and maximum flow range (m³/s) that you would like to consider, then selecting the Run FLDWAV button. Alternatively, if you have a hydraulic model that you have previously built and run in HECRAS you can import the HECRAS Summary Table (.csv format) by selecting Import HECRAS Profile Summary Table.

4.3 Water Levels

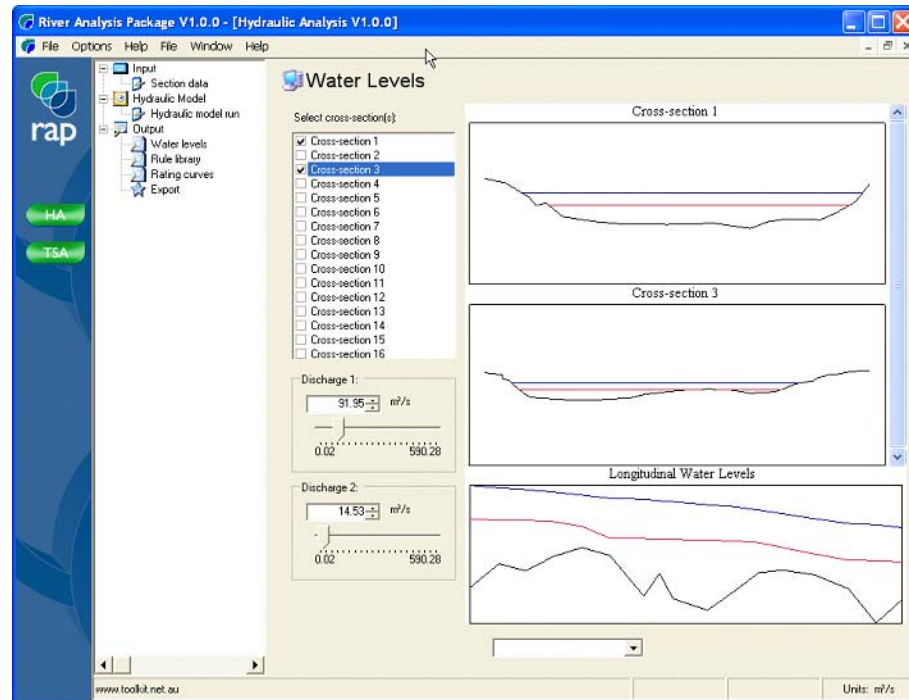


Figure 4-5: Water Levels screen

Once the hydraulic model has been run, or data imported from a hydraulic model elsewhere, you can investigate the water level at each cross-section for varying discharges. Select cross-sections from the available list then use the slider bars for the two alternative discharges to observe the water level change. The bottom plot shows the longitudinal water surface profiles for the modelled reach. By hovering the mouse over any of the plots the water surface elevations for the two discharges will appear near the mouse pointer. This is particularly useful if you are trying to determine at what discharges benches become inundated, or at what point the channel bed is likely to be out of the photic zone in turbid rivers with limited light penetration.

4.4 Rule Library

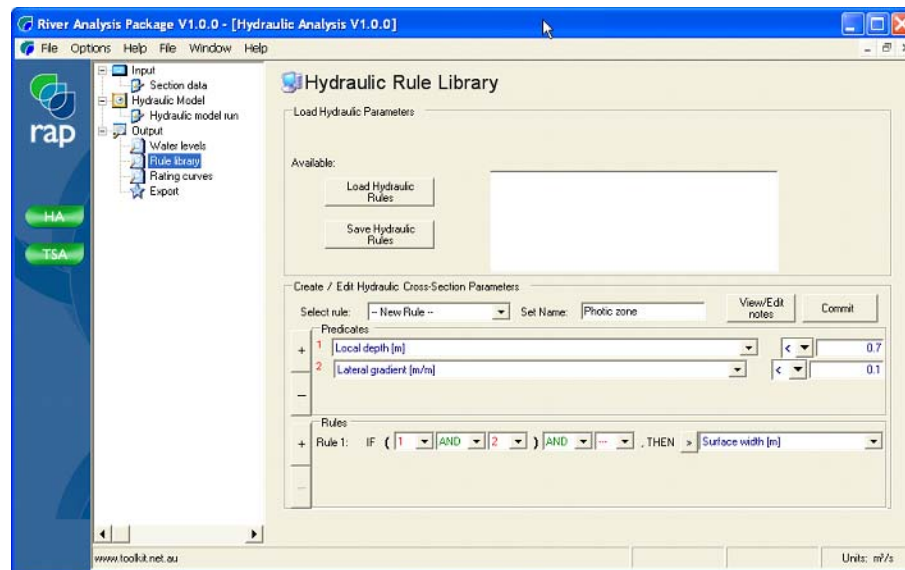


Figure 4-6: Rule Library screen

A key feature of the Hydraulic analysis package is the ability to investigate the effect of different combinations of hydraulic parameters. The Rule library allows you to use predefined hydraulic parameters and to create your own by combining hydraulic parameters.

Firstly select a rule (New Rule, for the first one), then name it, say “photic zone” for example. Select the first predicate, for example we may be interested in water depth less than 1 m, select the Local Depth, then select < in the drop down box then enter 1 in the right box.

Surface width [m]
 Wetted perimeter (=P) [m]
 Cross-sectional area (=A) [m²]
Local depth [m]
 Thalweg depth [m]
 Lateral gradient [m/m]
 Volumetric flow per width [m³/s]
 Bulk (mean) flow velocity [m/s]

Figure 4-7: Select the local depth in the predicate box

Suppose we are also interested in channel benches. Click + to add a predicate, select Lateral Gradient, Select < and type 0.1 (i.e lateral slope less than 1 in 10). Now we can combine these two predicates as a rule. In the rule box, say IF 1 and 2 then Select >> and enter 1. Hit the Commit button. You now have a photic zone rule. For a turbid river where benthic metabolisms is important and light penetration is limited, and horizontal surfaces are important for colonisation, you now have a rule that tells you the proportion of bench area with less than 1m water depth, i.e. the area available for benthic metabolism under a range of discharges. To take full advantage of the implications of this rule, go to the Rating Curves Screen.

4.5 Rating Curves

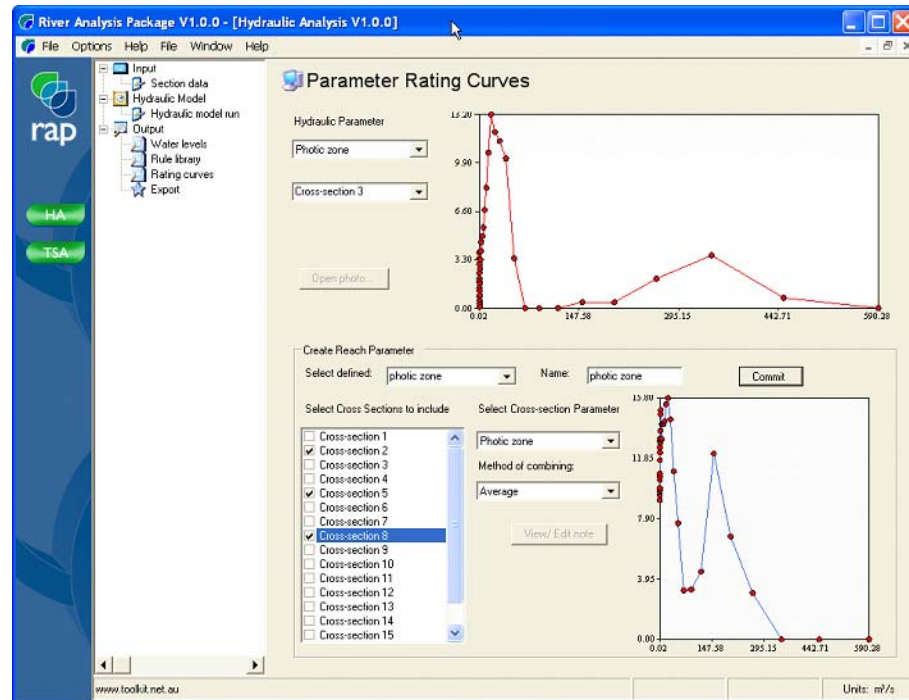


Figure 4-8: Rating Curves screen

Each of the pre-defined rules as well as any that you create can be viewed for each of the cross-sections that you have loaded. The rating curve shows the change in the rule or hydraulic parameter with discharge for each cross-section. If you are interested in a reach summary rating curve, select the cross-sections that represent your question (you may be interested in pools, riffles or the average of all cross-sections). Select the cross-section parameter, and the method of combining (minimum, maximum or average), and press **Commit** to see the final summary rating curve. You now have a summary measure of how your particular rule or hydraulic parameter varies with discharge across a range of cross-sections. This spatial summary is a great way to review the effect of discharge variation on the selected hydraulic parameter. However it is often very useful to investigate how this parameter changes through time by combining the rating curve with flow data.

4.6 Time Series Export

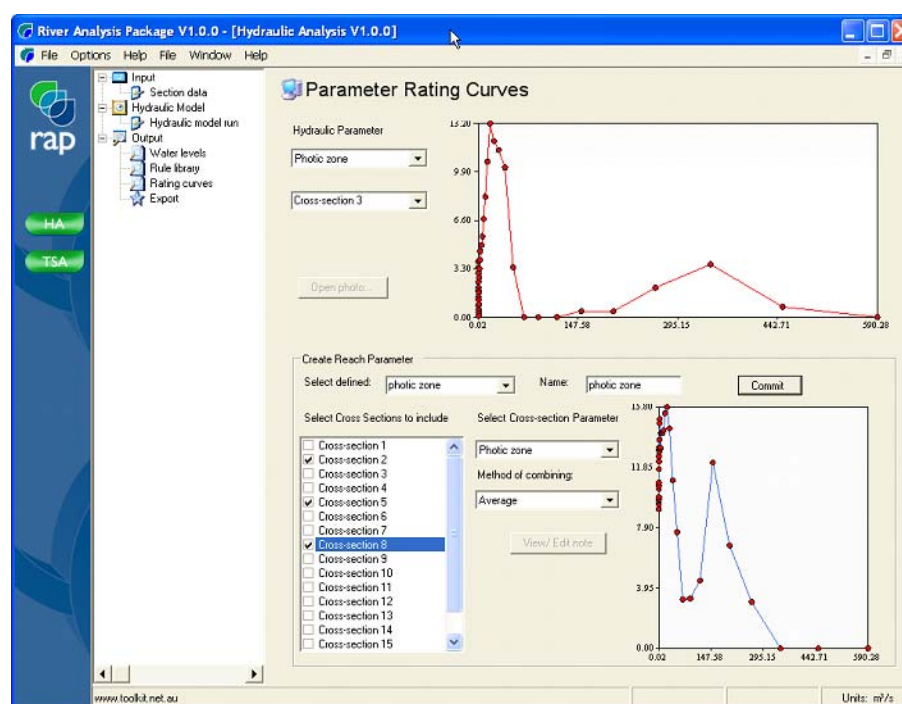


Figure 4-9: Time Series Export screen

Drag a flow time series on to the top plot (data in m³/s). Select a reach parameter that you have created a rating curve for, and review the time series of the reach parameter in the bottom plot. To further explore the time series of hydraulic parameter, pass the data to the Time Series Analysis module for exploring trends such as seasonal variation, distribution or skew and for comparing hydraulic parameters for alternate flow regimes.

5 Time Series Analysis

The Time Series Analysis module is started by selecting the button at the start up screen or going to File > New > Time Series Analysis. There is not restriction on the number of Time Series Analysis sessions open at any one time.

5.1 Input

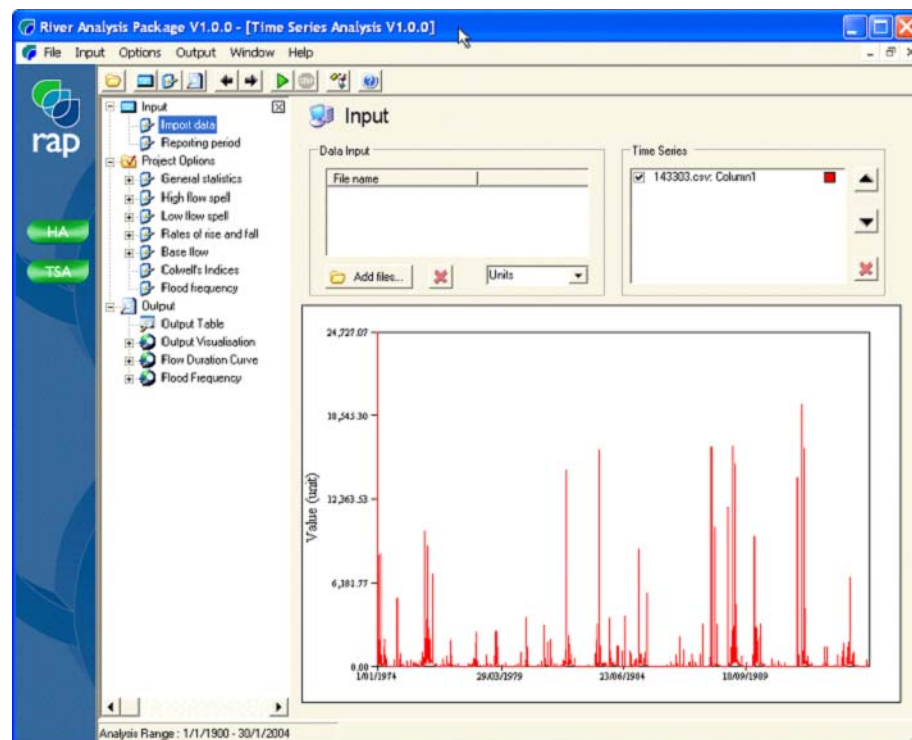


Figure 5-10: Time Series Input Screen

Time series data may be entered by dragging and dropping on to the view control (plot) on the bottom of the panel, or by selecting a file by clicking the Add files... button. To load time series they must be gap free and be free of null entries (i.e. -9999). TSA handles most common formats of input data. If there is a problem loading a particular data file, make the

input data two columns, one with date (based on the date setting on your computer, dd/mm/yyyy in Australia) the second with the flow data (exclude column headings, and make sure the file is saved as a comma delimited .csv file).

Loaded time series are listed in the list box to the top right. You can select and deselect the time series by clicking on the tick in the box. If you Right Click on the view control you can select to zoom in, pan or change the settings like colour as well as save the output from the plot.

Only time series that are loaded and selected on the time series are analysed in subsequent analysis. Only the concurrent period between multiple open input time series can be analysed, therefore input time series must have a concurrent period to allow analysis.

5.2 Reporting Period

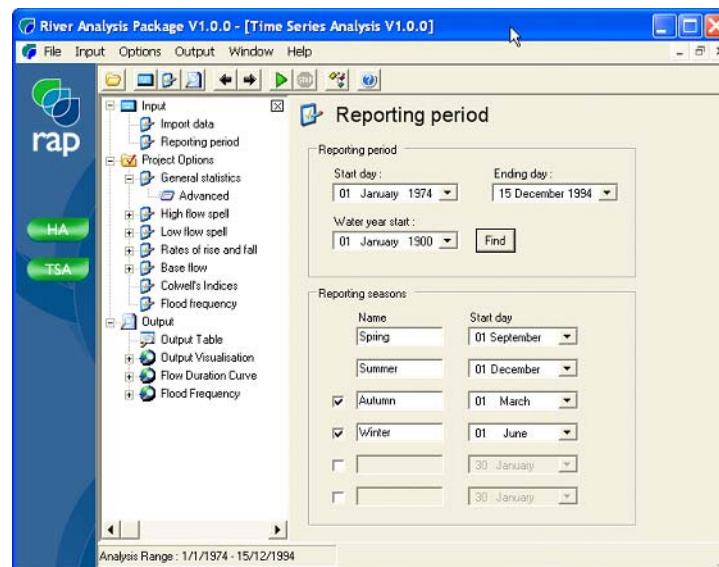


Figure 5-11:Reporting Period Screen

The period of analysis for RAP TSA does not need to be the entire period of the input record, you can specify a shorter period, however RAP TSA will not allow you to specify a reporting period outside the concurrent period of input time series. The water year operates from the start of the input period, however for future versions of RAP TSA you will be able to specify a water year start or ask RAP TSA to calculate it for you, where the water year start is the first day of the month of lowest mean daily flow for the input record.

RAP TSA can analyse time series data for the whole period, years, seasons and months. You can specify the seasons to report, there must be a minimum of two seasons and if more than two they must be in order of occurrence. An example may be to specify a wet season and dry season or maybe a spawning season, growing season and stress season.

5.3 General Summary statistics

TSA provides a range of summary statistics for quantifying commonly requested flow metrics.

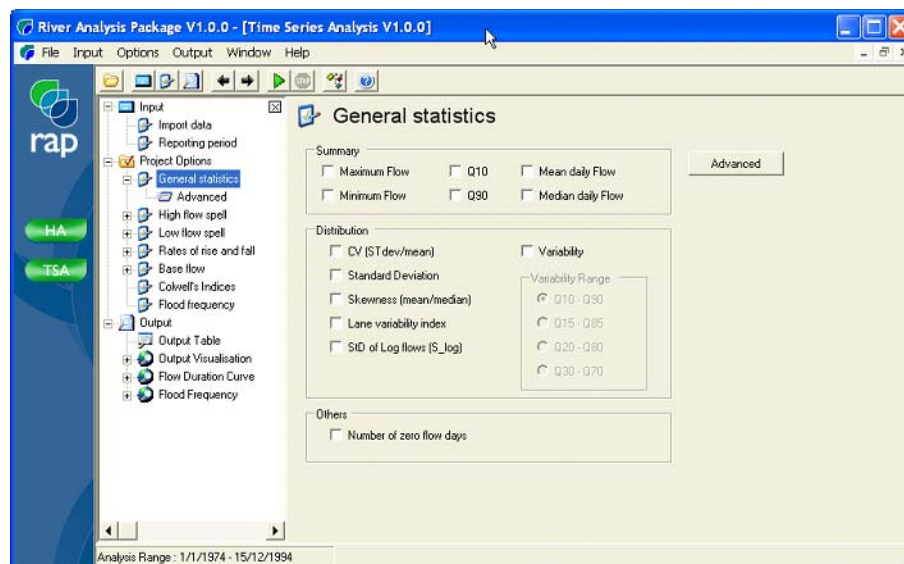


Figure 5-12: General Summary Statistics Screen

5.3.1 Summary

Minimum Daily Flow

The minimum flow is the smallest input value for the specific reporting period. See the advanced options for varying the reporting period.

Maximum flow

The maximum flow is the largest input value for the specific reporting period. See the advanced options for varying the reporting period.

Q10

The Q10 is the flow exceeded 10% of the time, that is, it is the discharge that indicates the top 10% of the flow for the reporting period. See the advanced options for varying the reporting period.

Q90

The Q90 is the flow exceeded 90% of the time, that is, it is the discharge that indicates the lower 10% of the flow for the reporting period. See the advanced options for varying the reporting period.

Mean daily Flow

The mean flow is a measure of central tendency. It is calculated as the average of all flow records considered over the analysis period (sum of flow values/number of days). See the advanced options for varying the reporting period.

Median Daily Flow

The Median Flow is a measure of central tendency. The Median Flow is the "middle" flow for the entire record. That is the median is the flow exceeded 50% of the time. The median is usually much lower than the mean daily flow because the distribution of discharge data is negatively skewed with a lower limit of zero and no upper limit. See the advanced options for varying the reporting period.

5.3.2 Distribution

Coefficient of Variation of Daily Flow

The coefficient of variation is the division of a mean by the standard deviation value. The CV of daily flow is the standard deviation for the daily flow values divided by the mean of all daily flow values. See the advanced options for varying the reporting period.

Standard Deviation of Daily Flow

The standard deviation is a measure of how widely the values are dispersed from the mean value. The Standard Deviation has the same units as the input data. See the advanced options for varying the reporting period.

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}}$$

$$\sqrt{\frac{n \sum x^2 - (\sum x)^2}{n(n-1)}}$$

where

n = number of values

x = value

Skewness of Daily Flow

Skewness is a measure of how different the mean and median flows are. Skew = mean/median flow. For a small catchment stream the base flow will normally be very low, with a dramatic change in discharge during a storm event. Most of the discharge thus occurs during a storm, however most of the days are low flow. Hence the median flow is low, and the mean flow is elevated by the much larger event-based discharges. As a consequence the Skewness of a small catchment would be greater than that of a large catchment. Similarly, the Skewness of an unregulated stream will tend to be greater than that of a regulated stream (depending on the flow release strategy). See the advanced options for varying the reporting period.

Variability of Daily Flow

The measure of variability used by TSA is based on the use of the median flow as a measure of central tendency. Variability is calculated as the range divided by the median. The range is defined by the user in terms of the percentile range of flows. The default setting for the range

is the difference between the Q10 and Q90 flows. Where the whole record is used, this measure of flow variability is used to describe the entire record. See the advanced options for varying the reporting period.

Range of Daily Flows

The range of daily flows is based on a user defined range of percentile values. The range is used to compute the Variability of Daily Flow. The default range is Q10-Q90, that is the flow exceeded 10% of the time minus the flow exceeded 90% of the time. The range is used in conjunction with the median flow to describe the variability of Daily Flow of flow using a median rather than mean based measure of central tendency.

The range is user defined by selecting the appropriate range value (on the right of the summary statistics page):

Q10-Q90

Q15-Q85

Q20-Q80

Q30-Q70

Standard deviation of the log of daily flows (S_Log)

The S_Log, is an estimate of the standard deviation of the logarithm (base 10) of the daily flow values. Flow data is often logged to reduce the skew, S_Log is a measure of the distribution of this transformed data, as such it provides a description of the skew of the input data (reference (Gordon et al., 1992), pp376).

$$S_{\log} = \frac{\log Q_5 - \log Q_{95}}{3.29}$$

$$S_{\log} = \frac{\log Q_5 - \log Q_{95}}{3.29}$$

where: Q= discharge

Lanes variability index (Lanes)

The Lanes variability index is described as the standard deviation of the logarithms of the Q5, Q15, Q25, ..., Q85 and Q95 values. Lanes variability index is unsuitable for data sets with more than 5% zero values (i.e. Q95 = 0) or data sets dominated by zero flows.(Gordon et al., 1992).

5.3.3 Others

Number of Zero Flow Days

The number of zero flow days for the entire record under analysis are counted. The number of zero flow days does not include days with a missing record unless they are filled with zero values. See the advanced options for varying the reporting period.

5.4 Advanced

Advanced provides alternative reporting techniques, such as a single summary value for the entire record, annual, seasonal or monthly values. The advanced reporting options applies to general statistics, high flow spell analysis, low flow spell analysis, rates of rise and fall and base flow.

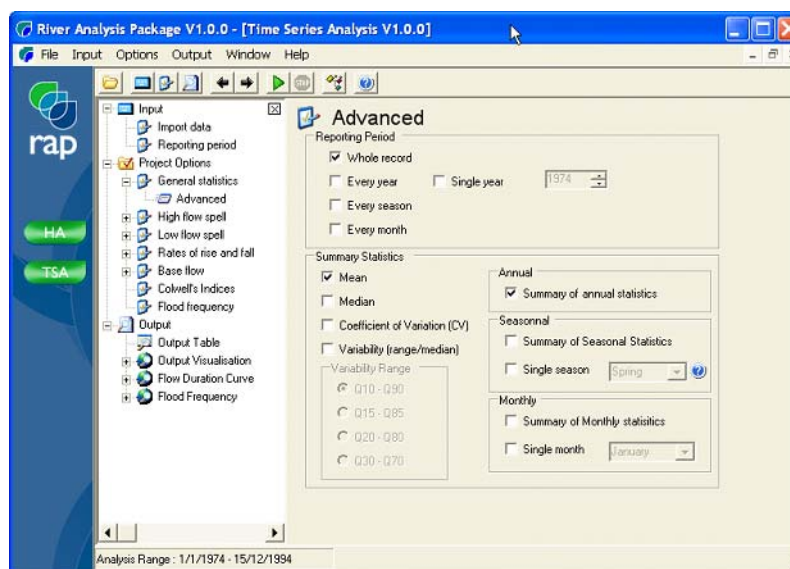


Figure 5-13: Advanced reporting options

5.4.1 Reporting Period

Whole Record

If Whole record is selected, the output is a single value for the whole period. If you have selected Minimum daily flow and Whole period, the output will be a single value for the minimum daily flow for the whole period.

Every Year

If Every Year is selected the output table will list statistics for every year of the record. For example if a 20 year record is entered, minimum daily flow is selected from General statistics, and Every Year is selected then the output grid will display a minimum daily flow for each of 20 years.

Single Year

If Single Year is selected (and a year selected in the scroll list box), the output grid will display data for a single year.

Every Season

If Every Season is selected, the output grid will display statistics for every season in the record. For example if a 20 year record is entered, and 4 seasons have been entered, and minimum daily flow is selected from General statistics, and Every Season is selected then the output grid will display a minimum daily flow for each of 4 seasons for each of 20 years (100 output values).

Users can alter the number and duration of seasons by selecting Input > Reporting Period. Up to 6 seasons can be entered, they must be entered in the order in which they occur (although you can start with any season). You can name the seasons anything you like. The minimum number of seasons is 2.

Every Month

If Every Month is selected, the output grid will display statistics for every Month in the record. For example if a 20 year record is entered and minimum daily flow is selected from General statistics, and Every Month is selected then the output grid will display a minimum daily flow for each of 12 months for each of 20 years (240 output values).

5.4.2 Summary Statistics

As well as reporting statistics for each year, season or month, you can also calculate summary statistics to represent these values. Two measures of central tendency are available, Mean and Median, and two associated measures of variability are also available, Coefficient of Variation (mean/Standard Deviation) and Variability (Median / (10th-90th percentile)). Be aware that CV will only provide a sensible value if the standard deviation is a real value (i.e. there must be more than 1 datum point to calculate a standard deviation). Also be aware that the variability measure will give a zero value for data sets with a zero median, and infinity value for zero ranges.

Annual summary

The mean, Median CV or variability can be determined from the record of annual values. For example, if a 20 year record is selected, the minimum daily flow is selected from the general statistics and annual and mean, median, CV and variability are selected in the reporting period (as well as annual), the output grid will have 4 values, the mean of annual minima, the median of annual minima, the CV of annual minima and the variability of annual minima.

Seasonal summary

The mean, Median CV or variability can be determined from the record of seasonal values. For example, if 4 seasons are selected for a 20 year record, the minimum daily flow is selected from the general statistics and annual and mean, median, CV and variability are selected in the reporting period (as well as seasonal), the output grid will have 16 values, the mean of seasonal minima, the median of seasonal minima, the CV of seasonal minima and the variability of seasonal minima for each of 4 seasons.

Single Season

The mean, Median CV or variability can be determined for a single season from the record of seasonal values. For example, if 4 seasons are selected for a 20 year record, the single season of "Summer" is selected as the single season, the minimum daily flow is selected from the general statistics and annual and mean, median, CV and variability are selected in the reporting period (as well as seasonal), the output grid will have 4 values, the mean of Summer minima, the median of Summer minima, the CV of Summer minima and the variability of summer minima.

Monthly Summary

The mean, Median CV or variability can be determined from the record of monthly values. For example, if a 20 year record is selected, the minimum daily flow is selected from the

general statistics and annual and mean, median, CV and variability are selected in the reporting period (as well as monthly), the output grid will have 240 values, the mean of monthly minima, the median of monthly minima, the CV of monthly minima and the variability of monthly minima for each of 12 months.

Single Month

The mean, Median CV or variability can be determined for a single month from the record of monthly values. For example, if a 20 year record is selected, the single month of "January" is selected as the single month, the minimum daily flow is selected from the general statistics and annual and mean, median, CV and variability are selected in the reporting period (as well as monthly), the output grid will have 4 values, the mean of January minima, the median of January minima, the CV of January minima and the variability of January minima.

5.5 Colwell's Indices

Colwell's indices are a measure of the seasonal predictability of environmental events. The method was developed for categorical data such as when a tree is fruiting or a fish spawning. The seasons in which this occurred or did not occur are recorded and a table of presence absence of different events can be constructed. The equations developed by Colwell (1974) can then be used to predict: 1) the predictability; a measure of how tightly an event is linked to a season, 2) Constancy; a measure of how uniform the event occurs through all seasons, and 3) Contingency; a measure of the repeatability of season patterns.

For detailed information on the calculation and description of Colwell's indices refer to (Colwell, 1974).

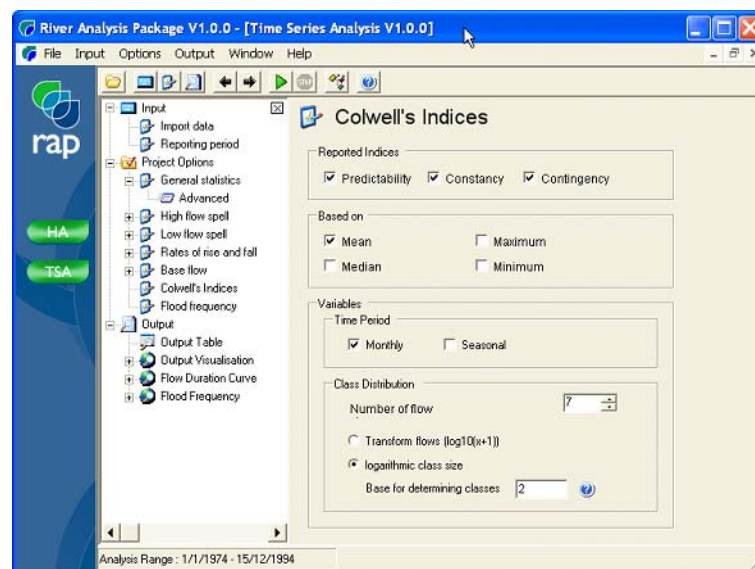


Figure 5-14: Colwell's Indices

Colwell's Indices are based on a tabular representation of the input data. Continuous time series data must be converted to categorical data. To convert from continuous data to categorical data, flow classes must be selected; the frequency of occurrence of flow in each class is recorded. The season in which the flow occurs is also recorded.

5.5.1 Reported Indices

Predictability

Predictability is the sum of Constancy and Contingency. Predictability is a likelihood of being able to predict a flow occurrence. Predictability is maximized when the flow is constant throughout the year (Constancy Maximised), or if the pattern of high or low flow occurrence is repeated across all years (Contingency maximized).

Constancy

Constancy is maximized when the flow is the same for all seasons, for example a desert river with many zero flows will have a high constancy value.

Contingency

Contingency is maximized when the pattern of flow is the same from year to year, for example, high flows occur every winter of the record.

5.5.2 Based on (basis for calculating Colwell's indices)

Mean

Colwell's indices are based on the mean value for each time period. If the time period is monthly, then the mean daily value of each month is used to construct the Colwell's data table from which the indices are calculated.

Median

Colwell's indices are based on the median value for each time period. If the time period is monthly, then the median daily value of each month is used to construct the Colwell's data table from which the indices are calculated.

Maximum

Colwell's indices are based on the maximum value for each time period. If the time period is monthly, then the maximum daily value of each month is used to construct the Colwell's data table from which the indices are calculated.

Minimum

Colwell's indices are based on the minimum value for each time period. If the time period is monthly, then the minimum daily value of each month is used to construct the Colwell's data table from which the indices are calculated.

5.5.3 Variables

Time Period

Traditionally, Colwell's indices have been considered by dividing the flow record on a month by month basis. TSA allows the user to interact with these 'seasonal' classifications by manually choosing up to six seasons rather than 12 calendar months.

Only entire years of record are considered such that there are an equal number of each of 12 months or each of 2-6 seasons.

Monthly

You can calculate Colwell's indices based on monthly flow records. Each calendar month of the record is considered as a single flow record, with either the mean, median, maximum or minimum daily flow for that month compared to all other months to develop Colwell's indices. You can select either the first whole month of the specified analysis period or select a starting month and year.

Seasonal

Instead of analysing flow on monthly basis it may be more relevant to consider flow on a seasonal basis. For example one may wish to determine the geographic location to delineate flow dominated by tropical wet season / dry season conditions from an area of more uniform flow. For this analysis the use of just two seasons is more relevant than 12 separate seasons (i.e. months) per year. When one considers all 12 seasons (months) a summer dominated stream flow may have the same predictability as a winter dominated stream flow, however from a water management perspective these may well mean very different things, hence one can define the particular period of interest. Seasons are defined in the Input > Reporting Period section.

5.5.4 Class Distribution

Basis for Calculation

When considering flow allocation, it may be important to gain an appreciation of the predictability of the mean monthly or seasonal flow conditions. However, from a biological perspective it may be the extremes of the hydrograph that stimulate activity such as spawning, hence one may wish to know the predictability of low or high flow. TSA allows Colwell's indices to be calculated based on the mean daily flow for a season (or month) which is the sum of all flows for that season divided by the number of days; the maximum daily flow for the season (or month), or the minimum daily flow for that season (or month).

The basic configuration for calculating Colwell's indices is to create table recording the frequency of occurrence of a range of flow classes for a number of "seasons" then conduct the numeric summary of the table as described by the equations below.

Figure 5-15: Example Colwell's input table

Flow class	Summer	Autumn	Winter	Spring
<100	1	2	3	2
100-199	2	2	3	2
200-299	2	2	4	3
300-399	2	4	4	3
400-499	3	4	3	4
500-599	4	3	2	3
600-699	5	3	2	3
>699	3	2	1	2
total	22	22	22	22

$$X_i = \sum_{j=1}^s N_{ij}$$

$$Y_i = \sum_{j=1}^t N_{ij}$$

$$Z = \sum_i \sum_j N_{ij} = \sum_j X_j = \sum_i Y_i$$

$$H(X) = - \sum_{j=1}^t \frac{X_j}{Z} \log \frac{X_j}{Z}$$

$$H(Y) = - \sum_{i=1}^s \frac{Y_i}{Z} \log \frac{Y_i}{Z}$$

$$H(XY) = - \sum_i \sum_j \frac{N_{ij}}{Z} \log \frac{N_{ij}}{Z}$$

$$\text{Predictability}(P) = 1 - \frac{H(XY) - H(X)}{\log s}$$

$$\text{Consistency}(C) = 1 - \frac{H(Y)}{\log s}$$

$$\text{Contingency}(M) = \frac{H(X) + H(Y) - H(XY)}{\log s}$$

$$X_i = \sum_{j=1}^s N_{ij}$$

$$Y_i = \sum_{j=1}^t N_{ij}$$

$$Z = \sum_i \sum_j N_{ij} = \sum_j X_j = \sum_i Y_i$$

$$H(X) = - \sum_{j=1}^t \frac{X_j}{Z} \log \frac{X_j}{Z}$$

$$H(Y) = - \sum_{i=1}^s \frac{Y_i}{Z} \log \frac{Y_i}{Z}$$

$$H(XY) = - \sum_i \sum_j \frac{N_{ij}}{Z} \log \frac{N_{ij}}{Z}$$

$$Predictability(P) = 1 - \frac{H(XY) - H(X)}{\log s}$$

$$Consistency(C) = 1 - \frac{H(Y)}{\log s}$$

$$Contingency(M) = \frac{H(X) + H(Y) - H(XY)}{\log s}$$

Where:

t = number of seasons

s = number of classes

N_{ij} = number of cycles for which the phenomenon was in state i at time j.

X_i = column totals

Y_i = row totals

Z = grand total

Number of Flow Classes

Flow data is a continuous record of different flow magnitudes from low to high flow, rather than categorical groups of different flow magnitude. In order to calculate Colwell's indices one must convert the continuous record of flow magnitude into categorical groups of flows. How the flow is divided into groups and how many groups are defined will depend on the purpose of the analysis. The number of flow classes does affect the calculated Colwell's indices because it changes the distribution of data in summary table from which Colwell's indices are calculated. TSA manages the selection of flow categories by allowing the user to have full control of how the flow classes are determined. The user can select the number of groups, the threshold daily flow for the lowest group and for the highest group. The division of flow in between these two groups into classes can be such that each flow group is of uniform size or each is some exponent of the previous.

Transform Flows

Transforming flows by taking the $\log(x+1)$ of the flows, effectively reduces the skew of the distribution, so that the data approaches normal distribution. The upper and lower bounds of the normalized data set are then found and flow classes are divided between these upper and lower limits according to the number of classes selected. Ideally, this approach provides a good distribution of data cross flow classes, resulting in a reasonable population across all flow classes. This distribution is very sensitive to the number of classes selected. If a low number of classes is selected (less than 5), then the skew (even the normalized data will still be slightly skewed) may result in most of the flow falling in a single flow class. This result will give a high Colwell's constancy across seasons. We would recommend >7 classes (from experience, around 11 classes gives consistent results in Contingency and Constancy that one would expect from the hydrographs).

Logarithmic Class Size

The paper by (Colwell, 1974), suggests that for time series data such as flow or rainfall, the divisions between classes could be defined by a logarithmic progression (e.g. base 2) and these flow classes applied to the raw time series data. For base-2 class distribution, the class sizes are effectively skewed in a similar way to the input data. The class boundaries are set with a central class of $20 \times$ mean daily flow (MDF), with classes spread either side of this central class depending on the number selected by the user. For example if the user selects 5 classes and base 2 then class boundaries would be;

- 1 2-2MDF
- 2 2-1MDF
- 3 20MDF
- 4 21MDF
- 5 22MDF

From experience, base 2 and 11 flow classes seems to give sensible Constancy and Contingency values across all basins in Australia.

5.6 Flood Frequency

Plots of the flood frequency curve are not featured in RAP V1.0.0

Flood Frequency has often been used in the design of Engineering structures such as culverts, bridges and dams. Flood Frequency analysis is used to provide a predictive capacity to the stochastic nature of stream flow. We use the existing, preferably long-term stream flow data to predict the likely magnitude of events of a given return period.

The Flood Frequency analysis uses only complete years of the record. The data used to determine the flood frequency commences at the start of the user-defined period and ends on the date that describes the maximum number of entire years of record. For example if 15.5 years of record have been entered then the flood frequency will be calculated based on the first 15 years of the record and the final 6 months will be discarded.

For long return period flows (i.e. greater than 10 years) the annual series is suitable, however for predicting floods with return periods of less than 10 years the partial series is more suitable (Institution of Engineers Australia, 1987). The Annual Series flood frequency is based on the maximum discharge for each year of the record. The Partial Duration flood frequency is based on a collection of the largest discharges for the entire record, i.e. some years can have several floods and other dry years have none.

Flood Frequency is calculated by ranking the selected floods in order of magnitude then applying a log-pearson type 3 curve to the data to predict ARI values from those given (Institution of Engineers Australia, 1987). In this way the Flood Frequency analysis builds a

predictive model based on existing data, as with all such empirical models the accuracy is greatly enhanced with a large data set. A general rule for flood frequency analysis is that the longer the flow record then the more accurate the predicted ARI.

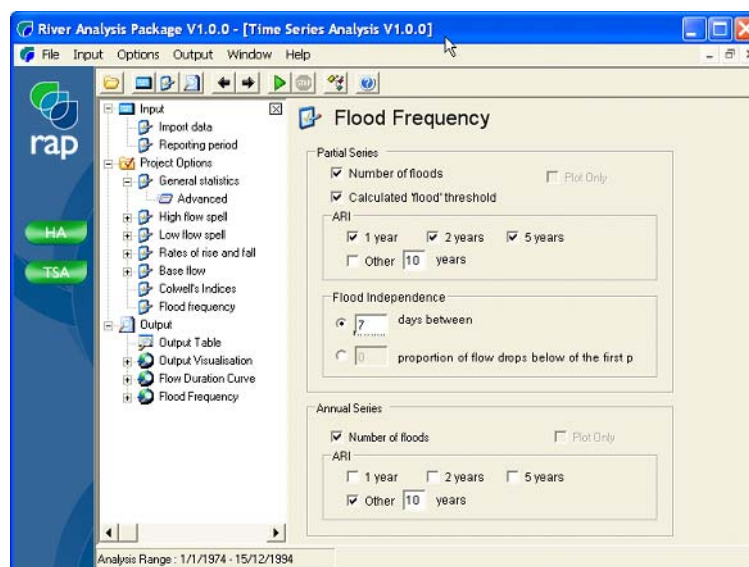


Figure 5-16: Flood Frequency input screen

5.6.1 Fitting a log Pearson Type 3 curve

Once the peak flows have been determined, the occurrence of outlier (upper or lower) in the flood series is considered and these outliers are discarded (See Australian rainfall and Runoff for the Procedure). A log Pearson Type 3 curve is fitted to the remaining flood series. ARI floods are predicted based on linear interpolation between predicted floods on the LP3 distribution.

5.6.2 Partial Duration

The method employed to determine the partial duration series is explained in detail in Australian Rainfall and Runoff (Institution of Engineers Australia, 1987) The partial duration flood frequency analysis is conducted by considering the peak flows whereby there is an average of 1 event per year. The floods have to be considered to be independent floods, hence a criteria for determining independence must be established. TSA allows you to specify the independence criteria as the minimum number of days between flood peaks or the flow must drop below some proportion of the previous flood peak before a new flood can occur.

Number of Floods

According to the method employed, the number of floods is equal to the number of years of the record. This considers only independent floods according to the user-defined independence criteria.

Magnitude of threshold flood

The threshold flood is determined by iteratively sorting the flow record to establish a number of independent floods equal to the number of years of the record.

ARI Partial Series

Annual Return Interval (ARI) returns the flood magnitude with a return period as specified. A one year ARI flood will on average occur every year, a 2 year ARI every 2 years and so on.

You can specify an ARI to calculate. For ARI's less than 10 years the partial duration series is likely to be more accurate than the annual series. The length of record should generally be much larger than the ARI intending to be calculated to avoid errors in the extrapolation of the data.

5.6.3 Annual Series

The annual series flood frequency is calculated using the largest flood in any given year of the record. No measure of independence of flood events is considered. Because there is no flood independence criteria, the start of the record would usually be the start of the water year, however TSA does not calculate this and relies on the user commencing the analysis period during low months of record.

ARI Annual series

Annual Return Interval (ARI) returns the flood magnitude with a return period as specified. A one year ARI flood will on average occur every year, a 2 year ARI every 2 years and so on. You can define an ARI for TSA to calculate. The length of record should generally be much larger than the ARI intending to be calculated to avoid errors in the extrapolation of the data.

5.6.4 Slope of the flow duration curve

Slope of the flow duration curve is not featured in RAPV1.0.0

A flow duration curve is different from a flood frequency curve because it considers all flows and not just the flood flow. The process of constructing a flood frequency curve is to sort all the flow data into ascending or descending order then plotting the flow magnitude (log scale on y axis) against the probability of flow exceedence (normal scale on x axis). The flow duration curve is usually shaped like a backward S with low probability of high flows, a central reasonably linear section of the curve and a flattening off with high probability of low flow. The central section of the plot is usually linear, and the slope (as well as linearity) of this section tells us something about the flow regime. Consider an intermittent ephemeral stream, there is a very high probability of low or zero flow, and a low probability of very large intermittent flow. The middle section of the curve is very steep because the proportion of time subjected to medium to high flows is low. Consider a perennial stream with a very large catchment; the range of flows can vary dramatically and the large catchment means that floods are often extended over a long time period, hence the central linear section of the curve would be much flatter.

The flow duration curve is often used by hydrologists to get a feel for the hydrological characteristics of a stream, however their interpretation is not always easy to objectively use as a numerical measure of a streams hydrology. The slope of the middle section of the flow duration curve (Q10-Q90) has been included in TSA as a means of quantifying the difference in one of the key characteristics of the flow duration curve. The R2 value of a line fitted to this section of the curve is also provided by TSA to aid the user in assessing the linearity of this section of the curve. It is hoped that in future versions of TSA a full graphics component may be added to allow the flood frequency and flow duration curves to be displayed and printed.

5.7 Low and High Flow Spell Analysis

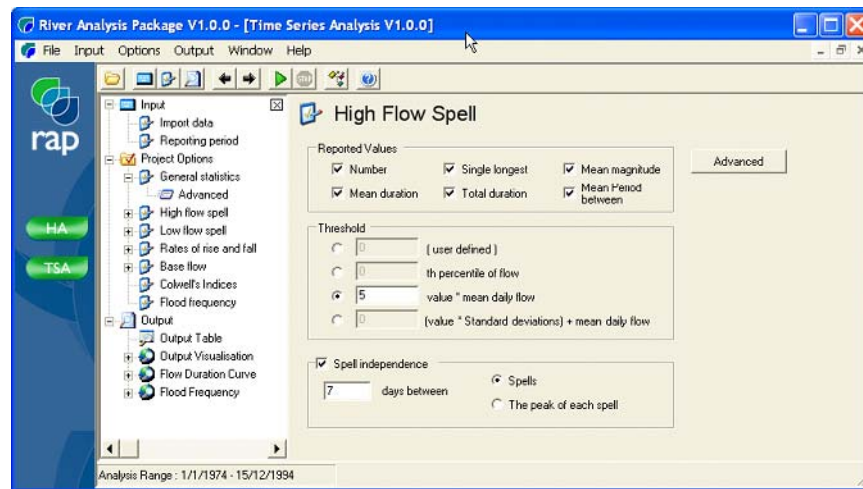


Figure 5-17: High Flow Spell analysis Input screen

Spell analysis is a common way to consider the extremes of the Hydrograph. Low Flow Spell Analysis calculates statistics based on when the stream flow drops to or below a predefined threshold level. Similarly High Flow Spell Analysis calculates statistics based on when flow equals or exceeds a predefined upper limit.

5.7.1 Low Flow Spell analysis

The key to successfully using spell analysis is to select meaningful thresholds. TSA allows you to input a discharge that has been determined to be important for the particular analysis. For example, for a low flow Spell Analysis one may be interested in how frequently the depth of flow over riffles drops below that which is navigable by some important fish species. This low flow threshold can be used to determine the frequency and duration of low flow events, and even the average minimum flow of each event. In addition to the user defined threshold, a threshold can be defined in terms of the mean daily flow. By defining flow thresholds in terms of some intrinsic factor of the flow record the same spell analysis may be applied to several flow records to help interpret differences in the flow regime.

Low Flow Spell Analysis Example

- Imagine that the spawning of some native fish species in Australia occurs during periods of stable low flows where water velocities and depths are low and temporally stable. This same period of low flow happens to be the time of peak demand for irrigation water to be delivered down the stream. The frequency and duration of the low flow periods could be compared between the natural low flow regime and a synthetic flow regime proposed by the irrigation facility.
- Consider the position of the irrigation facility in the example above:- Are we confident that it is the stable low flows that facilitates species spawning and recruitment? This hypothesis may be tested by comparing a long data set of temporally collected recruitment data with detailed spell analysis of the flow record over the same period. Do periods of high recruitment follow periods of low flow?

5.7.2 High Flow Spell Analysis

The High flow Spell Analysis is conducted in exactly the same manner as the Low Flow Spell Analysis, however it the frequency, duration and magnitude of events above the threshold that is important in this case.

High Flow Spell Analysis Example

- Fluvial Geomorphologists (those that describe the evolution of the landscape by water) have dedicated considerable attention to describing "channel forming flows". That is those flows with the capacity to transport sediment and reform the channel. One can consider not only the frequency of such flows (as described in flood frequency analysis) but also the duration that is critical to being able to do work on the stream.
- Consider a small hydroelectric power plant that discharge near bankfull flow when operating at peak discharge. If this discharge corresponds to that required to transport sediment, then the management of the power station may be required to no increase the rate of sediment transport due to the operation of the power plant. To address this problem one may compare the high Flow Spell analysis of the natural hydrograph with that of a modified hydrograph due to power generation.

5.7.3 Reported Values

Number

The number of spells for the reporting period. The reporting period can be the whole record, annual, seasonal or monthly, see the advanced options section.

Average duration

The average duration of spells for the reporting period.

Single Longest

The single longest spell during the reporting period.

Total duration

The total duration of spells for the reporting period.

Magnitude

The mean peak for high spells or minima for low spells is reported.

Period Between

The mean of the period of time between spells.

5.7.4 Threshold

The threshold flow (above or equal to which a high flow spell commences, or below which or equal to which a low spell commences) can be selected using several alternative criteria:

- Mean daily flow: A number of mean daily flows (can be a decimal)
- Standard deviation: The mean daily flow plus some number of standard deviations of the daily flow
- Percentile: a percentile of the daily flow, for example the 10th percentile flow is that flow which is exceeded 10% of the time.

- User defined: and user defined flow value. The Hydraulic Analysis module can be used to determine the appropriate user defined threshold level. For example this may be the discharge at which benches become inundated, or riffles have adequate depth of flow to allow fish passage.

5.7.5 Independence Criteria

Independence criteria determines if spells above or below a threshold (defined above) are separate events or part of the same event. Where consecutive spell events are not deemed to be independent, their duration is simply added. Two alternative independence criteria are available;

- 1 Number of days between spells: the number of days between the last day of an event and the start day of the next event.
- 2 Number of days between peaks: the number of days between event peaks.

How TSA handles overlapping spells between time periods

When analysing annual, seasonal or monthly time periods, it is necessary to know if we are in an event at the end of the time period. TSA records this information and considers it for the start of the next period. The occurrence of the event is recorded for the period in which it began, however the length is recorded in whichever period it occurs. If a spell starts in one period and ends in another (e.g. a flood that spans the December 31 and January 1) the occurrence of the spell is recorded for the first period, and the duration of above spell periods is attributed to the year in which it occurs. It is therefore possible to have a year when the only spell is one that spans from the end of the preceding year, in this case there will be no spell in the year, but there will be a spell duration recorded for the year. TSA also compares independence criteria between analysis periods. That is the number of days between peaks or the end and start of spells can span the end of an analysis period without affecting the output.

5.8 Base Flow Analysis

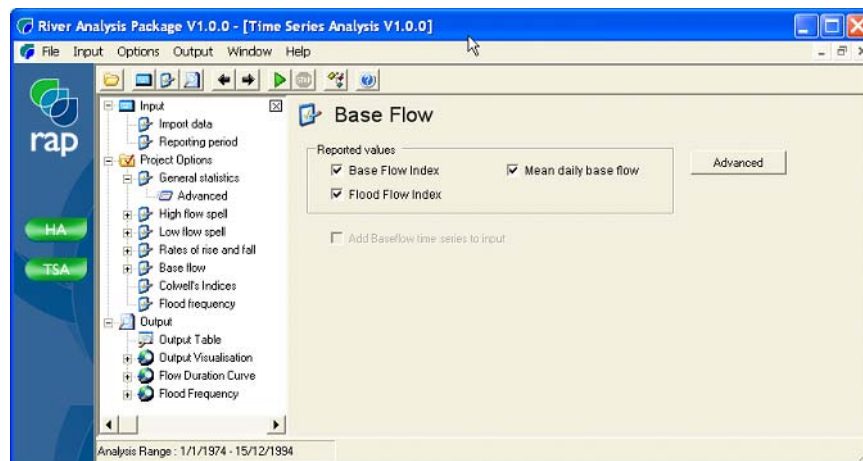


Figure 5-18: Base flow analysis input screen

Base Flow is considered here to be that flow which occurs in the absence of runoff due to rainfall events. A hydrograph will generally have long periods of relatively consistent low flow when the stream is groundwater fed interspersed with periods of high flow due to storm

events (see figure). The purpose of base flow analysis is to divide the hydrograph into the base flow and flood flow component parts.

Base Flow Analysis Example

- The Base Flow may be considered to be important for the establishment of macrophyte beds on which algae grow and which is subsequently harvested by macroinvertebrates. Two alternative irrigation schemes are being considered, one is based on water extraction whenever needed, the other is based on "harvesting" floodplain flows. The impact of the two irrigation techniques on the base flow can be assessed by examining the alternative effect on the base flows. The scheme with the least impact on the development on macrophyte beds can be adopted.
- Consider the assumption of the previous example that base flows are important for the establishment of macrophyte beds. This hypothesis can be tested by comparing the macrophytes and base flow of several similar streams.

5.8.1 Base Flow Method

The method of calculating the base flow component of the hydrograph is through the use a 3 way digital filter as described in (Grayson et al., 1996). The purpose of the digital filters is to create a relatively smooth transition from the period of base flow before a storm event to the usually elevated base flow following the storm event. In practice there is no way to accurately describe the base flow during periods of runoff, however Lyn and Holick method is generally accepted as a suitable approximation (Grayson et al., 1996).

Base flow index

The base flow index is the ratio of total base flow discharge for the reporting period to total discharge.

Flood flow index

The Flood flow index is the ratio of non-base flow (discharge – base flow) and total discharge. The intention of the flood flow index is to provide an indication of the likely proportion of discharge from overland flow.

Mean daily base flow

The daily base flow is calculated as the total base flow component of the hydrograph divided by the number of days of the record.

Base flow time series plot

A plot of the base flow time series is placed on the Input plot after running the analysis. The base flow time series can be analysed just like any other time series to detect patterns such as seasonality.

5.9 Rises and falls

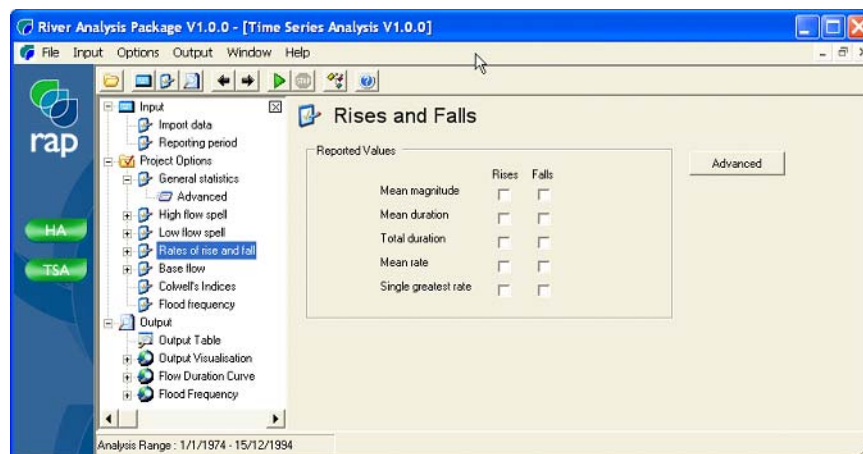


Figure 5-19: Rates of rise and fall

The rate of rise and fall of the hydrograph could be particularly relevant for cases such as;

- fish that use flow as triggers for migration and spawning,
- The 'intensity' of a flood disturbance (i.e. the rate of discharge increase) may affect how fish species respond and seek refuge.
- rooted, floating macrophytes that rely on relatively constant water levels,
- Benthic metabolism that relies on photosynthesis of algae attached to the substrate is highly influenced by water depth in turbid rivers.

The rates of rise and fall calculations are done by comparing the values of consecutive days, to determine if discharge is increasing, decreasing or constant.

Mean magnitude

The mean magnitude is the average of the total change in discharge for all rises or falls for the period of analysis. For example a rise may occur over several days, the rise of each day is added together to provide a total rise for that rising event, the total of all these rises for the analysis period is computed and divided by the number of rising events.

Mean duration

Periods of rise and fall could occur over a single day or could go for months for the receding limb of a flood on a big river. The mean duration is the addition of the duration of all rises or falls for the analysis period divided by the number of rises or falls.

Total duration

The total duration is simply the addition of all days of rising or falling flows for the analysis period.

Mean rate

For each rise or fall event the rate is the change in discharge for the event divided by the length of the event, the result is usually in Ml/d/d (depending on the units for the input). The

mean rate is the addition of all the rates for all rises or falls divided by the number of rises or falls.

Single greatest rate

The single greatest rate of rise or fall is the largest rate of discharge change.

5.10 Haines Seasonality measure

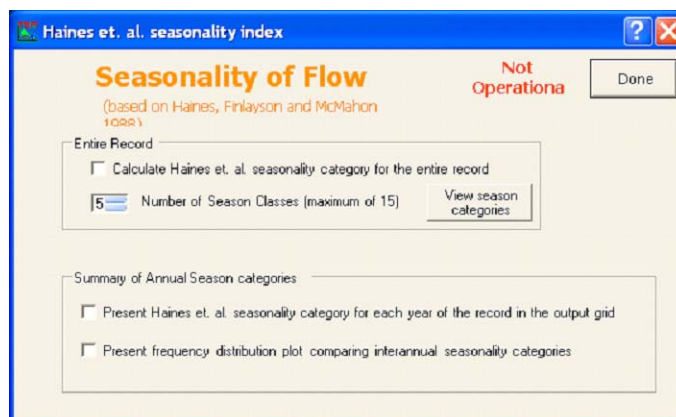


Figure 5-20: Haines input screen

Not implemented for RAP TV1.0.0

5.11 Wettest versus driest years



Figure 5-21: Wettest vs driest input screen

Not implemented for RAP V1.0.0

5.12 Output Table

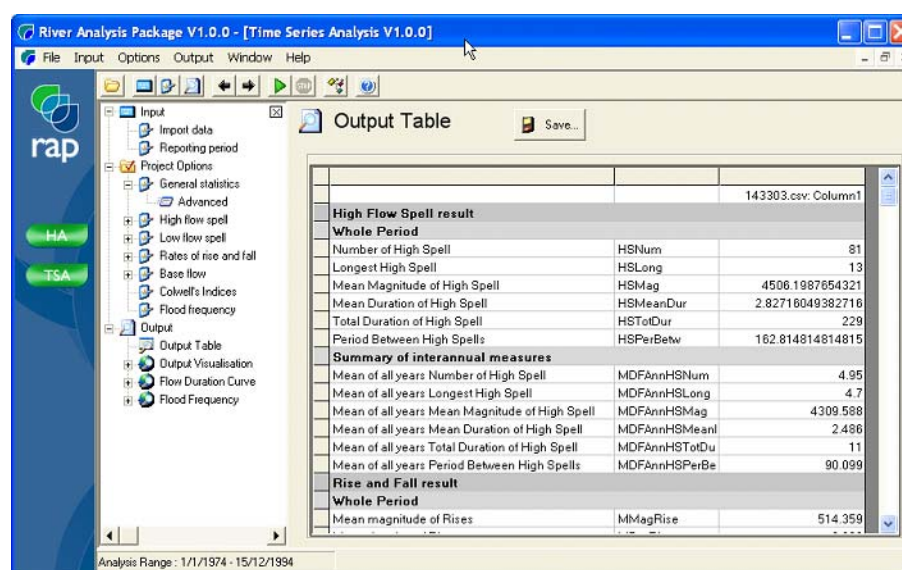


Figure 5-22: Output Table

Once statistics have been selected and the run button pressed, the results are displayed in the output table. You can navigate around the output table using the scroll bar on the right and resize rows and columns by selecting and dragging at the boundaries of the columns and rows. The output table can be saved as a .csv file.

5.13 Output Visualisation

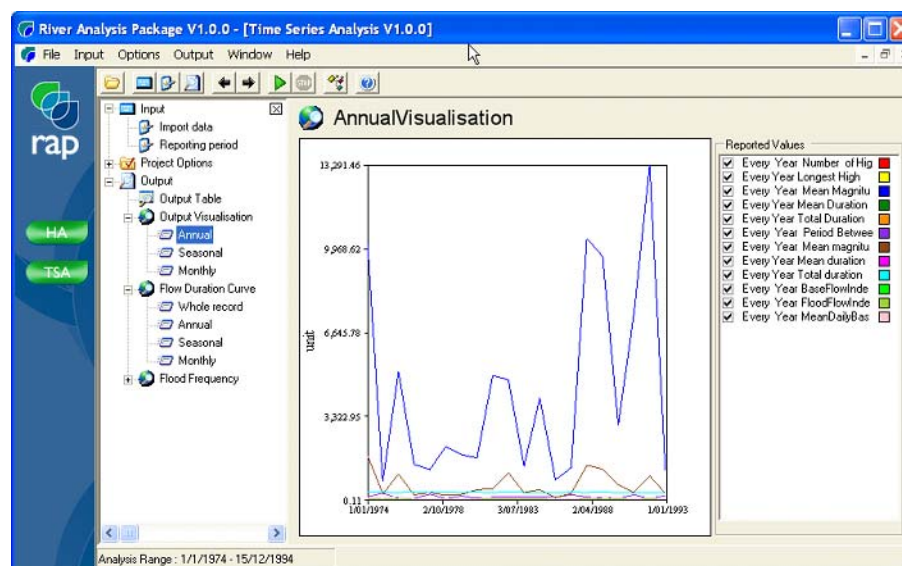


Figure 5-23: Output visualisation screen

In addition to the tabular output in the output table, the output for annual, seasonal and monthly is plotted to visualisation plots. These plots give you the opportunity to view at a glance how particular statistics vary through time. An example may be to compare the mean monthly discharge through time for alternate modelled flow scenarios. You can zoom into

the plots by right clicking with the mouse, select zoom, then left click with the mouse and drag a square over the area of interest. To zoom back out simply right click the mouse button. You can pan by right clicking select pan, then dragging the mouse back and forward while holding down the left mouse button to scroll through the record.

5.13.1 Flow Duration Curves

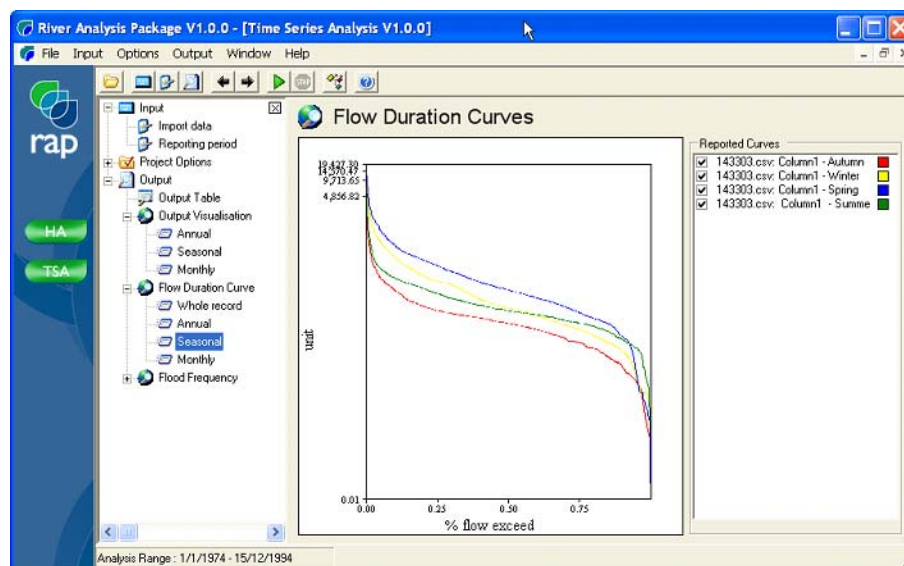


Figure 5-24:Flow Duration curves

Flow duration curves are an interesting way to visualise the difference in flow patterns between streams or comparing different times. Flow duration curves for the whole record, years, seasons and months are plotted. You can see how the summer flow pattern differs from the winter due to the shape of the flow duration curve.

5.13.2 Flood Frequency

Flood frequency plots are not featured in RAPV1.0.0

Appendix A - References

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