Hydrological Characterisation for Wetlands and Wetland Imagery

Users guide to attribute and evaluate hydro-climatic conditions using the Wetland*Info* tools for hydrological characterisation for wetlands and wetland imagery

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This document forms one part of the three-part tool Hydrological Characterisation for Wetlands and Wetland Imagery that includes a user guide, methodology and frequently asked questions.

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1. Introduction and background

This Users Guide provides step-by-step guidance for the use of the associated Wetland*Info* web based tools and interfaces. A framework supported by examples is provided to illustrate the steps required for specific actions.

The tools to characterise wetland hydrological processes were developed to help explain the context and circumstances leading to wetland inundation. Each wetland is expected to be unique with its own behaviour for filling by different water sources at different times over different durations. The Methodology that provides the data and supports the tools (see DERM 2011 Hydrological Characterisation for Wetlands and Wetland Imagery: A method to attribute and evaluate hydro-climatic conditions for the Queensland wetland mapping) facilitates the identification and evaluation of the characteristics for wetland inundation, by allowing the behaviour of wetland filling to emerge from the data and imagery evaluated.

Management of wetlands occurs within a regional context of landscapes of similar environmental values, processes and characteristics. These tools operate in assessment zones to facilitate assessment and decision making for management, and make use of zones to enrich the spatial distribution and the temporal depth of statistics. The methods used are evidence based and are provided to help characterise the variability of hydro-climatic conditions rather than to provide determined and smoothed expectations. This is an important methodological feature which helps to distinguish and profile small differences in inundation processes between wetland environments.

1.1. Hydrological characterisation

Users are encouraged to explore the layout and use of the tools. The tools are provided through three interfaces. First, characterisation of general assessable conditions over the 32 000 km^2 area that comprises an average scene area can be achieved through the 'Launch Landsat Scenes' interface. This enables scene area selection and the charting of summary statistics for specific data types, time scales and dates. The individual scenes used in inundation mapping can be selected and previewed.

Second, comprehensive rainfall and run-off index data can be characterised through the 'Launch Sub-bioregions' interface. All detailed assessments are performed within assessment zones (ecoregions), and for rainfall and run-off data this is the scale for similar rainfall, run-off and landform and terrestrial environment variability. Within this interface the detailed time series data can be viewed, compared with benchmark information, metadata can be queried and the patterns of reference series for different reference time scales can be interpreted. Data can be extracted and further evaluated, especially to characterise the variability of the data, the appropriateness of different time scales for assessment, and to evaluate trends and seasonality in data series.

Third, through the 'Launch Sub-bioregions' interface, sub-basin areas within sub-bioregions may be selected. The resulting sub-basin drainage interface is provided to define the ecoregions for stream discharge and stage (i.e. stream) height interpretation. The drainage index data archive is less comprehensive than the rainfall and run-off data, but the zonal assessment approach provides as much information as possible to characterise hydrologic conditions. The interface operates the same way as the sub-bioregion interface, but provides additional information about the location and use of stream gauge stations. Due to the shorter duration of data series and localised nature of flow data, users should focus more on the characteristics of the timing, duration and variability of the statistics.

All zonal values are statistics and indices that represent states and variations in hydro-climatic conditions. To maximise the benefit of these statistics detailed interpretations should be made at a zonal scale with comparison to the reference hydro-climate regimes. Download and calibration of zonal statistics and reference regimes are encouraged to facilitate calibration to local observations and more detailed analysis for research and educational purposes. The disclaimers and limitations for the data and its use must be acknowledged prior to more detailed use.

Users must note that the data has no mechanistic basis to support predictive or diagnostic applications. This means that the information must not be used to guide or influence assessments relevant to water resource planning and allocation, which is a statutory activity supported by other tools (see <http://www.derm.qld.gov.au/wrp/index.html>).

1.2. Scope of this guide

This guide is provided to facilitate tool use and application of the hydro-climate statistics and indices. For additional information about the methods used to create the statistics and indices please refer to the Methodology. Answers to frequently asked questions may be obtained in the FAQ report (DERM 2011 *Hydrological Characterisation for Wetlands and Wetland Imagery: General FAQ for hydrological and climatological attribution*).

2. A framework for tool use

The schematic below (Figure 1) is provided to relate tasks to actions to obtain information using the tools. This illustrates the content described in the remainder of the guide. Users are recommended to explore tool operation in contrasting environmental contexts to best understand the potential applications and limitations to use before downloading data for more detailed evaluation

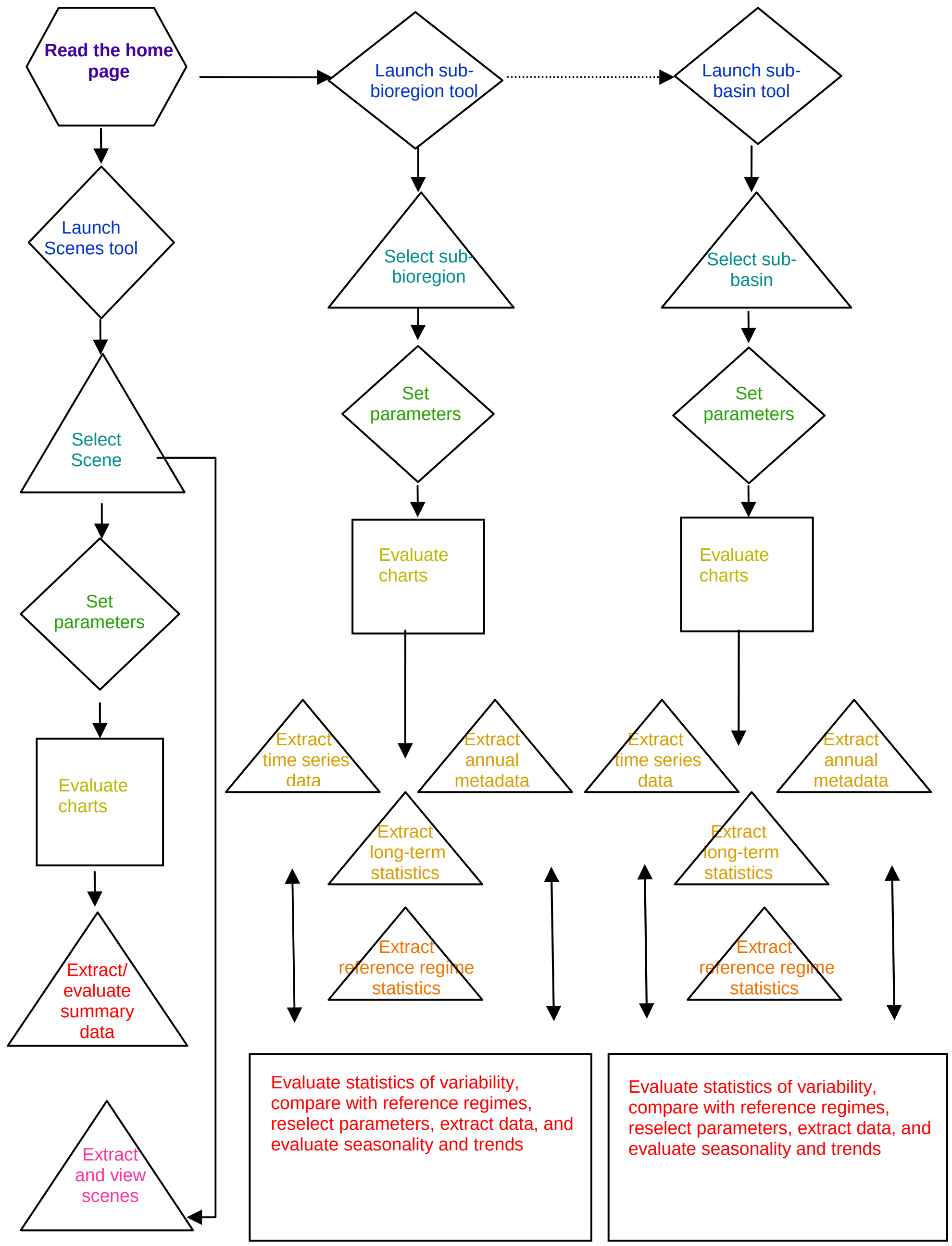


Figure 1 Steps for use of the wetland hydrological characterisation tool. Similar steps have the same colour coding. Final actions are coloured red.

3. Tasks

Three main task themes are addressed by the Users Guide:

1. Query aggregated statistics for index quantities of rainfall, run-off, discharge and stage height assessed for a scene area. Preview the scenes sourced for inundation classification in wetland mapping and link to the wetland mapping.

2. Characterise, with quantity and probability state and variability statistics and indices, metadata and regime information, rainfall and run-off index data for a zone area.

3. Characterise, with quantity and probability state and variability statistics and indices, metadata and regime information, discharge and stage height index data for a zone area.

3.1. Characterise conditions for a scene

Figure 2 The home page that launches Landsat Scene based hydro-climate assessments.

This information should be used for a broad scale appraisal of potential scene wide hydro-climatic conditions. Quantities of rainfall, run-off, discharge and stage height are aggregated across zones using proportional area weights. Zonal statistics are obtained from normalised observations and scene up-scaling provides a good representation of sample values weighted by contributing assessable area.

Scene wide appraisals are useful to characterise the suitability of imagery for the classification of inundation extent. They may also be used to characterise broad scale conditions, although users are recommended to perform assessments at the zone assessment scale to provide more precise and locally meaningful information.

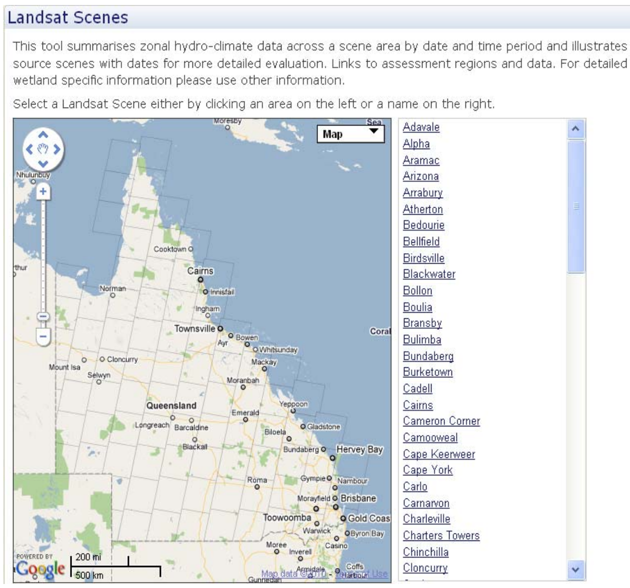


Figure 3 The Landsat Scenes interface.

3.1.1. Accessing a scene

Select 'Launch Landsat Scenes' application.

3.1.2. Define area of interest

Familiarise yourself with the Landsat Scenes interface by moving the cursor over the Google map and the index in the right margin.

3.1.2.1. Scene name

Scroll through the index of scene names in the right margin to select a single scene by its name.

3.1.2.2. Scene location

Move your cursor across the interactive Google map of Queensland and Landsat Scenes to select a single scene by location.

3.1.2.3. View scenes and link to wetland mapping

The individual scene interface is opened after selecting a scene. Notice the WRS path/row ID of the scene. This can be used to facilitate download of alternative imagery from the Australian Centre of Remote Sensing (GeoScience Australia <https://acres.ga.gov.au/intro.html>) or the USA USGS facility (<http://landsat.usgs.gov/USGS_Archive_and_Available_Scenes.php>).

Click on the 'Satellite Images' link to select an image by date to preview. These images were sourced to classify persistent and maximum inundation extent in the wetland mapping product (see diagrams below).

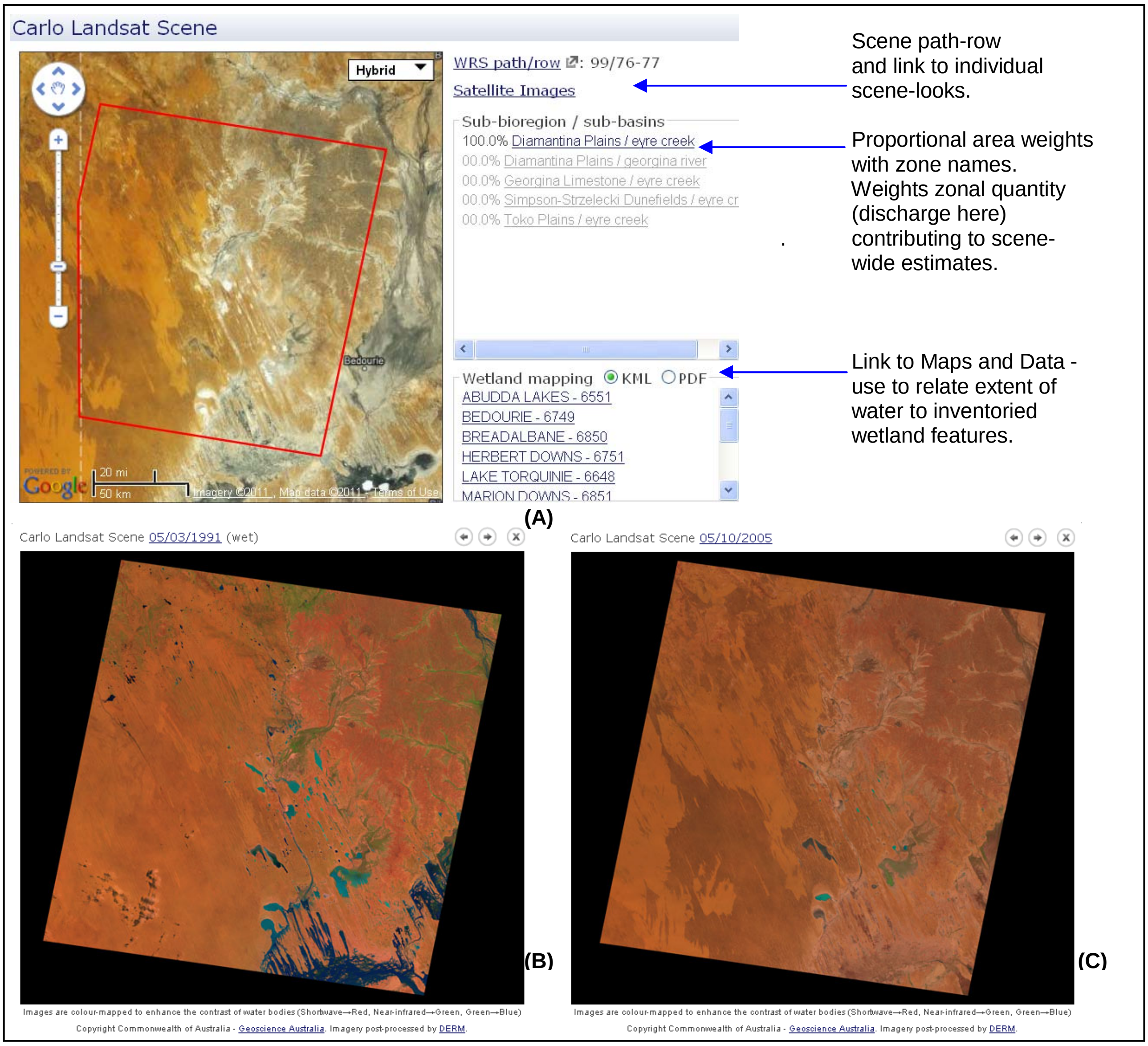


Figure 4 The individual scene interface (A) with links to Satellite Images (Wet scene (B) and multi-temporal dry scenes (C)).

For the steps here and below, select the Carlo Landsat Scene link with scene row 76-77 in path 99 (A), then peruse individual source images for wet (B) and dry conditions (C). The interface (A) provides a link to the wetland mapping tools. Hover the cursor over the map tile names (e.g. 'Lake Torquinie - 6648') to reveal their location relative to the scene. Link to the wetland maps via KML (Google Earth) or PDF systems. The KML system provides more detailed classification information as shown by the attribution in figure 5 below, whilst PDF systems support the production of standardised maps. Figure 5 provides an example of a link to wetland map and data for the Lake Torquinie reference wetlands map in the Carlo scene area using KML Google Earth services. This link facilitates the assessment of relationships between scene date, imaged inundation extent and regional hydro-climate statistics, to mapped wetland extent, wetland type and the proportion of inundation (labelled 'Regime') occurrences identified by imagery within the mapped wetland extent.

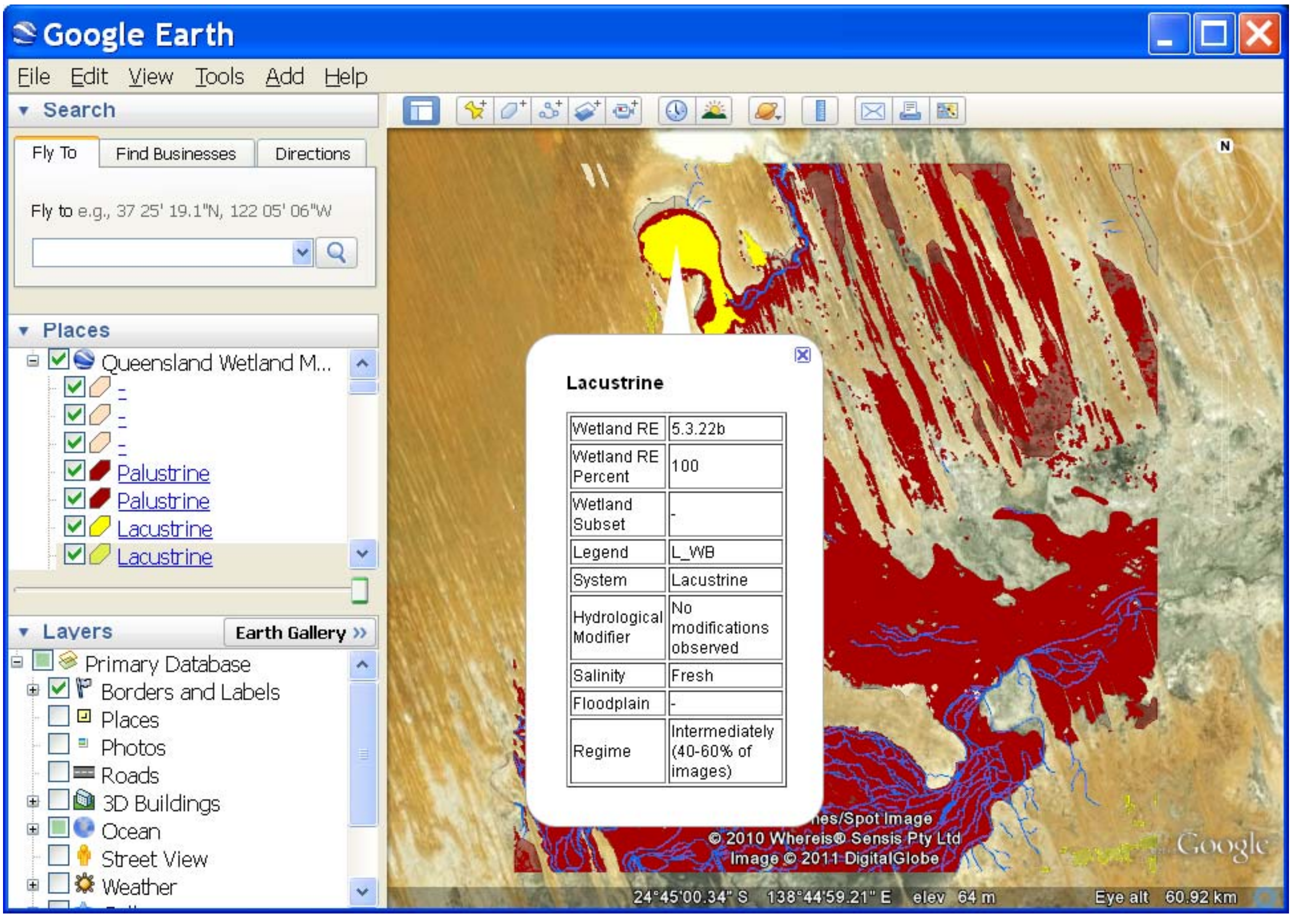


Figure 5 Google Earth display of Wetland Mapping, linked through KML systems from the individual scene interface.

3.1.2.4. *Select parameters and references*

In the individual scene interface (i.e. the page with the 'satellite images' link), select the parameters and reference information required to control the display of data type, period of information displayed, end date for time series, reference time scale and the benchmark reference information to compare against the time series data. The selected information will also be listed in extracted data.

The zones for the selected data type will be revealed by hovering the cursor over the scene area. In addition the proportional weight used to combine zone data within a scene is revealed under the cursor and in the right hand margin of the scene area description (e.g. Carlo scene example above). The zonal weight can be used to evaluate the contribution of zones to scene estimates to facilitate surrogate data assessments at a zonal scale if required.

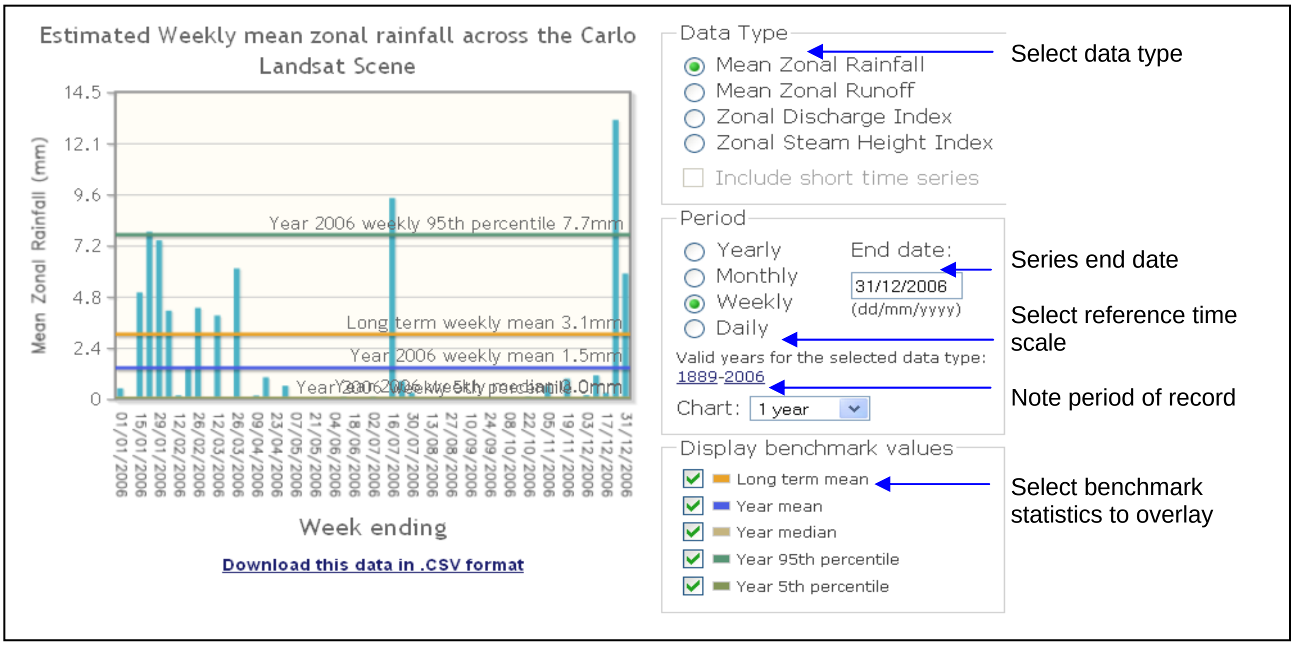


Figure 6 Example of scene summary statistics and chart, and selection options available at the individual scene interface.

3.1.2.5. View time series chart

The time series chart is interactive. Hover the cursor over bars to identify the zonal statistic for the date queried. Compare data quantities against benchmark statistics for:

1. the long term mean for that zone
2. the mean for the end year selected, and the regime statistics for the end year
3. the median
4. the 95th (wet) percentile
5. the 5th (dry) percentile quantities. Look for unusual seasonal variations that may be of interest for further evaluation.

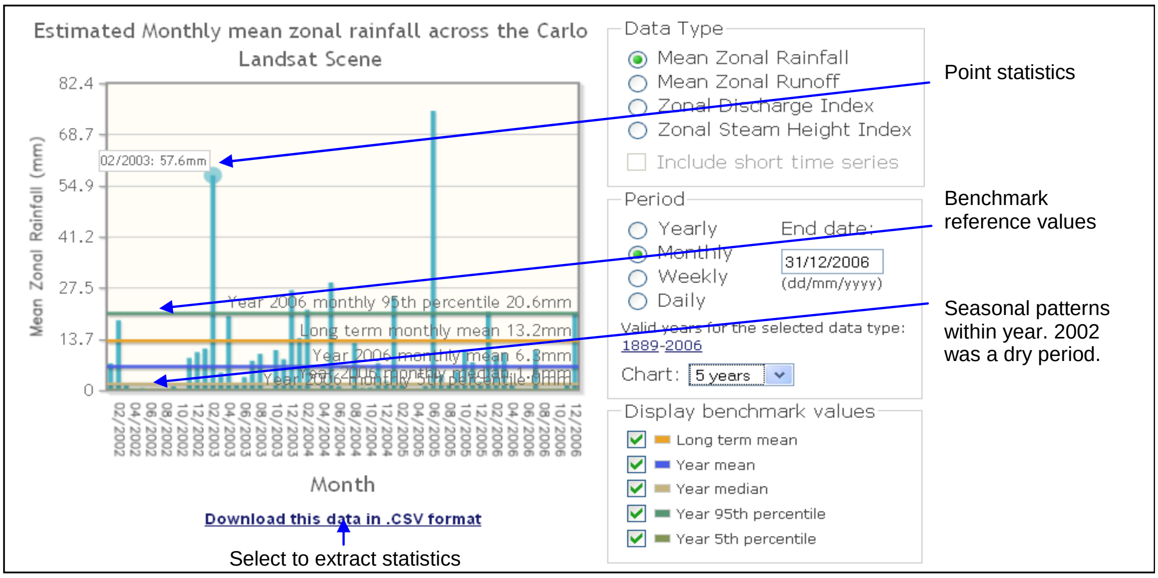


Figure 7 Explore the scene summary statistics and chart.

3.1.2.6. *Extract summary data*

The charted data that estimate scene wide conditions in terms of quantities using proportional area weights may be extracted using the download data to .CSV format selection. You may save the data for further evaluation. Comprehensive period of record information exists for rainfall and run-off, but if available, stream discharge and stage height information has more restricted periods of record.

Table 1 Example of extracted summary scene data obtained through the 'Download this data in .CSV format' link in the individual interface.

Month	Mean Zonal Rainfall quantity (mm)	Long term mean	Year 2006 mean	Year 2006 .95 series value	Year 2006 .5 series value	Year 2006 .05 series value
Jan-06	21.04828	13.22177	6.306406	20.57951	1.629695	0
Feb-06	9.427376	13.22177	6.306406	20.57951	1.629695	0
Mar-06	10.07923	13.22177	6.306406	20.57951	1.629695	0
Apr-06	1.822957	13.22177	6.306406	20.57951	1.629695	0
May-06	0.081432	13.22177	6.306406	20.57951	1.629695	0
Jun-06	0.181962	13.22177	6.306406	20.57951	1.629695	0
Jul-06	10.63492	13.22177	6.306406	20.57951	1.629695	0
Aug-06	0	13.22177	6.306406	20.57951	1.629695	0
Sep-06	9.93E-06	13.22177	6.306406	20.57951	1.629695	0
Oct-06	0.202866	13.22177	6.306406	20.57951	1.629695	0
Nov-06	1.557181	13.22177	6.306406	20.57951	1.629695	0
Dec-06	20.64065	13.22177	6.306406	20.57951	1.629695	0

3.1.2.7. *Interpret data*

Vary the timing, reference time scale and period of record to interpret change in statistic state and trend. Evaluate trends or cyclic behaviour using your own statistical or charting software using downloaded data, being aware that the precision of the statistics, especially for stream gauged data, may be poor and is not suitable for localised modelling unless they are calibrated to local observations.

Use your custom profiled time series information to identify periods that may meet requirements for selection of imagery to be used to map water extent.

If probabilities of exceedence are required these are only relevant for assessment zones. Interrogation of statistics for zones overlaying areas of interest can be used to identify zonal estimates of probabilities of exceedence. This is useful to generalise or compare hydro-climatic conditions across zones.

3.1.3. Surrogate information

Scene statistics cannot be produced from combined zonal data when one or more assessable zone cannot contribute information. In addition stream gauge data is not comprehensive. The example below for the Kingaroy scene illustrates how the availability of stream gauge data is identified.

When hydrologic information is required but stream gauge data is not available, the run-off or rainfall statistics provide a useful surrogate. Run-off provides a point simulated representation of surplus rainfall from small plots, calibrated to biomass, soils and ground cover, and when accumulated over an area has hydrologic characteristics similar to local discharge, although it is more local in nature and does not account for other surface water detention and transfer processes (Carter 2007). Whilst the rainfall, run-off and stream gauge data should not be combined for deterministic modelling because of the simple spatial and index nature of the data and lack of local calibration, rainfall and run-off may provide sufficient information to explain the significance of wetland filling events in the absence of stream gauge data.

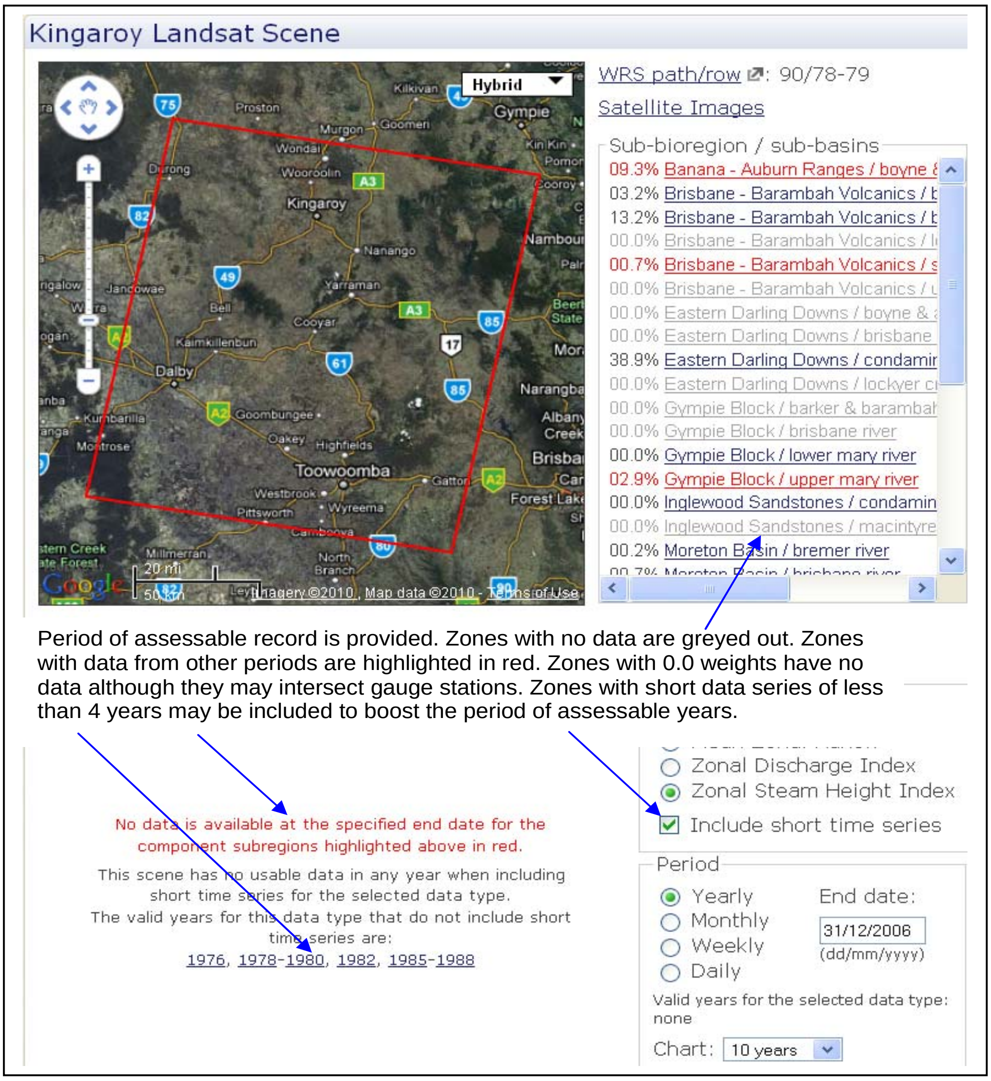


Figure 8 Use of options to extract relevant summary information in the individual scene interface when few data records exist. The use of surrogate rainfall or run-off summaries may be required.

3.1.3.1. For scene-wide discharge assessment

For example stream gauge data is not available after 1989 in the Carlo scene area and so does not include the 1991 wet scene (5 March 1991) period. It is reasonable to query the run-off statistics at a monthly time reference to provide surrogate information. The run-off statistics for this time (Table 2) clearly show the January and February period greatly exceeded the long term mean, the 1991 monthly mean and that the February statistic is 57% larger than the 95th percentile value for that year. It is therefore reasonable to suggest that wetland filling would occur in January to March 1991 in response to the excessive run-off. This does not account for inflows from upstream outside of the scene area.

Table 2 Example extraction of scene wide run-off data to summarise conditions when no discharge information is available.

Month	Mean Zonal Run-off quantity (mm)	Long term mean	Year 1991 mean	Year 1991 .95 series value	Year 1991 .5 series value	Year 1991 .05 series value
Jan-91	15.04941	0.765436	4.966154	28.14979	0	0
Feb-91	44.16137	0.765436	4.966154	28.14979	0	0
Mar-91	0	0.765436	4.966154	28.14979	0	0
Apr-91	0	0.765436	4.966154	28.14979	0	0
May-91	0	0.765436	4.966154	28.14979	0	0
Jun-91	0	0.765436	4.966154	28.14979	0	0
Jul-91	0	0.765436	4.966154	28.14979	0	0
Aug-91	0	0.765436	4.966154	28.14979	0	0
Sep-91	0	0.765436	4.966154	28.14979	0	0
Oct-91	0	0.765436	4.966154	28.14979	0	0
Nov-91	1.38E-04	0.765436	4.966154	28.14979	0	0
Dec-91	0.382934	0.765436	4.966154	28.14979	0	0

3.1.3.2. To generalise discharge characteristics

Scene wide statistics are not represented as combined probabilities of exceedence. However comprehensive run-off zonal information may be characterised to identify zonal probabilities of exceedence to attempt to relate scene-wide quantities to more localised conditions. For example the Diamantina Plains sub-bioregion (ecoregion) is characterised in Table 3 below at two reference time scales to characterise probabilities for potentially associated discharge conditions in that zone and for comparison with the scene-wide statistics.

Once a general relationship between event size and extent is understood, time series data could be filtered by event size using different time scales to identify dates that may present flood conditions suitable for image selection and mapping. This could be used to improve the representation of different hydro-climate regimes and their effect on the distribution of inundation.

Table 3 Estimated run-off quantities for the Carlo scene and key sub-bioregion (Diamantina Plains), with interpolated probabilities of exceedence obtained from the sub-bioregion for the 95% regime (wet assessment) and 5% regime (dry assessment) statistics relative to image dates for wet and dry image and reference time scales*.

Three month period preceding 5 March 1991, Wet Carlo scene				Three month period preceding 5 October 2005, Dry Carlo scene			
Scene Wide (run-off, mm)		Sub-bioregion (probability of exceedence)		Scene Wide (run-off, mm)		Sub-bioregion (probability of exceedence)	
Week	Month	Week	Month	Week	Month	Week**	Month**
0.0004	0.0004	0.75	0.997	0.0	0.0	≤1	≤1
0.0	15.05	0.75	**0.06**	0.0	0.0	≤1	≤1
0.0	44.16	0.75	**0.0**	0.0	0.0	≤1	≤1
0.0		0.75		0.0		≤1	
12.12		**0.007**		0.0		≤1	
0.8842		**0.312**		0.0		≤1	
2.045		**0.0134**		0.0		≤1	
1.476		**0.02**		0.0		≤1	
42.68		**0.0**		0.0		≤1	
0.0094		0.557		0.0		≤1	
0.0003		0.75		0.0		≤1	
0.0		0.75		0.0		≤1	

*The final cell in each column is equivalent to the end date (e.g. 5 March) up to which the preceding time values are assessed. Periods that may be associated with flooding due to regional run-off have probabilities highlighted in bold.
For monthly values the final month listed is February or September. It is the user's responsibility to include the current/end/target month if weekly values indicate the need for it.
**All reference quantiles are zero for the 5% regime and zero states are certain to occur every year and effectively for all of the year if the 5% (drought) regime prevails through a year.

3.2. Characterise conditions for a zone

The hydro-climatic conditions of zones are described by a more rich assemblage of statistics and indicators. This includes the provision of information directly represented by the zone sample, the provision of reference quantile-probability statistics and chart by regime level (wet, median, dry), the provision of 90% confidence intervals for the median regime, and the provision of annual and long term metadata, which includes information about the sample size, period of record and variability of statistics within and between years.

This array of information can be used to provide more precise and comprehensive characterisation of wetland filling processes by regime states through time and generalised by probabilities of exceedence.

The appropriateness of different reference time scales can be assessed by comparing indices of variation and the reference quantile-probability series to ensure relevant state and trend assessments are performed on extracted data.

3.2.1. Accessing zones

At the hydrological characterisation home page, select 'Launch Sub-bioregions' to access the sub-bioregion (ecoregion) interface.

Figure 9 The home page that launches sub-bioregion based hydro-climate assessments.

3.2.2. Define area of interest

Familiarise yourself with the sub-bioregions interface by moving the cursor over the Google map and the index in the right margin.

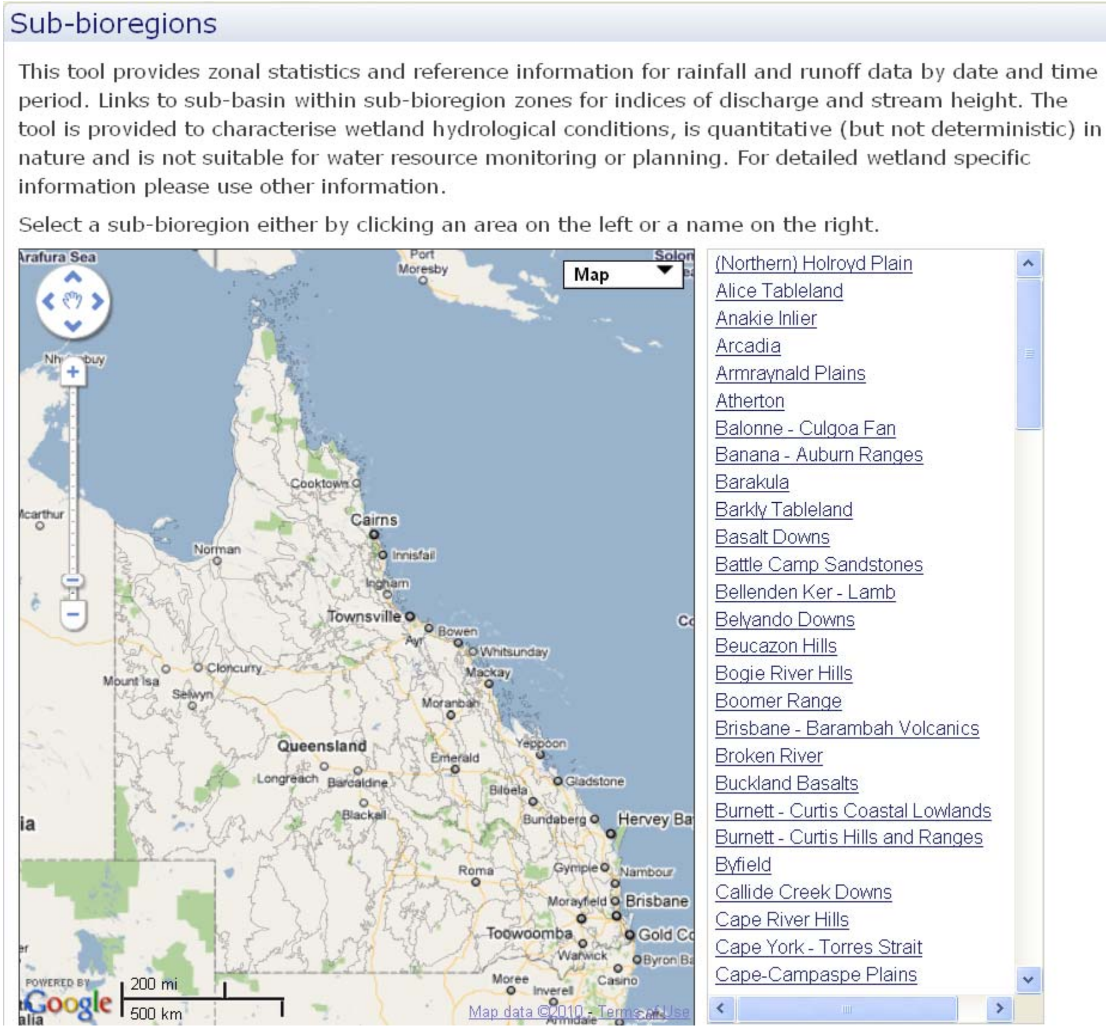


Figure 10 The sub-bioregions interface.

3.2.2.1. Zones for different data types

Sub-bioregion zones are used to define ecologically similar and relevant areas for ecological processes on the basis of landform pattern, elevation, geology, terrestrial ecosystems and rainfall variability (Sattler and Williams 1999). The ecoregions are similar to the eco-hydrological zones of Pusey et al. (2009) but were derived using established terrestrial bioregional mapping.

Rainfall and run-off assessments are provided for the established sub-bioregion areas. In comparison, drainage and discharge processes such as aquatic connections could only be considered similar for similar established sub-basin areas. Therefore to force hierarchical concurrence between rainfall and stream gauge information, sub-basin assessment zones are formed by the intersect of sub-basins with sub-bioregions. Stream discharge and stage height statistics are characterised within these smaller zones, which are accessible through the sub-bioregion interface.

3.2.2.2. Rainfall and run-off

1 Roam location

Within the sub-bioregion interface, select sub-bioregions spartially by roaming the cursor over the interactive map. The names of the zones are revealed in the bottom left corner of the Google map and / or under the cursor. Alter the format of the map between 'map', 'satellite', 'hybrid' and 'terrain' to help select an assessment zone based on landscape or other geographic context.

2 Roam names

Scroll through the index of sub-bioregion names to select an ecoregional zone by its formal, nationally recognised name.

3.2.2.3. Discharge and stage height

Access to stream gauge zonal statistics requires the prior selection of a sub-bioregion. For example the Diamantina River basin may be selected from the Diamantina Plains sub-bioregion in the western desert channel area (area delineated in green below). Note the sub-bioregion name and code number for identification purposes.

Select the sub-basin zone of interest to enter the sub-basin within sub-bioregion interface (coloured indigo here). Return to scene extents for scenes intersecting a sub-bioregion using the scene index in the top right hand margin if required.

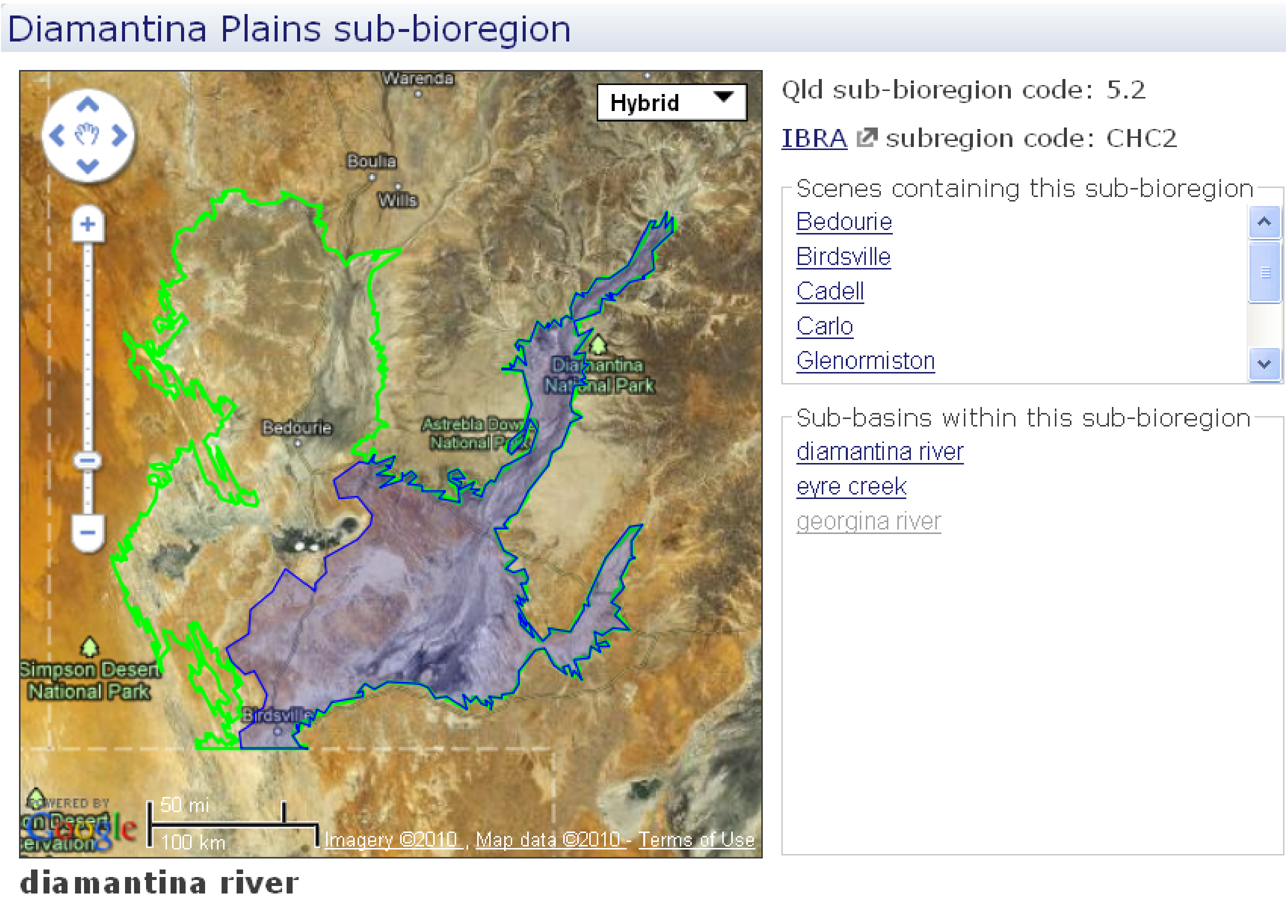


Figure 11 The individual sub-bioregion interface with intersecting sub-basin areas.

1 Roam location

Location roaming is restricted to interactive cursor selections around the area of interest. Zoom out using the sliding zoom scale and slowly move the cursor over the area of interest. The outline and names of other sub-basin in sub-bioregion zone will be provided at the cursor and / or bottom left of the diagram. Select a zone of interest. Within a zone, gauge station locations may be identified. Click on the gauge station option and click on individual stations to reveal whether they contribute data to the selected zone, and the type of data contributed. Station identification code is provided and this can be used to link to the same stations in real time monitoring if they are still operational and listed in Queensland data base. The map may be zoomed in to provide a closer examination of landscape characteristics in the vicinity of the station.

Return to the parent sub-bioregion or to scenes intersecting the region by selecting the relevant links in the right margin.

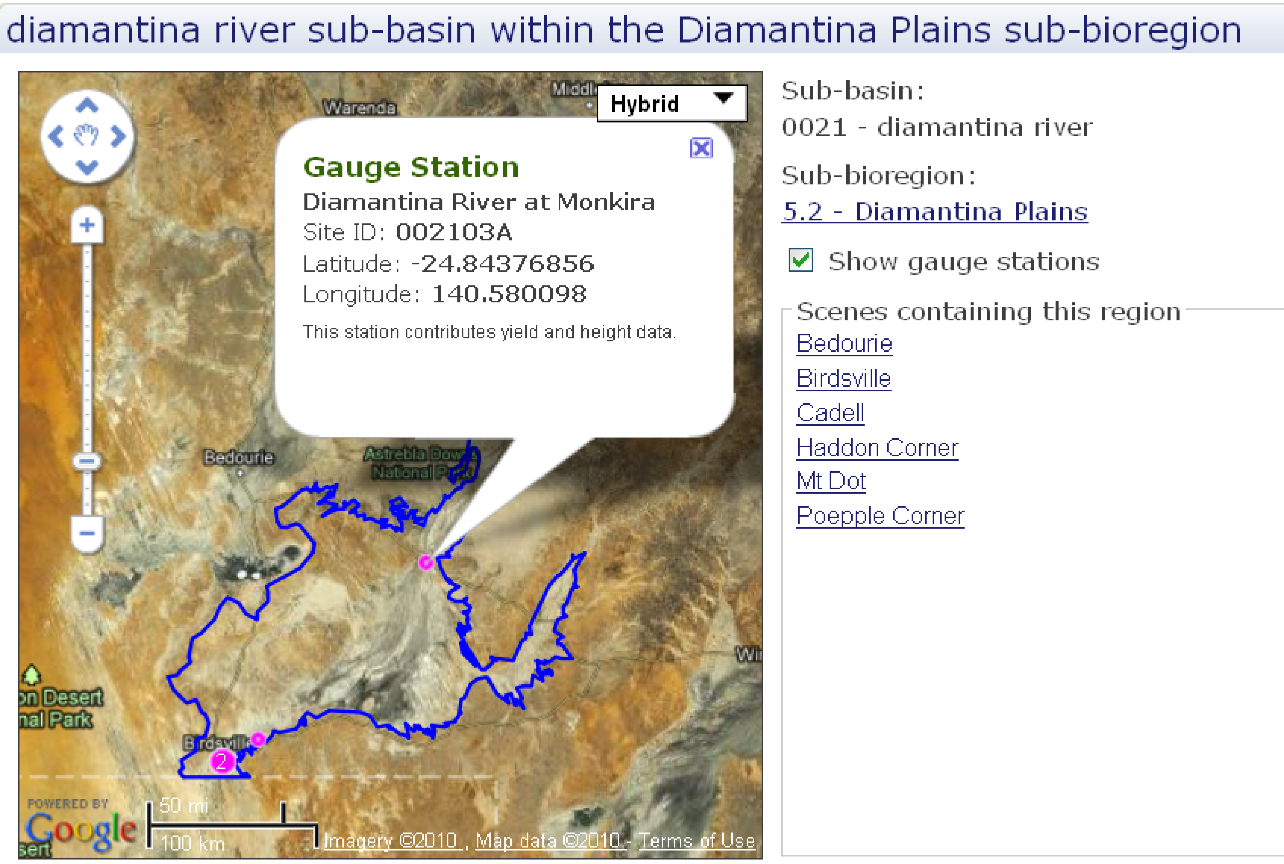


Figure 12 Explore the sub-bioregion and intersecting sub-basin area.

2 Roam names

Selection by name is available through links revealed by hovering the cursor over sub-bioregion zones, or by selecting sub-basin names from the right hand margin for the selected sub-bioregion. Sub-basin names that are greyed out do not provide assessable data.

3.2.3. Surrogate information

No stream gauge data is available if no gauge stations directly contribute to assessments within a zone. This will be revealed at the sub-bioregion level where sub-basin labels will be greyed out, or when a sub-basin zone is selected but no gauge station are visible. In addition, stream gauge data may be available for limited periods or periodically due to station maintenance. In this case, the period of assessable record is annotated, and the available periods may be assessed by selecting the relevant time-period hyperlink.

If the required gauge data is not available, surrogate data, such as run-off, may be sought to represent discharge processes.

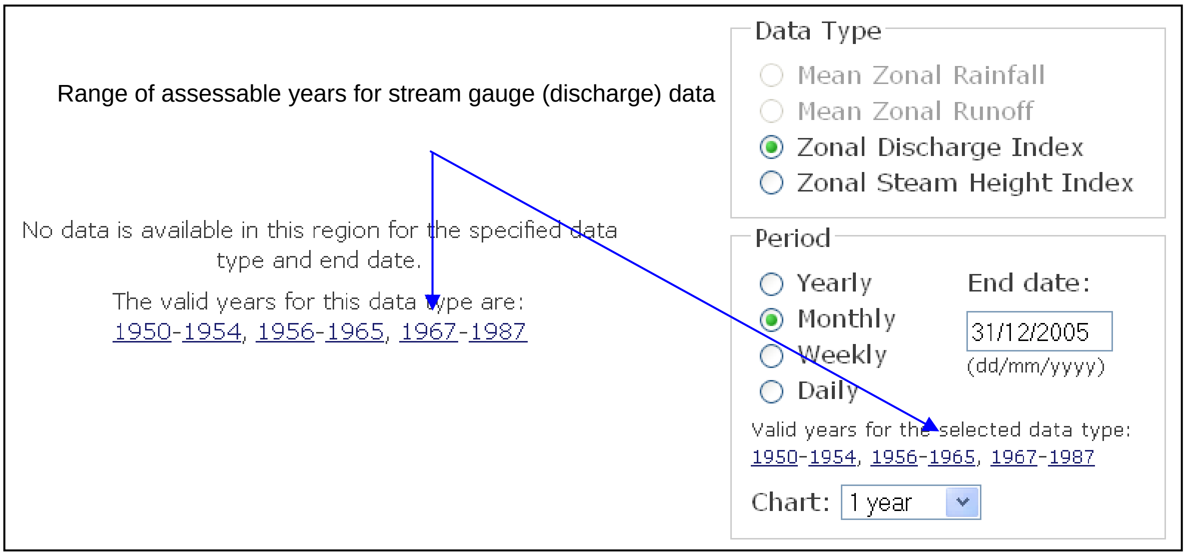


Figure 13 Use options to select information for assessable stream gauge data.

3.2.3.1. *To represent discharge processes*

The process for presenting surrogate zonal information is the same as illustrated in Table 3, although the parent sub-bioregion can be directly assessed for its rainfall and run-off characteristics without the need to generalize the assessment area or rainfall/run-off characteristics. If the upstream sub-basin and sub-bioregion zone is required for more detailed assessment, this may be selected by hovering the cursor over the area of interest and selecting that area as required.

3.2.4. Zone information

The evaluation of zone time series data and reference information may occur in a developmental fashion, whereby how the data are interpreted with respect to (for example) time series for a specific reference time scale depends on the purpose for the application (e.g. seasonal versus event specific information) and the within and between year variability of the data. This section deals more specifically with data capture whilst section 3.3 guides the assessment of variability with additional implications to data extraction and assessment.

3.2.4.1. *Rainfall and Run-off*

Rainfall and run-off data are represented comprehensively in the data archive. The source data are pre-conditioned to reduce localised variability and so provide smoother time-series than the stream gauge data. Therefore the data are applicable to larger zones and should require fewer reference time scale adjustments to reliably characterise change in wetland conditions.

1 Select parameters and references

Within the sub-bioregion selection interface, select the zone for assessment. View the period of record (valid years) information to scope the period of assessment. Zonal statistics will be available to the end of the year 2006 and no surrogate statistics will be required.

Select the parameters and reference information required to define the data type (rainfall or run-off), period of information, the end date for time series extraction, the reference time scale and the benchmark reference information to compare with the time series data. The selected information will be listed if the data is extracted.

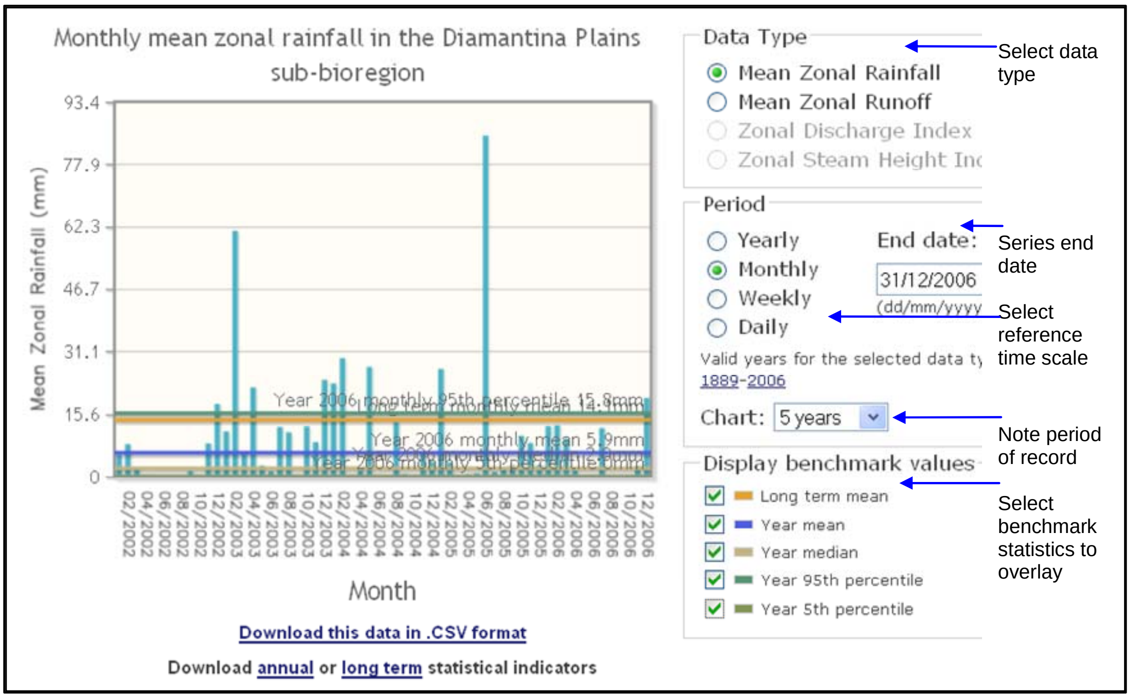


Figure 14 Example of sub-bioregion summary statistics and chart, and selection options available at the individual sub-bioregion interface.

The example above is for the Diamantina Plains sub-bioregion, which is the key zone of interest in the Carlo scene example in section 3.1.3.2.

2 View time series chart

As per the scene charts, hover the cursor over individual bars to identify zonal statistics by date. Benchmark statistics for comparison include:

1. the long term mean for the zone
2. the mean for the end year selected and the regime statistics for the end year
3. the median
4. the 95th (wet) percentile
5. the 5th (dry) percentile quantity.

Look for unusual seasonal variations that may be of interest for further evaluation.

3 Interpret time series chart

Zone statistic characteristics of interest include the values of statistics (bar values) relative to reference statistics and in the context of the period leading up to dates of reference. For example the statistics in Figure 15 suggest that the rainfall in summer 2002 / 2003 through to autumn 2003 broke a drier than normal period in 2002. The summer-autumn period in the 2002 to 2006 record is characterised by more frequent rainfall events. Very large events may also occur in winter, and this suggests that a rigid framework for seasonal assessments of local flooding processes is not appropriate and that aseasonal characteristics for flooding need to be accommodated in assessments.

For 2006, the year mean and regime statistics were generally less than the long term mean, and this is characteristic of conditions that are representative of the dry end of reference quantile-probability series. Wetlands that retain water during these times may have special refugia values.

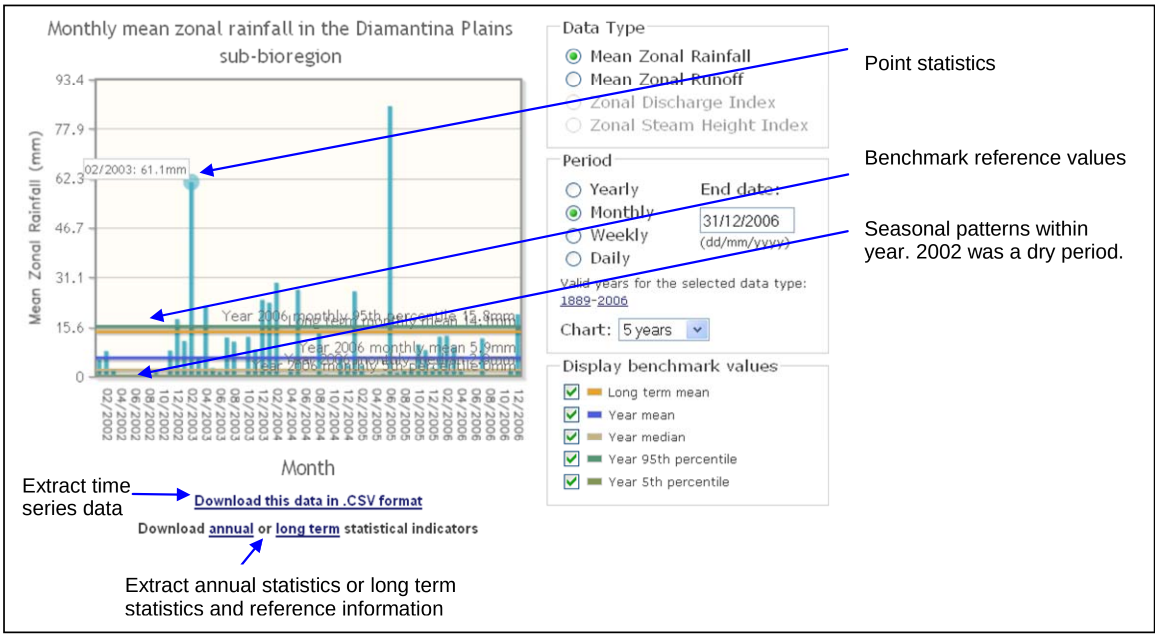


Figure 15 Explore the sub-basin summary statistics and chart.

4 Extract time series data

Zone time series data is richer in information than the broader scaled scene summaries. Illustrated below is the data for the 2006 time series rainfall statistics charted above using the 'download this data in .CSV format' tool.

Table 4 Example of extracted sub-bioregion time series data obtained through the 'Download this data in .CSV format' link in the individual sub-bioregion interface.

Month	Mean Zonal Rainfall quantity (mm)	Probability for quantity (.95 series)	Probability for quantity (.5 series)	Probability for quantity (.05 series)	Long term mean	Year 2006 mean	Year 2006 .95 series value	Year 2006 .5 series value	Year 2006 .05 series value
Jan-06	12.41089	0.956094	0.074756	0	14.0804	5.860563	15.75817	2.015494	0
Feb-06	12.68715	0.953589	0.06465	0	14.0804	5.860563	15.75817	2.015494	0
Mar-06	9.309255	0.993676	0.160675	0	14.0804	5.860563	15.75817	2.015494	0
Apr-06	1.459757	NaN	0.757566	0.010265	14.0804	5.860563	15.75817	2.015494	0
May-06	0.181597	NaN	NaN	0.216848	14.0804	5.860563	15.75817	2.015494	0
Jun-06	0.168535	NaN	NaN	0.224187	14.0804	5.860563	15.75817	2.015494	0
Jul-06	11.91232	0.9619	0.086006	0	14.0804	5.860563	15.75817	2.015494	0
Aug-06	0	NaN	NaN	0.73	14.0804	5.860563	15.75817	2.015494	0
Sep-06	0	NaN	NaN	0.73	14.0804	5.860563	15.75817	2.015494	0
Oct-06	0.114384	NaN	NaN	0.291763	14.0804	5.860563	15.75817	2.015494	0
Nov-06	2.571232	NaN	0.637215	0.006934	14.0804	5.860563	15.75817	2.015494	0
Dec-06	19.51164	0.885923	0.01108	0	14.0804	5.860563	15.75817	2.015494	0

5 Interpret time series data

Like the scene summary, the zonal information provides quantity statistics for the reference time units (months) and the benchmark quantities for the long term mean, the end year (2006) mean and the representative 2006 values for each rainfall regime. The zone statistics demonstrate the average and regime statistics are low, with zero millimetres of rainfall representative of the 5% regime. However some larger rainfalls in five of the twelve months fell within the 95% regime, and whilst these were small events they were similar to the long term mean so it is unlikely the year is representative of severe drought.

In addition to the scene summary information, the quantities for each time unit (month in this case) are interpolated through the reference quantile-probability series (section 3.2.4.1 part 10) to provide probabilities of exceedence per regime per time unit. Probabilities of zero indicate the quantities are larger than a regime can assess. Probabilities of 1.0 indicate that the quantity is certain to occur in the assessed regime in any year relative to the reference record. Values of NaN (Not a Number) mean the quantities are below the assessable range of the reference series and are not expected to be represented by that regime.

If the data are downloaded, the averages of the probabilities for each regime may be compared (excluding missing values (NaN)) to identify which regimes characterise the year's statistics. In this case the average exceedence value in the wet regime is large (0.95), indicating wet conditions were not prevalent and are often exceeded in years represented by the full record. The average exceedence probability in the median regime is 0.256, which is closer to 50th percentile for that regime than other values are to their regime's 50th percentile. Therefore median regime conditions were in general wetter than the reference median statistics but not far from normal expectations for that regime, and this further suggests rainfall supply is similar to a normal year. The average exceedence probability in the 5% regime was 0.18, which is much less than the 50th percentile for the dry regime, and this confirms that severe drought conditions are not representative of 2006 at a monthly time scale.

6 Extract annual data

The annual data should be extracted to identify and characterise the sampling conditions and variability in the data observed per year. The data are extracted using the 'download annual statistical indicators' tool.

Table 5 Annual reference information includes data type and time scale and parameters for annual levels and the degree of dispersion and variability of sampled data. Annual summaries are extracted from the sub-bioregion interface when a time period of less than one year is selected.

Timescale	Data type	Year	Record count in year	Mean (mm) in year	Coefficient of variation	Variance ratio
Monthly	Mean Zonal Rainfall	2000	12	31.0345	1.195232	1.732833
Monthly	Mean Zonal Rainfall	2001	12	9.492425	1.031736	0.830779
Monthly	Mean Zonal Rainfall	2002	12	3.62552	1.514219	0.593765
Monthly	Mean Zonal Rainfall	2003	12	14.37233	1.14575	0.607033
Monthly	Mean Zonal Rainfall	2004	12	8.800009	1.306705	0.987277
Monthly	Mean Zonal Rainfall	2005	12	11.95285	2.021731	0.872688
Monthly	Mean Zonal Rainfall	2006	12	5.860563	1.174227	0.784903

7 Interpret annual data

In this example for the seven years to 2006, the reference time scale, data type, year and number of months evaluated per year is attributed. The annual monthly mean for years help to identify potentially wetter or drier conditions (depending on how even the rainfall was spread over each month in a year). The coefficient of determination (CV) provides the relative dispersion (scaleless) (Zar 1984) of monthly values within the year, whilst the variance ratio is an F-test statistic testable index based on logged values that can be used to identify years with much greater or lesser within-year variability to the long term measure of annual variability (this is explained in significant detail in section 3.3).

In this data set it is clear that the record is continuous through the evaluated period and that 2002 and 2006 were the driest years during the assessment period. Whilst 2002 has a larger CV than 2006, its variance ratio is the smallest of the period. This suggests that consistently smaller values of rainfall were characteristic of 2002, which is not characteristic of normal years, resulting in smaller overall variation. Therefore 2002 may be more representative of drier, more severe drought conditions, than is represented by most years for that region, relative to the expected range of within-year rainfall variation for that region.

The full period of records (e.g. 118 years in annualised form for rainfall) are available for review through the annual data extraction tool.

8 Extract long term data

The long term data should be extracted to identify the period of record and the key benchmark statistics. The data are extracted using the 'download long term statistical indicators' tool.

Table 6 Long term sub-bioregion data is available from the sub-bioregion interface and provides key benchmark and meta-data information for the assessed zone.

Timescale	Data type	Grid cell count	Start year	End year	Year count	Long term mean (mm)	Coefficient of variation
Monthly	Mean Zonal Rainfall	1891	1889	2006	118	14.0804	1.502643

9 Interpret long term data

For rainfall and run-off this table identifies the data type, the reference time scale, the number of 0.05 degree grid cells assessed in that zone, the start and end year (inclusive) for assessment and the duration (year count) this relates to. With 118 years of data, from 1889 to 2006, the data is confirmed as comprehensive in its record. The long term mean and coefficient of variation (which is the mean of each year's coefficient of variation across sample times) are provided. These statistics are useful to compare average levels and relative dispersion between assessment zones. In this example, average rainfall quantities are small and overall dispersion is not particularly large. This suggests that if significant flooding (wetland filling) occurs in this region that a significant component of the filling process may be due to run-off and discharge accumulated locally and / or combined with flows from up-stream rather than from direct rainfall only.

10 View reference regime chart

The reference quantities for probabilities of exceedence are obtained by statistical interpolation of quantiles through reference probabilities using the full set of annualised statistics for each regime (and for the confidence intervals for the median regime) using the empirical quantile function (S-PLUS ® 8 2007). The reference information is provided for each assessment zone. This chart and associated data provide critical additional information that can be used to interpret the characteristics of hydro-climate regimes and the relative dispersion of seasonal conditions across regimes. The chart is viewed in the sub-bioregion interface once a zone and the parameters for assessment have been selected.

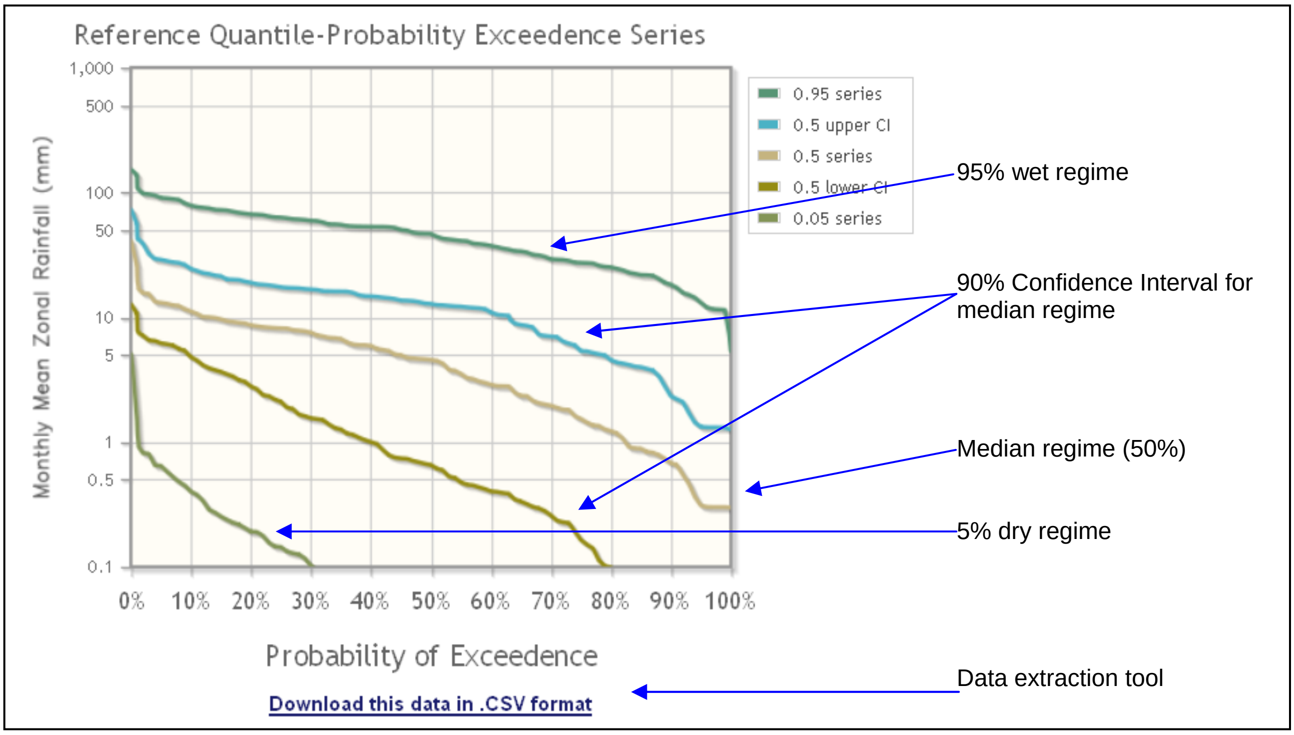


Figure 16 Reference quantile-probability of exceedence charts and data are provided for each assessable zone from the sub-bioregion assessment interface.

11 Interpret reference regime chart

Reference statistics are obtained across all data types using the following conceptual framework.

The period of record for observations (zonal statistics) for each full year of assessments provide interpolated quantities (e.g. rainfall) for three profiled (thresholded) probabilities of occurrence: the 5th, 50th and 95th empirical percentiles (Figure 17). Confidence intervals for the 50th percentile are calculated by rank position using binomial theory across the sample of statistics (Conover 1980) and are only calculable for daily through monthly time scales. Statistics for year time scales are totals and these are treated as period of record statistics and no profiling occurs.

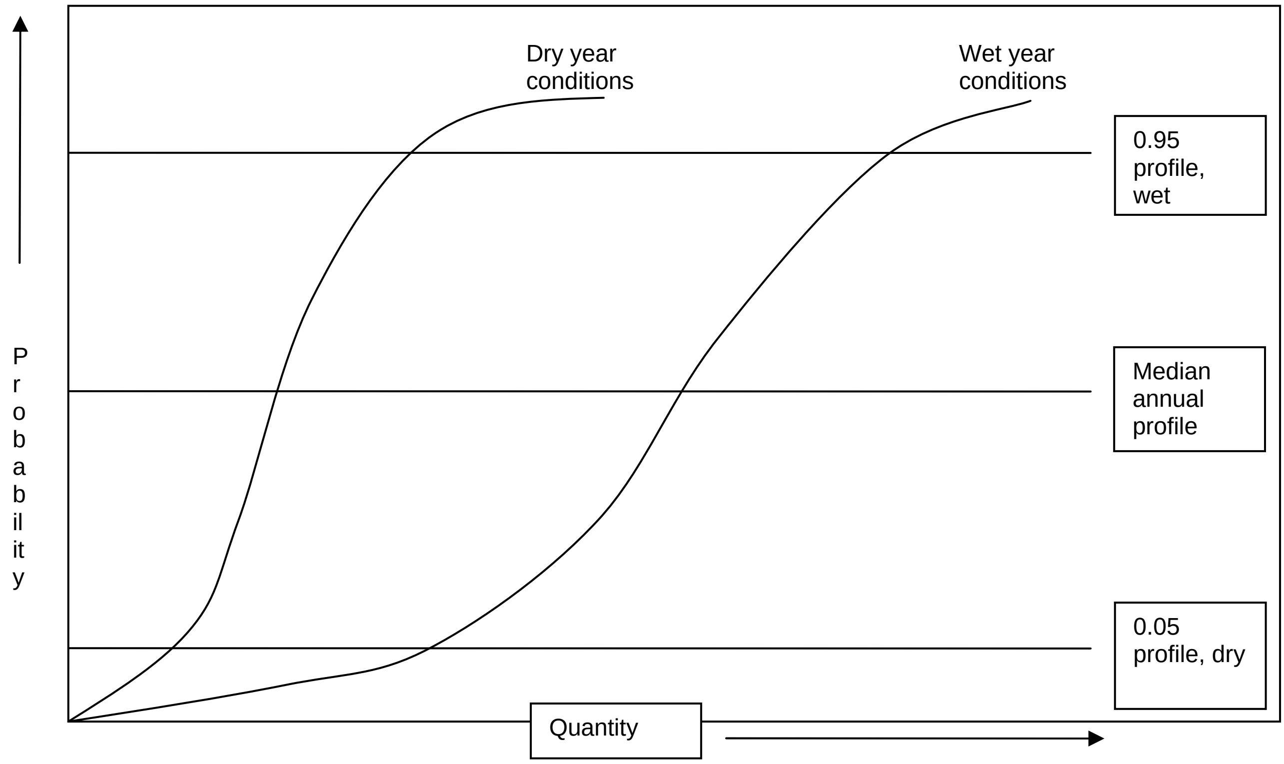


Figure 17 Example for annual dry, median and wet profiling of ordered probability of exceedence for annual period of records for each data type and daily to six monthly temporal scales.

The annualised values for each profile (e.g. annual median) are collated for the full assessable period. The empirical quantile function then interpolates quantities for a regularised array of percentiles for consistent comparisons. The resultant series are the reference regime series and curves. These curves characterise the overall within-year variation of conditions (dry to wet regimes), between year variability per regime, and overall membership of data per regime based on probabilities of exceedence. When the majority of data lie near the probability of exceedence of 0.5 for a regime, then that year's data is mainly representative of the conditions characteristic of that regime (Figure 18).

The annual totals provide one period of record probability of exceedence series using the same regularised array of probabilities. Period of record statistics are more likely to be biased to persistent conditions (Vogel and Fennessey 1994). If they were assessed on a multi-decadal basis, they could be profiled, but this is not attempted here because it would often not be achieved using shorter-term stream gauge data.

In both annualised and period of record series the quantity statistics are presented on log-transformed axes. This facilitates comparisons across a large range of quantity sizes. In addition, series that are linear across probabilities of exceedence indicate zonal data that are representative of normal and log-normal probability distribution functions, which are more often useful for common methods of analysis.

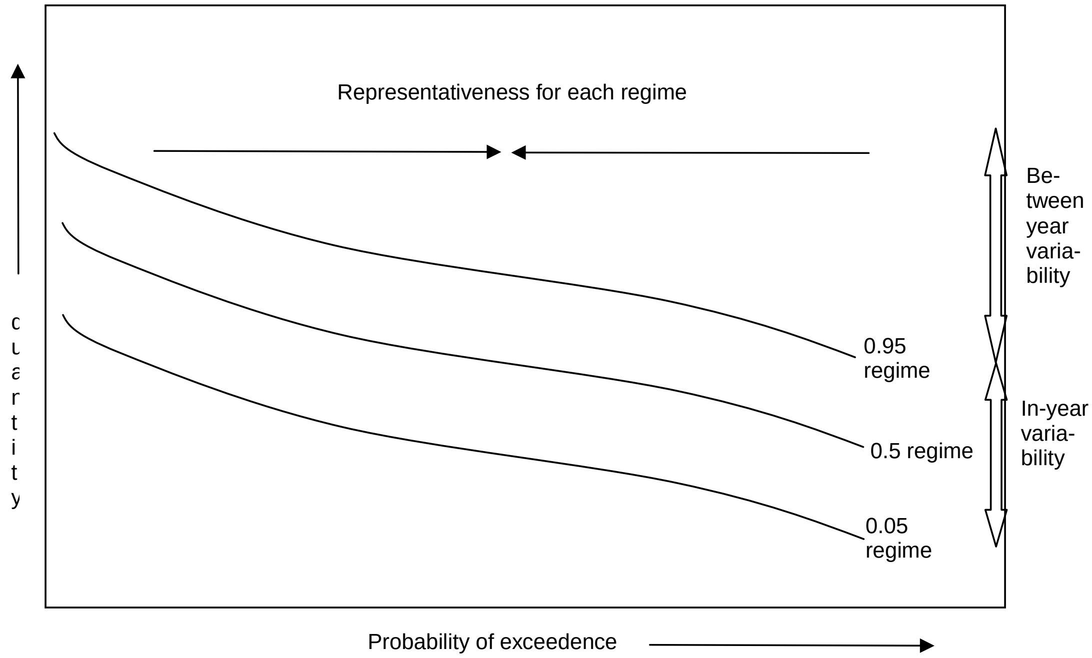


Figure 18 Idealised example for the interpretation of variability and representativeness of quantities ordered by probability of exceedence by regime.

Therefore the reference series chart for monthly rainfall in the Diamantina Plains in section 3.2.1.4 part 10 characterises the relative rainfall zonal statistics (and therefore expected conditions) in the following ways:

1. At a monthly reference time scale, rainfall zonal statistics are expected to be near log-normal, although the dry regime is heavily skewed to dry conditions.
2. There is some inflation of within-year variation across regimes with the more common drier conditions (where probabilities approach 100%), implying relatively greater seasonal variability in years that are drier over-all. The widening confidence intervals for the annual median series as probabilities increase supports this proposition.
3. The dry regime and lower confidence interval are sensitive to dry conditions within each year. However the expectation is that for any year, seasonal dry conditions will result in about 70% of statistics for the dry regime and seasonal analogue having months of very little (<0.1 mm) rainfall. A year of conditions representative of the dry regime would represent severe drought.
4. Inter-annual range in rainfall quantity is most pronounced for the wet regime, but is also significant through to the median regime.
5. The more skewed and offset nature of the dry regime suggests that it is less well characterised by the zonal statistics than the other series. This may be partly due to the nature of zonal statistics, which cannot accurately represent the range and extremes of observations. These differences between regimes are reduced by temporal up-scaling or may attenuated by calibration to local meteorological reference information. Section 3.3 examines these issues of variability in more detail.
6. For annualised data, the inversion of probabilities provides an estimate of the annual recurrence interval. For example a probability of 0.01 obtained for a monthly quantity is equivalent to a 1 in 100 recurrence for the data assessed. In the desert channel country represented by this chart 1 in 100 year flood events frequently span one to three month durations, so discharge measures spanning a month provide event-comparable recurrence information. For rainfall, the comparable reference time scale may be closer to a week in duration.

12 Extract reference regime data

Select the 'download this data in .CSV format' data extraction tool located under the reference series chart. One hundred and seven reference probabilities are registered to five interpolated quantile series: the 0.95, 0.5 and 0.05 regimes and the upper and lower 90% confidence intervals for the 0.5 regime. The probabilities occur at one percentile increments, although additional detail is provided at the tails to enhance sensitivity or the conversion of probabilities to frequently used recurrence intervals for discharge such as for 1 in 1.58 year or 1 in 90 year events which are sometimes used as indices of bankfull floods in agrarian coastal landscapes or the upper limit of large floods for most accurate characterisations.

Statistics for yearly scaled data are registered to the same probabilities. However only the interpolated annual totals are provided as no regimes or confidence intervals could be directly calculated for this period of record data.

A probability of zero is assigned to the maximum observed quantity in each regime whilst a value of one is assigned to the smallest quantity, which is certain to be equalled or exceeded. Note that seasonal drought is a common feature in most Queensland landscapes and that it is common for annualised series to frequently register zero rainfall or discharge, resulting in the expectation that zero states will be observed in all years with increasing duration in drier years.

Quantiles are linearly interpolated for all regimes and data types. Linear interpolation results in less smoothed curves, especially when the period of record is short (at least four years of record are required to record a reference series), but this roughness should be used to identify issues such as data sensitivity through to divergent seasonal effects.

Table 7 The quantile-probability of exceedence data downloaded using the 'Download this data in .CSV format' link under the reference chart on the sub-bioregion assessment page.

Probability of Exceedence	0.95 series	0.5 upper CI	0.5 series	0.5 lower CI	0.05 series
0	151.712	73.08456	40.90904	12.75473	5.07982
0.002732	149.0275	68.28224	36.37145	12.14897	3.961694
0.01	138.3908	56.11873	25.8887	10.71168	1.556422
0.010526	112.661	45.20776	21.64094	9.246742	1.364708
0.011111	107.7405	42.15281	19.394	7.803025	1.164359
0.013333	104.6751	41.80967	16.69131	7.437747	0.910512
0.02	97.87862	39.0792	15.63297	7.152218	0.815206
Section Deleted For	Display	Purposes			
0.7	29.19372	7.01852	1.959289	0.258518	1.10E-04
0.71	28.99342	6.956014	1.885178	0.23495	4.13E-05
0.72	28.83902	6.40234	1.822501	0.22808	7.27E-06
0.73	28.33483	6.158014	1.81313	0.224694	0
Section Deleted For	Display	Purposes			
0.97	11.62274	1.309487	0.301219	3.49E-04	0
0.98	11.52866	1.308843	0.301062	2.69E-04	0
0.99	11.444	1.308263	0.30092	1.98E-04	0
0.997268	7.222896	1.276154	0.299072	0	0
1	5.34936	1.261819	0.298387	0	0

13 Interpret reference regime data

These data provide the chart for the reference series. They may be evaluated using spreadsheet or statistical software to interpolate probabilities or quantiles. For example a user may have a quantity obtained at a monthly scale and use linear interpolation to identify the associated probability value.

It may be helpful to first view the yearly reference series, followed by increasingly finer temporal scales, to understand and better characterise how influenced regional conditions may be to seasonal through to daily or weekly synoptic climatic features. This knowledge may facilitate a more appropriate filtering of the time series data by quantity, time scale and duration to identify the optimal expected conditions for the selection of imagery or the characterisation of environmental processes.

14 Link to time series data

Linking reference information to time series data enhances the interpretation of the data substantially. This is achieved by the attribution of the data to each regime through the probabilities of exceedence. This is beneficial because the probabilities are more generalised and comparable within and between assessment zones. This enables, for example, the characterisation of emergent seasonal behaviour, such that the timing of monthly conditions can be characterised and bounded by expected limits. An example of extracted time series data is provided in Table 4 for the year 2006 in the Diamantina Plains sub-bioregion.

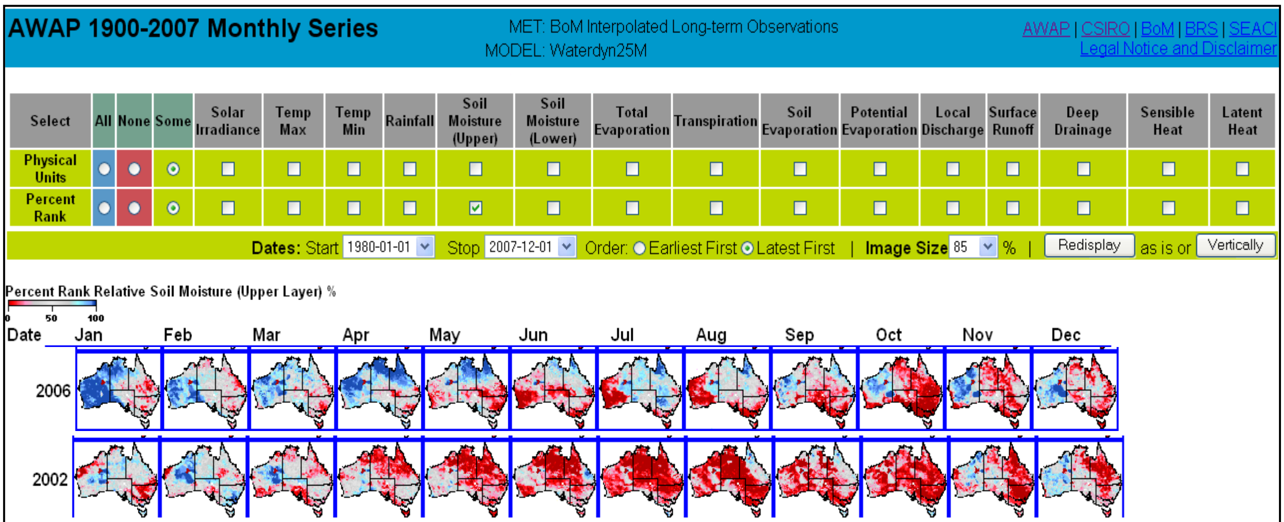
The bar chart below (Figure 21) illustrates the component probabilities for monthly rainfall quantities represented by each reference regime for the period 2001 to 2006 in the Diamantina Plains sub-bioregion. The period shows the annual 0.95 and 0.5 regimes are most often represented as wet conditions in spring-summer periods whilst median to dry conditions are best represented in autumn and winter periods. A major wet period occurred in June 2005 whilst significant dry months include April 2001 and 2002, and September 2003 and October 2004.

The rainfall quantities are illustrated below in the probability chart (Figure 22). It shows that rainfall quantities without the context of long term records may provide a misleading perspective on the significance of conditions. For example Figure 22 shows that whilst the low rainfall months of May and June 2006 are good representatives of dry conditions and the dry regime, they are relatively not as severe as the dry months of June to August and October 2002, or August and September 2006. The main difference between 2002 and 2006 is that the 2002 rainfall has little wet regime representation (except for December), whilst 2006 rainfall shows five months that were more representative of the wet regime. Therefore the profile of the 2002 statistics is in agreement with the dry year assessment in section 3.2.4.1 part 7.

Monthly spatialised soil moisture data for this assessment region is required to distinguish and confirm the actual severity of drought conditions. Water balance modelling of surface soil moisture for this region by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for these months and years provides an insight into comparative drought conditions for these years (screen shot (Figure 20) directly below). It clearly demonstrates that 2002 and 2006 were dry years for the assessment area but that 2002 had only moderate moisture in January, November and December, whilst 2006 had equally or better soil moisture conditions in February, March, July, and August and December. Therefore the climatic information provided by this facility can provide a good characterisation of the likely climatic conditions in comparison to the long term record when applied at appropriate temporal scales.

Location of the Diamantina Plains assessment region in eastern central Australia.

Figure 19 Location of the Diamantina Plains sub-bioregion using the Google Map window. This should be used to locate CSIRO modelled relative soil moisture expectations (Figure 20) for comparison with rainfall statistics provided by the Diamantina Plains zone.



Soil moisture determined through the Waterdyn25M water balance model with calibration/optimisation.
Sourced from <http://www.csiro.au/awap/cgi/awap2.pl?ser=Australia_monthly_25a&width=12&tf=85>
Report located at <http://www.csiro.au/awap/>

Figure 20 Relative soil moisture expectations provided by the CSIRO Australian Water Availability Project provide a useful indicator of potential soil moisture stress or surplus due to regional rainfall events identified by zone statistics.

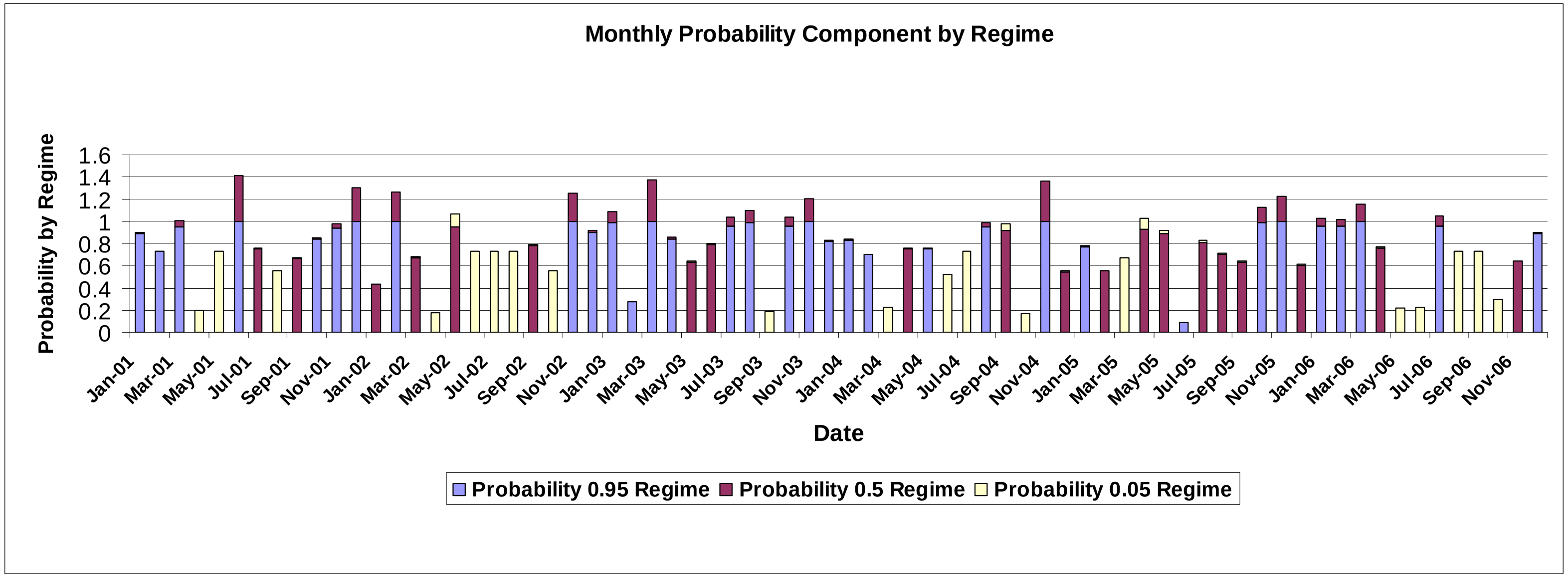


Figure 21 Attributes of reference regime (context) assigned to each month of rainfall values as a component probability of exceedence. Up to two regime attributes may be assigned to a value in this example. This method for interpretation clearly distinguishes rainfall regimes along a simple linear scale, thereby enhancing the interpretation of state and trend in rainfall conditions*.

*Notes: A component probability of 0.5 for a regime indicates the observed monthly total is a good representative for the regime. A small probability for the 0.95 regime with no other regimes apparent represents situations of large wet events (e.g. June 2005) with zero probabilities in other regimes. Probabilities in the 0.05 regime with no other apparent regime contributions is a situation where only the 0.05 regime is represented because the assessed quantity falls below the assessable range of the other regimes. The maximum bar length for this assessment zone for the 0.05 regime is 0.73, as this represents the commencement of the 0.73 to 1.0 probability range for zero rainfall conditions, and larger probabilities are not shown.

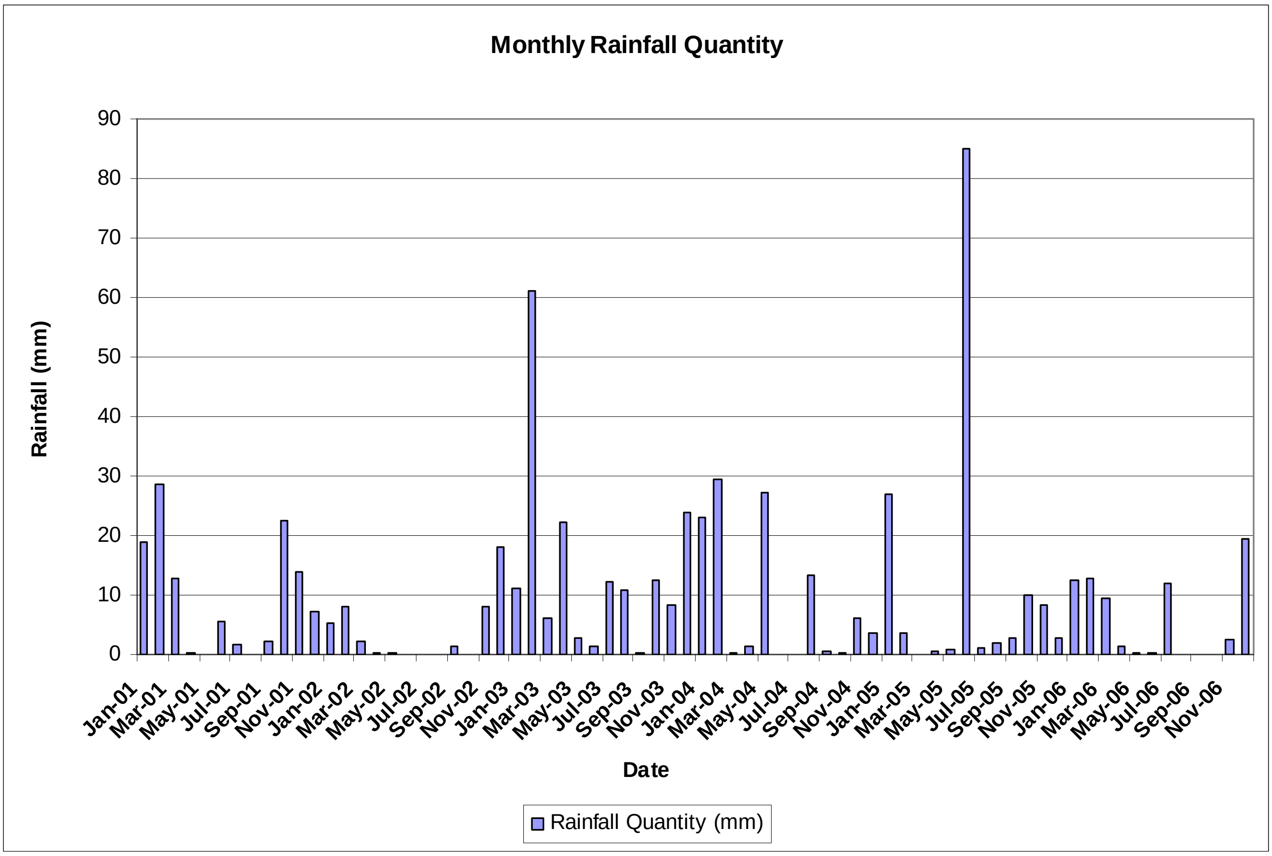


Figure 22 Monthly time series of mean zonal rainfall quantities for the Diamantina Plains assessment area, from 2001 to 2006 which input to Figure 21.

3.2.4.2. *Discharge and stage height*

The extraction and characterisation of gauge station discharge and stage height information is similar to the previous rainfall examples, although more care is required to assess and manage the inherent variability of the zonal statistics before reporting regional hydrological characteristics. The methods for data collation and reference statistic development are the same as for rainfall and run-off statistics. The main difference for gauge station data is that gauge station inputs are scaled (normalised) to the long term mean for each station prior to collation, and after a daily zone average is obtained, values are scaled up by an estimate of the long term zonal mean obtained from the inversion of daily normalised zonal statistics. This means that variations in statistics between zones may appear larger than for rainfall and run-off data, but the use of smaller assessment regions should reduce the degree of these differences between neighbouring regions within sub-bioregions.

Stream gauge data may be accessed from the sub-bioregion interface as explained in section 3.2.2.3.

1 Select parameters and references

Within the sub-basin in sub-bioregion selection interface, select the zone for assessment. Ensure that the zone selected has available data, as the majority of potential assessment areas are ungauged. View the period of record (valid years) information to scope the period of assessment. Most stream gauge zonal statistics are not available beyond 2005. Surrogate run-off and rainfall data will need to be assessed in areas without stream gauge data or that have data that falls outside of the period of interest.

Select the parameters and reference information required to define the data type (index of discharge or stage height), period of information, the end date for time series extraction, the reference time scale and the benchmark reference information to compare with the time series data. The selected information will be listed if the data is extracted.

The examples here are for discharge for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion (as per section 3.2.2.3).

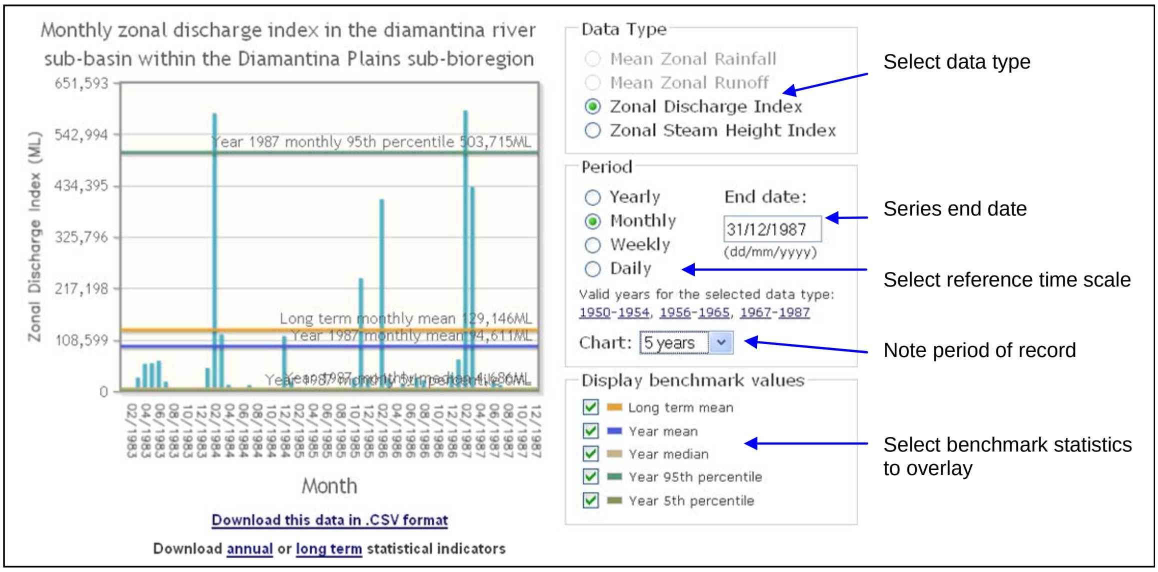


Figure 23 Example of sub-basin within sub-bioregion summary statistics and chart, and selection options available at the individual zone assessment interface.

2 View time series chart

The discharge and stage height time series charts have the same format as the rainfall / run-off data. In this example the assessed period of record spans 1983 to 1987.

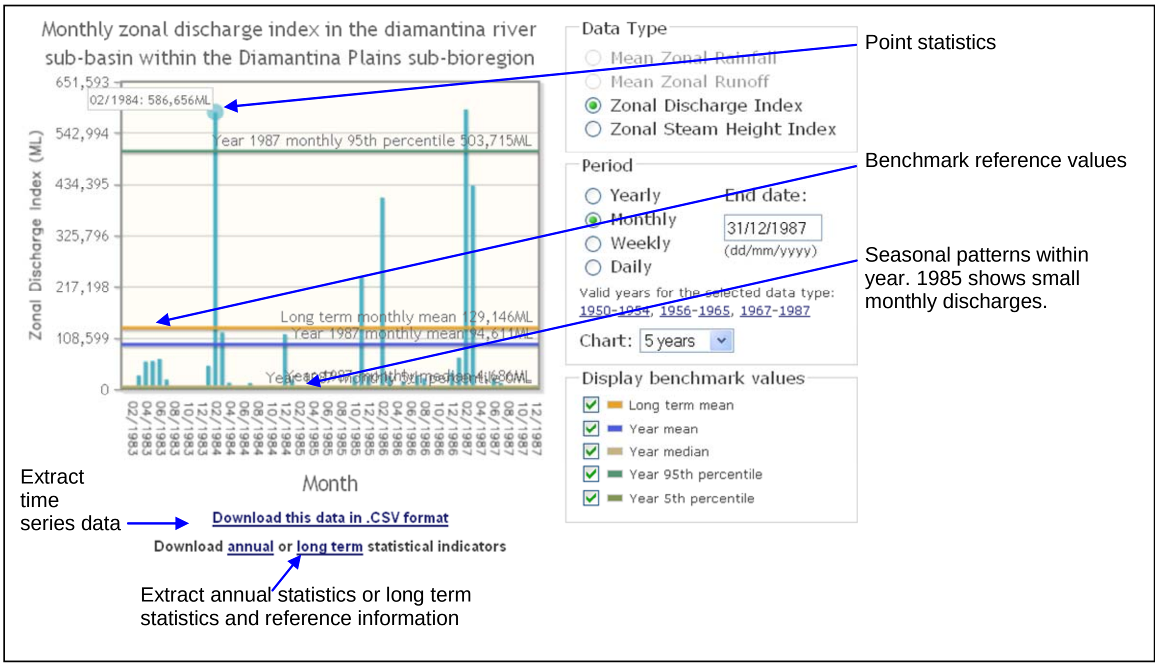


Figure 24 Explore the sub-basin within sub-bioregion summary statistics and chart.

3 Interpret time series chart

Zone statistic characteristics of interest include the values of statistics (bar values) relative to reference statistics and in the context of the period leading up to dates of reference. For example the statistics in Figure 24 suggest that the discharge during 1985, except for November was a period of stream drying and stress for lotic systems, whilst early 1987 was a period of flooding. Most significant discharge events occur during the summer seasons, and this may be linked to inflows from tropical catchments influenced by monsoonal and other tropical depression systems.

The wide range of statistics and reference statistics suggests that the period of record for discharge will be characterised by a wide range of flow conditions.

4 Extract time series data

Zone time series data is richer in information than the broader scaled scene summaries. Illustrated below is the data for the 1987 time series discharge statistics charted above using the 'download this data in .CSV format' tool.

Table 8 Example of extracted sub-basin within sub-bioregion time series data obtained through the 'Download this data in .CSV format' link in the individual assessment interface.

Month	Zonal Discharge Index quantity (ML)	Probability for quantity (.95 series)	Probability for quantity (.5 series)	Probability for quantity (.05 series)	Long term mean	Year 1987 mean	Year 1987 .95 series value	Year 1987 .5 series value	Year 1987 .05 series value
Jan-87	66809.95	0.84441	0	0	129145.7	94611	503714.8	4685.711	0
Feb-87	592357.2	0.229809	0	0	129145.7	94611	503714.8	4685.711	0
Mar-87	431189.2	0.270297	0	0	129145.7	94611	503714.8	4685.711	0
Apr-87	111.2868	NaN	0.809372	0.061047	129145.7	94611	503714.8	4685.711	0
May-87	1802.236	NaN	0.562309	0.010763	129145.7	94611	503714.8	4685.711	0
Jun-87	21434.88	0.915845	0.133915	0	129145.7	94611	503714.8	4685.711	0
Jul-87	13195.25	0.932528	0.213552	0	129145.7	94611	503714.8	4685.711	0
Aug-87	862.5369	NaN	0.604559	0.011046	129145.7	94611	503714.8	4685.711	0
Sep-87	0.226605	NaN	0.89399	0.179403	129145.7	94611	503714.8	4685.711	0
Oct-87	0	NaN	0.92	0.23	129145.7	94611	503714.8	4685.711	0
Nov-87	0	NaN	0.92	0.23	129145.7	94611	503714.8	4685.711	0
Dec-87	7569.188	NaN	0.309828	0	129145.7	94611	503714.8	4685.711	0

5 Interpret time series data

Like the rainfall zonal information the discharge time series provides quantity statistics for the reference time units (months) and the benchmark quantities for the long term mean, the mean for the reference year (1987) and the representative reference year values for each discharge regime. The zone statistics indicate through the average and regime statistics that 1987 conditions may represent a spectrum of normal conditions with zero discharge representative of the 5% regime through to two large discharges captured by the 95% regime.

The quantities for each time unit (month) are interpolated through the reference quantile-probability series (section 3.2.4.2 part 10) to provide probabilities of exceedence per regime per time unit. Probabilities of zero indicate the quantities are larger than a regime can assess. Probabilities of 1.0 indicate that the quantity is certain to occur in the assessed regime in any year relative to the reference record. Values of NaN (Not a Number) mean the quantities are below the assessable range of the reference series and are not expected to be represented by that regime.

If the data are downloaded, the averages of the probabilities for each regime may be compared (excluding missing values (NaN)) to identify which regimes characterise the year's statistics. In this case the average exceedence value in the wet regime is only a little larger than 50th percentile (0.639), indicating wet conditions, when they registered, were representative (though slightly drier) of normal wet regimes in comparison to the full period of record. The average exceedence probability in the median regime is 0.447, which is closer to 50th percentile for that regime than other average values and regimes, indicating normal conditions may have prevailed on average across the year. The average exceedence probability in the 5% regime was 0.060 (indicating wet conditions for a dry regime), which is much less than the 23rd percentile for the dry regime (the threshold at which zero flow becomes established), which indicates relative to the historical data that no severe dry conditions were influential in the overall hydrological conditions for 1987.

6 Extract annual data

The annual data should be extracted to identify and characterise the sampling conditions and variability in the data observed per year. The data are extracted using the 'download annual statistical indicators' tool.

Table 9 Annual reference information includes data type and time scale and parameters for annual levels and the degree of dispersion and variability of sampled data. Annual summaries are extracted from the zone interface when a time period of less than one year is selected.

Timescale	Data type	Year	Record count in year	Mean (ML) in year	Coefficient of variation	Variance ratio
Monthly	Zonal Discharge Index	1981	12	211323.4	2.035164	1.426779
Monthly	Zonal Discharge Index	1982	12	4050.16	2.317935	0.18155
Monthly	Zonal Discharge Index	1983	12	19242.29	1.372485	0.546485
Monthly	Zonal Discharge Index	1984	12	75411.67	2.2134	0.984996
Monthly	Zonal Discharge Index	1985	12	26837.61	2.514631	0.592473
Monthly	Zonal Discharge Index	1986	12	45104.91	2.529962	0.62307
Monthly	Zonal Discharge Index	1987	12	94611	2.100798	1.154153

7 Interpret annual data

In this example for the 7 years to 1987, the reference time scale, data type, year and number of months evaluated per year is attributed. The annual monthly mean for the years help to identify potentially wetter or drier conditions (depending on how even the discharge was spread over each month in a year). The coefficient of determination (CV) provides the relative dispersion (scaleless) (Zar 1984) of monthly values within the year, whilst the variance ratio is an F-test statistic testable index based on logged values that can be used to identify years with much greater or lesser within-year variability to the long term measure of annual variability (this is explained in significant detail in section 3.3).

In this data set it is clear that the record is continuous through the evaluated period and that 1981 is the wettest year followed by 1987. 1982 was very low discharge year with much lower variability than normal years. For the wetter years, the CV for discharge in 1981 is similar to 1987 suggesting a similar dispersion of values relative to the mean. However the comparison of annual to long term variance clearly distinguishes 1981 as a year of greater within-year variation than 1987. This information suggests that the 1981 flood was more punctuated and larger in scale than the 1987 event whilst the 1987 conditions are much more representative of normal hydrological conditions relative to the expected range of within-year discharge variation for that region, and this was confirmed by the 1987 time series statistics.

Whilst only 36 years of discharge data are available for this region, the annual data can be used to identify annual periods of data that best characterise discharge over the recorded period of record. Section 3.3 demonstrates that the monthly time scale is an appropriate scale to perform this characterisation, especially across discharge regimes. At a daily scale the variability is so large that it is usually significantly different to the long term measure, so that whilst time series statistics provide useful information, more care is required for the interpretation of membership with different regimes because their dispersion of values are quite different over the period of record.

8 Extract long term data

The long term data should be extracted to identify the period of assessable record and sampling constraints and the key benchmark statistics. The data are extracted using the 'download long term statistical indicators' tool.

Table 10 Long term zonal data is available from the zone interface and provides key benchmark and meta-data information for the assessed zone.

Timescale	Data type	Min station count	Max station count	Start year	End year	Year count	Long term mean (ML)	Coefficient of variation
Monthly	Zonal Discharge Index	0	2	1950	1987	36	129145.7	2.051636

9 Interpret long term data

For discharge and stage height data, the time scale, data type, number of sampled years (36 years), minimum and maximum number of stations contributing in any one year and start and end year is provided. Data quality control on stream gauge data ensures that 95% of all calendar days per year have assessable data, and that no more than two consecutive days have missing data (i.e. a station count of zero).

The long term mean and coefficient of variation (which is the mean of each year's coefficient of variation across sample times) are provided. These statistics are useful to compare average levels and relative dispersion between assessment zones. In this example, average discharge quantities are fairly large and overall dispersion is larger than observed in the rainfall statistics. This information suggests that significant inter-annual flood variation is likely but that the events are punctuated or strongly seasonal within-year. The rainfall statistics are generally not as large or variable, so major flooding events are likely to be due to flow accumulation upstream of the assessed area.

10 View reference regime chart

The reference quantile-probabilities of exceedence are obtained using the same statistical procedures as used for rainfall and run-off statistics. The reference series chart and associated data provide critical additional information that can be used to interpret the characteristics of hydro-climate regimes and the relative dispersion of seasonal conditions across regimes. The chart is viewed in the sub-basin in sub-bioregion interface once a zone and the parameters for assessment have been selected.

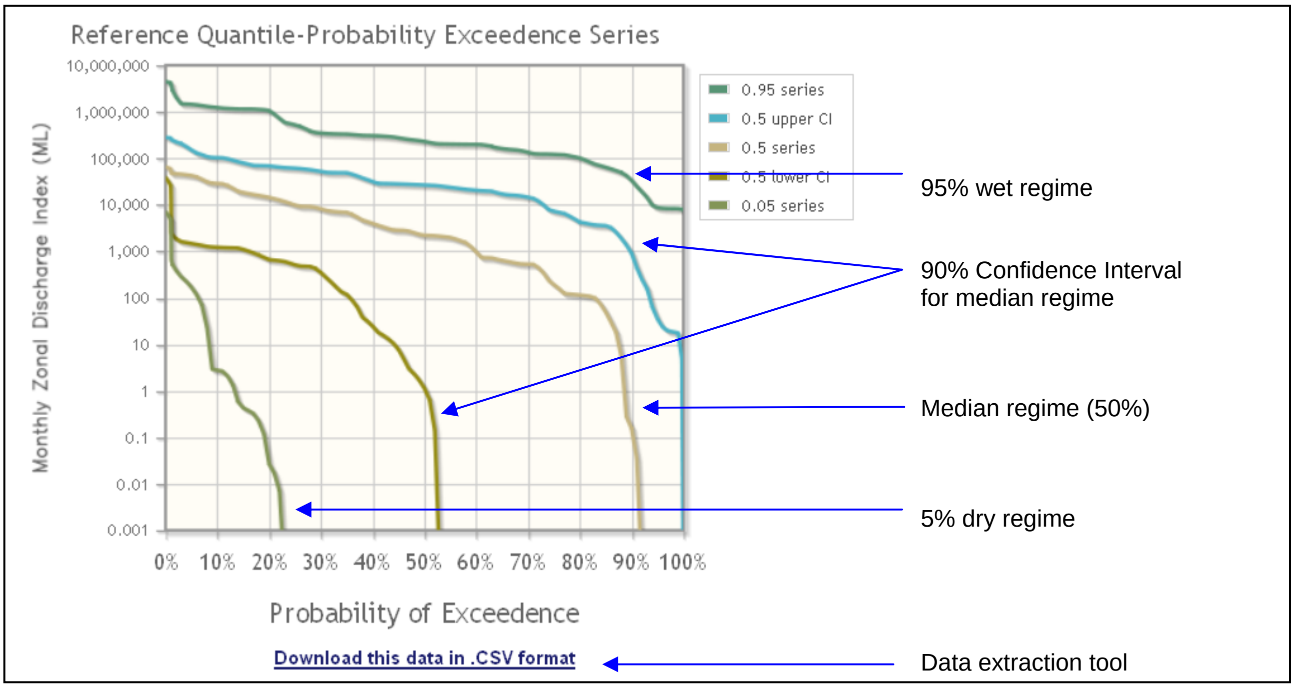


Figure 25 Reference quantile-probability of exceedence charts and data are provided for each assessable zone from the sub-basin within sub-bioregion assessment interface.

11 Interpret reference regime chart

The reference series chart for the statistic of monthly discharge in the Diamantina River sub-basin in the Diamantina Plains characterises the relative nature of annual discharge zonal statistics (and therefore expected conditions) in the following ways:

1. At a monthly reference time scale, the dry regime is heavily skewed to zero flow conditions. The lower confidence limit for the median regime shows similar characteristics to the dry regime whilst the upper confidence limit is more similar to the wet regime. Overall the wet and median regime have a similar form whilst the dry and lower median conditions are more similar. This dichotomy between regimes is characteristic of two dominant but contrasting within-year conditions, and this is further explored in section 3.3.
2. There is significant inflation of within-year variation across regimes with increasing dryness (where probabilities approach 100%), implying relatively greater seasonal variability in years that are drier over-all. The widening confidence intervals for the annual median series as probabilities increase supports this proposition. These conditions are characteristic of strongly pulsed or ‘boom and bust’ aquatic ecosystems where connectivity is vital for the persistence of meta-populations.
3. The dry regime and lower confidence interval are sensitive to dry conditions within each year. However the expectation is that for any year, seasonal dry conditions will result in about 77% of statistics for the dry regime and seasonal analogue having months with less than 0.001 ML discharge. A year of conditions representative of the dry regime would represent severe drought.
4. Inter-annual range in discharge quantity is most pronounced for the wet regime. However non-linear change in discharge quantity between years is evident in the median through to dry regime, so from an aquatic connection perspective inter-annual variation in discharge could result in significant effects on meta-population persistence.
5. The more skewed and offset nature of the dry regime suggests that it is less well characterised by the zonal statistics than the other series. The separation in form of the dry discharge regime from the others is more marked than for the rainfall data. This may be partly due to the nature of zonal statistics, which cannot accurately represent the range and extremes of observations or due to differences in measurements between gauge stations. It may also be indicative of much greater rates of transmission loss (e.g. to ground water and evaporation) when drier and hotter conditions prevail. These differences between regimes are reduced by temporal up-scaling or may attenuated by calibration to local hydrological reference information. Section 3.3 examines these issues of variability in more detail.
6. For annualised data, the inversion of probabilities provides an estimate of the annual recurrence interval. For example a probability of 0.01 obtained for a monthly quantity is equivalent to a 1 in 100 recurrence for the data assessed. In the desert channel country represented by this chart 1 in 100 year flood events frequently span one to three month durations, so discharge measures spanning a month provide event-comparable recurrence information. The observation of zero discharge statistics in the median and dry regimes indicates that stream stagnation and stream bed drying is expected to occur for at least one month every year when normal conditions prevail.

12 Extract reference regime data

The probability values for discharge are calculated in the same manner as applied to rainfall and run-off. A probability of zero is assigned to the maximum observed quantity in each regime whilst a value of one is assigned to the smallest quantity, which is certain to be equalled or exceeded. Note that seasonal drought is a common feature in most Queensland landscapes and that it is common for annualised series to frequently register zero rainfall or discharge, resulting in the expectation that zero states will be observed for at least one month in all years with increasing duration in drier years.

Select the 'download this data in .CSV format' data extraction tool under the reference series chart to extract the reference series statistics.

Table 11 The quantile-probability of exceedence data downloaded using the 'Download this data in .CSV format' link under the reference chart on the zone assessment page.

Probability of Exceedence	0.95 series	0.5 upper CI	0.5 series	0.5 lower CI	0.05 series
0	4459255	280153.8	65289.98	38705.5	7080.37
0.002732	4397051	278173.9	63581.95	35248.04	6466.712
0.01	4231585	272907.1	59038.52	26051.01	4834.349
0.010526	4003915	265660.3	52787.06	13396.52	2588.327
0.011111	3692955	257232	47357.72	2504.177	645.0012
0.013333	2882253	241715.1	46861.13	2184.686	517.8445
0.02	2071551	226198.1	46364.55	1865.195	390.6878
Section Deleted For	Display	Purposes			
0.7	134636.1	14495.76	527.5252	0	0
0.71	125726.8	13751.72	524.2666	0	0
0.72	122982.2	12042.91	447.571	0	0
Section Deleted For	Display	Purposes			
0.91	24842.62	444.646	0.034316	0	0
0.92	19012.58	247.6369	0	0	0
Section Deleted For	Display	Purposes			
0.99	8280.559	17.54252	0	0	0
0.997268	7974.551	4.792965	0	0	0
1	7859.513	0	0	0	0

13 Interpret reference regime data

These data provide the chart for the reference series. They may be evaluated using spreadsheet or statistical software to interpolate probabilities or quantiles. For example a user may have a quantity obtained at a monthly scale and use linear interpolation to identify the associated probability value.

It may be helpful to first view the yearly reference series, followed by increasingly finer temporal scales, to understand and better characterise how influenced regional conditions may be to seasonal through to daily or weekly synoptic climatic features. This knowledge may facilitate a more appropriate filtering of the time series data by quantity, time scale and duration to identify the optimal expected conditions for the selection of imagery or the characterisation of environmental processes.

14 Link to time series data

Linking reference information to time series data enhances the interpretation of the data substantially. This is achieved by the attribution of the data to each regime through the probabilities of exceedence. This is beneficial because the probabilities are more generalised and comparable within and between assessment zones. This enables, for example, the characterisation of emergent seasonal behaviour, such that the timing of monthly conditions can be characterised and bounded by expected limits. An example of an extracted table of time series data is provided in Table 8 for the year 1987 in the Diamantina River sub-basin in the Diamantina Plains sub-bioregion.

The regime attributed bar chart below illustrates the component probabilities for monthly discharge quantities represented by each reference regime for the period 1981 to 1987 in the Diamantina River sub-basin in the Diamantina Plains sub-bioregion (Figure 28). The period shows the annual 0.95 and 0.5 regimes most often represent wet conditions (e.g. areas with the smallest blue and or brown bars) in late summer through to early autumn periods, which is often followed by modest discharge through early winter, with severe dry periods (small yellow bars with large brown bars) apparent from winter to early summer. A major exception to this was 1982 when significant low discharge conditions occurred for nine out of 12 months, with some modest discharge observed in autumn.

The discharge quantities are illustrated below the probability chart with logarithmic values to ensure small discharges are shown (Figure 29). In this case the combined monthly hydrograph is complimentary to the regime attributed discharge because it shows the transition from wet to dry regimes at about 8000 ML per month (e.g. discharge levels between the April 1981 (10 500 ML) and February 1985 (7000 ML) record). At this threshold the blue bars vanish and increasingly longer brown and yellow bars dominate, making regime change across two orders of magnitude (e.g. February versus April 1981) much more apparent against a simple linear axis. The chart of the reference series in Figure 25 shows drier regimes are distinguished in the upper confidence limit at 3600 ML, where the curve shows a sudden and continuous loss in discharge for larger probabilities of exceedence.

The combined hydrograph appears to indicate that the October 1985 to August 1987 period supported generally large flows. The regime attributed statistics show otherwise: for the 22 months in this period, five months showed wet regime flows (blue bars only), nine months show a wet to median regime transition (blue and brown bars) and eight months show median or median to dry transitions (brown only or brown and yellow bars). So about 64% of months show reasonably wet conditions for instream discharge relative to historic records rather than what appears to be quite reasonable conditions for 91% of the bars in the hydrograph for the seven year period assessed. The March to July 1983 period provides another good comparison: here the hydrograph discharges appear to be quite large (around 30 000 ML) but the regime attributed statistics show that whilst they are representative of the wet regime, discharge conditions are at the dry end of the wet regime and that conditions quickly transition to median and then dry conditions in August and September 1983. The dry conditions for most of 1985 suggested in section 3.2.4.2 part 3 are in agreement with the regime attributed data. The punctuated variability in 1981 and average overall conditions for 1987 suggested in section 3.2.4.2 part 5 and 3.2.4.2 part 7 are evident.

Independent monthly discharge is required to evaluate the performance of the zonal statistics; however no such mapping exists. The CSIRO AWAP simulated local run-off is used as a surrogate for stream discharge. This is a poor surrogate because it is localised in nature and approximates net local flow from a simulated water balance. The graphics for the seven year period are provided in Figure 27 below. It shows moderately large run-off in the area of interest in 1981 and 1984 with only localised moderately large run-off in 1987. The 1984 run-off events are localised in the south and west of the area of interest whilst the 1981 and 1987 run-off events are more concentrated in the northern catchment and upstream areas, which are the main contributing areas to stream flow. The 1982 low discharge conditions identified in the bar chart are in agreement with the AWAP simulated run-off which shows almost no contribution in the region during that year, with relief to these conditions observed in autumn 1983.

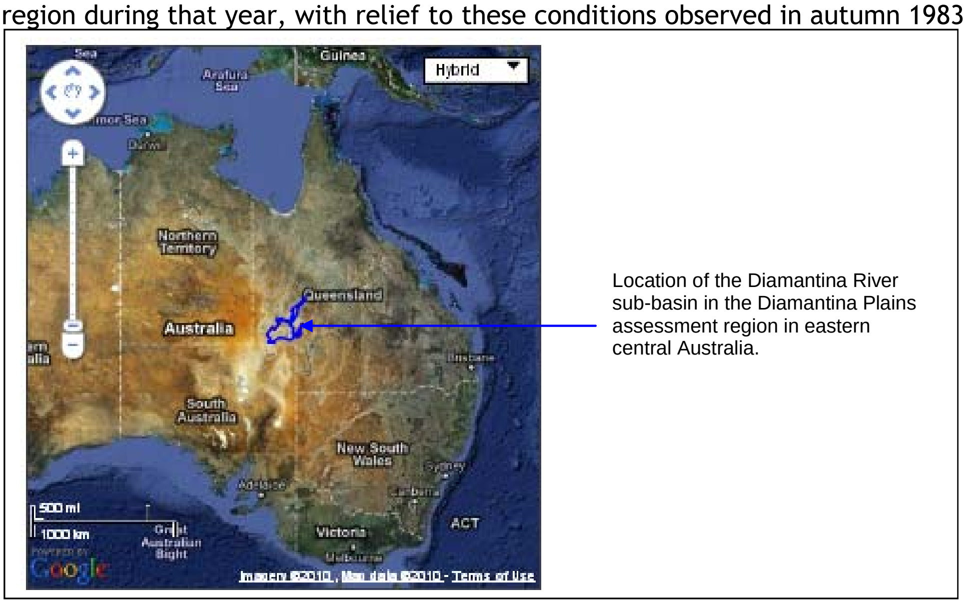
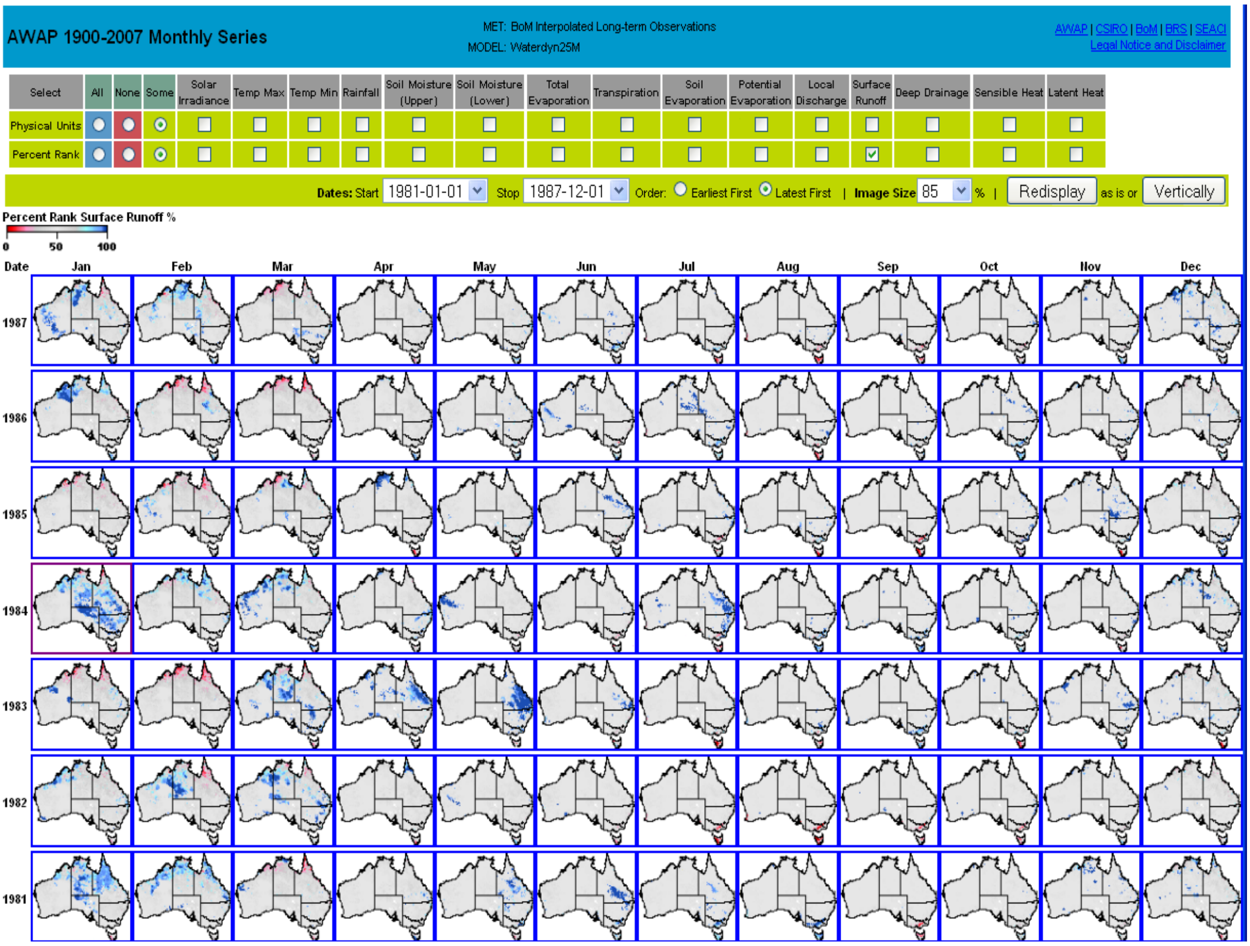


Figure 26 Location of the Diamantina River sub-basin in the Diamantina Plains sub-bioregion using the Google Map window. This should be used to locate CSIRO modelled run-off expectations (Figure 27) for comparison with discharge statistics provided by the assessment zone.



Local run-off determined through the Waterdyn25M water balance model with calibration/optimisation.
Sourced from <http://www.csiro.au/awap/cgi/awap2.pl?ser=Australia_monthly_25a&width=12&tf=85>
Report located at <http://www.csiro.au/awap/>

Figure 27 Run-off expectations provided by the CSIRO Australian Water Availability Project provide a useful indicator of potential surplus flow to stream for comparison with zone discharge statistics.

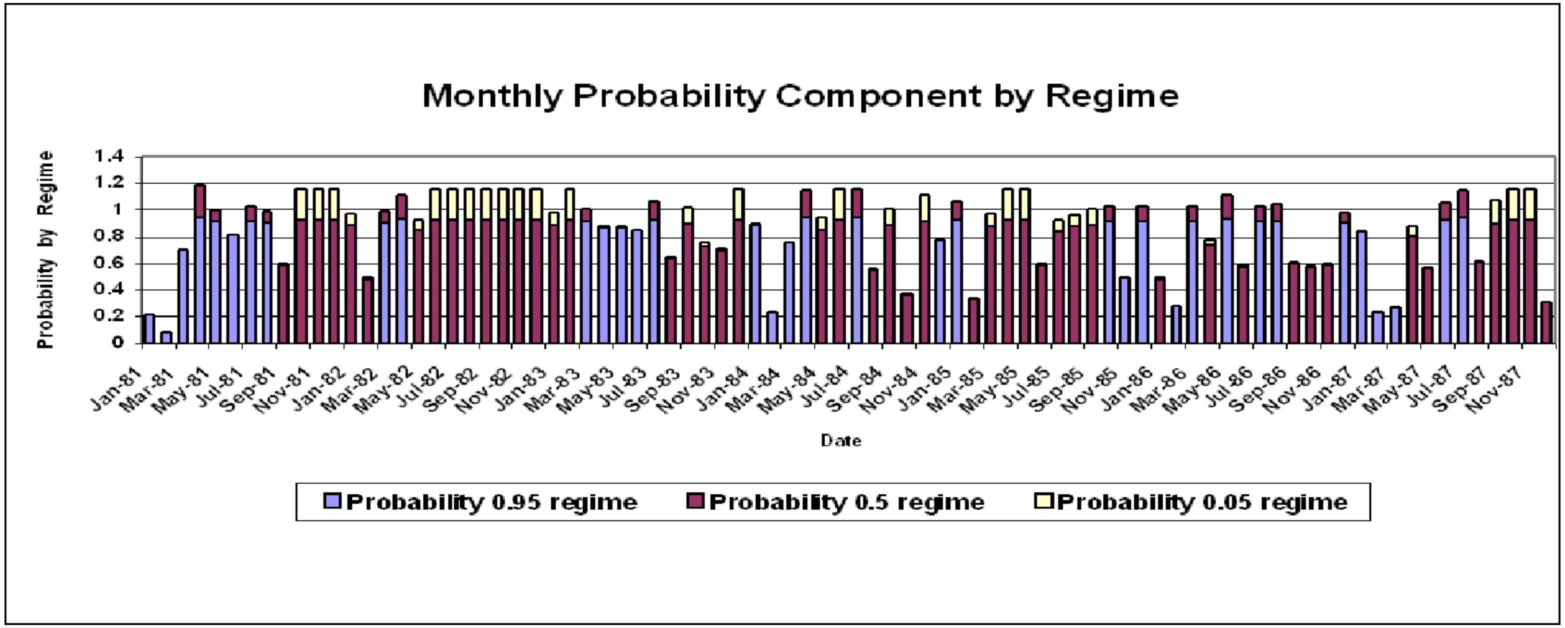


Figure 28 Attributes of reference regime (context) assigned to each month of discharge as a component probability of exceedence. Up to two regime attributes may be assigned to a value in this example. This method for interpretation clearly distinguishes discharge regimes along a simple linear scale, thereby enhancing the interpretation of state and trend in discharge conditions*.

*Notes: A component probability of 0.5 for a regime indicates the observed monthly total is a good representative for the regime. A small probability for the 0.95 regime with no other regimes apparent represents situations of large flood events (e.g. February 1981) with zero probabilities in other regimes. Large probabilities in the 0.05 regime (with a maximum of 0.23 in this assessment zone) indicate major dry conditions with zero flow: bars do not exceed 0.23 because 77% of probabilities for this regime are attributed to a discharge value of 0 ML, spanning probabilities of 0.23 to 1.0. Zero flows in the 0.05 regime coincide with the 0.5 regime for probabilities 0.92 to 1.0.

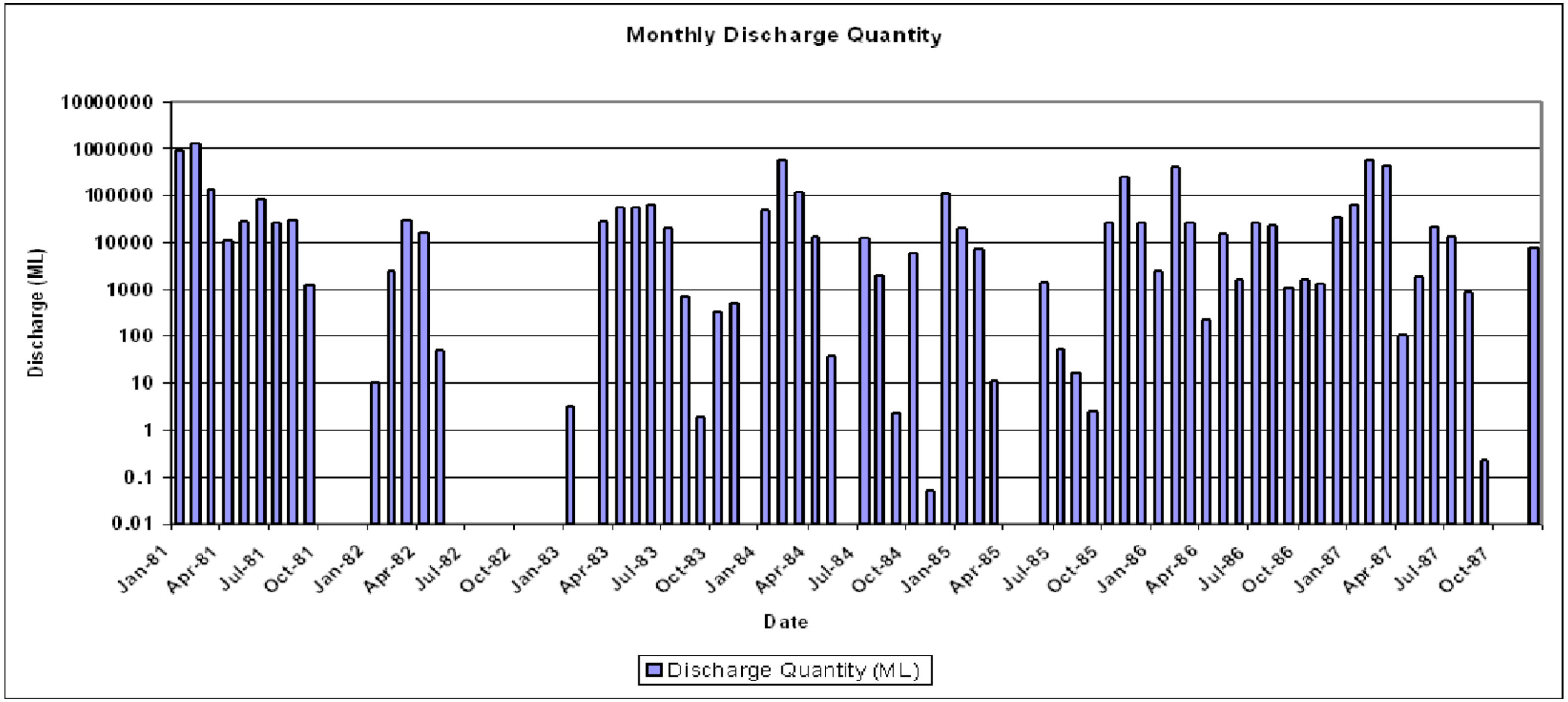


Figure 29 Monthly time series of discharge index quantities for the Diamantina River basin in the Diamantina Plains assessment area, from 1981 to 1987 which input to Figure 28.

3.3. Characterise hydro-climate variability

The discharge statistics and reference information for the Diamantina sub-basin clearly showed that:

1. thresholds to regime and interannual conditions may be apparent
2. increasing within year variation in discharge with increasing dryness may occur
3. significant variation can occur in conditions between year and within-year.

To complicate comparisons further, differences in the performance of gauge stations or conditions measured between stream gauge stations may induce heteroscedastic effects into the variability of statistics. Heteroscedastic effects may cause variance inflation or suppression within each year's statistics.

3.3.1. General

This section outlines the use of tools and assessment techniques to detect years with inflated or reduced variability. The section then evaluates the beneficial effect that increasing the reference time scale can bring to improve the comparability of reference statistics between regimes and across the period of record. This does not reduce the validity of daily time series information but asserts the need to perform analyses at appropriate time scales to ensure that appropriate characterisations and comparisons to long term references are conducted. In most cases a decision to change time scale will be associated with the influence of the duration of seasonal flood or drought conditions, thereby providing improvement in the sensitivity and applicability of wetland filling analyses.

3.3.2. Evaluate the effects of variability and select appropriate time scales for assessment

The ratio of the variance of logged values may be tested using the F-test statistic to identify anomalous variation in within-year statistics between years. It is within within-year statistics that heteroscedastic effects or unusual effects by event or season will be apparent.

The F-test statistic is typically derived from:

F = (explained variance) / (unexplained variance)

However the test used in this method is not a controlled analysis of variance, but a comparison of the variability of different populations or hydro-climatic conditions through time.

Therefore a two-tail test should be applied to two ratios.

F1 = (variance between intervals within-year) / (variance within-year across years at time scale)

and for the reciprocal ratio,

F2 = (variance within-year across years at time scale) / (variance between intervals within-year)

This method compares the variance of logged values (Zar 1984) in downloaded data. In normal circumstances the variance ratio would compare variances for the period of record within-year to variance of the overall period. This was not desirable for annualised data where marked yearly effects on dispersion, such as heteroscedasticity may have an influential effect on annualised values. Heteroscedasticity can be caused by differences in measures between samples within a sampling period because they may belong to different populations due to their underlying processes (factors) differing (e.g. combining different stream gauge station data throughout a year).

The zonal approach used incorporates but attenuates heteroscedasticity by normalising station values before averaging, and by independently profiling statistics annually rather than by assessing the complete period of record. Therefore to make the test sufficiently sensitive, including situations of non-normality / non-log normality where the test errs on the side of caution, the measure of variance across years is centralised to the mean annual within-year variance of logged values. This non-standard application of the test should therefore be considered an index of annual to long term annual variability rather than a traditional test for heteroscedasticity or treatment effect. An example hypothesis would have:

Numerator within-year degrees of freedom (d.f.) = number of time intervals in year – 1

Denominator degrees of freedom (d.f.) = number of years – 1

Hypothesis: This year's variability may be representative of the long term expected within-year variability for annualised data.

Alternative: This year's variability may not be similar to the long term expected within-year variability for annualised data: it is either less than or greater than what is expected.

Whilst high internal relative dispersion may occur within a year relative to that year's mean level, the overall variability may be representative of the long term variance. In other cases yearly data can be polarised by large / unusual events that may influence either the coefficient of variation within-year or comparison of variance between years. A ratio of within to between (within) year variance detects variance inflation within-year whilst the reciprocal ratio of between year to within year variance detects deflated variability within-year.

The examples below identify variance inflation and deflation conditions in the Diamantina River basin in the Diamantina Plains sub-bioregion. In this area significant non-normality in hydrograph characteristics occur. Potential significance varies with the influence of specific events or overall conditions. In this time series only one gauge station contributed in 1950 to 1965 whilst two stations contributed during 1967 to 1987. In this series variability within-year may be less for single station series whilst the two station series may be more similar to the long term value as indicated by the reciprocal ratio test.

This zone provides a worst-case example for the influence of the effect of punctuated variability and gauge station integration on time series comparison. Users should evaluate the coefficient of variation and the within-year variation relative to the long term benchmark to identify anomalous statistical conditions and what this might mean to the interpretation of reference probability-quantile series. However the annualised basis for the reference series is sound, resulting in generally consistent curves between discharge regimes, so users should use the reference information for comparison. In these circumstances extreme variability is reduced by using larger reference time periods (weekly and monthly) (compare daily to monthly time reference effects in Tables 12 and 13 and Figures 30 and 31). Monthly values are accumulated from daily normalised values, aggregating over daily variations, and are allocated to the end of each month. Normalised values are not scaled up to discharge totals for some of the time series statistics to simplify comparision.

The index of discharge is more evenly distributed in the monthly statistics and no systematic variance inflation effects are apparent within-year in the monthly series. This is consistent with the more uniform spread of reference probability-quantiles at a monthly scale than the three-way clustering observed in probabilities and quantiles for daily data (Figures 32 and 33).

A range of F statistic values may be accessed for assessments at <http://www.itl.nist.gov/div898/handbook/eda/section3/eda3673.htm> and <http://www.statsoft.com/textbook/distribution-tables/#f> .

Table 12 Annualised daily discharge statistics for variance ratio evaluation in sub-basin 0021 in sub-bioregion 5.2. Degrees of freedom are 364,35 (F.05(2)=1.75) for variance ratio within year:between (within) years (VR(yr:lt)), and 35,364 (F.05(2)=1.62) for the reciprocal ratio (VR(lt:yr)). Significant variance ratios are listed in bold.

Timescale	Data type	Year	Record count in year	Daily mean (ML) in year	Coefficient of variation	VR(yr:lt)	VR(lt:yr)
Daily	Disch.	1950	365	29437.18	2.746323	**4.304084**	0.232337
Daily	Disch.	1951	365	1145.468	2.812522	0.357917	**2.793943**
Daily	Disch.	1952	366	94.13402	2.8864	0.008767	**114.065**
Daily	Disch.	1953	365	8633.936	3.562146	**2.1693**	0.460978
Daily	Disch.	1954	365	1213.389	1.779797	0.284506	**3.514868**
Daily	Disch.	1956	366	5083.675	2.123751	1.278038	0.78245
Daily	Disch.	1957	365	2016.094	2.604078	0.602986	**1.658413**
Daily	Disch.	1958	365	586.1099	2.226925	0.126376	**7.912924**
Daily	Disch.	1959	365	369.382	2.214341	0.063515	**15.74421**
Daily	Disch.	1960	366	1562.889	2.545161	0.465163	**2.149783**
Daily	Disch.	1961	365	757.1898	2.57037	0.216508	**4.618777**
Daily	Disch.	1962	365	2508.989	1.63066	0.597301	**1.674198**
Daily	Disch.	1963	365	7402.498	3.30675	1.721927	0.580745
Daily	Disch.	1964	366	2650.751	2.553925	0.690375	1.448487
Daily	Disch.	1965	365	56.51355	3.368099	0.004752	**210.4269**
Daily	Disch.	1967	365	1001.218	2.931019	0.30432	**3.286018**
Daily	Disch.	1968	366	3217.148	2.092761	0.918246	1.089033
Daily	Disch.	1969	365	660.4348	5.57497	0.231627	**4.317285**
Daily	Disch.	1970	365	1554.271	4.005062	0.49684	**2.012722**
Daily	Disch.	1971	365	7528.267	2.530076	**2.056736**	0.486207
Daily	Disch.	1972	366	1602.976	2.958192	0.535745	**1.866558**
Daily	Disch.	1973	365	10666.38	1.874691	**2.80643**	0.356325
Daily	Disch.	1974	365	24388.51	2.430298	**4.609401**	0.216948
Daily	Disch.	1975	365	2446.993	2.479484	0.726957	1.375598
Daily	Disch.	1976	366	9085.441	2.633889	**2.450653**	0.408055
Daily	Disch.	1977	365	7978.166	2.469881	**2.246246**	0.445187
Daily	Disch.	1978	365	887.6771	3.066042	0.248607	**4.022405**
Daily	Disch.	1979	365	1309.934	2.451006	0.417918	**2.392814**
Daily	Disch.	1980	366	1270.574	4.102049	0.401865	**2.488397**
Daily	Disch.	1981	365	6947.619	2.480385	**1.903901**	0.525237
Daily	Disch.	1982	365	133.156	3.253591	0.01968	**50.81314**
Daily	Disch.	1983	365	632.6233	2.487223	0.134728	**7.422373**
Daily	Disch.	1984	366	2472.514	2.75434	0.79538	1.257261
Daily	Disch.	1985	365	882.3325	3.467257	0.276427	**3.617585**
Daily	Disch.	1986	365	1482.901	4.390432	0.432926	**2.309866**
Daily	Disch.	1987	364	3119.044	2.839303	1.093853	0.9142

Table 13 Annualised monthly discharge statistics for variance ratio evaluation in sub-basin 0021 in sub-bioregion 5.2. Degrees of freedom are 11,35 (F.05(2)=2.39) for variance ratio within year:between (within) years (VR(yr:lt)), and 35,11 (F.05(2)=3.09) for the reciprocal ratio (VR(lt:yr)). Significant variance ratios are listed in bold.

Timescale	Data type	Year	Record count in year	Monthly mean (ML) in year	Coefficient of variation	VR(yr:lt)	VR(lt:yr)
Monthly	Disch.	1950	12	895380.8	2.013444	1.640566	0.609546
Monthly	Disch.	1951	12	34841.31	1.983588	0.840064	1.190385
Monthly	Disch.	1952	12	2871.088	1.348331	0.091167	**10.96882**
Monthly	Disch.	1953	12	262615.5	2.958099	1.594295	0.627237
Monthly	Disch.	1954	12	36907.25	1.678104	0.78406	1.275413
Monthly	Disch.	1956	12	155052.1	1.840712	1.380205	0.72453
Monthly	Disch.	1957	12	61322.85	1.961046	0.929528	1.075815
Monthly	Disch.	1958	12	17827.51	1.611669	0.492965	2.02854
Monthly	Disch.	1959	12	11235.37	1.794284	0.333635	2.997292
Monthly	Disch.	1960	12	47668.13	2.303611	0.634259	1.576643
Monthly	Disch.	1961	12	23031.19	2.169956	0.665625	1.502347
Monthly	Disch.	1962	12	76315.08	1.446365	0.964692	1.0366
Monthly	Disch.	1963	12	225159.3	2.142603	1.599707	0.625114
Monthly	Disch.	1964	12	80847.91	1.611776	1.013078	0.987091
Monthly	Disch.	1965	12	1718.954	2.084924	0.067424	**14.83145**
Monthly	Disch.	1967	12	30453.7	1.981523	0.734221	1.361988
Monthly	Disch.	1968	12	98123.01	1.475061	1.166868	0.856995
Monthly	Disch.	1969	12	20088.23	2.763068	0.489582	2.042558
Monthly	Disch.	1970	12	47275.73	2.580683	0.893302	1.119443
Monthly	Disch.	1971	12	228984.8	2.271788	1.70839	0.585347
Monthly	Disch.	1972	12	48890.75	2.107071	0.935213	1.069275
Monthly	Disch.	1973	12	324435.7	1.558126	1.977671	0.505645
Monthly	Disch.	1974	12	741817.3	2.135469	**2.544114**	0.393064
Monthly	Disch.	1975	12	74429.38	1.599005	1.060429	0.943014
Monthly	Disch.	1976	12	277106	2.217121	1.881916	0.531373
Monthly	Disch.	1977	12	242669.2	2.217623	1.913187	0.522688
Monthly	Disch.	1978	12	27000.18	2.120587	0.503886	1.984575
Monthly	Disch.	1979	12	39843.83	2.193534	0.844261	1.184467
Monthly	Disch.	1980	12	38752.49	2.605328	0.806183	1.240413
Monthly	Disch.	1981	12	211323.4	2.035164	1.426779	0.700879
Monthly	Disch.	1982	12	4050.16	2.317935	0.18155	**5.508134**
Monthly	Disch.	1983	12	19242.29	1.372485	0.546485	1.829876
Monthly	Disch.	1984	12	75411.67	2.2134	0.984996	1.015232
Monthly	Disch.	1985	12	26837.61	2.514631	0.592473	1.68784
Monthly	Disch.	1986	12	45104.91	2.529962	0.62307	1.604956
Monthly	Disch.	1987	12	94611	2.100798	1.154153	0.866436

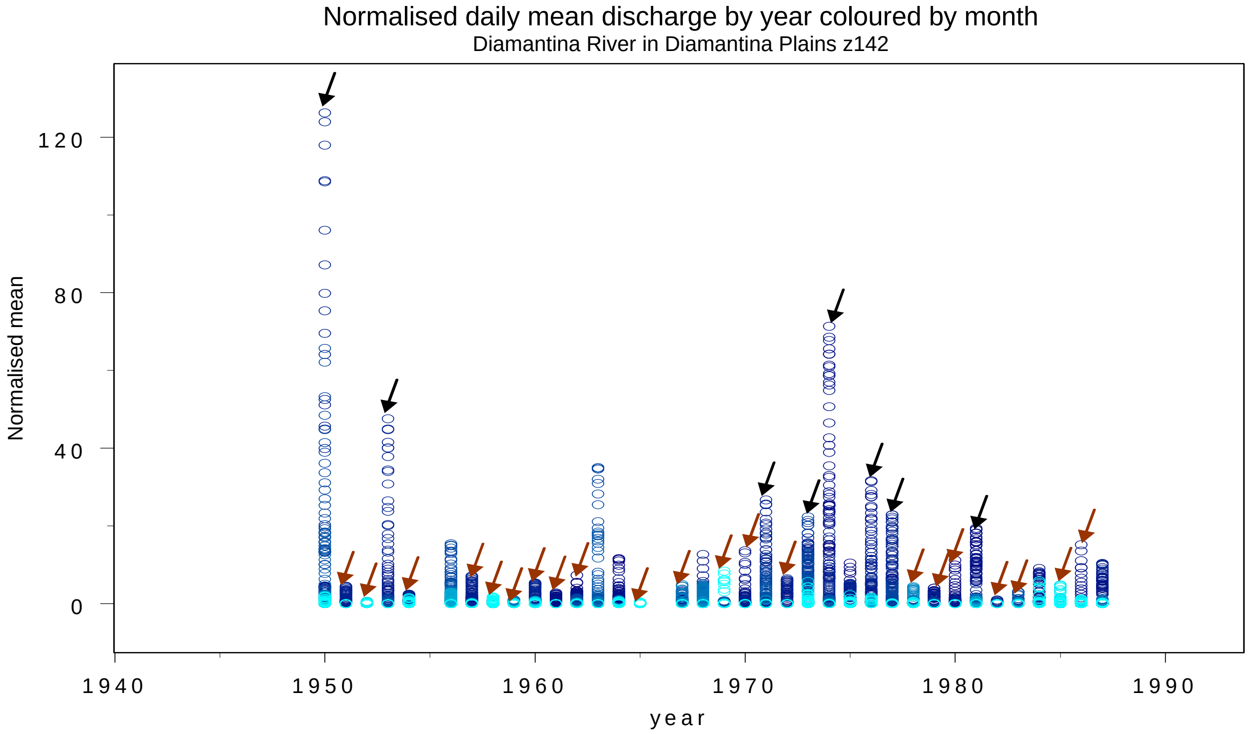


Figure 30 Illustration of extremes of variability apparent in Table 12 caused by 1) inflation due to major punctuated (e.g. unimodal) discharge events in the year (black arrows) and 2) deflation due to an absence of major events and a more even distribution of small events (brown arrows). Dark blue indicates months at the start of the year, light cyan months at the end of the year. A combination of two stations contributed data from 1967 to 1987. Years with 'normal variability' are 1956, 1963, 1964, 1968, 1975, 1984, 1987. It may be asserted that the extremes of variability, especially the dry regime are more frequent and therefore more representative of normal conditions at a daily time scale (see also Figures 32, 33 and 38 to 40).

It is sensible to advise that evaluations of discharge in this zone be performed at a monthly time scale, not only because of the statistical nature of the hydrograph but because most flows are accumulated from monsoonal or other rain depression effects from catchments located some 1000 km upstream resulting in very marked 'seasonal' conditions in an arid environment. In situations when variability or heterogeneity effects on data useability is of concern, users may choose as a general rule to perform evaluations using the longest practical reference time scale and to perform analyses using only the annual median reference series. Users should be aware though that this precautionary approach will remove a significant amount of useful information that represents real within and between year variability.

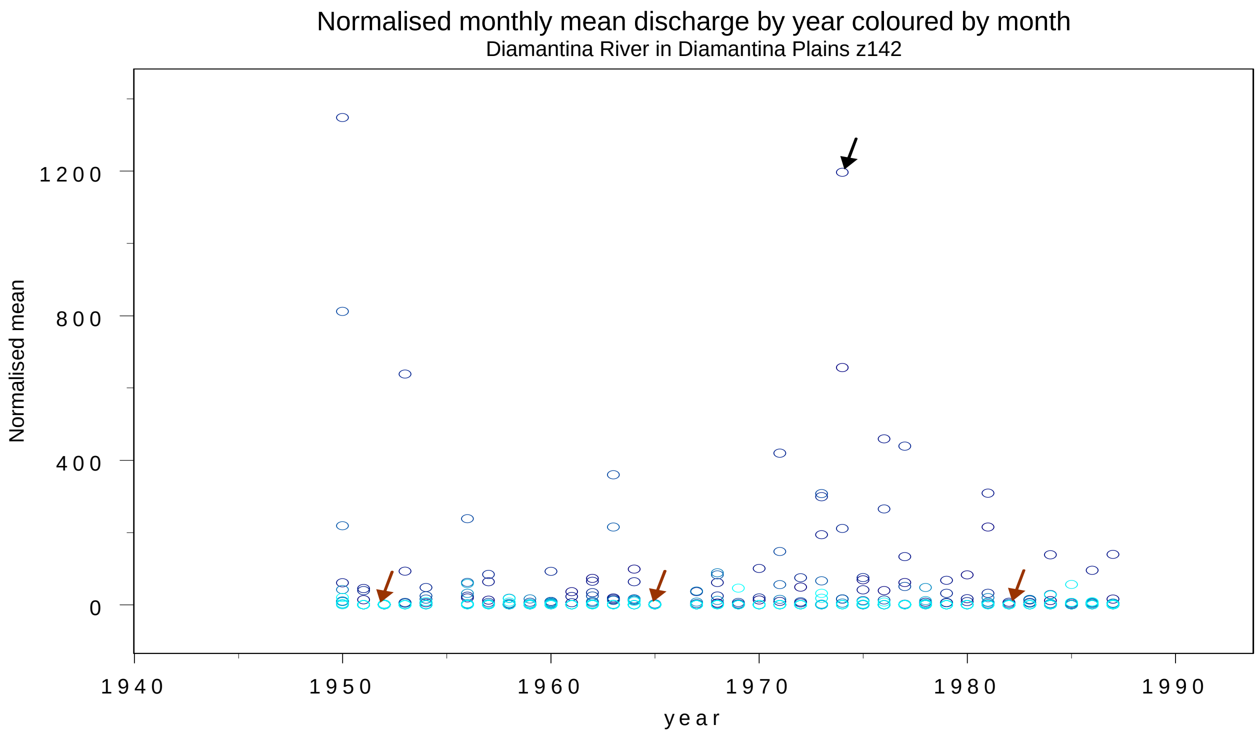


Figure 31 Illustration of extremes of variability apparent in Table 13 caused by 1) inflation due to major punctuated (e.g. unimodal) discharge events in the year (black arrows) and 2) deflation due to an absence of major events and a more even distribution of small events (brown arrows). Dark blue indicates the first months of year, light cyan the last months of the year. A combination of two stations contributed data from 1967 to 1987. Years with 'normal variability' are in the majority with 1974 experiencing a very punctuated event whilst 1952, 1965 and 1982 were particularly dry. Variability within-year is much more evenly distributed between years at a monthly temporal scale of assessment (see also Figures 32, 33 and 38 to 40).

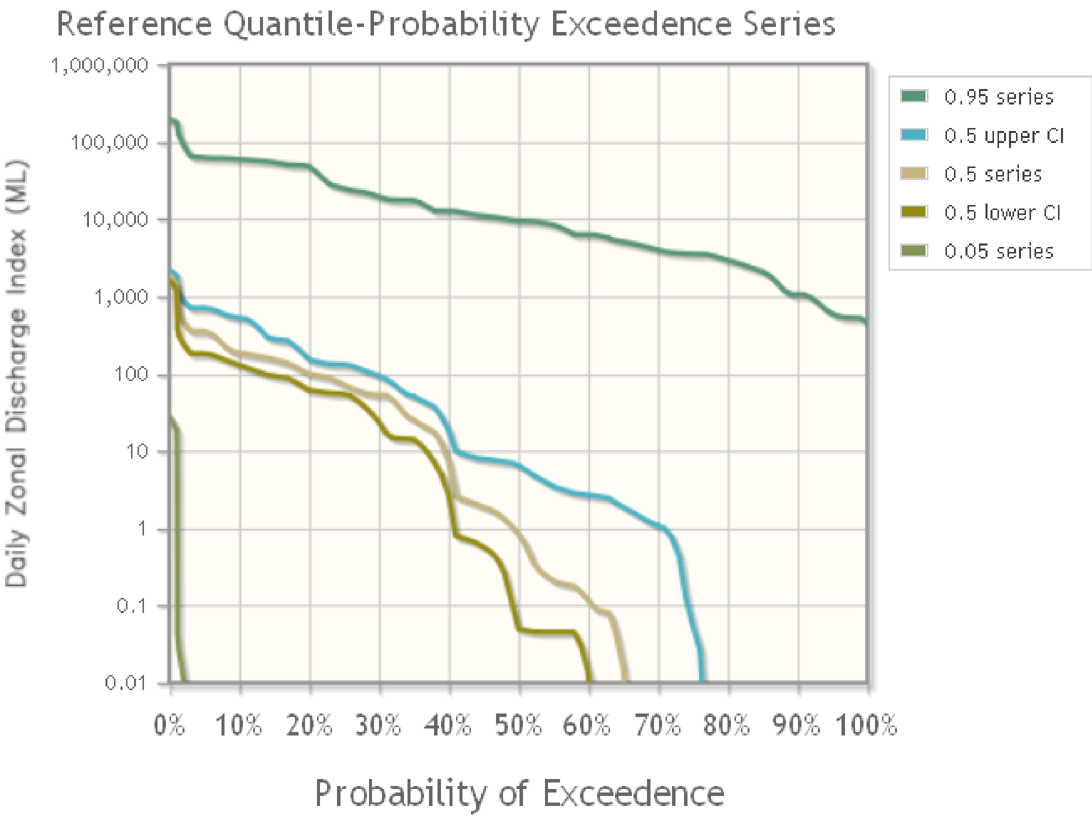


Figure 32 Reference daily probability-quantile discharge series for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion. Note the dichotomous split in the domains of probability between the wet regime (0.95) and dry regime (0.05) conditions with annual median conditions showing variable precision composed of wet and dry series characteristics.

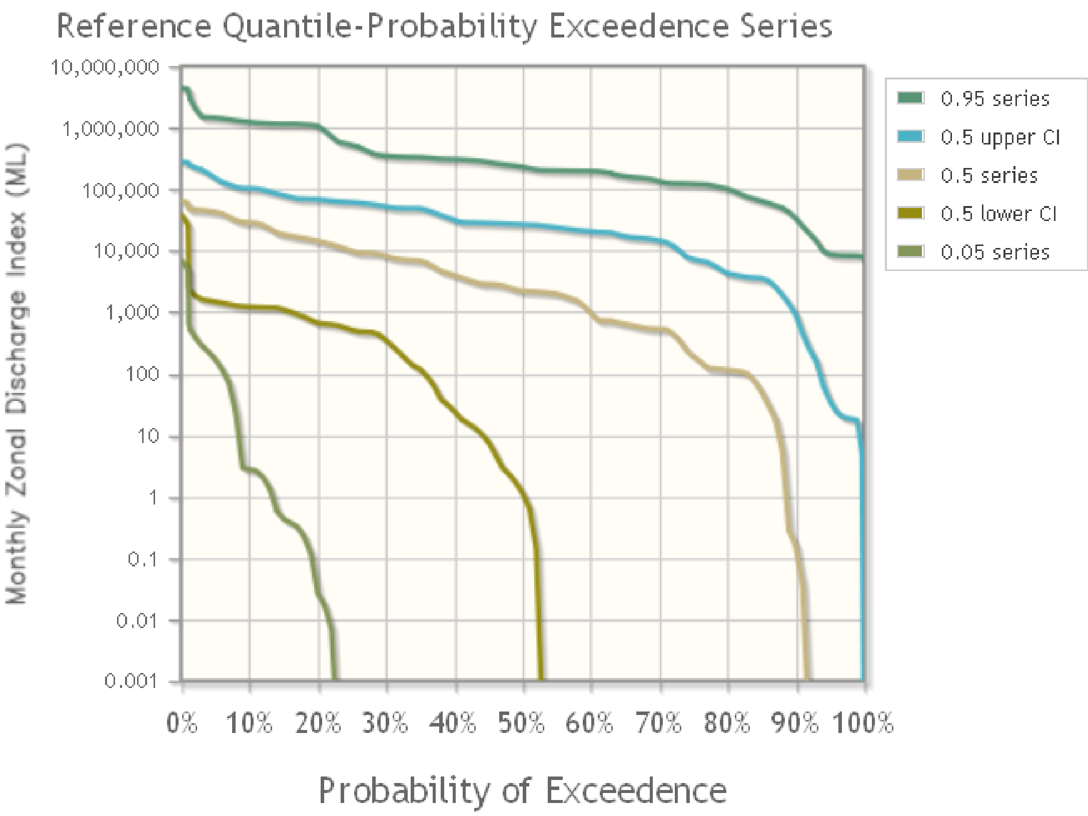


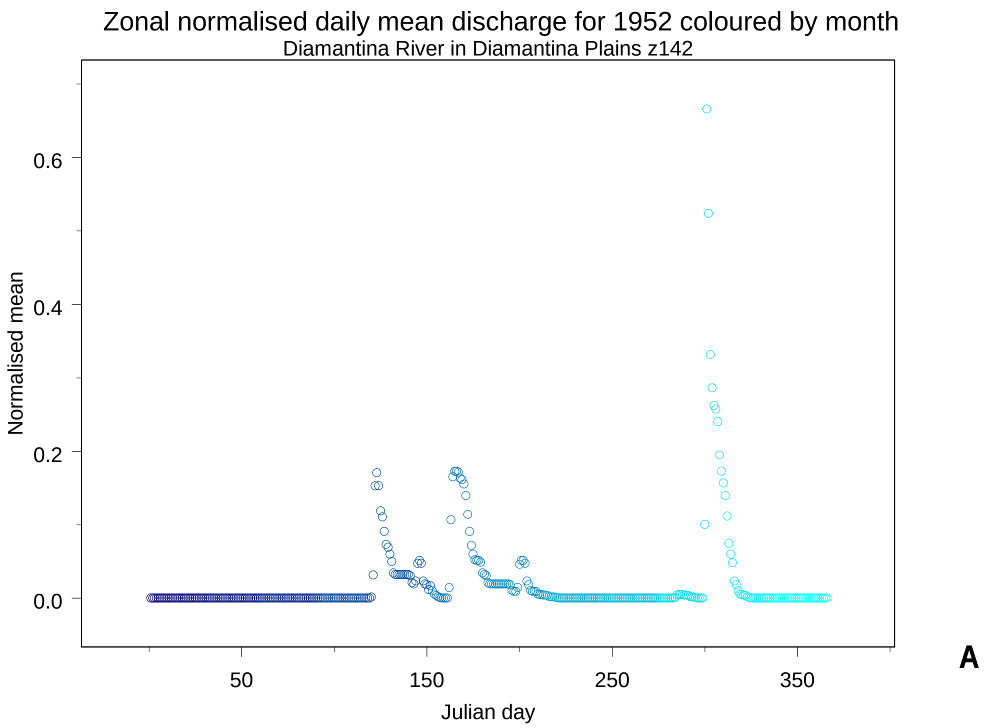
Figure 33 Reference monthly probability-quantile discharge series for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion. The domains of probability between the wet regime (0.95) and dry regime (0.05) conditions are more similar although the dry series variability may be less consistent as seen by the variance ratio test of the long term to within-year variability.

3.3.3. Time Series Analysis

The following examples illustrate hydrographs of reduced variability at daily and monthly scales (for 1952 and 1982, Figures 34 and 35), inflated variance in 1974 (Figure 36) and a ‘normal’ hydrograph in 1968 (Figure 37). The discharge index (normalised mean) is a daily zonal value centred around 1.0 across years prior to scaling up by a standardised zonal average (note that similar plot patterns would be obtained from downloaded (i.e. tool extracted and scaled up) data series). Therefore relatively low daily discharges have values less than one whilst relatively large discharges exceed one. Years with inflated variance are characterised by very influential events relative to the hydrograph for the majority of the year that skew or polarise discharge characteristics.

Different models can be fitted to time series data extracted from different time scales. The influence of time scale on three time series model fits is illustrated by Figures 38 to 40 below for daily (A series) and monthly (B series) zonal discharge statistics extracted from the period of record from 1978 to 1987. The models are Friedman Super Smoother (uses variable span cross validation with linear least squares) (Figures 38A and B), LOESS (local regression) (Figures 39A and B) and Robust Linear (least trimmed squares regression) (Figures 40A and B) (S-PLUS ® 2007), with each successive model showing less sensitivity to seasonal effects. Statistics are coloured and sized by representation with the median regime. Large cyan coloured circles represent probabilities of one while small pink circles are probabilities of zero. These models illustrate that the fitted quantities lie within the median domain, but that the daily data is more sensitive to the leverage of extreme values, and this is particularly evident in the Friedman (Figure 38A and 38B) and Robust linear models (Figure 40A and 40B) where zero-flow periods in 1983 to 1987 leverage a reduction in the rate of increase in the modelled linear trend by more than a factor of ten to the monthly data, when assessed in daily units.

Whilst this may indicate that the dichotomous regime split between wet and dry regimes shown in Figure 32 is a physical reality for regional hydrology in that area rather than heterogeneous gauge station effects, it also indicates with more certainty that daily data, even when logged, may be too variable over the period of a year to model through time series analysis at an inter-annual or full period of record scale. This is in agreement with the F-test analysis on daily and monthly data (Figures 30 and 31). Once a time scale for modelling has been selected, other types of explanatory assessments not illustrated here may be explored. These may include functions applied to component regime probabilities or to annual variance ratios to evaluate broad-scale hydro-climatic states, trends or anomalies in regimes within and between assessment zones. Users must acknowledge that outcomes from these analyses are zonal and non-deterministic in nature, requiring local calibration through measurement and mapping to become relevant at a local scale.



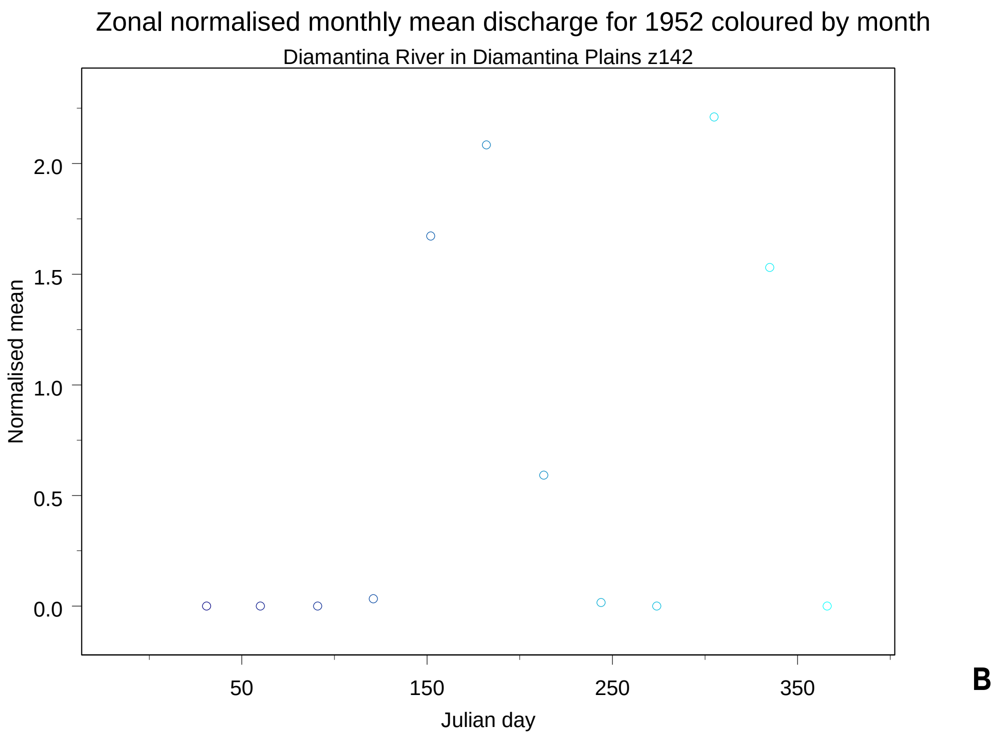
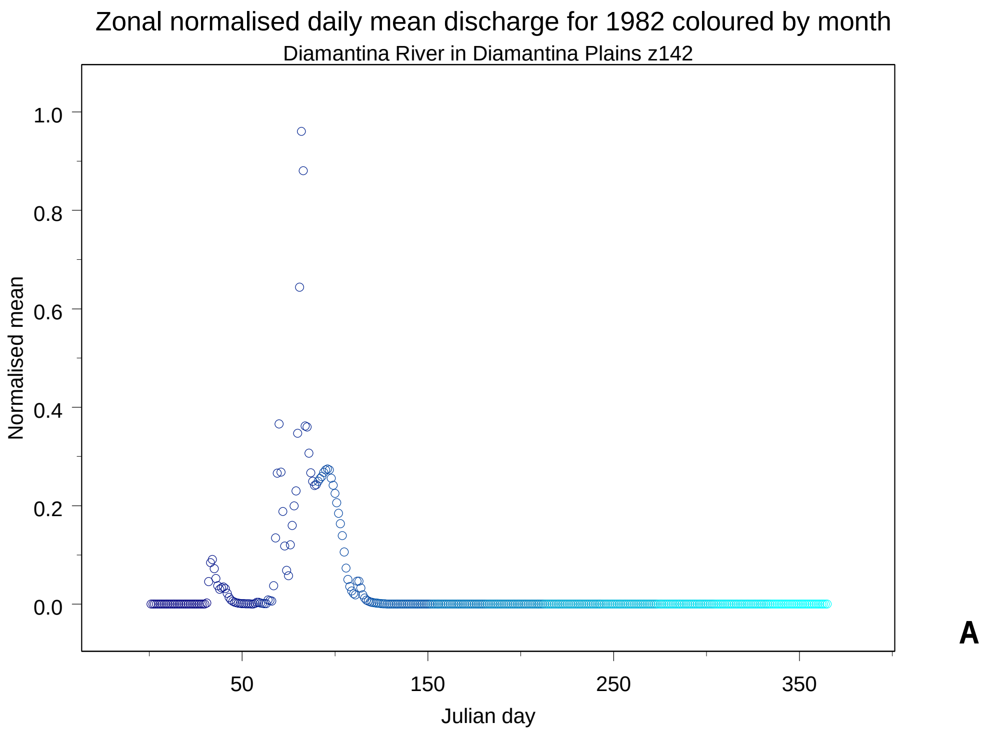


Figure 34 Discharge hydrographs at daily (A) and monthly (B) scales in 1952 have significantly reduced variability relative to the long term index (VR(lt:yr) = 114.065 and 10.969 respectively) although this is less easily detected in coefficients of variation within year (CV = 2.886 and 1.348 respectively).



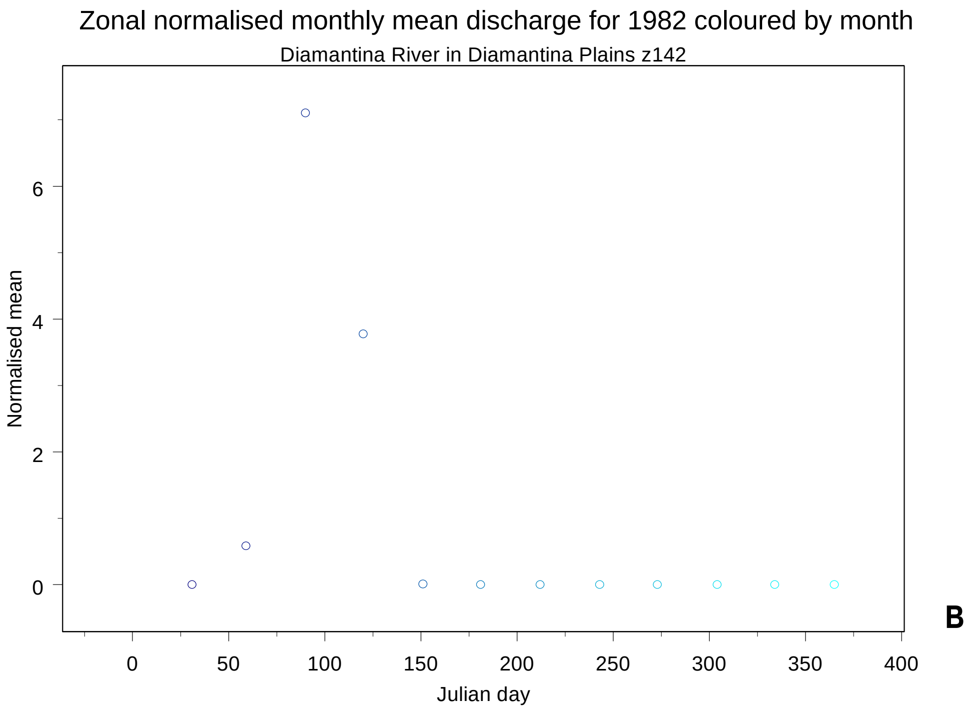
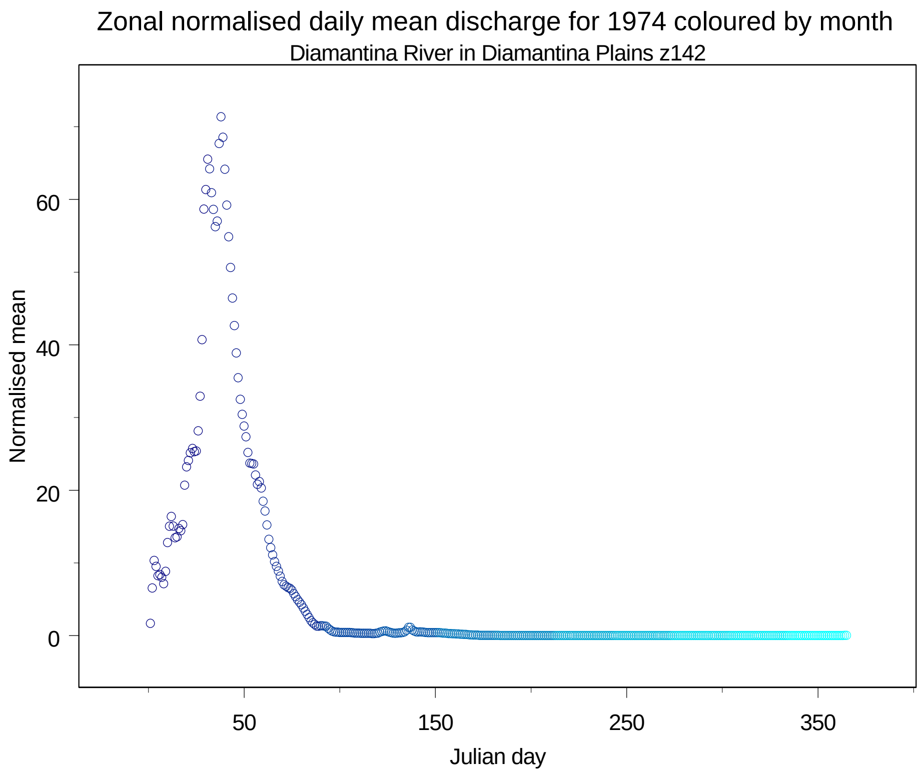
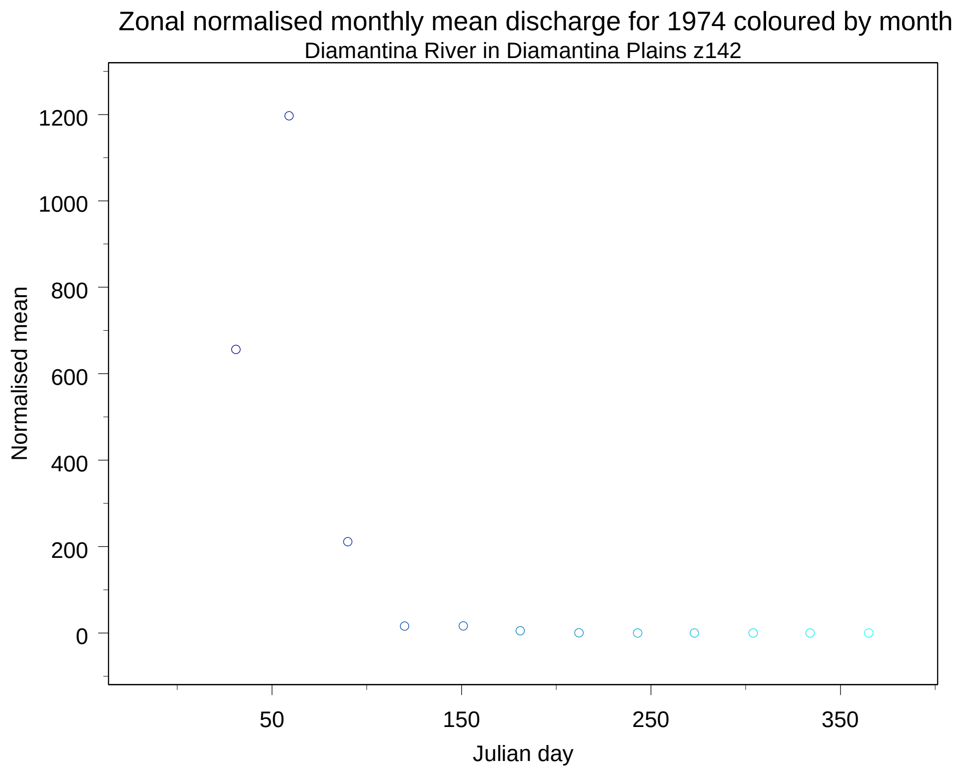


Figure 35 Discharge hydrographs at daily (A) and monthly (B) scales in 1982 have significantly reduced variability relative to the long term index (VR(lt:yr) = 50.813 and 5.508 respectively) although this is less easily detected in coefficients of variation within year (CV = 3.254 and 2.318 respectively).



A



B

Figure 36 Discharge hydrographs at daily (A) and monthly (B) scales in 1974 have significantly inflated variability relative to the long term index (VR(yr:lt) = 4.609 and 2.544 respectively) although this is less easily detected in coefficients of variation within year (CV = 2.430 and 2.135 respectively).

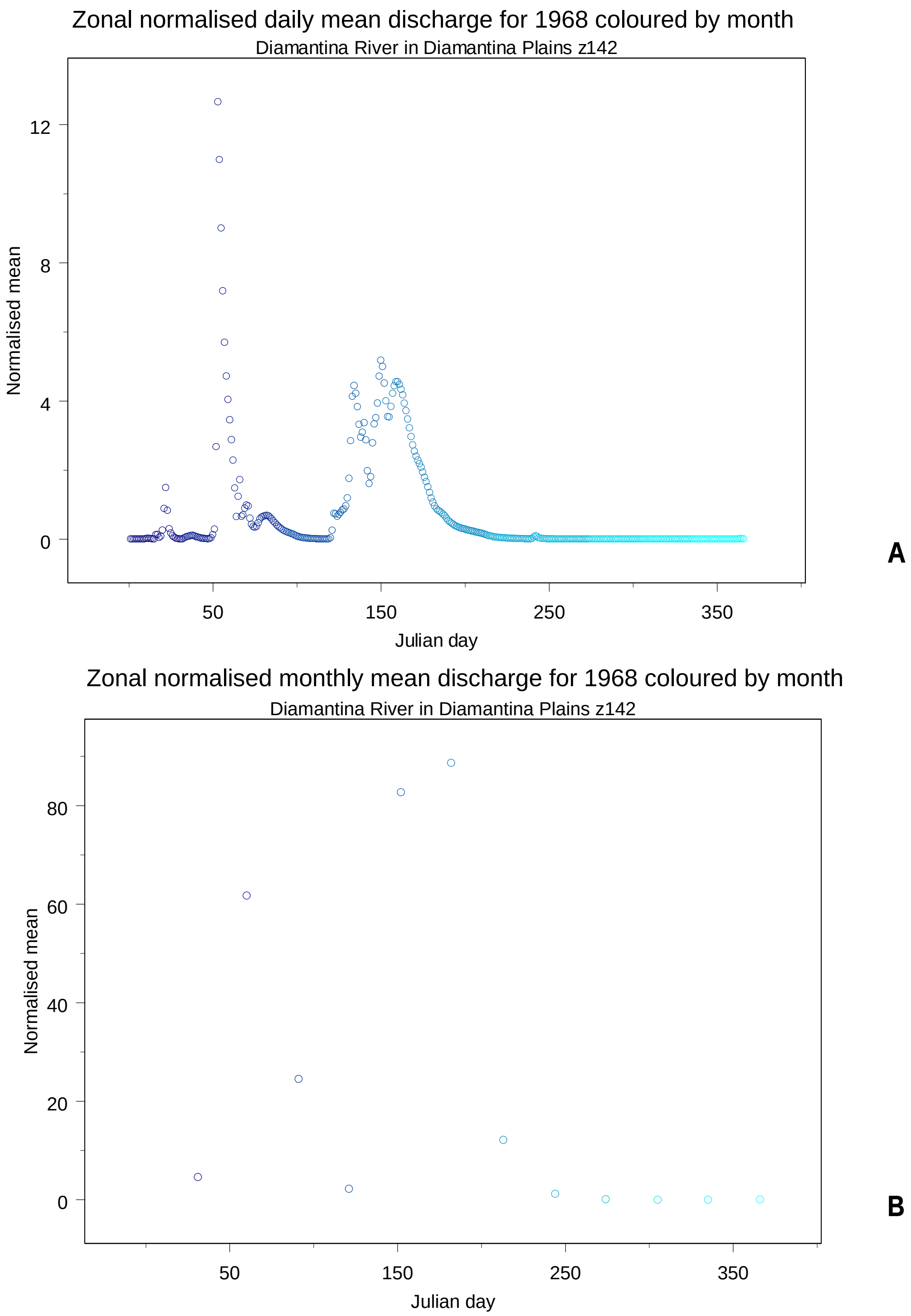


Figure 37 Discharge hydrographs at daily (A) and monthly (B) scales in 1968 provides a good example of normal ariability relative to the long term index (VR(lt:yr) = 1.089 and 0.857, VR(yr:lt) = 0.918246 and 1.166868 respectively) although this is less easily identified in coefficients of variation within year (CV = 2.093 and 1.475 respectively). Note that months 5 and 6 in the monthly data accumulate substantial discharge over a long duration flood resulting in relatively large peak monthly discharge.

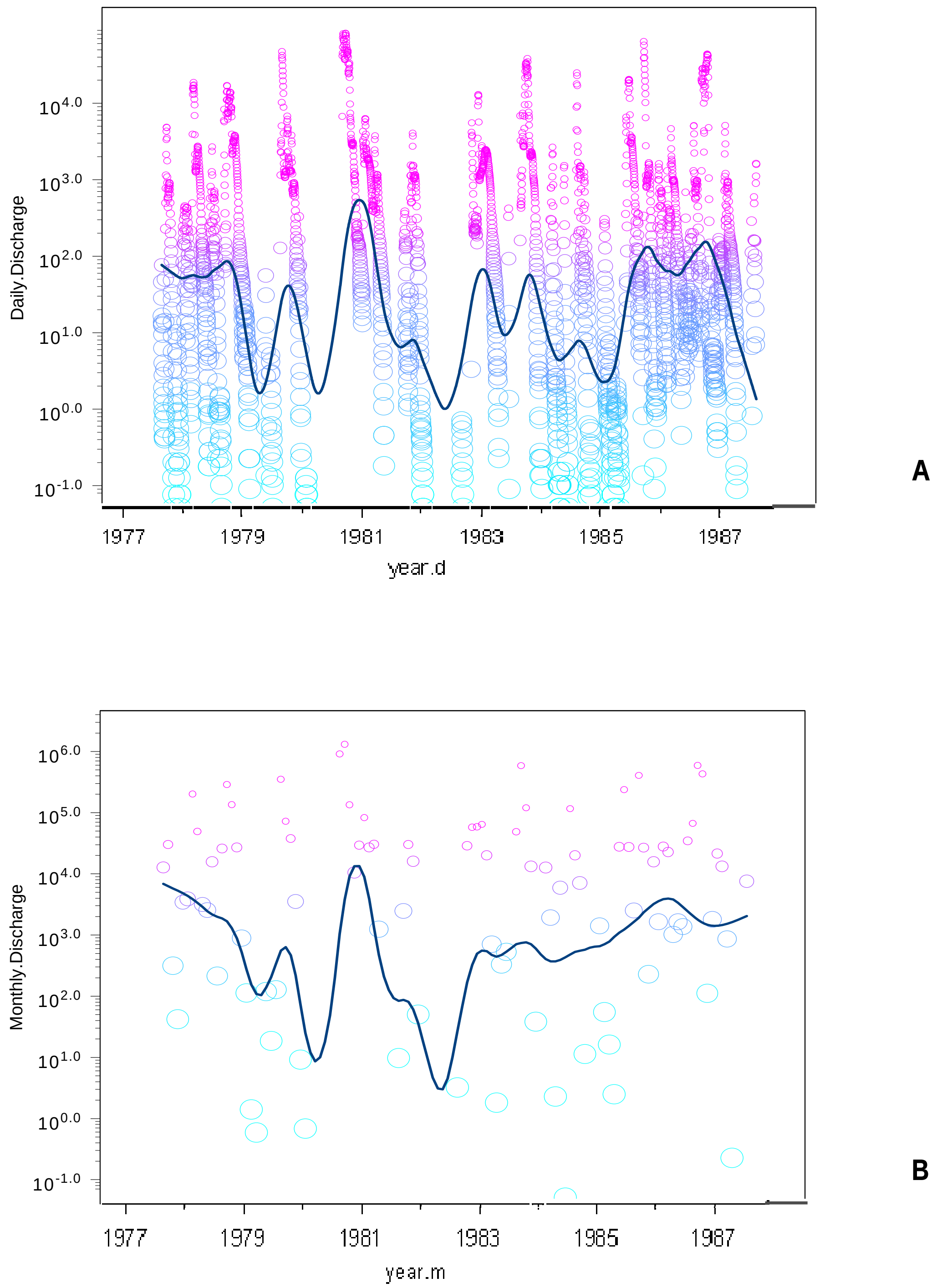
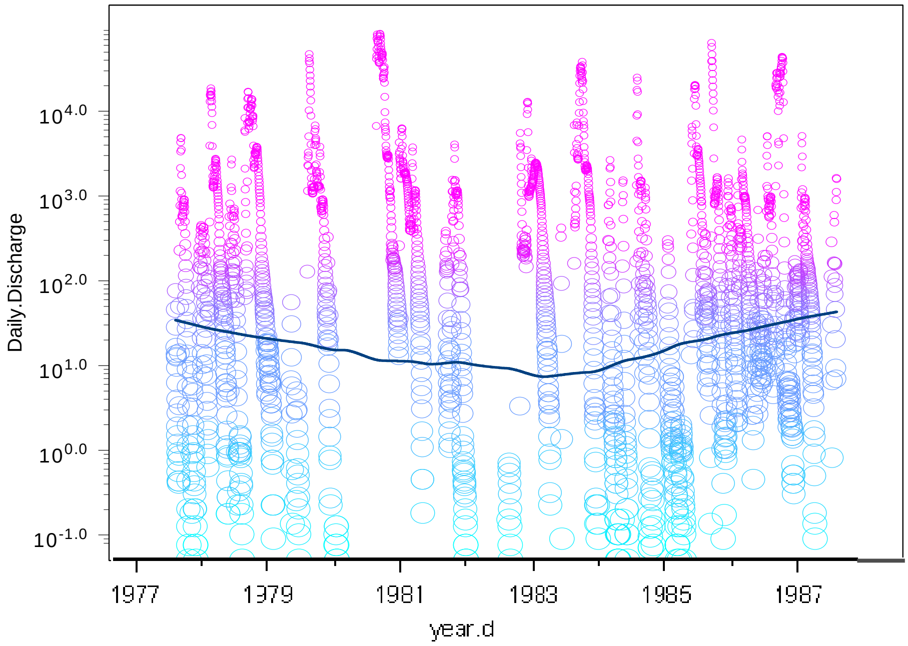
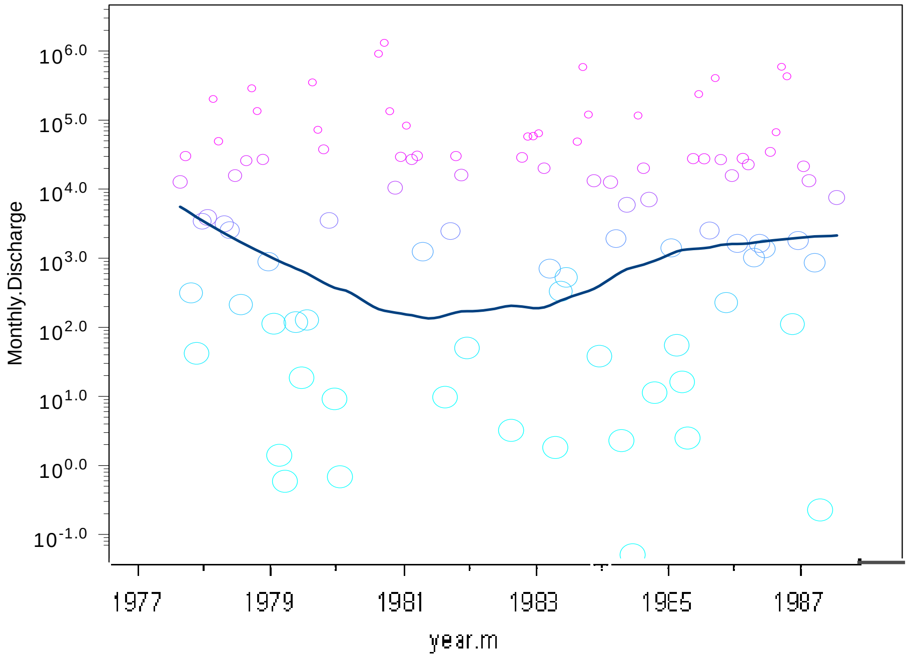


Figure 38 Friedman Super Smoother functions (uses variable span cross validation with linear least squares) for daily (A) and monthly (B) zonal discharge index for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion.

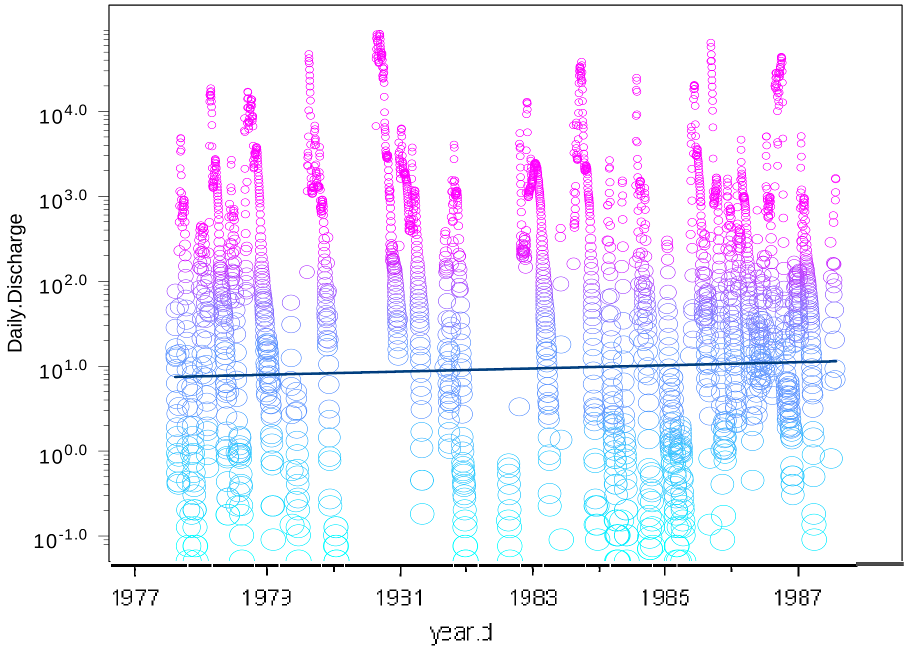


A

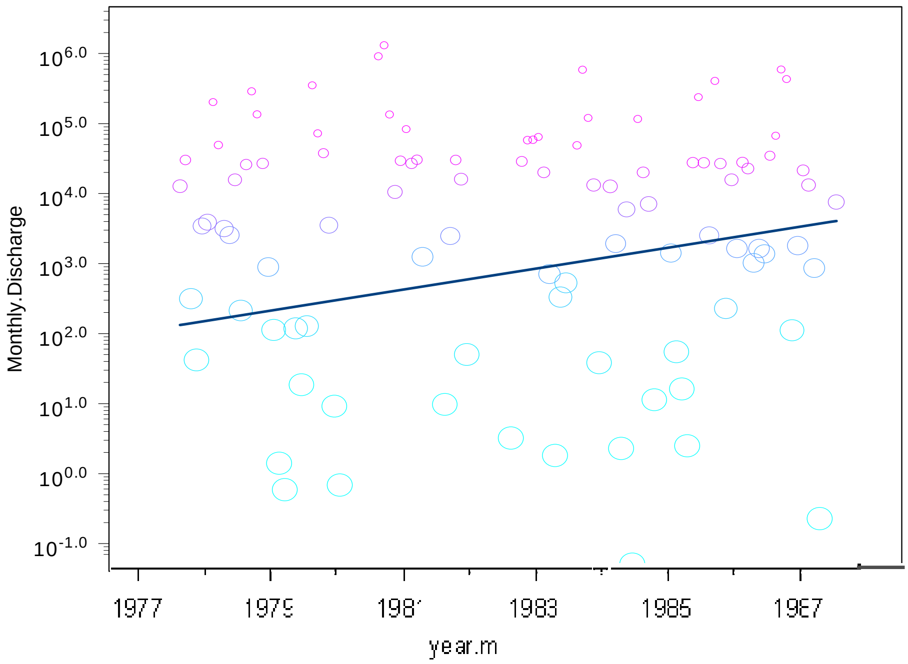


B

Figure 39 LOESS (local regression) functions for daily (A) and monthly (B) zonal discharge index for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion.



A



B

Figure 40 Robust Linear (least trimmed squares regression) functions for daily (A) and monthly (B) zonal discharge index for the Diamantina River sub-basin in the Diamantina Plains sub-bioregion.

4. Resources

This guide links to the following key resources which are provided in other documents associated with the development and use of the web tools. These are the Method and FAQ documents with links provided below.

4.1. Method

The details for the method used to create the statistics described in this document are located in the Methods document (Hydrological characterisation for wetlands and wetland imagery). A method to attribute and evaluate the hydro-climatic conditions for the Queensland wetland mapping. <http://www.epa.qld.gov.au/wetlandinfo/resources/static/pdf/hydro-climate/QWP_hydrology-methods_final.pdf>

4.2. FAQs

Frequently asked questions and the answers to these are found in the FAQ document (General FAQs for hydrological and climatological attribution <http://www.epa.qld.gov.au/wetlandinfo/site/MappingFandD/WetlandMapsAndData/hydro-climate/HydroFAQ.html>).

The FAQ document includes information about licence conditions. Users are advised to extract as much information as possible from the web interfaces before submitting a request for additional data.

4.3. Potential applications

This user guide has illustrated a number of potential applications. Please refer to the Methods and FAQs documents for additional applications and description about the limitations for applications.

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