Alluvium and EcoFutures Regional Waterway Condition Method for Central Queensland

DOCUMENT DETAILS

Method Name: Alluvium and EcoFutures Regional Waterway Condition Method for Central Queensland

Method Reference #: AfN-METHOD-W-01

Relevant Environmental Asset Class: Water

Confidence Levels: Level 1, 2, 3

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Date of Accreditation by the Standards & Accreditation Committee: 08 February 2022

Date of Approval by the Accounting for Nature Ltd Executive: 08 February 2022

Last updated: 12 September 2022

License fees associated with using this Method: Open

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Alluvium and EcoFutures

Regional Waterway Condition Method for Central Queensland

Version

Version	Date	Description	Author	Approver
1.0	03 March 2022	Submission to SAC	Paul Maxwell	Science Accreditation Committee
2.0	12 September 2022	Final Document	Paul Maxwell	Science Accreditation Committee

Acknowledgements

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1. Introduction

This method has been developed to assess the condition of waterways within freshwater and estuarine river systems at the regional scale. Specifically, it aims to assess ecological flows, riparian vegetation, and concentrations of key water quality indicators to give an understanding of waterway condition within a region. This method can also be used with AfN-METHOD-F-05 to include an indicator class for aquatic vertebrates. This method is applicable to the Central Queensland Coast and South-East Queensland catchments (Figure 1) as defined by the Queensland Water Quality Guidelines (2009).

Sediment, nutrient, and pesticide run-off are key threats to water quality resulting from anthropogenic activities, which impact upon the health of waterways and receiving coastal waters. In Queensland, regional and reef scale Water Quality Improvement Plans (WQIP) have been developed to facilitate management actions that are designed to improve water quality for the benefit of a range of critical environmental values like fauna, seagrasses, coral reefs, mangroves and saltmarshes. Sediment and nutrient run-off are recognised in the Reef 2050 Long-Term Sustainability Plan as part of the key threats to water quality resulting from anthropogenic activities, and which impact upon the health of the Great Barrier Reef (GBR) (Commonwealth of Australia, 2018). Consequently, sediments, nutrients and the physical and chemical parameters of the water column are good indicators of the condition of waterways. While these indicators have known impact on reef ecosystems, there are similar impacts on receiving environments more broadly and the iconic aquatic organisms that reside within these environments and therefore are a useful minimum dataset for water quality targets.

Riparian vegetation is a critical component of a waterway and important to monitor when assessing waterway condition. Vegetation provides habitat for a wide variety of organisms, reduces streambank erosion of riverbanks and acts as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increased input of sediments and nutrients.

Ecological flow is another critical indicator of waterway condition. The timing and magnitude of water flows through the rivers in the region is a critical determinant of the breeding and migratory success of the region's iconic species. Water impoundments like dams and weirs alter the hydrology of rivers which impacts on those species. However, these structures do come with positive attributes such as preventing trout migrating upstream, thereby increasing the survivability of *Galaxias sp*. Environmental flow strategies in modified rivers that minimise changes to natural flow regimes provide suitable conditions not only for these iconic species but for the broader aquatic ecosystem. The Queensland Department of Regional Development, Mines and Water (DRDMW) manages the flow regime in the region's rivers with ecohydrological rules outlined in the *Water Plan*, specific for each catchment.

This Method therefore incorporates the above three indicator themes (water quality, ecological flow, and riparian extent), and builds off the existing monitoring guidelines and programs (such as the Queensland Government's Water Monitoring and Sampling Manual (2019), the Central Queensland Estuarine Monitoring program, (Report on Condition and trends in Water Quality in Central Queensland Estuaries 1993 to 2015) and the Gladstone Healthy waterways Estuary monitoring Program) to assess the waterway condition of estuarine and freshwater systems along Queensland in accordance with the Accounting for Nature Framework. Water Quality is assessed in ambient condition, which describes the conditions when flow is NOT derived from rainfall runoff (e.g. an 'event' such as a period of high rainfall and/or flooding), that is – the base flow. It is acknowledged that extreme events take the system temporarily outside the bounds of what the method is set up to monitor, however, the annual

monitoring will pick up the generalised change in condition. The intention of the method is to include an assessment of event generated pollutant loads to align the method with the targets set out for the Burnett Mary Catchments in the Reef 2050 Plan.

This Method includes instructions on how to measure several key waterway condition indicators. Using the Queensland Water Quality Guidelines and relevant Water Plans to inform Reference Condition Benchmarks, the indicator values are then converted into Indicator Condition Scores (a measure between 0 and 100) which are then further aggregated into an Econd® which is an estimate of Environmental Condition for the environmental asset, in this case the waterways in Central and South East Queensland. The Econd® is an index between 0 and 100, where 100 describes the 'best-on-offer' or 'pre-development' Reference Condition of the environmental asset, and 0 indicates the asset is completely degraded. The Econd® is calculated by comparing the current condition of the waterways within the region, to the expected undegraded Reference Condition of the waterway. Accounts developed with this method will produce credible and verifiable metrics that can support public claims about change in waterway condition.

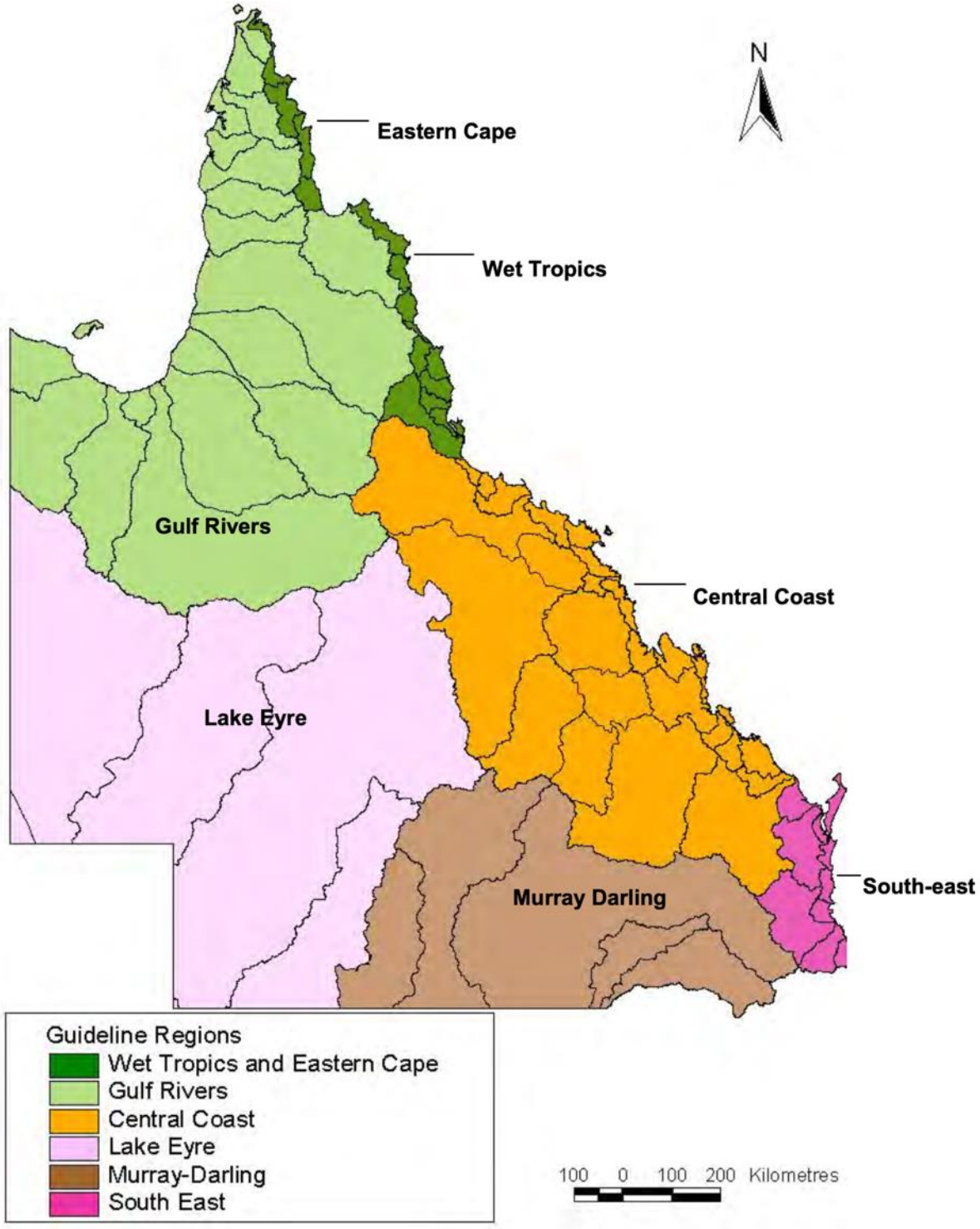

Figure 1. Overview of Regions adopted for the Queensland Water Quality Guidelines (Source: Figure 2.3.1 Queensland Water Quality Guidelines 2009)

1.1. Aim and scope of this Method

Purpose	The purpose of this Method is for Regional Land Managers (such as Natural Resource Management Groups or Local Governments) to assess the condition of and monitor the change of waterway condition within freshwater, and estuarine waterways in Central and South-East Queensland.
Application	Central Queensland and South-East Queensland
Scale	Regional
Target Audience	NRM organisations, landholders, public
Decisions to inform	1. To inform better land management 2. To communicate to stakeholders and the wider community the state of waterways within the region 3. To showcase the region's values
Confidence Level/s	Level 2 (or Level 1, 2, or 3, if supported by a power analysis)

1.2. Justification of Confidence Level

This Method has been written in accordance with several published (and peer reviewed) monitoring manuals, in particular:

- Report on Condition and trends in Water Quality in Central Queensland Estuaries 1993 to 2015
- Gladstone Healthy waterways Estuary monitoring Program
- Queensland Monitoring and Sampling Manual *Environmental Protection (Water) Policy 2009*
- Mary River Catchment Waterwatch Results 2021

The Reference Benchmarks are derived from published Water Quality Guidelines and relevant Water Plans.

In addition, the 90th percentile (90%ile) and/or 10th percentile (10%ile) and/or worst-case scenario (WCS) values are recommended to be derived from data collected from the Queensland Department of Environment and Science Water Monitoring programs.

Therefore, as this Method is based off existing established monitoring programs and guidelines developed and implemented by the Queensland State Government, then it is expected to be able to achieve Level 1 (95% accurate), Level 2 (90% accurate) and Level 3 (80% accurate) Confidence Level, depending on the sampling intensity. This is further supported by the frequency of sampling, (monthly during baseflow conditions) which is required to account for natural variability in the indicator values.

1.3. What an Environmental account looks like

The *Accounting for Nature®* Framework requires accounts to be comprised of three key components for them to be certified:

1. An **Environmental Account Summary** – a public document that summarises the results of the environmental account in a form that is readily communicated to the public.
2. An **Information Statement** – describes in detail the method used and the actions taken to address each of the eight steps under the framework including rationale behind asset selection, choice of indicators, Method used, analysis and management of data and calculation of the Econd®.
3. The **Environmental Account** – a database (such as an excel file) that contains all the data described in Asset Tables, Data Tables, and Balance Sheets.
4. An **Audit Report** (for 'certified' Accounts) or **AfN Technical Assessment** (for 'self-verified' Accounts)– an independent report that is completed by an AfN Accredited Auditor or AfN, that verifies the Account was prepared in accordance with the approved Methods, the *AfN Certification Standard* and AfN Audit rules.

Upon certification of the account, the Environmental Account Summary and Information Statement will be published on the AfN Environmental Account Registry.

1.4. Overview of Process

This method includes the following steps:

Preliminary Work

- Step 1. Define purpose, scope and accounting area
- Step 2. Compile existing data
- Step 3. Stratify accounting area
- Step 4. Implement Indicator-class specific approaches and calculate ICS

Ambient Water Quality	Ecological Flow	Riparian Extent
Step 4.1.a. Describe Indicators	Step 4.2.a. Describe Indicators	Step 4.3.a. Describe Indicators
Step 4.1.b. Identify Sample Sites	Step 4.2.b. Collate data	Step 4.3.b. Define Reference Benchmarks
Step 4.1.c. Define Reference Benchmarks	Step 4.2.c. Define Reference Benchmarks	Step 4.3.c. Collect and analyse data
Step 4.1.d. Collect and process samples	Step 4.2.d. Calculate Indicator Condition Scores	Step 4.3.d. Calculate Indicator Condition Scores
Step 4.1.e. Calculate Indicator Condition Scores		

- Step 5. Calculate Econd®

2. Creating the Environmental Account – Preliminary Work

Step 1. Define purpose, scope, and accounting area

The preliminary step to developing an Environmental Account is to **describe** the Environmental Account through defining its intended **purpose**, **scope** and **accounting area.**

Purpose:	Describe the specific purpose of the account.
Scope:	Describe the scope of the account. - *Snapshot* – a single assessment of environmental condition - *Change over time* – an ongoing assessment of the change of environmental condition through time
Accounting Area:	Describe the accounting area (include location and size details). Provide a map of the accounting area that shows location and size information and identify the freshwater waterways of interest. NB. The accounting area must stay the same for the lifespan of the account. If the accounting area changes (such as a new area to be added, or an area to be removed), then a new account must be developed, or the account, 're-set' and started again with the new accounting area.

Output of Step 1

- A description of the accounting area including **location** and **size**
- A table describing the **purpose** and **scope** of the account
- A **map** showing the accounting area

Step 2. Compile existing data

Data collection

Before starting to build your account, the following preliminary data must be collated and prepared.

Data Collation

- Aerial imagery
- Tide data
- River mapping or existing estuary shapefile (such as '*Amendment Policy (No.1) 2020 - Water Types – Queensland*' which can be downloaded from QSpatial)
- Location of water storages
- Understand the variability of the water bodies being assessed
- Existing or past site locations
- Queensland Department of Environment and Science historic estuary water quality data for each water type for each region
- Riparian vegetation extent mapping

Things you will need

- Permits and approvals
- Organise a laboratory for water samples.
- Collect sample bottles from laboratory
- Sampling apparatus

Output of Step 2

- A map, table and description of the account area including waterways
- Sampling apparatus

Step 3. Stratify the accounting area

Identify sub-assets

Sub-assets in this Method are defined as the individual river catchments included in the Account. The catchments (identified by their major River name) to be included in the Account are to be shown on a map in a commonly applied datum. For example, Figure 2 shows an example of stratification into sub-assets based on the major waterways within the Burnett-Mary Region.

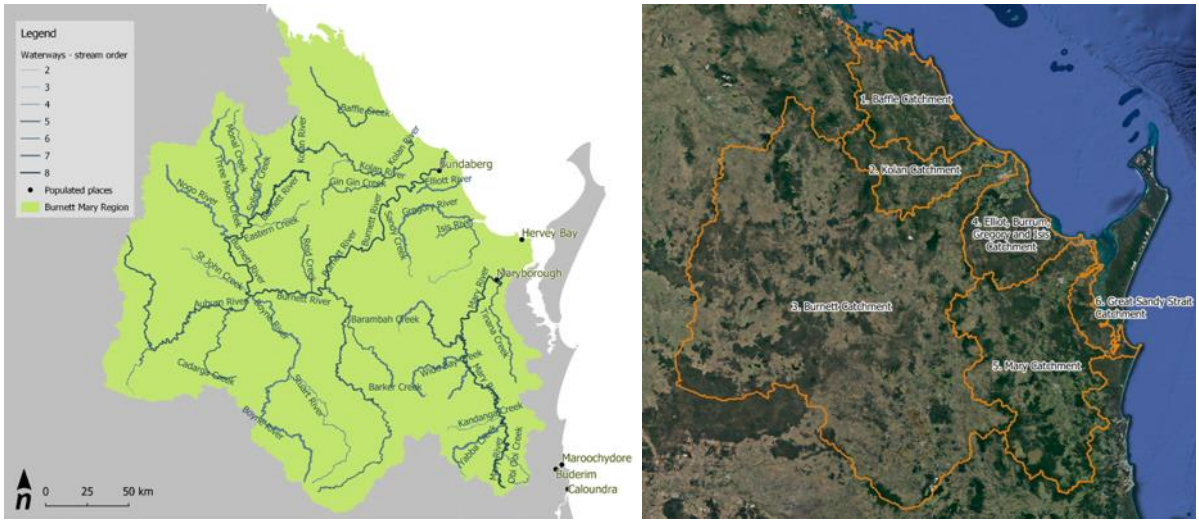

Figure 2. Waterways and catchments within the Burnett-Mary Region

Output of Step 3

- A map and table showing the **stratification** of the accounting area

3. Creating the Environmental Account – Indicator-class Specific Approaches

The waterway condition method employs a diverse toolkit of environmental indicators to provide complementary perspectives on the condition of a waterway. It is our intention to add additional indicator classes to this toolkit over time, as outlined in the preface to this method. While the current set of indicators allow a valuable minimum assessment of environmental change, they are not complete and where new technologies and data sources allow it, the intention is to broaden the assessment to more completely cover the drivers of environmental condition. The following section defines those indicator classes, the indicators they include, and the reference benchmarks, then outlines the steps for producing an account, including sampling approach, data collection procedure and data analysis. It is acknowledged that the indictor classes are sourced from a third party, which may have a level of uncertainty associated with the data and models. However, it should be noted the third party is the State Government (eg. DES), which follow a rigorous sampling methodology that has been peer-reviewed by scientist within the field. The ongoing quality assurance associated with these sampling regimes are published making it possible monitor the level of error. As such, the assurance processes will continue to be monitored to ensure the quality of this account

Indicator classes

This method includes three indicator-classes, Water Quality, Ecological Flows, and Riparian Extent (Table 1). The waterway indicator classes (and their indicators) described below have been selected as they have been identified in the Reef 2050 WQIP as important indicators contributing to the pressures on critical environmental, social and economic values of the region. Ecological flows and riparian vegetation are also included as they are needed to assess waterway condition in its entirety. *Table 2* outlines the recommended riparian buffer widths according to the stream order which takes into account cane-growing areas. The riparian buffers are based on evidence from scientific literature, with a detailed explanation of each source within Appendix B.

Table 1. Summary of Indicators used in the method.

Indicator Classes	Indicator		Units	Measure
Water Quality	Nutrients	Total Nitrogen	µg/L	Lab
		Dissolved Inorganic Nitrogen	µg/L	Lab
		Total Phosphorus	µg/L	Lab
		Filterable Reactive Phosphorus	µg/L	Lab
	Sediments	Turbidity	NTU	Field
		Total Suspended Sediments	mg/L	Lab
	Phytoplankton	Chlorophyll-a	µg/L	Lab
	Physiochemical	Dissolved Oxygen	% Saturation	Field
		Conductivity	µS/cm	Field
		pH	-	Field
Ecological Flows	River flow	Volumetric Flowrate	ML/d	Online
		Mean	ML/d	RAP*
		Median	ML/d	RAP*
		10%ile	ML/d	RAP*
		90%ile	ML/d	RAP*
		10cm daily flow (annual)	ML/d	RAP*
		30 cm daily flow (annual)	ML/d	RAP*
Riparian Vegetation	Riparian Veg Extent	% Coverage	%	Desktop

* RAP is defined as the River Analysis Package, which is used to calculate the various ecological flow indicators

Table 2. Recommended riparian buffer widths according to various sources.*

Stream order	Riparian buffer width (m)
Streams in sugar growing areas	25
Rivers in sugar growing areas	50
1-2	50
3-4	75
5-6	100
7-8	125

* Lovett and Price (2001), Department of Primary Industries [NSW GOV] (2012) & Hansen et al. (2010).

3.1 Ambient Water Quality

Sediment, nutrient, and pesticide run-off are key threats to water quality resulting from anthropogenic activities, and which impact upon the health of waterways and receiving coastal waters. Consequently, sediments and nutrients within the broader receiving environments form a useful minimum dataset for water quality targets throughout the region. They also impact on the health of estuary environments and wetlands in the Burnett Mary region. Alongside sediments and nutrients, physical and chemical parameters of the water column are good indicators of the condition of rivers and estuaries.

A benefit of water quality sampling using this method, is that it does not require a highly specialised skill-set and existing programs are run by NRM organisations, Landcare and other community groups. The suite of water quality indicators measured are based on the Queensland Water Quality Guidelines (2009) but are broadly applicable in other waterways around Australia. However, the benchmarks presented in this section are limited to coastal catchments of Central and Southeast Queensland. Following the Burnett-Mary pilot of this method, we intend to adapt these methods to make them more broadly applicable to other regions.

Step 4.1.a. Describe environmental indicators

Nutrients

Nitrogen and phosphorus are nutrients essential to biota in waterways. Both nutrients are present in waters in both dissolved and particulate forms. Particulate forms include those bound up in living organisms, organic compounds like proteins, and those bound to suspended particulate matter like clay, detritus and other sediments. Dissolved nitrogen may either be inorganic nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+) or organic (e.g. urea; dissolved proteins).

Nitrogen and phosphorus are derived from natural ecological events such as oceanic upwelling, litter fall, weathering, and from human sources (e.g. sewage outfalls, leaching from cleared land, fertiliser runoff, and industrial and agricultural effluents). In more highly populated areas, nutrients can result from wastewater discharges, sediments, and diffuse urban runoff.

Excess nutrients in waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species (e.g. seagrass and coral communities), and cause excessive fluctuations in pH and dissolved oxygen which can stress and eliminate sensitive species.

Sediments

There are two parameters that indicate the concentration and load of sediments in fresh and estuarine waters: turbidity and total suspended sediments (TSS). Turbidity is the measure of the amount of light scattered by suspended particles in the water column, providing an indirect indication of light penetration. It is a concentration-based measure and not always a good indication of sediment load through a system. TSS is typically measured as the amount of sediment in a known volume of water so is a precursor to understanding the sediment load that leaves a system.

Excess amounts of suspended particles can contribute to environmental damage including, reduced light penetration through the water column, smothering of benthic organisms like corals and seagrass, irritation of fish gills and transportation of contaminants. Changes to the availability of light within the water column influence the ability of aquatic plants to photosynthesise and fix energy. Sediment enters waterways through erosion and runoff accelerated by catchment alterations and can also bring excess nutrients with it. Once in inshore coastal waterways, fine sediments are readily resuspended by wave and tidal energy.

Phytoplankton

Phytoplankton biomass is largely influenced by the availability of nutrients, light, and optimal water temperature. Measuring phytoplankton biomass provides an indication of the nutrient and light conditions present at the time of sampling and their resulting biological effect. Under certain environmental conditions, in particular elevated light and high nutrients, phytoplankton blooms can result. When phytoplankton blooms decay, the resulting bacterial activity can reduce dissolved oxygen concentrations in the water column, possibly leading to fish kills.

Phytoplankton response is measured by the concentration of chlorophyll-a in the water column. Chlorophyll-a (chl-a) is a pigment found in photosynthetic organisms. It is an essential molecule for the process of photosynthesis (the conversion of light energy to chemical energy resulting in the consumption of carbon dioxide and the production of oxygen). In surface waters, chl-a is present in phytoplankton such as cyanobacteria, diatoms, and dinoflagellates and the volume of chl-a will be measured though lab analysis.

Physicochemical parameters

These parameters are indicators of the physical and chemical properties of a water body. These parameters are typically measured together with a single water quality instrument. As values are recorded in situ at the time of sampling, these parameters can be measured nearly continuously at a very high frequency with some systems outfitted with the capability to provide data in real time to online data platforms.

Dissolved oxygen

Dissolved oxygen (DO) concentration is a measure of the oxygen in a water body. Many freshwater, estuarine and marine processes are dependent on the concentration of DO in the water. DO concentration in a water body is affected primarily by the rate of transfer from the atmosphere but also by oxygen-consuming (e.g. respiration) and oxygen-releasing (e.g. photosynthesis) processes. Organic matter, such as sewage effluent or dead plant material that is readily available to microorganisms has the greatest impact on DO concentrations. Microorganisms use water column DO during decomposition of the organic matter. DO concentration in the water column is highly dependent on temperature, salinity and biological activity. Consequently, DO concentrations under natural conditions may change substantially over a 24-hour period. Variations in DO concentrations may affect many organisms such as fish, invertebrates and microorganisms, which depend upon oxygen for surviving. The oxygen requirements of aquatic organisms vary widely depending on which species, their life stage and different metabolic requirements. Dissolved Oxygen is most commonly measured with a water quality meter. Under the Queensland Water Quality Guideline (2009) Dissolved Oxygen levels should be between 85 – 110 %sat (refer to *Figure 3*).

Conductivity

Conductivity is a measure of the salinity or total concentration of mineral salts in the water column. Clean oceanic water has a conductivity of between 50,000 to 53,000 uS/cm with freshwater approaching 0. Conductivity affects the types of organisms that can live in a water body. Changes in conductivity in a freshwater stream or river can come from exposure and the subsequent erosion of saline soil types, via groundwater influences into a waterbody or through tidal inundation from surrounding estuaries.

pH

pH is a measure of the acidity or alkalinity of a waterbody. The pH scale ranges from 0 (highly acidic) to 7 (neutral) through to 14 (highly alkaline). Changes to the pH of marine waters can affect the types of vegetation, fish and invertebrates that can live in Queensland's freshwaters. Changes in pH can also change the toxic effects of pollutants present in a waterbody, changing how they are metabolised in aquatic organisms. Excess catchment runoff from various agricultural and urban landuses can cause changes to pH of surface waters.

Output of Step 4a

- A table describing the **environmental indicators** to be measured in the account

Step 4.1.b. Identify sample sites

The sampling requirements for this method are outlined in Table 3 below. For Water Quality Sampling within each catchment, each waterway within the catchment should be stratified into 'sampling units' based on the following five water types:

- enclosed coastal/lower estuary (ECLE) – reaches near the mouth of the estuary and adjacent nearshore coastal waters
- mid-estuary (ME) – the main body of the estuary
- upper estuary (UE) – the poorly flushed most upstream reaches of estuaries.
- lowland freshwater (LF)
- upland freshwater (UF)

The sampling units determine where sites are to be located. The five water-types can be determined using the Queensland Water Types shapefile or the Water Types shown in the Queensland Water Quality Guidelines (2009) and are important in determining water quality reference values. A map in a commonly applied datum should be produced showing the extent of the water quality sampling units.

Table 3. Overview of how to select and establish sampling sites within each water quality sampling unit

Sample	Implementation
Number of sites per sampling unit	It is likely that variation within each sampling unit varies, and therefore, it is recommended that prior to sampling, and if feasible (considering data availability and budget constraints), an initial account-specific power analysis be conducted to establish the required number of samples per sampling unit for the target confidence level (i.e. level 1 – 95 % accurate, Level 2 – 90% accurate, and Level 3 – 80% accurate). The methodology for power analysis can be found here: https://www.waterquality.gov.au/anz-guidelines/monitoring/study-design/preparation and https://www.epa.gov/sites/default/files/2015-10/documents/tech_memo_3_oct15.pdf If a power analysis cannot be undertaken, then a general rule of thumb to achieve confidence level 2 is a total of 5-7 spatial sample sites per sampling unit (i.e. 5 – 7 sample sites per water type within each catchment). This was chosen to get a statistically robust median value for calculation of the indicator condition score. It is recommended that the water quality sampling is completed seasonally at each site. Event monitoring is also recommended in order to incorporate high-flow events.
Site selection	For water quality, sample sites are to be selected as representative sites within each sampling unit, but must consider tributary location, spatial variation, such as depth and distance from the bank (based on the advice given in the Qld Water Quality Sampling Manual). Sites should be selected where historical pollutant load data is available, or pollutant concentration coupled with daily flow volume data. If wanting to identify the impacts of tributaries, point sources and land-use changes, sites should be placed downstream. In estuaries, samples should be taken on the outgoing tide (2 hours after the high-tide).
Site establishment	GPS Coordinates are to be recorded at each sample site. Subsequent samples to be taken from the same location.
Frequency and timing	Water Quality samples are to be taken once a month for estuarine samples and once per quarter for freshwater samples, which is an appropriate frequency for base-flow samples. To reduce the effect of tidal variation in the estuarine samples, sampling should be taken as close to 2 hours after high tide as possible. Efforts should be made to take freshwater samples at base-flow conditions (based on government flood gauges upstream, where available). The calculations for base-flow can be found here: A_standard_approach_to_baseflow_separati20160520-30084-19rh1pj-with-cover-page-v2.pdf (d1wqtxts1xzle7.cloudfront.net)

Output of Step 4b.

- A **map, GIS layer and/or table** providing details of the monitoring sites, grouped by sub-assets.
- A **map** that delineates between key estuary and freshwater systems. This map will provide detail on the start and end point of these systems.

Step 4.1.c.Determine reference benchmarks

All water quality samples should be assessed against the Queensland Ambient Water Quality Guidelines (QWQG) under the Central Coast Queensland and Southeast Queensland regional guidelines (**Error! Reference source not found.**, and **Error! Reference source not found.**). The QWQG were established in 2009 and are currently being updated by the Department of Environment and Science. Until gazetted, the current QWQG should be used to provide a Reference Benchmark value for all the water quality indicators. This Method will be updated with new values when they are available, and any Accounts using the old values should be re-calculated with the revised Reference Benchmark values.

Each water-type has separate Reference Benchmark values. The Reference Benchmark values, in **Error! Reference source not found.**, are derived from the Annual Median values of the Queensland Ambient Water Quality Guidelines. The guidelines were determined as the 80th percentile of all data taken from best on offer reference sites. The 80th percentile was used as this is the scientifically established value that supports full ecological function (QWQG, 2009). If there are sub-regional guidelines for a particular area, then these should be used instead of the regional guidelines. There are no published reference benchmark values for DIN, so a proxy reference benchmark is calculated as the sum of ammonia and Nitrogen oxide benchmarks.

It should be noted that Moss (2018) highlights that turbidity in long estuaries (>40 km) is naturally high due to sediment trapping and continual resuspension by tidal currents (Uncles, Stephen & Smith 2002). There are no suitable QWQG turbidity guidelines for naturally turbid estuaries, however it is still recommended that turbidity be measured to assess how it changes over time.

The median value of water quality at test sites is to be compared and assessed against the values presented in Error! Reference source not found. **and**

Table 5. Table 4 presents the reference benchmarks for all waterways located in Central Queensland. For values collected in the Mary catchment, use the benchmarks in Table 5 which have been calculated specifically for the water types in the Mary Catchment using Mary River Catchment Coordinating Committee data. An example for dissolved oxygen upper and lower limits is presented in *Figure 3*. For more information on how the reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).

*Table 4. Summary of the Reference Benchmarks for the **Central Queensland** taken from QWQG 2009. Apply to non-Mary River sub-catchments. For more information on how these guidelines and reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).*

Central Coast Queensland							
Indicator		Measure	Enclosed coastal/lower estuary (ECLE)	Mid estuary (ME)	Upper estuary (UE)	Lowland freshwater (LF) **	Upland freshwater (UF) **
Nutrients	Total Nitrogen (µg/L)	Lab	200 µg/L	300 µg/L	450 µg/L	500 µg/L	250 µg/L
	Dissolved Inorganic Nitrogen (µg/L)	Lab	11 µg/L	20 µg/L	45 µg/L	80 µg/L	25 µg/L
	Total Phosphorus (µg/L)	Lab	0.02 mg/L	0.025 mg/L	0.04 mg/L	50 µg/L	30 µg/L
	Filterable Reactive Phosphorus (µg/L)	Lab	6 µg/L	8 µg/L	10 µg/L	20 µg/L	15 µg/L
Sediments	Turbidity (NTU)	Field	6 NTU	8 NTU*	25 NTU*	50	25
	Total suspended Sediments (mg/L)	Lab	15 mg/L	20 mg/L*	25 mg/L*	10 mg/L	N/A
Phytoplankton	Chlorophyll-a (µg/L)	Lab	2 µg/L	4 µg/L	10 µg/L	5 µg/L	N/A
Physiochemical	Dissolved Oxygen	Field	90 – 100 %	85 – 100 %	70 – 100 %	85 – 110 %	90 – 110%
	Conductivity	Field	N/A	N/A	N/A	Varies by zone***	Varies by Zone***
	pH	Field	8.0 – 8.4	7.0 – 8.4	7.0 – 8.4	6.5 – 8.0	6.5 – 7.5

*These guidelines apply to estuaries less than 40 km in length. Longer estuaries have naturally higher turbidity levels (and corresponding higher SS values) due to longer retention times for suspended particulates and also to the continual re-suspension of fine particles by high tide velocities. Values are variable and site specific, however most values are <100 NTU and very few values are >200 NTU

** In the absence of better data, the guidelines adopted for freshwaters are for the most part are the default ANZECC 2000 Guidelines. It is acknowledged that these need to be updated with local data as soon as it is available.

*** See Appendix G of the Queensland Water Quality Guidelines (2009) for EC percentiles for Queensland Salinity Zones. It is recommended to use the 75%ile value as the reference benchmark.

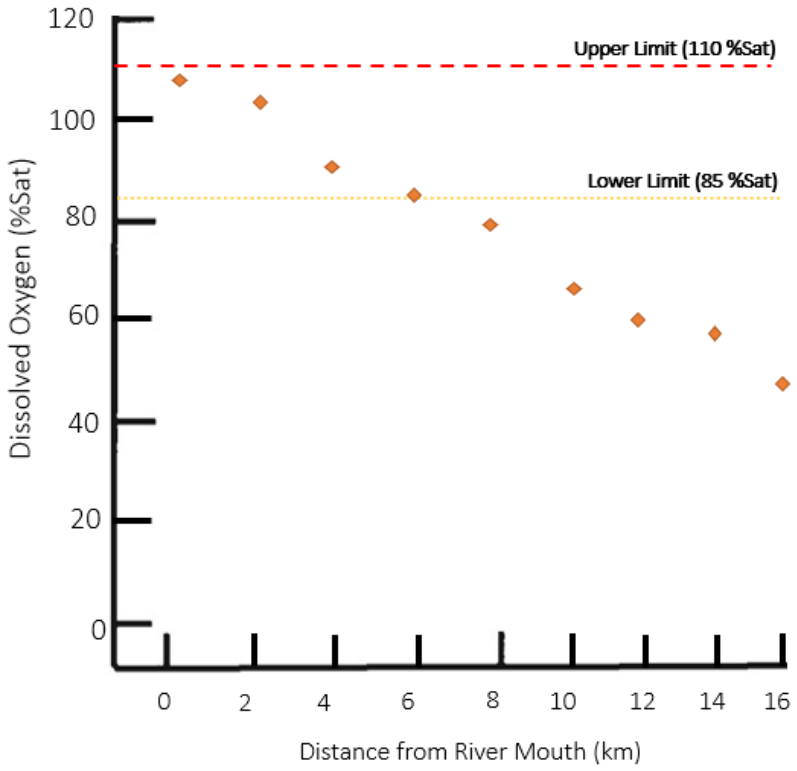

Figure 3. An example of dissolved oxygen guideline limits to show how observed values are compared to the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection (2009). The orange diamonds represent an example of observed values within the field.

*Table 5. Summary of the Reference Benchmarks for the **South-East Queensland** taken from QWQG 2009 and Mary river Catchment Waterwatch Results (MRCCC 2021). Apply to Mary River sub-catchments. For more information on how these guidelines and reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).*

Southeast Queensland													
Indicator		Measure	Enclosed coastal/lower estuary (ECLE)	Mid estuary (ME)	Upper estuary (UE)	Lowland freshwater (LF) **	Upland freshwater (UF) **	Maleny Plateau (Southern Upland Acid Waters)	Upper Mary River (Southern Upland Freshwaters)	Mary River and southern tributaries (Southern Lowland Waters)	Western Tributaries (North Western Lowland Waters)	Tinana Creek (North Eastern Lowlands)	East Tributaries of Tinana Creek (Eastern Sandplain Tannin Stained)
Nutrients	Total Nitrogen (µg/L)	Lab	200 µg/L	300 µg/L	450 µg/L	500 µg/L	250 µg/L	250 µg/L	250 µg/L	500 µg/L	500 µg/L	500 µg/L	250 µg/L
	Dissolved Inorganic Nitrogen (µg/L)	Lab	11 µg/L	20 µg/L	45 µg/L	80 µg/L	50 µg/L	50 µg/L	50 µg/L	80 µg/L	80 µg/L	80 µg/L	50 µg/L
	Total Phosphorus (µg/L)	Lab	20 µg/L	25 µg/L	30 µg/L	50 µg/L	30 µg/L	30 µg/L	30 µg/L	50 µg/L	50 µg/L	50 µg/L	30 µg/L
	Filterable Reactive Phosphorus (µg/L)	Lab	6 µg/L	6 µg/L	10 µg/L	20 µg/L	15 µg/L	15 µg/L	15 µg/L	20 µg/L	20 µg/L	20 µg/L	15 µg/L
Sediments	Turbidity (NTU)	Field	6 NTU	8 NTU*	25 NTU*	50 NTU	25 NTU	25 NTU	25 NTU	50 NTU	50 NTU	50 NTU	50 NTU
	Total suspended Sediments (mg/L)	Lab	15 mg/L	20 mg/L*	25 mg/L*	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L
Phytoplankton	Chlorophyll-a (µg/L)	Lab	2 µg/L	4 µg/L	8 µg/L	5 µg/L	2 µg/L	2 µg/L	2 µg/L	5 µg/L	5 µg/L	5 µg/L	2 µg/L
Physiochemical	Dissolved Oxygen	Field	90 to 105	85 to 105	80 to 105	85 – 110 %	90 – 110%	90 – 110%	90 – 110%	85 – 110 %	85 – 110 %	85 – 110 %	85 – 110 %
	Conductivity	Field	N/A	N/A	N/A	Varies by zone***	Varies by Zone***	580 – 900 µS/cm	580 – 900 µS/cm	580 – 2600 µS/cm	1200 – 3000 µS/cm	580 – 900 µS/cm	580 – 900 µS/cm
	pH	Field	8.0 – 8.4	7.0 – 8.4	7.0 – 8.4	6.5 – 8.0	6.5 – 8.2	6 – 8	6.5 – 8.2	6.5 – 8	6.5 – 8	6.5 – 8	3.6 – 6

*These guidelines apply to estuaries less than 40 km in length. Longer estuaries have naturally higher turbidity levels (and corresponding higher SS values) due to longer retention times for suspended particulates and also to the continual re-suspension of fine particles by high tide velocities. Values are variable and site specific, however most values are <100 NTU and very few values are >200 NTU

** In the absence of better data, the guidelines adopted for freshwaters are for the most part are the default ANZECC 2000 Guidelines. It is acknowledged that these need to be updated with local data as soon as it is available.

*** See Appendix G of the Queensland Water Quality Guidelines (2009) for EC percentiles for Queensland Salinity Zones. It is recommended to use the 75%ile value as the reference benchmark.

Calculating a worst case scenario - 90th Percentile value

Most of the water quality indicators in this method are continuous meaning that values can theoretically continue to increase away from the benchmark without an upper limit. In order to calculate an Econd (between 0-1) a suitable upper limit or worst case scenario needs to be established. We have chosen the 90th percentile as this upper limit. The 90%ile value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Step 6). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the 90%ile value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores.

90%ile value is to be calculated as the 90th percentile of all the available observed historic data from the relevant water type (as per the designations of the Queensland Water Quality guidelines). The 90th percentile value is to be calculated using the Queensland Department of Environment and Science historical water quality data for each water type for each region (WMIP: Queensland Government (information.qld.gov.au, Water Data Online: Water Information: Bureau of Meteorology (bom.gov.au) and Water Data Online - Dataset - data.gov.au. If there is not sufficient data to calculate the 90%ile value, then expert opinion may be used to determine suitable values. An expert is considered as an AfN accredited expert or an external expert in the field. The 90%ile value is to be determined only at the start of the account with the same 90%ile values used in subsequent years of the account.

10th Percentile Value

The benchmark for dissolved oxygen is a range (lower and upper values) so that values can be either above the benchmark range or below. This means that two 'worst case scenarios' must be calculated in order to calculate an Econd. This requires a '10th Percentile' (10%ile) value to be identified for the dissolved oxygen indicator. The 10%ile value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Step 6). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the 10%ile value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores.

10%ile value is to be calculated as the 10th percentile of all the available observed historic data from the relevant water type (as per the designations of the Queensland Water Quality guidelines). The 10th percentile value is to be calculated using the Queensland Department of Environment and Science historic water quality data for each water type for each region (link to data source). If there is not sufficient data to calculate the 10%ile value, then expert opinion may be used to determine suitable values. The 10%ile value is to be determined only at the start of the account with the same 10%ile values used in subsequent years of the account.

Output of Step 4c

- A **data table** (e.g. a spreadsheet) containing reference values for each indicator, grouped by sampling unit.

Step 4.1.d. Collect data and process samples

The sampling techniques that must be used to measure each of the water quality indicator is summarised in Table 6 below. These techniques are in accordance with the Queensland Water Monitoring and Sampling Guideline (DES, 2018). Tables 7-9 provide additional details on how to implement these techniques. In general, samples taken must be reliable, representative, not contaminated, degraded, or transformed, and a sufficient volume to meet detection limits for particular lab analyses.

As this method is focused on Base Flow, the State government flood gauge stations should be checked prior to sampling to ensure that the estuaries are at 'base flow' condition. Sampling during baseflow should be undertaken with an appropriate lag time after an event to ensure samples are truly baseflow. If in doubt, Hydrographs can be used to check base flow separation (refer to Section B 8.5 of the Queensland Monitoring and Sampling Manual (2009), and page 77 of Grayson et al, 1996). **If the water is not considered to be base flow, then samples should not be taken (or can be taken, but not included in ICS or Econd® calculations).**

Table 6. Summary of Sample Techniques for indicators

Indicator		Measure	Technique description
Nutrients	Total Nitrogen (µg/L)	Grab Sample – Lab Analysis	
	Dissolved Inorganic Nitrogen (µg/L)	Filtered Sample – Lab Analysis	Table 8. How to collect a Filtered *Sample*
	Total Phosphorus (µg/L)	Grab Sample – Lab Analysis	
	Filterable Reactive Phosphorus (µg/L)	Filtered Sample – Lab Analysis	Table 8. How to collect a Filtered *Sample*
Sediments	Turbidity (NTU)	Insitu field sampling using water quality instrument	
	Total Suspended Sediments (mg/L)	Grab Sample – Lab Analysis	
Phytoplankton	Chlorophyll-a (µg/L)	Grab Sample – Lab Analysis	
Physiochemical	Dissolved Oxygen	Insitu field sampling using water quality instrument	
	Conductivity	Insitu field sampling using water quality instrument	
	pH	Insitu field sampling using water quality instrument	

Table 7. How to collect a Grab Sample

Grab Sample for: - Total Nutrients (Nitrogen and Phosphorus) - Total Suspended Sediments - Chlorophyll-a	
Timing	Non-event conditions
Sampling	1. It is important to ensure that the sampling regime is representative of the system and parameter/s of interest. For example, where a water body is well mixed and a parameter of interest is evenly distributed in the water column, a single grab sample may be appropriate. However, if water quality changes with depth, a number of samples at different depths may be required. 2. Take a water sample by Inserting a Perspex pole sampler with a 1 L acid rinsed Nalgene bottle to a depth of about 0.5 m (or deeper, if required) 3. Individually fill a laboratory sample bottle for each of the four measures, Total Nitrogen, Total Phosphorus and Chlorophyll-a. Always store samples in a cooler box with ice or ice bricks, label appropriately and fill out the chain of custody form. The samples will then be sent to the lab to analyse the above four indicators.

Table 8. How to collect a Filtered Sample

Filtered Sample for: - Dissolved Inorganic Nitrogen - Filterable Reactive Phosphorus	
Timing	Non-event conditions
Sampling	1. Take a water sample by Inserting a Perspex pole sampler with a 1 L acid rinsed Nalgene bottle to a depth of about 0.5 m. 2. Rinse the syringe three times in sample water. 3. Fill the syringe with sample water and place 0.45 µm membrane filter on end of syringe. 4. Push a couple of millilitres of sample through the filter to rinse. 5. Push approximately 5mL of sample through the syringe and filter into the 'filtered' sample container. 6. Replace the lid on the labelled sample container and shake gently to rinse all internal surfaces including the lid. 7. Remove the lid and discard the rinsate away from the sample processing area. 8. Repeat the rinse of the 'filtered' sample container three times. 9. Fill the 'filtered' sample container with water pushed through the syringe and filter. Always store samples in a cooler box with ice or ice bricks, label appropriately and fill out the chain of custody form. The samples will then be sent to the lab within 24 hours to analyse the above four indicators. However, nutrient samples can be frozen to extend holding times.
Reference	Queensland Water Monitoring and Sampling Guideline (DES, 2018)

Table 9. How to use a Water Quality Meter

Water Quality Meter measures for: - Turbidity - Dissolved Oxygen - Conductivity - pH	
Timing	Early in the morning (when DO levels are at their lowest) and in non-event conditions (e.g. no rain in catchment in xx days?)
Sampling	Ensure the Water Quality Meter is calibrated and checked prior to monitoring Measure at 0.2 m to avoid surface scums and floating material
Reference	Queensland Water Monitoring and Sampling Guideline (DES, 2018)

Laboratory Analyses for water quality

All analyses for Nutrients, Total Suspended Solids and Chlorophyll-a must be performed by laboratories that are accredited by the National Association of Testing Authorities Australia. Options include Australian Laboratory Services, and Queensland Health Laboratories.

Data

All measured indicator data should be stored in a data table that lists the values for each indicator for each site.

Output of Step 4d

- A **data table** (e.g. a spreadsheet) containing all the raw data for each environmental indicator for each sample.

Step 4.1.e. Calculate indicator condition scores

In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the range between the reference benchmark value and the worst-case scenario (e.g. the 90th or 10th percentile values). Based on that principle, the scoring formula is based on converting the observed indicator values to a "distance from benchmark" value. The distance from benchmark is expressed as a proportion (0 to 1) using the equations below. An observed value that equals or exceeds the Reference Benchmark will receive an ICS of 1 and an observed value that equals or exceeds the 90th Percentile value will receive an ICS of 0. Final indicator scores are calculated as a mean of the site-based distance scores. The following excel equations are to be used to calculate the ICS. The below equations are explained in Table 10.

To calculate the Indicator and Summary ICS for Water Quality:

1. Calculate the ICS for each water quality indicator within each sampling unit using the ICS formulas below.
2. Calculate the **water quality summary ICS** for each sampling unit
    - Averaging the ICS for each water quality indicator within that sampling unit
3. Calculate the **water quality summary ICS** for each sub-asset (catchment)
    - Aggregate the water quality summary ICS of each sampling unit within a catchment using the length-weighted average of all
        - Note. The 'length' of the waterways within each catchment is to be calculated and used to scale the aggregation of the final Econd. The length of waterways should be determined using the Adopted Middle Thread Distances (AMTD) established by the Queensland Water Resources Commission in the 1950s for all major streams in the state in accordance with the Report on Condition and trends in Water Quality in Central Queensland Estuaries (1993 to 2015).
    - The water quality summary ICS is used in the Econd calculations, see Step 5.

All Water Quality Indicators (except Dissolved Oxygen)

1.

=(OBS-WCS)/(REF-WCS)

2.

=IF(CALCULATEDSCORE >1, 1, 0)

For Water Quality Indicators the observed value is the annual median value for each sampling unit.

Dissolved Oxygen

1.

=IF(K2 <REF, (OBS-WCS_{LOWER})/(REF-WCS_{LOWER}), 1)

2.

=IF(K2 <REF, (OBS-WCS_{UPPER})/(REF-WCS_{UPPER}), 1)

3.

=IF(CALCULATEDSCORE >1, 1, 0)

Where:

REF = Reference Benchmark
OBS = Observed annual median value
WCS = Worst case scenario (upper= 90%ile and lower = 10%ile)

Table 10. Summary of Indicator Condition Scoring, where REF = reference value, OBS = observed value, 90%ile = 90th percentile value and 10%ile = 10th percentile value.

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Total Nitrogen (µg/L)
Dissolved Inorganic Nitrogen (µg/L)
Total Phosphorus (µg/L)
Filterable Reactive Phosphorus (µg/L)
Turbidity (NTU)
Conductivity
Total suspended Sediments (mg/L)
Chlorophyll-a (µg/L)</td><td>Where REF < 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS < REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{\text{90\%ile-OBS}}{\text{90\%ile-REF}}$</td></tr>
<tr><td>If OBS > 90%ile</td><td>0</td></tr>
</table></td></tr>
<tr><td>pH (if OBS > REF)</td><td>Where REF < 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{\text{90\%ile-OBS}}{\text{90\%ile-REF}}$</td></tr>
<tr><td>If OBS > 90%ile</td><td>0</td></tr>
</table></td></tr>
<tr><td>pH (if OBS < REF)</td><td>Where REF > 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>1</td></tr>
<tr><td>If OBS < REF</td><td>$\frac{\text{OBS-90\%ile}}{\text{REF-90\%ile}}$</td></tr>
<tr><td>If OBS < 90%ile</td><td>0</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Dissolved Oxygen</td><td>The following scoring is to be used for Dissolved Oxygen which has an upper and lower Reference Benchmark and 90th Percentile value, where:
90%ile = 90th Percentile value
10%ile = 10th Percentile value
<table>
<tr><th>Scenario</th><th>ICS Calculation</th></tr>
<tr><td>IF OBS < 10%ile</td><td>0</td></tr>
<tr><td>If 10%ile < OBS < REF_{Lower}</td><td>$\frac{OBS-10\%ile}{REF_{Lower}-10\%ile}$</td></tr>
<tr><td>If REF_{Lower} < OBS < REF_{Upper}</td><td>1</td></tr>
<tr><td>If REF_{Upper} < OBS < 90%ile</td><td>$\frac{90\%ile-OBS}{90\%ile-REF_{Upper}}$</td></tr>
<tr><td>IF OBS < 90%ile</td><td>0</td></tr>
</table></td></tr>
</table>

Output of Step 4e

- A **Data Table** (e.g. a spreadsheet) containing reference values, observed value and calculated Indicator Condition Scores

3.2 Ecological Flow – Burnett-Mary Region

The following section on ecological flow describe indicators and reference benchmarks that are specific to the waterways of the Burnett-Mary Region, where this Method is being piloted. Following this pilot, we are intending to revise this document to make it more generally applicable to other Australian catchments. There are numerous ways to measure flow that have relevance for specific environmental objectives. As such, it is difficult to prescribe a 'one-size-fits-all' approach to ecological flow measurement. Our approach is to prescribe catchment specific indicators and benchmarks for flow, as each river system has different management issues and objectives. Application of this indicator class requires expertise in hydrology and familiarity with the data sources required for analyses. It is anticipated that a consultant will be required to assist NRM organisations to produce an account using this method.

Within the Burnett-Mary Region, there are three water plans (Burnett Basin, Mary Basin and Baffle Creek), which hold specific environmental flow objectives and associated ecological outcomes (Figure 4).

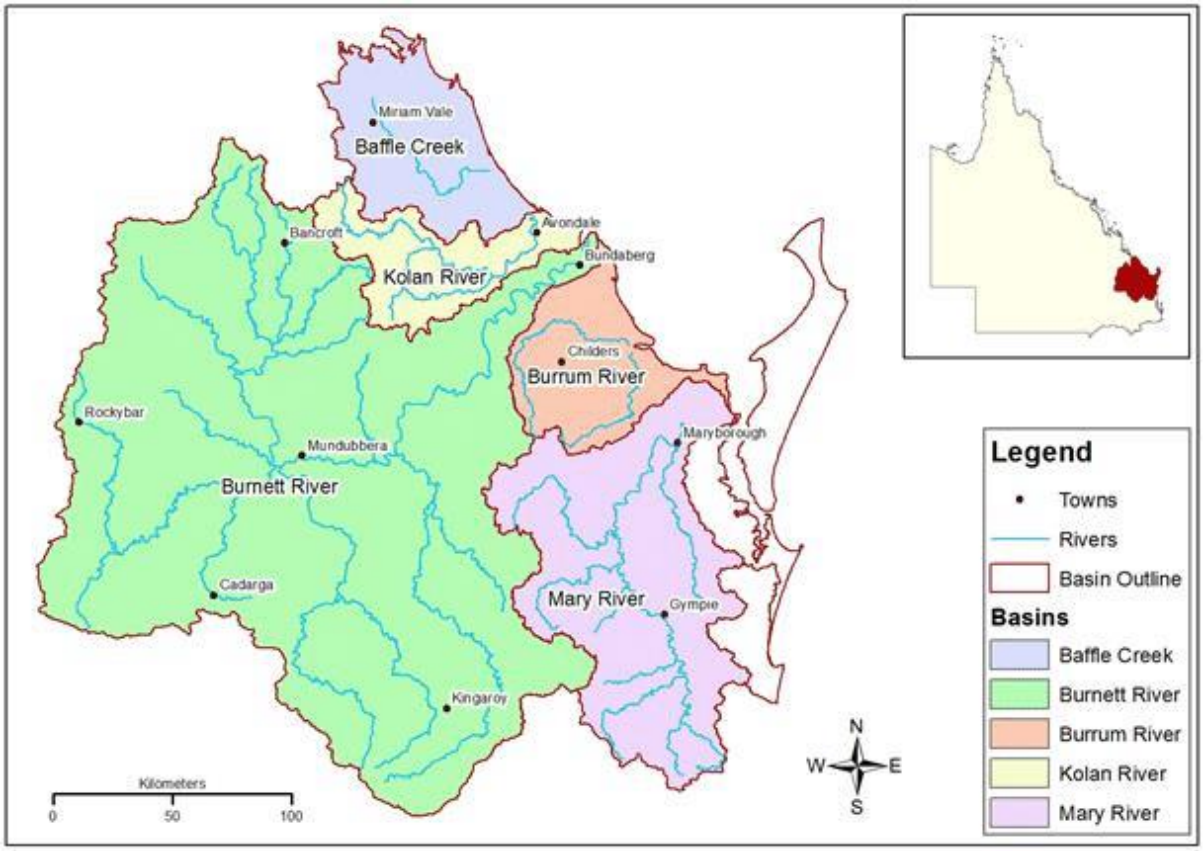

Figure 4. An overview of the Burnett-Mary Basin and the associated sub-catchments. Note: Kolan/Elliot/Gregory/Burrum and Isis Rivers are lumped together with the Burnett Basin Water Plan. Source: Beverly et al. (2016).

Step 4.2.a. Describe environmental indicators

The timing and magnitude of water flows through the rivers in the region is a critical determinant of the breeding and migratory success of the region's iconic species. Water impoundments like dams and weirs alter the hydrology of rivers which impacts on those species. Environmental flow strategies in modified rivers that minimise changes to natural flow regimes provide suitable conditions not only for these iconic species but for the broader aquatic ecosystem. The Queensland Government manages the flow regime in the region's rivers with ecohydrological rules outlined in the *Water Plan's* (In force legislation - Queensland Legislation - Queensland Government), specific for each catchment. Within each of the *Water Plan's* there is a schedule that outlines the water flow objectives, with these objectives varying between the three basins.

The method outlined in the sections below is based on the ecological objectives within each Water Plan, however, has it has been simplified to enable robust data collection at small to large scales and for consistency across the entire Burnett-Mary region.

Below outlines the ecohydrological rules as they apply to each catchment in the Burnett-Mary Region.

Baffle Creek – The *Water Plan (Baffle Creek) 2010 (Qld)* (Queensland Government, 2010) states that the ecological outcomes for managing water flows are:

a. to minimise changes to the natural variability of flows that support aquatic ecosystems
b. to provide for the continued capability of one part of an aquatic system to be connected to another, including by maintaining flows that
    i. allow for the movement of native aquatic species between riverine, floodplain, wetland, estuarine and marine environments
    ii. support natural processes such as breeding, growth and migration in riverine, floodplain, wetland, estuarine and marine environments
    iii. support river-forming processes

c. to minimise changes to natural variability in water levels to support natural ecological processes, including maintaining refugia associated with waterholes and lakes.
d. to minimise adverse impacts on aquatic ecosystems immediately downstream of new water resource development
e. to improve understanding of the matters affecting flow ecology responses of ecosystems within the plan area.

Specific ecological outcomes (*Chapter 3, Section 13 of the Water Plan (Baffle Creek) 2010*)) for water in the plan area are outlined below:

a. to maintain the near-natural flow regime that supports waterholes and estuarine ecosystems in the Eurimbula Creek catchment area and Worthington Creek catchment area
b. to minimise changes to flows that maintain existing brackish habitat downstream of barrages in the Broadwater Creek catchment area
c. in the Baffle Creek catchment area
    i. to maintain connectivity between Baffle Creek and its adjacent floodplain system including lakes
    ii. to maintain the near-natural flow regime that provides for intermittent brackish habitat through the entire length of the Baffle Creek estuary
    iii. to minimise changes to the low flow regime that provides for riffle habitat and maintains waterholes
    iv. to minimise changes to the persistence of waterholes

d. to minimise changes to the flow regime that maintains brackish habitat in the upper reaches of Littabella Creek estuary.

Burnett Basin – In Chapter 3, Part 16 of the *Water Plan (Burnett Basin) 2014 (Qld)* (Queensland Government, 2014) states that the ecological outcomes for managing water flows include the following:

a. minimisation of changes to the natural variability of flows that support aquatic ecosystems.
b. the continued capability of a part of the river system to be connected to another, including by maintaining flows that—
   i. allow for the movement of native aquatic fauna between riverine, floodplain, wetland, estuarine and marine environments
   ii. support water-related ecosystems
   iii support river-forming processes
c. protection and maintenance of refugia associated with waterholes, lakes and wetlands.
d. the support of ecosystems dependent on groundwater, including, for example, riparian vegetation and wetlands
e. e. provision of flows and hydraulic habitat for flow-spawning fish and endemic species, including, for example, the Australian lungfish (*Neoceratodus forsteri*) and the white-throated snapping turtle (*Elseya albagula*)
f. maintenance of flows necessary for estuarine ecosystem functions, including flows for—
   i. barramundi (*Lates calcarifer*) and sea mullet (*Mugil cephalus*) recruitment; and
   ii. banana prawn (*Fenneropenaeus merguiensis*) growth; and
   iii. river mangroves (*Aegiceras corniculatum*);
g. maintenance of a near natural flow regime that supports waterholes and riverine ecosystems in subcatchment area M.

Mary Basin – In Part 3, Section 13 of the *Water Plan (Mary Basin) 2006 (Qld)* (Queensland Government, 2006) the ecological outcomes for managing water flows include the following:

a. for the Noosa River, Mooloolah River and coastal streams north of Noosa River mouth—
   i. to minimise changes to river-forming processes; and
   ii. to minimise changes to a near-natural flow regime.
b. for the Mary River, upstream of the Mary River barrage pondage—
   i. to minimise changes to the low flow regime of the river; and
   ii. to minimise changes to the hydraulic habitat requirements of species such as the Mary River cod, the Mary River turtle and lungfish;
c. for Six Mile Creek—
   i. to minimise changes to the low flow regime of the creek; and
   ii.to minimise changes to the hydraulic habitat requirements of species such as the Mary River cod and lungfish;
d. for Tinana Creek, upstream of Tallegalla Weir—to minimise changes to the hydraulic habitat requirements of existing ecological assets in the area;
e. for Obi Obi Creek, in the Obi Obi Creek Gorge area—to minimise changes to the hydraulic habitat requirements of existing ecological assets in the area;
f. for the Burrum River—
   i. in the Upper Burrum River above Lenthalls Dam—to minimise changes to the flooding regime at Wongi Waterholes; and

ii. in the Lower Burrum River system below Lenthalls Dam—to minimise changes to variability in the low flow regime of the river system to improve opportunities for fish passage.

Output of Step 4a

- A table describing the **environmental indicators** to be measured in the account, grouped by sub-asset (waterway).

Step 4.2.b. Collate data

The data used for calculating the scores of this method is from the stream gauging network co-ordinated by the state government. To calculate the reference benchmarks and current conditions of the waterways, stream gauge data will need to be downloaded from the Water Monitoring Information Portal (WMIP), instructions on how to download and calculate the data can be found in Appendix D. The following gauge datasets will need to be downloaded:

Mary

- Amamoor Creek at Zachariah
- Glastonbury Creek at Glastonbury
- Kandanga Creek at Hygait
- Mary River at Home Park
- Mary River at Bellbird Creek
- Mary River at Miva
- Mary River at Moy Pocket
- Munna Creek at Marodian
- Obi Obi Creek at Gardners Falls
- Six Mile Creek at Cooran
- Teewah Creek at Coops Corner
- Tinana Creek at Bauple East
- Tinana Creek at Tagigan
- Wide Bay at Brooyar
- Wide Bay at Kilkivan

Burnett

- Auburn River at Dykehead
- Barambah Creek at West Barambah
- Barambah Creek at Ban Ban
- Barambah Creek at Litzows
- Barker Creek at Brooklands
- Barker Creek at Glenmore
- Boyne River at Carters
- Boyne River at Ceratodus
- Boyne River at Cooranga
- Burnett River at Eidsvold
- Burnett River at Jones Weir Headwater
- Burnett River at Tailwater
- Burnett River at Gayandah

- Burnett River at Mount Lawless
- Cadarga Creek at Brovinia
- Eastern Creek at Lands End
- Elliot River at Dr Mays
- Elliot River at Figtree
- Gregory River at Isis Highway
- Isis River at Bruce Highway
- Kolan River at Springfield
- Monal Creek at Upper Monal
- Reid Creek ay Mungy
- Splinter Creek at Dakiel
- Stuart River at Proston
- Stuart River at Weens Bridge
- Three Moon Creek at Abercorn

Baffle

- Oyster Creek at Rapleys
- Baffle Creek at Mimdale

Output of Step 4b

- **Data tables** (e.g. individual spreadsheets) containing all the raw data, derived from the latest WMIP for each stream gauge used for the analysis.
- **Cleaned and organised data -** Prior to any data analysis, the data will need to be cleaned and organised for the analysis software to read it properly.

Step 4.2.c.Determine reference benchmarks

In general, reference benchmarks for ecological flow are based on the Integrated Quality and Quantity Model (IQQM) pre-development flow pattern. However, pre-development flow pattern data is not available for all basins. As such, historical benchmarks will need to be generated from the year the stream gauge started collecting data (e.g. 1979) to 31st December 2020 for all performance indicators listed below:

a. The mean annual flow
b. The median annual flow
c. The 10th percentile annual flow
d. The 90th percentile annual flow
e. The number of days with no flow in the judgement period
f. The number of no flow spells in the judgement period
g. The maximum duration (in days) of one of the no flow spells in the judgement period
h. The 10 cm annual flow (number of spells)
i. The 30 cm annual flow (number of spells)

Where possible pre-development data will be required for the calculation of the 10cm and 30cm annual flow indicator scores. The pre-development data for the Mary basin can be found in the Environment Conditions Report – Volume 2. The available pre-development data for the Burnett and Baffle Creek Basin is outlined in Appendix D.

Calculating Reference Benchmarks

To calculate reference benchmarks for each indicator a software called River Analysis Package (RAP) will need to be used. This involves calculating the benchmarks with the relevant thresholds outlined in the Environment Conditions Report – Volume 2 for the Mary Basin. The thresholds for the Burnett and Baffle basins can be found in Appendix D below.

For the detailed method on the calculations for the reference benchmarks please refer to Appendix D.

Calculating the Annual Data

To calculate the annual results for each indicator the River Analysis Package (RAP) will need to be used. This involves calculating the annual results with the relevant thresholds outlined in the Environment Conditions Report – Volume 2 for the Mary Basin. The thresholds for the Burnett and Baffle basins can be found in Appendix D below. The annual year should be a full calendar year (e.g. January 1st to December 31st for 2021).

For the detailed step by step method on the calculations for the reference benchmarks please refer to Appendix D.

Calculating a Worst-Case Scenario

Most of the ecological flow indicators in this method are continuous meaning that values can theoretically continue to increase away from the benchmark without an upper or lower limit. In order to calculate an Econd (between 0-1) a suitable upper or lower limit (referred to as a worst case scenario) needs to be established. We have chosen either the 90th percentile as the upper limit or the 10th percentile as the lower limit depending on the indicator.

The WCS value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Appendix G). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the WCS value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores. The WCS score for ecological flows depends on the respective Water Plan and gauge. For the WCS for each reference benchmark with the individual Water Plans, refer to Appendix E.

Output of Step 4c

- **Historical benchmarks** – all historical benchmarks should be calculated for each environmental indicator for each stream gauge as per Appendix D
- **Annual calculations –** All current data (e.g. 2021) should be calculated for each environmental indicator for each stream gauge as per Appendix D.
- A **data table** (e.g. a spreadsheet) containing the historical benchmarks and annual calculations.

Step 4.2.d. Calculate indicator condition scores

Indicator condition scores for ecological flow are all calculated using the formula presented below, which has as its inputs, the observed values taken from the IQQM model and the Reference and Worst-Case Scenario values as described in the appropriate Water Plan and as outlined in this document. For each catchment, there may be more than one set of indicators that are aggregated to provide an indicator condition score for that catchment (see Table 11). The calculations can be performed in MS Excel or adapted for use in another statistical package. For Ecological Flow, the observed value is the annual median value for the catchment.

In separate columns have the following equations:

1.

$=(OBS-WCS_{LOWER})/(REF-WCS_{LOWER})$

2.

$=(OBS-WCS_{UPPER})/(REF-WCS_{UPPER})$

3.

=IF(CALCULATEDSCORE >1, 1, 0)

Where:

REF = Reference Benchmark
OBS = Observed annual median value
WCS = Worst case scenario

Table 11. Calculation of indicator condition scores for ecological flow

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Ecological Flow</td><td>
Where REF < WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS < REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{WCS-OBS}{WCS-REF}$</td></tr>
<tr><td>If OBS > WCS</td><td>0</td></tr>
</table>
Where REF > WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS > REF</td><td>1</td></tr>
<tr><td>If OBS < REF</td><td>$\frac{WCS-OBS}{WCS-REF}$</td></tr>
<tr><td>If OBS < WCS</td><td>0</td></tr>
</table>
Where the performance indicator involves a range, the score is binomial. Inside the range should be given an ICS of 1 and outside the range should be given an ICS of 0.

The final ICS should be taken as the mean of all scores for all gauges within a catchment (refer to Figure 5 below).
</td></tr>
</table>

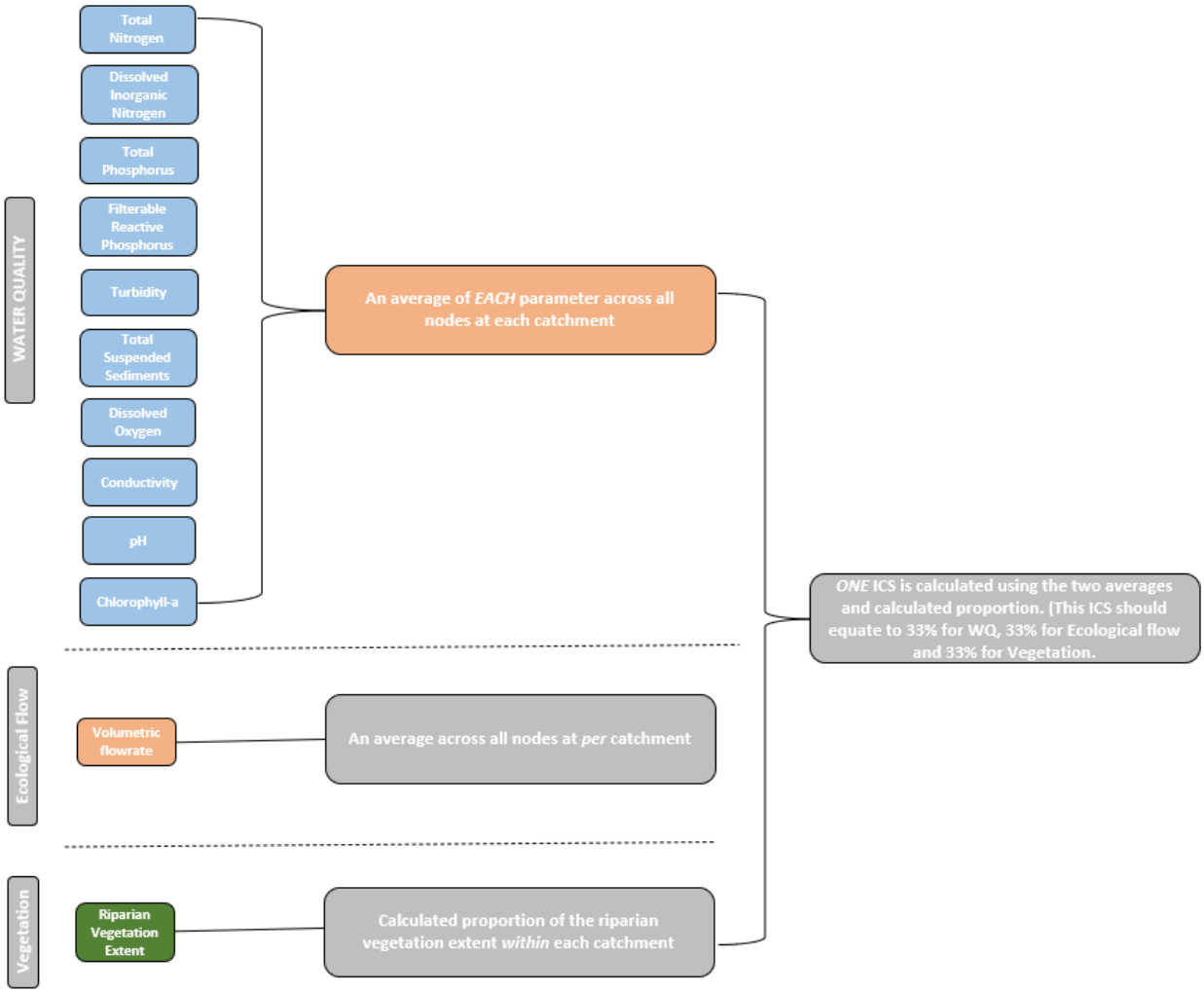

Figure 5. Flow chart outlining how the ICS is calculated.

Output of Step 4d

- A **Data Table** (e.g. a spreadsheet) containing all the data, including observed values, reference values and calculated Indicator Condition Scores.

3.3 Riparian Vegetation Extent – Queensland Catchments

Riparian vegetation is a critical component of a waterway. Vegetation provides habitat for a wide variety of organisms, prevent erosion of riverbanks and acts as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increased input of sediments and nutrients.

Our approach to measuring riparian vegetation focuses on the functional value of vegetation for waterway condition. We recognise that riparian vegetation condition is a valuable indicator of environmental condition in its own right, but the types of on-ground measurements required to assess vegetation condition are outside the scope of this Method at present. We aim to expand the scope of our measurement of riparian vegetation to include condition indicators as we further develop this Method.

The measurement of this indicator is based on a foliage projective cover GIS layer produced by the Queensland Government. As such, the scope of this method is at this stage limited to Queensland waterways. Other layers are available that measure and classify vegetation cover at various scales from State, to National to Global. We have selected this layer for assessment of Queensland catchments because it is consistent with the approach used by the Queensland Government and other organisations to assess vegetation cover change. As with other indicators in this method, following the Burnett Mary regional pilot, it is our intention to expand the scope of the methods, to facilitate adoption in other Australian regions. In the case of riparian extent, it would involve identifying the most appropriate spatial products in other jurisdictions. These layers are constantly being developed and refined, so will require regular updates to this method. Where local scale mapping is available (e.g known weed location and fire scar extent), they will be overlayed on the satellite imagery and masked out for the calculation of the riparian extent. Of note, foliage protection cover layer does come with its limitations, and where a new product that further enhances the analysis becomes available, the method will be updated to reflect that.

Step 4.3.a. Define environmental indicators

Riparian vegetation is defined as riparian woody vegetation to include riparian forest (trees > 5m height with dense foliage cover) (Specht, 1970); riparian woodlands (trees >5m in height with sparse foliage cover and shrublands (shrubs < 5m in height). Riparian areas that are non-woody and have low ground cover levels may be areas of concern for soil and nutrient loss to the stream. The recommended width of the riparian zone is described in *Section 3 Table 2*.

Output of Step 4a

- The **riparian vegetation extent indicator** is defined as the area of existing woody extent and ground cover vegetation in the riparian buffer zone compared to the area of the total riparian buffer zone for all waterways in the catchment.

Step 4.3.b. Determine reference benchmarks

The benchmark for riparian vegetation is what is considered pristine condition and/or the most desirable state. The reference benchmark for riparian vegetation is 100%, this is due to the assumption the waterways had full riparian coverage prior to the clearance of native vegetation.

The Worst-Case Scenario score for the riparian vegetation extent indicator is a value of 0% of the riparian zone along all of the waterways covered. The WCS value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring.

The size or width of the riparian zone varies with different sized streams. For a riparian zone to function as described above, it should be an appropriate width for the size of the stream.

Output of Step 4b

The width of the riparian zone, or buffer width, are dependent on the stream order of the waterway and the presence of sugar cane growing areas. The table below outlines the recommended riparian buffer widths according to the stream order which takes into account cane-growing areas. The riparian buffers are based on evidence from scientific literature, with a detailed explanation of each source within Appendix B.

Stream order	Riparian buffer width (m)
1-2	50*
3-4	75*
5-6	100*
7-8	150

* Derived from Lovett and Price (2001), Department of Primary Industries [NSW GOV] (2012) & Hansen et al. (2010).

Step 4.3.c.Collect and analyse data

The extent of woody vegetation is mapped using the indicator, Foliage Projective Cover (FPC). FPC is mapped by the QDL state government through the State-wide Landcover and Trees Study (SLATS) each year. It is produced from satellite imagery and is available as a raster dataset which represents the FPC for the previous 2-year period (rather than at a single date). The satellite imagery has a resolution (i.e. pixel size) of 10m x 10m. Each pixel is classified between 0 and 100 and represents the level of coverage.

The extent of riparian woody vegetation is mapped using the QLD Statewide Landcover and Trees Study (SLATS) Sentinel-2 - 2019 woody vegetation extent layer (DES, 2021). This woody vegetation extent layer is based on a U-net convolutional neural network classification, fitted on very high spatial resolution (i.e. ~1m) Earth-i satellite imagery to produce an initial binary woody presence/absence classification, as described in Flood et al (2019). The classification is subsequently down-sampled to 10m to approximate the spatial resolution of Sentinel-2, given it will be used for ongoing monitoring.

Features on the satellite imagery are categorised as either woody or non-woody, where woody vegetation defined in DES (2021) as stands of woody vegetation greater than 0.5ha with a crown cover greater than 10% are represented. A minimum width of 20m was applied to linear features. No distinction is made between native and non-native vegetation; woody vegetation such as woody weeds and horticultural crops are included as woody in the final classification. Both woody and nonwoody features smaller than these sizes have been filtered out of the data set. Ancillary data on dams and waterbodies were also used to further refine the woody classification for the riparian analysis. These waterbodies were classified as 'no data'.

For riparian areas classed as non-woody, ground cover is estimated for the dry (winter) season (July - August 2019). Ground cover monitoring is included to recognise the importance of having some level of vegetation cover in riparian areas to help minimise erosion and filter sediment and nutrient runoff, particularly where woody vegetation is not present to stabilise the soil through deeper root structures. Ground cover reporting in riparian areas is based on Sentinel-2 seasonal fractional cover data derived using the method described by Flood (2017). The Sentinel-2 fractional cover product is not specifically a ground cover product and does contain woody vegetation. However, as its use is restricted to non-woody areas it is suitable for the purposes of assessing ground cover. Three classes of ground cover were used for reporting: 0-30%; 30-70%; and, greater than 70% ground cover. Very low ground cover can indicate degraded areas, such as gullies. It may also be present naturally in areas containing sandbars, sand dunes and rocky streams.

The indicator condition score is based on summing the area of highest ground cover (>70%) with the area of medium (30 -70%) and high (>70%) woody extent within the riparian layer. As ground cover is not as effective at stabilising river banks, the area of ground cover in each catchment is weighted at 20%.

To calculate the riparian vegetation extent, the following procedure should be followed:

Measures for Riparian Veg % coverage within each catchment (or sub-asset)

1. Download the following layers:

- Watercourse lines – this dataset is the centre line of a waterway which is suitable for analysing the smaller stream orders. This dataset also includes the stream order which enables the correct buffer width to be selected.
- Watercourse areas – this dataset presents the outline of the wider stream orders (e.g. larger rivers). The riparian buffer width is then taken from the edge of this layer so that the water is not included in the analysis
- Three monthly seasonal fraction cover June – August 2021 (request from DES via email)
- Woody extent (request from DES)
- Statewide Landcover and Trees Study (SLATS) Sentinel-2-2019 woody vegetation extent
- Foliage Projection Cover (2019)
- Drainage basin – sub areas

2. Import all layers into spatial software (such as QGIS or ArcMap). Ensure that all of the layers have been imported in the correct projection and horizontal datum (i.e., the coordinate reference system (CRS)) and change if needed.
3. The first step is to erase all watercourse areas from the watercourse line dataset. This is to ensure that both of the datasets are not calculated twice.
4. Create the relevant riparian buffers with FLAT ends on both the watercourse line and area datasets. The recommended riparian buffers areas are outlined in Table 2.
5. Merge the created buffers into one shapefile.
6. Remove the estuarine wetlands from the buffer dataset. Estuarine areas are to be excluded from this assessment using Queensland's wetland layer
7. Clip the Seasonal Fractional Cover (groundcover) and Woody Extent to the created buffer shapefile.
8. Clip the Foliage Projective Cover (woody vegetation) to the riparian buffer zone (anything outside of the riparian buffer is to be removed).
9. Calculate the zonal statistics for each sub catchment. The zonal statistics are to be calculated based on rasters (Pixel Count X Pixel size) / 10,000 for hectares.
10. Calculate the following statistics for each catchment:

- Total riparian buffer area
- Seasonal fractional cover (ground cover) within the buffer area
    i. Low cover (<30%)
    ii. Medium cover (30%-70%)
    iii. High (>70%)
- Foliage projection cover of the woody extent within the buffer area
    i. Low cover (<30%)
    ii. Medium cover (30%-70%)
    iii. High (>70%)

Output of Step 4c

- A regional **GIS layer** of woody extent and ground cover clipped to the relevant buffers in accordance with their stream order. This is outlined in Table 2.

Step 4.3.d. Calculate Indicator Condition Scores

In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the Reference Benchmark value, however this method also incorporates a Worst Case Scenario value. The scoring formula is based on converting the observed indicator values to a "distance from benchmark" value. The distance from benchmark is expressed as a proportion (0 to 100) using the equations below. The riparian extent is calculated for all waterways within a catchment (or sub-asset).

Riparian Vegetation Indicator

For Riparian Vegetation for each catchment, the score is derived from a combination of the highest ground cover and the area of medium and highest woody extent. The ground cover extent component is weighted at 20% in recognition that it is not as effective as woody extent in stabilising river banks and providing habitat for aquatic and riparian biodiversity. Therefore, the observed value is the sum of the area within the riparian buffer area of highest category ground cover (e.g. >70%) weighted at 20%, with the area of the two highest woody extent categories, medium (30 -70%) and high (>70%) within the riparian buffer area.

Where:

REF = Reference Benchmark (in all cases 100%)
OBS = The sum of the sum of the area within the riparian buffer area of highest ground cover (>70%) weighted as 20% of that area, with the area of medium (30 -70%) and high (>70%) woody extent
WCS = Worst case scenario (in all cases 0%)

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Riparian Veg % coverage</td><td>Where REF > WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>100</td></tr>
<tr><td>If OBS < REF</td><td>$100 \times \frac{OBS-WCS}{REF-WCS}$</td></tr>
<tr><td>If OBS =WCS</td><td>0</td></tr>
</table></td></tr>
</table>

Output of Step 4d

- A **Data Table** (e.g. a spreadsheet) containing all the data., including observed values, reference values and calculated Indicator Condition Scores

4. Creating the Environmental Account – Calculating the Econd®

Step 5. Calculate the Econd®

The Econd® is an index between 0 and 100, where 100 describes the 'best-on-offer' or 'pre-development' reference condition of an environmental asset, and 0 indicates the asset is completely degraded.

This Method prescribes instructions for calculating Econd® indices for each sub-asset (each catchment) and then aggregating these into the overall Econd® for the Waterway Environmental Asset.

The following steps must be taken to calculate the Econd®:

1. The **catchment** Econd® scores are calculated as the average of the Indicator Condition Scores for each Indicator Class – Water Quality, Ecological Flow and Riparian Extent (i.e 33% WQ, 33% Riparian and 33% Ecological Flow). If using the eDNA Method (AfN-METHOD-F-05) to also assess aquatic vertebrate condition, then include the results from the eDNA analysis with equal weighting of all indicator classes.
2. Next, the Econd® for the waterway asset is calculated for the whole Account as a length weighted average of the **catchment** Econd® indices.
    - Note. The 'length' of the waterways within each catchment is to be calculated and used to scale the aggregation of the final Econd®. The length of waterways should be determined using the Adopted Middle Thread Distances (AMTD) established by the Queensland Water Resources Commission in the 1950s for all major streams in the state in accordance with the Report on Condition and trends in Water Quality in Central Queensland Estuaries (1993 to 2015).

Output of Step 5.

- A **data table** (e.g. a spreadsheet) containing all the raw data for each indicator for each sample, including the calculations for the ICS and Econd®, grouped by sub-asset (waterway).
- A **summary table** showing the Econd® scores for the region, grouped by sub-asset.

5. Compile Environmental Account and submit for certification

Steps five to seven should be repeated at regular intervals (a minimum of every five years or where Base Year recalculation is required, as specified under the *Accounting for Nature®* Framework) to establish a trend over time. Ideally, site surveys should occur annually, even if accounts are only certified once every five years.

If you wish for your account to be certified, it must be verified in accordance with the *Accounting for Nature® Standard*, which outlines the criteria that must be satisfied. The benefit of having an account certified is that AfN allows you to display the Certified Account logo and you are able to make public claims about your account. AfN Certified Accounts require the Environmental Account Summary and Information Statement to be made publicly available.

An Certified Environmental Account may incorporate multiple environmental assets, and always needs to include the following information:

- Information Statement and Environmental Account Summary,
- Environmental Account (including raw data tables); and;
- An **Audit Report** or **Self-verification Report** that verifies the account was prepared in accordance with the approved Methods, the AfN Standard and Audit Rules.
    - An **Audit Report** is completed by an AfN Accredited Auditor and is required if you are seeking to have your account "Certified" (Tier 1); OR
    - A **Self-verification Report** contains the results of your self-verification assessment and AfN's technical Assessment and is required if you are seeking to have your account "Self-verified" (Tier 2).

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Appendix A - Glossary

Table 12. Glossary

Term	Definition
Assessment unit	Assessment units are homogenous units within the accounting area which determine where samples are to be taken.
Econd®	An index between 0 and 100 that describes the condition of an environmental asset where 0 means the asset is completely degraded, and 100 means the asset is in pristine condition.
Enclosed coastal/lower estuary (ECLE)	Coastal waters with reduced influence or exchange with ocean waters. It includes shallower coastal waters enclosed by offshore islands or in embayments. It also includes the most downstream reaches of estuaries – the zone which exchanges with coastal waters on every tide. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Indicator Condition Score	In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the Reference Benchmark value. However, the formulas for calculating this can vary considerably between indicators—some incorporate weightings and conditional clauses to reflect the ecological thresholds associated with some vegetation attributes.
Upper estuary (UE)	The most upstream reaches of estuaries – areas subject to very little tidal movement and poor flushing/dispersion during dry weather. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Mid estuary (ME)	All estuarine waters upstream of the immediate influence of strong daily tidal exchange but excluding upper estuarine waters. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Reference Benchmark	The Reference Benchmark is the condition of the native vegetation sub-asset in an 'undegraded' state. For example, a vegetation community that has not experienced any negative impacts as a result of disturbance, edge effects, invasive species, or altered management regimes (e.g. fire) would be considered to exist in an 'undegraded' or 'ideal' state.

Appendix B- Riparian Buffer Width

Lovett and Price (2001) suggest the recommended buffers outlined in the table below are sufficient to protect and maintain bank stability, aquatic health, water quality and terrestrial habitat.

Table 13. Recommended buffers by Lovett and Price (2001)

Stream order	Riparian buffer width (m)
Creeks and watercourses in sugar growing areas	25
Rivers in sugar growing areas	50
1-2	50
3-4	75
5-6	200

Lovett, S. and Price, P., 2001. Managing Riparian Lands in the Sugar Industry: A Guide to Principles and Practices, Sugar Research and Development Corporation/Land and Water Australia, Brisbane.

This guideline has been generated to ensure that waterfront land is minimally damaged due to any proposed controlled activity. The riparian buffer widths are based on the stream order, that has been classified under the Strahler System.

Table 14. Recommended riparian buffers in New South Wales.

Stream order	Riparian buffer width (m)
1	20
2	40
3	60
4	80

Department of Primary Industries, Office of Water (2012) Guidelines for riparian corridors on waterfront land. New South Wales Government.

The recommended riparian buffer widths in Victoria have been based on management objectives of the landscape. The land use intensity was calculated using the median value and was increased by the 25th percentile for each increase in intensity (Hansen et al. 2010).

Table 15. Recommended riparian buffers in Victoria.

Management Objective	Land use intensity high	Land use intensity moderate	Land use intensity low	Wetland/low floodplain/off-stream water bodies	Steep catchment/cleared hillslopes/low order streams
Improve water quality	60	45	30	120	40
Moderate steam temperatures	95	65	35	40	35
Provide food and resources	95	65	35	40	35

Improve in-stream biodiversity	100	70	40	Variable*	40
Improve terrestrial biodiversity	200	150	100	Variable*	200

* Variability in width is related to the lateral extent of hydrological connectivity. As such recommendations for this will have to be site specific.

Hansen, B, Reich, P, Lake, PS, Cavagnaro, T (2010) Minimum width requirements for riparian zones to protect flowing waters and to conserve biodiversity: a review and recommendations, with application to the State of Victoria.

Appendix C- Definitions

Table 16. Definitions utilised throughout the ecological flow section.

Term used in Water Plan	Definition
Mean annual flow.	Means the total volume of flow in the simulation period divided by the number of years in the simulation period
50% daily flow for a month	Means the flow, in megalitres, that is equalled or exceeded on 50% of days in the month in the simulation period.
90% daily flow for a month	Means the flow, in megalitres, that is equalled or exceeded on 90% of days in the month in the simulation period.
10cm daily flow (ML/day) (annual)	Means the total number of days in the judgement period that the watercourse's daily flow is at least 10cm above the cease-to-flow level in the watercourse.
30cm daily flow (ML/day) (annual)	Means the total number of days in the judgement period that the watercourse's daily flow is at least 30cm above the cease-to-flow level in the watercourse.
1.5-year daily flow volume	Means the daily flow that has a 67% probability of being reached at least once a year.
5-year daily flow volume	Means the daily flow that has a 20% probability of being reached at least once a year.
20-year daily flow volume	Means the daily flow that has a 5% probability of being reached at least once a year.
Refugia	Means the habitat required by a species during a time of stress, for example, drought.

Appendix D- Determining Ecological Flows

Thresholds used to calculate the 10cm and 30cm flow benchmarks

Two of the indicators for the Mary River catchment required benchmarks calculated from pre-development data. This is because these values have been derived from models that depict unimpeded or natural flow conditions of each catchment.

For the pre-development data within Environment Conditions Report – Volume 2 for the Mary Basin the following tables in the linked document:

- Table B7 – 10cm flow (Number of Spells)
- Table B8 – 30cm flow (Number of Spells)

These values have been summarised below in Table 17

Table 17. 10 cm and 30 cm flow thresholds for the Mary Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Amamoor Creek at Zachariah	16	86
Glastonbury Creek at Glastonbury	5	55
Kandanga Creek at Hygait	3	50
Mary River at Home Park	2	105
Mary River at Bellbird Creek	13	130
Mary River at Miva	3	52
Mary River at Moy Pocket	4	43
Munna Creek at Marodian	5	55
Obi Obi Creek at Gardners Falls	5	55
Six Mile Creek at Cooran	1	20
Teewah Creek at Coops Corner	-	-
Tinana Creek at Bauple East	5	55
Tinana Creek at Tagigan	5	55
Wide Bay at Brooyar	5	67
Wide Bay at Kilkivan	5	67

Pre-development data is missing for the 10cm and 30cm daily flow indicators for both the Burnett and Baffle Basins so these thresholds were calculated using long term data from each gauge. Table 18 and 19 present the calculated thresholds, which was determined using data from a rating table from WMIP and a natural cubic spline analysis.

Table 18. Calculated 10 cm and 30 cm flow thresholds for the Burnett Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Auburne River at Dykehead	3	59
Barambah Creek at Ban Ban	77	89
Barambah Creek at West Barambah	5	69
Barambah Creek at Litzows	0.39	1.2
Barker Creek at Brooklands	8	71
Barker Creek at Glenmore	4	40
Boyne River at Carters	0.5	2
Boyne River at Cooranga	14	93
Burnett River at Ceratodus	7	91
Burnett River at Eidsvold	4	48
Burnett River at Fig Tree	32	246
Burnett River at Gayandah	-	-
Burnett River at Jones Weir	-	-
Burnett River at Tailwater	17	34
Burnett River at Mount Lawless	11	197
Burnett River at Walla	-	-
Cadarga Creek at Brovinia Station	1	23
Eastern Creek at Lands End	10	170
Elliot River at Dr Mays	7	33
Elliot River at Elliot	-	-
Gin Gin Creek at Brushy Creek	35	287
Gregory River at Isis Highway	10	67
Isis River at Bruce Highway	4	75
Kolan River at Springfield	6	57
Monal Creek at Upper Monal	0.3	27
Reid Creek at Mungy	7	71
Splinter Creek at Dakiel	2	42
Stuart River at Proston Rifle Range	7	70
Stuart River at Weens Bridge	0.09	10
Three Moon Creek at Abercorn	23	29

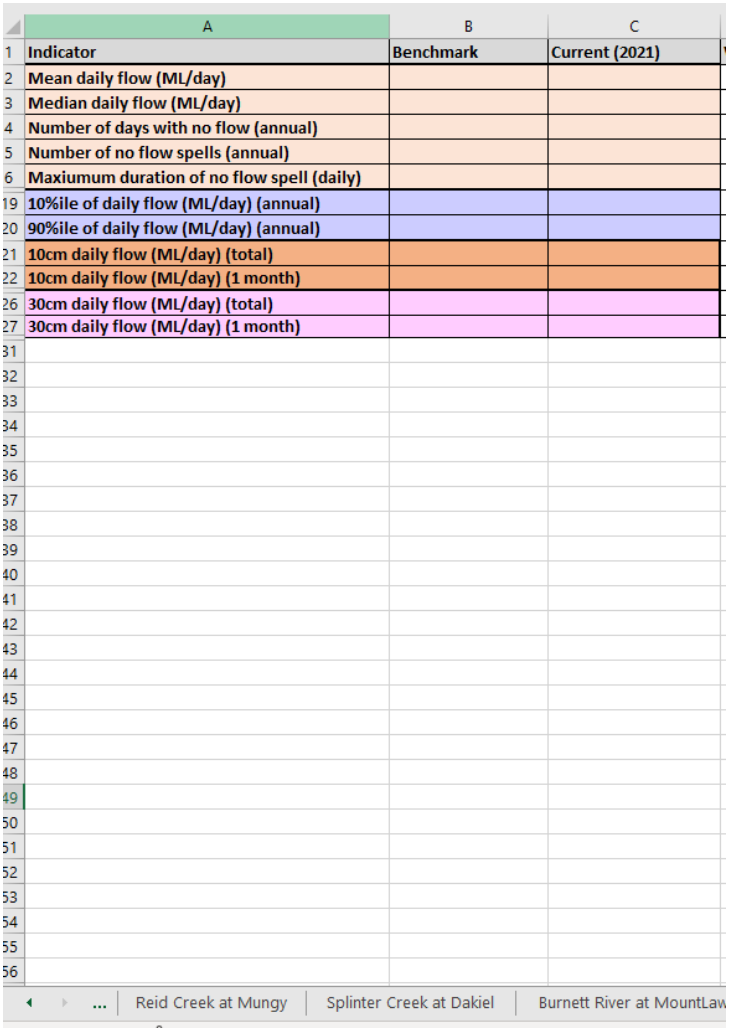
Table 19. Calculated 10 cm and 30 cm flow thresholds for the Baffle Creek Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Baffle Creek at Mimdale	4	89
Oyster Creek at Rapleys	2	76

Reference Benchmark Calculation Method

Set-up spreadsheet

1. Prior to the benchmark calculation, a spreadsheet will need to be setup for each stream gauge, refer to the Figure below as an example on how to set up the spreadsheets. When filling in the spreadsheet ensure that you enter it into the "benchmark" column. The benchmark column will be used as a reference benchmark. The "current" column will be used for data analysed for the annual reporting period (e.g. 2021).



	A	B	C
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)		
3	Median daily flow (ML/day)		
4	Number of days with no flow (annual)		
5	Number of no flow spells (annual)		
6	Maxiumum duration of no flow spell (daily)		
19	10%ile of daily flow (ML/day) (annual)		
20	90%ile of daily flow (ML/day) (annual)		
21	10cm daily flow (ML/day) (total)		
22	10cm daily flow (ML/day) (1 month)		
26	30cm daily flow (ML/day) (total)		
27	30cm daily flow (ML/day) (1 month)		

... | Reid Creek at Mungy | Splinter Creek at Dakiel | Burnett River at MountLaw

Data Organisation and Cleaning

To calculate the reference benchmarks and current conditions of the waterways, stream gauge data will need to be downloaded from the Water Monitoring Information Portal (WMIP). The following gauge datasets will need to be downloaded:

Mary

- Amamoor Creek at Zachariah
- Glastonbury Creek at Glastonbury
- Kandanga Creek at Hygait
- Mary River at Home Park
- Mary River at Bellbird Creek
- Mary River at Miva

- Mary River at Moy Pocket
- Munna Creek at Marodian
- Obi Obi Creek at Gardners Falls
- Six Mile Creek at Cooran
- Teewah Creek at Coops Corner
- Tinana Creek at Bauple East
- Tinana Creek at Tagigan
- Wide Bay at Brooyar
- Wide Bay at Kilkivan

Burnett

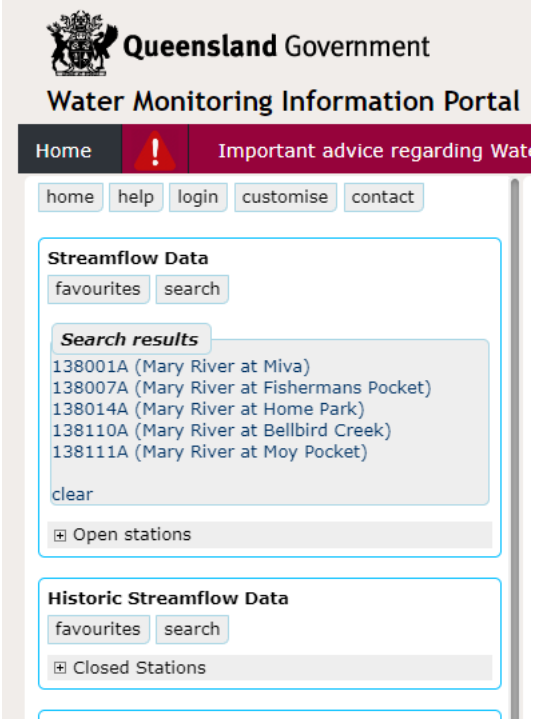
- Auburn River at Dykehead
- Barambah Creek at West Barambah
- Barambah Creek at Ban Ban
- Barambah Creek at Litzows
- Barker Creek at Brooklands
- Barker Creek at Glenmore
- Boyne River at Carters
- Boyne River at Ceratodus
- Boyne River at Cooranga
- Burnett River at Eidsvold
- Burnett River at Jones Weir Headwater
- Burnett River at Tailwater
- Burnett River at Gayandah
- Burnett River at Mount Lawless
- Cadarga Creek at Brovinia
- Eastern Creek at Lands End
- Elliot River at Dr Mays
- Elliot River at Figtree
- Gregory River at Isis Highway
- Isis River at Bruce Highway
- Kolan River at Springfield
- Monal Creek at Upper Monal
- Reid Creek ay Mungy
- Splinter Creek at Dakiel
- Stuart River at Proston
- Stuart River at Weens Bridge
- Three Moon Creek at Abercorn

Baffle

- Oyster Creek at Rapleys
- Baffle Creek at Mimdale

2. To download the data from Water Monitoring Information Portal (WMIP) do the following:

- Search for the waterway :

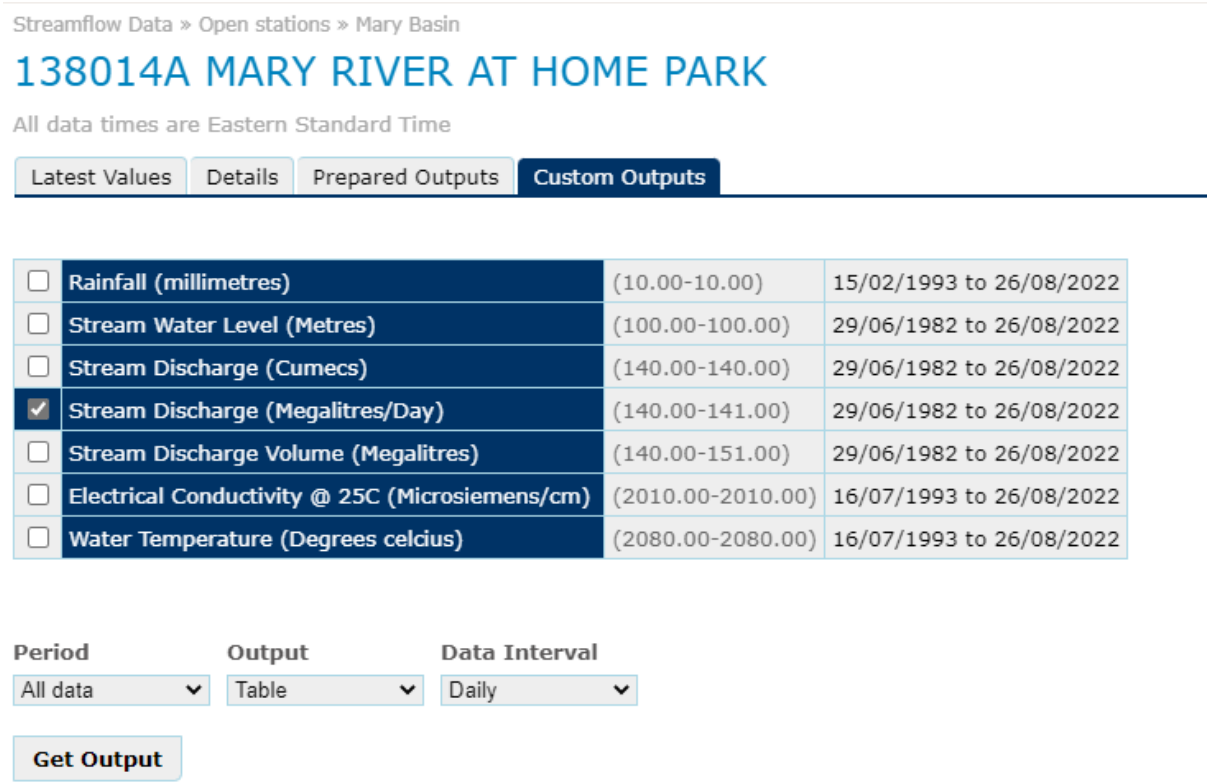


- Click custom outputs: stream discharge (megalitres/day)

Period: All data

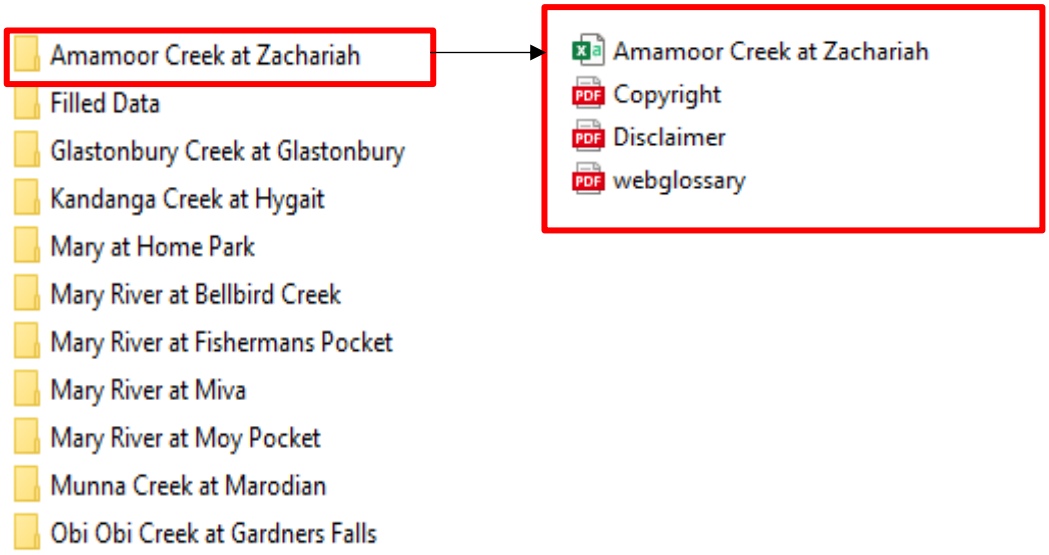
Output: Table

Data Interval: Daily



- Click 'Get Output' and the file will automatically download.

3. Once the data has been downloaded from Water Monitoring Information Portal (WMIP) it will need to be organised into folders and clearly labelled for future use (refer below).



4. Each spreadsheet will need to be opened and cleaned (see example below) so that it can be recognised by the River Analysis Package (RAP) software. If the data is not cleaned it will not be recognised by RAP.

5. Only two columns should be left in the spreadsheet, which includes the time/date and mean ML/day (refer below).

6. Ensure that the stream gauge number is changed to the stream gauge name (refer below). If the name is not changed from the stream gauge number to the stream gauge name, there could be added confusion on what dataset you are analysing.

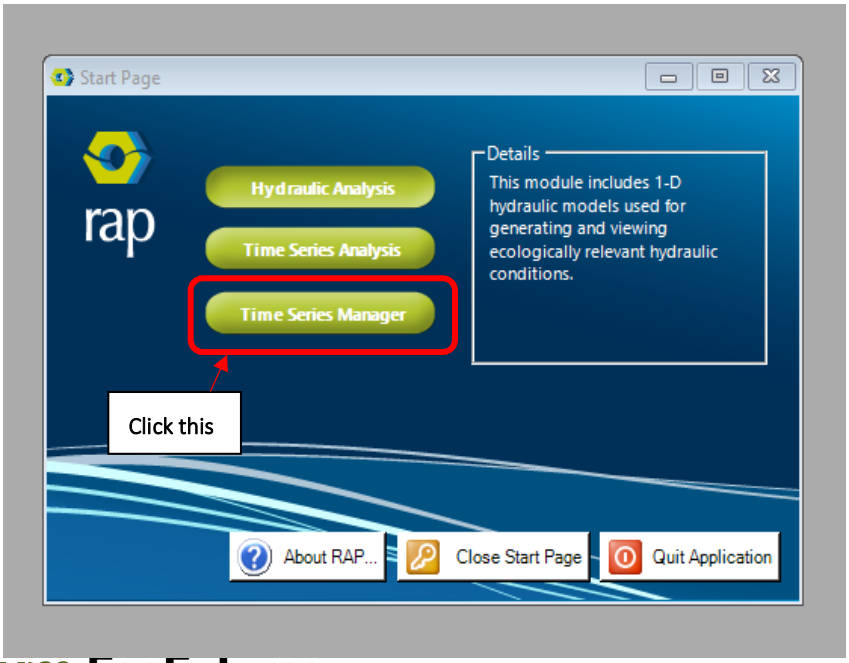
	A	B	C	D	E	F	G
1	Time	Amamoor Creek at Zachariah					
2	and	141					
3	Date	Discharge (ML/day)					
4	Date and time	Mean					
5	29/11/1984 0:00	12.78					
6	30/11/1984 0:00	10.32					
7	1/12/1984 0:00	9.59					
8	2/12/1984 0:00	7.69					
9	3/12/1984 0:00	8.72					
10	4/12/1984 0:00	12.61					
11	5/12/1984 0:00	14.57					
12	6/12/1984 0:00	13.27					
13	7/12/1984 0:00	25.6					
14	8/12/1984 0:00	60.21					
15	9/12/1984 0:00	39.56					
16	10/12/1984 0:00	29.04					
17	11/12/1984 0:00	25.3					
18	12/12/1984 0:00	22.8					
19	13/12/1984 0:00	21.87					
20	14/12/1984 0:00	20.02					
21	15/12/1984 0:00	22.33					
22	16/12/1984 0:00	17.36					
23	17/12/1984 0:00	13.69					
24	18/12/1984 0:00	13.22					
25	19/12/1984 0:00	15.33					
26	20/12/1984 0:00	294.9					
27	21/12/1984 0:00	120.64					
28	22/12/1984 0:00	59.9					
29	23/12/1984 0:00	39.57					
30	24/12/1984 0:00	29.19					
31	25/12/1984 0:00	25.3					
32	26/12/1984 0:00	22.8					
33	27/12/1984 0:00	21.77					
34	28/12/1984 0:00	17.92					
35	29/12/1984 0:00	22.59					
36	30/12/1984 0:00	40.4					
37	31/12/1984 0:00	28.94					

Amamoor Creek at Zachariah

7. Once the data is organised it can now be uploaded into RAP for gap analysis and filling using the Time Series Manager (TSM) in the River Analysis Package tool. The RAP is a software package that examines the hydraulic characteristics of waterways to determine the discharge for a waterway. The TSM manipulates and manages the time series data and fills in gaps within the dataset where there are missing values.

Time Series Manager

1. Open up RAP and select 'time series manager'

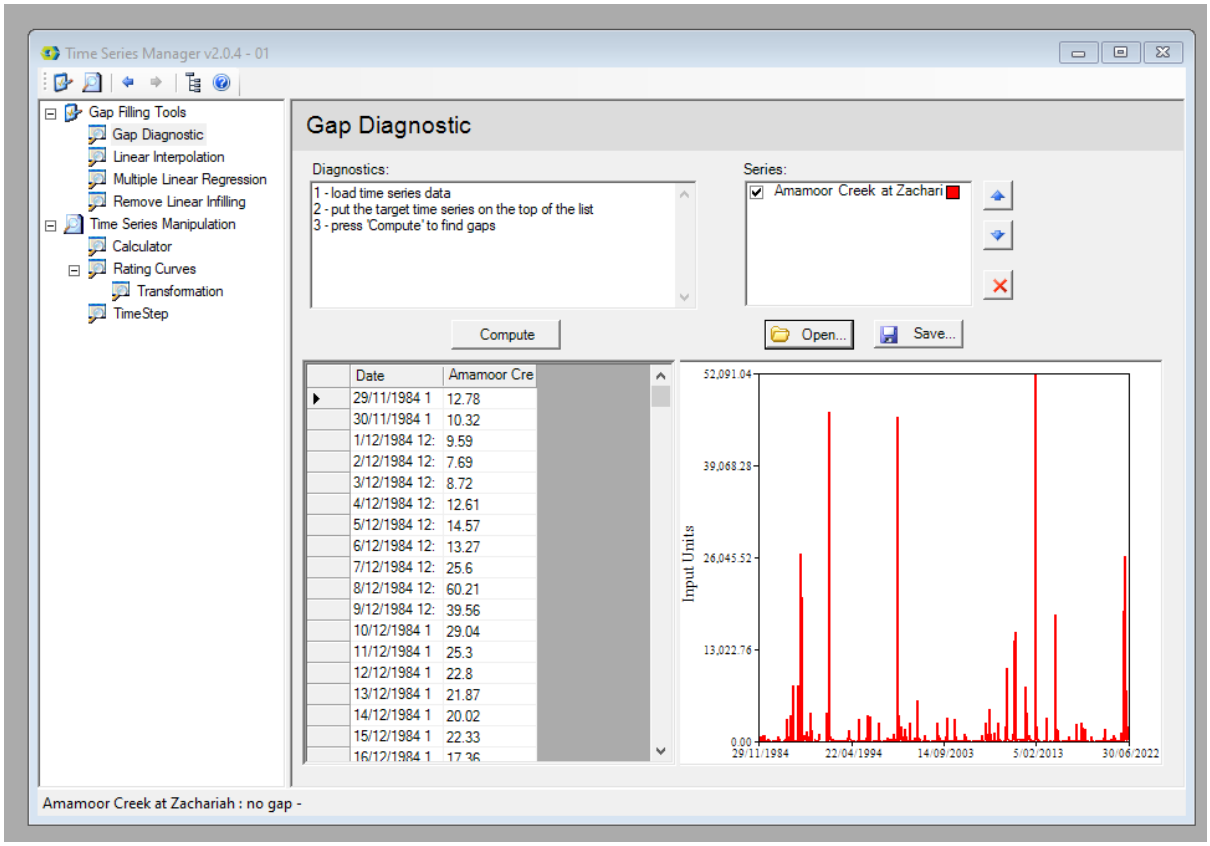


2. Click gap diagnostic and click open and upload a cleaned spreadsheet. The cleaned spreadsheet should look like this:

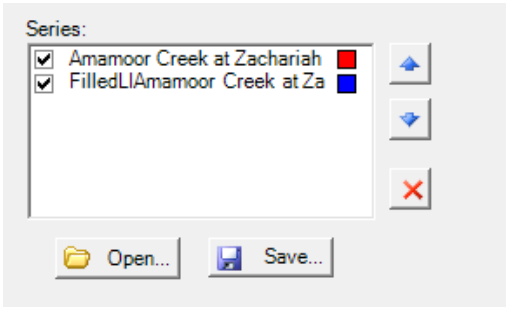
	A	B	C	D	E	F	G
1	Time	Amamoor Creek at Zachariah					
2	and	141					
3	Date	Discharge (ML/day)					
4	Date and time	Mean					
5	29/11/1984 0:00	12.78					
6	30/11/1984 0:00	10.32					
7	1/12/1984 0:00	9.59					
8	2/12/1984 0:00	7.69					
9	3/12/1984 0:00	8.72					
10	4/12/1984 0:00	12.61					
11	5/12/1984 0:00	14.57					
12	6/12/1984 0:00	13.27					
13	7/12/1984 0:00	25.6					
14	8/12/1984 0:00	60.21					
15	9/12/1984 0:00	39.56					
16	10/12/1984 0:00	29.04					
17	11/12/1984 0:00	25.3					
18	12/12/1984 0:00	22.8					
19	13/12/1984 0:00	21.87					
20	14/12/1984 0:00	20.02					
21	15/12/1984 0:00	22.33					
22	16/12/1984 0:00	17.36					
23	17/12/1984 0:00	13.69					
24	18/12/1984 0:00	13.22					
25	19/12/1984 0:00	15.33					
26	20/12/1984 0:00	294.9					
27	21/12/1984 0:00	120.64					
28	22/12/1984 0:00	59.9					
29	23/12/1984 0:00	39.57					
30	24/12/1984 0:00	29.19					
31	25/12/1984 0:00	25.3					
32	26/12/1984 0:00	22.8					
33	27/12/1984 0:00	21.77					
34	28/12/1984 0:00	17.92					
35	29/12/1984 0:00	22.59					
36	30/12/1984 0:00	40.4					
37	31/12/1984 0:00	28.94					

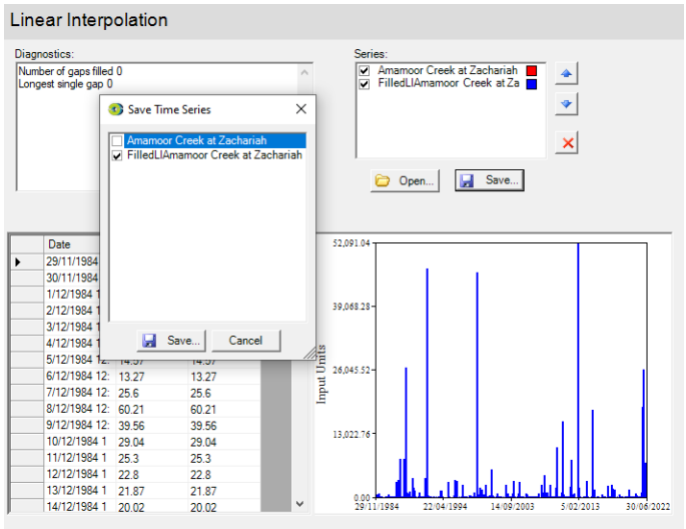
Amamoor Creek at Zachariah

3. When the data has been uploaded to RAP it should look like this:



4. This tool is being used to identify any gaps (i.e. missing values) within the dataset. RAP cannot do any analyses with missing values. Once the file has been uploaded click compute and check the diagnostic box to see if there are any gaps within the data.
5. Where gaps are identified a linear interpolation will be required. The linear interpolation fills in the gaps, with interpolating between the last and next value within the spreadsheet.
6. On the side-bar click linear interpolation and then click compute, once the gaps are filled save the new filled datasheet into a new folder called 'filled data'. This will be the data that will be used for the analysis process.



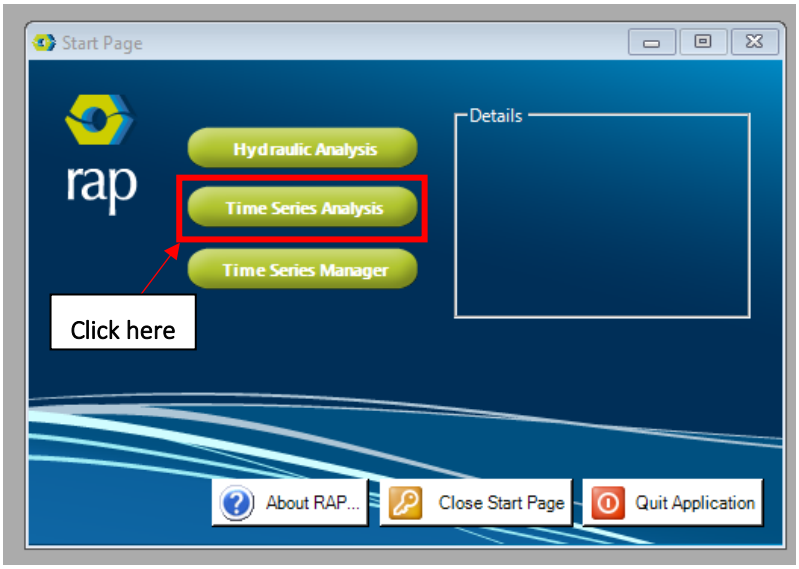


7. Repeat this step for all of the stream gauge data downloaded from WMIP.

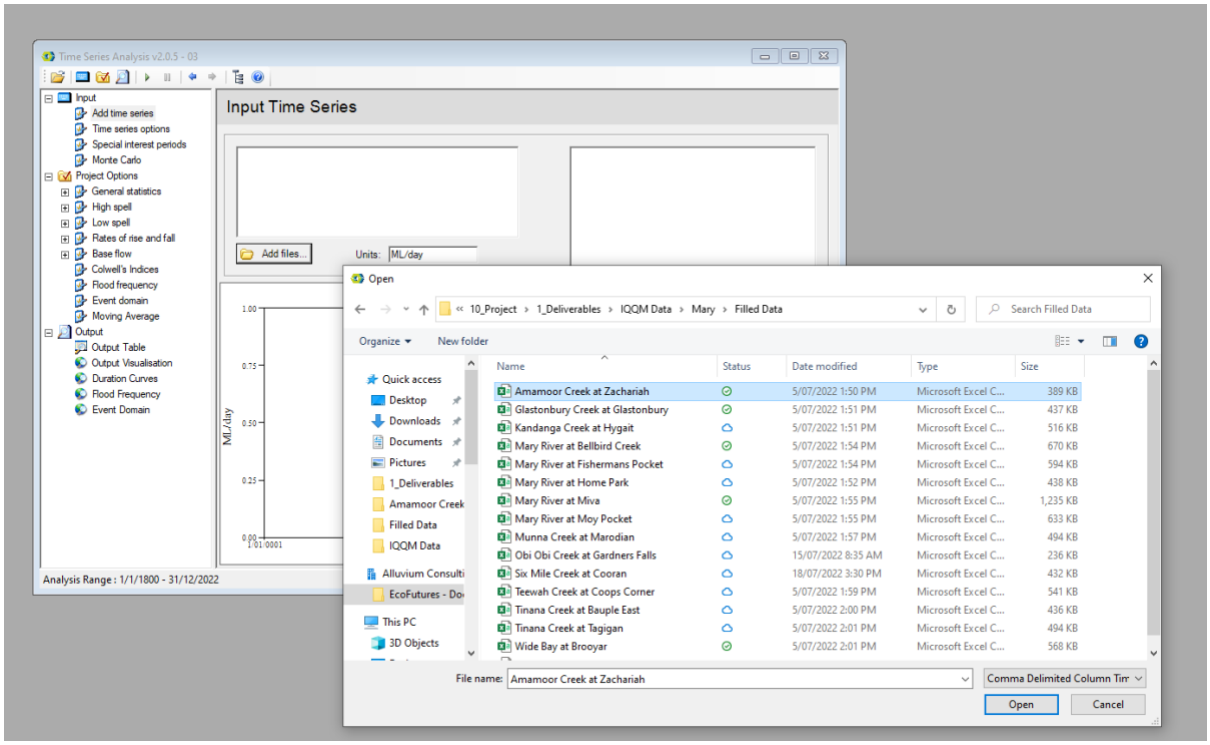
8. Where there are no gaps, copy and paste the stream gauge sheet into the filled data folder so you are working from one working space.
9. Now you have a full dataset ready for analysis.

Time Series Analysis

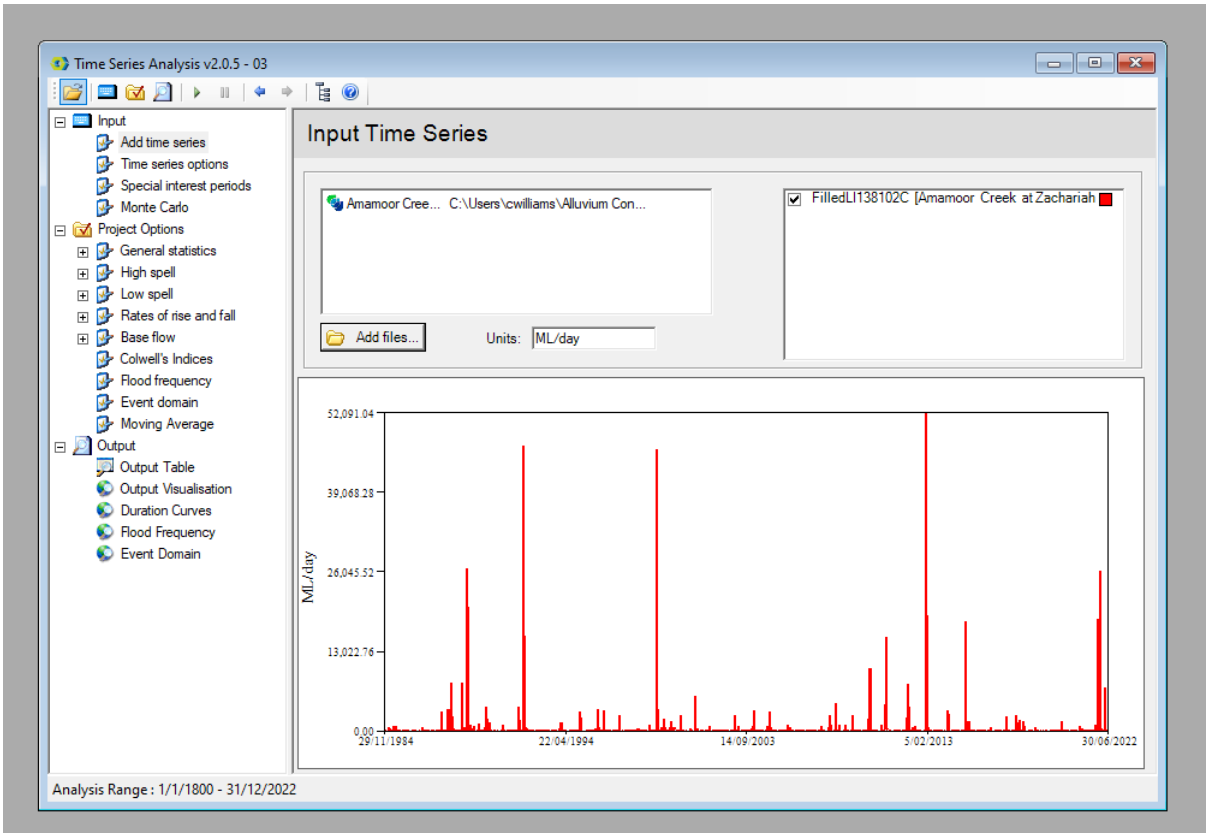
8. Click 'Time Series Analysis'



9. Upload a filled spreadsheet by clicking 'Add files' and choose one stream gauge at a time. If multiple spreadsheet are chosen it can cause errors in the data analysis.

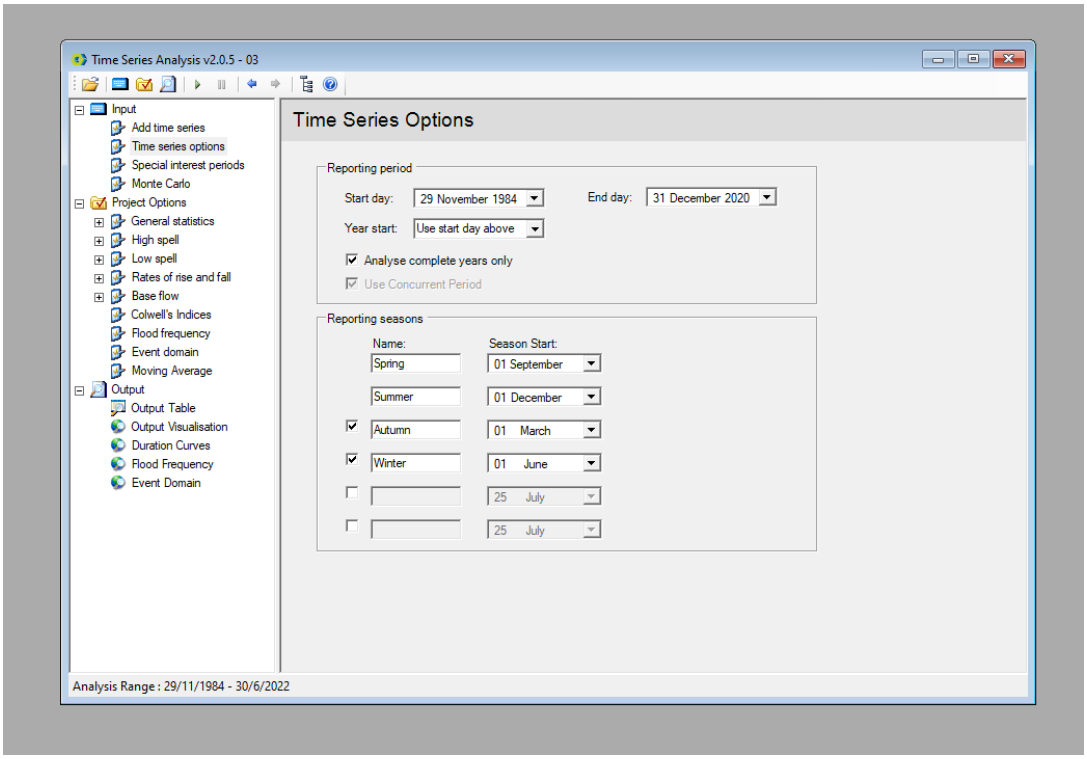


10. When uploaded it should look like this:



11. Now we are going to calculate the historical benchmarks. The historical benchmarks will be used to calculate the indicator condition scores where pre-development data is not available. To do that, the 'time series option' in the package will need to be changed.

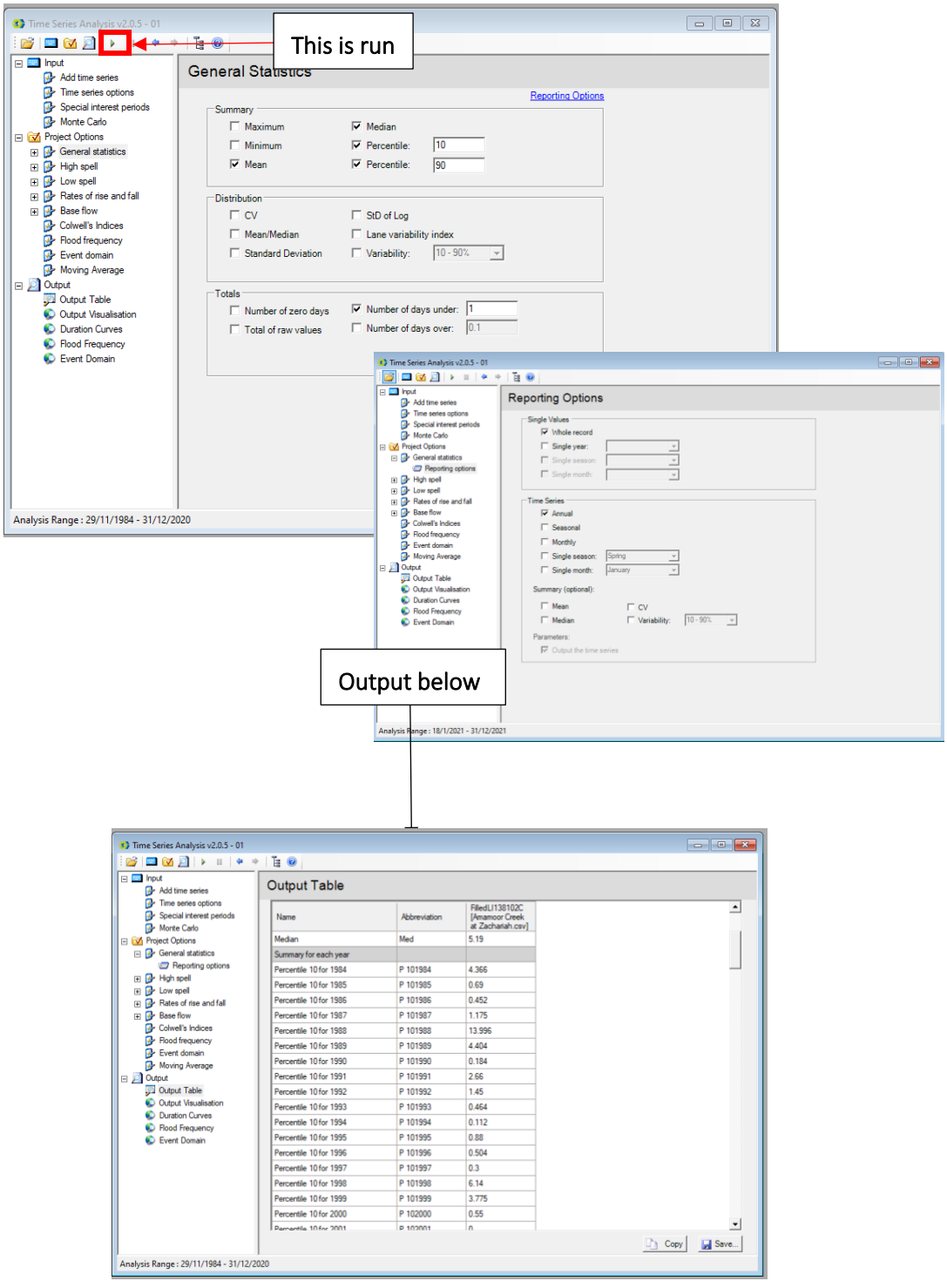
12. Go to 'time series options' and ensure the time frame for the start day is when the stream gauge started collecting data (e.g. 1984), and change the end date to 31st December 2020.



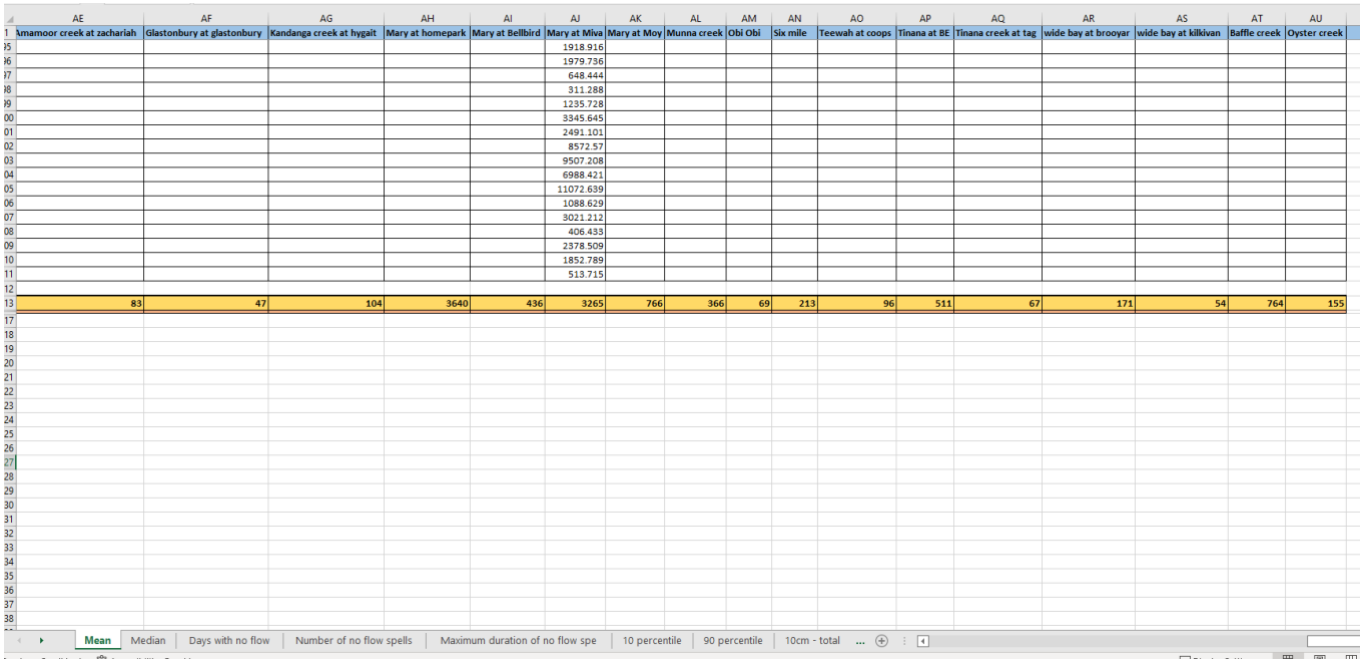
13. To calculate the general statistics, start by clicking the general statistics tab and ticking the following:
    - Mean
    - Median
    - 10th percentile
    - 90th percentile

This will tell the tool to calculate the data needed for these indicators.

14. Go to reporting options and tick 'Annual'
15. Click run



16. From the output table, copy and paste each indicator for each year into a new spreadsheet in order to calculate the mean annual value for each indicator across the historical period (refer to the example below). To calculate the mean use the following equation =AVERAGE(REF:REF). The REF represents the number of rows selected within a column.



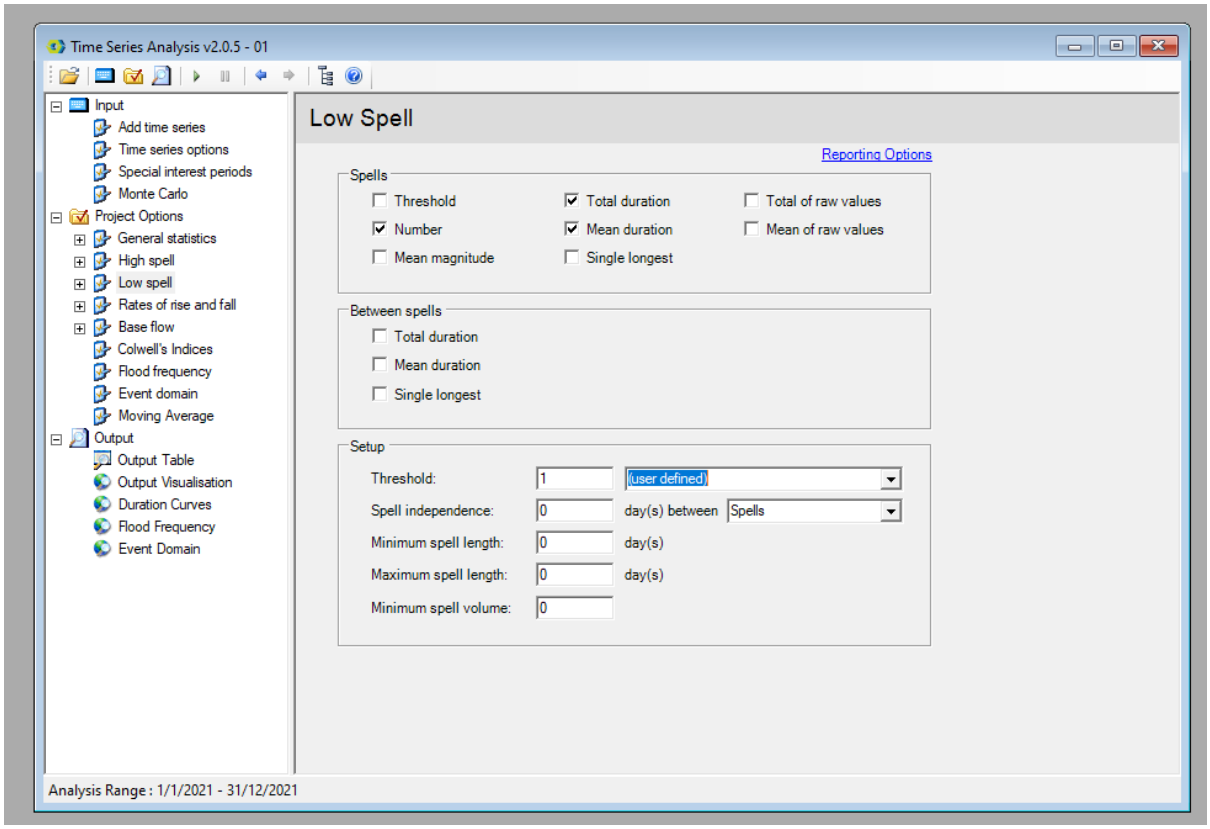
	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1	Amamoor creek at zachariah	Glastonbury at glastonbury	Kandanga creek at hygait	Mary at homepark	Mary at Bellbird	Mary at Miva	Mary at Moy	Munna creek	Obi Obi	Six mile	Teewah at coops	Tinana at BE	Tinana creek at tag	wide bay at brooyar	wide bay at kilkivan	Baffle creek	Oyster creek
95						1918.916											
96						1979.736											
97						648.444											
98						311.288											
99						1235.728											
00						3345.645											
01						2491.101											
02						8572.57											
03						9507.208											
04						6988.421											
05						11072.639											
06						1088.629											
07						3021.212											
08						406.433											
09						2378.509											
10						1852.789											
11						513.715											
12																	
13	83	47	104	3640	436	3265	766	366	69	213	96	511	67	171	54	764	155

Mean | Median | Days with no flow | Number of no flow spells | Maximum duration of no flow spe | 10 percentile | 90 percentile | 10cm - total

17. Enter the generated data (mean) into the 'Benchmark' column of the prepared spreadsheet:

Indicator	Benchmark	Current (2021)
Mean daily flow (ML/day)		
Median daily flow (ML/day)		
Number of days with no flow (annual)		
Number of no flow spells (annual)		
Maxiumum duration of no flow spell (daily)		
10%ile of daily flow (ML/day) (annual)		
90%ile of daily flow (ML/day) (annual)		
10cm daily flow (ML/day) (total)		
10cm daily flow (ML/day) (1 month)		
30cm daily flow (ML/day) (total)		
30cm daily flow (ML/day) (1 month)		

18. The next part of the analysis will give you the number of days with no flow (total duration), number of no flow spells historically (number) and will outline out of those no flow spells (single longest), which one last the longest in terms of duration (days in a row with flow <1ML/day).
19. To do that, go back to the "general statistic tab' and unclick all of the boxes in general statistics.
20. Go to 'Low Spell', click under spells: total duration, number and single longest. In the section called 'setup' click the drop-down box and change it to 'user defined' and change threshold to 1.
21. Go to reporting options and tick 'Annual'
22. Click run

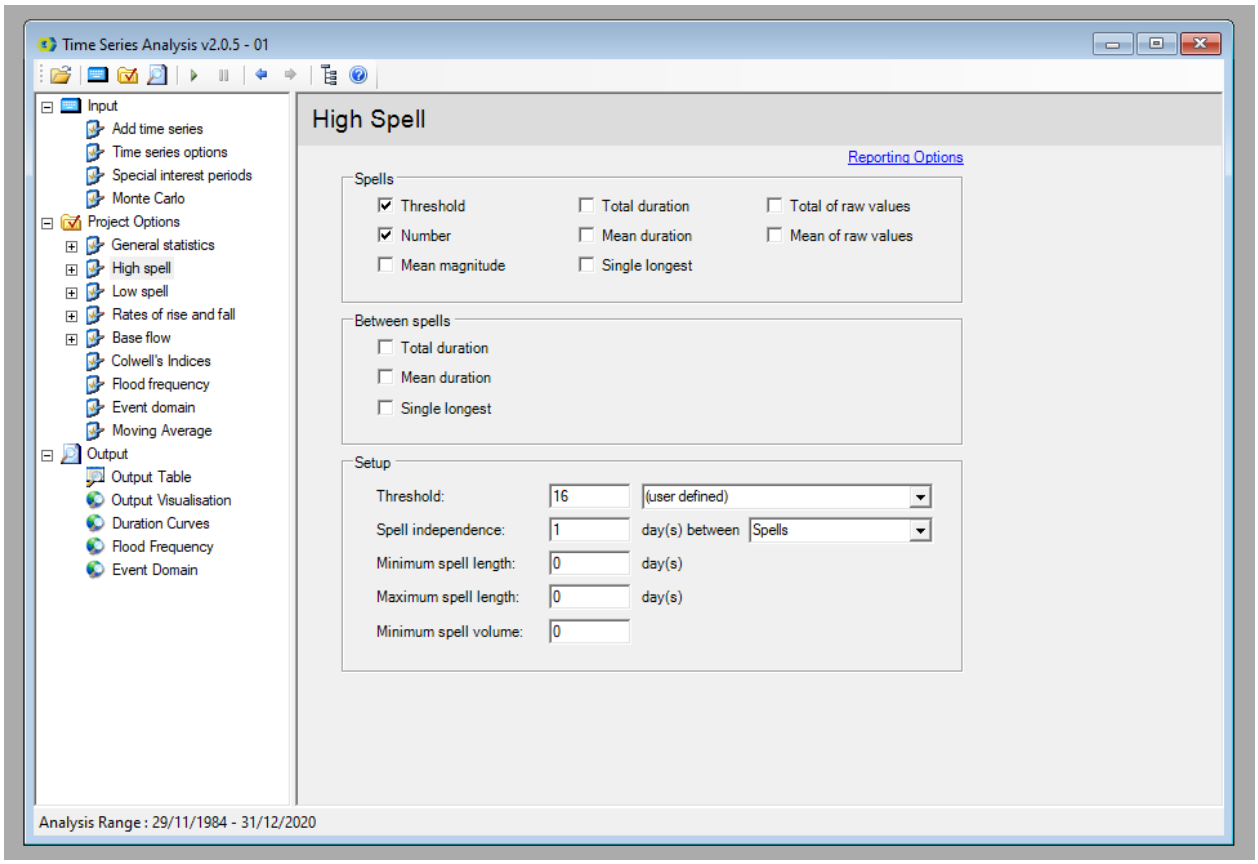


23. Copy and paste each indicator for each year into an excel spreadsheet in order to calculate the average across the historical period (refer to the example below). To calculate the average use the following equation =AVERAGE(REF:REF). The REF represents the number of rows selected within a column.
24. The averaged data will need to be added into the spreadsheet:

	A	B	D
1	**Indicator**	**Benchmark**	**Current (2021)**
2	**Mean daily flow (ML/day)**	54	51
3	**Median daily flow (ML/day)**	7	0
4	**Number of days with no flow (annual)**	220	160
5	**Number of no flow spells (annual)**	5	6
6	**Maxiumum duration of no flow spell (daily)**	97	92
19	**10%ile of daily flow (ML/day) (annual)**	2	0
20	**90%ile of daily flow (ML/day) (annual)**	44	37
21	**10cm daily flow (ML/day) (total)**	5	8
22	**10cm daily flow (ML/day) (1 month)**	1	0
26	**30cm daily flow (ML/day) (total)**	5	5
27	**30cm daily flow (ML/day) (1 month)**	0.1	0

25. Once the data has been entered, go back to the 'low spell' tab and unclick all of the boxes.

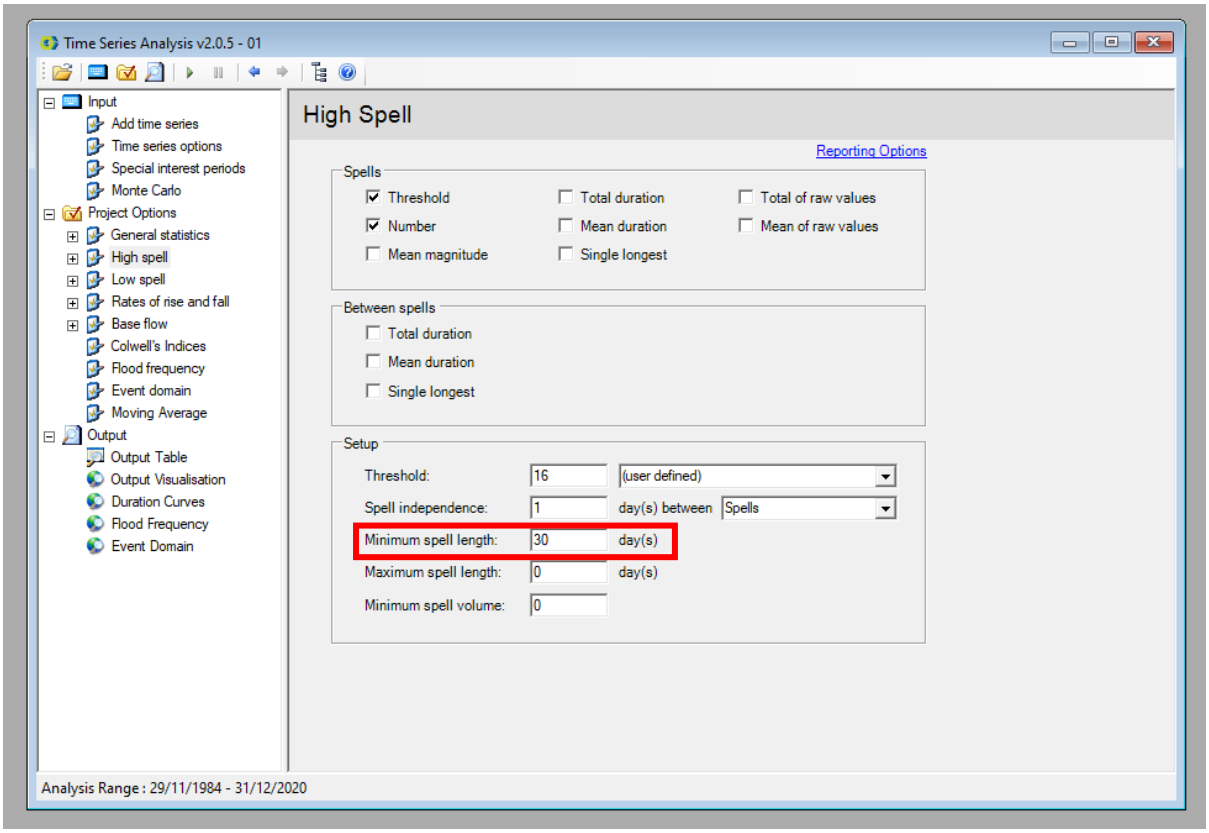
26. To calculate the 10cm and 30cm flow data, go to the 'High Spell' tab and click threshold and number under spells. In setup click the drop-down box and change it to user defined and place the threshold in the 'threshold' box and leave the minimum spell length as zero for the total.
27. Go to reporting options and tick 'Annual'.
28. Click run.
29. The threshold values for this assessment can be found in the Table 17, Table 18 and Table 19.



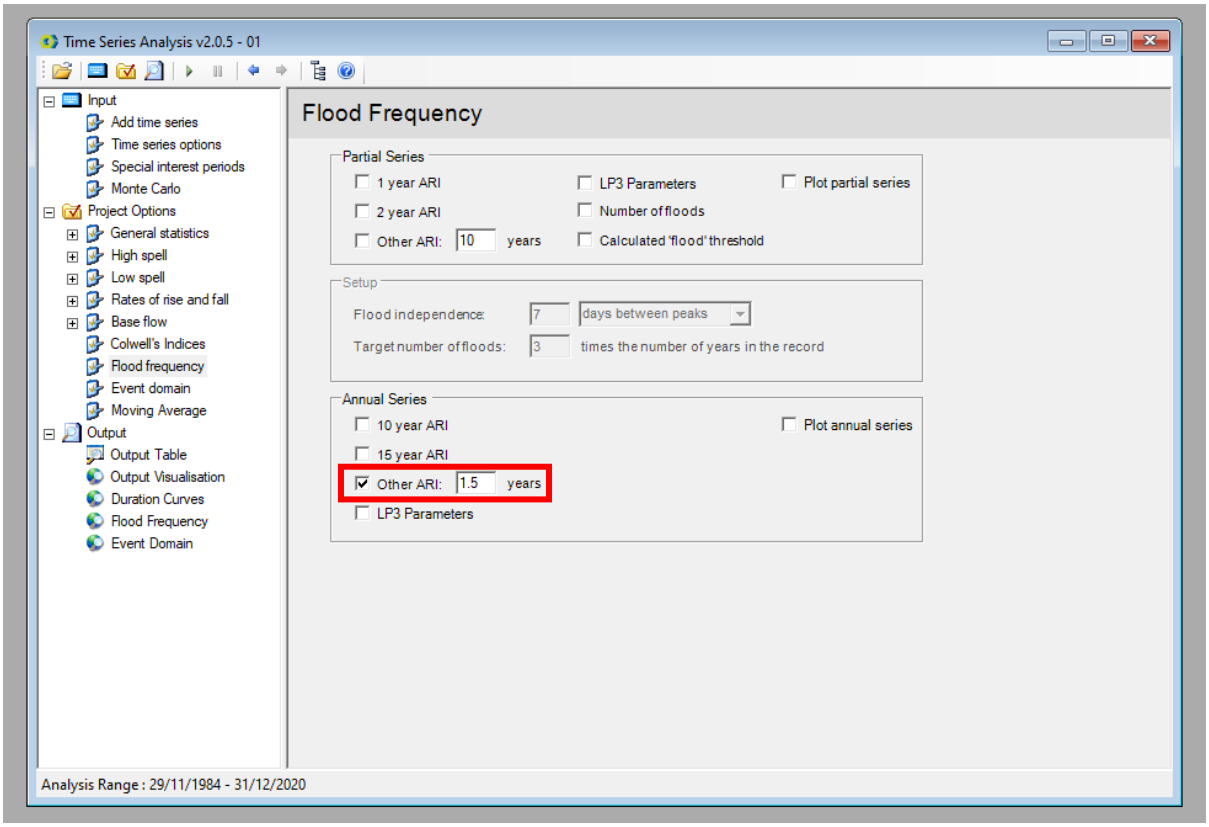
30. Once you have the averaged value, add it into the spreadsheet row called '10cm daily flow (ML/day) (total)' and 30cm daily flow (ML/day) (total).

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

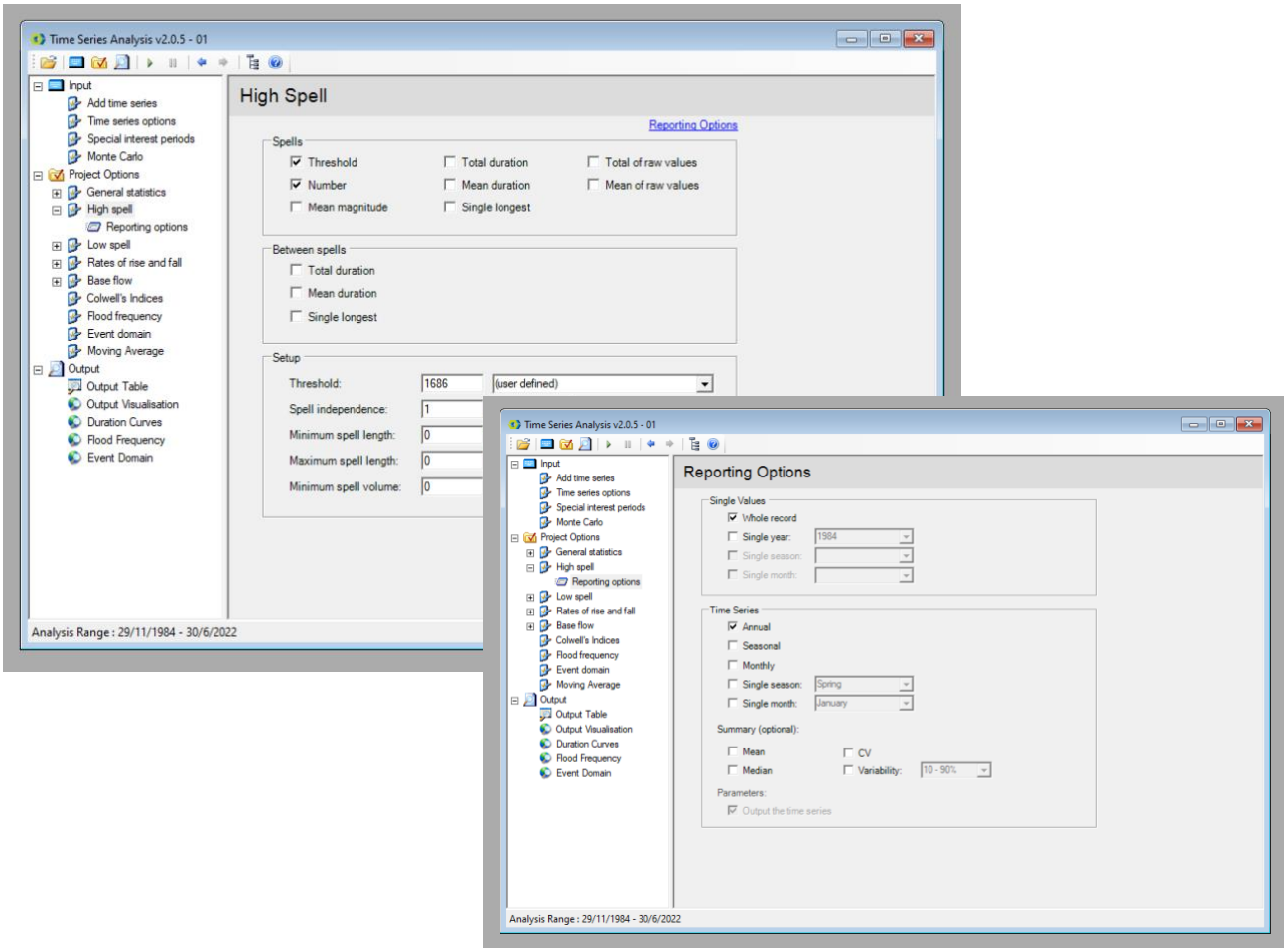
31. To calculate the values for the 1 month daily flow, go back to 'High spell' and change the minimum spell length to 30 days and add the averaged value into the spreadsheet, as above.



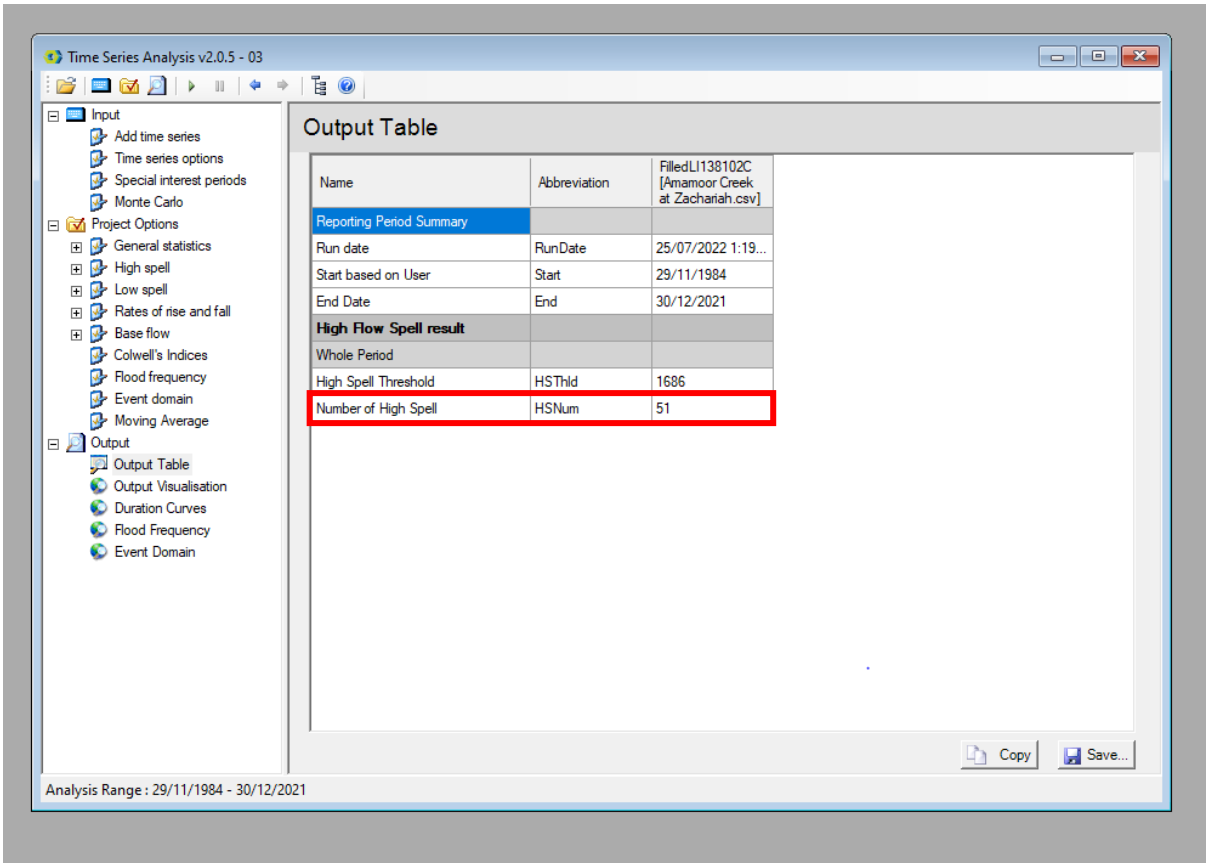
32. The next step is to calculate the average recurrence interval (ARI). ARI provides an indication of the size of a flow event relative to the historical events at the gauge. ARI calculations are not a part of the 'ECond' assessment but should be used as a descriptor to provide some level of interpretation of the annual data.
33. To calculate the ARI's go to 'Flood Frequency', and click the box called other ARI under the annual series. Change the value to 1.5 years and click run:



34. Once you get the value enter it into the spreadsheet. Repeat this step for all ARI's by changing the value to 5 and followed by 20 to get the 5-year and 20-year daily flow.
35. To calculate the number of times the benchmark 1.5-year, 5-year and 20-year ARI's have occurred historically go to 'High Spell'. In 'High Spell', click threshold, number, change the drop down box to user defined and enter in the pre-development value and/or benchmark value (where pre-development data is absent) from Environment Conditions Report – Volume 2 for the Mary Basin. For Burnett and Baffle Creek basin refer to the pre-development data section. Where pre-development data is missing, use the calculated historical benchmark from the steps above.
36. Make sure you change the minimum spell length back to zero (0).
37. Go to reporting options and click annual and then click run.



38. Enter in the number of times the 1.5-year, 5-year and 20-year pre-development ARI occurred in historically by looking at the output:



39. Make sure when entering the results that you place it in the current column, and the row called 'Number of that have occurred between the gauge starting period to 2021 (refer below).

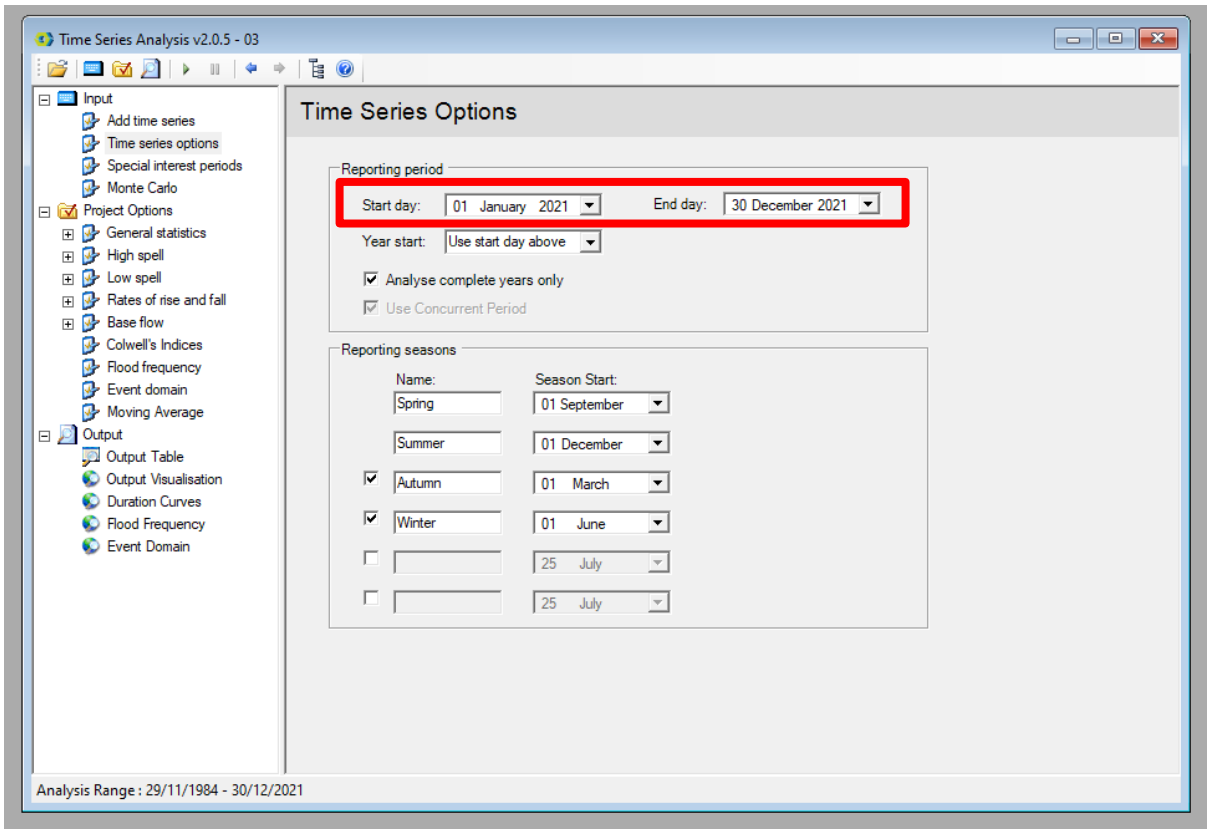
	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

40. Repeat this step for the 5-year and 20-year daily flow ARI pre-development values.
41. All of the historical benchmarks should now be calculated.

Annual Data Calculation Method

Time Series Analysis

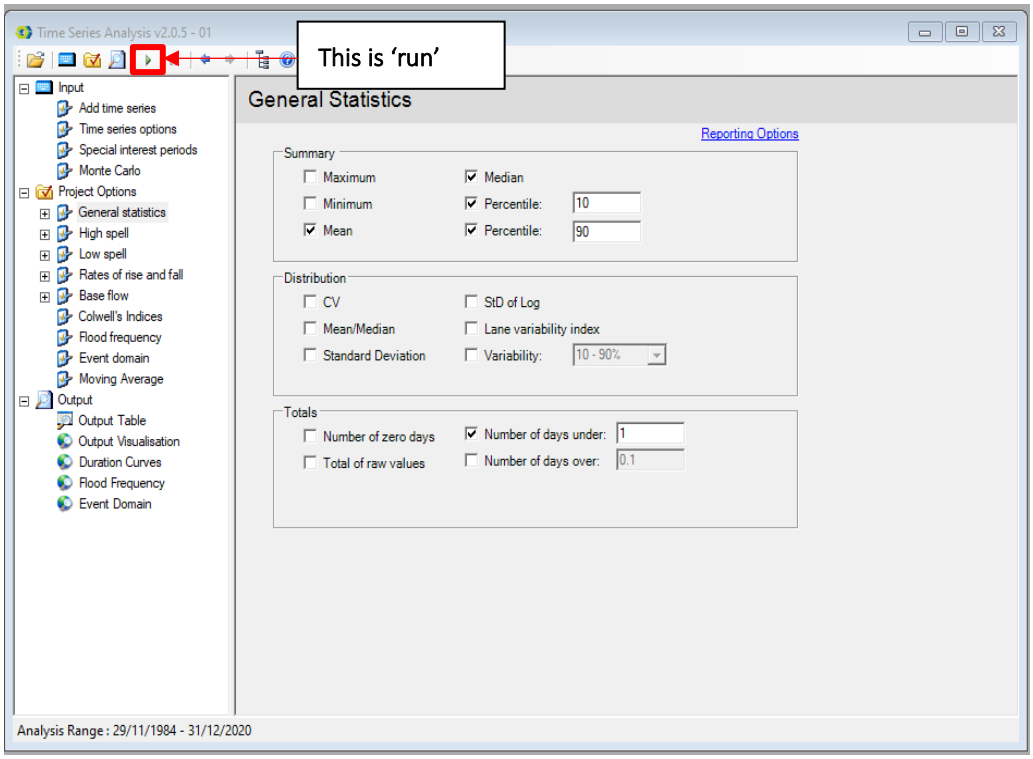
42. After the historical benchmarks are calculated, use the same spreadsheet to calculate the values for the annual reporting period. To do that, the times series options in the package will need to be changed to the annual reporting period that is being analysed (e.g. 2021):



43. To conduct the general statistics, start by clicking the general statistics tab and ticking the following:
    - Mean
    - Median
    - 10th percentile
    - 90th percentile

This will tell the tool to calculate the data needed for these indicators.

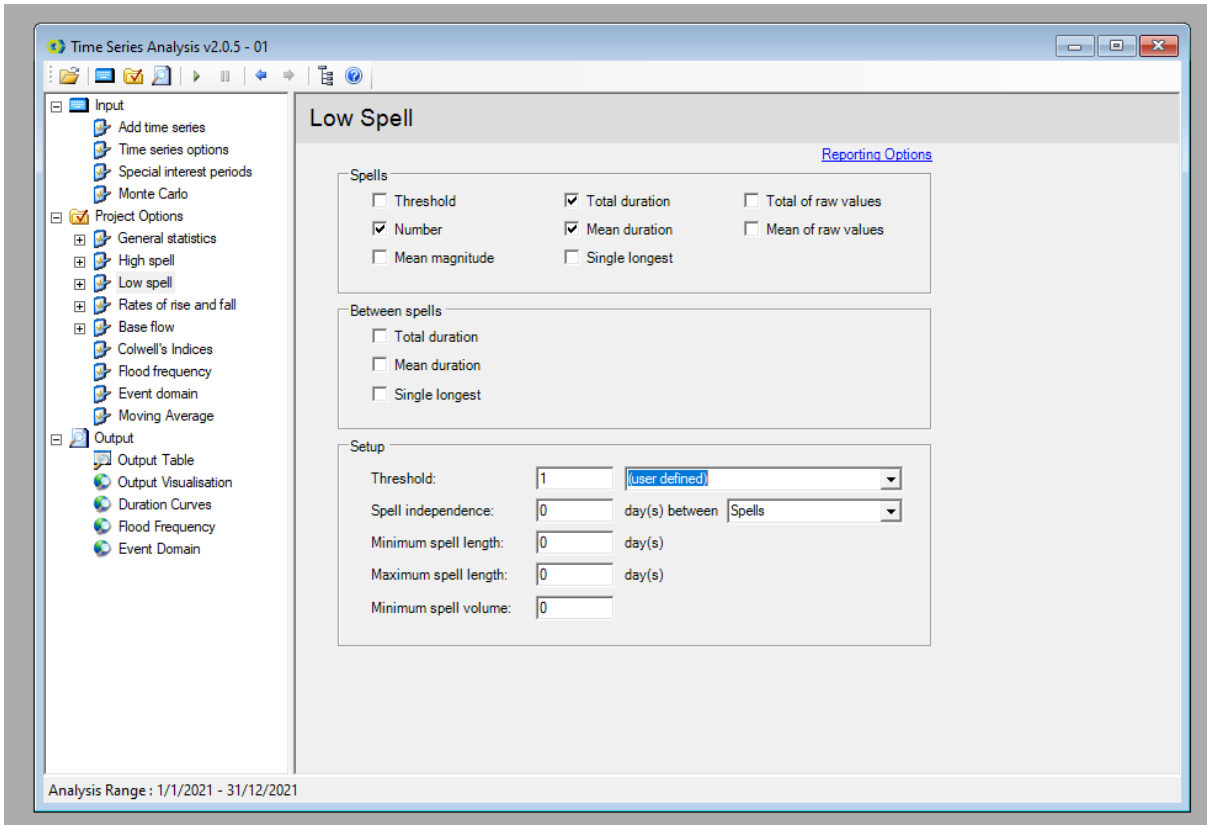
- Click run (on the bar above)



44. Enter the calculated data into the 'current' column of the prepared spreadsheet that was set-up earlier.

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

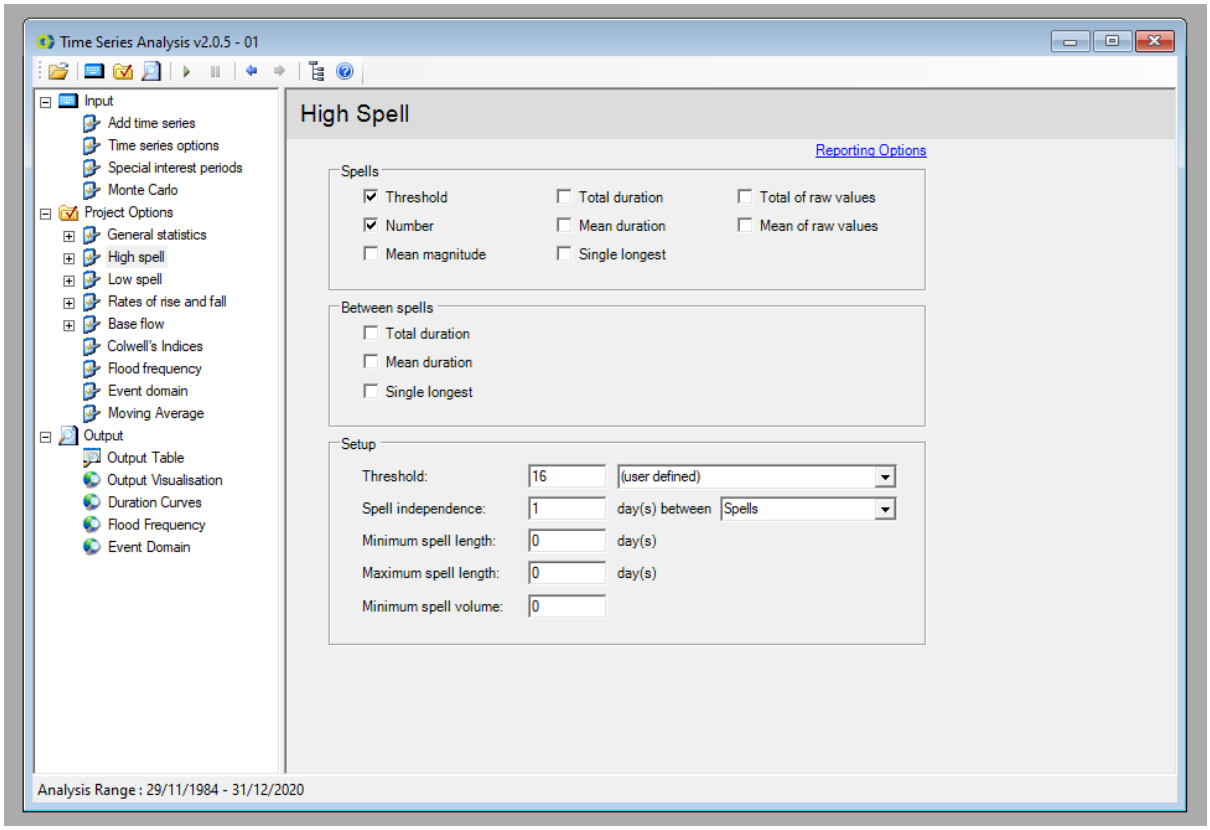
45. The next part of the analysis will give you the number of days with no flow (total duration), number of no flow spells historically (number) and will outline out of those no flow spells (single longest), which one last the longest in terms of duration (days in a row with flow <1ML/day).
46. To do that, go back to the "general statistic tab' and unclick all of the boxes in general statistics.
47. Go to 'Low Spell', click under spells: total duration, number and single longest. In the section called 'setup' click the drop-down box and change it to 'user defined' and change threshold to 1:



48. This will need to be added into the spreadsheet:

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

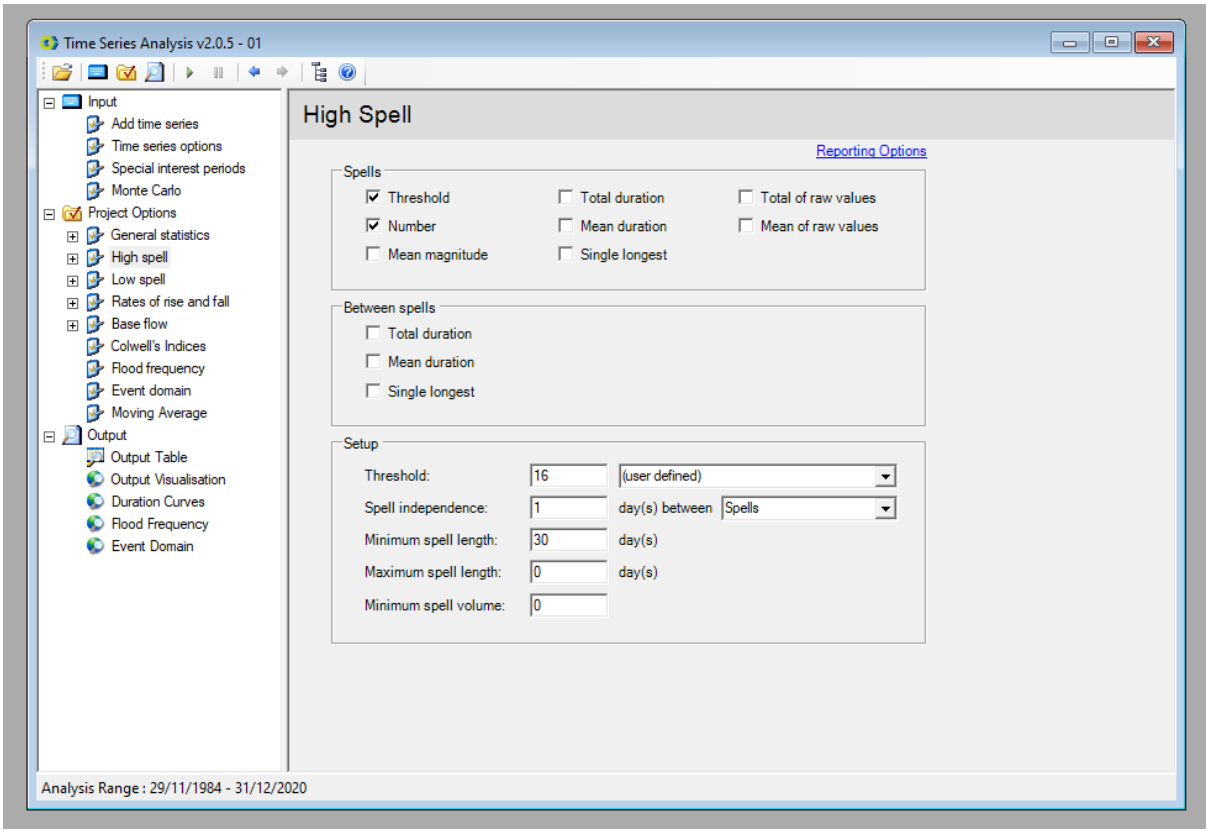
49. Once the data has been entered, go back to the 'low spell' tab and unclick all of the boxes.
50. To calculate the 10cm and 30cm flow data, go to the 'High Spell' tab and click threshold and number under spells. In setup click the drop-down box and change it to user defined and place the threshold in the 'threshold' box and leave the minimum spell length as zero for the total.
51. The threshold values for this assessment can be found in the Table 17, Table 18 and Table 19.



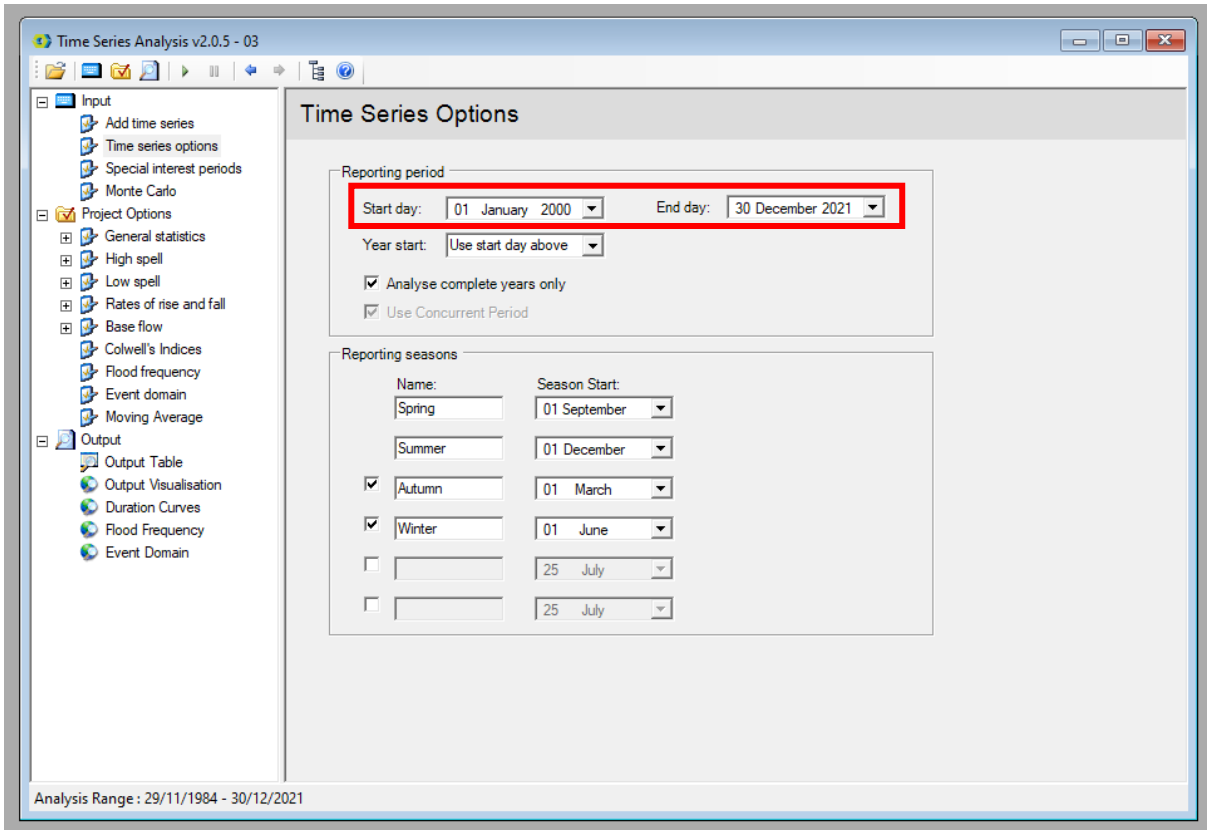
52. Once you have the total value, add it into the spreadsheet:

	A	B	D
1	**Indicator**	**Benchmark**	**Current (2021)**
2	**Mean daily flow (ML/day)**	54	51
3	**Median daily flow (ML/day)**	7	0
4	**Number of days with no flow (annual)**	220	160
5	**Number of no flow spells (annual)**	5	6
6	**Maxiumum duration of no flow spell (daily)**	97	92
19	**10%ile of daily flow (ML/day) (annual)**	2	0
20	**90%ile of daily flow (ML/day) (annual)**	44	37
21	**10cm daily flow (ML/day) (total)**	5	8
22	**10cm daily flow (ML/day) (1 month)**	1	0
26	**30cm daily flow (ML/day) (total)**	5	5
27	**30cm daily flow (ML/day) (1 month)**	0.1	0

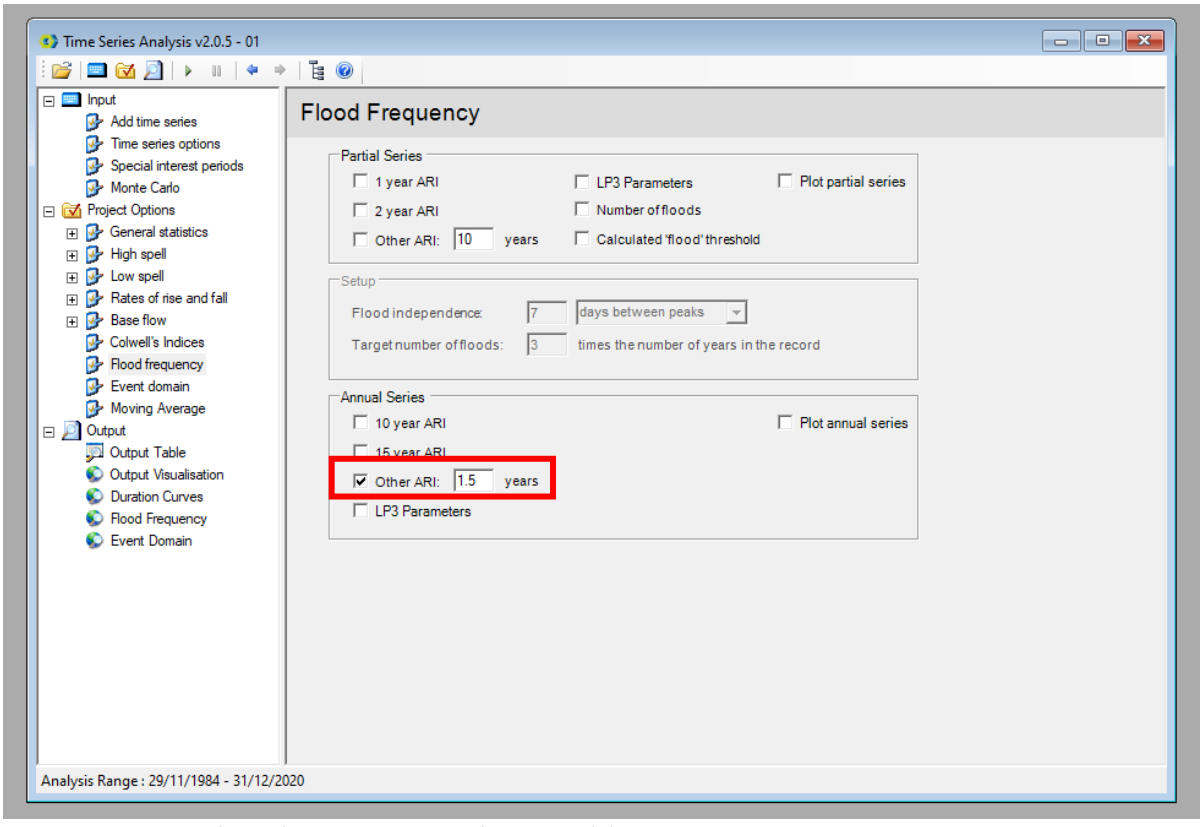
53. To calculate the values for the 1 month daily flow, go back to 'High spell' and change the minimum spell length to 30 days and add the averaged value into the spreadsheet, as above.



54. The next step is to calculate the average recurrence interval (ARI). ARI provides an indication of the size of a flow event relative to the historical events at the gauge. ARI calculations are not a part of the 'ECond' assessment but should be used as a descriptor to provide some level of interpretation of the annual data.
55. To calculate the ARI's go to 'Flood Frequency', and click the box called other ARI under the annual series. Change the value to 1.5 years and click run:



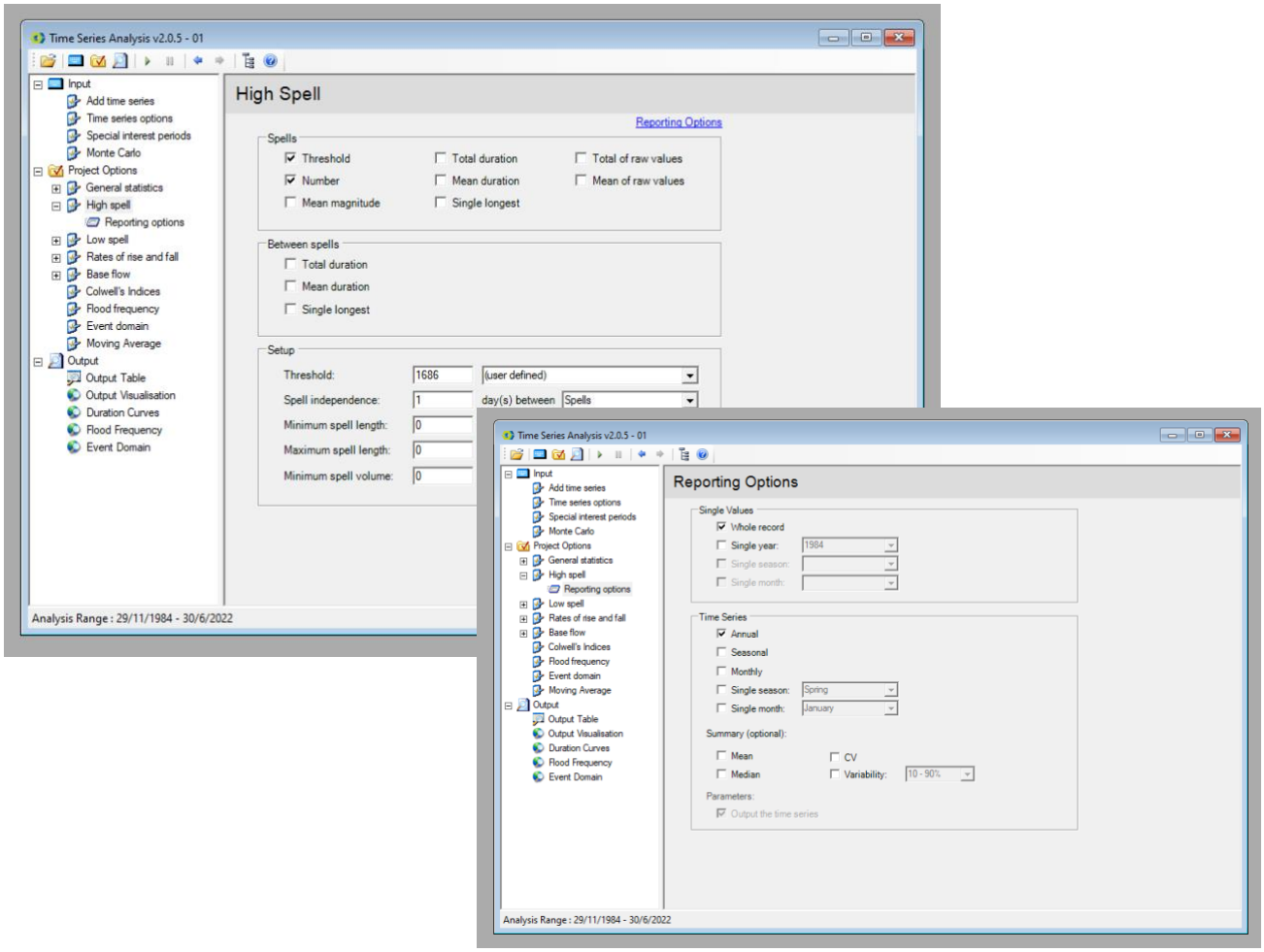
56. Go to 'Flood Frequency' and click the box called other ARI under the annual series. Change the value to 1.5 years and click run.



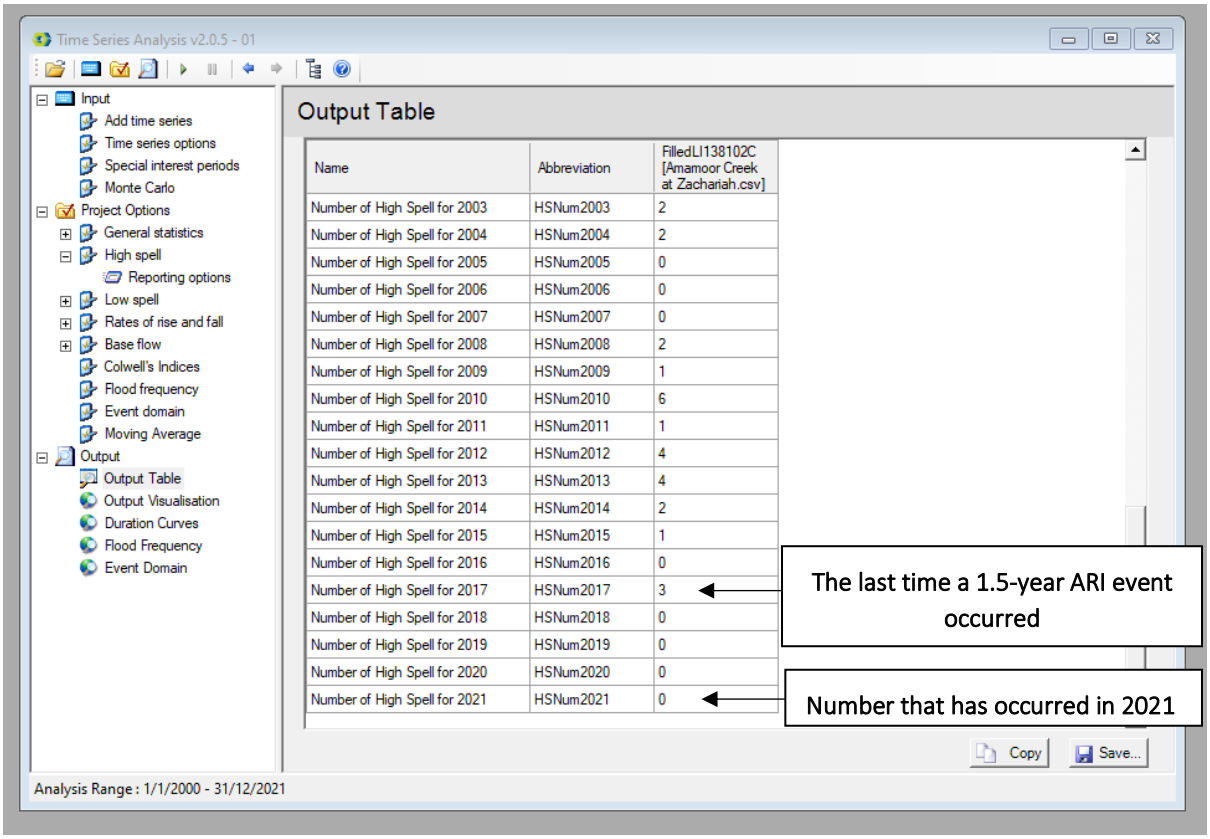
57. Once you get the value enter it into the spreadsheet:

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

58. Repeat this step by changing the value to 5 and followed by 20 to get the 5-year and 20-year daily flow.
59. Unclick the box tick in the ‘flood frequency’ tab.
60. To calculate the number of times the benchmark 1.5-year, 5-year and 20-year ARI’s have occurred between 2000 -2021 go to ‘High Spell’. In ‘High Spell’, click threshold, number, change the drop down box to user defined and enter in the benchmark.
61. Make sure that the minimum spell length is zero (0).
62. Go to reporting options and click 'Annual’ followed by run:



63. Once it's been run you would need to identify if an event occurred in the annual reporting period (e.g. 2021) and when an event of each magnitude last occurred (refer below for reference).



64. Repeat this step for the 5-year and 20-year daily flow ARI pre-development values.
65. Your spreadsheet should look like the example below.

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

66. This process will need to be repeated for all gauges outlined in the data organisation and cleaning section in Appendix E.

Appendix E - Worst Case Scenarios for Ecological Flows

The tables below are the worst case scenarios for the ecological flows that have been calculated for each gauge in the region.

Table 20. Worst case scenario for each performance indicator.

Performance indicator	Worst case scenario
# days with daily flow <1ML, # of no flow spells and maximum duration of a no flow spell	90%ile of all years for each gauge's data.
Mean annual flow and Median annual flow	10%ile and 90%ile annual flow for all years for each gauge's data.
10%ile and 90%ile of daily flow	10%ile of daily flow for all years for each gauge's data.
Number periods of 10 cm flows that lasted at least 1 month, 3 month, 6 months and 12 months.	10%ile of daily flow over 10cm for all years for each gauge's data.
Number periods of 30 cm flows that lasted at least 1 month, 3 month, 6 months and 12 months.	10%ile of daily flow over 30cm for all years for each gauge's data.

Table 21. Worst case scenario for Mean, Median, Number of days with no flow, Number of no flow spells and Maximum duration of the no flow spells

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Auburne River at Dykehead	6	799	0	11	336	7	234	0	0.05
Barambah Creek at Ban Ban	52	1515	1.73	166	186	5	107	0	58
Barambah Creek at West Barambah	7	346	0	26	336	8	296	0	0.26
Barambah Creek at Litzows	4	376	0.28	39	239	11	177	0	7
Barker Creek at Brooklands	1	132	0	15	352	7	341	0	0
Barker Creek at Glenmore	10	307	0	44	282	9	211	0	10
Boyne River at Carters	0	318	0	11	365	7	359	0	0
Boyne River at Cooranga	25	1,544	0	49	311	5	182	0	31
Burnett River at Ceratodus	3	1,159	0	57	325	13	198	0	2
Burnett River at Eidsvold	3	227	0	22	345	12	255	0	0

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Burnett River at Fig Tree	54	12,868	23	401	37	2	33	3.45	127
Burnett River at Gayandah	54	2,736	13	195	0	2	0	2.97	74
Burnett River at Jones Weir	50	4,385	0	695	300	6	255	0	80
Burnett River at Tailwater	36	2,302	1	236	231	3	215	0	37
Burnett River at Mount Lawless	224	3,673	21	556	185	2	96	0.14	334
Cadarga Creek at Brovinia Station	0	151	0	0.73	358	7	288	0	0
Eastern Creek at Lands End	1	148	0	2	358	8	341	0	0
Elliot River at Dr Mays	0	69	0	4	365	6	365	0	0
Elliot River at Elliot	4	207	2	25	152	8	109	0	8
Gin Gin Creek at Brushy Creek	6	530	0	33	309	8	207	0	6
Gregory River at Isis Highway	11	440	0	12	280	14	192	0	5
Isis River at Bruce Highway	10	516	0	14	280	13	153	0	8
Kolan River at Springfield	0	546	0	25	361	7	310	0	0
Monal Creek at Upper Monal	0	69	0	4	365	6	365	0	0
Reid Creek at Mungy	3	227	0	22	345	12	252	0	0
Splinter Creek at Dakiel	0	86	0	4	362	7	342	0	0
Stuart River at Proston Rifle Range	4	324	0	25	331	9	243	0	2
Stuart River at Weens Bridge	4	121	1	12	230	14	86	0	6
Three Moon Creek at Abercorn	1	450	0	18	336	12	244	0	0.38
Amamoor at Zachariah	7	304	1	25	208	11	90	0.02	8
Glastonbury at Glastonbury	2	142	0.4	17	261	11	184	0	3
Kandanga Creek at Hygait	5	375	0	34	243	7	160	0	9
Mary River at Homepark	627	10,234	97	1,377	-	1	-	5	806
Mary River at Bellbird	62	1,059	15	178	73	3	56	0.45	93

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Mary River at Miva	528	7,839	150	1,332	25	1	17	22	877
Mary River at Moy Pocket	124	1,885	28	421	71	3	71	0.39	171
Munna Creek at Marodian	34	975	0.11	74	247	6	202	0.83	28
Obi Obi Creek at Gardners Falls	23	134	9	45	46	7	32	0	42
Six Mile Creek at Cooran	43	475	9	91	108	6	67	0	57
Teewah at Coops Corner	56	155	41	103	-	0	-	30	76
Tinana Creek at Tagigan Road	7	204	0.28	14	225	7	153	0	13
Tinana Creek at Bauple East	45	1,621	11	72	-	2	-	1	89
Wide Bay at Brooyar	6	525	0	56	313	7	255	0	2
Wide Bay at Kilkivan	1	143	0	23	355	11	300	0	0
Baffle Creek at Mimdale	57	2,104	0.39	140	254	7	144	0	82
Oyster Creek at Rapleys	1	472	0	12	330	9	152	0	0.86

Table 22. Worst case scenario for 10cm daily flow and 30cm daily flow

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Auburne River at Dykehead	1	0	2	0
Barambah Creek at Ban Ban	1	1	3	0
Barambah Creek at West Barambah	1	0	1	0
Barambah Creek at Litzows	1	1	1	1
Barker Creek at Brooklands	1	0	0.1	0
Barker Creek at Glenmore	1	1	1	0
Boyne River at Carters	0.2	0	0.2	0
Boyne River at Cooranga	1.7	0.7	3	0

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Burnett River at Ceratodus	2	0	1	0
Burnett River at Eidsvold	2	0	1	0
Burnett River at Fig Tree	3	1.4	4	0
Burnett River at Gayandah	-	-	-	-
Burnett River at Jones Weir	-	-	-	-
Burnett River at Tailwater	1	1	1	0
Burnett River at Mount Lawless	1	1	3	0
Cadarga Creek at Brovinia Station	1	0	1	0
Eastern Creek at Lands End	1	0	1	0
Elliot River at Dr Mays	0	0	0	0
Elliot River at Elliot	-	-	-	-
Gin Gin Creek at Brushy Creek	3	0	0.6	0
Gregory River at Isis Highway	3.5	0	2	0
Isis River at Bruce Highway	4.5	4.5	2.5	0
Kolan River at Springfield	1	0	0	0
Monal Creek at Upper Monal	0	0	0	0
Reid Creek at Mungy	2	0	1	0
Splinter Creek at Dakiel	1	0	0	0
Stuart River at Proston Rifle Range	2	0	2	0
Stuart River at Weens Bridge	1	1	0	0
Three Moon Creek at Abercorn	2	0	1	0
Amamoor at Zachariah	3	0	2	0
Glastonbury at Glastonbury	2	0	1	0
Kandanga Creek at Hygait	1	1	1	0

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Mary River at Homepark	1	1	1	1
Mary River at Bellbird	1	1	3	0
Mary River at Miva	1	1	1	1
Mary River at Moy Pocket	1	1	1	1
Munna Creek at Marodian	2	1	4	0
Obi Obi Creek at Gardners Falls	2	1	6	0
Six Mile Creek at Cooran	1	1	2	1
Teewah at Coops Corner	-	-	-	-
Tinana Creek at Tagigan Road	2	1	2	0
Tinana Creek at Bauple East	1	1	0	0
Wide Bay at Brooyar	1	0	1	0
Wide Bay at Kilkivan	1	0	1	0
Baffle Creek at Mimdale	1	1	2	0
Oyster Creek at Rapleys	3	0	1	0

Appendix F - Worst Case Scenarios for Water Quality

Table 23. Worst case scenario for Estuaries

Water type	pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
Lower estuary (QWQ) - SEQ	7.8	8.5	85.6	103	12	85	4.4	0.4	0.057	0.03	0.087	0.067	0.041
Lower estuary (QWQ) - CQLD	7.8	8.5	89	104	13	85	3	0.265	0.0075	0.011	0.0185	0.0195	0.007
Middle estuary (QWQ) - SEQ	7.12	8.5	57.9	107	65	85	11	1.3	0.71	0.13	0.772	0.43	0.310
Middle estuary (QWQ) -CQLD	6.5	8.5	73	102	32.12	85	7.62	0.727	0.0907	0.041	0.1317	0.057	0.015
Upper estuary (QWQ) - SEQ	6.93	8.5	51.4	107	71.7	85	26	1.5	0.695	0.14	0.756	0.55	0.400

Table 24. Worst case scenario for Freshwater

Water type	EC					pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
	Sandy coastal	Central	Southern	Callide	Mary													
Lowland Streams (QWQ)	1195	1500	1570	1450	-	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
Upland streams (QWQ)	1195	1500	1570	1450	-	5.5	9	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Maleny Plateau (Southern Upland Acid Waters)	-	-	-	-	900	5	10	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Upper Mary River (Southern Upland Freshwaters)	-	-	-	-	900	5.5	9	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Mary River and southern tribs (Southern Lowland Waters)	-	-	-	-	2600	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
Western Tribs (North Western Lowland Waters)	-	-	-	-	3000	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050

Water type	EC					pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
	Sandy coastal	Central	Southern	Callide	Mary													
Tinana Creek (North Eastern Lowlands)	-	-	-	-	900	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
East tribs of Tinana Creek (easternm Sandplain Tannin Stained)	-	-	-	-	900	3.2	7.5	20	160	100	85	12	0.4	0.06	0.02	0.08	0.2	0.100

Alluvium and EcoFutures

Regional Waterway Condition Method for Central Queensland

Version

Version	Date	Description	Author	Approver
1.0	03 March 2022	Submission to SAC	Paul Maxwell	Science Accreditation Committee
2.0	12 September 2022	Final Document	Paul Maxwell	Science Accreditation Committee

Acknowledgements

From 2008 to 2018, the Wentworth Group of Concerned Scientists developed the Accounting for Nature® model. The model sought to establish a practical, affordable and scientifically robust methodology for creating a common unit of measurement to describe the condition of environmental assets and measure any change in the condition of those assets over a period of time.

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1. Introduction

This method has been developed to assess the condition of waterways within freshwater and estuarine river systems at the regional scale. Specifically, it aims to assess ecological flows, riparian vegetation, and concentrations of key water quality indicators to give an understanding of waterway condition within a region. This method can also be used with AfN-METHOD-F-05 to include an indicator class for aquatic vertebrates. This method is applicable to the Central Queensland Coast and South-East Queensland catchments (Figure 1) as defined by the Queensland Water Quality Guidelines (2009).

Sediment, nutrient, and pesticide run-off are key threats to water quality resulting from anthropogenic activities, which impact upon the health of waterways and receiving coastal waters. In Queensland, regional and reef scale Water Quality Improvement Plans (WQIP) have been developed to facilitate management actions that are designed to improve water quality for the benefit of a range of critical environmental values like fauna, seagrasses, coral reefs, mangroves and saltmarshes. Sediment and nutrient run-off are recognised in the Reef 2050 Long-Term Sustainability Plan as part of the key threats to water quality resulting from anthropogenic activities, and which impact upon the health of the Great Barrier Reef (GBR) (Commonwealth of Australia, 2018). Consequently, sediments, nutrients and the physical and chemical parameters of the water column are good indicators of the condition of waterways. While these indicators have known impact on reef ecosystems, there are similar impacts on receiving environments more broadly and the iconic aquatic organisms that reside within these environments and therefore are a useful minimum dataset for water quality targets.

Riparian vegetation is a critical component of a waterway and important to monitor when assessing waterway condition. Vegetation provides habitat for a wide variety of organisms, reduces streambank erosion of riverbanks and acts as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increased input of sediments and nutrients.

Ecological flow is another critical indicator of waterway condition. The timing and magnitude of water flows through the rivers in the region is a critical determinant of the breeding and migratory success of the region's iconic species. Water impoundments like dams and weirs alter the hydrology of rivers which impacts on those species. However, these structures do come with positive attributes such as preventing trout migrating upstream, thereby increasing the survivability of *Galaxias sp*. Environmental flow strategies in modified rivers that minimise changes to natural flow regimes provide suitable conditions not only for these iconic species but for the broader aquatic ecosystem. The Queensland Department of Regional Development, Mines and Water (DRDMW) manages the flow regime in the region's rivers with ecohydrological rules outlined in the *Water Plan*, specific for each catchment.

This Method therefore incorporates the above three indicator themes (water quality, ecological flow, and riparian extent), and builds off the existing monitoring guidelines and programs (such as the Queensland Government's Water Monitoring and Sampling Manual (2019), the Central Queensland Estuarine Monitoring program, (Report on Condition and trends in Water Quality in Central Queensland Estuaries 1993 to 2015) and the Gladstone Healthy waterways Estuary monitoring Program) to assess the waterway condition of estuarine and freshwater systems along Queensland in accordance with the Accounting for Nature Framework. Water Quality is assessed in ambient condition, which describes the conditions when flow is NOT derived from rainfall runoff (e.g. an 'event' such as a period of high rainfall and/or flooding), that is – the base flow. It is acknowledged that extreme events take the system temporarily outside the bounds of what the method is set up to monitor, however, the annual

monitoring will pick up the generalised change in condition. The intention of the method is to include an assessment of event generated pollutant loads to align the method with the targets set out for the Burnett Mary Catchments in the Reef 2050 Plan.

This Method includes instructions on how to measure several key waterway condition indicators. Using the Queensland Water Quality Guidelines and relevant Water Plans to inform Reference Condition Benchmarks, the indicator values are then converted into Indicator Condition Scores (a measure between 0 and 100) which are then further aggregated into an Econd® which is an estimate of Environmental Condition for the environmental asset, in this case the waterways in Central and South East Queensland. The Econd® is an index between 0 and 100, where 100 describes the 'best-on-offer' or 'pre-development' Reference Condition of the environmental asset, and 0 indicates the asset is completely degraded. The Econd® is calculated by comparing the current condition of the waterways within the region, to the expected undegraded Reference Condition of the waterway. Accounts developed with this method will produce credible and verifiable metrics that can support public claims about change in waterway condition.

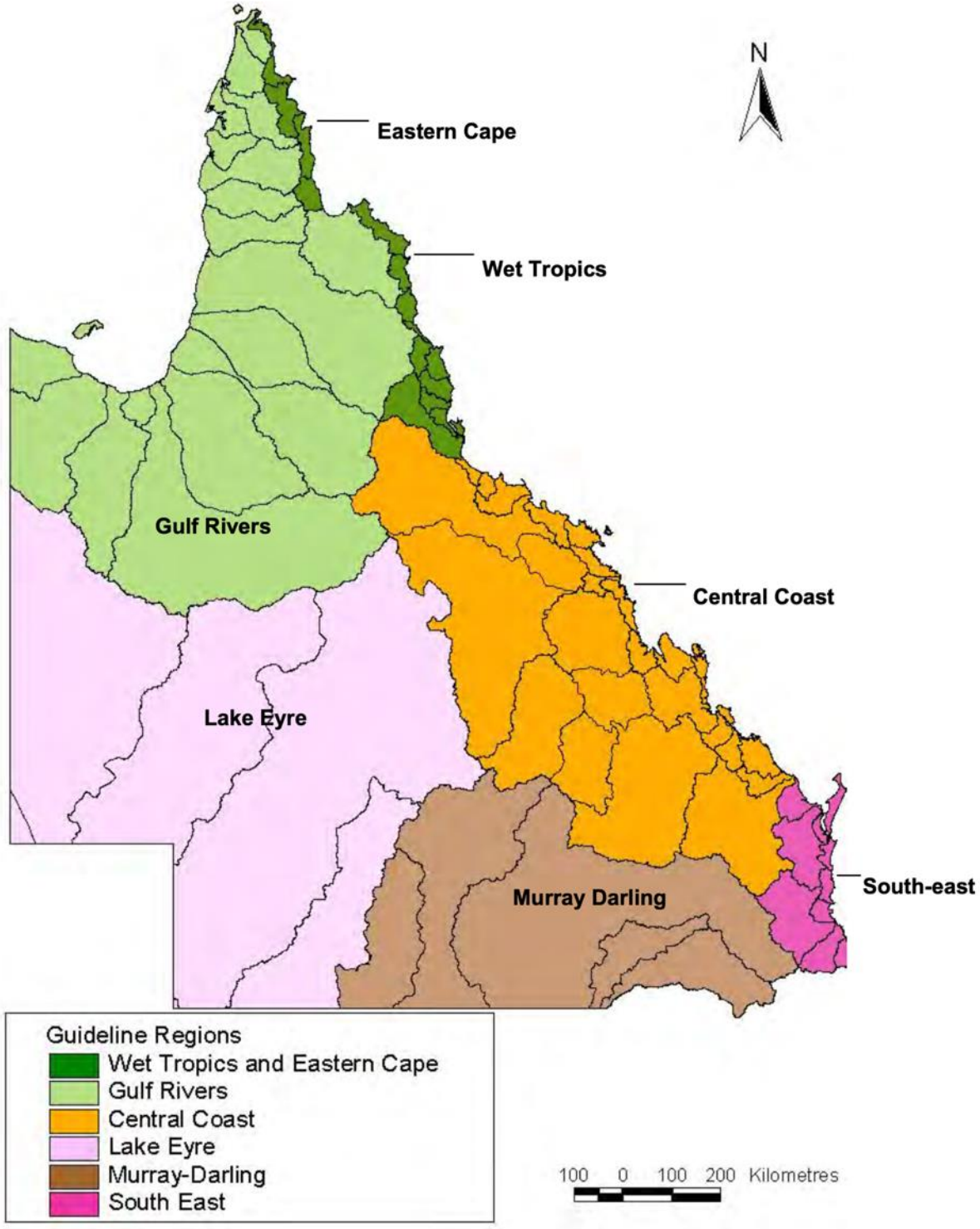

Figure 1. Overview of Regions adopted for the Queensland Water Quality Guidelines (Source: Figure 2.3.1 Queensland Water Quality Guidelines 2009)

1.1. Aim and scope of this Method

Purpose	The purpose of this Method is for Regional Land Managers (such as Natural Resource Management Groups or Local Governments) to assess the condition of and monitor the change of waterway condition within freshwater, and estuarine waterways in Central and South-East Queensland.
Application	Central Queensland and South-East Queensland
Scale	Regional
Target Audience	NRM organisations, landholders, public
Decisions to inform	1. To inform better land management 2. To communicate to stakeholders and the wider community the state of waterways within the region 3. To showcase the region's values
Confidence Level/s	Level 2 (or Level 1, 2, or 3, if supported by a power analysis)

1.2. Justification of Confidence Level

This Method has been written in accordance with several published (and peer reviewed) monitoring manuals, in particular:

- Report on Condition and trends in Water Quality in Central Queensland Estuaries 1993 to 2015
- Gladstone Healthy waterways Estuary monitoring Program
- Queensland Monitoring and Sampling Manual *Environmental Protection (Water) Policy 2009*
- Mary River Catchment Waterwatch Results 2021

The Reference Benchmarks are derived from published Water Quality Guidelines and relevant Water Plans.

In addition, the 90th percentile (90%ile) and/or 10th percentile (10%ile) and/or worst-case scenario (WCS) values are recommended to be derived from data collected from the Queensland Department of Environment and Science Water Monitoring programs.

Therefore, as this Method is based off existing established monitoring programs and guidelines developed and implemented by the Queensland State Government, then it is expected to be able to achieve Level 1 (95% accurate), Level 2 (90% accurate) and Level 3 (80% accurate) Confidence Level, depending on the sampling intensity. This is further supported by the frequency of sampling, (monthly during baseflow conditions) which is required to account for natural variability in the indicator values.

1.3. What an Environmental account looks like

The *Accounting for Nature®* Framework requires accounts to be comprised of three key components for them to be certified:

1. An **Environmental Account Summary** – a public document that summarises the results of the environmental account in a form that is readily communicated to the public.
2. An **Information Statement** – describes in detail the method used and the actions taken to address each of the eight steps under the framework including rationale behind asset selection, choice of indicators, Method used, analysis and management of data and calculation of the Econd®.
3. The **Environmental Account** – a database (such as an excel file) that contains all the data described in Asset Tables, Data Tables, and Balance Sheets.
4. An **Audit Report** (for 'certified' Accounts) or **AfN Technical Assessment** (for 'self-verified' Accounts)– an independent report that is completed by an AfN Accredited Auditor or AfN, that verifies the Account was prepared in accordance with the approved Methods, the *AfN Certification Standard* and AfN Audit rules.

Upon certification of the account, the Environmental Account Summary and Information Statement will be published on the AfN Environmental Account Registry.

1.4. Overview of Process

This method includes the following steps:

Preliminary Work

- Step 1. Define purpose, scope and accounting area
- Step 2. Compile existing data
- Step 3. Stratify accounting area
- Step 4. Implement Indicator-class specific approaches and calculate ICS

Ambient Water Quality	Ecological Flow	Riparian Extent
Step 4.1.a. Describe Indicators	Step 4.2.a. Describe Indicators	Step 4.3.a. Describe Indicators
Step 4.1.b. Identify Sample Sites	Step 4.2.b. Collate data	Step 4.3.b. Define Reference Benchmarks
Step 4.1.c. Define Reference Benchmarks	Step 4.2.c. Define Reference Benchmarks	Step 4.3.c. Collect and analyse data
Step 4.1.d. Collect and process samples	Step 4.2.d. Calculate Indicator Condition Scores	Step 4.3.d. Calculate Indicator Condition Scores
Step 4.1.e. Calculate Indicator Condition Scores		

- Step 5. Calculate Econd®

2. Creating the Environmental Account – Preliminary Work

Step 1. Define purpose, scope, and accounting area

The preliminary step to developing an Environmental Account is to **describe** the Environmental Account through defining its intended **purpose**, **scope** and **accounting area.**

Purpose:	Describe the specific purpose of the account.
Scope:	Describe the scope of the account. - *Snapshot* – a single assessment of environmental condition - *Change over time* – an ongoing assessment of the change of environmental condition through time
Accounting Area:	Describe the accounting area (include location and size details). Provide a map of the accounting area that shows location and size information and identify the freshwater waterways of interest. NB. The accounting area must stay the same for the lifespan of the account. If the accounting area changes (such as a new area to be added, or an area to be removed), then a new account must be developed, or the account, 're-set' and started again with the new accounting area.

Output of Step 1

- A description of the accounting area including **location** and **size**
- A table describing the **purpose** and **scope** of the account
- A **map** showing the accounting area

Step 2. Compile existing data

Data collection

Before starting to build your account, the following preliminary data must be collated and prepared.

Data Collation

- Aerial imagery
- Tide data
- River mapping or existing estuary shapefile (such as '*Amendment Policy (No.1) 2020 - Water Types – Queensland*' which can be downloaded from QSpatial)
- Location of water storages
- Understand the variability of the water bodies being assessed
- Existing or past site locations
- Queensland Department of Environment and Science historic estuary water quality data for each water type for each region
- Riparian vegetation extent mapping

Things you will need

- Permits and approvals
- Organise a laboratory for water samples.
- Collect sample bottles from laboratory
- Sampling apparatus

Output of Step 2

- A map, table and description of the account area including waterways
- Sampling apparatus

Step 3. Stratify the accounting area

Identify sub-assets

Sub-assets in this Method are defined as the individual river catchments included in the Account. The catchments (identified by their major River name) to be included in the Account are to be shown on a map in a commonly applied datum. For example, Figure 2 shows an example of stratification into sub-assets based on the major waterways within the Burnett-Mary Region.

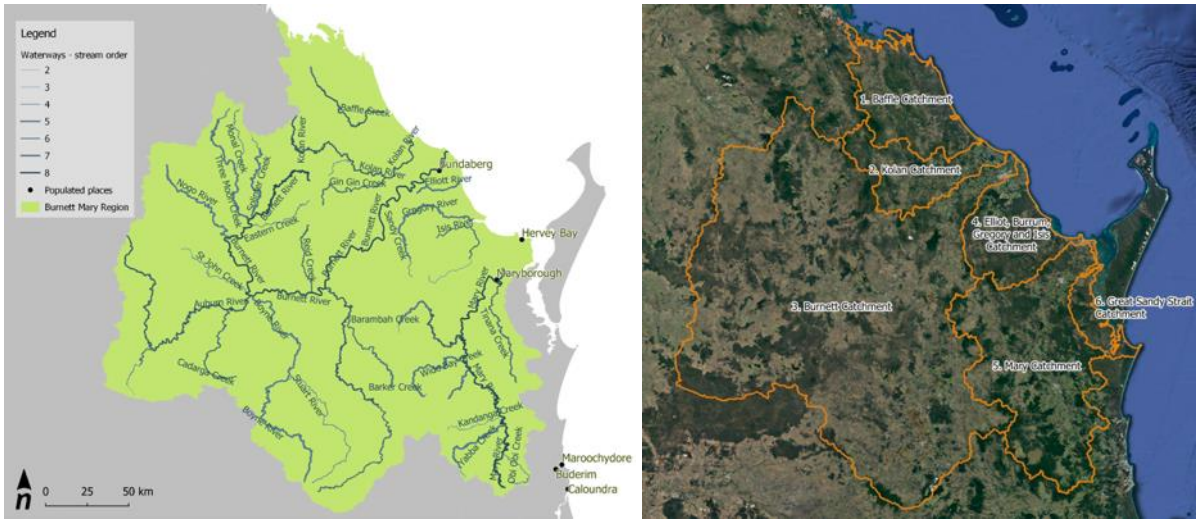

Figure 2. Waterways and catchments within the Burnett-Mary Region

Output of Step 3

- A map and table showing the **stratification** of the accounting area

3. Creating the Environmental Account – Indicator-class Specific Approaches

The waterway condition method employs a diverse toolkit of environmental indicators to provide complementary perspectives on the condition of a waterway. It is our intention to add additional indicator classes to this toolkit over time, as outlined in the preface to this method. While the current set of indicators allow a valuable minimum assessment of environmental change, they are not complete and where new technologies and data sources allow it, the intention is to broaden the assessment to more completely cover the drivers of environmental condition. The following section defines those indicator classes, the indicators they include, and the reference benchmarks, then outlines the steps for producing an account, including sampling approach, data collection procedure and data analysis. It is acknowledged that the indictor classes are sourced from a third party, which may have a level of uncertainty associated with the data and models. However, it should be noted the third party is the State Government (eg. DES), which follow a rigorous sampling methodology that has been peer-reviewed by scientist within the field. The ongoing quality assurance associated with these sampling regimes are published making it possible monitor the level of error. As such, the assurance processes will continue to be monitored to ensure the quality of this account

Indicator classes

This method includes three indicator-classes, Water Quality, Ecological Flows, and Riparian Extent (Table 1). The waterway indicator classes (and their indicators) described below have been selected as they have been identified in the Reef 2050 WQIP as important indicators contributing to the pressures on critical environmental, social and economic values of the region. Ecological flows and riparian vegetation are also included as they are needed to assess waterway condition in its entirety. *Table 2* outlines the recommended riparian buffer widths according to the stream order which takes into account cane-growing areas. The riparian buffers are based on evidence from scientific literature, with a detailed explanation of each source within Appendix B.

Table 1. Summary of Indicators used in the method.

Indicator Classes	Indicator		Units	Measure
Water Quality	Nutrients	Total Nitrogen	µg/L	Lab
		Dissolved Inorganic Nitrogen	µg/L	Lab
		Total Phosphorus	µg/L	Lab
		Filterable Reactive Phosphorus	µg/L	Lab
	Sediments	Turbidity	NTU	Field
		Total Suspended Sediments	mg/L	Lab
	Phytoplankton	Chlorophyll-a	µg/L	Lab
	Physiochemical	Dissolved Oxygen	% Saturation	Field
		Conductivity	µS/cm	Field
		pH	-	Field
Ecological Flows	River flow	Volumetric Flowrate	ML/d	Online
		Mean	ML/d	RAP*
		Median	ML/d	RAP*
		10%ile	ML/d	RAP*
		90%ile	ML/d	RAP*
		10cm daily flow (annual)	ML/d	RAP*
		30 cm daily flow (annual)	ML/d	RAP*
Riparian Vegetation	Riparian Veg Extent	% Coverage	%	Desktop

* RAP is defined as the River Analysis Package, which is used to calculate the various ecological flow indicators

Table 2. Recommended riparian buffer widths according to various sources.*

Stream order	Riparian buffer width (m)
Streams in sugar growing areas	25
Rivers in sugar growing areas	50
1-2	50
3-4	75
5-6	100
7-8	125

* Lovett and Price (2001), Department of Primary Industries [NSW GOV] (2012) & Hansen et al. (2010).

3.1 Ambient Water Quality

Sediment, nutrient, and pesticide run-off are key threats to water quality resulting from anthropogenic activities, and which impact upon the health of waterways and receiving coastal waters. Consequently, sediments and nutrients within the broader receiving environments form a useful minimum dataset for water quality targets throughout the region. They also impact on the health of estuary environments and wetlands in the Burnett Mary region. Alongside sediments and nutrients, physical and chemical parameters of the water column are good indicators of the condition of rivers and estuaries.

A benefit of water quality sampling using this method, is that it does not require a highly specialised skill-set and existing programs are run by NRM organisations, Landcare and other community groups. The suite of water quality indicators measured are based on the Queensland Water Quality Guidelines (2009) but are broadly applicable in other waterways around Australia. However, the benchmarks presented in this section are limited to coastal catchments of Central and Southeast Queensland. Following the Burnett-Mary pilot of this method, we intend to adapt these methods to make them more broadly applicable to other regions.

Step 4.1.a. Describe environmental indicators

Nutrients

Nitrogen and phosphorus are nutrients essential to biota in waterways. Both nutrients are present in waters in both dissolved and particulate forms. Particulate forms include those bound up in living organisms, organic compounds like proteins, and those bound to suspended particulate matter like clay, detritus and other sediments. Dissolved nitrogen may either be inorganic nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+) or organic (e.g. urea; dissolved proteins).

Nitrogen and phosphorus are derived from natural ecological events such as oceanic upwelling, litter fall, weathering, and from human sources (e.g. sewage outfalls, leaching from cleared land, fertiliser runoff, and industrial and agricultural effluents). In more highly populated areas, nutrients can result from wastewater discharges, sediments, and diffuse urban runoff.

Excess nutrients in waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species (e.g. seagrass and coral communities), and cause excessive fluctuations in pH and dissolved oxygen which can stress and eliminate sensitive species.

Sediments

There are two parameters that indicate the concentration and load of sediments in fresh and estuarine waters: turbidity and total suspended sediments (TSS). Turbidity is the measure of the amount of light scattered by suspended particles in the water column, providing an indirect indication of light penetration. It is a concentration-based measure and not always a good indication of sediment load through a system. TSS is typically measured as the amount of sediment in a known volume of water so is a precursor to understanding the sediment load that leaves a system.

Excess amounts of suspended particles can contribute to environmental damage including, reduced light penetration through the water column, smothering of benthic organisms like corals and seagrass, irritation of fish gills and transportation of contaminants. Changes to the availability of light within the water column influence the ability of aquatic plants to photosynthesise and fix energy. Sediment enters waterways through erosion and runoff accelerated by catchment alterations and can also bring excess nutrients with it. Once in inshore coastal waterways, fine sediments are readily resuspended by wave and tidal energy.

Phytoplankton

Phytoplankton biomass is largely influenced by the availability of nutrients, light, and optimal water temperature. Measuring phytoplankton biomass provides an indication of the nutrient and light conditions present at the time of sampling and their resulting biological effect. Under certain environmental conditions, in particular elevated light and high nutrients, phytoplankton blooms can result. When phytoplankton blooms decay, the resulting bacterial activity can reduce dissolved oxygen concentrations in the water column, possibly leading to fish kills.

Phytoplankton response is measured by the concentration of chlorophyll-a in the water column. Chlorophyll-a (chl-a) is a pigment found in photosynthetic organisms. It is an essential molecule for the process of photosynthesis (the conversion of light energy to chemical energy resulting in the consumption of carbon dioxide and the production of oxygen). In surface waters, chl-a is present in phytoplankton such as cyanobacteria, diatoms, and dinoflagellates and the volume of chl-a will be measured though lab analysis.

Physicochemical parameters

These parameters are indicators of the physical and chemical properties of a water body. These parameters are typically measured together with a single water quality instrument. As values are recorded in situ at the time of sampling, these parameters can be measured nearly continuously at a very high frequency with some systems outfitted with the capability to provide data in real time to online data platforms.

Dissolved oxygen

Dissolved oxygen (DO) concentration is a measure of the oxygen in a water body. Many freshwater, estuarine and marine processes are dependent on the concentration of DO in the water. DO concentration in a water body is affected primarily by the rate of transfer from the atmosphere but also by oxygen-consuming (e.g. respiration) and oxygen-releasing (e.g. photosynthesis) processes. Organic matter, such as sewage effluent or dead plant material that is readily available to microorganisms has the greatest impact on DO concentrations. Microorganisms use water column DO during decomposition of the organic matter. DO concentration in the water column is highly dependent on temperature, salinity and biological activity. Consequently, DO concentrations under natural conditions may change substantially over a 24-hour period. Variations in DO concentrations may affect many organisms such as fish, invertebrates and microorganisms, which depend upon oxygen for surviving. The oxygen requirements of aquatic organisms vary widely depending on which species, their life stage and different metabolic requirements. Dissolved Oxygen is most commonly measured with a water quality meter. Under the Queensland Water Quality Guideline (2009) Dissolved Oxygen levels should be between 85 – 110 %sat (refer to *Figure 3*).

Conductivity

Conductivity is a measure of the salinity or total concentration of mineral salts in the water column. Clean oceanic water has a conductivity of between 50,000 to 53,000 uS/cm with freshwater approaching 0. Conductivity affects the types of organisms that can live in a water body. Changes in conductivity in a freshwater stream or river can come from exposure and the subsequent erosion of saline soil types, via groundwater influences into a waterbody or through tidal inundation from surrounding estuaries.

pH

pH is a measure of the acidity or alkalinity of a waterbody. The pH scale ranges from 0 (highly acidic) to 7 (neutral) through to 14 (highly alkaline). Changes to the pH of marine waters can affect the types of vegetation, fish and invertebrates that can live in Queensland's freshwaters. Changes in pH can also change the toxic effects of pollutants present in a waterbody, changing how they are metabolised in aquatic organisms. Excess catchment runoff from various agricultural and urban landuses can cause changes to pH of surface waters.

Output of Step 4a

- A table describing the **environmental indicators** to be measured in the account

Step 4.1.b. Identify sample sites

The sampling requirements for this method are outlined in Table 3 below. For Water Quality Sampling within each catchment, each waterway within the catchment should be stratified into 'sampling units' based on the following five water types:

- enclosed coastal/lower estuary (ECLE) – reaches near the mouth of the estuary and adjacent nearshore coastal waters
- mid-estuary (ME) – the main body of the estuary
- upper estuary (UE) – the poorly flushed most upstream reaches of estuaries.
- lowland freshwater (LF)
- upland freshwater (UF)

The sampling units determine where sites are to be located. The five water-types can be determined using the Queensland Water Types shapefile or the Water Types shown in the Queensland Water Quality Guidelines (2009) and are important in determining water quality reference values. A map in a commonly applied datum should be produced showing the extent of the water quality sampling units.

Table 3. Overview of how to select and establish sampling sites within each water quality sampling unit

Sample	Implementation
Number of sites per sampling unit	It is likely that variation within each sampling unit varies, and therefore, it is recommended that prior to sampling, and if feasible (considering data availability and budget constraints), an initial account-specific power analysis be conducted to establish the required number of samples per sampling unit for the target confidence level (i.e. level 1 – 95 % accurate, Level 2 – 90% accurate, and Level 3 – 80% accurate). The methodology for power analysis can be found here: https://www.waterquality.gov.au/anz-guidelines/monitoring/study-design/preparation and https://www.epa.gov/sites/default/files/2015-10/documents/tech_memo_3_oct15.pdf If a power analysis cannot be undertaken, then a general rule of thumb to achieve confidence level 2 is a total of 5-7 spatial sample sites per sampling unit (i.e. 5 – 7 sample sites per water type within each catchment). This was chosen to get a statistically robust median value for calculation of the indicator condition score. It is recommended that the water quality sampling is completed seasonally at each site. Event monitoring is also recommended in order to incorporate high-flow events.
Site selection	For water quality, sample sites are to be selected as representative sites within each sampling unit, but must consider tributary location, spatial variation, such as depth and distance from the bank (based on the advice given in the Qld Water Quality Sampling Manual). Sites should be selected where historical pollutant load data is available, or pollutant concentration coupled with daily flow volume data. If wanting to identify the impacts of tributaries, point sources and land-use changes, sites should be placed downstream. In estuaries, samples should be taken on the outgoing tide (2 hours after the high-tide).
Site establishment	GPS Coordinates are to be recorded at each sample site. Subsequent samples to be taken from the same location.
Frequency and timing	Water Quality samples are to be taken once a month for estuarine samples and once per quarter for freshwater samples, which is an appropriate frequency for base-flow samples. To reduce the effect of tidal variation in the estuarine samples, sampling should be taken as close to 2 hours after high tide as possible. Efforts should be made to take freshwater samples at base-flow conditions (based on government flood gauges upstream, where available). The calculations for base-flow can be found here: A_standard_approach_to_baseflow_separati20160520-30084-19rh1pj-with-cover-page-v2.pdf (d1wqtxts1xzle7.cloudfront.net)

Output of Step 4b.

- A **map, GIS layer and/or table** providing details of the monitoring sites, grouped by sub-assets.
- A **map** that delineates between key estuary and freshwater systems. This map will provide detail on the start and end point of these systems.

Step 4.1.c.Determine reference benchmarks

All water quality samples should be assessed against the Queensland Ambient Water Quality Guidelines (QWQG) under the Central Coast Queensland and Southeast Queensland regional guidelines (**Error! Reference source not found.**, and **Error! Reference source not found.**). The QWQG were established in 2009 and are currently being updated by the Department of Environment and Science. Until gazetted, the current QWQG should be used to provide a Reference Benchmark value for all the water quality indicators. This Method will be updated with new values when they are available, and any Accounts using the old values should be re-calculated with the revised Reference Benchmark values.

Each water-type has separate Reference Benchmark values. The Reference Benchmark values, in **Error! Reference source not found.**, are derived from the Annual Median values of the Queensland Ambient Water Quality Guidelines. The guidelines were determined as the 80th percentile of all data taken from best on offer reference sites. The 80th percentile was used as this is the scientifically established value that supports full ecological function (QWQG, 2009). If there are sub-regional guidelines for a particular area, then these should be used instead of the regional guidelines. There are no published reference benchmark values for DIN, so a proxy reference benchmark is calculated as the sum of ammonia and Nitrogen oxide benchmarks.

It should be noted that Moss (2018) highlights that turbidity in long estuaries (>40 km) is naturally high due to sediment trapping and continual resuspension by tidal currents (Uncles, Stephen & Smith 2002). There are no suitable QWQG turbidity guidelines for naturally turbid estuaries, however it is still recommended that turbidity be measured to assess how it changes over time.

The median value of water quality at test sites is to be compared and assessed against the values presented in Error! Reference source not found. **and**

Table 5. Table 4 presents the reference benchmarks for all waterways located in Central Queensland. For values collected in the Mary catchment, use the benchmarks in Table 5 which have been calculated specifically for the water types in the Mary Catchment using Mary River Catchment Coordinating Committee data. An example for dissolved oxygen upper and lower limits is presented in *Figure 3*. For more information on how the reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).

*Table 4. Summary of the Reference Benchmarks for the **Central Queensland** taken from QWQG 2009. Apply to non-Mary River sub-catchments. For more information on how these guidelines and reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).*

Central Coast Queensland							
Indicator		Measure	Enclosed coastal/lower estuary (ECLE)	Mid estuary (ME)	Upper estuary (UE)	Lowland freshwater (LF) **	Upland freshwater (UF) **
Nutrients	Total Nitrogen (µg/L)	Lab	200 µg/L	300 µg/L	450 µg/L	500 µg/L	250 µg/L
	Dissolved Inorganic Nitrogen (µg/L)	Lab	11 µg/L	20 µg/L	45 µg/L	80 µg/L	25 µg/L
	Total Phosphorus (µg/L)	Lab	0.02 mg/L	0.025 mg/L	0.04 mg/L	50 µg/L	30 µg/L
	Filterable Reactive Phosphorus (µg/L)	Lab	6 µg/L	8 µg/L	10 µg/L	20 µg/L	15 µg/L
Sediments	Turbidity (NTU)	Field	6 NTU	8 NTU*	25 NTU*	50	25
	Total suspended Sediments (mg/L)	Lab	15 mg/L	20 mg/L*	25 mg/L*	10 mg/L	N/A
Phytoplankton	Chlorophyll-a (µg/L)	Lab	2 µg/L	4 µg/L	10 µg/L	5 µg/L	N/A
Physiochemical	Dissolved Oxygen	Field	90 – 100 %	85 – 100 %	70 – 100 %	85 – 110 %	90 – 110%
	Conductivity	Field	N/A	N/A	N/A	Varies by zone***	Varies by Zone***
	pH	Field	8.0 – 8.4	7.0 – 8.4	7.0 – 8.4	6.5 – 8.0	6.5 – 7.5

*These guidelines apply to estuaries less than 40 km in length. Longer estuaries have naturally higher turbidity levels (and corresponding higher SS values) due to longer retention times for suspended particulates and also to the continual re-suspension of fine particles by high tide velocities. Values are variable and site specific, however most values are <100 NTU and very few values are >200 NTU

** In the absence of better data, the guidelines adopted for freshwaters are for the most part are the default ANZECC 2000 Guidelines. It is acknowledged that these need to be updated with local data as soon as it is available.

*** See Appendix G of the Queensland Water Quality Guidelines (2009) for EC percentiles for Queensland Salinity Zones. It is recommended to use the 75%ile value as the reference benchmark.

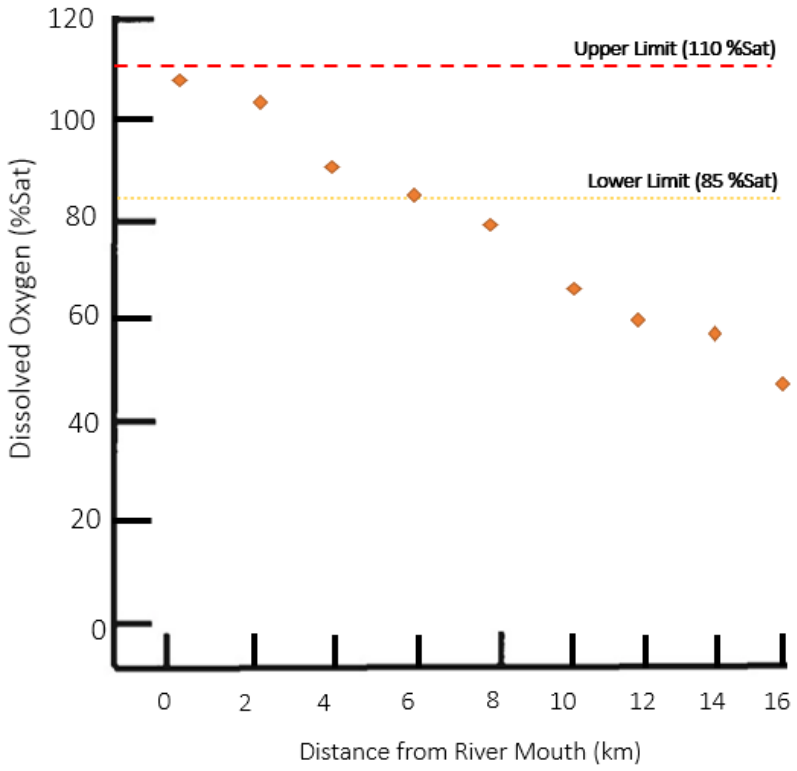

Figure 3. An example of dissolved oxygen guideline limits to show how observed values are compared to the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection (2009). The orange diamonds represent an example of observed values within the field.

*Table 5. Summary of the Reference Benchmarks for the **South-East Queensland** taken from QWQG 2009 and Mary river Catchment Waterwatch Results (MRCCC 2021). Apply to Mary River sub-catchments. For more information on how these guidelines and reference benchmarks are derived please refer to Queensland Water Quality Guidelines 2009 (des.qld.gov.au).*

Southeast Queensland													
Indicator		Measure	Enclosed coastal/lower estuary (ECLE)	Mid estuary (ME)	Upper estuary (UE)	Lowland freshwater (LF) **	Upland freshwater (UF) **	Maleny Plateau (Southern Upland Acid Waters)	Upper Mary River (Southern Upland Freshwaters)	Mary River and southern tributaries (Southern Lowland Waters)	Western Tributaries (North Western Lowland Waters)	Tinana Creek (North Eastern Lowlands)	East Tributaries of Tinana Creek (Eastern Sandplain Tannin Stained)
Nutrients	Total Nitrogen (µg/L)	Lab	200 µg/L	300 µg/L	450 µg/L	500 µg/L	250 µg/L	250 µg/L	250 µg/L	500 µg/L	500 µg/L	500 µg/L	250 µg/L
	Dissolved Inorganic Nitrogen (µg/L)	Lab	11 µg/L	20 µg/L	45 µg/L	80 µg/L	50 µg/L	50 µg/L	50 µg/L	80 µg/L	80 µg/L	80 µg/L	50 µg/L
	Total Phosphorus (µg/L)	Lab	20 µg/L	25 µg/L	30 µg/L	50 µg/L	30 µg/L	30 µg/L	30 µg/L	50 µg/L	50 µg/L	50 µg/L	30 µg/L
	Filterable Reactive Phosphorus (µg/L)	Lab	6 µg/L	6 µg/L	10 µg/L	20 µg/L	15 µg/L	15 µg/L	15 µg/L	20 µg/L	20 µg/L	20 µg/L	15 µg/L
Sediments	Turbidity (NTU)	Field	6 NTU	8 NTU*	25 NTU*	50 NTU	25 NTU	25 NTU	25 NTU	50 NTU	50 NTU	50 NTU	50 NTU
	Total suspended Sediments (mg/L)	Lab	15 mg/L	20 mg/L*	25 mg/L*	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L	6 mg/L
Phytoplankton	Chlorophyll-a (µg/L)	Lab	2 µg/L	4 µg/L	8 µg/L	5 µg/L	2 µg/L	2 µg/L	2 µg/L	5 µg/L	5 µg/L	5 µg/L	2 µg/L
Physiochemical	Dissolved Oxygen	Field	90 to 105	85 to 105	80 to 105	85 – 110 %	90 – 110%	90 – 110%	90 – 110%	85 – 110 %	85 – 110 %	85 – 110 %	85 – 110 %
	Conductivity	Field	N/A	N/A	N/A	Varies by zone***	Varies by Zone***	580 – 900 µS/cm	580 – 900 µS/cm	580 – 2600 µS/cm	1200 – 3000 µS/cm	580 – 900 µS/cm	580 – 900 µS/cm
	pH	Field	8.0 – 8.4	7.0 – 8.4	7.0 – 8.4	6.5 – 8.0	6.5 – 8.2	6 – 8	6.5 – 8.2	6.5 – 8	6.5 – 8	6.5 – 8	3.6 – 6

*These guidelines apply to estuaries less than 40 km in length. Longer estuaries have naturally higher turbidity levels (and corresponding higher SS values) due to longer retention times for suspended particulates and also to the continual re-suspension of fine particles by high tide velocities. Values are variable and site specific, however most values are <100 NTU and very few values are >200 NTU

** In the absence of better data, the guidelines adopted for freshwaters are for the most part are the default ANZECC 2000 Guidelines. It is acknowledged that these need to be updated with local data as soon as it is available.

*** See Appendix G of the Queensland Water Quality Guidelines (2009) for EC percentiles for Queensland Salinity Zones. It is recommended to use the 75%ile value as the reference benchmark.

Calculating a worst case scenario - 90th Percentile value

Most of the water quality indicators in this method are continuous meaning that values can theoretically continue to increase away from the benchmark without an upper limit. In order to calculate an Econd (between 0-1) a suitable upper limit or worst case scenario needs to be established. We have chosen the 90th percentile as this upper limit. The 90%ile value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Step 6). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the 90%ile value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores.

90%ile value is to be calculated as the 90th percentile of all the available observed historic data from the relevant water type (as per the designations of the Queensland Water Quality guidelines). The 90th percentile value is to be calculated using the Queensland Department of Environment and Science historical water quality data for each water type for each region (WMIP: Queensland Government (information.qld.gov.au, Water Data Online: Water Information: Bureau of Meteorology (bom.gov.au) and Water Data Online - Dataset - data.gov.au. If there is not sufficient data to calculate the 90%ile value, then expert opinion may be used to determine suitable values. An expert is considered as an AfN accredited expert or an external expert in the field. The 90%ile value is to be determined only at the start of the account with the same 90%ile values used in subsequent years of the account.

10th Percentile Value

The benchmark for dissolved oxygen is a range (lower and upper values) so that values can be either above the benchmark range or below. This means that two 'worst case scenarios' must be calculated in order to calculate an Econd. This requires a '10th Percentile' (10%ile) value to be identified for the dissolved oxygen indicator. The 10%ile value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Step 6). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the 10%ile value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores.

10%ile value is to be calculated as the 10th percentile of all the available observed historic data from the relevant water type (as per the designations of the Queensland Water Quality guidelines). The 10th percentile value is to be calculated using the Queensland Department of Environment and Science historic water quality data for each water type for each region (link to data source). If there is not sufficient data to calculate the 10%ile value, then expert opinion may be used to determine suitable values. The 10%ile value is to be determined only at the start of the account with the same 10%ile values used in subsequent years of the account.

Output of Step 4c

- A **data table** (e.g. a spreadsheet) containing reference values for each indicator, grouped by sampling unit.

Step 4.1.d. Collect data and process samples

The sampling techniques that must be used to measure each of the water quality indicator is summarised in Table 6 below. These techniques are in accordance with the Queensland Water Monitoring and Sampling Guideline (DES, 2018). Tables 7-9 provide additional details on how to implement these techniques. In general, samples taken must be reliable, representative, not contaminated, degraded, or transformed, and a sufficient volume to meet detection limits for particular lab analyses.

As this method is focused on Base Flow, the State government flood gauge stations should be checked prior to sampling to ensure that the estuaries are at 'base flow' condition. Sampling during baseflow should be undertaken with an appropriate lag time after an event to ensure samples are truly baseflow. If in doubt, Hydrographs can be used to check base flow separation (refer to Section B 8.5 of the Queensland Monitoring and Sampling Manual (2009), and page 77 of Grayson et al, 1996). **If the water is not considered to be base flow, then samples should not be taken (or can be taken, but not included in ICS or Econd® calculations).**

Table 6. Summary of Sample Techniques for indicators

Indicator		Measure	Technique description
Nutrients	Total Nitrogen (µg/L)	Grab Sample – Lab Analysis	
	Dissolved Inorganic Nitrogen (µg/L)	Filtered Sample – Lab Analysis	Table 8. How to collect a Filtered *Sample*
	Total Phosphorus (µg/L)	Grab Sample – Lab Analysis	
	Filterable Reactive Phosphorus (µg/L)	Filtered Sample – Lab Analysis	Table 8. How to collect a Filtered *Sample*
Sediments	Turbidity (NTU)	Insitu field sampling using water quality instrument	
	Total Suspended Sediments (mg/L)	Grab Sample – Lab Analysis	
Phytoplankton	Chlorophyll-a (µg/L)	Grab Sample – Lab Analysis	
Physiochemical	Dissolved Oxygen	Insitu field sampling using water quality instrument	
	Conductivity	Insitu field sampling using water quality instrument	
	pH	Insitu field sampling using water quality instrument	

Table 7. How to collect a Grab Sample

Grab Sample for: - Total Nutrients (Nitrogen and Phosphorus) - Total Suspended Sediments - Chlorophyll-a	
Timing	Non-event conditions
Sampling	1. It is important to ensure that the sampling regime is representative of the system and parameter/s of interest. For example, where a water body is well mixed and a parameter of interest is evenly distributed in the water column, a single grab sample may be appropriate. However, if water quality changes with depth, a number of samples at different depths may be required. 2. Take a water sample by Inserting a Perspex pole sampler with a 1 L acid rinsed Nalgene bottle to a depth of about 0.5 m (or deeper, if required) 3. Individually fill a laboratory sample bottle for each of the four measures, Total Nitrogen, Total Phosphorus and Chlorophyll-a. Always store samples in a cooler box with ice or ice bricks, label appropriately and fill out the chain of custody form. The samples will then be sent to the lab to analyse the above four indicators.

Table 8. How to collect a Filtered Sample

Filtered Sample for: - Dissolved Inorganic Nitrogen - Filterable Reactive Phosphorus	
Timing	Non-event conditions
Sampling	1. Take a water sample by Inserting a Perspex pole sampler with a 1 L acid rinsed Nalgene bottle to a depth of about 0.5 m. 2. Rinse the syringe three times in sample water. 3. Fill the syringe with sample water and place 0.45 µm membrane filter on end of syringe. 4. Push a couple of millilitres of sample through the filter to rinse. 5. Push approximately 5mL of sample through the syringe and filter into the 'filtered' sample container. 6. Replace the lid on the labelled sample container and shake gently to rinse all internal surfaces including the lid. 7. Remove the lid and discard the rinsate away from the sample processing area. 8. Repeat the rinse of the 'filtered' sample container three times. 9. Fill the 'filtered' sample container with water pushed through the syringe and filter. Always store samples in a cooler box with ice or ice bricks, label appropriately and fill out the chain of custody form. The samples will then be sent to the lab within 24 hours to analyse the above four indicators. However, nutrient samples can be frozen to extend holding times.
Reference	Queensland Water Monitoring and Sampling Guideline (DES, 2018)

Table 9. How to use a Water Quality Meter

Water Quality Meter measures for: - Turbidity - Dissolved Oxygen - Conductivity - pH	
Timing	Early in the morning (when DO levels are at their lowest) and in non-event conditions (e.g. no rain in catchment in xx days?)
Sampling	Ensure the Water Quality Meter is calibrated and checked prior to monitoring Measure at 0.2 m to avoid surface scums and floating material
Reference	Queensland Water Monitoring and Sampling Guideline (DES, 2018)

Laboratory Analyses for water quality

All analyses for Nutrients, Total Suspended Solids and Chlorophyll-a must be performed by laboratories that are accredited by the National Association of Testing Authorities Australia. Options include Australian Laboratory Services, and Queensland Health Laboratories.

Data

All measured indicator data should be stored in a data table that lists the values for each indicator for each site.

Output of Step 4d

- A **data table** (e.g. a spreadsheet) containing all the raw data for each environmental indicator for each sample.

Step 4.1.e. Calculate indicator condition scores

In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the range between the reference benchmark value and the worst-case scenario (e.g. the 90th or 10th percentile values). Based on that principle, the scoring formula is based on converting the observed indicator values to a "distance from benchmark" value. The distance from benchmark is expressed as a proportion (0 to 1) using the equations below. An observed value that equals or exceeds the Reference Benchmark will receive an ICS of 1 and an observed value that equals or exceeds the 90th Percentile value will receive an ICS of 0. Final indicator scores are calculated as a mean of the site-based distance scores. The following excel equations are to be used to calculate the ICS. The below equations are explained in Table 10.

To calculate the Indicator and Summary ICS for Water Quality:

1. Calculate the ICS for each water quality indicator within each sampling unit using the ICS formulas below.
2. Calculate the **water quality summary ICS** for each sampling unit
    - Averaging the ICS for each water quality indicator within that sampling unit
3. Calculate the **water quality summary ICS** for each sub-asset (catchment)
    - Aggregate the water quality summary ICS of each sampling unit within a catchment using the length-weighted average of all
        - Note. The 'length' of the waterways within each catchment is to be calculated and used to scale the aggregation of the final Econd. The length of waterways should be determined using the Adopted Middle Thread Distances (AMTD) established by the Queensland Water Resources Commission in the 1950s for all major streams in the state in accordance with the Report on Condition and trends in Water Quality in Central Queensland Estuaries (1993 to 2015).
    - The water quality summary ICS is used in the Econd calculations, see Step 5.

All Water Quality Indicators (except Dissolved Oxygen)

1.

=(OBS-WCS)/(REF-WCS)

2.

=IF(CALCULATEDSCORE >1, 1, 0)

For Water Quality Indicators the observed value is the annual median value for each sampling unit.

Dissolved Oxygen

1.

=IF(K2 <REF, (OBS-WCS_{LOWER})/(REF-WCS_{LOWER}), 1)

2.

=IF(K2 <REF, (OBS-WCS_{UPPER})/(REF-WCS_{UPPER}), 1)

3.

=IF(CALCULATEDSCORE >1, 1, 0)

Where:

REF = Reference Benchmark
OBS = Observed annual median value
WCS = Worst case scenario (upper= 90%ile and lower = 10%ile)

Table 10. Summary of Indicator Condition Scoring, where REF = reference value, OBS = observed value, 90%ile = 90th percentile value and 10%ile = 10th percentile value.

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Total Nitrogen (µg/L)
Dissolved Inorganic Nitrogen (µg/L)
Total Phosphorus (µg/L)
Filterable Reactive Phosphorus (µg/L)
Turbidity (NTU)
Conductivity
Total suspended Sediments (mg/L)
Chlorophyll-a (µg/L)</td><td>Where REF < 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS < REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{\text{90\%ile-OBS}}{\text{90\%ile-REF}}$</td></tr>
<tr><td>If OBS > 90%ile</td><td>0</td></tr>
</table></td></tr>
<tr><td>pH (if OBS > REF)</td><td>Where REF < 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{\text{90\%ile-OBS}}{\text{90\%ile-REF}}$</td></tr>
<tr><td>If OBS > 90%ile</td><td>0</td></tr>
</table></td></tr>
<tr><td>pH (if OBS < REF)</td><td>Where REF > 90%ile, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>1</td></tr>
<tr><td>If OBS < REF</td><td>$\frac{\text{OBS-90\%ile}}{\text{REF-90\%ile}}$</td></tr>
<tr><td>If OBS < 90%ile</td><td>0</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Dissolved Oxygen</td><td>The following scoring is to be used for Dissolved Oxygen which has an upper and lower Reference Benchmark and 90th Percentile value, where:
90%ile = 90th Percentile value
10%ile = 10th Percentile value
<table>
<tr><th>Scenario</th><th>ICS Calculation</th></tr>
<tr><td>IF OBS < 10%ile</td><td>0</td></tr>
<tr><td>If 10%ile < OBS < REF_{Lower}</td><td>$\frac{OBS-10\%ile}{REF_{Lower}-10\%ile}$</td></tr>
<tr><td>If REF_{Lower} < OBS < REF_{Upper}</td><td>1</td></tr>
<tr><td>If REF_{Upper} < OBS < 90%ile</td><td>$\frac{90\%ile-OBS}{90\%ile-REF_{Upper}}$</td></tr>
<tr><td>IF OBS < 90%ile</td><td>0</td></tr>
</table></td></tr>
</table>

Output of Step 4e

- A **Data Table** (e.g. a spreadsheet) containing reference values, observed value and calculated Indicator Condition Scores

3.2 Ecological Flow – Burnett-Mary Region

The following section on ecological flow describe indicators and reference benchmarks that are specific to the waterways of the Burnett-Mary Region, where this Method is being piloted. Following this pilot, we are intending to revise this document to make it more generally applicable to other Australian catchments. There are numerous ways to measure flow that have relevance for specific environmental objectives. As such, it is difficult to prescribe a 'one-size-fits-all' approach to ecological flow measurement. Our approach is to prescribe catchment specific indicators and benchmarks for flow, as each river system has different management issues and objectives. Application of this indicator class requires expertise in hydrology and familiarity with the data sources required for analyses. It is anticipated that a consultant will be required to assist NRM organisations to produce an account using this method.

Within the Burnett-Mary Region, there are three water plans (Burnett Basin, Mary Basin and Baffle Creek), which hold specific environmental flow objectives and associated ecological outcomes (Figure 4).

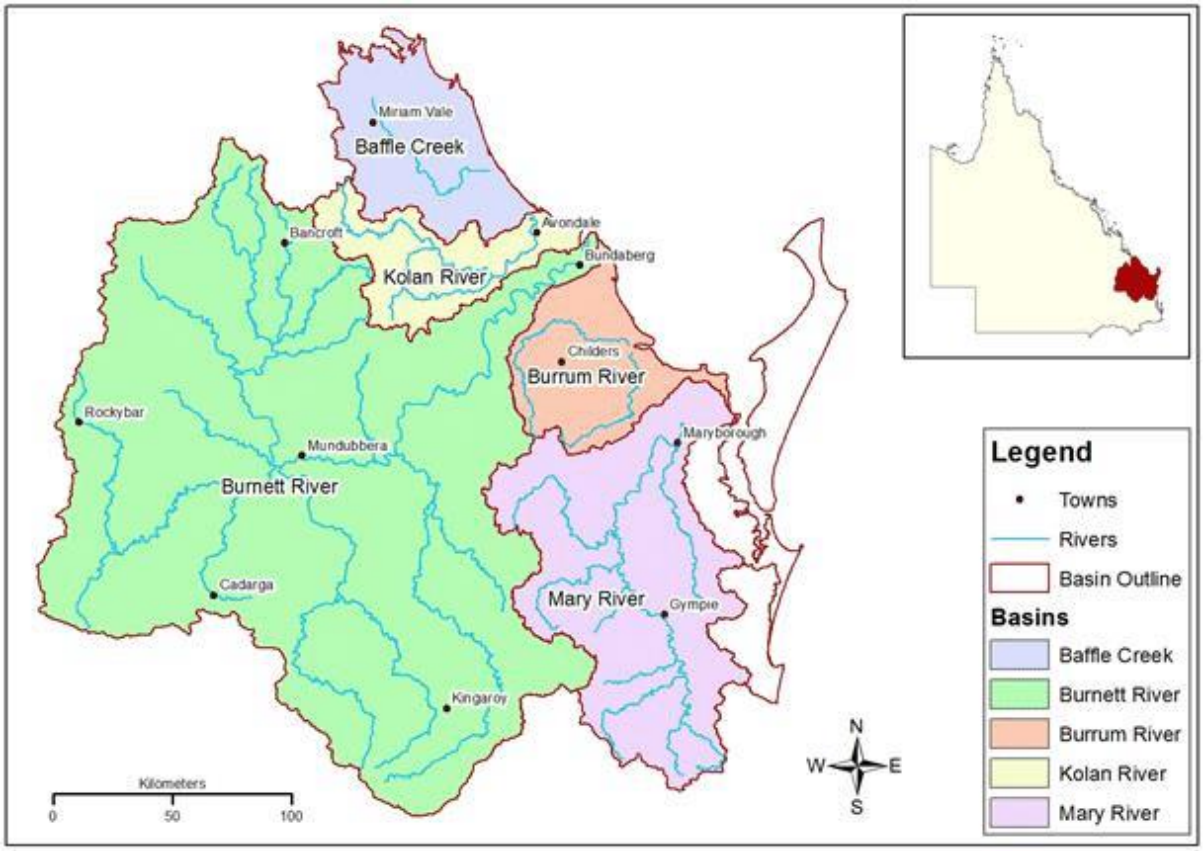

Figure 4. An overview of the Burnett-Mary Basin and the associated sub-catchments. Note: Kolan/Elliot/Gregory/Burrum and Isis Rivers are lumped together with the Burnett Basin Water Plan. Source: Beverly et al. (2016).

Step 4.2.a. Describe environmental indicators

The timing and magnitude of water flows through the rivers in the region is a critical determinant of the breeding and migratory success of the region's iconic species. Water impoundments like dams and weirs alter the hydrology of rivers which impacts on those species. Environmental flow strategies in modified rivers that minimise changes to natural flow regimes provide suitable conditions not only for these iconic species but for the broader aquatic ecosystem. The Queensland Government manages the flow regime in the region's rivers with ecohydrological rules outlined in the *Water Plan's* (In force legislation - Queensland Legislation - Queensland Government), specific for each catchment. Within each of the *Water Plan's* there is a schedule that outlines the water flow objectives, with these objectives varying between the three basins.

The method outlined in the sections below is based on the ecological objectives within each Water Plan, however, has it has been simplified to enable robust data collection at small to large scales and for consistency across the entire Burnett-Mary region.

Below outlines the ecohydrological rules as they apply to each catchment in the Burnett-Mary Region.

Baffle Creek – The *Water Plan (Baffle Creek) 2010 (Qld)* (Queensland Government, 2010) states that the ecological outcomes for managing water flows are:

a. to minimise changes to the natural variability of flows that support aquatic ecosystems
b. to provide for the continued capability of one part of an aquatic system to be connected to another, including by maintaining flows that
    i. allow for the movement of native aquatic species between riverine, floodplain, wetland, estuarine and marine environments
    ii. support natural processes such as breeding, growth and migration in riverine, floodplain, wetland, estuarine and marine environments
    iii. support river-forming processes

c. to minimise changes to natural variability in water levels to support natural ecological processes, including maintaining refugia associated with waterholes and lakes.
d. to minimise adverse impacts on aquatic ecosystems immediately downstream of new water resource development
e. to improve understanding of the matters affecting flow ecology responses of ecosystems within the plan area.

Specific ecological outcomes (*Chapter 3, Section 13 of the Water Plan (Baffle Creek) 2010*)) for water in the plan area are outlined below:

a. to maintain the near-natural flow regime that supports waterholes and estuarine ecosystems in the Eurimbula Creek catchment area and Worthington Creek catchment area
b. to minimise changes to flows that maintain existing brackish habitat downstream of barrages in the Broadwater Creek catchment area
c. in the Baffle Creek catchment area
    i. to maintain connectivity between Baffle Creek and its adjacent floodplain system including lakes
    ii. to maintain the near-natural flow regime that provides for intermittent brackish habitat through the entire length of the Baffle Creek estuary
    iii. to minimise changes to the low flow regime that provides for riffle habitat and maintains waterholes
    iv. to minimise changes to the persistence of waterholes

d. to minimise changes to the flow regime that maintains brackish habitat in the upper reaches of Littabella Creek estuary.

Burnett Basin – In Chapter 3, Part 16 of the *Water Plan (Burnett Basin) 2014 (Qld)* (Queensland Government, 2014) states that the ecological outcomes for managing water flows include the following:

a. minimisation of changes to the natural variability of flows that support aquatic ecosystems.
b. the continued capability of a part of the river system to be connected to another, including by maintaining flows that—
   i. allow for the movement of native aquatic fauna between riverine, floodplain, wetland, estuarine and marine environments
   ii. support water-related ecosystems
   iii support river-forming processes
c. protection and maintenance of refugia associated with waterholes, lakes and wetlands.
d. the support of ecosystems dependent on groundwater, including, for example, riparian vegetation and wetlands
e. e. provision of flows and hydraulic habitat for flow-spawning fish and endemic species, including, for example, the Australian lungfish (*Neoceratodus forsteri*) and the white-throated snapping turtle (*Elseya albagula*)
f. maintenance of flows necessary for estuarine ecosystem functions, including flows for—
   i. barramundi (*Lates calcarifer*) and sea mullet (*Mugil cephalus*) recruitment; and
   ii. banana prawn (*Fenneropenaeus merguiensis*) growth; and
   iii. river mangroves (*Aegiceras corniculatum*);
g. maintenance of a near natural flow regime that supports waterholes and riverine ecosystems in subcatchment area M.

Mary Basin – In Part 3, Section 13 of the *Water Plan (Mary Basin) 2006 (Qld)* (Queensland Government, 2006) the ecological outcomes for managing water flows include the following:

a. for the Noosa River, Mooloolah River and coastal streams north of Noosa River mouth—
   i. to minimise changes to river-forming processes; and
   ii. to minimise changes to a near-natural flow regime.
b. for the Mary River, upstream of the Mary River barrage pondage—
   i. to minimise changes to the low flow regime of the river; and
   ii. to minimise changes to the hydraulic habitat requirements of species such as the Mary River cod, the Mary River turtle and lungfish;
c. for Six Mile Creek—
   i. to minimise changes to the low flow regime of the creek; and
   ii.to minimise changes to the hydraulic habitat requirements of species such as the Mary River cod and lungfish;
d. for Tinana Creek, upstream of Tallegalla Weir—to minimise changes to the hydraulic habitat requirements of existing ecological assets in the area;
e. for Obi Obi Creek, in the Obi Obi Creek Gorge area—to minimise changes to the hydraulic habitat requirements of existing ecological assets in the area;
f. for the Burrum River—
   i. in the Upper Burrum River above Lenthalls Dam—to minimise changes to the flooding regime at Wongi Waterholes; and

ii. in the Lower Burrum River system below Lenthalls Dam—to minimise changes to variability in the low flow regime of the river system to improve opportunities for fish passage.

Output of Step 4a

- A table describing the **environmental indicators** to be measured in the account, grouped by sub-asset (waterway).

Step 4.2.b. Collate data

The data used for calculating the scores of this method is from the stream gauging network co-ordinated by the state government. To calculate the reference benchmarks and current conditions of the waterways, stream gauge data will need to be downloaded from the Water Monitoring Information Portal (WMIP), instructions on how to download and calculate the data can be found in Appendix D. The following gauge datasets will need to be downloaded:

Mary

- Amamoor Creek at Zachariah
- Glastonbury Creek at Glastonbury
- Kandanga Creek at Hygait
- Mary River at Home Park
- Mary River at Bellbird Creek
- Mary River at Miva
- Mary River at Moy Pocket
- Munna Creek at Marodian
- Obi Obi Creek at Gardners Falls
- Six Mile Creek at Cooran
- Teewah Creek at Coops Corner
- Tinana Creek at Bauple East
- Tinana Creek at Tagigan
- Wide Bay at Brooyar
- Wide Bay at Kilkivan

Burnett

- Auburn River at Dykehead
- Barambah Creek at West Barambah
- Barambah Creek at Ban Ban
- Barambah Creek at Litzows
- Barker Creek at Brooklands
- Barker Creek at Glenmore
- Boyne River at Carters
- Boyne River at Ceratodus
- Boyne River at Cooranga
- Burnett River at Eidsvold
- Burnett River at Jones Weir Headwater
- Burnett River at Tailwater
- Burnett River at Gayandah

- Burnett River at Mount Lawless
- Cadarga Creek at Brovinia
- Eastern Creek at Lands End
- Elliot River at Dr Mays
- Elliot River at Figtree
- Gregory River at Isis Highway
- Isis River at Bruce Highway
- Kolan River at Springfield
- Monal Creek at Upper Monal
- Reid Creek ay Mungy
- Splinter Creek at Dakiel
- Stuart River at Proston
- Stuart River at Weens Bridge
- Three Moon Creek at Abercorn

Baffle

- Oyster Creek at Rapleys
- Baffle Creek at Mimdale

Output of Step 4b

- **Data tables** (e.g. individual spreadsheets) containing all the raw data, derived from the latest WMIP for each stream gauge used for the analysis.
- **Cleaned and organised data -** Prior to any data analysis, the data will need to be cleaned and organised for the analysis software to read it properly.

Step 4.2.c.Determine reference benchmarks

In general, reference benchmarks for ecological flow are based on the Integrated Quality and Quantity Model (IQQM) pre-development flow pattern. However, pre-development flow pattern data is not available for all basins. As such, historical benchmarks will need to be generated from the year the stream gauge started collecting data (e.g. 1979) to 31st December 2020 for all performance indicators listed below:

a. The mean annual flow
b. The median annual flow
c. The 10th percentile annual flow
d. The 90th percentile annual flow
e. The number of days with no flow in the judgement period
f. The number of no flow spells in the judgement period
g. The maximum duration (in days) of one of the no flow spells in the judgement period
h. The 10 cm annual flow (number of spells)
i. The 30 cm annual flow (number of spells)

Where possible pre-development data will be required for the calculation of the 10cm and 30cm annual flow indicator scores. The pre-development data for the Mary basin can be found in the Environment Conditions Report – Volume 2. The available pre-development data for the Burnett and Baffle Creek Basin is outlined in Appendix D.

Calculating Reference Benchmarks

To calculate reference benchmarks for each indicator a software called River Analysis Package (RAP) will need to be used. This involves calculating the benchmarks with the relevant thresholds outlined in the Environment Conditions Report – Volume 2 for the Mary Basin. The thresholds for the Burnett and Baffle basins can be found in Appendix D below.

For the detailed method on the calculations for the reference benchmarks please refer to Appendix D.

Calculating the Annual Data

To calculate the annual results for each indicator the River Analysis Package (RAP) will need to be used. This involves calculating the annual results with the relevant thresholds outlined in the Environment Conditions Report – Volume 2 for the Mary Basin. The thresholds for the Burnett and Baffle basins can be found in Appendix D below. The annual year should be a full calendar year (e.g. January 1st to December 31st for 2021).

For the detailed step by step method on the calculations for the reference benchmarks please refer to Appendix D.

Calculating a Worst-Case Scenario

Most of the ecological flow indicators in this method are continuous meaning that values can theoretically continue to increase away from the benchmark without an upper or lower limit. In order to calculate an Econd (between 0-1) a suitable upper or lower limit (referred to as a worst case scenario) needs to be established. We have chosen either the 90th percentile as the upper limit or the 10th percentile as the lower limit depending on the indicator.

The WCS value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring (refer to Appendix G). A site that is equal to or better than the Reference Benchmark will receive a value of 1 and a site approaching the WCS value will receive a value approaching 0. Final indicator scores are calculated as a mean of the site-based distance scores. The WCS score for ecological flows depends on the respective Water Plan and gauge. For the WCS for each reference benchmark with the individual Water Plans, refer to Appendix E.

Output of Step 4c

- **Historical benchmarks** – all historical benchmarks should be calculated for each environmental indicator for each stream gauge as per Appendix D
- **Annual calculations –** All current data (e.g. 2021) should be calculated for each environmental indicator for each stream gauge as per Appendix D.
- A **data table** (e.g. a spreadsheet) containing the historical benchmarks and annual calculations.

Step 4.2.d. Calculate indicator condition scores

Indicator condition scores for ecological flow are all calculated using the formula presented below, which has as its inputs, the observed values taken from the IQQM model and the Reference and Worst-Case Scenario values as described in the appropriate Water Plan and as outlined in this document. For each catchment, there may be more than one set of indicators that are aggregated to provide an indicator condition score for that catchment (see Table 11). The calculations can be performed in MS Excel or adapted for use in another statistical package. For Ecological Flow, the observed value is the annual median value for the catchment.

In separate columns have the following equations:

1.

$=(OBS-WCS_{LOWER})/(REF-WCS_{LOWER})$

2.

$=(OBS-WCS_{UPPER})/(REF-WCS_{UPPER})$

3.

=IF(CALCULATEDSCORE >1, 1, 0)

Where:

REF = Reference Benchmark
OBS = Observed annual median value
WCS = Worst case scenario

Table 11. Calculation of indicator condition scores for ecological flow

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Ecological Flow</td><td>
Where REF < WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS < REF</td><td>1</td></tr>
<tr><td>If OBS > REF</td><td>$\frac{WCS-OBS}{WCS-REF}$</td></tr>
<tr><td>If OBS > WCS</td><td>0</td></tr>
</table>
Where REF > WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS > REF</td><td>1</td></tr>
<tr><td>If OBS < REF</td><td>$\frac{WCS-OBS}{WCS-REF}$</td></tr>
<tr><td>If OBS < WCS</td><td>0</td></tr>
</table>
Where the performance indicator involves a range, the score is binomial. Inside the range should be given an ICS of 1 and outside the range should be given an ICS of 0.

The final ICS should be taken as the mean of all scores for all gauges within a catchment (refer to Figure 5 below).
</td></tr>
</table>

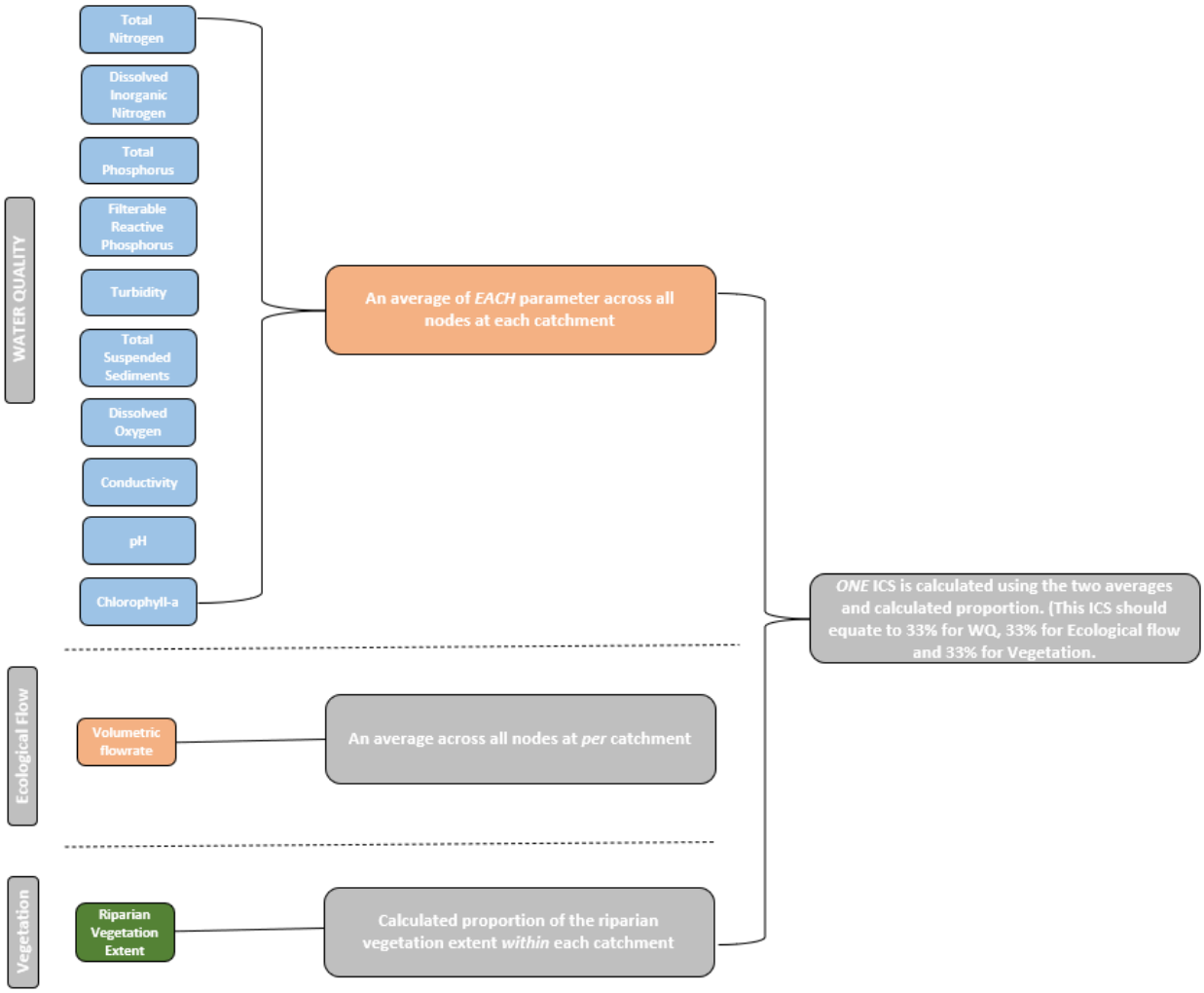

Figure 5. Flow chart outlining how the ICS is calculated.

Output of Step 4d

- A **Data Table** (e.g. a spreadsheet) containing all the data, including observed values, reference values and calculated Indicator Condition Scores.

3.3 Riparian Vegetation Extent – Queensland Catchments

Riparian vegetation is a critical component of a waterway. Vegetation provides habitat for a wide variety of organisms, prevent erosion of riverbanks and acts as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increased input of sediments and nutrients.

Our approach to measuring riparian vegetation focuses on the functional value of vegetation for waterway condition. We recognise that riparian vegetation condition is a valuable indicator of environmental condition in its own right, but the types of on-ground measurements required to assess vegetation condition are outside the scope of this Method at present. We aim to expand the scope of our measurement of riparian vegetation to include condition indicators as we further develop this Method.

The measurement of this indicator is based on a foliage projective cover GIS layer produced by the Queensland Government. As such, the scope of this method is at this stage limited to Queensland waterways. Other layers are available that measure and classify vegetation cover at various scales from State, to National to Global. We have selected this layer for assessment of Queensland catchments because it is consistent with the approach used by the Queensland Government and other organisations to assess vegetation cover change. As with other indicators in this method, following the Burnett Mary regional pilot, it is our intention to expand the scope of the methods, to facilitate adoption in other Australian regions. In the case of riparian extent, it would involve identifying the most appropriate spatial products in other jurisdictions. These layers are constantly being developed and refined, so will require regular updates to this method. Where local scale mapping is available (e.g known weed location and fire scar extent), they will be overlayed on the satellite imagery and masked out for the calculation of the riparian extent. Of note, foliage protection cover layer does come with its limitations, and where a new product that further enhances the analysis becomes available, the method will be updated to reflect that.

Step 4.3.a. Define environmental indicators

Riparian vegetation is defined as riparian woody vegetation to include riparian forest (trees > 5m height with dense foliage cover) (Specht, 1970); riparian woodlands (trees >5m in height with sparse foliage cover and shrublands (shrubs < 5m in height). Riparian areas that are non-woody and have low ground cover levels may be areas of concern for soil and nutrient loss to the stream. The recommended width of the riparian zone is described in *Section 3 Table 2*.

Output of Step 4a

- The **riparian vegetation extent indicator** is defined as the area of existing woody extent and ground cover vegetation in the riparian buffer zone compared to the area of the total riparian buffer zone for all waterways in the catchment.

Step 4.3.b. Determine reference benchmarks

The benchmark for riparian vegetation is what is considered pristine condition and/or the most desirable state. The reference benchmark for riparian vegetation is 100%, this is due to the assumption the waterways had full riparian coverage prior to the clearance of native vegetation.

The Worst-Case Scenario score for the riparian vegetation extent indicator is a value of 0% of the riparian zone along all of the waterways covered. The WCS value is used as a scaling factor along with the Reference Benchmark in the Indicator Condition Scoring.

The size or width of the riparian zone varies with different sized streams. For a riparian zone to function as described above, it should be an appropriate width for the size of the stream.

Output of Step 4b

The width of the riparian zone, or buffer width, are dependent on the stream order of the waterway and the presence of sugar cane growing areas. The table below outlines the recommended riparian buffer widths according to the stream order which takes into account cane-growing areas. The riparian buffers are based on evidence from scientific literature, with a detailed explanation of each source within Appendix B.

Stream order	Riparian buffer width (m)
1-2	50*
3-4	75*
5-6	100*
7-8	150

* Derived from Lovett and Price (2001), Department of Primary Industries [NSW GOV] (2012) & Hansen et al. (2010).

Step 4.3.c.Collect and analyse data

The extent of woody vegetation is mapped using the indicator, Foliage Projective Cover (FPC). FPC is mapped by the QDL state government through the State-wide Landcover and Trees Study (SLATS) each year. It is produced from satellite imagery and is available as a raster dataset which represents the FPC for the previous 2-year period (rather than at a single date). The satellite imagery has a resolution (i.e. pixel size) of 10m x 10m. Each pixel is classified between 0 and 100 and represents the level of coverage.

The extent of riparian woody vegetation is mapped using the QLD Statewide Landcover and Trees Study (SLATS) Sentinel-2 - 2019 woody vegetation extent layer (DES, 2021). This woody vegetation extent layer is based on a U-net convolutional neural network classification, fitted on very high spatial resolution (i.e. ~1m) Earth-i satellite imagery to produce an initial binary woody presence/absence classification, as described in Flood et al (2019). The classification is subsequently down-sampled to 10m to approximate the spatial resolution of Sentinel-2, given it will be used for ongoing monitoring.

Features on the satellite imagery are categorised as either woody or non-woody, where woody vegetation defined in DES (2021) as stands of woody vegetation greater than 0.5ha with a crown cover greater than 10% are represented. A minimum width of 20m was applied to linear features. No distinction is made between native and non-native vegetation; woody vegetation such as woody weeds and horticultural crops are included as woody in the final classification. Both woody and nonwoody features smaller than these sizes have been filtered out of the data set. Ancillary data on dams and waterbodies were also used to further refine the woody classification for the riparian analysis. These waterbodies were classified as 'no data'.

For riparian areas classed as non-woody, ground cover is estimated for the dry (winter) season (July - August 2019). Ground cover monitoring is included to recognise the importance of having some level of vegetation cover in riparian areas to help minimise erosion and filter sediment and nutrient runoff, particularly where woody vegetation is not present to stabilise the soil through deeper root structures. Ground cover reporting in riparian areas is based on Sentinel-2 seasonal fractional cover data derived using the method described by Flood (2017). The Sentinel-2 fractional cover product is not specifically a ground cover product and does contain woody vegetation. However, as its use is restricted to non-woody areas it is suitable for the purposes of assessing ground cover. Three classes of ground cover were used for reporting: 0-30%; 30-70%; and, greater than 70% ground cover. Very low ground cover can indicate degraded areas, such as gullies. It may also be present naturally in areas containing sandbars, sand dunes and rocky streams.

The indicator condition score is based on summing the area of highest ground cover (>70%) with the area of medium (30 -70%) and high (>70%) woody extent within the riparian layer. As ground cover is not as effective at stabilising river banks, the area of ground cover in each catchment is weighted at 20%.

To calculate the riparian vegetation extent, the following procedure should be followed:

Measures for Riparian Veg % coverage within each catchment (or sub-asset)

1. Download the following layers:

- Watercourse lines – this dataset is the centre line of a waterway which is suitable for analysing the smaller stream orders. This dataset also includes the stream order which enables the correct buffer width to be selected.
- Watercourse areas – this dataset presents the outline of the wider stream orders (e.g. larger rivers). The riparian buffer width is then taken from the edge of this layer so that the water is not included in the analysis
- Three monthly seasonal fraction cover June – August 2021 (request from DES via email)
- Woody extent (request from DES)
- Statewide Landcover and Trees Study (SLATS) Sentinel-2-2019 woody vegetation extent
- Foliage Projection Cover (2019)
- Drainage basin – sub areas

2. Import all layers into spatial software (such as QGIS or ArcMap). Ensure that all of the layers have been imported in the correct projection and horizontal datum (i.e., the coordinate reference system (CRS)) and change if needed.
3. The first step is to erase all watercourse areas from the watercourse line dataset. This is to ensure that both of the datasets are not calculated twice.
4. Create the relevant riparian buffers with FLAT ends on both the watercourse line and area datasets. The recommended riparian buffers areas are outlined in Table 2.
5. Merge the created buffers into one shapefile.
6. Remove the estuarine wetlands from the buffer dataset. Estuarine areas are to be excluded from this assessment using Queensland's wetland layer
7. Clip the Seasonal Fractional Cover (groundcover) and Woody Extent to the created buffer shapefile.
8. Clip the Foliage Projective Cover (woody vegetation) to the riparian buffer zone (anything outside of the riparian buffer is to be removed).
9. Calculate the zonal statistics for each sub catchment. The zonal statistics are to be calculated based on rasters (Pixel Count X Pixel size) / 10,000 for hectares.
10. Calculate the following statistics for each catchment:

- Total riparian buffer area
- Seasonal fractional cover (ground cover) within the buffer area
    i. Low cover (<30%)
    ii. Medium cover (30%-70%)
    iii. High (>70%)
- Foliage projection cover of the woody extent within the buffer area
    i. Low cover (<30%)
    ii. Medium cover (30%-70%)
    iii. High (>70%)

Output of Step 4c

- A regional **GIS layer** of woody extent and ground cover clipped to the relevant buffers in accordance with their stream order. This is outlined in Table 2.

Step 4.3.d. Calculate Indicator Condition Scores

In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the Reference Benchmark value, however this method also incorporates a Worst Case Scenario value. The scoring formula is based on converting the observed indicator values to a "distance from benchmark" value. The distance from benchmark is expressed as a proportion (0 to 100) using the equations below. The riparian extent is calculated for all waterways within a catchment (or sub-asset).

Riparian Vegetation Indicator

For Riparian Vegetation for each catchment, the score is derived from a combination of the highest ground cover and the area of medium and highest woody extent. The ground cover extent component is weighted at 20% in recognition that it is not as effective as woody extent in stabilising river banks and providing habitat for aquatic and riparian biodiversity. Therefore, the observed value is the sum of the area within the riparian buffer area of highest category ground cover (e.g. >70%) weighted at 20%, with the area of the two highest woody extent categories, medium (30 -70%) and high (>70%) within the riparian buffer area.

Where:

REF = Reference Benchmark (in all cases 100%)
OBS = The sum of the sum of the area within the riparian buffer area of highest ground cover (>70%) weighted as 20% of that area, with the area of medium (30 -70%) and high (>70%) woody extent
WCS = Worst case scenario (in all cases 0%)

<table>
<tr><th>Indicator</th><th>Indicator Condition Scoring</th></tr>
<tr><td>Riparian Veg % coverage</td><td>Where REF > WCS, the following scoring is to be used:
<table>
<tr><th>Scenario</th><th>ICS</th></tr>
<tr><td>If OBS = REF</td><td>100</td></tr>
<tr><td>If OBS < REF</td><td>$100 \times \frac{OBS-WCS}{REF-WCS}$</td></tr>
<tr><td>If OBS =WCS</td><td>0</td></tr>
</table></td></tr>
</table>

Output of Step 4d

- A **Data Table** (e.g. a spreadsheet) containing all the data., including observed values, reference values and calculated Indicator Condition Scores

4. Creating the Environmental Account – Calculating the Econd®

Step 5. Calculate the Econd®

The Econd® is an index between 0 and 100, where 100 describes the 'best-on-offer' or 'pre-development' reference condition of an environmental asset, and 0 indicates the asset is completely degraded.

This Method prescribes instructions for calculating Econd® indices for each sub-asset (each catchment) and then aggregating these into the overall Econd® for the Waterway Environmental Asset.

The following steps must be taken to calculate the Econd®:

1. The **catchment** Econd® scores are calculated as the average of the Indicator Condition Scores for each Indicator Class – Water Quality, Ecological Flow and Riparian Extent (i.e 33% WQ, 33% Riparian and 33% Ecological Flow). If using the eDNA Method (AfN-METHOD-F-05) to also assess aquatic vertebrate condition, then include the results from the eDNA analysis with equal weighting of all indicator classes.
2. Next, the Econd® for the waterway asset is calculated for the whole Account as a length weighted average of the **catchment** Econd® indices.
    - Note. The 'length' of the waterways within each catchment is to be calculated and used to scale the aggregation of the final Econd®. The length of waterways should be determined using the Adopted Middle Thread Distances (AMTD) established by the Queensland Water Resources Commission in the 1950s for all major streams in the state in accordance with the Report on Condition and trends in Water Quality in Central Queensland Estuaries (1993 to 2015).

Output of Step 5.

- A **data table** (e.g. a spreadsheet) containing all the raw data for each indicator for each sample, including the calculations for the ICS and Econd®, grouped by sub-asset (waterway).
- A **summary table** showing the Econd® scores for the region, grouped by sub-asset.

5. Compile Environmental Account and submit for certification

Steps five to seven should be repeated at regular intervals (a minimum of every five years or where Base Year recalculation is required, as specified under the *Accounting for Nature®* Framework) to establish a trend over time. Ideally, site surveys should occur annually, even if accounts are only certified once every five years.

If you wish for your account to be certified, it must be verified in accordance with the *Accounting for Nature® Standard*, which outlines the criteria that must be satisfied. The benefit of having an account certified is that AfN allows you to display the Certified Account logo and you are able to make public claims about your account. AfN Certified Accounts require the Environmental Account Summary and Information Statement to be made publicly available.

An Certified Environmental Account may incorporate multiple environmental assets, and always needs to include the following information:

- Information Statement and Environmental Account Summary,
- Environmental Account (including raw data tables); and;
- An **Audit Report** or **Self-verification Report** that verifies the account was prepared in accordance with the approved Methods, the AfN Standard and Audit Rules.
    - An **Audit Report** is completed by an AfN Accredited Auditor and is required if you are seeking to have your account "Certified" (Tier 1); OR
    - A **Self-verification Report** contains the results of your self-verification assessment and AfN's technical Assessment and is required if you are seeking to have your account "Self-verified" (Tier 2).

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Appendix A - Glossary

Table 12. Glossary

Term	Definition
Assessment unit	Assessment units are homogenous units within the accounting area which determine where samples are to be taken.
Econd®	An index between 0 and 100 that describes the condition of an environmental asset where 0 means the asset is completely degraded, and 100 means the asset is in pristine condition.
Enclosed coastal/lower estuary (ECLE)	Coastal waters with reduced influence or exchange with ocean waters. It includes shallower coastal waters enclosed by offshore islands or in embayments. It also includes the most downstream reaches of estuaries – the zone which exchanges with coastal waters on every tide. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Indicator Condition Score	In general terms, the Indicator Condition Score (ICS) is a proportion of the observed value compared to the Reference Benchmark value. However, the formulas for calculating this can vary considerably between indicators—some incorporate weightings and conditional clauses to reflect the ecological thresholds associated with some vegetation attributes.
Upper estuary (UE)	The most upstream reaches of estuaries – areas subject to very little tidal movement and poor flushing/dispersion during dry weather. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Mid estuary (ME)	All estuarine waters upstream of the immediate influence of strong daily tidal exchange but excluding upper estuarine waters. Refer to Appendix B.2 of the Queensland Water Quality Guidelines (2009) for more detailed descriptions.
Reference Benchmark	The Reference Benchmark is the condition of the native vegetation sub-asset in an 'undegraded' state. For example, a vegetation community that has not experienced any negative impacts as a result of disturbance, edge effects, invasive species, or altered management regimes (e.g. fire) would be considered to exist in an 'undegraded' or 'ideal' state.

Appendix B- Riparian Buffer Width

Lovett and Price (2001) suggest the recommended buffers outlined in the table below are sufficient to protect and maintain bank stability, aquatic health, water quality and terrestrial habitat.

Table 13. Recommended buffers by Lovett and Price (2001)

Stream order	Riparian buffer width (m)
Creeks and watercourses in sugar growing areas	25
Rivers in sugar growing areas	50
1-2	50
3-4	75
5-6	200

Lovett, S. and Price, P., 2001. Managing Riparian Lands in the Sugar Industry: A Guide to Principles and Practices, Sugar Research and Development Corporation/Land and Water Australia, Brisbane.

This guideline has been generated to ensure that waterfront land is minimally damaged due to any proposed controlled activity. The riparian buffer widths are based on the stream order, that has been classified under the Strahler System.

Table 14. Recommended riparian buffers in New South Wales.

Stream order	Riparian buffer width (m)
1	20
2	40
3	60
4	80

Department of Primary Industries, Office of Water (2012) Guidelines for riparian corridors on waterfront land. New South Wales Government.

The recommended riparian buffer widths in Victoria have been based on management objectives of the landscape. The land use intensity was calculated using the median value and was increased by the 25th percentile for each increase in intensity (Hansen et al. 2010).

Table 15. Recommended riparian buffers in Victoria.

Management Objective	Land use intensity high	Land use intensity moderate	Land use intensity low	Wetland/low floodplain/off-stream water bodies	Steep catchment/cleared hillslopes/low order streams
Improve water quality	60	45	30	120	40
Moderate steam temperatures	95	65	35	40	35
Provide food and resources	95	65	35	40	35

Improve in-stream biodiversity	100	70	40	Variable*	40
Improve terrestrial biodiversity	200	150	100	Variable*	200

* Variability in width is related to the lateral extent of hydrological connectivity. As such recommendations for this will have to be site specific.

Hansen, B, Reich, P, Lake, PS, Cavagnaro, T (2010) Minimum width requirements for riparian zones to protect flowing waters and to conserve biodiversity: a review and recommendations, with application to the State of Victoria.

Appendix C- Definitions

Table 16. Definitions utilised throughout the ecological flow section.

Term used in Water Plan	Definition
Mean annual flow.	Means the total volume of flow in the simulation period divided by the number of years in the simulation period
50% daily flow for a month	Means the flow, in megalitres, that is equalled or exceeded on 50% of days in the month in the simulation period.
90% daily flow for a month	Means the flow, in megalitres, that is equalled or exceeded on 90% of days in the month in the simulation period.
10cm daily flow (ML/day) (annual)	Means the total number of days in the judgement period that the watercourse's daily flow is at least 10cm above the cease-to-flow level in the watercourse.
30cm daily flow (ML/day) (annual)	Means the total number of days in the judgement period that the watercourse's daily flow is at least 30cm above the cease-to-flow level in the watercourse.
1.5-year daily flow volume	Means the daily flow that has a 67% probability of being reached at least once a year.
5-year daily flow volume	Means the daily flow that has a 20% probability of being reached at least once a year.
20-year daily flow volume	Means the daily flow that has a 5% probability of being reached at least once a year.
Refugia	Means the habitat required by a species during a time of stress, for example, drought.

Appendix D- Determining Ecological Flows

Thresholds used to calculate the 10cm and 30cm flow benchmarks

Two of the indicators for the Mary River catchment required benchmarks calculated from pre-development data. This is because these values have been derived from models that depict unimpeded or natural flow conditions of each catchment.

For the pre-development data within Environment Conditions Report – Volume 2 for the Mary Basin the following tables in the linked document:

- Table B7 – 10cm flow (Number of Spells)
- Table B8 – 30cm flow (Number of Spells)

These values have been summarised below in Table 17

Table 17. 10 cm and 30 cm flow thresholds for the Mary Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Amamoor Creek at Zachariah	16	86
Glastonbury Creek at Glastonbury	5	55
Kandanga Creek at Hygait	3	50
Mary River at Home Park	2	105
Mary River at Bellbird Creek	13	130
Mary River at Miva	3	52
Mary River at Moy Pocket	4	43
Munna Creek at Marodian	5	55
Obi Obi Creek at Gardners Falls	5	55
Six Mile Creek at Cooran	1	20
Teewah Creek at Coops Corner	-	-
Tinana Creek at Bauple East	5	55
Tinana Creek at Tagigan	5	55
Wide Bay at Brooyar	5	67
Wide Bay at Kilkivan	5	67

Pre-development data is missing for the 10cm and 30cm daily flow indicators for both the Burnett and Baffle Basins so these thresholds were calculated using long term data from each gauge. Table 18 and 19 present the calculated thresholds, which was determined using data from a rating table from WMIP and a natural cubic spline analysis.

Table 18. Calculated 10 cm and 30 cm flow thresholds for the Burnett Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Auburne River at Dykehead	3	59
Barambah Creek at Ban Ban	77	89
Barambah Creek at West Barambah	5	69
Barambah Creek at Litzows	0.39	1.2
Barker Creek at Brooklands	8	71
Barker Creek at Glenmore	4	40
Boyne River at Carters	0.5	2
Boyne River at Cooranga	14	93
Burnett River at Ceratodus	7	91
Burnett River at Eidsvold	4	48
Burnett River at Fig Tree	32	246
Burnett River at Gayandah	-	-
Burnett River at Jones Weir	-	-
Burnett River at Tailwater	17	34
Burnett River at Mount Lawless	11	197
Burnett River at Walla	-	-
Cadarga Creek at Brovinia Station	1	23
Eastern Creek at Lands End	10	170
Elliot River at Dr Mays	7	33
Elliot River at Elliot	-	-
Gin Gin Creek at Brushy Creek	35	287
Gregory River at Isis Highway	10	67
Isis River at Bruce Highway	4	75
Kolan River at Springfield	6	57
Monal Creek at Upper Monal	0.3	27
Reid Creek at Mungy	7	71
Splinter Creek at Dakiel	2	42
Stuart River at Proston Rifle Range	7	70
Stuart River at Weens Bridge	0.09	10
Three Moon Creek at Abercorn	23	29

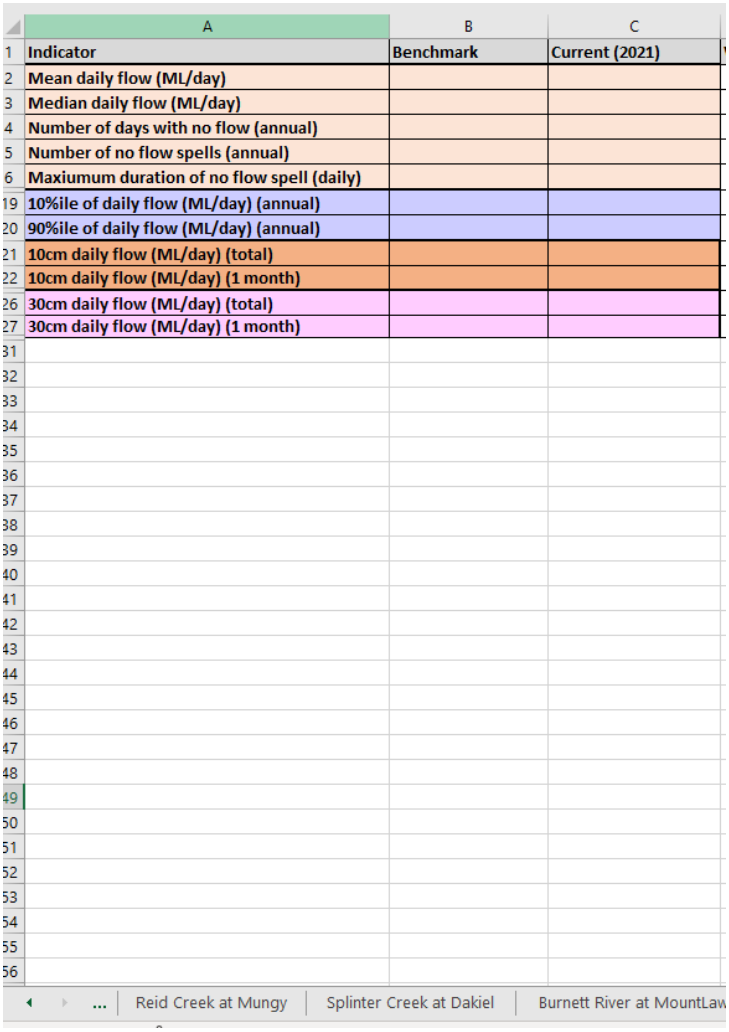
Table 19. Calculated 10 cm and 30 cm flow thresholds for the Baffle Creek Basin.

Name of stream gauge	10 cm threshold (ML/day)	30 cm threshold (ML/day)
Baffle Creek at Mimdale	4	89
Oyster Creek at Rapleys	2	76

Reference Benchmark Calculation Method

Set-up spreadsheet

1. Prior to the benchmark calculation, a spreadsheet will need to be setup for each stream gauge, refer to the Figure below as an example on how to set up the spreadsheets. When filling in the spreadsheet ensure that you enter it into the "benchmark" column. The benchmark column will be used as a reference benchmark. The "current" column will be used for data analysed for the annual reporting period (e.g. 2021).



	A	B	C
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)		
3	Median daily flow (ML/day)		
4	Number of days with no flow (annual)		
5	Number of no flow spells (annual)		
6	Maxiumum duration of no flow spell (daily)		
19	10%ile of daily flow (ML/day) (annual)		
20	90%ile of daily flow (ML/day) (annual)		
21	10cm daily flow (ML/day) (total)		
22	10cm daily flow (ML/day) (1 month)		
26	30cm daily flow (ML/day) (total)		
27	30cm daily flow (ML/day) (1 month)		

... | Reid Creek at Mungy | Splinter Creek at Dakiel | Burnett River at MountLaw

Data Organisation and Cleaning

To calculate the reference benchmarks and current conditions of the waterways, stream gauge data will need to be downloaded from the Water Monitoring Information Portal (WMIP). The following gauge datasets will need to be downloaded:

Mary

- Amamoor Creek at Zachariah
- Glastonbury Creek at Glastonbury
- Kandanga Creek at Hygait
- Mary River at Home Park
- Mary River at Bellbird Creek
- Mary River at Miva

- Mary River at Moy Pocket
- Munna Creek at Marodian
- Obi Obi Creek at Gardners Falls
- Six Mile Creek at Cooran
- Teewah Creek at Coops Corner
- Tinana Creek at Bauple East
- Tinana Creek at Tagigan
- Wide Bay at Brooyar
- Wide Bay at Kilkivan

Burnett

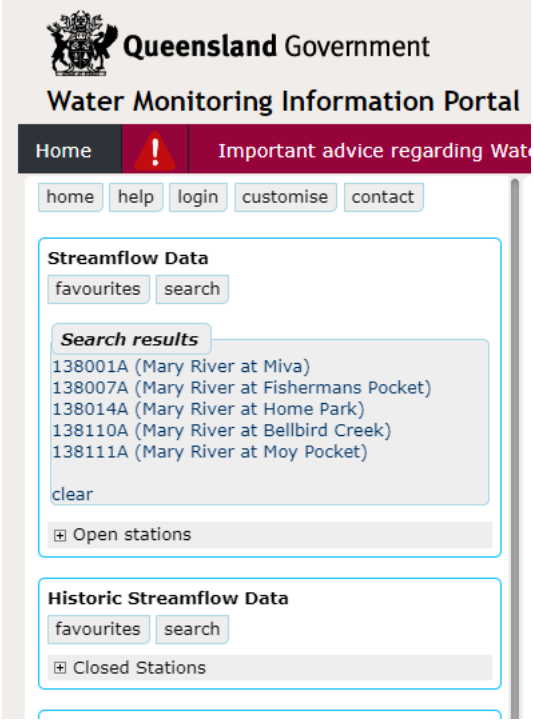
- Auburn River at Dykehead
- Barambah Creek at West Barambah
- Barambah Creek at Ban Ban
- Barambah Creek at Litzows
- Barker Creek at Brooklands
- Barker Creek at Glenmore
- Boyne River at Carters
- Boyne River at Ceratodus
- Boyne River at Cooranga
- Burnett River at Eidsvold
- Burnett River at Jones Weir Headwater
- Burnett River at Tailwater
- Burnett River at Gayandah
- Burnett River at Mount Lawless
- Cadarga Creek at Brovinia
- Eastern Creek at Lands End
- Elliot River at Dr Mays
- Elliot River at Figtree
- Gregory River at Isis Highway
- Isis River at Bruce Highway
- Kolan River at Springfield
- Monal Creek at Upper Monal
- Reid Creek ay Mungy
- Splinter Creek at Dakiel
- Stuart River at Proston
- Stuart River at Weens Bridge
- Three Moon Creek at Abercorn

Baffle

- Oyster Creek at Rapleys
- Baffle Creek at Mimdale

2. To download the data from Water Monitoring Information Portal (WMIP) do the following:

- Search for the waterway :

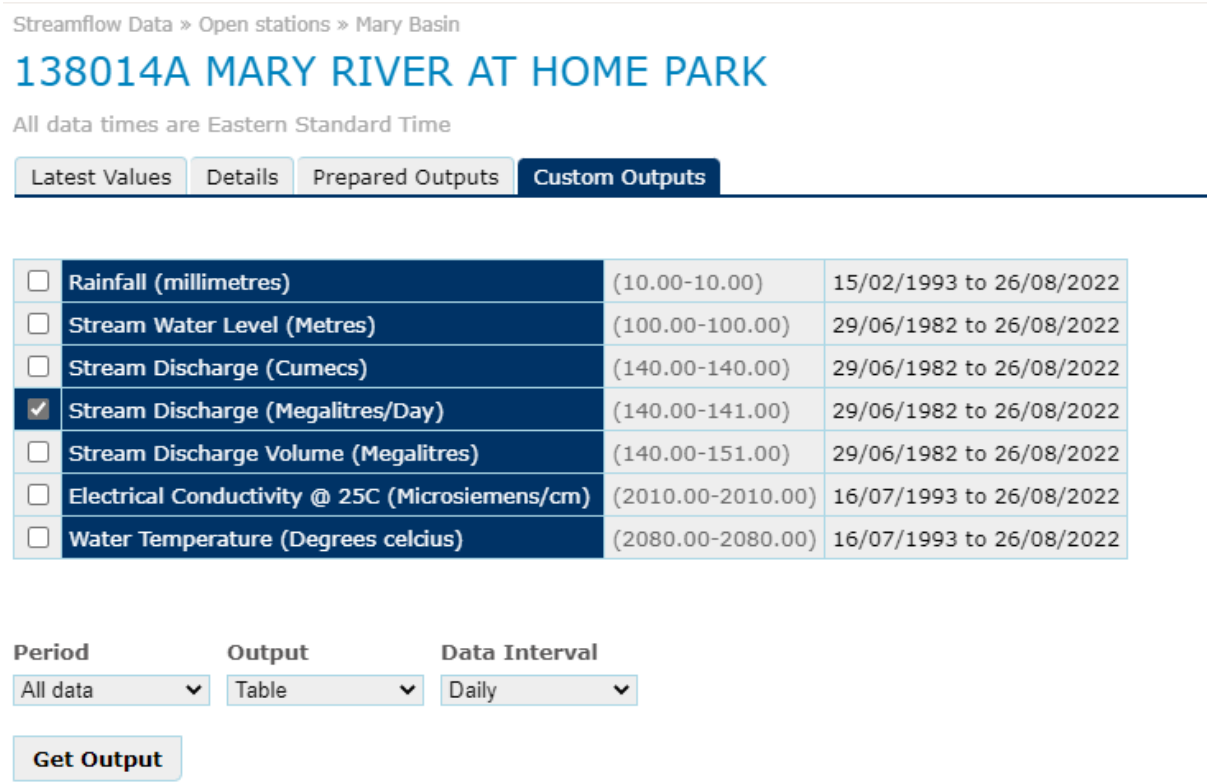


- Click custom outputs: stream discharge (megalitres/day)

Period: All data

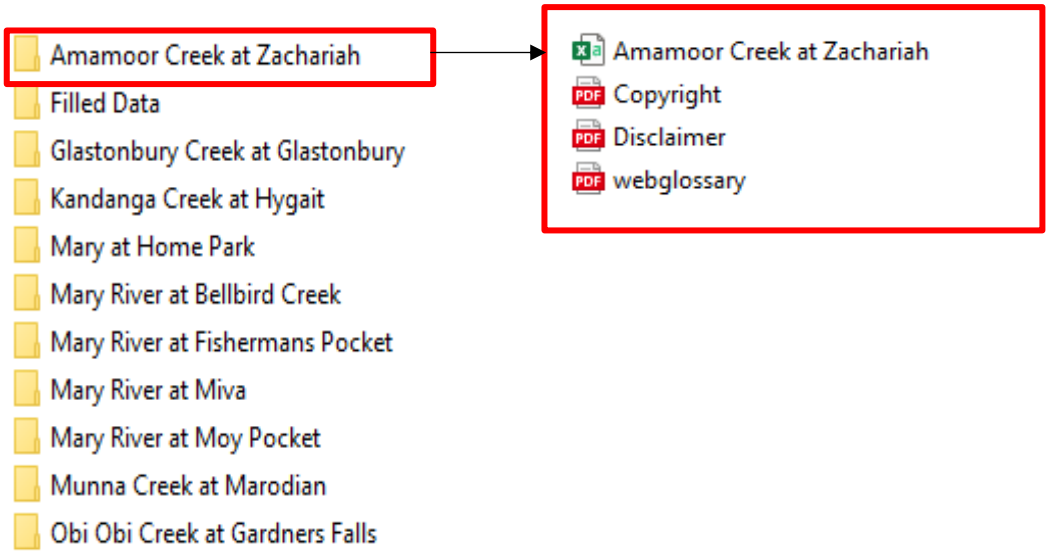
Output: Table

Data Interval: Daily



- Click 'Get Output' and the file will automatically download.

3. Once the data has been downloaded from Water Monitoring Information Portal (WMIP) it will need to be organised into folders and clearly labelled for future use (refer below).



4. Each spreadsheet will need to be opened and cleaned (see example below) so that it can be recognised by the River Analysis Package (RAP) software. If the data is not cleaned it will not be recognised by RAP.

5. Only two columns should be left in the spreadsheet, which includes the time/date and mean ML/day (refer below).

6. Ensure that the stream gauge number is changed to the stream gauge name (refer below). If the name is not changed from the stream gauge number to the stream gauge name, there could be added confusion on what dataset you are analysing.

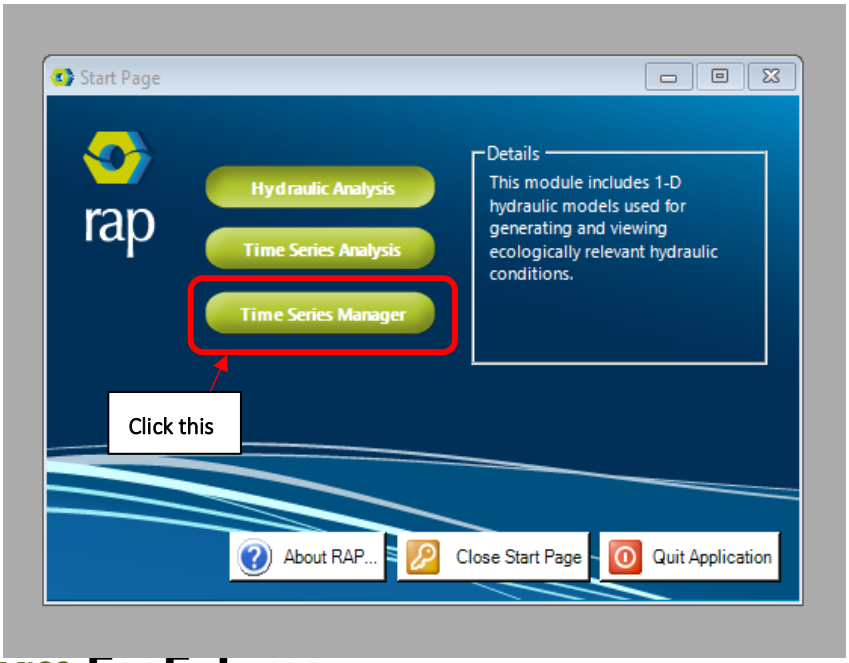
	A	B	C	D	E	F	G
1	Time	Amamoor Creek at Zachariah					
2	and	141					
3	Date	Discharge (ML/day)					
4	Date and time	Mean					
5	29/11/1984 0:00	12.78					
6	30/11/1984 0:00	10.32					
7	1/12/1984 0:00	9.59					
8	2/12/1984 0:00	7.69					
9	3/12/1984 0:00	8.72					
10	4/12/1984 0:00	12.61					
11	5/12/1984 0:00	14.57					
12	6/12/1984 0:00	13.27					
13	7/12/1984 0:00	25.6					
14	8/12/1984 0:00	60.21					
15	9/12/1984 0:00	39.56					
16	10/12/1984 0:00	29.04					
17	11/12/1984 0:00	25.3					
18	12/12/1984 0:00	22.8					
19	13/12/1984 0:00	21.87					
20	14/12/1984 0:00	20.02					
21	15/12/1984 0:00	22.33					
22	16/12/1984 0:00	17.36					
23	17/12/1984 0:00	13.69					
24	18/12/1984 0:00	13.22					
25	19/12/1984 0:00	15.33					
26	20/12/1984 0:00	294.9					
27	21/12/1984 0:00	120.64					
28	22/12/1984 0:00	59.9					
29	23/12/1984 0:00	39.57					
30	24/12/1984 0:00	29.19					
31	25/12/1984 0:00	25.3					
32	26/12/1984 0:00	22.8					
33	27/12/1984 0:00	21.77					
34	28/12/1984 0:00	17.92					
35	29/12/1984 0:00	22.59					
36	30/12/1984 0:00	40.4					
37	31/12/1984 0:00	28.94					

Amamoor Creek at Zachariah

7. Once the data is organised it can now be uploaded into RAP for gap analysis and filling using the Time Series Manager (TSM) in the River Analysis Package tool. The RAP is a software package that examines the hydraulic characteristics of waterways to determine the discharge for a waterway. The TSM manipulates and manages the time series data and fills in gaps within the dataset where there are missing values.

Time Series Manager

1. Open up RAP and select 'time series manager'

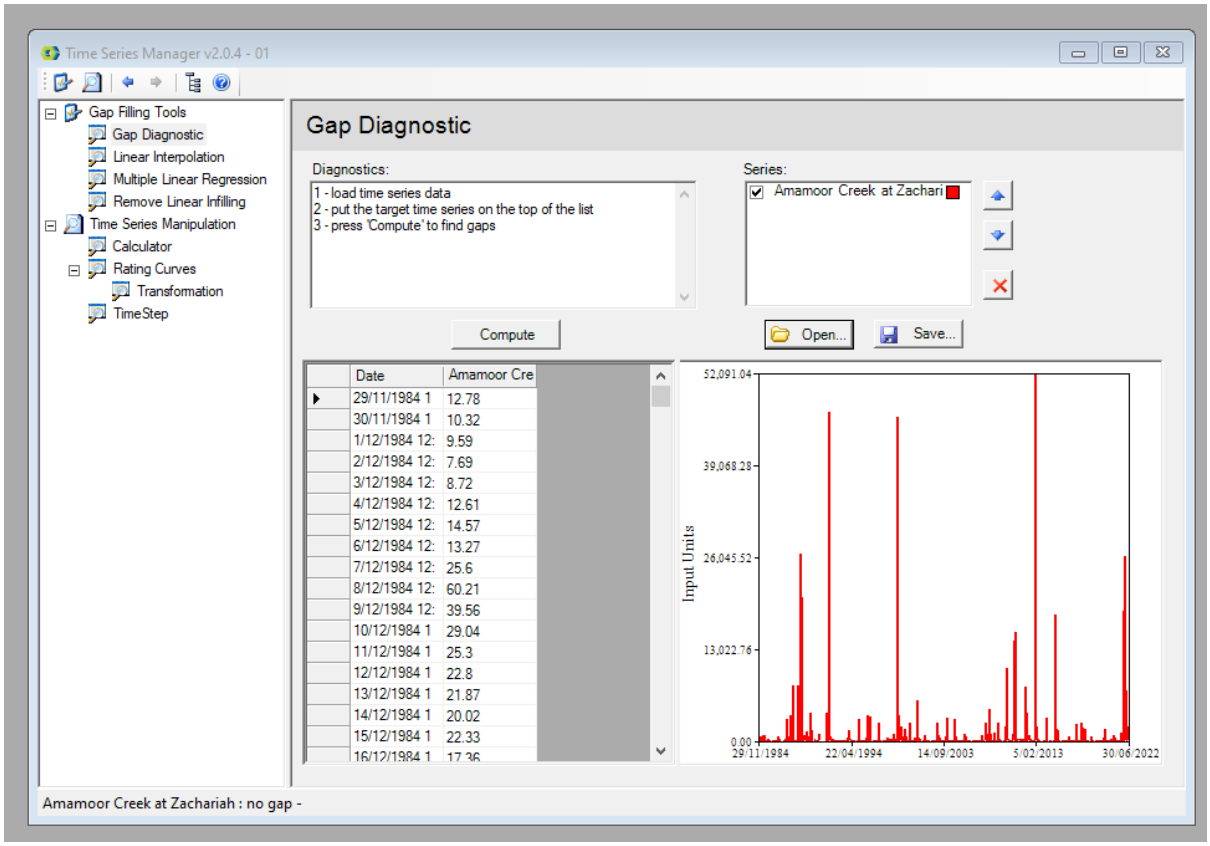


2. Click gap diagnostic and click open and upload a cleaned spreadsheet. The cleaned spreadsheet should look like this:

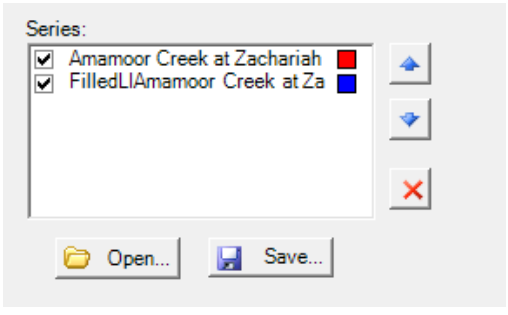
	A	B	C	D	E	F	G
1	Time	Amamoor Creek at Zachariah					
2	and	141					
3	Date	Discharge (ML/day)					
4	Date and time	Mean					
5	29/11/1984 0:00	12.78					
6	30/11/1984 0:00	10.32					
7	1/12/1984 0:00	9.59					
8	2/12/1984 0:00	7.69					
9	3/12/1984 0:00	8.72					
10	4/12/1984 0:00	12.61					
11	5/12/1984 0:00	14.57					
12	6/12/1984 0:00	13.27					
13	7/12/1984 0:00	25.6					
14	8/12/1984 0:00	60.21					
15	9/12/1984 0:00	39.56					
16	10/12/1984 0:00	29.04					
17	11/12/1984 0:00	25.3					
18	12/12/1984 0:00	22.8					
19	13/12/1984 0:00	21.87					
20	14/12/1984 0:00	20.02					
21	15/12/1984 0:00	22.33					
22	16/12/1984 0:00	17.36					
23	17/12/1984 0:00	13.69					
24	18/12/1984 0:00	13.22					
25	19/12/1984 0:00	15.33					
26	20/12/1984 0:00	294.9					
27	21/12/1984 0:00	120.64					
28	22/12/1984 0:00	59.9					
29	23/12/1984 0:00	39.57					
30	24/12/1984 0:00	29.19					
31	25/12/1984 0:00	25.3					
32	26/12/1984 0:00	22.8					
33	27/12/1984 0:00	21.77					
34	28/12/1984 0:00	17.92					
35	29/12/1984 0:00	22.59					
36	30/12/1984 0:00	40.4					
37	31/12/1984 0:00	28.94					

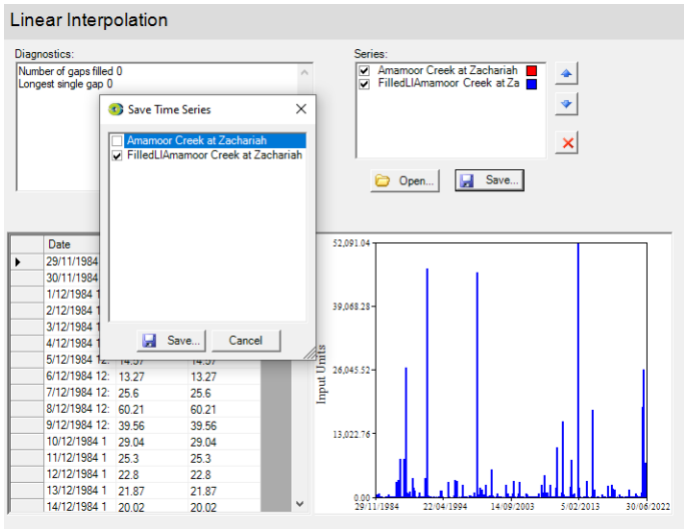
Amamoor Creek at Zachariah

3. When the data has been uploaded to RAP it should look like this:



4. This tool is being used to identify any gaps (i.e. missing values) within the dataset. RAP cannot do any analyses with missing values. Once the file has been uploaded click compute and check the diagnostic box to see if there are any gaps within the data.
5. Where gaps are identified a linear interpolation will be required. The linear interpolation fills in the gaps, with interpolating between the last and next value within the spreadsheet.
6. On the side-bar click linear interpolation and then click compute, once the gaps are filled save the new filled datasheet into a new folder called 'filled data'. This will be the data that will be used for the analysis process.



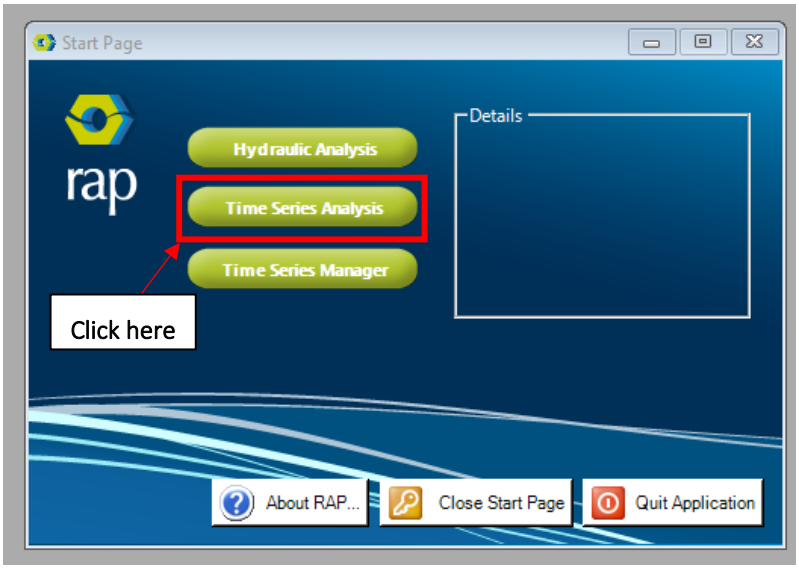


7. Repeat this step for all of the stream gauge data downloaded from WMIP.

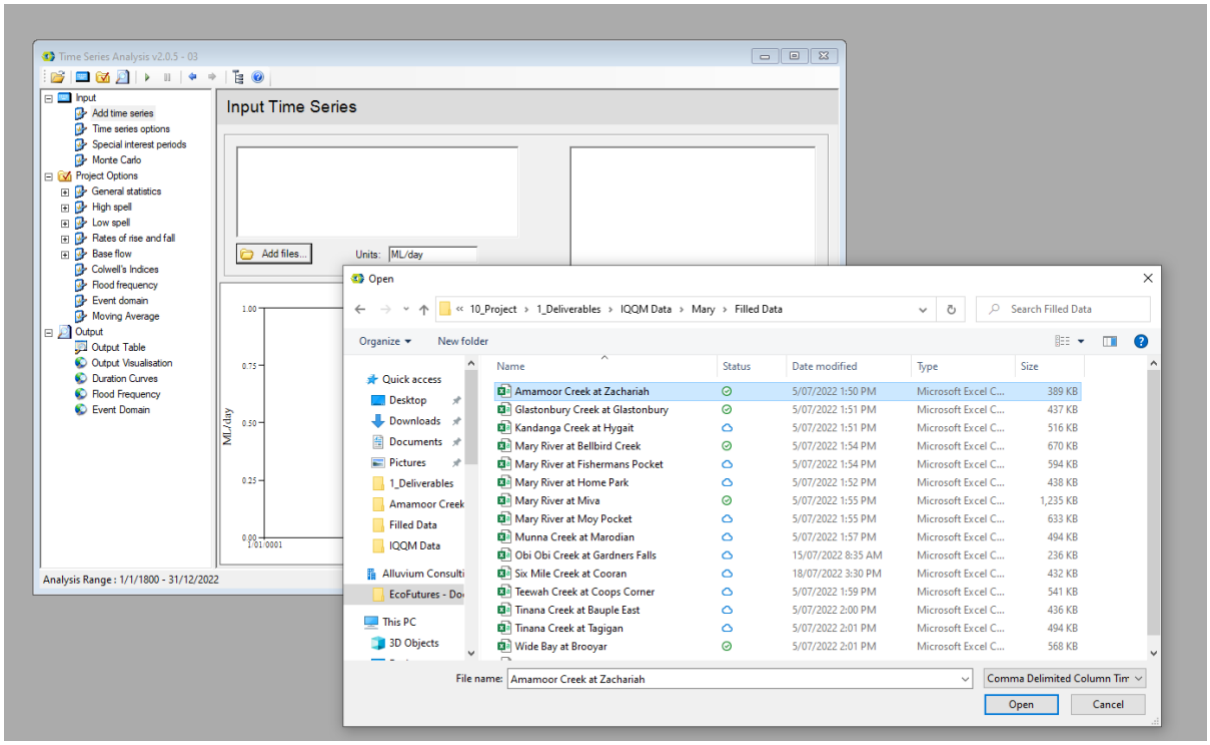
8. Where there are no gaps, copy and paste the stream gauge sheet into the filled data folder so you are working from one working space.
9. Now you have a full dataset ready for analysis.

Time Series Analysis

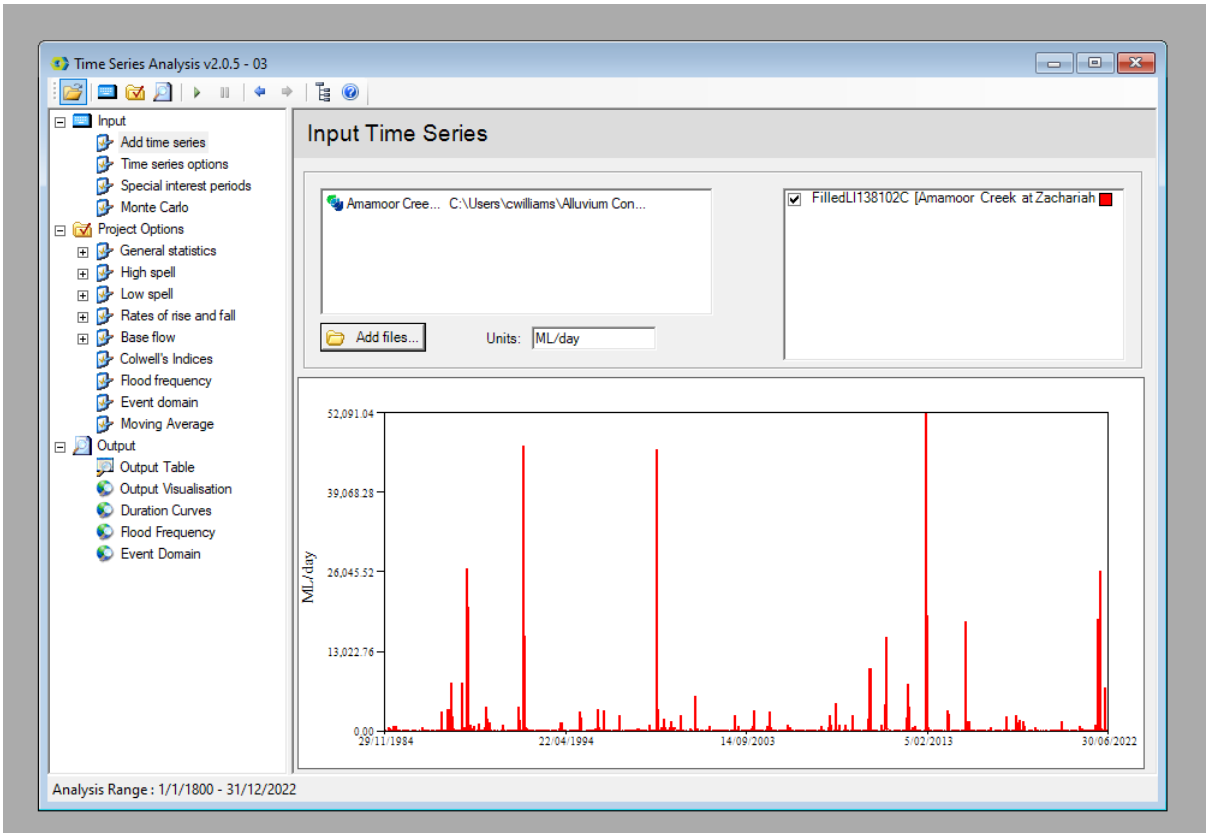
8. Click 'Time Series Analysis'



9. Upload a filled spreadsheet by clicking 'Add files' and choose one stream gauge at a time. If multiple spreadsheet are chosen it can cause errors in the data analysis.

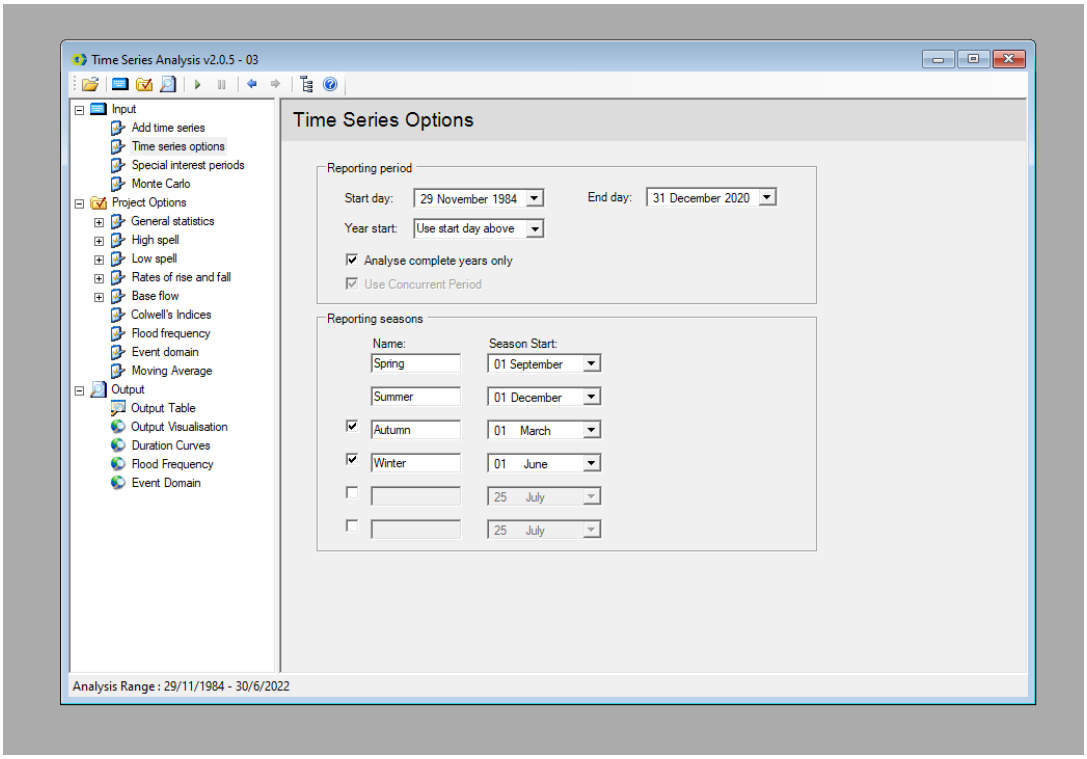


10. When uploaded it should look like this:



11. Now we are going to calculate the historical benchmarks. The historical benchmarks will be used to calculate the indicator condition scores where pre-development data is not available. To do that, the 'time series option' in the package will need to be changed.

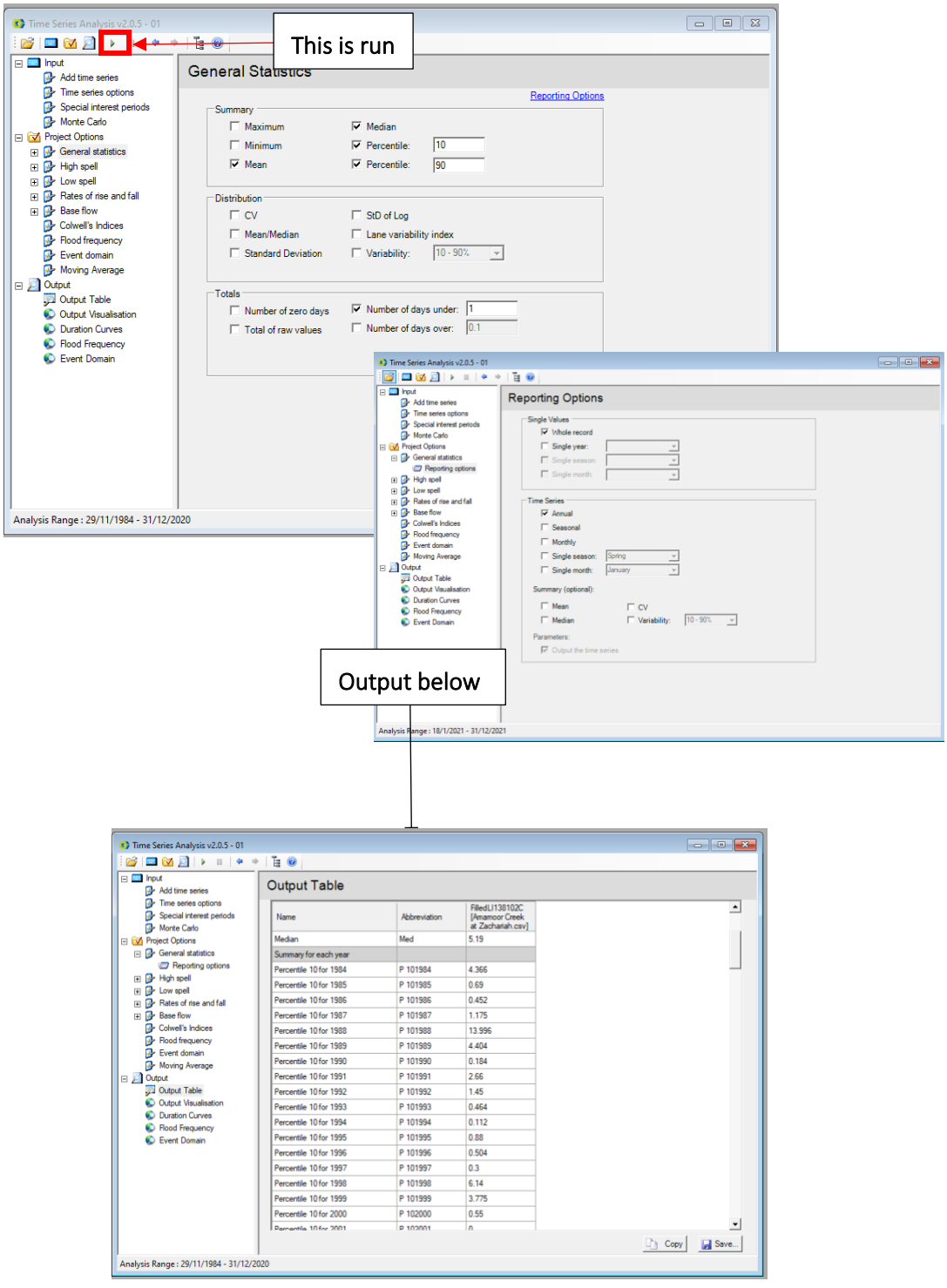
12. Go to 'time series options' and ensure the time frame for the start day is when the stream gauge started collecting data (e.g. 1984), and change the end date to 31st December 2020.



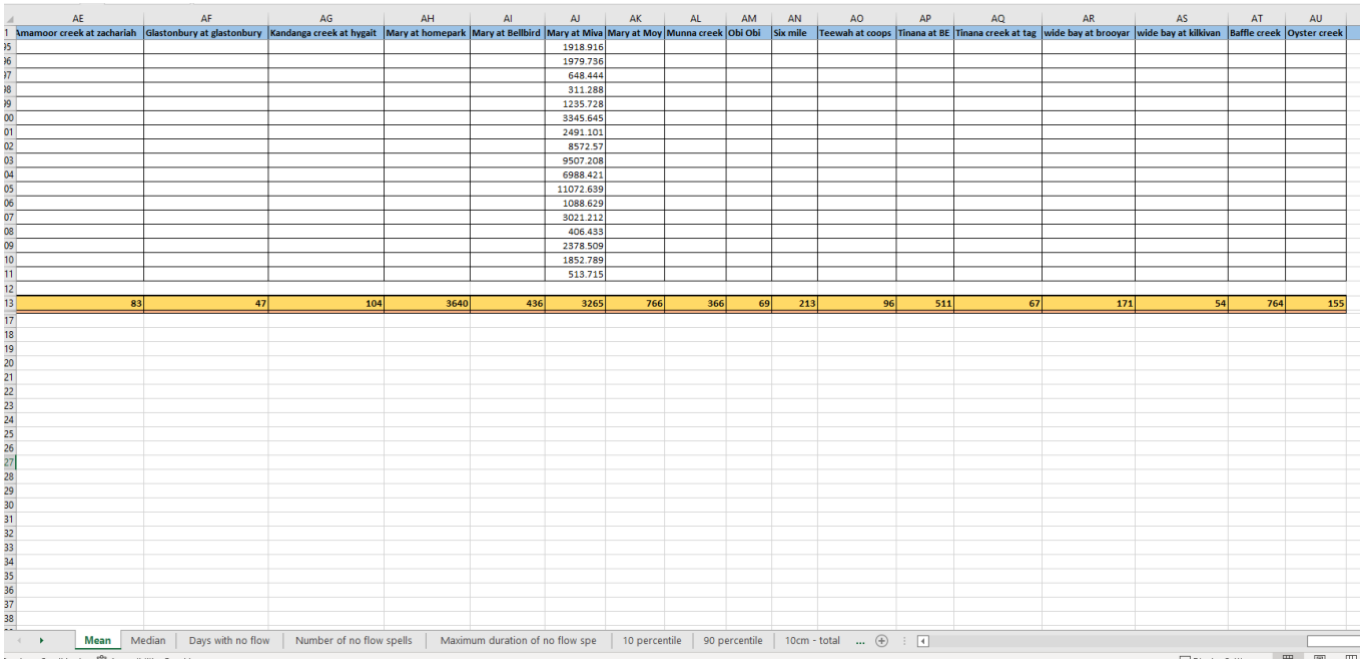
13. To calculate the general statistics, start by clicking the general statistics tab and ticking the following:
    - Mean
    - Median
    - 10th percentile
    - 90th percentile

This will tell the tool to calculate the data needed for these indicators.

14. Go to reporting options and tick 'Annual'
15. Click run



16. From the output table, copy and paste each indicator for each year into a new spreadsheet in order to calculate the mean annual value for each indicator across the historical period (refer to the example below). To calculate the mean use the following equation =AVERAGE(REF:REF). The REF represents the number of rows selected within a column.



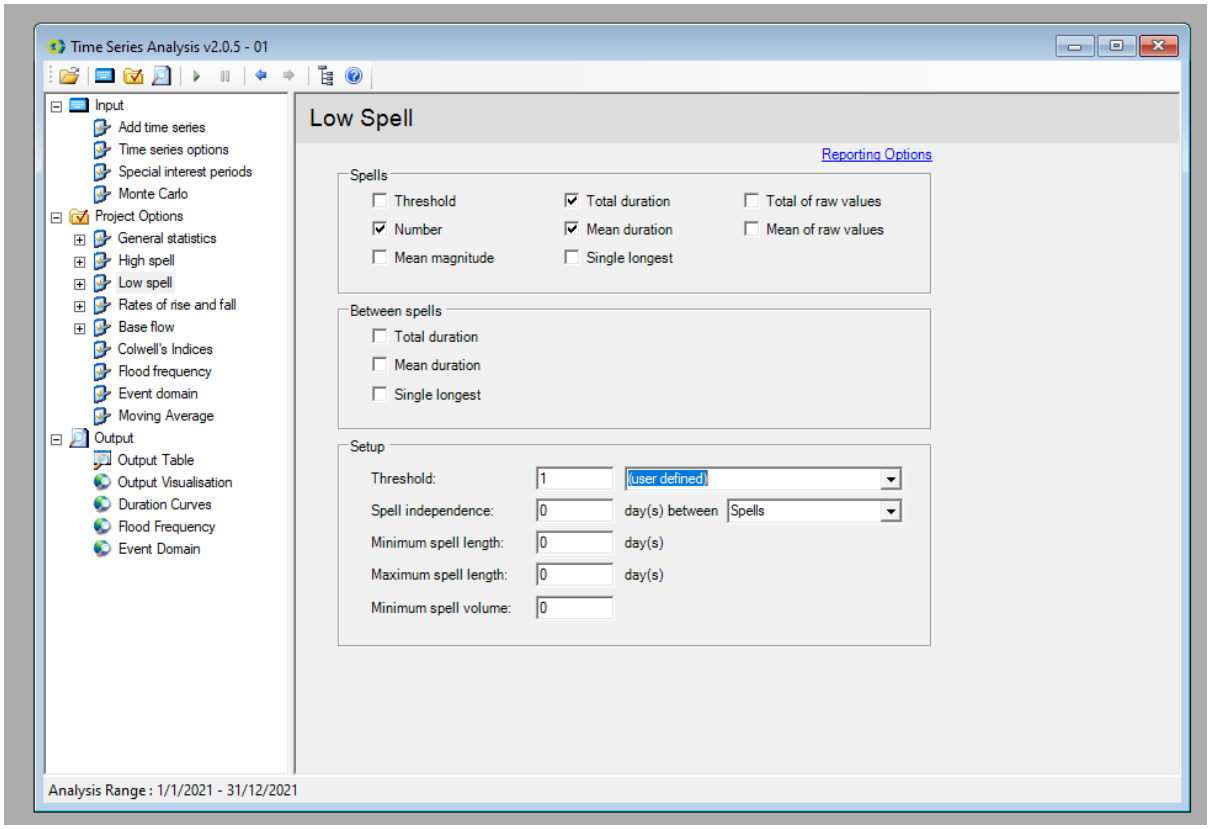
	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1	Amamoor creek at zachariah	Glastonbury at glastonbury	Kandanga creek at hygait	Mary at homepark	Mary at Bellbird	Mary at Miva	Mary at Moy	Munna creek	Obi Obi	Six mile	Teewah at coops	Tinana at BE	Tinana creek at tag	wide bay at brooyar	wide bay at kilkivan	Baffle creek	Oyster creek
95						1918.916											
96						1979.736											
97						648.444											
98						311.288											
99						1235.728											
00						3345.645											
01						2491.101											
02						8572.57											
03						9507.208											
04						6988.421											
05						11072.639											
06						1088.629											
07						3021.212											
08						406.433											
09						2378.509											
10						1852.789											
11						513.715											
12																	
13	83	47	104	3640	436	3265	766	366	69	213	96	511	67	171	54	764	155

Mean | Median | Days with no flow | Number of no flow spells | Maximum duration of no flow spe | 10 percentile | 90 percentile | 10cm - total

17. Enter the generated data (mean) into the 'Benchmark' column of the prepared spreadsheet:

Indicator	Benchmark	Current (2021)
Mean daily flow (ML/day)		
Median daily flow (ML/day)		
Number of days with no flow (annual)		
Number of no flow spells (annual)		
Maxiumum duration of no flow spell (daily)		
10%ile of daily flow (ML/day) (annual)		
90%ile of daily flow (ML/day) (annual)		
10cm daily flow (ML/day) (total)		
10cm daily flow (ML/day) (1 month)		
30cm daily flow (ML/day) (total)		
30cm daily flow (ML/day) (1 month)		

18. The next part of the analysis will give you the number of days with no flow (total duration), number of no flow spells historically (number) and will outline out of those no flow spells (single longest), which one last the longest in terms of duration (days in a row with flow <1ML/day).
19. To do that, go back to the "general statistic tab' and unclick all of the boxes in general statistics.
20. Go to 'Low Spell', click under spells: total duration, number and single longest. In the section called 'setup' click the drop-down box and change it to 'user defined' and change threshold to 1.
21. Go to reporting options and tick 'Annual'
22. Click run

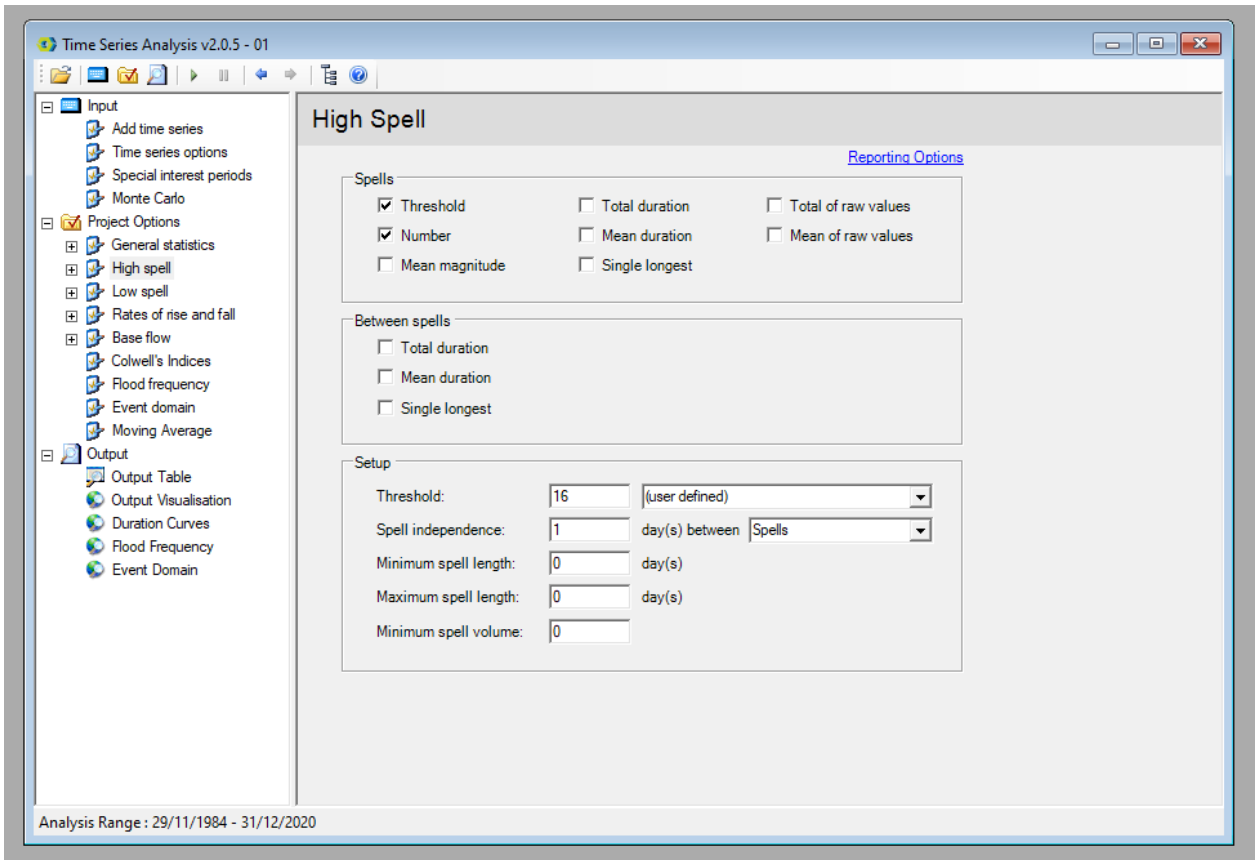


23. Copy and paste each indicator for each year into an excel spreadsheet in order to calculate the average across the historical period (refer to the example below). To calculate the average use the following equation =AVERAGE(REF:REF). The REF represents the number of rows selected within a column.
24. The averaged data will need to be added into the spreadsheet:

	A	B	D
1	**Indicator**	**Benchmark**	**Current (2021)**
2	**Mean daily flow (ML/day)**	54	51
3	**Median daily flow (ML/day)**	7	0
4	**Number of days with no flow (annual)**	220	160
5	**Number of no flow spells (annual)**	5	6
6	**Maxiumum duration of no flow spell (daily)**	97	92
19	**10%ile of daily flow (ML/day) (annual)**	2	0
20	**90%ile of daily flow (ML/day) (annual)**	44	37
21	**10cm daily flow (ML/day) (total)**	5	8
22	**10cm daily flow (ML/day) (1 month)**	1	0
26	**30cm daily flow (ML/day) (total)**	5	5
27	**30cm daily flow (ML/day) (1 month)**	0.1	0

25. Once the data has been entered, go back to the 'low spell' tab and unclick all of the boxes.

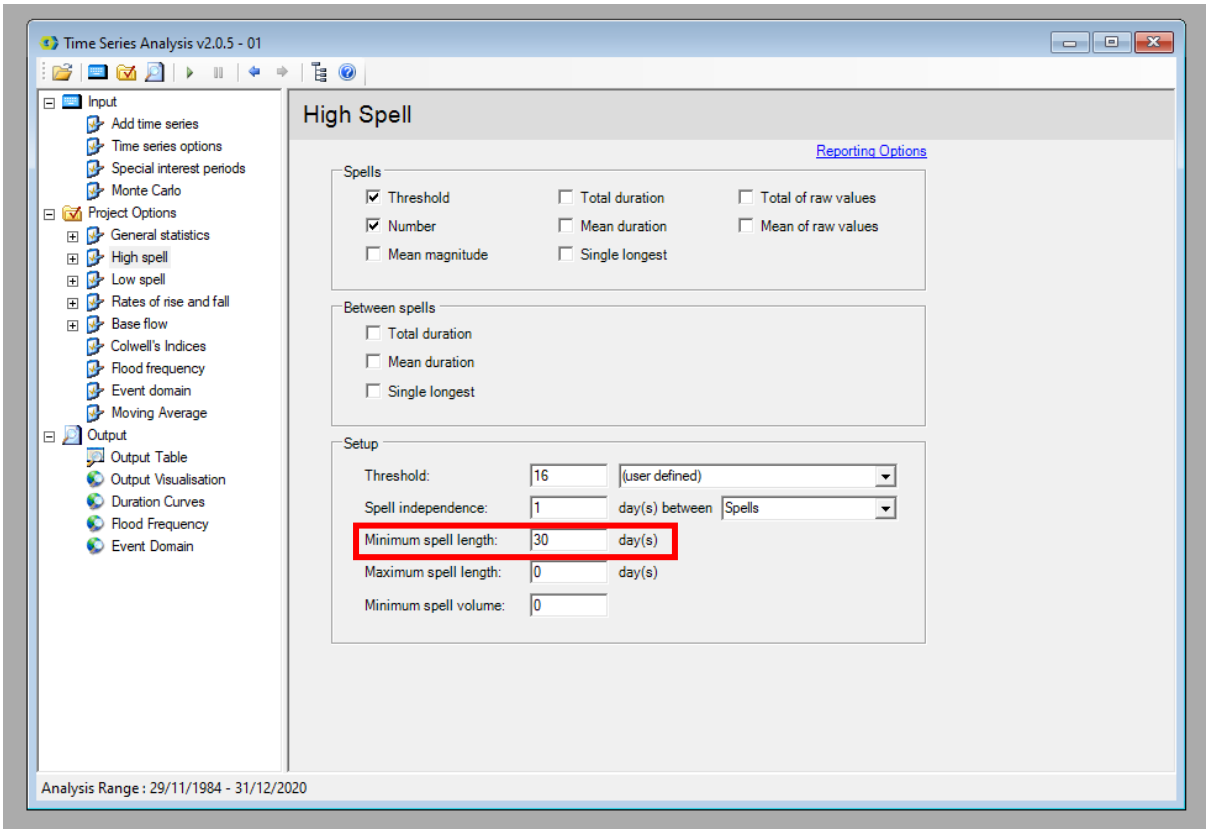
26. To calculate the 10cm and 30cm flow data, go to the 'High Spell' tab and click threshold and number under spells. In setup click the drop-down box and change it to user defined and place the threshold in the 'threshold' box and leave the minimum spell length as zero for the total.
27. Go to reporting options and tick 'Annual'.
28. Click run.
29. The threshold values for this assessment can be found in the Table 17, Table 18 and Table 19.



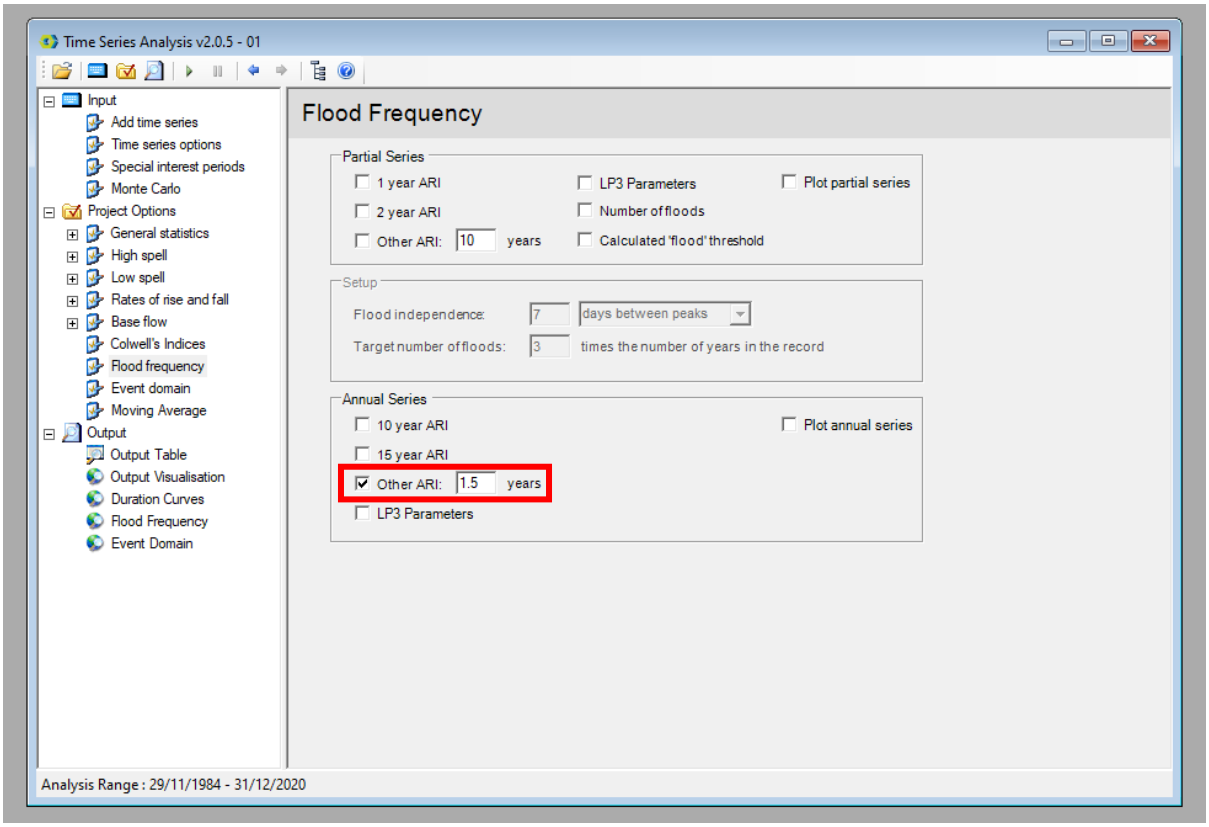
30. Once you have the averaged value, add it into the spreadsheet row called '10cm daily flow (ML/day) (total)' and 30cm daily flow (ML/day) (total).

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

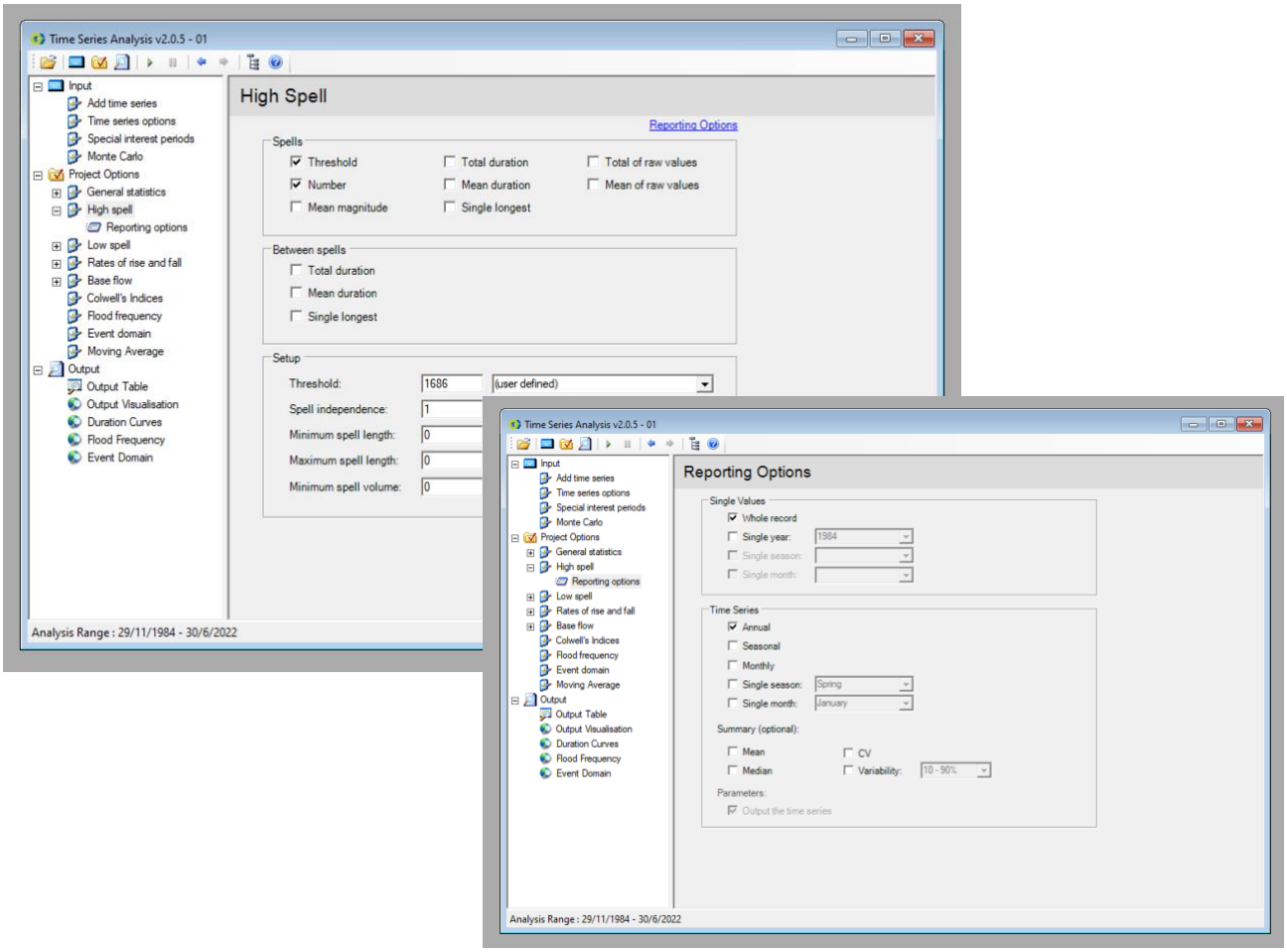
31. To calculate the values for the 1 month daily flow, go back to 'High spell' and change the minimum spell length to 30 days and add the averaged value into the spreadsheet, as above.



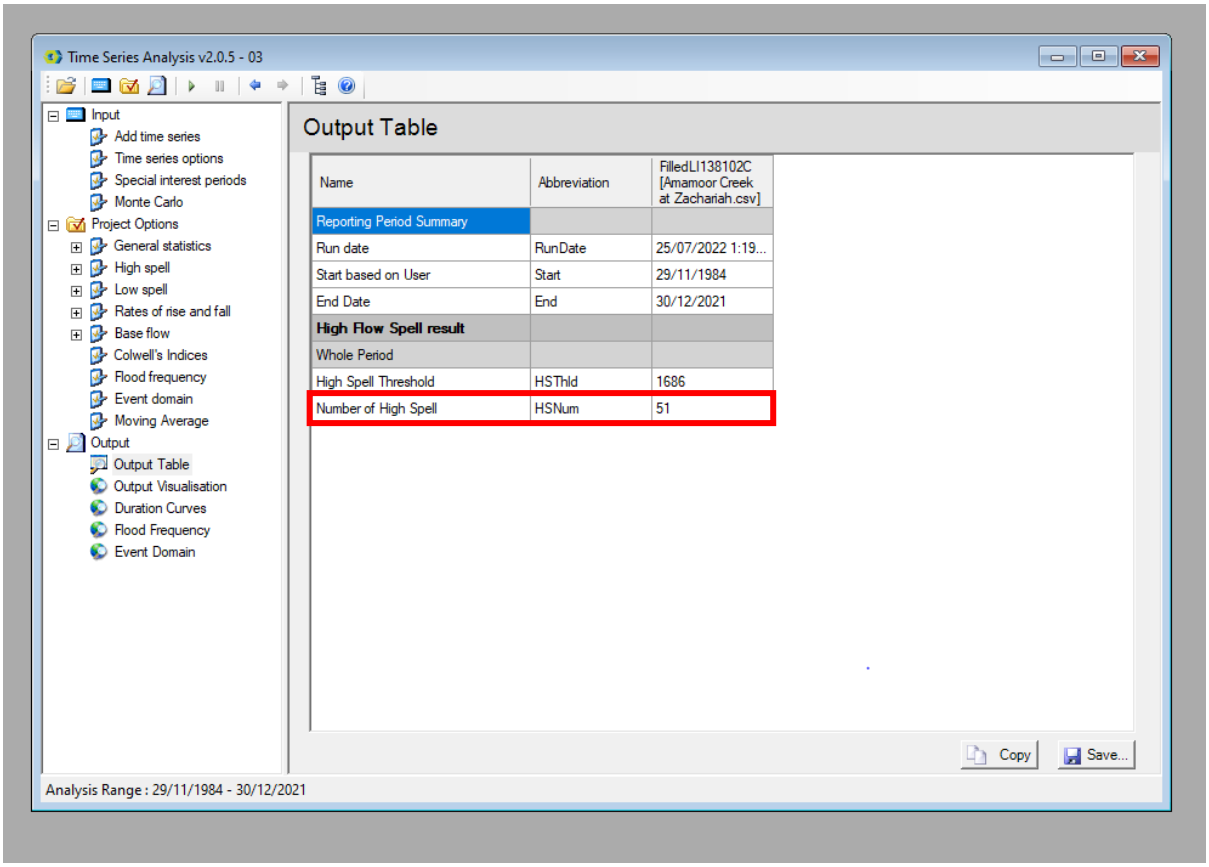
32. The next step is to calculate the average recurrence interval (ARI). ARI provides an indication of the size of a flow event relative to the historical events at the gauge. ARI calculations are not a part of the 'ECond' assessment but should be used as a descriptor to provide some level of interpretation of the annual data.
33. To calculate the ARI's go to 'Flood Frequency', and click the box called other ARI under the annual series. Change the value to 1.5 years and click run:



34. Once you get the value enter it into the spreadsheet. Repeat this step for all ARI's by changing the value to 5 and followed by 20 to get the 5-year and 20-year daily flow.
35. To calculate the number of times the benchmark 1.5-year, 5-year and 20-year ARI's have occurred historically go to 'High Spell'. In 'High Spell', click threshold, number, change the drop down box to user defined and enter in the pre-development value and/or benchmark value (where pre-development data is absent) from Environment Conditions Report – Volume 2 for the Mary Basin. For Burnett and Baffle Creek basin refer to the pre-development data section. Where pre-development data is missing, use the calculated historical benchmark from the steps above.
36. Make sure you change the minimum spell length back to zero (0).
37. Go to reporting options and click annual and then click run.



38. Enter in the number of times the 1.5-year, 5-year and 20-year pre-development ARI occurred in historically by looking at the output:



39. Make sure when entering the results that you place it in the current column, and the row called 'Number of that have occurred between the gauge starting period to 2021 (refer below).

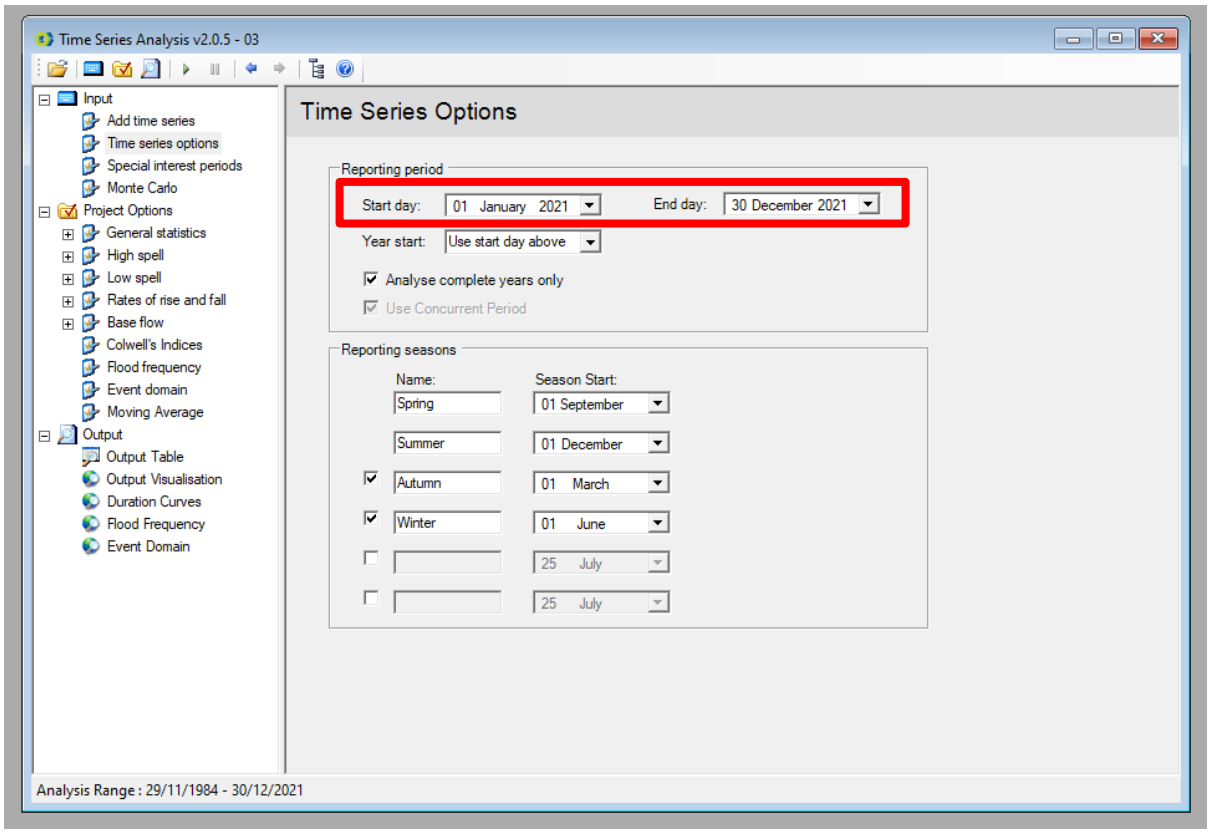
	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

40. Repeat this step for the 5-year and 20-year daily flow ARI pre-development values.
41. All of the historical benchmarks should now be calculated.

Annual Data Calculation Method

Time Series Analysis

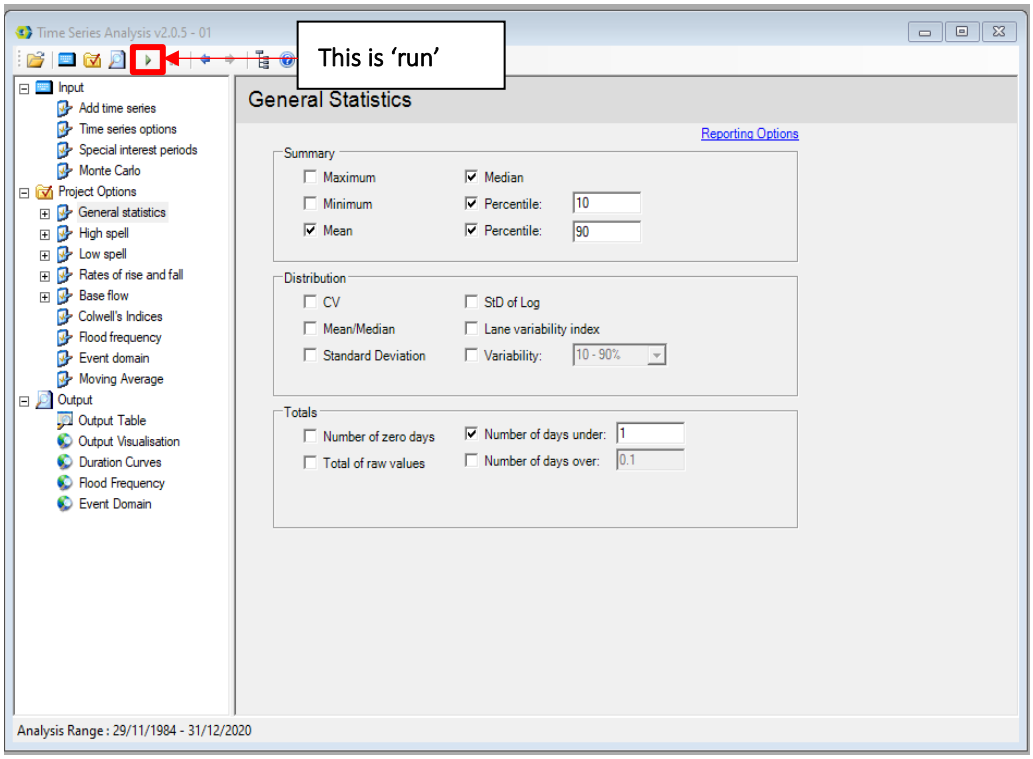
42. After the historical benchmarks are calculated, use the same spreadsheet to calculate the values for the annual reporting period. To do that, the times series options in the package will need to be changed to the annual reporting period that is being analysed (e.g. 2021):



43. To conduct the general statistics, start by clicking the general statistics tab and ticking the following:
    - Mean
    - Median
    - 10th percentile
    - 90th percentile

This will tell the tool to calculate the data needed for these indicators.

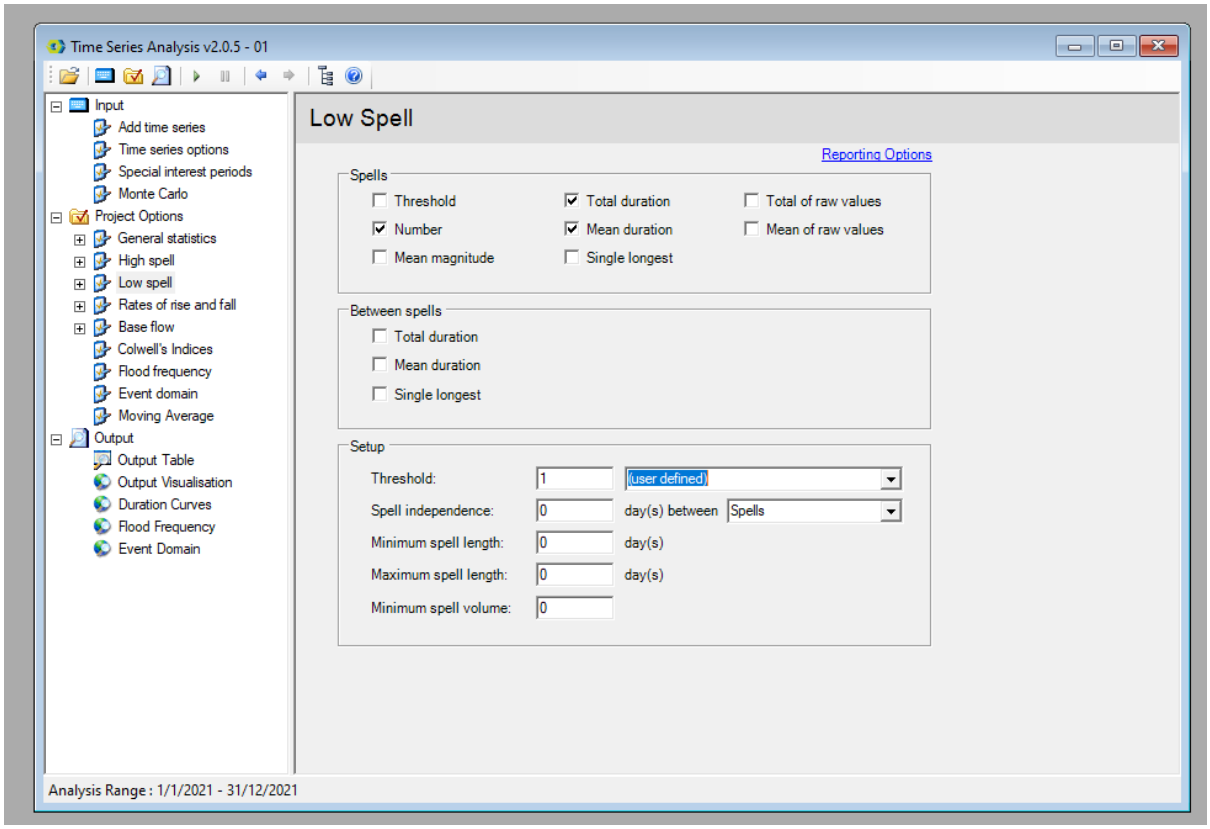
- Click run (on the bar above)



44. Enter the calculated data into the 'current' column of the prepared spreadsheet that was set-up earlier.

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

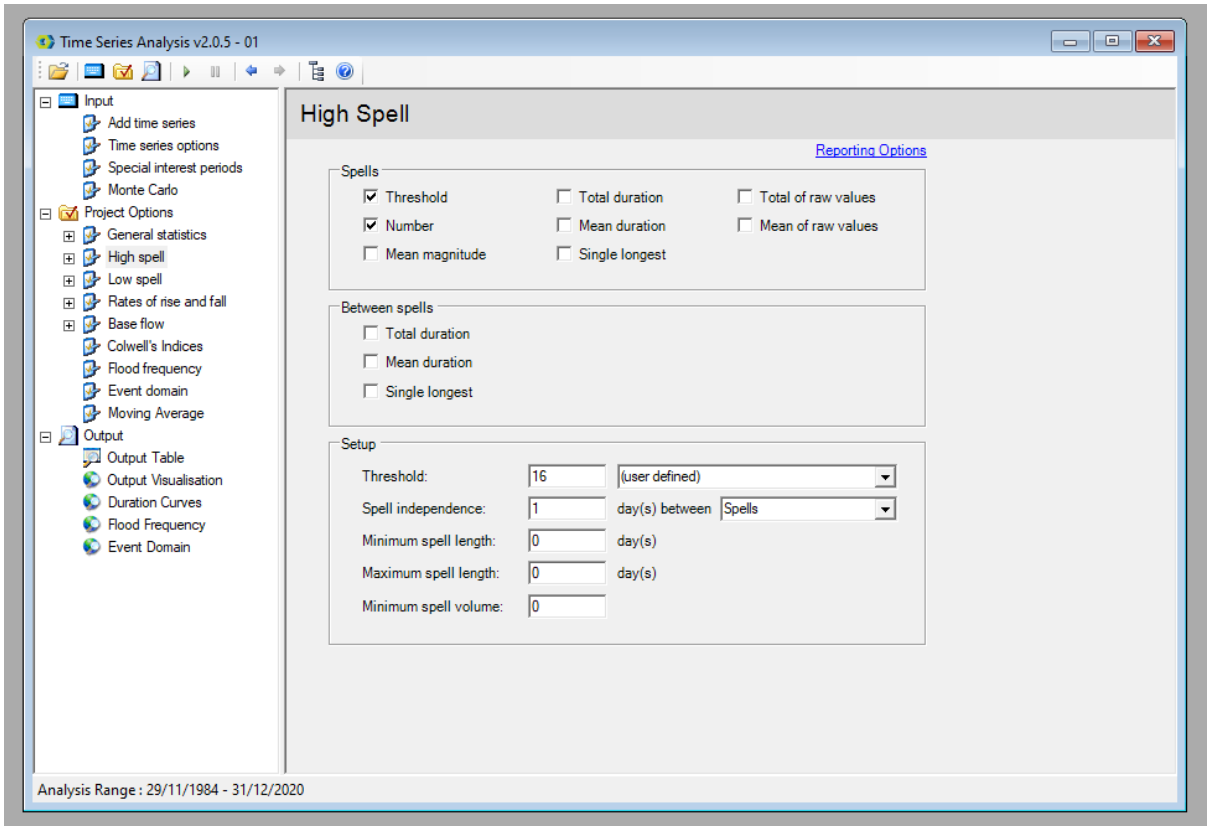
45. The next part of the analysis will give you the number of days with no flow (total duration), number of no flow spells historically (number) and will outline out of those no flow spells (single longest), which one last the longest in terms of duration (days in a row with flow <1ML/day).
46. To do that, go back to the "general statistic tab' and unclick all of the boxes in general statistics.
47. Go to 'Low Spell', click under spells: total duration, number and single longest. In the section called 'setup' click the drop-down box and change it to 'user defined' and change threshold to 1:



48. This will need to be added into the spreadsheet:

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (daily)	97	92
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0

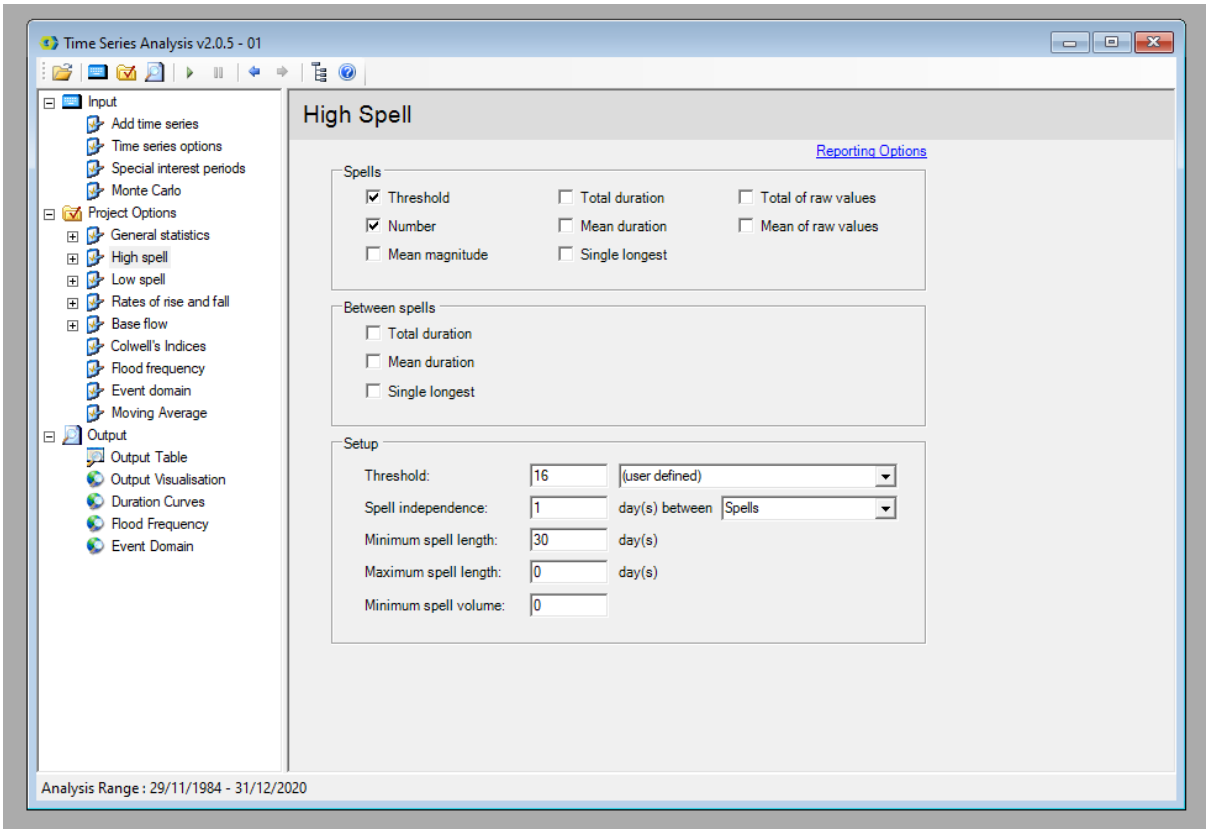
49. Once the data has been entered, go back to the 'low spell' tab and unclick all of the boxes.
50. To calculate the 10cm and 30cm flow data, go to the 'High Spell' tab and click threshold and number under spells. In setup click the drop-down box and change it to user defined and place the threshold in the 'threshold' box and leave the minimum spell length as zero for the total.
51. The threshold values for this assessment can be found in the Table 17, Table 18 and Table 19.



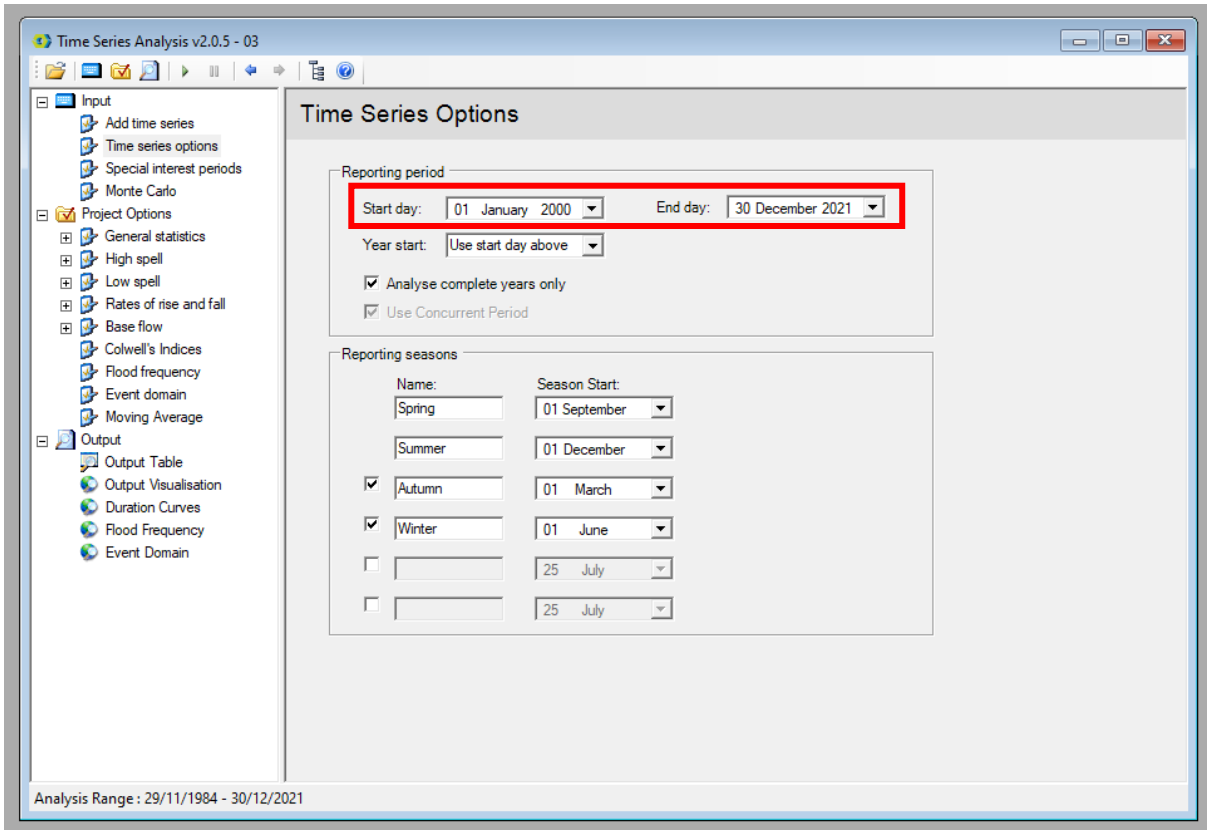
52. Once you have the total value, add it into the spreadsheet:

	A	B	D
1	**Indicator**	**Benchmark**	**Current (2021)**
2	**Mean daily flow (ML/day)**	54	51
3	**Median daily flow (ML/day)**	7	0
4	**Number of days with no flow (annual)**	220	160
5	**Number of no flow spells (annual)**	5	6
6	**Maxiumum duration of no flow spell (daily)**	97	92
19	**10%ile of daily flow (ML/day) (annual)**	2	0
20	**90%ile of daily flow (ML/day) (annual)**	44	37
21	**10cm daily flow (ML/day) (total)**	5	8
22	**10cm daily flow (ML/day) (1 month)**	1	0
26	**30cm daily flow (ML/day) (total)**	5	5
27	**30cm daily flow (ML/day) (1 month)**	0.1	0

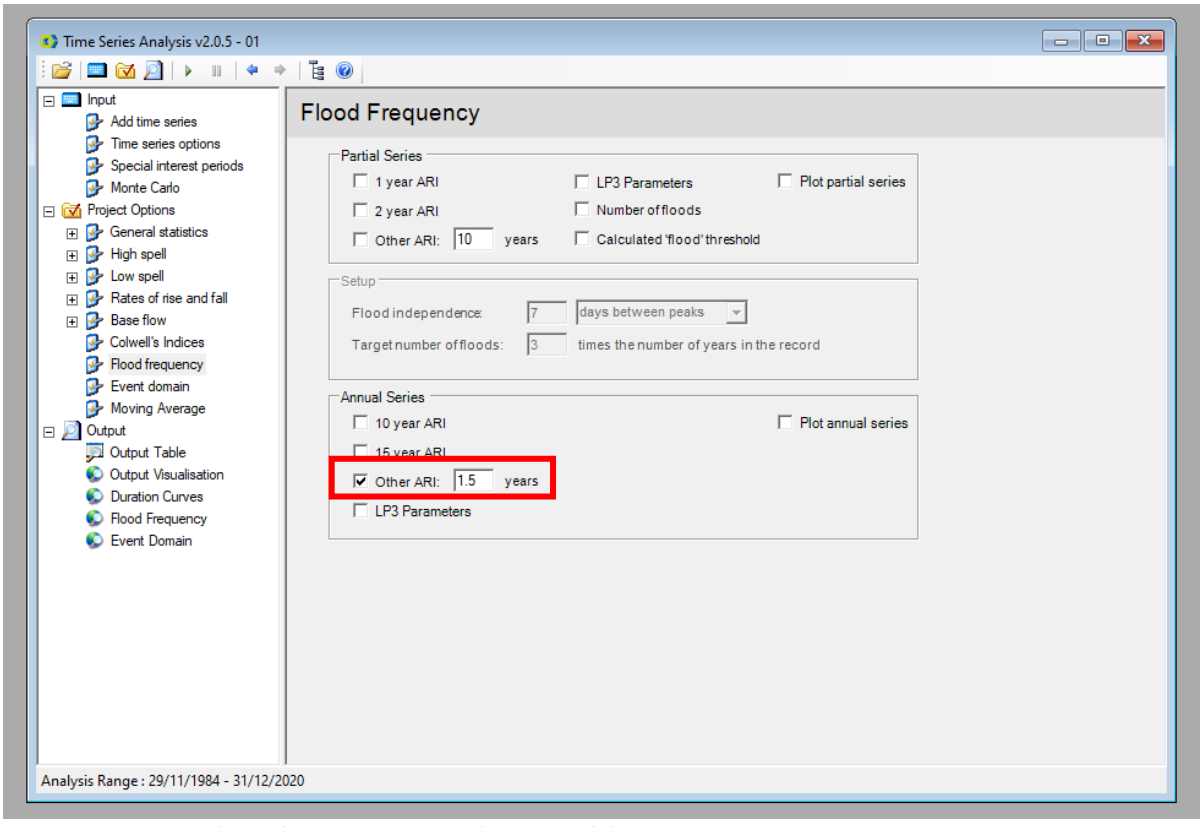
53. To calculate the values for the 1 month daily flow, go back to 'High spell' and change the minimum spell length to 30 days and add the averaged value into the spreadsheet, as above.



54. The next step is to calculate the average recurrence interval (ARI). ARI provides an indication of the size of a flow event relative to the historical events at the gauge. ARI calculations are not a part of the 'ECond' assessment but should be used as a descriptor to provide some level of interpretation of the annual data.
55. To calculate the ARI's go to 'Flood Frequency', and click the box called other ARI under the annual series. Change the value to 1.5 years and click run:



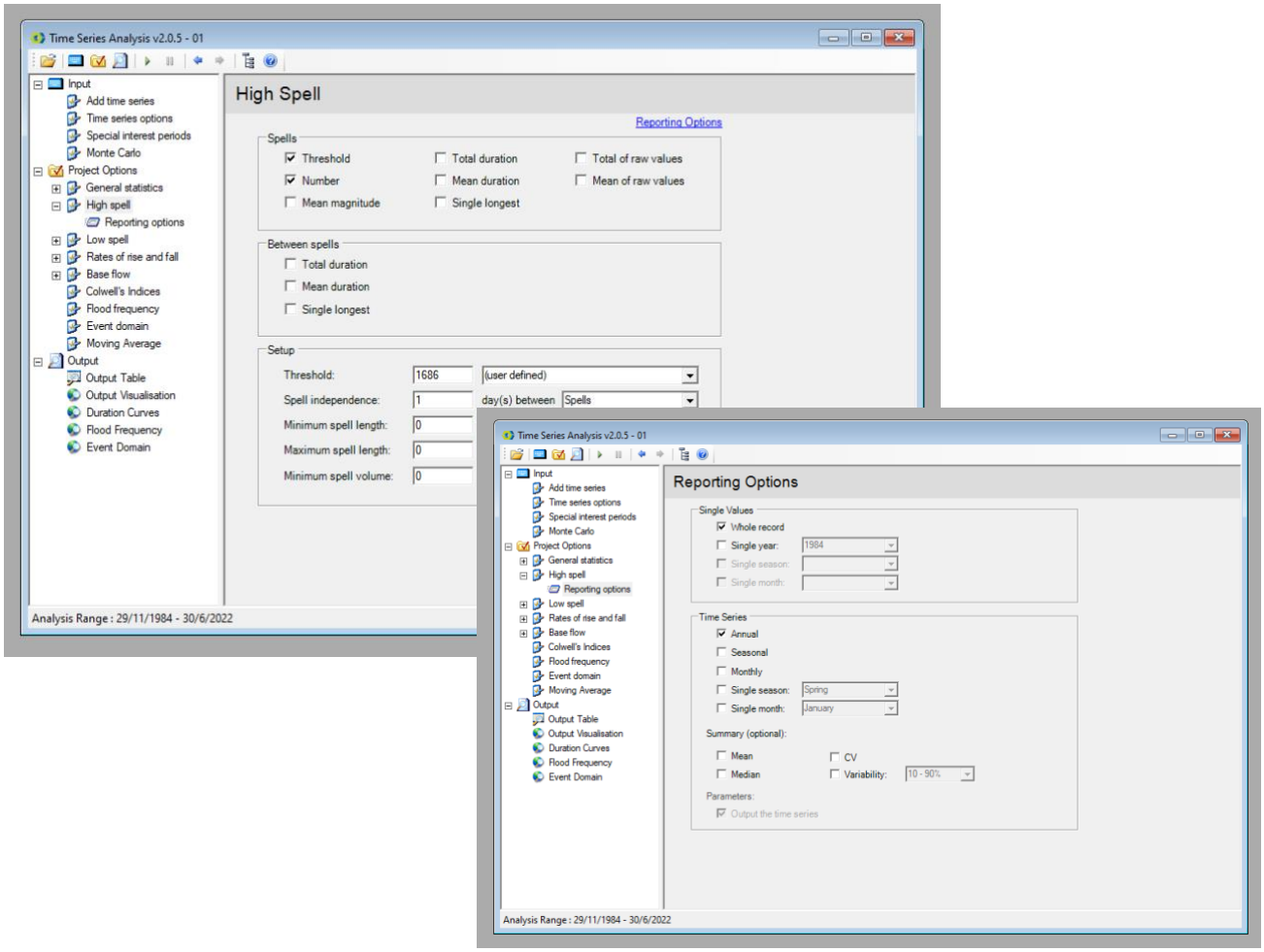
56. Go to 'Flood Frequency' and click the box called other ARI under the annual series. Change the value to 1.5 years and click run.



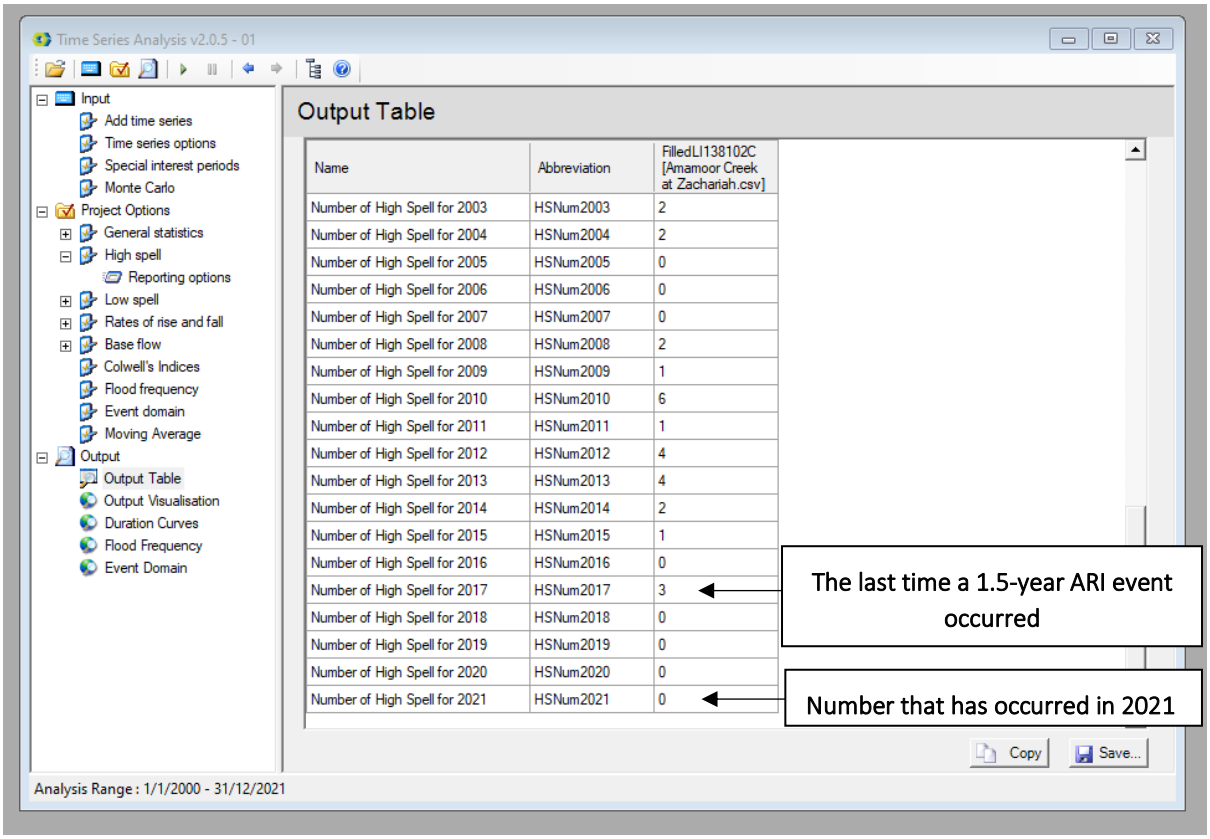
57. Once you get the value enter it into the spreadsheet:

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

58. Repeat this step by changing the value to 5 and followed by 20 to get the 5-year and 20-year daily flow.
59. Unclick the box tick in the ‘flood frequency’ tab.
60. To calculate the number of times the benchmark 1.5-year, 5-year and 20-year ARI’s have occurred between 2000 -2021 go to ‘High Spell’. In ‘High Spell’, click threshold, number, change the drop down box to user defined and enter in the benchmark.
61. Make sure that the minimum spell length is zero (0).
62. Go to reporting options and click 'Annual’ followed by run:



63. Once it's been run you would need to identify if an event occurred in the annual reporting period (e.g. 2021) and when an event of each magnitude last occurred (refer below for reference).



64. Repeat this step for the 5-year and 20-year daily flow ARI pre-development values.
65. Your spreadsheet should look like the example below.

	A	B	D
1	Indicator	Benchmark	Current (2021)
2	Mean daily flow (ML/day)	54	51
3	Median daily flow (ML/day)	7	0
4	Number of days with no flow (annual)	220	160
5	Number of no flow spells (annual)	5	6
6	Maxiumum duration of no flow spell (dail	97	92
7	Daily flow - 1.5 year	799.26	688
8	Number that have occurred within 2021	-	5
9	Number that have occurred across the whole period 1991-2021	-	90
10	Last occurrence	-	2021
11	Daily flow - 5 year	6356.76	7740
12	Number that have occurred within 2021	-	0
13	Number that have occurred across the whole period 1991-2021	-	12
14	Last occurrence	-	2017
15	Daily flow - 20 year	25442.424	36643
16	Number that have occurred within 2021	-	0
17	Number that have occurred across the whole period 1991-2021	-	3
18	Last occurrence	-	2013
19	10%ile of daily flow (ML/day) (annual)	2	0
20	90%ile of daily flow (ML/day) (annual)	44	37
21	10cm daily flow (ML/day) (total)	5	8
22	10cm daily flow (ML/day) (1 month)	1	0
26	30cm daily flow (ML/day) (total)	5	5
27	30cm daily flow (ML/day) (1 month)	0.1	0
28			

66. This process will need to be repeated for all gauges outlined in the data organisation and cleaning section in Appendix E.

Appendix E - Worst Case Scenarios for Ecological Flows

The tables below are the worst case scenarios for the ecological flows that have been calculated for each gauge in the region.

Table 20. Worst case scenario for each performance indicator.

Performance indicator	Worst case scenario
# days with daily flow <1ML, # of no flow spells and maximum duration of a no flow spell	90%ile of all years for each gauge's data.
Mean annual flow and Median annual flow	10%ile and 90%ile annual flow for all years for each gauge's data.
10%ile and 90%ile of daily flow	10%ile of daily flow for all years for each gauge's data.
Number periods of 10 cm flows that lasted at least 1 month, 3 month, 6 months and 12 months.	10%ile of daily flow over 10cm for all years for each gauge's data.
Number periods of 30 cm flows that lasted at least 1 month, 3 month, 6 months and 12 months.	10%ile of daily flow over 30cm for all years for each gauge's data.

Table 21. Worst case scenario for Mean, Median, Number of days with no flow, Number of no flow spells and Maximum duration of the no flow spells

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Auburne River at Dykehead	6	799	0	11	336	7	234	0	0.05
Barambah Creek at Ban Ban	52	1515	1.73	166	186	5	107	0	58
Barambah Creek at West Barambah	7	346	0	26	336	8	296	0	0.26
Barambah Creek at Litzows	4	376	0.28	39	239	11	177	0	7
Barker Creek at Brooklands	1	132	0	15	352	7	341	0	0
Barker Creek at Glenmore	10	307	0	44	282	9	211	0	10
Boyne River at Carters	0	318	0	11	365	7	359	0	0
Boyne River at Cooranga	25	1,544	0	49	311	5	182	0	31
Burnett River at Ceratodus	3	1,159	0	57	325	13	198	0	2
Burnett River at Eidsvold	3	227	0	22	345	12	255	0	0

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Burnett River at Fig Tree	54	12,868	23	401	37	2	33	3.45	127
Burnett River at Gayandah	54	2,736	13	195	0	2	0	2.97	74
Burnett River at Jones Weir	50	4,385	0	695	300	6	255	0	80
Burnett River at Tailwater	36	2,302	1	236	231	3	215	0	37
Burnett River at Mount Lawless	224	3,673	21	556	185	2	96	0.14	334
Cadarga Creek at Brovinia Station	0	151	0	0.73	358	7	288	0	0
Eastern Creek at Lands End	1	148	0	2	358	8	341	0	0
Elliot River at Dr Mays	0	69	0	4	365	6	365	0	0
Elliot River at Elliot	4	207	2	25	152	8	109	0	8
Gin Gin Creek at Brushy Creek	6	530	0	33	309	8	207	0	6
Gregory River at Isis Highway	11	440	0	12	280	14	192	0	5
Isis River at Bruce Highway	10	516	0	14	280	13	153	0	8
Kolan River at Springfield	0	546	0	25	361	7	310	0	0
Monal Creek at Upper Monal	0	69	0	4	365	6	365	0	0
Reid Creek at Mungy	3	227	0	22	345	12	252	0	0
Splinter Creek at Dakiel	0	86	0	4	362	7	342	0	0
Stuart River at Proston Rifle Range	4	324	0	25	331	9	243	0	2
Stuart River at Weens Bridge	4	121	1	12	230	14	86	0	6
Three Moon Creek at Abercorn	1	450	0	18	336	12	244	0	0.38
Amamoor at Zachariah	7	304	1	25	208	11	90	0.02	8
Glastonbury at Glastonbury	2	142	0.4	17	261	11	184	0	3
Kandanga Creek at Hygait	5	375	0	34	243	7	160	0	9
Mary River at Homepark	627	10,234	97	1,377	-	1	-	5	806
Mary River at Bellbird	62	1,059	15	178	73	3	56	0.45	93

Waterway	Mean daily flow (ML/day) (lower WCS)	Mean daily flow (ML/day) (upper WCS)	Median daily flow (ML/day) (lower WCS)	Median daily flow (ML/day) (upper WCS)	Number of days with no flow (annual)	Number of no flow spells (annual)	Maximum duration of no flow spells (days over the year)	10%ile of daily flow (ML/day) (annual)	90%ile of daily flow (ML/day) (annual)
Mary River at Miva	528	7,839	150	1,332	25	1	17	22	877
Mary River at Moy Pocket	124	1,885	28	421	71	3	71	0.39	171
Munna Creek at Marodian	34	975	0.11	74	247	6	202	0.83	28
Obi Obi Creek at Gardners Falls	23	134	9	45	46	7	32	0	42
Six Mile Creek at Cooran	43	475	9	91	108	6	67	0	57
Teewah at Coops Corner	56	155	41	103	-	0	-	30	76
Tinana Creek at Tagigan Road	7	204	0.28	14	225	7	153	0	13
Tinana Creek at Bauple East	45	1,621	11	72	-	2	-	1	89
Wide Bay at Brooyar	6	525	0	56	313	7	255	0	2
Wide Bay at Kilkivan	1	143	0	23	355	11	300	0	0
Baffle Creek at Mimdale	57	2,104	0.39	140	254	7	144	0	82
Oyster Creek at Rapleys	1	472	0	12	330	9	152	0	0.86

Table 22. Worst case scenario for 10cm daily flow and 30cm daily flow

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Auburne River at Dykehead	1	0	2	0
Barambah Creek at Ban Ban	1	1	3	0
Barambah Creek at West Barambah	1	0	1	0
Barambah Creek at Litzows	1	1	1	1
Barker Creek at Brooklands	1	0	0.1	0
Barker Creek at Glenmore	1	1	1	0
Boyne River at Carters	0.2	0	0.2	0
Boyne River at Cooranga	1.7	0.7	3	0

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Burnett River at Ceratodus	2	0	1	0
Burnett River at Eidsvold	2	0	1	0
Burnett River at Fig Tree	3	1.4	4	0
Burnett River at Gayandah	-	-	-	-
Burnett River at Jones Weir	-	-	-	-
Burnett River at Tailwater	1	1	1	0
Burnett River at Mount Lawless	1	1	3	0
Cadarga Creek at Brovinia Station	1	0	1	0
Eastern Creek at Lands End	1	0	1	0
Elliot River at Dr Mays	0	0	0	0
Elliot River at Elliot	-	-	-	-
Gin Gin Creek at Brushy Creek	3	0	0.6	0
Gregory River at Isis Highway	3.5	0	2	0
Isis River at Bruce Highway	4.5	4.5	2.5	0
Kolan River at Springfield	1	0	0	0
Monal Creek at Upper Monal	0	0	0	0
Reid Creek at Mungy	2	0	1	0
Splinter Creek at Dakiel	1	0	0	0
Stuart River at Proston Rifle Range	2	0	2	0
Stuart River at Weens Bridge	1	1	0	0
Three Moon Creek at Abercorn	2	0	1	0
Amamoor at Zachariah	3	0	2	0
Glastonbury at Glastonbury	2	0	1	0
Kandanga Creek at Hygait	1	1	1	0

Waterway	10cm daily flow (total) (ML/day)	10cm daily flow (30 days) (ML/day)	30cm daily flow (total) (ML/day)	30cm daily flow (30 days) (ML/day)
Mary River at Homepark	1	1	1	1
Mary River at Bellbird	1	1	3	0
Mary River at Miva	1	1	1	1
Mary River at Moy Pocket	1	1	1	1
Munna Creek at Marodian	2	1	4	0
Obi Obi Creek at Gardners Falls	2	1	6	0
Six Mile Creek at Cooran	1	1	2	1
Teewah at Coops Corner	-	-	-	-
Tinana Creek at Tagigan Road	2	1	2	0
Tinana Creek at Bauple East	1	1	0	0
Wide Bay at Brooyar	1	0	1	0
Wide Bay at Kilkivan	1	0	1	0
Baffle Creek at Mimdale	1	1	2	0
Oyster Creek at Rapleys	3	0	1	0

Appendix F - Worst Case Scenarios for Water Quality

Table 23. Worst case scenario for Estuaries

Water type	pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
Lower estuary (QWQ) - SEQ	7.8	8.5	85.6	103	12	85	4.4	0.4	0.057	0.03	0.087	0.067	0.041
Lower estuary (QWQ) - CQLD	7.8	8.5	89	104	13	85	3	0.265	0.0075	0.011	0.0185	0.0195	0.007
Middle estuary (QWQ) - SEQ	7.12	8.5	57.9	107	65	85	11	1.3	0.71	0.13	0.772	0.43	0.310
Middle estuary (QWQ) -CQLD	6.5	8.5	73	102	32.12	85	7.62	0.727	0.0907	0.041	0.1317	0.057	0.015
Upper estuary (QWQ) - SEQ	6.93	8.5	51.4	107	71.7	85	26	1.5	0.695	0.14	0.756	0.55	0.400

Table 24. Worst case scenario for Freshwater

Water type	EC					pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
	Sandy coastal	Central	Southern	Callide	Mary													
Lowland Streams (QWQ)	1195	1500	1570	1450	-	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
Upland streams (QWQ)	1195	1500	1570	1450	-	5.5	9	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Maleny Plateau (Southern Upland Acid Waters)	-	-	-	-	900	5	10	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Upper Mary River (Southern Upland Freshwaters)	-	-	-	-	900	5.5	9	20	160	75	85	12	0.4	0.06	0.02	0.08	0.2	0.100
Mary River and southern tribs (Southern Lowland Waters)	-	-	-	-	2600	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
Western Tribs (North Western Lowland Waters)	-	-	-	-	3000	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050

Water type	EC					pH		DO%sat		Turbidity (NTU)	TSS (mg/L)	Chlor (ug/L)	TN (mg/L)	Nox (mg/L)	Amm (mg/L)	DIN (mg/L)	TP (mg/L)	FRP (mg/L)
	Sandy coastal	Central	Southern	Callide	Mary													
Tinana Creek (North Eastern Lowlands)	-	-	-	-	900	5.5	9	20	160	100	85	12	1.5	0.15	0.1	0.25	0.1	0.050
East tribs of Tinana Creek (easternm Sandplain Tannin Stained)	-	-	-	-	900	3.2	7.5	20	160	100	85	12	0.4	0.06	0.02	0.08	0.2	0.100